State of the Art Report (Position Paper)

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1. DIAGNOSIS

Borrowed from the medical sciences, the term *diagnosis* (gr. *diagnosis,* a distinguishing; from dia & gnosis: *dia-*, through, across; *-gnosis,* knowledge, recognition) denominates the *'judgement through which a phenomenon is generally defined, by analysing its symptoms and the aspects in which it is manifest'.* [1]

Like in medicine, in the case of existing buildings making a correct diagnosis is an essential condition for choosing the best treatment able to ensure the 'health' of the 'patient'.

Aiming to assess the nature of a disease, the diagnosis does based on *'a complex of doctrines and manual, instrumental and laboratory techniques'* [2] which constitute *the 'diagnostics'.*

In medicine, but also in building conservation, modern diagnostics combines the information on the patient's health history ('anamnesis'), a physical examination, laboratory analyses and radiological examinations.

Some 'diseases' are fairly easy to identify by appearance. Other problems are often suspected on the basis of symptoms and confirmed by instrumental observation; with many symptoms, however, more complex testing is needed. Laboratory tests are becoming more important in diagnostics. Many 'diseases' are difficult to diagnose because they may have many causes. Some 'diseases' can be identified with certainty only after a rather long time of observing the 'patient's' symptoms. To sharpen their diagnostic skills, various 'medical' professionals have to hold conferences to discuss difficult cases.

Assumed by the construction field, the diagnosis concept can be referred to different integration levels of built systems (from territory, to single building, its component parts and its materials). For each level of integration, the diagnosis acquires different roles and significance, uses specific methods and gives various categories of assessments, which integrates each other.

In the construction field, the diagnosis concept was initially associated to the examination of the structural damages and the assessment of the safety level of an existing building. Lately the diagnosis concept has been extended to the general valuation of the performances offered by the building.

For certain performances (by 'tradition' those related to the seismic safety) the diagnostics methods are currently used in Romania (the structural diagnosis is imposed by Law for any intervention on existing buildings). But rather frequently this kind of diagnosis is taxed by minimising the role of instrumental analyses and by the low technical level characterising the non-destructive analyses area - especially important in the case of historic monuments.

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[1] Dizionario Enciclopedico Italiano, Roma 1980.

[2] Dizionario Enciclopedico Italiano, Roma 1980.

For some other diagnostic aspects, concerning other categories of performances, such as masonry dampness and space hygiene, the diagnostics methods are not very well known and the utility of instrumental measurements is practically ignored.

The 'chronic' humidity and the consequent pathology are very frequent in old buildings, either ordinary houses or historic monuments. Many interventions on existing buildings pointed out failures in dampness treatment. The causes are to be looked for in the fortuitous choice and wrong use of materials and products offered by the construction market, but first of all in the total neglect of the diagnostics aspects.

As Massari says, in dampness problems of old buildings *'non fidarsi del buon senso - l'umidita' si misura'* [1] (don't trust in common sense - the humidity has to be measured). *'Very often the real cures, able to eliminate the cause of dampness, are non-intuitive, hidden to our instinct and specially to our common sense. (...) The affirmation 'damp space' is permanently made without a reference scale, so that the adjective is equally valid for all spaces and all masonry with moisture: it is like being content with knowing that the patient has fever, without being preoccupied by the degrees'.* [2] In medicine, but also in the case of dampness 'sick' construction, this means not having the exactly dimension of the phenomenon's gravity.

Rather easy to be made, the quantitative assessment of the humidity contained in masonry allows to the valuation of the space hygiene. Such data make also possible the deduction of the water distribution in constructive components and the correct identification of its *origin*, strictly necessary for an effective healing treatment. Unfortunately this kind of diagnostics are not usually made in Romania. Sometimes quantitative determinations of material moisture are made (by 'in site' investigations or by laboratory analyses) for *local* diagnostics related to the conservation of frescoes. But there is no usual practice of making measurements and interpreting such information in a *general* diagnosis of the building aiming to establish (and eliminate) the causes of the dampness by an integrative holistic approach.

So, we consider that in Romania the dampness diagnosis needs a peculiar methodological approach and some efforts for implementing it in the more general practice of building rehabilitation.

We think that this above mentioned problem is only a particular reflex of the more general habitude to pay attention only to certain *punctual* aspects, without having an overall image on the 'patient'. In restoration is often manifested a certain tendency of neglecting the complexity of an historic building. Frequently it is considered only an inherited 'image' to be conserved, ignoring its qualities as complex environmental control system. Frequently the technological characteristics of the historic building are minimised and so is the role of a *general* diagnosis. The vicious communication between professionals of different scientific areas is evident.

Generally speaking, the diagnosis of an historic building implies the integration of many specific information and assessments, different as nature and structure; this situation creates in practice some real difficulties in obtaining and interpreting the data, which are not to be ignored, but solved.

The more complex is the hypothesis and/or more thoroughgoing the diagnostics, the more evident is the necessity to resort to various experts in peculiar problems (as physicists, chemists, biologists, geologists, etc). In this case, as well as always when different specialists make specific diagnoses (on structural safety, dampness, hygro-thermal comfort, degradation of frescoes, etc), a good co-ordination is requested, based on an overall view of the problems. For this reason, as for ensuring the correlation between diagnosis and project, it is to be expected that the diagnosis would be made, co-ordinate or at least directly surveyed by the project manager, generally an

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[1] MASSARI, Giovanni e Ippolito, *Risanamento dei locali umidi*. Hoepli, Milano 1992

[2] MASSARI, Giovanni e Ippolito, *Risanamento dei locali umidi*. Hoepli, Milano 1992

architect. In any case, this one has the specific task to interpret all the gathered data and that's why he should have general knowledge on all the aspects directly or indirectly involved by the general diagnosis of the building to be stated.

Conservation work is multidisciplinary, involving many specific skills. As B. Feilden says, *'the architect has a role similar to that of the conductor of an orchestra. (...) As in medicine the needs of the patient must come first and the architect should not hesitate to obtain second opinions when necessary and should have the right to receive scientific support. All practical alternatives should be explored and then evaluated in the light of theory in order to find the 'least bad' solution, which must respect the qualities in the historic building'.* [1]

In this order of thinking, the Romanian architectural high education system includes some technical disciplines studding the diagnosis methodology and technology, with regard to various specialised aspects; some of them are rather detailed presented (as the structural safety diagnosis, or the dampness diagnosis).[2] Various types of instrumental analyses (used in Romania and in the world) are presented in a general *theoretical* manner. Unfortunately there is no technical possibility to make practical exercises with the students in architecture (we don't have the necessary didactic equipment and laboratory) and nor the opportunities for interdisciplinary didactic work in diagnosis field.

We are thinking to the possibility of creating an academic multidisciplinary laboratory, by the co-operation of various interested Faculties. Such a laboratory could allow some practical exercises with the students of the mentioned technological disciplines (and others) and could also bring together in common practical works post-graduated students of various professional profiles willing to specialise in diagnostics of historic buildings.

2. DIAGNOSTICS OF HISTORIC MATERIALS

The methodology of diagnosis is generally based on *visual inspections* of the building, which leads to *specific investigations*.

The symptoms of physical decay visible on the surfaces in contact with the external agents, are the first sign of a 'disease'. Some of these symptoms are referring to sub-systems and technological units of the building (lack of some components, discontinuities, dysfunction and flaws), others are directly referring to the quality of the component materials. Most frequently the symptoms of the first category are accompanied by *component materials decay*.

The decay of any component material has various evolutions in time, according to the relationship between its properties, on one hand, and the nature, the intensity and the frequency of the decay agent's action, on the other hand.

The phenomenology of materials decay is very extended, very complex, and partially unexplored yet. Under these circumstances, the thorough knowledge and the detailed description of the decay process is not very easy, even in the case of ordinary materials. The most 'uncovered' is the field of the natural and handicraft historic materials for which the traditional receipts and skills has been lost in time.

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[1] FEILDEN, B.M., *Conservation of Historic Buildings.* Architectural Press, Oxford, 1996.

[2] For example, at the University of Architecture and Urban Planning 'Ion Mincu' in Bucharest (the oldest and the biggest 'school' of architecture in Romania) are activated optional disciplines as: History of Building Techniques, Technology of Building Rehabilitation, Techniques of Restoration, Structural Restoration. Such disciplines are referring to historic materials properties, decay phenomena, diagnosis methods and compatible treatments. At UAUIM is also available a Master degree course in Building Rehabilitation, focusing on technological aspects in the area.

So, in diagnostic context, we can distinguish two large categories of laboratory determinations concerning the historic materials:

- investigations on the properties of the historic component materials - important to understand the essence of the manifest decay process (and also useful for verifying the compatibility of the conservative treatment);
- investigations aiming to assess the materials decay.

Both these two categories of determinations are using various types of 'in situ' and laboratory investigations (physical, chemical, mechanical, mineralogical, biological, etc).

Without pretending to be exhaustive, in APPENDIX a synthetic report presents the main types of experimental investigations made in Romania; the report is based on information gathered from laboratories and experts well known in the Romanian restoration practice, so it could be considered rather relevant.

3. CONCLUSIONS

Focusing on the 'hot points', we can make the following assessments, mainly based on personal observations and opinions. These assessments are also meant to suggest **possible co-operation programs.**

3.1. The general level of theoretical activities (pointed out by studies, methodological researches and the high education system) is much superior than the practical possibilities in diagnostics area.

3.2. The research on historic materials and techniques is disadvantaged by the low national state financing, despite the existing intellectual potential and the interest in the field. International programs of research in the field should be considered as a possibility; we have in attention such programs aiming to point out local specific aspects (at 'euro-regions' level) and to join together countries with similar problems (as seismic risk and traditional techniques for its prevention).

3.3. The best represented field of instrumental analyses concerns the 'artistic components' and especially the restoration of frescoes (obviously related to the grate number of orthodox churches always painted in interior and the exceptionally valuable heritage of churches with external frescos in North Moldavia.

3.4. The scantiest field of diagnosis based on instrumental analyses concerns the old masonry's dampness, despite the great number of buildings - monuments and ordinary houses - affected by various pathologies associated to the presence of moisture. The danger of empirical interventions is evident: many available modern materials and products efficiently marketed by advertising are meeting the lack of scientific criteria in decisions.

3.5. We don't have any information about some Romanian experimental research concerning the behaviour of traditional materials in condition of moisture; such investigations could lead to practical conclusions useful for the effective drying of moist masonry, considering local material characteristics and environmental conditions.

3.6. Certain methodological and technical deficiencies are observed in the field of structural diagnosis, extremely important in a high seismic area like the Romanian territory, but also very delicate to operate in the case of historic buildings. From methodological point of view, the necessity of experimental assessment of historic material characteristics 'case by case' is not always taken in consideration. The techniques used in experimental analysis are not up-to-date and destructive methods are prevailing.

3.7. The laboratories, the technicians and the equipment are not sufficient and generally not up-to-date from technical point of view (except few cases). There is also a sort of professional 'isolation' concentrated on specific problems and a lack of communication between various technical competencies that normally should co-operate.

3.8. There is not any national specialised publication able to gather and to supply scientific information on historic materials and their diagnostics, such as research results, new techniques, etc. May be a specialised web-site could be in attention.

3.9. There is no system of 'testing' and 'certifying' the quality of materials and techniques according to the restoration principle of compatibility with the historic substance; such a practice would be able to ensure efficiency for treatments, rational investments and could prevent irreversible material loss in cultural heritage.

3.10. The Universities (first of all those of Architecture, Art and Civil Engineering) and especially the Post Graduated Specialisation Schools, have an essential role in implementing new diagnosis methodologies in accordance with the international practice. They also have the important mission to educate the future specialists in the spirit of a multidisciplinary teamwork. An academic laboratory could join in common practical works post-graduated students of various professional profiles (architects, engineers, artists, physicists, chemists, geologist, biologists, etc) interested in diagnostics of historic buildings. This could be a form of interdisciplinary post-graduated specialisation in diagnosis of historic buildings, based on common interest of various professionals and integrative change of information between complementary disciplines. An international construction of such a project, would be a benefit by allowing transfer of technology, knowledge and practical experience.

