INDOOR PERFORMANCES OF LIVING WALL SYSTEMS: TOOLS AND REQUIREMENTS

Roberto Giordano, Elena Montacchini, Silvia Tedesco

Politecnico di Torino – Department of Architecture and Design – Viale Pier Andrea Mattioli, 39 – 10125 –Turin (TO), Italy

ABSTRACT

The benefits of the use of vegetation in indoor environment, and in particular the use of Living Wall Systems (LWSs), are demonstrated by the international scientific literature. Such benefits can be listed as follows: acoustic comfort, indoor air quality and dilution of pollutants, thermo hygrometric comfort, psycho-emotional well-being (improvement of cognitive skills, stress reduction, user satisfaction).

During the last years the LWS' spread is confirmed by the increasing number of building featured by vegetation both on façades and partitioning.

Despite their diffusion there is a lack of data concerning the LWS' indoor performances as well as on properties and featuring about materials and products they are made-up.

With regards to outlined constraints the paper deals with a research focused on studies and on an indoor LWS project. Two tools are described: the Indoor LWS' datasheet and the Indoor Agronomic database. Further a methodological approach concerning the technologies and the materials selection is also illustrated. Such approach was finally adopted in designing and prototyping an advanced indoor LWS.

The Indoor LWS' datasheet was developed in order give to designers and enterprises information concerning the indoor LWS' featuring with regards to those available on the construction market. Every datasheet was developed on a common format in order to make them comparable. The information refer to: general data (e.g. manufacturing site); technical performances (e.g. size, weight, use of environmentally friendly materials); indoor featuring (e.g. acoustic comfort, air quality and thermo-hygrometric comfort).

The Indoor Agronomic database was addressed to select proper species fit for indoor use. The database was divided in two parts: the former provides information about botanical aspects; the latter compares the plant species hygro-thermal comfort to human comfort. Such comparison was carried out by the adoption of bioclimatic Olgyay chart on humidity and temperature data.

The effectiveness of mentioned tools was confirmed in further research tasks. The information available were used to define a proper set of technological and agronomical requirements to be included in a new indoor LWS design. Indoor requirements were divided according to LWS life cycle. They were adopted in order to fulfil the largest numbers of indoor environmental goals.

Keywords: Living Wall Systems (LWS), indoor performances, environment requirements

INTRODUCTION

The international scientific research is now interested in studying the many ecological benefits of Living Wall Systems (LWSs): vegetated wall with plants on pre-assembled panels using a growing medium as root support. Such benefits can be listed as follows: heat island effect mitigation, noise pollution insulation, heating and cooling energy demand reduction, enhancement of urban biodiversity [1].

Recently to indoor LWSs have been recognized other functions summarised as follows:

- Air purification and absorption of particulate matters as well as of Volatile Organic Compounds (VOCs). Some plants have the ability to absorb from 50 to 90% of the polluting substances present in the air [2].
- Psycho-emotional well-being (improvement of cognitive skills, stress reduction, user satisfaction). Studies have shown that simply having a view of greenery increases workplace productivity and patient recovery rates in hospitals [3, 4].
- Acoustic comfort and noise reduction. The acoustic benefit derived from green walls varies according to their construction and level of vegetation cover. Substrate effectively reduces sound at low to middle frequencies. A relatively smaller reduction is achieved at higher frequencies due to the scattering effect of the foliage. As the level of vegetation cover increases, the sound absorption properties of a green wall also increase [5].

Finally vegetated surfaces are generally considered aesthetically pleasing.

During the last years, several indoor and outdoor LWS patents have been developed but much more for improving their performances might be done. Both the technological and the agronomic aspects such as the structure, the materials, the irrigation system, the choice of plants, and the substrate or growing medium, may be improved.

On the whole few studies focus their attention on materials used in LWS manufacturing as well as on materials connections and to those ecological requirements usually taken into account in an environmentally friendly design approach. Thus the research here presented was focused on indoor LWS featuring and it was a step in the direction of the development of a new sustainable and performing modular indoor LWS. The paper deal with the outcomes and the outlooks of a research methodology based on the following tasks: development of the Indoor LWS' datasheet and the Indoor Agronomic database. Environmental requirements have been identified and prototyping activities carried out in order to develop an advanced indoor LWS.

