XLI CILAMCE
XLI Ibero-Latin American Congress on Computational Methods in Engineering
16-19 November, 2020 FOZ DO IGUAÇU PARANÁ - BRAZIL

# Computational Code for guide the decision on the type of structure: Steel, Wood or Concrete

Lays R.A. Costa [1], Hidelbrando J.F Diógenes[1], Andrea B. Silva[2]

[1]*PPGECAM, Federal University of Paraíba - UFPB*
*Campus Universitário, 58.051-900, João Pessoa/PB, Brazil*
*lays.costa@academico.ufpb.br, hjfd@academico.ufpb.br*
[2]*Dept. of civil and environmental engineering, Federal University of Paraiba - UFPB*
*Campus Universitário, 58.051-900, João Pessoa/PB, Brazil*
*andrebrasiliano@gmail.com*

**Abstract.** In views of rationalization in the civil construction, the knowledge about the properties of materials, such as steel and wood, it's necessary to compare their properties, in financial and structural terms with concrete. Thus, the objective of this study was to compare the structural and financial conditions obtained for beams, from the development of software in the Visual Basic programming language. The study was carried out from the adoption of fixed calculation parameters for the materials, with variation only in the span length of the beam to analyze each material performance. It was found that for the small spans, up to 5 meters, there were no significant variations in the values found for the materials. Above this interval, the advantage of using concrete beams was found, when only the cost of the reinforced concrete was considered. When the possibility of reducing the height and weight of the building elements was considered, the steel beams proved to be more advantageous. The analysis considered isolated parameters, and additional studies regarding the buildings' execution time, expenses with the materials' maintenance, and resistant properties are necessary to achieve the best parameter and adoption of the construction system that fits the requirements of each construction.

**Keywords:** concrete, steel, wood, visual basic.

## 1 Introduction

According to Acheampong, Adom-asamoah, and Afrifa [1], concrete is one of the most widely used construction materials in the world. Pedroso [2] mentioned that 11 billion tons of concrete are consumed annually, which is equivalent to a consumption of 1.9 tons of concrete per inhabitant per year. Araújo [3] believes that this fact may be related to its excellent resistance properties, facility to forms execution, resistance to fire, besides practically requiring no conservation or maintenance.

Despite the well-known advantages of using reinforced concrete, this material has some disadvantages, especially when considering the weight of structures and the difficulty of often carrying out demolitions and renovations. In addition, in cases where large spans are required, the adoption of reinforced concrete as a structural element requires the use of beams with high heights, which can become a limiting factor, especially when working with ceiling height up to 3.00 (three) meters.

In view of the difficulty of using reinforced concrete in some situations, it is important that the properties of other construction elements, such as steel and wood, are known, in order to be compared with reinforced concrete. This comparison may make it possible, from the point of view of Structural Engineering, to choose the most rational material.

According to Guanabarra [4], steel structures have been widely used in developed countries for providing clean and fast constructions. To be applied in structural systems, Pfeil and Pfeil [5] mentioned that good ductility, homogeneity, and a great relationship between the resistant stress and the yield strength are required properties.

For Bellei [6] the main advantages of steel structures are: 1) The high resistance in the various stress states (which allows them to withstand great efforts, even when using small sections); 2) The possibility to be produced in an industrial environment and only taken to works for assembly (which favors the rationalization of construction), 3) and because they can be easily disassembled and replaced, it makes possible to reinforce or replace various elements of the structures.

Concerning wood, this is a material that has been used in construction for a long time. In general, its use is due to its ease of handling, in addition to its excellent resistance/weight ratio. According to Pfeil and Pfeil [7], its main advantages are related to the fact that it can be easily transformed into several industrialized products, in addition to its good thermal insulation. But the fact that they are subject to biological degradation and the possibility to present knots and cracks that interfere with its mechanical properties (to being a natural material) seems to be its main disadvantage. However, these unfavorable aspects of wood are easily overcome with the use of industrial wood products, properly treated, in suitable structural systems, resulting in durable structures and with pleasant aesthetic characteristics.

The design of beams is a process that demands a considerable manual effort, since the load combination hypotheses need to be considered, as well as the formulations related to the design bases of each material, which are derived from the National Standards developed for this purpose. It is known that the manual calculation of such elements, although time-consuming, is not an impossible task to be done. In project situations, for example, there is a need for more practical means for such dimensioning, mentioning the possibility of developing calculation routines through programming. In some situations, well-known commercial computer packages can also be used, such as Eberick, TQS, CypeCAD, but which are not always available.

In our days, programming is an essential “tool” in the field of engineering, in all its specialties. Using programming to solve the most diverse problems has become an increasingly common practice. In this sense, the Visual Basic (VB) programming language, which is an improvement on the Basic language and which was developed by Microsoft, has many characteristics that make it attractive. In addition to having a well-designed programming environment, it is relatively easy to use, as its calculation routine is very similar to other languages such as Matlab and C ++. Another differential of VB, according to Lopes [8] is the possibility of designing and programming the graphical interface in a very varied range of applications.

This paper presents the computational code CONCREMAÇO® that was developed in the VB programming language. It was developed to dimensioning and detailing sections in reinforced concrete, wood, and steel, and to compare the dimensions obtained from the section for each material. In this way, it was possible to have a financial parameter capable of guide the initial choice of the structural system by engineers and architects in usual design situations. The budgets of the materials were carried out based on SINAPI composition sheets and also through research among local suppliers.

## 2 COMPUTATIONAL CODE: Concremaço® 1.0 beta version

Concremaço was developed to help and guide the first decision about buildings' Structural systems. The paragraphs below present some information about the program operation, about the data supply, and show the results that can be extracted.

In the Input stage, some information related to loads, span length of the beam, and environmental conditions are required to provide loads combinations and improve final loads definition. Besides, information about final sections geometry and materials strength is also required. The height of the concrete beams sections varies according to the span length variation, and the height of the steel and wood elements was obtained iteratively, as the safety conditions of the element were met for the considered span. For both steel and wood, a First section was defined in the input stage to provide the beginning of the iteration. The input stage only ends after complete data supply; otherwise, the program displays an error message and asks to fill in the information that was not presented.

After the input stage, the flexural dimensioning of each material is carried out following the recommendations contained in the technical standards, and only for the Ultimate limit state (ULS).

The dimensioning stage ends presenting final sections for steel and wood materials, the final steel section for concrete reinforced beams, and the costs corresponding to the dimensioned sections. For steel and wood materials, sections are chosen according to a “code directory” containing some commercial sections, but this directory can be easily accessed, and others profiles can be registered.

Users can also have access to an additional window with the details of the sections obtained and a comparison between the material costs for each span length.

The program works according to the workflow shown in Fig. 1. Fig. 2 to Fig. 5 presents the windows and information that must be filled, whereas Fig. 6, and Fig. 7 shows the results of the dimensioning and sections details that are obtained after data supply and processing.

