Paper 590: Environmental quality of materials: software tools of pertaining to architectural quality

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Abstract

Our work deals with the environmental quality of materials in the architectural design process. We focus on design tools related to the choice of materials, and their process of implementation.

At first, we present different types of design tools dedicated to architects. We then propose a criticism of current tools and their ability to be integrated into the design-process of building. We discuss the high levels of expertise required for their use. We point out the difficulty of collecting data on materials due to lack of information. We discuss the nature (volumes and mass of materials) of the data needed to evaluate the energy and carbon footprint of a building (informations known only at the end of the design process, when it is far too late to modify the founding choices of the design).

Then the global viewpoint of designers is discussed (aesthetic effects of materiality, cost of supply and setting work, impacts on comfort and consumption of the building, impacts on health…) and therefore, the energy and carbon footprint in the design process is of less importance.

Lastly, we propose various tracks for the development of basic design tools, which validate the main trends during the first steps of the design process. We point out the interest of orientating designers from the very beginning of the design process. We propose to modify the kind of input data required for future design tools on materials, by thinking of architectural devices (type of wall, of roof…) rather than of detailed volumes or weight of materials. In order to easily release a global and transverse view on the architectural quality of their projects, we propose a reduced number of architectural and environmental markers related to the choice of materials usually expected by designers.

Keywords: design tools, design process, material, process of implementation, environment

1. Introduction

Our work deals with the environmental quality of materials in the process of architectural design. We focus on tools related to the choice of materials and the processes of implementation. These tools are more recent in the world of environmental architecture than those dedicated to energetic and comfort. Tools on materials have changed drastically these last years, and particularly computer software.

Starting from a scope of existing tools that influences the choice of materials, we carried out discussions with specialists experienced in environmental architecture. These discussions led to various orientations likely to make future tools more operational in combining architectural quality and environmental quality.

2. Phases of our work

In the first stage of our study, we report on the various types of tools likely to help designers in architecture.

We then discuss their capacity to be integrated into the processes of architectural design.

This phase of identification, then of criticism of existing tools, is based on discussions carried out with about 20 specialists experienced on environmental questions. Half of them are specialized on materials. They work in engineering design offices, architecture and town planning companies.

Also, the structure of this work is based on the experience of teachers and researchers involved in the “Master of Advanced Studies en Architecture et Développement Durable” (ENSA de Toulouse-France, EPFL-Switzerland and UCL-Belgium).

In the second part, we expose various tracks for the development of future simplified tools. These tools aim at pragmatic information on the environmental quality of materials starting from the programming, through the start of the very first draft, in order to lead the various actors throughout the process of design.

We conclude by illustrating characteristics of future tools likely to better and better accompany

the various stages of architectural and urban design.

3. Design tools

We distinguish three main families of tools likely to help designers on the impact of materials and their implementation within a project:

- Database type tool,
- Tools of quantification, of a building impact,
- Tools tempting to integrate questions of material's choice by combining them with other environmental questionings.

3.1 Database type tool

There are quite a number of databases. We distinguish two main families:

- Those aiming to quantify the environmental impacts of construction materials,
- Those that mix aesthetic qualities of selected materials with simplified environmental indices.

Quantification of the impacts

All databases on environmental impacts have a similar way of operating. They deliver a large variety of mechanical, chemical, energy information… This information is mainly reported to ratios per weight or volume of material. The delivered information is given in a quantitative way on the energy impact, the carbon impact, the pollution of the manufacturing process, the health of the inhabitants… Their classification is generally ordered according to the destination of the considered material: foundation, structure, partition, roof, opening…

We note that the majority of experts approached during discussions, develop their own databases. These databases are developed in an isolated manner, based on computation software's like spreadsheets (Fig. 1).

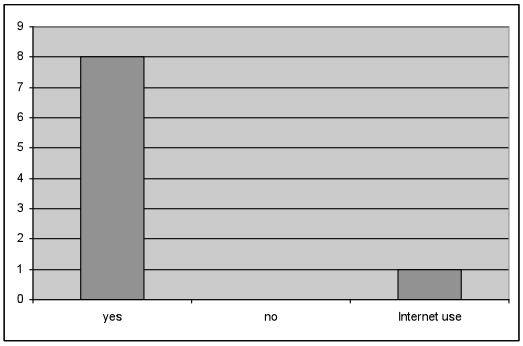

Fig 1. Synthesis of discussions with experts: question of the development of a personal database on materials

We can also identify collective databases developed within the framework of regional, national or international projects. As an example, we can quote the French database named Inies [1].

Databases on the environmental impact of materials are essential to the future of building's environmental quality. However, to date, they question on various points:

- The choice of a material for a partition, a structure, an opening… generally implies choosing complex devices made of various materials whose weights or volumes are difficult to estimate; ratios per weight or volume of materials constitute an information that is not in line with current questions of architectural design,
- From one database to another, the given indices or ratios generally deliver information on a small portion of materials available on the market… Very often, these databases remain to be fed,
- The validity of data from the various identified databases is not always explicit. Whenever we are informed of which method of measurement has been used, we often note that the same index, from one database to another, does not mean the same information,
- The source of the data of certain databases are not completely objective, particularly when they are directly indicated, without external control, by the material manufacturers themselves; it is for example the case of the French « cards of environmental and medical declaration » developed (FDES for « fiches de déclaration environnementale et sanitaire »).

Aesthetic qualities of materials

During our discussions with materials' specialists, another type of databases came as a surprise: those on aesthetic qualities of materials. They inform about the material aspect, about the effects of materiality.

These databases rest on a number of descriptive images and terms, as well as a few environmental, economic and constructive ratios. The images are photographs from projects of reference, close-ups of materials, construction details.

Many of these databases are developed individually, mainly in on a very small scale, within architecture companies. Some of them have been carried out collectively, in order to be diffused. It is the case, for example, of ArchINFORM [10], an international database classifying the architectures according to their name, their location and key words such as architectural materials or devices.

3.2 Environmental impact tools

The main objective of the quantification tools of the environmental impact of a building is to exploit more easily the data contained in the databases seen previously. Instead of reasoning by weight or volumes of materials, they use by architectural devices. These devices are themselves made of numerous materials.

There are very few tools dealing with the environmental impact of a building. They are primarily directed towards the quantification of environmental impacts of materials. Joint information of various impacts allows widening the vision of designers on the general impact of a studied building.
The use of these tools very often consists in minimizing the impact of architecture at various stages. Several material solutions are tested gradually, and then compared.

As examples, we can quote the tools Elodie [3] set up by the CSTB (Centre Scientifique et Technique du Bâtiment, France) or even the module of environmental analysis Equer [4] of the « École des Mines de Paris » and the Izuba Company.

These tools still remain confidential. They are not very much in use within the architectural community, if sometimes by experts leading missions of environmental assistance and technical council. Various questionings can explain the lack of interest towards these tools:

- They are often in development phase ,
- They depend on the very quality of the databases (see part 3.1) to which they refer. They also suffer from the lack of reliable and comparable data,
- They deliver quantified information whose comprehension requires a high level of expertise on the environmental impacts of the buildings. This way, this information happens to be difficult to interpret for the majority of the designers in terms of architectural choices,
- They do not crosscheck quantified information that they deliver with information essential to designers, such as the aesthetic effects, the cost or the technique of implementation on building site.

3.3 Tools combining materials and other environmental issues

With the aim of having a more global look on the environmental quality of the buildings, we distinguish, as well, tools that combine materials with other environmental fields (energy, thermal comfort, light…).

This type of tool is rare. The most famous is the software Ecotect [5]. These are tools, which are based on a computerized modeling of a building in three dimensions. Once the building is drawn precisely in 3 dimensions, one is informed by graphs of its environmental performances (daylight factors, heat balance in steady state, energy footprint, carbon footprint…).