ANALYTICAL TOOLS

Indoor LWS' datasheet

The Indoor LWS' datasheet was developed to give to designers and enterprises information concerning the indoor LWS' featuring with regards to those available on the construction market.

In order to make possible a comparison among several indoor LWSs a format-datasheet was developed to collect a wide range of information. The datasheet is an informative tool by means of designers might be conscious about technological and environmental performances and they might select the right one according to the needs to be matched.

The datasheet was divided in two parts. The first one includes the technical and performance data, providing information about technical characteristics, materials and products performance. Such part may be assumed as the core of the datasheet. The second one contains general information related to architectural design solutions, executive drawings and pictures taken from selected buildings, useful for a better understanding of formal and morphological aspects.

According to the above remarks the technical data filling concerns the following records: sizing, weighting, water consumption, plant species, plants number per square meter, type of substrate. Records on the location were also included, providing information about the manufacturing site (Italy, Europe, non European Countries).

A checklist was developed encompassing a number of parameters commonly used in the design process. The parameters may be quantitative or qualitative. Records were implemented on the datasheet as follows:

- Materials record: description concerning the materials and product performances used in a LWS (e.g. the growing medium, the plants, the frameworks, the insulation and the finish work).
- Connections record: description concerning the system assembly (e.g. bolting, gluing, screwing, etc.).
- Indoor environmental performances record: description concerning the acoustic comfort, air quality and thermo-hygrometric comfort.

On the whole the total number of filled datasheets reached 20.

Figure 1 shows an example of datasheet implemented. Above the LWS' name and the corresponding code (a); (b). From the top left a summery of the LWS featuring (c), a table including the records used for gathering the technological data (d), detailed drawings, renders, pictures and photos of built projects are even included (e).

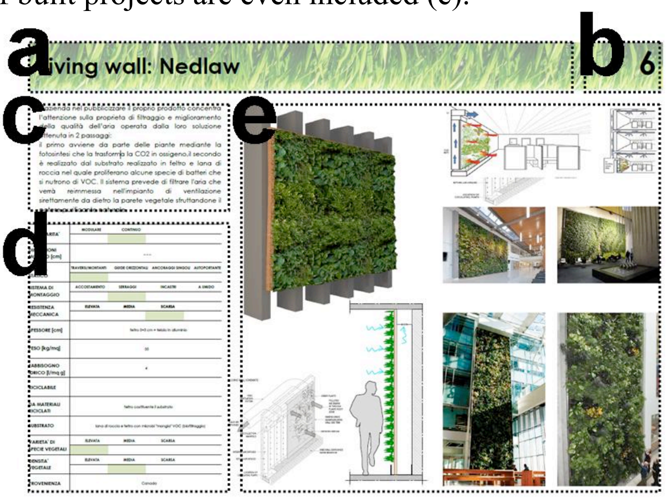

Figure 1: Example of Indoor LWS' datasheet: (a) product name and manufacturer; (b) progressive datasheet code number; (c) technology description; (d) performances assessment; (e) details and pictures.

Indoor Agronomic database

The Indoor Agronomic database was addressed to select proper species fit for indoor use and particularly for indoor living walls (based on available literature, internet sources, preview researches).

International research has clearly demonstrated that indoor plants can be used to reduce indoor concentrations of VOCs and CO_2, two classes of contaminants often in higher concentrations indoors than outside [6]. Two criteria were basically assumed for plants selection procedure:

- Plant species suitable for the indoor vertical installations.

- Plant species able to improve air quality.

The database was divided in: Part 1: botanical and ecological data; Part 2: hygro-thermal and comfort data. The former provides botanical data (e.g. species name, group and family, height, type, habit, leaf, root system) and ecological data (e.g. conditions of growth, watering, lighting, maintenance). The latter gives information on comfort requirements through a superimposition on bioclimatic chart of plant needs on bioclimatic chart of human needs. Such analysis was allowed to assess the plants effectiveness use with specific indoor conditions and their correlation with human comfort zone. It was carried out by the adoption of Olgyay chart with regards to a range of climatic variables. Indoor air temperature and relative humidity were assumed as climatic variables for plants comfort (see grey dashed area). Human requirements and comfort zone are featured with a ticked black line. The intersection between the total comfort zone area and vertical lines set up a perimeter of best comfort conditions. The human comfort zone is featured to a range of variables including indoor air temperature, relative humidity, solar radiation absorbed and internal air movement as well. On the whole 28 plants were analysed and assessed as suitable for indoor uses and compatible in terms of comfort needs.

Olgyay's bioclimatic chart specify different zones at different combinations of relative humidity and dry bulb temperatures; the level of comfort is applicable to indoor spaces according to a indoor level of clothing. Figure 2 displays an example of plant specie analysed (Scindapus). The percentage was obtained by dividing the human comfort zone by the plant comfort zone. Percentage calculated for plant specie shown in figure 2 was 54%. Such value was assumed as "good compatibility". Thirty-five percent was the limit value assumed as acceptable for considering the zones as each other compatible.

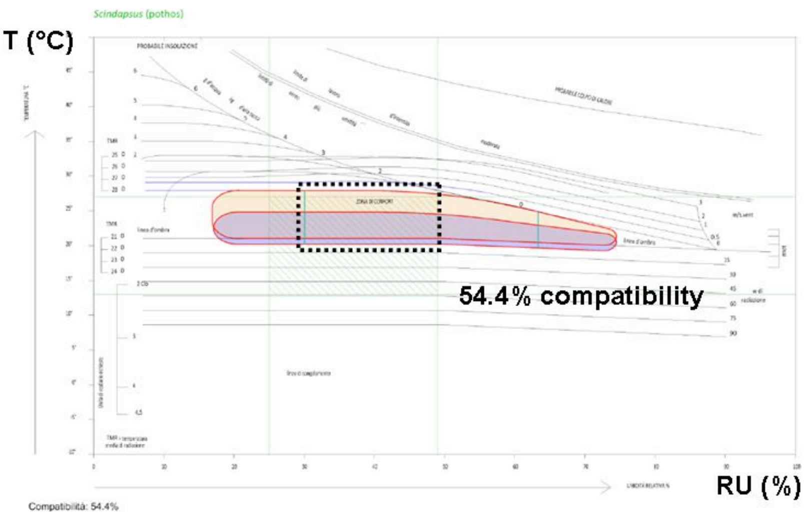

Figure 2: Olgyay's chart: superimposition between the human comfort zone and the Scindapsus (plant specie) one. The dotted line area shows the compatibility between the analysed zones.

The Indoor Agronomic database was finally completed collecting and assessing information concerning the 28 plants VOCs potential removal or dilution.

METHOD

The tools developed were used to define an appropriate set of ecological requirements to be included in a new indoor LWS design and prototyping. Such analytic approach was crucial for characterise the indoor LWS requirements and overcome those requirements usually implemented in the design process (e.g. LEED®: Leadership in Energy and Environmental Design) not properly fit for making an environmentally friendly LWS.

Indoor environmental requirements

The requirements were adopted in order to fulfil the largest numbers of indoor environment requirements over the LWS life cycle (manufacturing, on site assembling, use and maintenance as well as final disposal).
An Italian Technical Specification (TS) was used as general framework to implement the requirements (Environmental sustainability of construction works - Operational tools for sustainability assessment: part 1 and part 2).
Matching the technological and agronomical data - collected in the mentioned databases - with the TS requirements a selected and adapted number of requirements was set up. Such requirements were gathered, classified and arranged in a tabular format. Each requirement "fiche" includes: the life cycle stage (e.g. manufacturing, maintenance, etc.), the category impact (e.g. non-renewable source depletion, carbon dioxide emissions, etc.), the corresponding requirement (e.g. minimizing the water need and giving priority to organic fertilizer) and the indicator (qualitative and quantitative), and finally, the assessment method for the requirement characterization.
The requirement fiches were subsequently tested. The LWSs featured in the technological database were assessed through the indoor environmental requirements. Each requirement was converted into a quantitative score used to calculate strengths and weaknesses.
Such procedure therefore was provided to:

