In Search of Environmental Friendly Structures: A Comparative Evaluation of Steel Structures and Reinforced Concrete Structures

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1. **Introduction:** The concept of sustained development, as defined in the Brundtland report in 1987 and later on endorsed in Rio Earth Summit in 1992, is a complex and dynamic challenge that demands contributions of the most diverse sectors of activity. Research works concerning direct application of this concept for most industrial activities still is needed. The implementation of sustainable development in construction industry has led to concept of sustainable construction. Hence, the Life Cycle Assessment (LCA) approach is becoming, slowly but surely, the acceptable tool for selection of construction materials and products, as well as, construction processes and design. The application of Life Cycle Assessment (LCA) for selection of construction materials constitutes, at present, the first step in a more complex assessment of the whole life global environmental performance.

In order to assist designer different approaches to LCA have been suggested and a few software have been developed namely:

- Ø SimaPro (Netherlands); general applications of LCA studies.
- Ø GaBi (Germany); general applications of LCA studies.
- Ø BEES 3.0 (U.S.A); support of decisions making in the materials selection.
- Ø ATHENA (Canadá); support of decisions making in buildings conception.
- Ø GBTool (Canadá); support in complete buildings system valuation.

However, it was found that the software available could not be used directly for the case at hand and hence it was deemed necessary to develop a simple software for this research work. This research work is an attempt for gathering the necessary data for evaluation of reinforced concrete structures and steel structures, as well as, developing a user friendly software for quick comparison of these two construction materials that are used most frequently.

2. **Methodology of the research work**

Selection of the structure: The structure studied is the structure of a multi-storey residential building. The specific object of this research work was a portion of the main frame which consisted of a three span continuous beam and four columns. It is assumed that in as a first approach this will be representative of the whole structure (see fig 1).

The second step was to design the structure for the same function using the two construction materials considered. This step followed the conventional procedures for such designs using EU codes of practice.

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Quantification of the building materials consisted of detailed estimation of the necessary primary materials and products to carry out the construction of the structure.
Environmental data for this research work was not readily available and, hence, it became necessary to create a data base of the main emissions caused in the extraction, processing, production of the materials quantified for the structure. The water consumption and the energy consumption in the materials production were also considered. The data was gathered from producers of materials in the north of Portugal and some published data [1-4]. In the case of steel profiles data was gathered from the Spanish corporation (Arcelor) [5] that is the main supplier of such materials for the North of Portugal.

The selection of the environmental parameters was based on their significance and impact and is those usually selected for such purposes. A major obstacle was availability of the same parameters for all the materials considered so that the comparison would be possible.

Once all the data were gathered and processed it was possible to estimate the total value of the environmental parameters for the materials considered. Based on the obtained values of the parameters considered and graphically presented a detailed analysis of the environmental profiles were made and conclusions of their sustainability was performed. It should be noted that recycling, reutilization and deposition of structure at the end of the design service life was not considered in this research work. A more detailed and through evaluation of the structure is under way that considers maintenance and end of life usage.

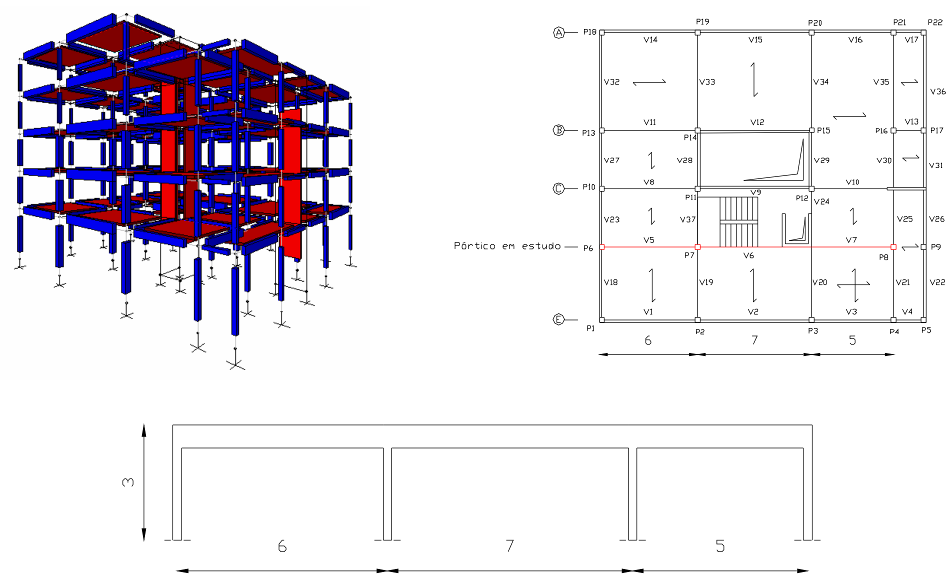

Figure 1 – structural scheme and the frame considered

3. Research

3.1. Reinforced concrete structure

The environmental parameters related to the cement production were supplied by Cimpor [1]. For the aggregates, the parameters were gathered from an aggregate producing mine [2]. The environmental data regarding the production of the reinforcement steel were made available by the Siderurgia Nacional [3]. The data regarding wood for formworks were obtained from published literature [4].