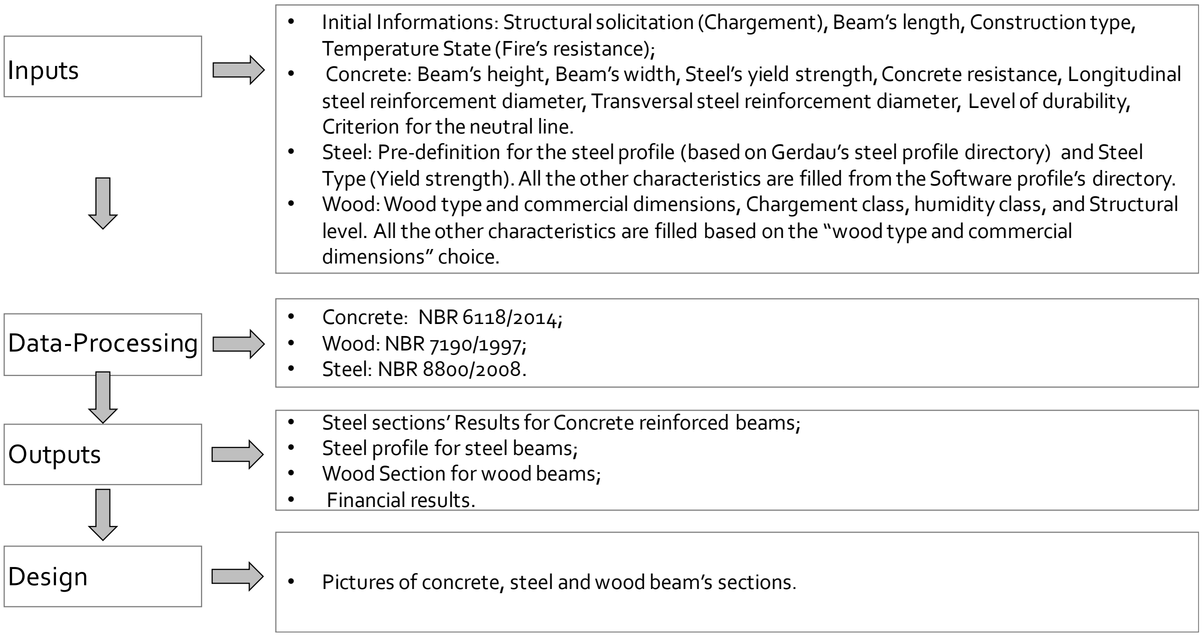


Figure 1. Concremaço® Work-flow

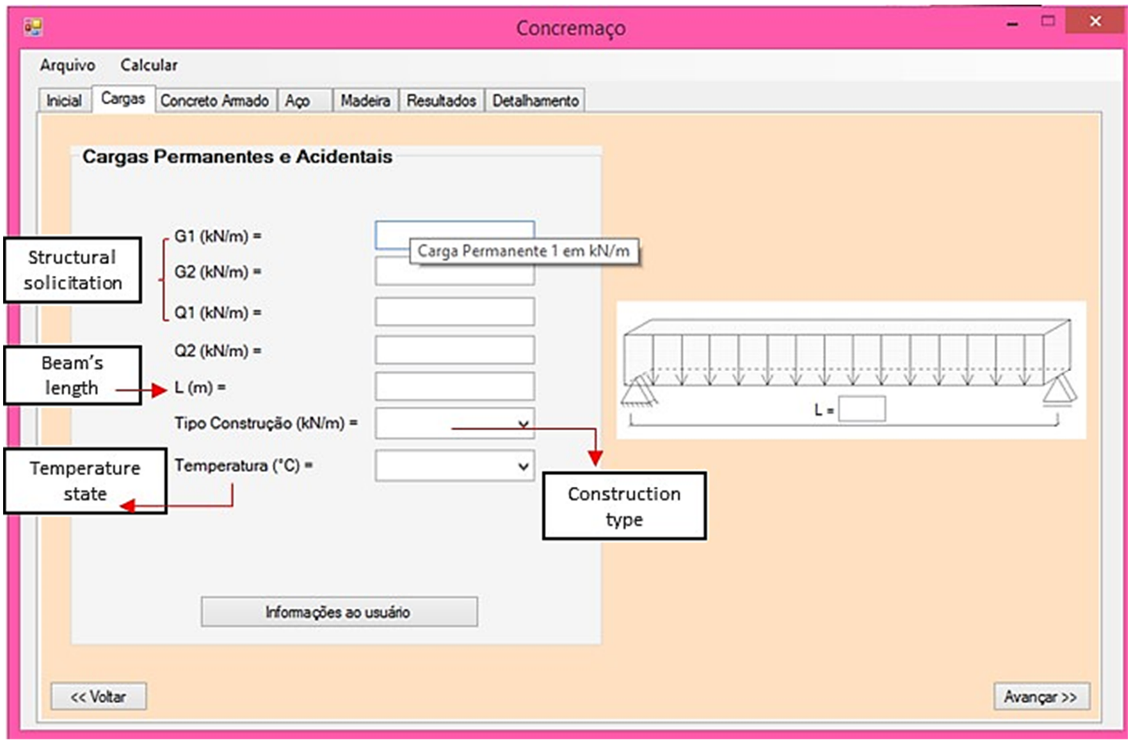


Figure 2. Data about span length and loads

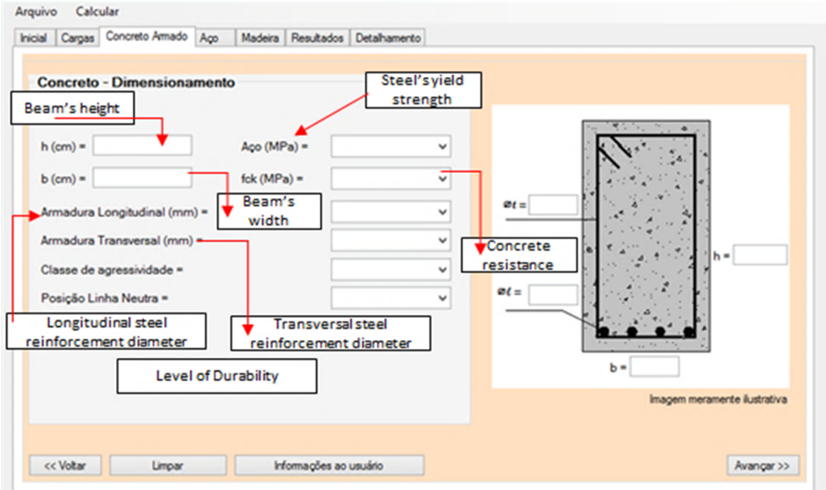


Figure 3. Data about concrete sections

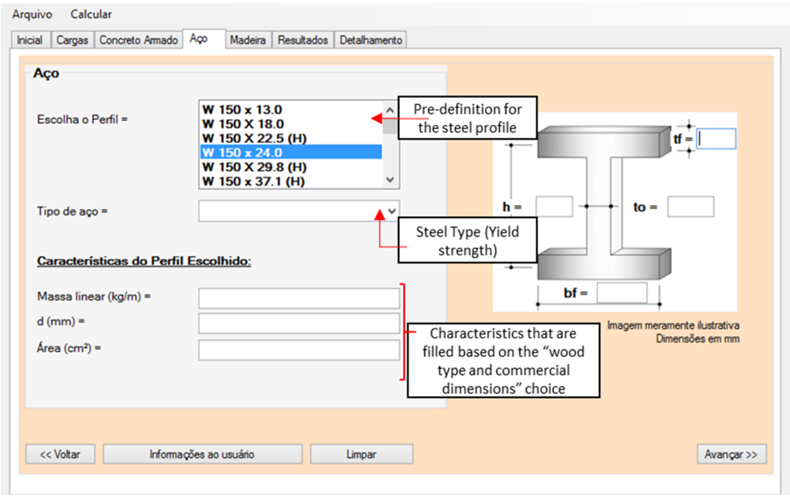


Figure 4. Data About Steel sections

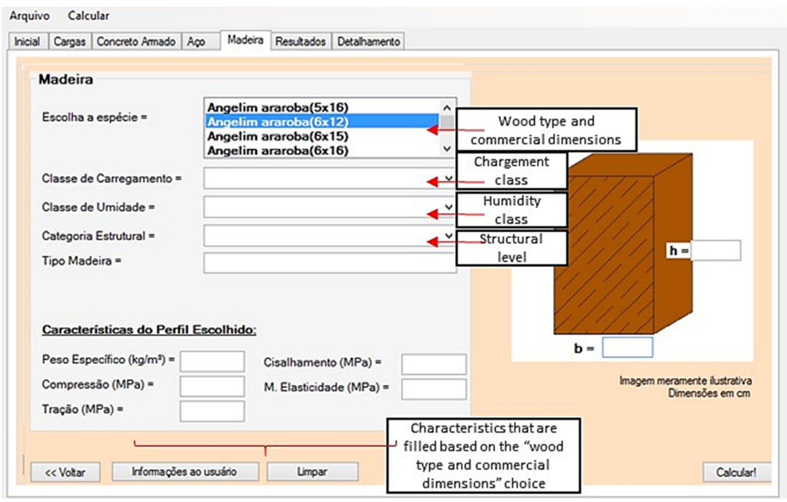


Figure 5. Data about wood sections

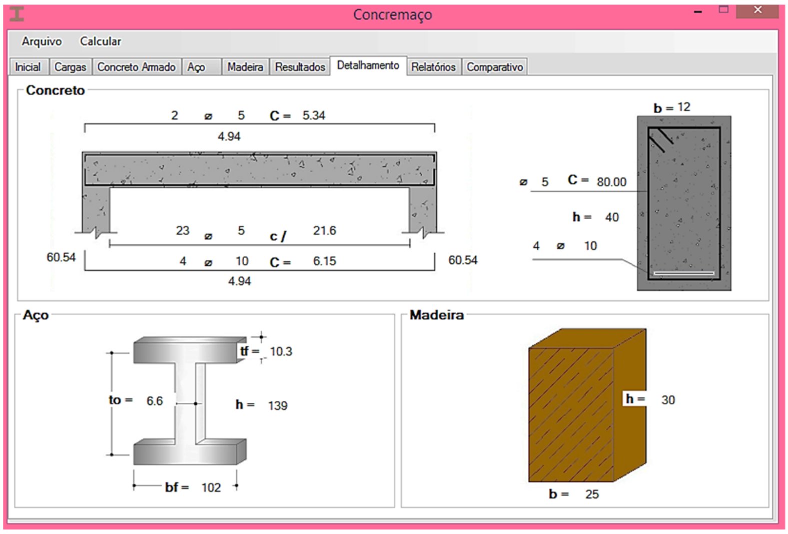


Figure 6. Materials sections details

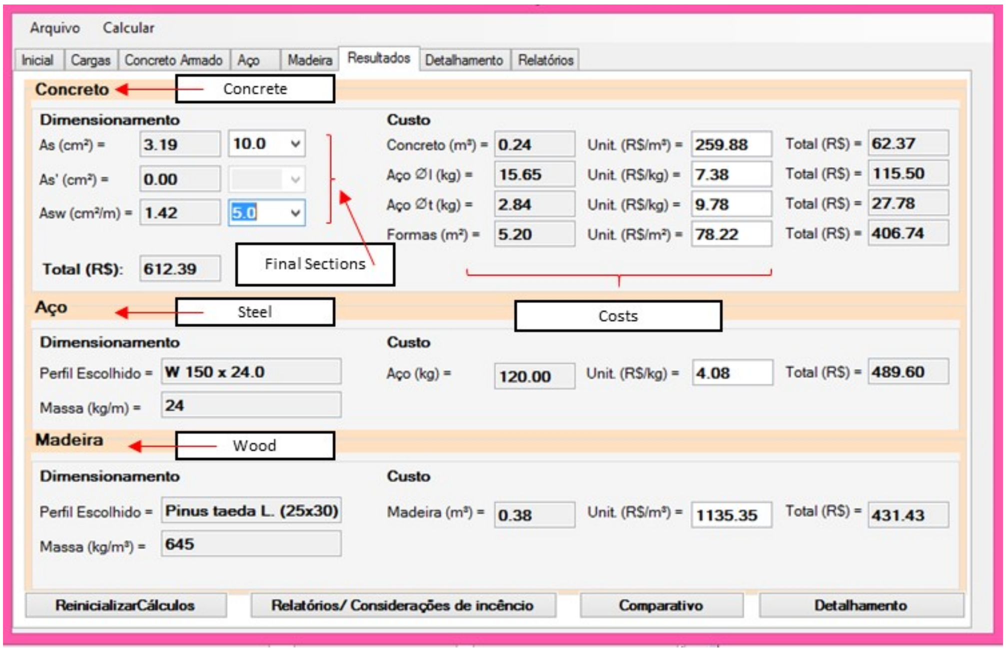


Figure 7. Final sections dimensioning and costs

## 2.1 Application example

It will be shown an application example of the program. Table 1 presents the initial data that was provided in the input stage, and Table 2 presents the results of the processing using data provided in Table 1. It's also shown the comparison of these results with Commercial Computacional packages as TQS and Cype 3D.

Regarding the results from Table 2, it can be seen that Concremaço® returns valid values for the design of Profiles in reinforced concrete, wood, and steel, being, therefore, a viable tool for the analysis of the cost-benefit between the materials. Fig 8a. and Fig. 8b shows a cost-benefit analysis that was made using Concremaço to investigate the behavior of the beams to each material, in the face of the increase in beam spans length (It were used spans from 1 to 15 meters). In this way, it was possible to obtain the limit values for which each of the materials is more or less economical.

Table 1. Input Data

| Initial Data | Concrete | Steel | Value |
|---|---|---|---|
| G1: 8 kN/m<br>G2: 0<br>Q1: 1 kN/m<br>Q2: 0 | h = 20 cm | Steel type: ASTM A572 G50 | Chargement Class: Permanente;<br>Humidity class: Class 1;<br>Structural Class: Class 1; |
| L: 5 m<br>Construction type: Residential<br>Temperature: 20°C | b = 12 cm<br>Øℓ = 10.0, Øt = 5.0, Level of durability: II<br>Fck = 25 Mpa/ Fyk = 500 Mpa | Other parameters were defined according to the profile directory (based on the first chosen profile that was chosen). | Other parameters were defined according to the profile directory (based on the first profile that was chosen). |

Table 2. Outputs after processing software and comparison with computational packages

| Concrete | | Steel | | Wood | |
|---|---|---|---|---|---|
| Concremaço | TQS | Concremaço | Cype 3D | Concremaço | - |
| As: 3.19 cm²<br>A's: 0<br>Asw: 1.42 cm²/m<br>Md: 44.625 kN.m | As: 3.31 cm²<br>A's: 0<br>Asw: 1.2 cm²/m<br>Md: 44.8 kN.m | