A Tutorial Experiment Concerning Dampness Diagnosis Supported by an Expert System.

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Summary

A. The teaching of Technology of Building Rehabilitation in Italian Universities

In the sectors of building rehabilitation and urban complexity intervention in Italy has taken place on a theoretical plain, closely examined and clarified by research in the area of building and environment, especially in the Universities of Genoa, Milan Naples and Turin (Master of building, urban and environmental rehabilitation). In the operative plain the lack of specific professional qualifications has led to a shortage of adequate intervention.

The Universities of the European Common Market countries have reacted toward a growing demand for expert technicians, qualified to work in this complex sector of building rehabilitation, by creating specialised courses and post-graduate doctorates. In fact faculties of architecture and/or engineering are characterized, in most European countries, by a tendency to supply students with a unified teaching methodology in the technology not differentiated through specific courses (e.g. Spain and some French Schools, Denmark and Belgium). The technological education in these countries take up a large part of the training of an architect and is continuously present throughout the period of study (4-5 years compared to the teaching periods of the 3 years in Italy or other countries); however, the courses are not organised according to a detailed specialisation or individual disciplines. Moreover, in this plan the teaching of the technology of building rehabilitation is not treated as a specific subject but is dealt with on a post-graduate level, as is the case in Belgium (University of Leuven), in countries where Spanish is the mother tongue (Master in Rehabilitation) and in France (Ecole d'Architecture de Normandie).

The Technology of Building Rehabilitation has only been recently introduced in Italy, in the Faculty of Architecture, and in some degree courses in Civil Building Engineering. In all the faculties in which it has been instituted, the tendency has emerged to characterize the Technology of Building Rehabilitation as a planned and procedural discipline, that is to create a *co-ordinator of rehabilitation projects,* apable of a multidisciplinary approach. A second tendency has emerged, regarding the width and complexity of the discipline, which carries with it the necessity to connect this study to a methodological aim, as an element of synthesis between disciplinary approaches. This approach assumes a specialist knowledge, at the time connecting this knowledge in a unified synthesis, which must be expressed through a rehabilitation project.

The particular approach which characterizes building rehabilitation has to be defined in this overall view. In fact, the complex character of this view, which is at the same time intellectual, material and social, requires a period of identification and reconstruction of these processes in a disciplinary approach which unites the individual approaches in a "project of knowledge" which is unitary in character, in Naples, in particular, the courses in Building Rehabilitation Technology have always been experimental in nature in the

In the original courses, since 1987, these have been carried out partly through university teaching and partly in the workplace, particularly in rehabilitation building yards following the 1981 earthquake in Naples. In these experimental courses only a small number of students could be catered for. Today the growing number of students requires an approach using computer tool which, particularly in the field of architecture, has no precedent.(fig. 1)

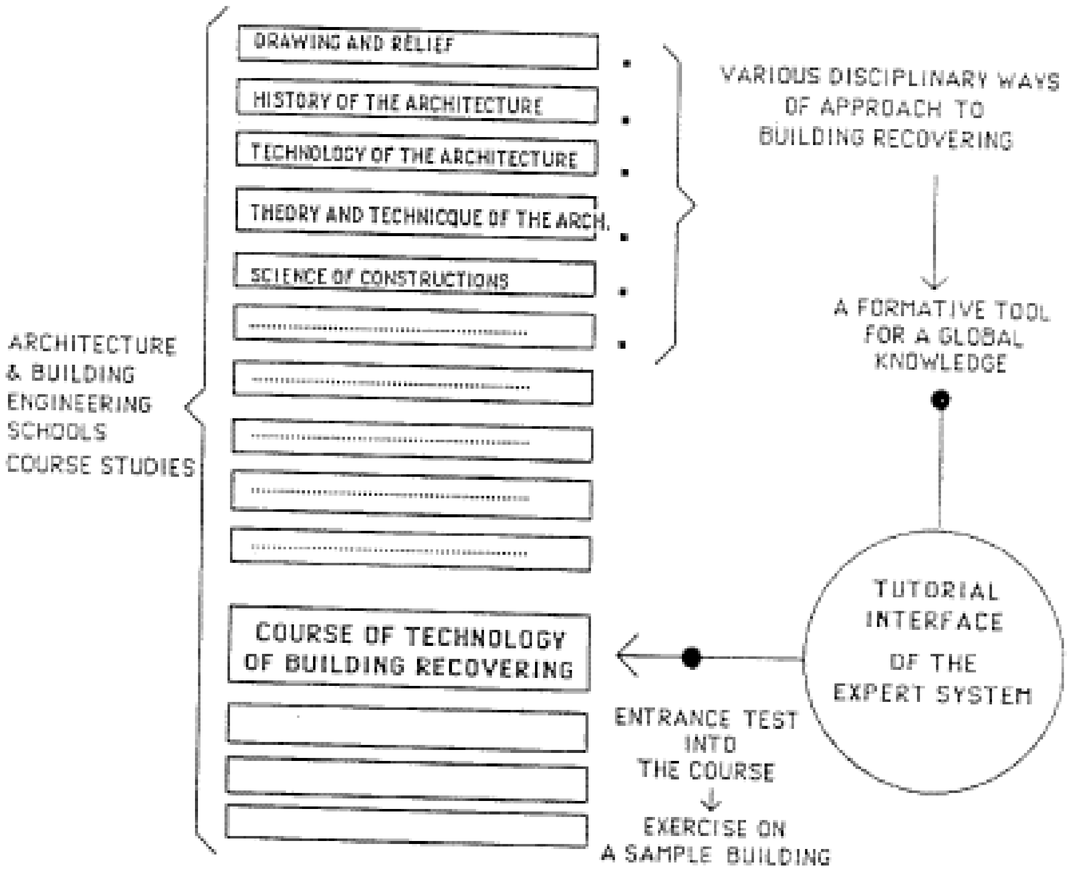


FIG. 1 *Tutorial relevance*

B Experimental course of technological rehabilitation with computer tools

The actual tutorial experiment at the Architectural School of the University of Naples originated as an application of an Expert System for pre-industrial building rehabilitation diagnosis, coordinated by Ernesto Burattini, knowledge theory engineer of CNR. This expert system has been designed for real-life situations on the basis of many experts in architectural composition, structural consolidation and technological adjustment, and tested on real cases solved by those experts.
Two different users were involved in the Expert System: fourth year students and undergraduates.

This experiment, as referred to in the paper of Claudio Cajati [1] regards the structural and technological diagnosis. During the course the two aspects were presented to the students with some differences in aims and in the methodology.

The authors of this paper will develop especially the technological aspects of the diagnosis.

The field of Technology of Architecture, with reference to the Expert System, has identified, at the first opportunity, the diagnosis of dampness problems in premodern masonry buildings.

The first step of the tutorial experiment concerns the heuristic of diagnostic technological approach, specifically applied to dampness decay; the second step concerns the structure of the knowledge base, through four main logical processes. Students are led to detect dampness causes through decay effects.

The further aim is testing difficulties and queries of a non-expert user who faces this kind of problem for the first time.

The first results can be dealt with as follows:

- the analysis of difficulties which have arisen in applying the knowledge process of the Expert System;
- a specific information set constituting the minimum of supplementary help, when considering a wider use of the tutorial application of the Expert System;
- a progressive increase in case history;
- a systematic comparison with the general scientific knowledge in the dampness diagnosis field;
- a further acquisition of specific items.

C. Synthesis of technological approach

Dampness is one of the most frequent causes of building wearout. Moreover the ambiguity and complexity of interpreting the decay phenomena is due to the co-occurrence of more than one cause which may determine wearout situations not promptly definable. On the other hand, since the water runs in an unforeseeable way along the building structures, often damage may appear very far from the origin of the decay.

The water action - in liquid as well as in vapour form - is one of the most frequent causes of building wearout.

The water can get into a building in four different ways:

- meteoric water (snow, hail, rain or wind-rain) which acts periodically and in a non eliminable way on outside walls;
- running water, which, for different reasons, passes through the plants (feeding grid, sink, heating, antifire) leaking inside the building in various ways, in relation to the different typologies both of the plants and of the existing building;
- water-bearing, which can penetrate both through capillarity and through rising, at the lower base-level, through foundations;
- urban-grids water (sewer, main running water grid, and so on) which owing to unrecognizable damage, may rise through the basement area.

Other motivations which lead us to the implementation of a diagnostic expert system are: frequency, gravity and ambiguity of cases, with particular reference to existing building. These cases may occur in the whole building, both outside or inside. A particular case is that of premodern buildings, in which the technical plants are frequently anything but rational. Moreover in these buildings the water penetration frequency is generally very high. The interpretation of these cases could be ambiguous and complex, firstly due to the co-occurence of various different causes which may determine wearout situations not immediately definable.

Secondly ambiguity arises from the fact that water runs in a non foreseeable way along the building structures, with the consequence that damage may happen in places located very far from the site of origin. The gravity of damage is often such as to influence the welfare, the security, the aspect and the management of the building.

The interest in this subjects confirmed through the fact that there are a large number of publications concerning dampness diagnosis, both based on real cases solved by experts, and

[1] "The new teaching of an architect: the rèl of Expert System in technological culture"

on research studies. Moreover a useful reference is given by the legal technical reports, recorded in cases of legal controversy.

The method used for building analysis is based on systemic logic, elaborated by the UNI for residential buildings. This logic allows a type of reading of building structure that we could call "tree-reading" -from the general to the particular. In that way it is possible to tightly bind human needs, requisites required (norm) and performances give both by the unities of the building and by the whole building.

Particularly the division of the building into two different sub-systems, an internal environment and a technological one, allows us to distinguish between spatial qualities and technical performance. This fact is very useful in the diagnosis of dampness damage which, besides compromising building structures, could also cause damage to the users' health. In order to simulate the logical procedures used by an expert during a diagnosis path, it has been necessary to:

- understand the expert logic,
- translate this logic into informatic speech,
- make it easier for it to be understood by a non-expert user. **(**fig.2**)**

D. Dampness diagnostic process using the Expert System

The diagnostic process adopted by the expert in recognising dampness wearout is essentially characterized by three phases which can be conducted in one or more operations according to the circumstances. The first phase can he defined as preliminary and collects informations on the building itself, the second is based on the specific observation of phenomena, the third on the correlation between cause and effect. These operations are strictly inter-related and are not always carried out following the same sequence, as it is frequently necessary to check the preliminary observation during subsequent phases.

The gathering of information relevant to the characteristics of the analysed system is followed by a complex phase of interpretation and correlation of data.

This is supported by a fund of knowledge on the part of the expert, which derives essentially from analogous case and the study of relevant literature. The final aim is to find the main cause and the possible secondary co-causes which have caused the analysed phenomena. In some cases, moreover, it is not possible to eliminate all the uncertainty and ambiguity in the interpretation of the correlation between cause and effect. It then becomes necessary to carry out supplementary in situ investigation with the help of technical instruments and non destructive tests, or through taking samples of material for analysis in the laboratory.

After having described the diagnostic process adopted by the expert, it is useful to define the sequence of described operations above which must be carried out in order to use the Expert System in the technological sector.

Essentially, problems caused by dampness can be of two types:

- the first, a general one, affecting a whole building or a large part of it,
- the second, connected to localized damages affecting a particular part of the building or its components, the latter being a typical cause of legal controversy.

In both cases the diagnostic process used by the expert is similar.

In relation to the first phase, having carried out a complete metric relief of the building, also noting the specific use of single internal environmental units, it is necessary to proceed to the technological analysis of the building. This is based on systemic analysis which allows the user not only to define the characteristics of individual elements but also to establish the system of correlation.

To simplify this operation we have prepared a specific form which can be filled in on site, which deals with component materials, relevant dimensions, typologies and constructive techniques (Fig 3).

During this phase information regarding context condition (fig 4) is also collected, which permits the evaluation of the building in its natural and urban setting. Regarding the natural setting, it is important to evaluate the effects of the structure in an urban context on the microclimatic characteristics of the area in which it is situated. It is suggested that a series of sections orthogonal to the facades be drown which illustrate the skyline and consequently define the degree of exposure of different facades to the combined wind and rain action.

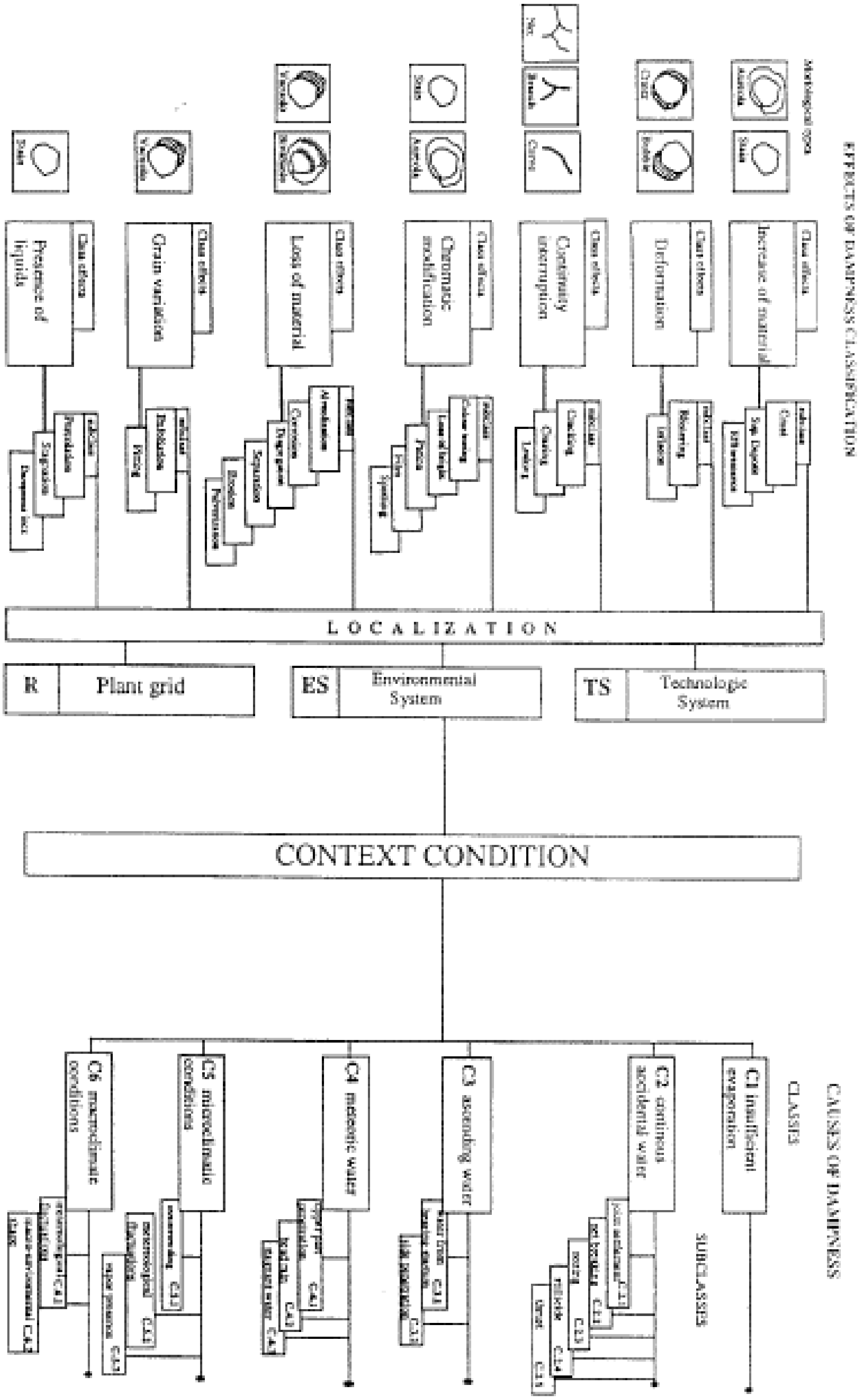


FIG. 2 *Scheme of an expert system for the diagnosis of dampness in masonry buildings.*

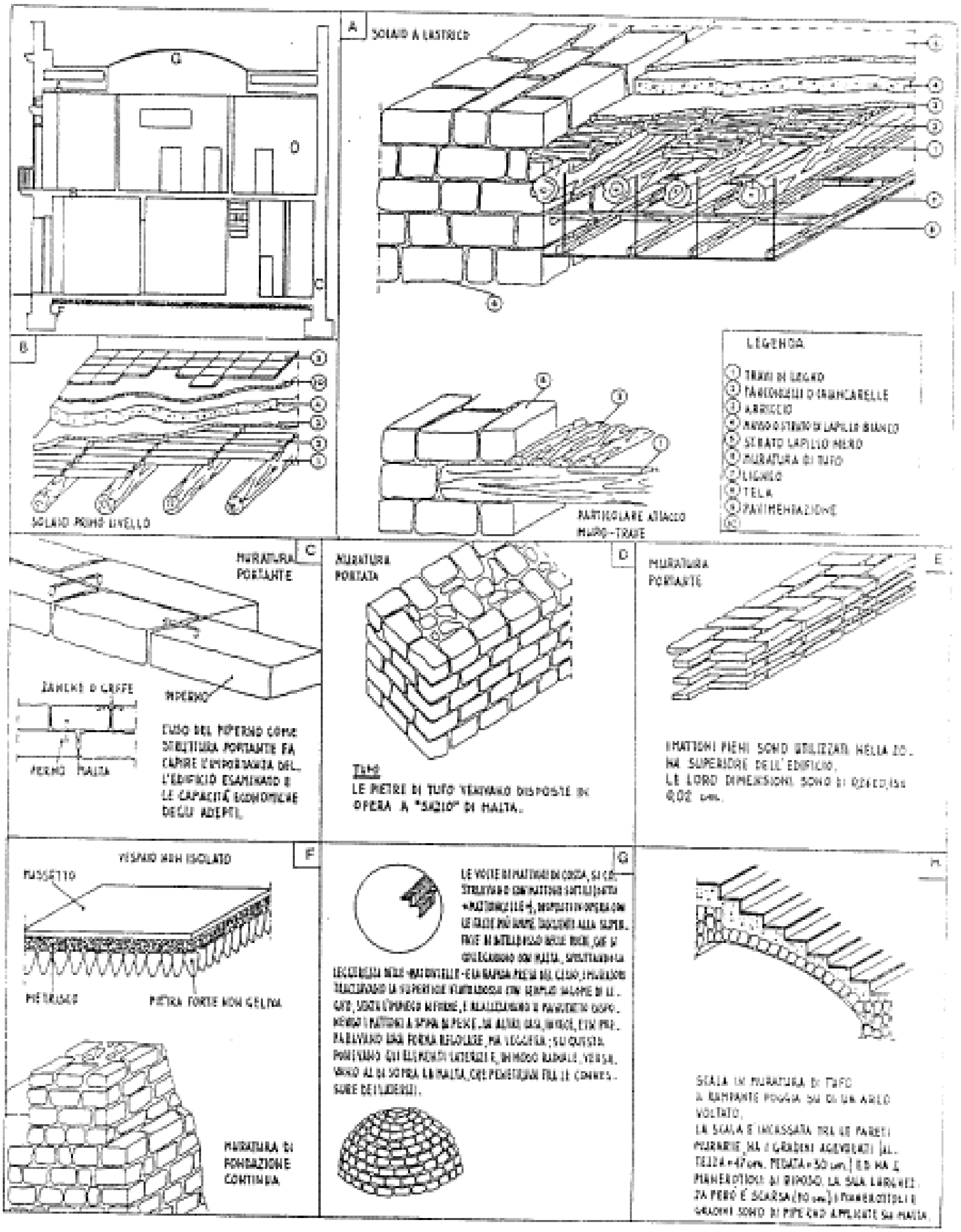


FIG.3 *Technological analysis whith componenet materials, relevant dimensions, typologies and constructive techniques.*

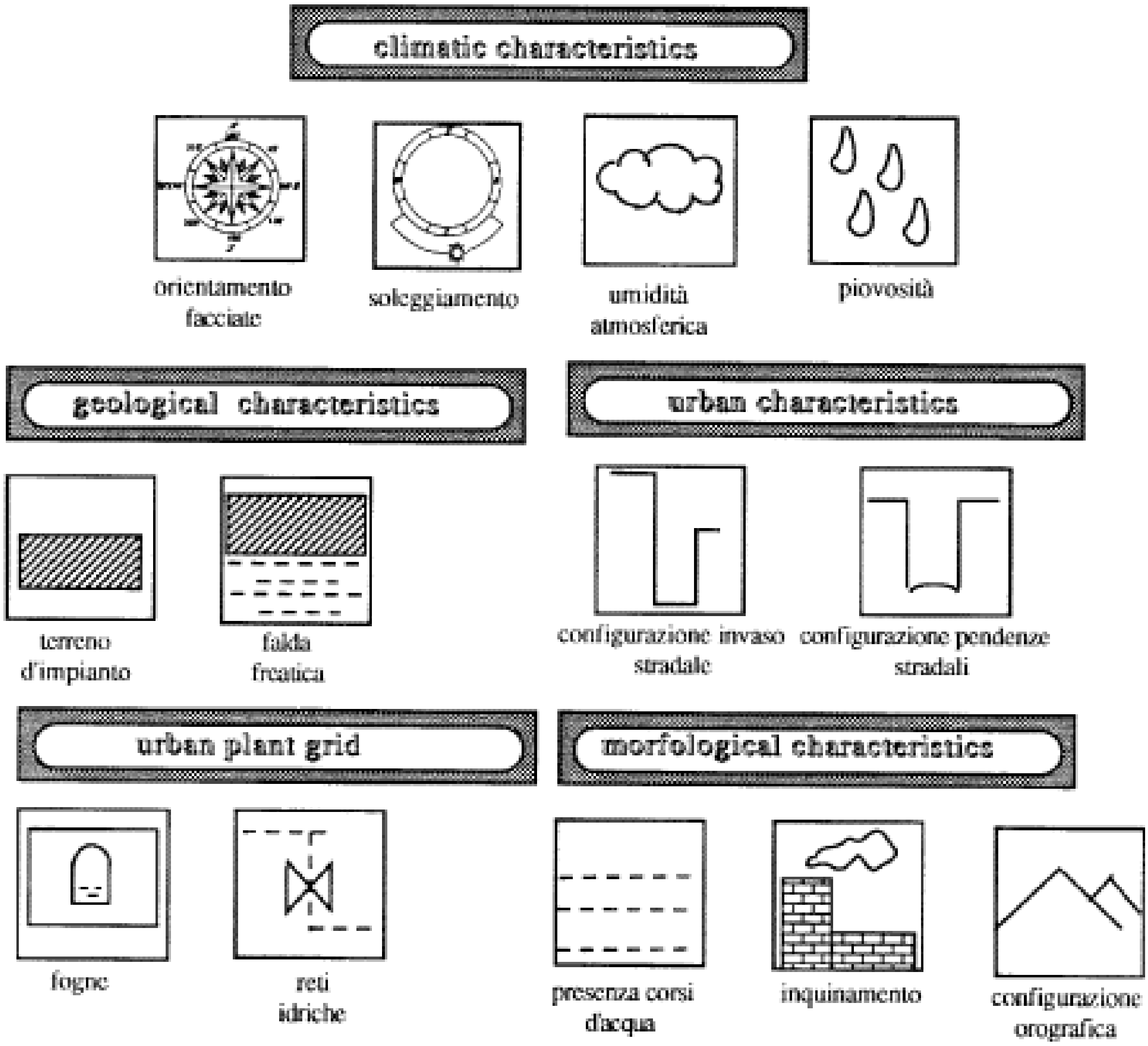


FIG. 4 *Context condition*

Regarding the urban setting, the following data are collected:

- geological characteristics, in particular those concerning the nature of subsoil and the siting of waterbearing strata which are significant in diagnosing rising dampness;
- the location of underground siting of urban grids which are significant in diagnosing continuous accidental water;
- climatic characteristics dealing with local shade, orientation and insolation of facades, seasonal averages related to rain fall and relative humidity which are significant in diagnosing meteoric water and condensation due to macroclimatic conditions.

Already at this phase of investigation it is possible to shorten the diagnostic procedure based on a few simple observations based on general knowledge of the area and its conditions. This does not exclude verification of causal efficiency as a control of the diagnosis.

The observation and recognition of alteration phenomena is the first step in the diagnostic process dealt with by the Expert System. The state of degradation of a building system or a pall of it, is recognised both through visible phenomena and signs perceived by other senses (cold sensation, moul smell, wet sensation).

During the on-the-spot investigation it is vital to recognise and name the individual phenomena, in order to select the correct way to the cause.

For this reason the Expert System recommends the use of classes of recognisable phenomena based on morphological modifications produced, these being similar to terminological definition commonly used in literature.
The relief and localisation of the phenomena is carried out using photography and graphic reference representation (fig.5).
The classes of effects are :

3. *increase of materials:* with reference to phenomena such as accumulation of materials or presence of crusts, imputable to a superimposition of new materials on the existing ones;
4. *deformation:* with reference to the variations of the surfaces flatness (bubbles, wood swelling, and so on);
5. *continuity interruption :* with reference to the formation of masonry cracking and surface breaking;
6. *chromatic interruption:* with reference to the modification of dye and tone of materials (stains, patina, fading);
7. *loss of material:* with reference to deformations producing separation or disgregation of materials (plaster separation, erosion, corrosion of metallic components);

- *grain variation :* with reference to the phenomena which modify the tactile surface characteristics, with loss of smoothness or, in the case of wrinkled surfaces, loss of roughness;
- *- presence of liquids :* with reference to evident wet surfaces (percolation, stagnation, etc.).

