COST C12 – WG3

Datasheet III.3.2

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SUSTAINABILITY ASSESSEMENT DATASHEET

Introduction

- The construction industry in general and the buildings sector in particular, contributes to the degradation of the environment through the depletion of natural resources. Building construction consumes 40% of the raw stone, gravel, and sand used globally each year, and 25% of the virgin wood. Building also account for 40% of the energy and 16% of the water used annually worldwide (Roodman, 1995).
- New materials and constructive solutions tend to be more sustainable than the conventional ones. Construction systems with light gauge steel framing structures are one of the solutions that appeared in response to the thrive for sustainable construction.
- In the assessment of the solutions' sustainability, several parameters could be analysed, some of them not correlated and/or not expressed in the same units. On the other hand, the way that each parameter influences the sustainability is neither consensual nor unalterable in time. So, it is difficult to express a solution' sustainability in absolute terms, through an indicator that integrates all of the analyzed parameters and that allows the quantitative classification of a solution' sustainability. In this way, the sustainability is a relative subject that should be evaluated comparatively and relatively to the most widely used solution – conventional /reference solution - in a certain country/local.
- In a constructive solution sustainability assessment process, the first step consists in gathering the most relevant functional and technical data about the constructive solution. The second step consists in selecting an appropriate method that allows the quantitatively assessment of the sustainability.
- The methodology to adopt should be simple and flexible, to conveniently help the design teams in choosing a certain technology in detriment of others less sustainable.

Sustainability Assessment Methods and Tools

- The most important systems and tools for the sustainable assessment:
    - i) Building Research Establishment Environmental Assessment Method (BREEAM) (BRE, 2004);
    - ii) Leadership in Energy & Environmental Design (LEED) (USGBC, 2004);
    - iii) Green Building Challenge (GBTool) (Greenbuilding, 2004).

- These methodologies aim the evaluation of the overall sustainability of a building. Their application is complex and needs the previous knowledge of some data. The sustainability assessment tools have datasheets, although the data is related with the particular aspects of the country of origin, which makes its application in a different country very difficult. These systems focus on the building environmental impact assessment, mainly in a global perspective. The sustainability of the constructive solutions is one of the analysed aspects in the assessment of the buildings global sustainability.

- In this perspective one good methodology is the Methodology for the Relative Assessment of the Constructive Solutions Sustainability (MARS-SC[1])(Mateus, 2004). In MARSC-SC the evaluation of the sustainability is accomplished relatively to the most applied solution – conventional/reference solution - in a certain place. Three groups of parameters are approached: **environmental**, **functional** and **economical**. The number of parameters analyzed on each group can be adjusted depending on the specific characteristics of each constructive solution, on its functional demands, on the evaluation objectives and on the available data. The table 1 shows some of the most important parameters that could be analysed in this methodology. The methodology follows the following steps:
    i) **Selecting the parameters to analyse**;
    ii) **Calculation of the comparison indexes**. The comparison between the solution under analysis and the reference solution is accomplished at the level of each parameter through a comparison between indexes. These indexes express the relationship between the value of a certain parameter in the solution under analysis and the same parameter in the conventional solution that allows verifying, relatively to each analyzed parameter, if the solution is better or worse than the conventional constructive solution. The indexes are calculated by the equation 1:

$$I_X = \frac{V_X}{V'_X} \qquad \text{[Equation 1]}$$

with,

I_X – Index of the parameter X;

V_X – Value of the parameter X in the solution in analysis;

V'_X – Value of the parameter X in the conventional/reference solution.

iii) **Graphical representation of the indexes**. The indexes are represented graphically in a geometric illustration with the same number of sides as the number of parameters in analysis. The graphical representation of the indexes is the Sustainable Profile. The smaller the area of the sustainable profile is, the more sustainable is the solution.

iv) **Sustainable score calculation**. This sustainable score (SS) of the constructive solution is calculated from equation 2.