- Categorizing the recurring building systems or assembling processes used in the LWSs technologies (e.g. lightweight systems vs. heavyweight systems, modular box systems vs. green walls or bolted materials vs. welded materials).
- Categorizing the recurring sizes and thickness used in the LWSs technologies (e.g. square modular box vs. panel systems).
- Categorizing the recurring materials used in the LWSs technologies (e.g. plastic based materials vs. metal alloys).

Every category was then assessed. For instance, if a system or a material belonging to a category fulfills an indoor environmental requirement it gets a positive score (from 1 to 3). The more a system (or a material) implements its score, the more is assumed as best solution to be used in indoor LWS.

The procedure was enabled to improve the LWS' design process as well as the prototyping stage enhancing strengths and minimizing weaknesses.

Designing an advanced indoor LWS

Environmental requirements provide both a broad knowledge about the technological connections and information about suitable materials to be used for designing an ecological indoor LWS.

The advanced modular LWS was designed with the following technological solutions here listed:

- Structural system: freestanding stick system.
- Panel size: 0,6 x 0,6 m: easy assembling and handling.

- Growing medium: recycled felt fabric. To improve water retention felt fabric should be integrated with sphagnum
- Fertirrigation plant: integrated in the stick system, with water harvesting system.
- Framework: recycled aluminium
- Lighting: led tubes.
- System assembly: screws, fast and reverse connection.

CONCLUSION AND OUTLOOKS

The method described was extremely effective for the research purposes. The LWS design was carried out through a preliminary assessment procedure based on environmental requirements developed according to LWSs featuring. Databases were necessary to enhancing the strengths of those materials, connections and plant species analyzed.

Further research activities will be planned. For instance, some environmental aspects to be investigated concerns: the effects on VOC in the indoor environment due to the number of plants per square meter; VOC's absorption will be monitored (according to CEN/TC 350 scenario) in a chamber test and in an indoor installation. With regards to acoustic performance, sound absorption coefficient will be measured according to the ISO 354 standard in a reverberation room to test the properties of plant species with the change characteristics such as density of the leaves, shape, etc.

However the tools described are an open issue source allowing the implementation and integration of data. It may carry in effect the optimization of indoor LWS design.

Acknowledgments

The research was developed in the framework of DOUBLE_FAÇE project developed by Politecnico di Torino, Department of Architecture and Design. Authors thank Massimo Consolandi for his technical advice.

REFERENCES

1. Weinmaster, M. (2009). Are Green Wall as Green as they look? An introduction to the various technologies and ecological benefits of Green Wall. Journal of Green Building, vol. 4, pp. 3-5.
2. Wolverton, B. C., Douglas, W. L., Bounds, K. (1989). A study of interior landscape plants for indoor air pollution abatement. NASA techdocs.
3. Bringslimark, T., Hartig, T., Patil, G. G. (2009). Psychological benefits of indoor plants in workplaces: putting experimental results into context. HortScience, vol. 42, pp. 581-587.
4. Bringslimark, T., Hartig, T., Patil, G. G. (2006). The associations between indoor plants and perceived stress, sick leave and performance. Proceedings of the 26th International Horticulural Congress, Seoul, Korea, pp. 117-121.
5. Wong, N., Tan, A., Tan, P., Chian, K., Wong, N. (2010). Acoustics evaluation of vertical greenery systems for building walls. Building and Environment, vol. 45, pp. 411-420.
6. Burchett , M. et al. (2010). Greening the Great Indoors for Human Health and Wellbeing. Final Report to Horticolture Australia Ltd, online available: http://www.ngia.com.au.