Special iconic symbols have been connected to each class of effects based on morphologic characteristics.
The subclasses are defined with the *lexical* description referring both to the NORMAL definition issued by the National High Institute of Restoration in Italy and to the extensive specific literature.
Another aid for recognizing individual subclasses of phenomena is given by photographic archives implemented directly inside the Expert System.
Those iconic symbols can be a useful reference for the user because they allow a direct comparison between visible phenomena and classes of effects.
The second phase of diagnostic process, following the recognition of dampness effects, is done through a first hypothetical correlation between dampness effects and possible causes.
These possible causes have been articulated into classes and sub-classes with reference to different types of circumstances:
1) Insufficient evaporation: this class of causes is generally found in new building or rehabilitation interventions in cases of imperfect and speedy workmanship.
2) Continuous accidental water, caused by leakage of different types of grid inside the building (subclasses: joint settlement, net breaking, oozing, stillicide, thrust).
3) Ascending water, which can rise, by capillarity, through the basement (subclasses: water from bearing stratum, side penetration).
4) Meteoric water, with reference to actions given through meteorological precipitations (subclasses: upper part penetrations, head rain, stagnant water).
5) Microclimatic conditions, condensation due to thermo-hygrometric exchanges inside the building (subclasses: overcrowding, meteorological fluctuations, vapor presence).
6) Macroclimatic conditions, condensation due to thermo-hygrometic exchanges between the building and its context or environment, (subclasses: meteorological fluctuations, macroenvironmental shape).
At this point of the process begins the first approach to effect-cause correlation (logical nexus), which can be elaborated with reference to visible evidence, to the entity of the phenomenon and its diffusion inside the building.
According to that, the logical nexus connects the effects with all the possible causes to which it can be related, neglecting the impossible one.
The localisation of dampness effects in the following steps, in the Expert System procedure, the ubicational nexus, allows users to pick out these localisations with reference to specific areas in the building.
In order to facilitate this singling out, the building has been divided into three sub-systems, internal environment system, technological system and plant grid. In the internal environment system individual units correspond to delimitated spaces, related to their different localisation, with different functions. Each environmental unit is composed of different technological units.
The plant grid has been differentiated by the other two; the reason for this choice originates from the consideration that plant grid cannot be sub-divided, as done in the two previous Systems.

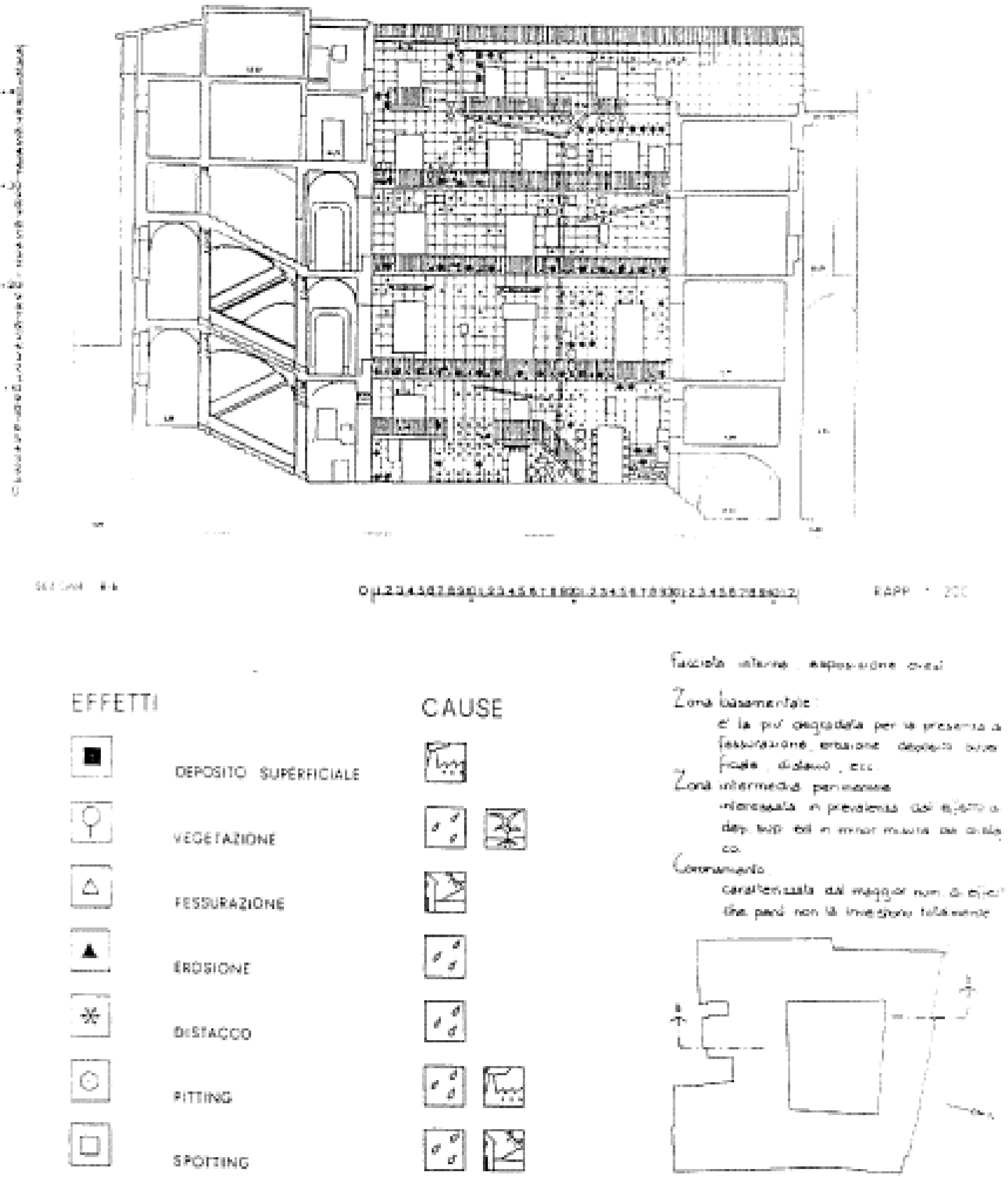


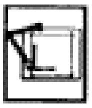
FIG. 5 *Localisation of the phenomena is carried out using photography and graphic reference representation*

Among the three different sub-system a series of connections have been established in order to facilitate the successive phase of diagnosis procedure.
Other correlations may refer to the context condition, that, as we have already explained, permits the evaluation of the building in its natural and urban setting.
It is, then, through the chronological nexus that it is possible to pick out causes using temporal information.
At the end of this procedure it is possible to elaborate a diagnosis of dampness causes that may define one, or also more than one, cause (principal and coexisting causes). We defined this phase as *evaluation of causes of dampness.*
The result may be more or less precise in connection with the capacity of the user to insert correct answers through the different steps proposed by the Expert System procedure.
Consequently we can have different level of response:
a) the reaching of a satisfactory precision of dampness diagnosis that could eliminate the necessity of verifying the causal efficiency nexus;
b) the need to go back to a previous step of the procedure, in order to integrate the lack of information precedently given;
c) the co-occurence of more than one cause; these could be alternative and/or incompatible. In these cases it is necessary to begin a different phase that we could define *oriented investigation or precise diagnosis*, that involves other different technical expertise and could need investigation *in situ* the building, such as previously mentioned.

E. Primary consideration on tutorial experience

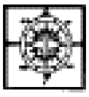
The didactic experience was carried out on students following the course using the Expert System logic but without completing the use of information technology support, as illustrated by Claudio Cajati in his paper; this was caused due to the lack of an instruction manual for the programme and the lack of library material to help the student-user through the system.
As a result the experiment concentrated on the mode of approach by non-expert users. To provide this basic information it became necessary to give the students lessons on building-reliabilitation theory also using outside experts.
On the other hand the *in-situ* inspection and investigation was guided by technologists with the aim of defining the minimum information required (observation and gathering of data) to permit the student to use the Expert System without returning to the site. The case studies were chosen to verify the above criteria, defining the minimum information required and considering the variety of problems which may arise in a building which is to be rehabilitated.
As a result of the above, at the same time a group of graduates (Anna Gnazzo e Clementina Pugliese) were involved in creating the first edition of a particular guide to the procedures required for a dampness diagnosis, divided in four phases: knowledge of the building, context analysis, observation phenomena and the building in the expert system, according to the logic we used in the Expert System (fig.).
The results we obtained were very encouraging, since the description of the reasoning and the steps followed in diagnosing the causes of the different types of dampness were very close to those implemented in our Expert System. (fig. 6 - 7)
The next step will be that of developing an adequate tutorial user interface in accord with the experience we made in this course.
This tutorial user interface could in some stages of the teaching phase substitute the teacher, guiding the student along the more plausible path of reasoning and helping him to infer the correct answer for classic case study. This tutorial use of the Expert System will permit to the teacher to be free from a heavy educational engagement .
This way the teacher could: explain the whole development of the recovering process; concentrate the interaction with the students on the design phase which is the most important; strengthen the connections among the different phases: knowledge, design and execution; transfer the rich and composite range of crucial cognitive elements from the analytical phase into a looking for the project solutions.
On the other side the advantages for the student could be: the increased awareness of the cognitive tools acquired; the actual application on local buildings.