$$SS = W_1 x \sum_{i=1}^{m} \frac{I_{Env.\,P.(i)}}{m} + W_2 x \sum_{i=1}^{n} \frac{I_{F.\,P.(i)}}{n} + W_3 x \sum_{i=1}^{o} \frac{I_{Ec.\,P.(i)}}{o} \qquad \text{[Equation 2]}$$

with,

$W_1+W_2+W_3=1$;

SS – Sustainable score of the solution in analysis;

W_1 – Weighting factor of the environmental performance;

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[1] From the Portuguese “Metodologia de Avaliação Relativa da Sustentabilidade de Soluções Construtivas”

W_2 – Weighting factor of the functional performance;
W_3 – Weighting factor of the economical performance;
$I_{Env.\ P.\ (i)}$ – Environmental parameters index i;
$I_{F.\ P.\ (i)}$ – Functional parameters index i;
$I_{Ec.\ P.\ (i)}$ – Economical parameters index i;
m – number of environmental parameters in analysis;
n – number of functional parameters in analysis;
o – number of economical parameters in analysis.

There is no consensus on the way as each group of parameters influences the sustainability of a constructive solution. However, it’s a current consideration that in terms of turning the artificial environment more compatible with the natural one, without forgetting the functionality of the solutions, the weight of the environmental and functional parameters should be higher than weight of the economical parameters. Through the sustainable score value it is possible to evaluate if the solution in analysis is worse or better than the conventional/reference solution. The more close to zero the sustainable score is, the more sustainable is the solution.

Table 1 – *Parameters that could be analysed in the MARS-SC methodology*

Parameter Group		
Environmental	**Functional**	**Economical**
• Mass • Primary energy consumption (PEC) • Recycled content • Reuse potential • Recycling potential • Raw materials reserves • Distance of transportation • Global warming potential • Eutrophication potential • Water intake • (…)	• Air born sound insulation • Percussion sound insulation • Thermal insulation • Durability • Fire resistance • Constructability • Flexibility • Aesthetics and innovation • (…)	• Construction cost (first cost) • Utilization cost • Maintenance cost • Rehabilitation cost • End use value • End use treatment cost • (…)

Table 2 – Classification of the constructive solution sustainability throw the Sustainable Score (SS)

Sustainable Score (SS) value	**Classification**
< 1	The solution in analysis sustainability is better than the conventional/reference solution one
≈ 1	The solution in analysis sustainability is equivalent to the conventional/reference solution one
> 1	The solution in analysis sustainability is worse than the conventional/reference solution one

Example of application

- **Applied methodology**: In this example the sustainability was assessed through the methodology MARS-SC (Mateus, 2004). The sustainability of the constructive solution was evaluated relatively to the conventional solution through the comparison of two environmental parameters (mass -m- and primary energy consumption -PEC-), three functional (air born sound insulation -$D_{n,w}$-, thermal insulation -U- and occupied space –os-) and one economical (construction cost –cc-). In this way there are six indexes: i) mass index (I_m); ii) primary energy consumption index (I_{PEC}); iii) air born sound insulation index ($L_{Dn,w}$); iv) thermal insulation index (I_U); v) construction cost index (L_{cc}); vi) occupied space index (I_{os}). The weighting factors of each group of parameters considered in this study were: i) environmental parameters (W_1) = 0.45; ii) functional parameters (W_2) = 0.45; iv) economical parameters (W_3) = 0.10.
- **Description of the solution in study**: The structure of the wall is formed by 14cm height lightweight steel profiles. The interior covering is composed by two plasterboard layers, with a total thickness of 2,5cm. The external covering is composed by the structural covering and by the external thermal insulation with rendering. The structural covering is formed by 1,2cm thick OSB panels. The external continuous insulation, composed by 1cm thick expanded polystyrene plates, is fastened to the OSB panels. The final covering is a 1cm thick layer of render. The cavity between the exterior and interior coverings is filled out with 14 cm thick rock wool blankets (figure 3).
- **Description of the conventional/reference solution**: The conventional/reference solution is one of the most applied technologies in exterior walls in Portugal. The solution is a double (15+11 cm) hollow brick wall with a 2 cm thick extruded polystyrene layer placed on the air gap. Each surface of the wall is covered by a 1,5cm thick layer of render.
- **Local of study**: The presented data and the results refer to the present construction context in the North of Portugal.

Technology Description

- The light constructive technologies are one of the possible answers to the aims of the sustainable construction through: the decrease of the raw material consumption in the construction, the use of more ecological constructive materials and the superior industrialization level of the constructive processes.
- The structure of a LGSF wall is composed by a system of horizontal and vertical light weight steel profiles (Figure 1). The average thickness of this type of walls varies between 95 and 146 mm.
- The parts of this type of wall are shown in Figure 3.

Figure 1. Structural elements of a light gauge steel framing exterior wall.

Figure 2. Exterior view of a lightweight exterior wall.

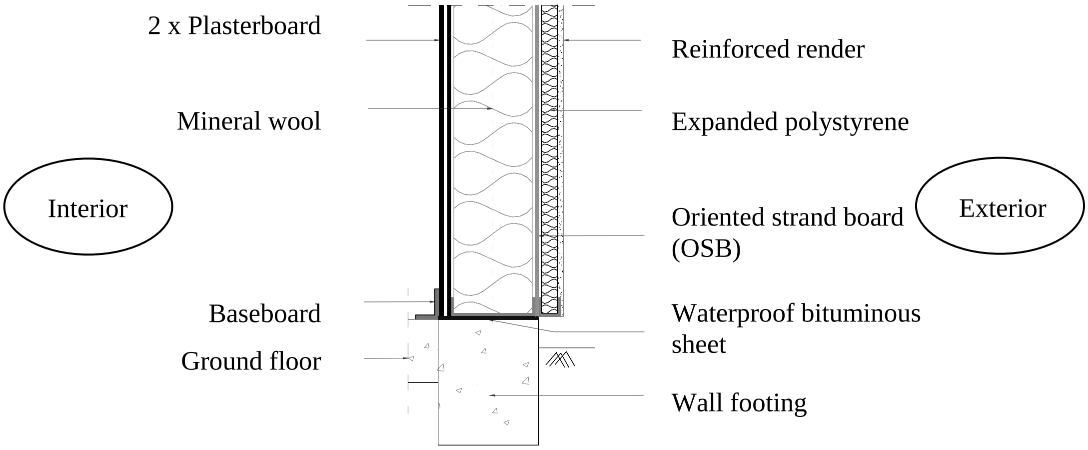


Figure 3. Sketch of a typical light gauge steel framing exterior wall.

Functional Aspects

- **Structural capability**: the steel is one of the construction materials that have the best relation resistance/weight. So, it is possible to build with slender structural elements and consequently with smaller mass. With this technology it’s possible to build buildings with 2 to 3 floors with load walls.
- **Thermal mass**: The mass per unit of surface in this type of walls is significantly inferior to the mass of the conventional masonry walls (Almeida, 2002). This situation can negatively influence the buildings thermal behaviour, unless the mass of the remaining constructive elements is enough for the thermal storage.
- **Insulation**: The application of high thickness insulating materials between the two covering faces turns the global coefficient of thermal transmission quite lower than the conventional masonry walls one (Almeida, 2002). The application of the external continuous insulation contributes to the high insulation of this solution while corrects the thermal bridges at the level of the structural elements
- **Sound insulation**: In spite of the lower mass of this solution, experimental results showed that the use of great thickness absorbent materials, as the rock wool, turns, in equality of thickness, the air born sound insulation of this technology higher than the conventional masonry walls one (Bragança, 2002a).
- **Fire resistance**: The structural elements of this technology are sensitive to the fire.

Although they are protected with low thermal conductivity materials with a great fire resistance (rock wool and plasterboard). Studies, made in agreement with the EC3 methodology, showed that the fire resistance of this technology is about 60 minutes (Gervásio, 2002).