Appendix

INVESTIGATION METHODS

1. LABORATORY INVESTIGATIONS (ON SAMPLES)

1.1 CHEMICAL AND PHYSIC-CHEMICAL ANALYSES

- CHEMICAL ANALYSES on medium sample and on soluble/insoluble fractions (classical determination of elementary/oxidative chemical composition of historic materials and chemical decay products)
- X-RAY FLUORESCENCE SPECTRAL ANALYSES (for corrosion products composition, mineral pigments composition, inner structure of building materials, etc)
- CATHODE-LUMINESCENCE (for mineralogical composition of rocks, ores and mineral artefacts)
- X-RAY DIFFRACTION ANALYSES (for mineralogical composition of rocks, ores and mineral artefacts with crystalline structure; corrosion products composition, mineral pigments composition, inner structure of building materials, etc)
- THERMAL NON-ISOTHERM ANALYSES ATD, TG, DTG (to identify and quantify the presence of thermal effects and mass loss, by worming up the sample)
- SPECTRAL ANALYSES OF MOLECULAR VIBRATION BANDS IN INFRARED (pointing out specific bands for certain molecular groups in the structure of the decay products)
- EDS ELECTRON MICROPROBE CHEMICAL ANALYSIS (giving the punctual chemical composition at micro-structural level of rocks, ores and mineral artefacts, etc)
- EDX (for corrosion products composition, mineral pigments composition, etc)
- PIXE ELECTRON EMISSIOGRAPHY (for mineral pigments composition, etc)
- X-RAY 20/200KV (for internal structure of objects)
- OPTICAL MICROSCOPY (for petrographyc analyses of rocks, ores and mineral artefacts)
- ELECTRONIC MICROSCOPY WITH SWEEPING
- POLARISED LIGHT MICROSCOPY + MICROSCOPIC PHOTOGRAPHY (for mineralogical composition of rocks, ores and mineral artefacts; stratigraphic composition of picture layers and mortars, etc)

1.2 MECHANICAL AND PHYSIC-MECHANICAL TESTS

- *compressive strength* (by standard procedure)
- *bending tension strength* (by standard procedure)
- *frost-defrost resistance* (by standard procedure)
- *water absorption* (by standard procedure)

1.3 BIOLOGICAL ANALYSES

1.3.1. BIODEGRADATION OF MATERIALS (biological depots on wall paintings, plasters, stone, etc; biodegradation of wood)

- optical microscopy of samples, cultivation on culture media, identification of isolated agents, microscopic photography

1.3.2. BIOLOGICAL ENVIRONMENTAL POLLUTION

- with sterilised Petri recipients containing culture medium

1.4 QUANTITATIVE DETERMINATION OF MATERIALS MOISTURE

- gravimetric analyses

2. 'IN SITU' INVESTIGATIONS

2.1 DETERMINATION OF STRUCTURE'S NON-HOMOGENEITY

- *ultrasonic method* (for pointing out non-homogeneous structures or hidden degradations as fissures, cracks, etc)
- *thermography* (temperature maps indicating non-homogeneous structures)

2.2 DETERMINATION OF COMPRESSIVE STRENGTH

- sclerometer methode

2.3 ADHERENCE TESTS ON PAINT LAYERS

- visual inspection and acoustic tests
- *visual inspection in normal and tangential light*
- *local superficial cleaning and contact tests*

2.4 STRATIGRAPHIC INVESTIGATIONS ON PAINT LAYERS

- *mechanical methods* (delimitation of investigation area by incision; splitting of the area in stages and consecutive removing of overlapping layers)
- *chemical methods* (with Arbocel or Sepiolite type compresses)

2.5 QUANTITATIVE DETERMINATION OF MATERIALS HUMIDITY

- *superficial electric measurements* (based on electric conductivity variation)
- *calibrated electronic measurements*

2.6 DETERMINATION OF MOISTURE LEVEL AND DISTRIBUTION

- *termography* (for moisture map of constructive parts)

2.7 MONITORING OF ENVIRONMENTAL CONDITION

- *electronic digital equipment* (for relative humidity and temperature of the air)
- *termography* (temperature map of an homogenous structure indicating variations of environmental conditions, such as stratification of internal air)