MATERIALS SELECTION IN A ECO-INDUSTRIAL PARK FOR AN ENVIRONMENTALLY-CONSCIOUS DESIGN

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KEY WORDS: Eco-town, Eco-design, LCA, materials selection

ABSTRACT

A project financed by the European Commission (CRAFT 1999-70125; 2001-2003) has as its objective the design of an Eco-Industrial Park (EIP) situated in a rural area in the North-West of Italy. Politecnico di Torino is one of the partners in the consortium and is charged with developing the analysis of the production processes of all materials involved in the construction of the campus with a LCA perspective, and classifying materials and design solutions from an eco-efficiency point of view. A first result of this stage is the availability of environmental life-cycle information about all materials which the designer of the campus intends to use. The LCA model of all technical solutions for campus construction is then used for the simulation step to provide the designer with a set of alternatives which have a lower impact to the environment.
The use of the Cambridge Engineering Selector (CES) software allows automation of this approach: CES is a toolkit for the evaluation and selection of materials and processes for engineering design developed at Cambridge University and Granta Design Ltd. (UK) to which LCA information has now been added to provide the designer with a standardised and automatic tool to select materials and processes on the basis of both technical and environmental properties.
In this paper these first steps of the project will be presented as well as preliminary results and next stages of the activity.

INTRODUCTION

The project "Optimisation of Resource use and waste Management in an Eco Industrial Park" (ORMA), financed by the European Commission for the period 2001-2003, aims to develop the concept of sustainable development in the construction and management of an Eco Industrial Park (EIP) in the northern part of Italy.
The choice of eco-efficient materials and technical solutions is the specific goal of the first part of the project that will be here briefly presented. The preliminary design of the eco-campus foresees the analysis of the production processes of all the materials involved from an environmental life cycle perspective and the classification of each candidate from an eco-efficiency point of view. All the main technical packages have been outlined in co-operation with the EIP designer in order to propose different sets of building materials which have the same function, thus allowing the designer to select from a number of environmentally-conscious alternatives. The point of the present paper is to move from the environmentally personal perception of the designer to the identification of objective information concerning eco-efficient material performance for the selected candidate materials and processes.
As a consequence of these activities, an Eco-design software tool has been generated on the basis of the Cambridge Engineering Selector (CES) system to provide designers with a standardised and automatic method of selecting materials and processes on the basis of their technical and environmental properties.

THE APPROACH TO THE PROJECT

Building materials initially chosen by the EIP designer have been catalogued and the LCA approach has supported the definition of a set of information cards ("LCA cards") describing the environmental burden in terms of energy and raw materials consumption as well as emissions to the environment from the cradle to the construction of the campus, transportation included.
The LCA cards have been organised in order to summarise the following information:

- **production process:** qualitative description of the system from raw materials extraction to construction operations, detailing system boundaries, functional unit and data quality. A flow chart of main operations is included and some hypotheses on end of life are proposed too;
- **main technical properties,** such as density [kg/m3], thickness [m], thermal conductance [also known as heat transfer coefficient, W/m^2°K], thermal conductivity [l, W/m°K], thermal resistance [R, m^2°K/W] and number of functional units per square meter or cubic meter.
- **environmental load** of the functional unit, in terms of gross energy consumption [MJ], gross raw materials consumption [kg], classified environmental effects (global warming, acidification, etc).

The organisation of this information was necessary to build a model of different possible solutions, the so-called technical packages, proposed by the designer. These technical packages represent the basis upon which it is possible to compare solutions from the point of view of environmental performance and to provide suggestions for the final choice, by means of a simulation stage. For instance, four different solutions for bearing walls have been proposed and analysed, each of them composed of different materials such as bricks, cement, insulation layer and so on. Technical solutions have been proposed also for floor (heavy), floor (light), roof covering and floor slabs as later described.

DATA ORIGIN AND INVENTORY PHASE

LCA cards are made up by primary and secondary data. Secondary data came from the Boustead Model data base, the Italian Data Base on LCA (I-LCA, developed by the Italian Environment Protection Agency - ANPA) and previous researches made at Politecnico di Torino. Regarding primary data, it is interesting to note that information about hard floor coverings production (ceramic tiles, concrete paving units, terrazzo tiles, agglomerated stones, clay tiles and natural stones) came from a European Commission recent project, regarding the development of a set of ecological criteria to award the Hard Floor Coverings (HFC) product group with the European Eco-label.

LCA results for the selected building materials are then included in the CES database and this stage allows integration of technical information about a material (such as Young's modulus, density, and so on, already included in CES database) with environmental life-cycle information. The CES software consists of graphical selection functionality and a material properties database. The database itself includes a full range of materials (ceramics, composites, metals, natural materials, polymers) and a range of mechanical, electrical, thermal and other properties. The inclusion of LCA information into CES led to the development of a database including environmental properties such as:

- Resource and consumption data: annual world production, reserves, average concentration in earth's crust / sea water, economic ore grade;
- Energy and emission data: production energy, recycling energy, energy to melt / vapourise / deform (ie different processing energies for polymers, ceramics, metals) , CO_2, NO_X, SO_X creation;
- End of life: recoverable energy, suitability for recycling, reuse, incineration, landfill
- Aggregated measures: EPS value and eco-indicator.

After the first year of activity within the ORMA project, some main aspects can be highlighted:

- Only a limited number of materials can be considered (at present, only those specified by the project architect, around fifty in number);
- Many environmental properties have been calculated and introduced into the CES database;
- Environmental properties are peculiar to the ORMA project (for example, they include transportation effects for each material to this particular location)

This data-gathering phase will result into a specific version of CES designed for the ORMA project, able to integrate environmental and design technical parameters in a simulation tool to optimise the selection of technical components with all the environmental life-cycle information about the considered materials.

The result of this activity will be an iterative selection of materials on the basis of their technical and environmental properties starting from any basic solutions presented by the campus architect.

In the following example it is possible to start to understand the way the initial Life Cycle Inventory results have been used for the simulation phase on selected technical solutions as aforementioned. To move from static LCA cards to a dynamic approach, a simulation of several technological solutions is to be performed for the eco-campus project and CES and the Boustead Model are to be used in parallel to each other. The external wall case hereafter described is an example of how this simulation phase has been developed.

THE EXTERNAL WALL CASE

The research activity (selection and simulation) has involved the analysis of technical data delivered by the designer of the campus. The following main technological components have been considered for the first stage of the simulation activity:

- external wall: 4 possible technical solutions;
- floor (heavy): 2 possible technical solutions;
- floor (light): 5 possible technical solutions;
- roof covering: 2 possible technical solutions;
- floor slab: 2 possible technical solutions.

In order to measure the environmental load of the different solutions proposed for each of the possible packages, which are intended to fulfil the same function, the LCA methodology is first applied to select the proposed solutions from an environmental point of view. LCA is then integrated with other considerations, such as economic ones, to suggest to the designer the best eco-compatible solution for campus construction. This approach is hereafter explained referring to a case-study, the external wall selection case.
The selection of the eco-compatible external wall started from the analysis of one of the solution proposed by the designer, made of the following components (Figure 1 in which are also specified the starting values of thickness for each layer):

1. an external stone wall gathered together by lime plaster (550 mm);
2. a cork panel as an insulation layer (50 mm, *l* = 0,04 W/m°K);
3. a wood grid to allow air circulation (30x30 mm and 40x50 mm);
4. an internal Gypsum panel (13 mm).

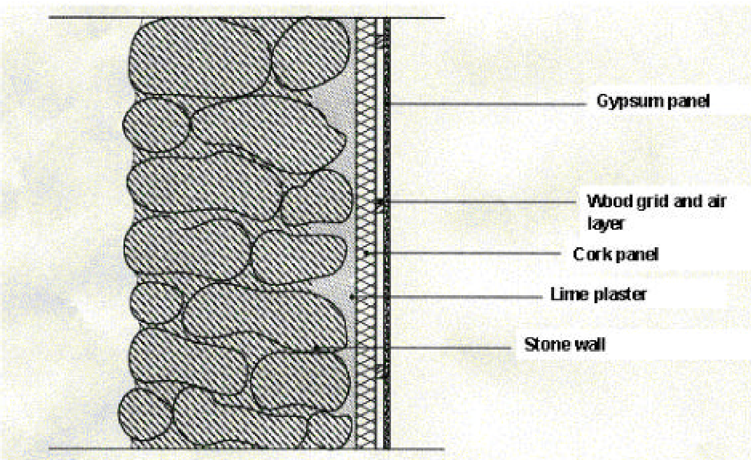

Figure 1 – The starting solution proposed for external wall.

Apart from consideration of the wall's static behaviour (in this context, no mention of mechanical performance of the wall is given) the main function here assumed for the external wall is its thermal insulation, which is measured by its thermal resistance *R*. Since the four alternative solutions proposed for this duty do not have the same initial thermal insulation factor, a first normalising step was to make them all comparable. Appropriate calculations have been performed to vary the insulation layer in order to obtain exactly the same value of thermal resistance. An *ad hoc* Excel model has been prepared to simplify the calculation procedure:

starting from the external wall basic configuration (as above reported, Figure 1) that has a thermal resistance *R* = 2,015 m^2°K/W and a *K* = 0.496 W/m^2°K, a new K_1 ("*Imposed K*") has been set at 0,4 W/m^2°K, which is the value used to compare the four solutions proposed for the external wall configuration. On the basis of this value, the new thickness of the insulation panel for each alternative solution was therefore calculated and the quantity (per m^2 of wall) necessary to obtain the appropriate K_1 (or R_1) obtained for each candidate material. These values were then used to integrate the EIP model into the Boustead Model to calculate the environmental load of the proposed solution.

The same problem can analysed from a different point of view: the calculated thermal resistance of the starting solution can be improved through the use of alternative materials. From this perspective, CES allows the user to rank materials on the basis of chosen properties, in this case thermal resistance. In the present example, the methodology highlights that a possible example of cork substitute is balsa wood, that has a thermal conductivity *l* = 0,03 W/m°K, is lighter and has a similar cost (around 10 Euros/kg). From an environmental point of view, the balsa choice is confirmed by the LCA analysis results; in Figure 2, for instance, the gross energy figure is presented divided in its main components (direct + indirect + feedstock energy).

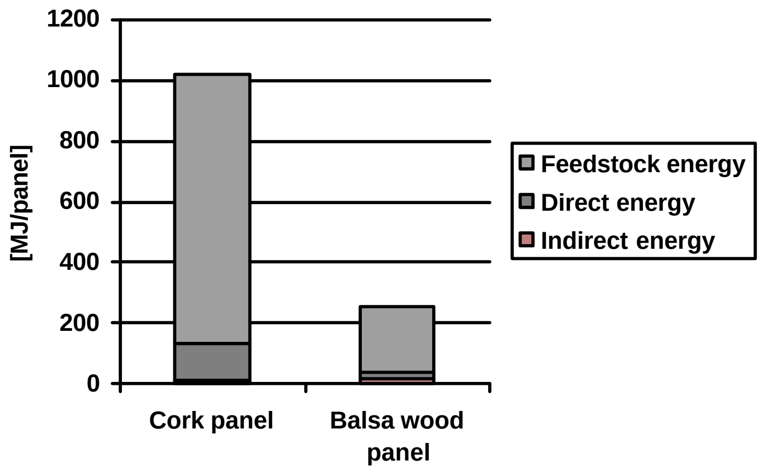

Figure 2 – Example of LCA results: gross energy for cork and balsa.

This method allows comparison between all the starting solutions proposed by the designer and the possibility to suggest other possible alternative materials to be used.

FINAL CONSIDERATIONS

The approach presented is now being used to develop an Eco-tool based on a "score method" which aims to evaluate the energy and environmental performances of technological components, in relation to a number of specific requirements.

In addition to environmental considerations, other factors influence the choice and suitability of different building choices. For example, the businesses units that are going to establish in the eco-park and their building constructors will be able to take into account the costs and building specifications associated with selecting environmentally friendly materials.

The LCA methodology together with the CES approach aims to analyse trade-offs between cost, performance and environmental-impact of the alternative solutions identified. Therefore physical and chemical characteristics, together with costs and materials environmental impacts will support the EIP design, allowing decisions to be made concerning the materials to be used during the construction of the industrial sites at the park.

REFERENCES

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