The pedagogical interest of this type of tool is undeniable: one has to assimilate a great number of concepts, and at the same time, this type of tool establishes a connection between the design of a project and certain environmental impacts, including those related to materials. From the point of view of their interest in operational activities of architectural design, we find at least two current limits to their use:

- They require high levels of expertise on a great number of environmental matters that very few designers hold. The delivered information requires the understanding of the concerned physical units, and of their interpretation in terms of architectural choices,
- These tools require to model in three dimensions the architectural project under study. This implies to know precisely its location, volumetry, structure, openings… These various choices are generally carried out in an advanced phase of the process of design, that is to say at a point in time when one does not have time to reconsider the founding choices of the conception, (the start of the first draft). It is however with the start of the first draft that the majority of the choices inherent in the architectural quality of a project are decided.

4. Ability of current tools to be integrated into design processes

We now observe the role of tools considering their capacity to be integrated into the processes of architectural and urban design. This leads us to tackle questions like the level of expertise required by the user, the collection of data about materials, the respect of phases of the design process and finally the need, for the sake of architectural quality, to reveal the designers' overall view.

4.1 Level of expertise required

The question of materials and their processes of implementation is tackled primarily in three types of books:

- The « Mémento » (memorandum) of Y. Couasnet [6]: a strictly technical book and understandable by qualified experts in this field. These works develop the technical side of materials and decline, in most of the cases, the characteristics of each material considered,
- The book of S. & P. Déoux on health [7] : works that detail a precise aspect of the question of materials,
- The handbook of Ademe [8] or one of the works of D. Gauzin-Muller [9]: works of sensibilisation on materials through an environmental approach.

The assimilation of this knowledge requires a high level of expertise. Therefore, data on environmental impact of a material proved far too complex for a non-expert to evaluate, and consequently to be taken into account for choices of design.

This limit to the use of existing knowledge on materials may be extended to various fields of building's environmental quality. Specialised tools (lighting, acoustics, thermics…) initially aim to

experts in each field. A non-informed person may encounter difficulties to analyse their results. As a consequence, a large majority of designers, including technicians, cannot take the most reliable and optimal decisions … except in the rare cases where they can afford being surrounded by experts.

4.2 Collection of data on materials

To date, physical aspects of materials and constructive systems are relatively well known and reliable for most of the studied criteria. Next to this, some data is missing, for instance, on the ageing of materials.

From an economic and political standpoint, the question of the collection of homogeneous and objective data about various materials is more critical. Consequently, databases nowadays are very shallow and their information incomplete.
Concerning environmental aspects, data are based, in their majority, on the analysis of life cycle of materials and devices. In France, this information is proposed and diffused by the means of cards of environmental and medical declaration (FDES). The limit of this system is that these cards are optional and produced on a self-declared basis, that is to say declared by the manufacturer of the material. It is then necessary to be cautious on the method that has been selected for the evaluation. For example, one may observe important differences between two databases (Switz and French) on the same material. Moreover, according to the type of product, certain data are never indicated. Other data are informed but seem sometimes improbable.

Economic aspects of materials are difficult to take into account because they are subject to exogenous factors like area, implementation, fluctuation of raw materials, inflation, etc.

Lastly, collection of data on materials raises the question of their regular updating.

4.3 Respect of the design process phases

Current knowledge and tools are based above all on precise quantities of materials that are being used.

This requires, in a situation of project, to be in an advanced phase of the design process, in order to be able to characterise the architectural proposal. Therefore, the tendency is that designers will be informed of the environmental impact of materials only at the very last stages of the project.

In other words, most of today's' knowledge and tools allow to note environmental characteristics of materials at a stage where it is generally far too late to reconsider the initial choices of the first draft.

Vis-à-vis that, certain tools under development, of which Elodie [3], announce reasoning in "distance of frontage" starting from the simplified choice of a selected material combination. This evolution of the tools seems interesting to allow a simplification of the input data that is informed by designers.