KNOWLEDGE OF THE BUILDING

1 

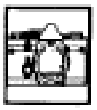
1.1 Metric relief: general problems and method
1.2.Other types of relief
1.3.Technological analysis

CONTEXT ANALYSIS

2 

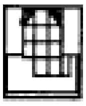
2.1.Survey / reading of climatic data
2.2.Materials degradation: atmospheric pollution and climatic condition
2.3.Subsoil analysis: its nature, hydrogeological data, urban water networks

OBSERVATION OF PHENOMENA

3 

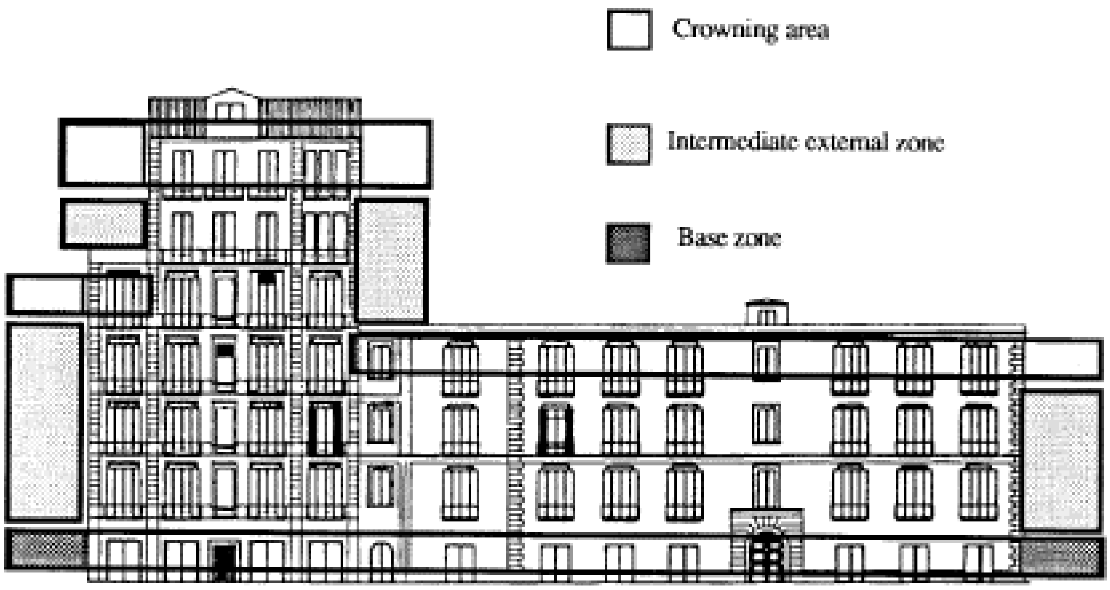
3.1.Observation regarding access water diagnosis
3.2.Phenomena relief
3.3 Grafic localisation ih phenomena
3.4.Ways of recognising the various effects

THE MODEL BUILDING IN THE EXPERT SYSTEM

4 

4.1.The building as a system
4.2.Subdivision of the building according to the Expert System
4.3.Case history of the building
4.4.Modifications over time of visible phenomena
4.5.Syntesis on the state of degradation of the building

FIG. 6 *General index of the manual for expert system students*



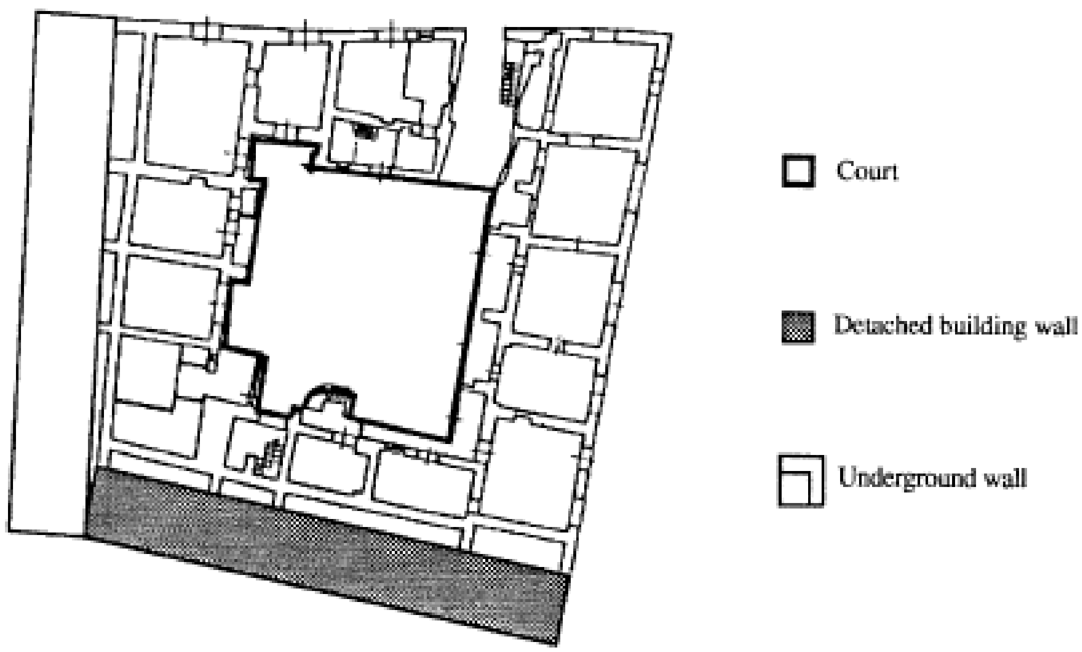


FIG.7 Subdivision of the building according to the Expert System

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