Environmental Sustainability

- **Construction mass**: The mass of this constructive solution is about 27% of the mass of a conventional masonry wall with the same thermal insulation. In this way, this solution is more maintainable under the point of view of the natural resources preservation (Mateus, 2004).
- **Primary energy consumption (PEC)**: In spite of its quite inferior mass, the primary energy consumption in this solution is just slightly inferior to the conventional masonry walls one. This situation is justified by the use of a big quantity of steel, material that needs great quantity of energy to be processed.
- **Waste production**: This technology is characterized by a great industrialization of the constructive process, being most of its elements prefabricated. The extremely controlled productive process allows the reduction of the residues. The elements are produced with the exact dimensions needed to accomplish their functions, not giving place to wastes.
- **Recycled content**: The steel could be 100% recycled, so, in this solution, the recycled raw materials content could be higher than the conventional walls one.
- **End use and recycling potential**: In this solution the constructive materials/elements are punctually joined, being easy to separate during dismantling. On the other hand, the biggest amount of the materials can be easily reused or recycled: the steel profiles can be easily reused in another building or 100% recycled; the mineral wool and the plasterboards can be directly reused; the OSB panels can also be reused or if its conservation do not allow, they could be energetically valued as combustible.

Buildability, Availability and Cost

- This constructive technology is new in Portugal, so the availability of specialized workmanship for this technology is still limited, what makes its buildability low. The small number of companies specialized in metallic structure technology also increases its cost and reduces its competitiveness
- In Portugal, the importation of the biggest amount of the consumed steel in association to the abundance of raw materials needed for the conventional construction, makes this solution less competitive in terms of construction cost.
- In a global economical analysis of the materials life cycle, the higher construction cost could be compensated by the biggest end value of this solution (most materials can be directly reused or recycled) and by the lower energy cost during the utilization phase (due to the superior thermal insulation of this solution).

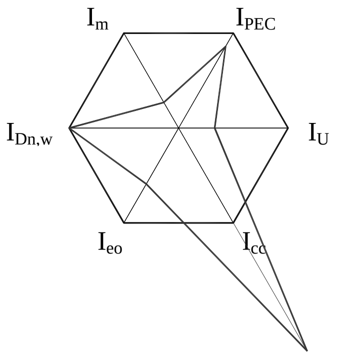
Sustainable Profile and Sustainable Score

- Table 1 lists the results obtained in the sustainability assessment. The results were obtained through numerical evaluation methods.

Table 1 – *Results obtained in the sustainability assessment*

Parameter group	Parameter	Conventional solution	Studied solution	Index	
Environmental	Mass (kg)	279.00	76.00	I_m =	0.27
	PEC (k.W.h/m^2)	197.00	171.00	$I_{PEC\,=}$	0.87
Functional	$D_{n,w}$ (dB)	51.00	51.00	$I_{Dn,w}$ =	1.00
	U (W/m^2.ºC)	0.70	0.23	I_U =	0.33
	Thickness (cm)	33.00	19.60	It =	0.59
Economical	Cost (€/m^2)	46.68	133.40	I_{cc} =	2.85

- **Sustainable profile**: The labels graphical representation results in the sustainable profile presented in figure 4.



SS = 0.83

Considering,
$W_1 = 0.45$
$W_2 = 0.45$
$W_3 = 0.10$

Figure 4. Sustainable profile and sustainable score (SS) of the solution in analysis.

- **Comments**: The results show that, relatively to the parameters in analysis, the constructive solution in study is more sustainable than the conventional one. The factors that contribute most to this result are: the lower mass, the lower thickness and the biggest thermal insulation. Although, the constructive cost of the analysed solution is about 185% higher than the cost of the conventional solution. However, in a global economical analyses that approaches the several phases of a building's life cycle, this difference could be lower, justified mainly by the following factors: the smaller mass allows important savings at the level of the footings; the smaller thickness allows the maximization of the marketable interior areas; the superior thermal isolation potentially decreases the energy consumption necessary for the maintenance of the interior temperature; in the end of the building's life, the deconstruction processes are simple, because the biggest amount of the elements are linked mechanically, which allows the reuse of elements that are in good conservation and the recycling - the steel is 100% recyclable.

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