4.4 Global outlook needed in architecture

Most of today's knowledge and tools with regard to the environmental quality of materials, concentrate on the energy or the carbon footprint. These fields of studies are important from the point of view of ecology, but often appear anecdotic to the eyes of architectural projects' designers, when they have to select materials and processes of implementation.

Indeed, as far as architecture is concerned, it is essential to have a more global outlook when it comes to the choice of materials: aesthetic effects of materiality, cost of supply and implementation, impacts on comfort and consumption of the building, impacts on health… The fact of tackling exclusively environmental questions is anecdotic and reducing vis-à-vis the complexity of the design process. In order to answer designers'expectations but also not to minimise the architectural quality, the process of architectural project integrates a multidisciplinary approach
Concerning the question of materials and processes of implementation, it comes out from our discussions with architects, that for a vast majority of them, there is no dominating criterion to help with the choices of materials and constructive systems. Indeed, this choice is done according to the project, the site and the whole of the following criteria (non-exhaustive list): esthetics, materiality, economic, environmental, technicality, durability, thermal, acoustic performances.

Therefore, it is necessary to propose a set of tools that will help to get a global vision with regard to the choice of material. All the same, designers should balance such or such criterion according to their main concerns. In doing so, the whole set of data will be taken into account. Designers are responsible for criteria that they choose to balance, according to the context of their projects and their sensitivities.

5. Conclusion: various tracks for future tools

We conclude by recapitulating various tracks for the development of innovating tools on the environmental quality of materials.

The setting of this type of tools takes the advantages of existing tools while improving their limits, as previously evoked.

5.1 An objective: steering designers as of the first draft

The question of materials and processes of implementation intervenes throughout the

process of the project, but in a various ways. As from the phases of programming, this field of studies is taken into account in the form of councils or of reflection tracks. At later phases of the draft, details are set up. Throughout the building process, changes, modifications, improvements can be operated, mainly following the proposals made by the contractors. Lastly, questions regarding materials and constructive systems also intervene when the building is being used, particularly through upkeep and maintenance, but also at the end-of-life of the building, during its destruction.

Our discussions with specialists in environmental architecture clearly validated that crucial choices are taken into account as of the very first phases of the project, during the draft phase, whatever the project, the site and the work method used by designers.

It is thus paramount to target this phase of the draft for developing future tools, so that designers' choices gain in effectiveness. This would allow sticking to choices easier to optimize at the later phases of the project.

5.2 Evolution of the nature of the requested input data

As we noticed previously, we remain to date on knowledge and tools that sanction or validate a relatively achieved architectural proposal.

Data to be fed in order to make tools operational are precise quantities of weight or volumes of materials. At this point in time, this means dealing with an already much detailed phase of the projects' conception. Owing to the cost of the design engineering, the phases are far too advanced to allow a reconsideration of the architectural concept of the project that was decided during the early stages of the first draft.

During our talks, we noted that architectural designers do not think in terms of materials, but rather of devices i.e., an assembly, a placement of several materials which form an envelope of frontage, a roof, a floor, etc.

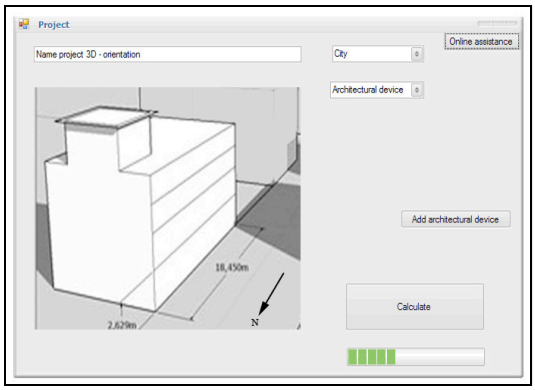

Fig 2. Illustration of an interface (project in progress) that aims at choosing in a rough way architectural device during the phase of first draft

In this logic of steering more efficiently the choice of designers, it would be interesting to develop tools where one can roughly indicates types of architectural devices: foundations, structures, partitions, envelope, openings, roofs. The idea would be to compare the impacts of these various choices as from the very start of the draft, i.e. without going into any constructive detail. In doing so, design of the projects would be based on choices easier to optimize during the later phases of the project's process.

We currently work on the installation of such an interface (Figure 2). This tendency is also under development with some tools of quantification of the impact of a building, such as the Elodie software, which attempts to follow this logic.

5.3 Helping to release a comprehensive view of the project

In a design phase, designers tackle the question of materials by combining simultaneously their constructive, environmental, aesthetic, economic, energy and normative aspects.

In order not to add complexity to the steps of the designers, and to simplify exchanges between them, it is interesting to reduce the number of architectural and environmental markers related to materials and devices of construction.

This reduction of markers must at the same time allow determining a whole set of criteria belonging to the environmental quality of materials selected.

Following a broad research on our subject, we gradually set up a structure in 3 levels which, to date, reduces the global vision on the quality of materials to 7 criteria (Figure 3).

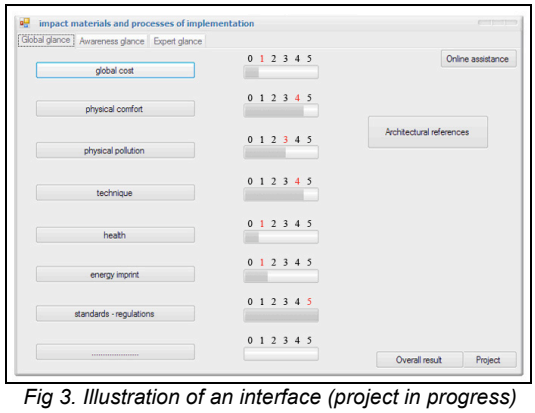

Fig 3. Illustration of an interface (project in progress) which proposes a speed reading and synthetic of the environmental quality of materials retained in the design of a project, according to 7 criteria

Each of the 7 criteria is declined under different sub-criteria, which are declined in indices. In doing so and according to the user's level of expertise, it is possible to benefit from an increasingly precise and complete approach.

5.4 Ease the comprehension and the training of non-experts

In addition to the structuring of the criteria that represent the environmental quality of materials chosen, it is important to ease the comprehension and the training of non-experts.

As indicated on figures 3 and 4, we propose a breakdown in three increasingly complex degrees of comprehension: from global vision, to awareness, to expert outlook. This breakdown is likely to help designers with their training on the environmental impact of materials.

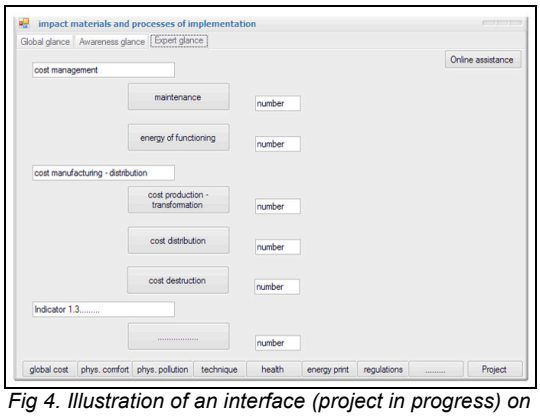

Fig 4. Illustration of an interface (project in progress) on the environmental quality of materials retained in the design of a project, according to 3 degrees of expertise.

5.5 Gathering of data on the environmental impacts of materials

As a conclusion, we come back to a crucial question about tools dedicated to the environmental quality of materials: the production of a homogeneous and reliable database.

This question is forced by political and economic tensions and will, no doubt, not evolve easily.

As far as we are concerned, we have established a database on materials that is as exhaustive as possible. It gathers information coming from various sources: Inies (FDES) [1], Ademe [10], Wufi [11], CTSB (RT2005) [12], works of Oliva [13, 14], Office of Swiss construction (KBOB) [16]… We will use it to feed the content of the innovating tool that we are trying to develop.

6. Acknowledgements

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