Table I- Environmental parameters used for production of reinforced concrete

Environmental Parameter	CEMENT		AGGREGATE		WATER		REINFORCEMENT		WOOD	
	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit
Energy Cons.	2,9	GJ/ton	0,010	GJ/ton	0		1,872	GJ/t	0,306	GJ/m^3
Water	0,18	m^3/ton	0	m^3/ton	0,500	m^3/m^3	0,660	m^3/t	0	m^3/m^3
CO_2	675	Kg/ton	0	Kg/ton	0		0,036	t/t	0	t/m^3
SO_2	0,15	Kg/ton	0	Kg/ton	0		0,005	t/t	0	t/m^3
NOx	2	Kg/ton	0	Kg/ton	0		0,001	t/t	0	t/m^3

3.2. Steel Structure

The environmental data for steel structure were obtained from Arcelor [5], a Spanish steel production company's web site. The value regarding the energy consumption was not available at this site, hence, an average standard value from Central Europe was used [6] (see table 2).

Furthermore, the environmental parameters for the transport of the steel to Portugal [6] were also considered. The resulting impact due to the transportation is obtained based on the weight of the steel, the distance between cities and the emissions caused by the truck (see table 3). The total environmental impact is given by the sum of the production and transportation.

Table 2 – Environmental parameters regarding the production of the steel.

	STEEL	
Parameter	Value	Units
Energy Consumption	10	GJ/t
Water	6,600	m^3/t
CO_2	1,510	t/t
SO_2	0,0011	t/t
NOx	0,001	t/t

Table 3 - Environmental parameters regarding the transportation of the steel.

	STEEL		
Gases	Quantity produced	Units	Distance (km)
CO_2	120,00	g/(ton.km)	700
SO_2	0,10	g/(ton.km)	
NOx	1,90	g/(ton.km)	

4. **Results Obtained**

The overall results of the environmental parameters considered for both structures, i.e. reinforced concrete and steel, are given in fig 2.

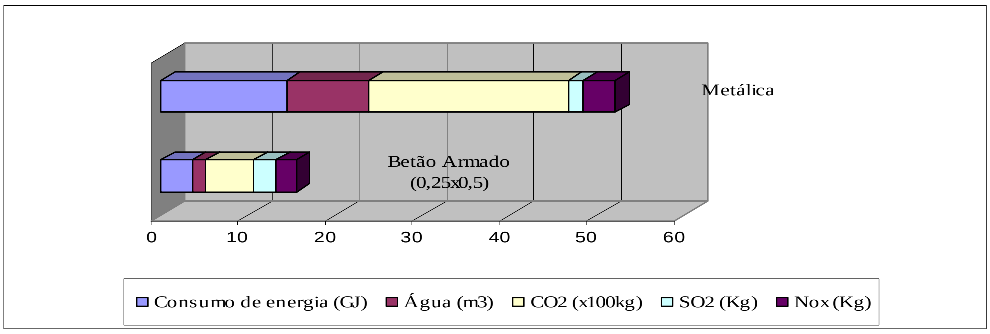

Figure 2 – Overall Values of the Environment Parameters for the Structure Studied

It can be noted that the steel structure has greater energy consumption than the reinforced concrete structure. The steel structure consumes about 14 GJ while the reinforced concrete structure consumes about 4 GJ, resulting in four folds energy consumption. The data regarding the water consumption indicates that the steel structure consumes about 9 m^3 and the reinforced concrete structure consumes approximately 2 m^3. When the carbon dioxide emission is considered the difference is still more significant. The steel structure releases 2300 kg of CO_2 while the reinforced concrete structure releases only 550 kg. The SO_2 emissions, however, is larger for the reinforced concrete structure that releases 2.5 Kg. The use of a steel structure releases some 1.7 Kg of SO_2. For NO_x emissions, it can be noted that once again the reinforced concrete structure releases less, approximately 2 kg, while the steel structure releases 4 kg.

The global analysis of fig 2 indicates that there is a significant difference in environmental terms comparing steel structure with reinforced concrete. However, it should be noted that consideration of the end of life recycling and reutilization of materials and the maintenance required may alter the results obtained here.

5. **Conclusions:**

It can be observed that the environmental impacts caused by the steel structure are significantly higher than the ones caused by the reinforced concrete structure. Consequently, the structural material that is environment friendly appears to be the reinforced concrete. There is only one parameter that is larger for reinforced concrete structure which is the SO_2 emissions. However, the absolute value of this parameter will not alter the option (2.5 kg of SO_2 versus 1.7 kg of SO_2). It is conclude that globally the steel structure is less sustainable when the material is considered and maintenance and end of service life usage is not considered.

6. **References**

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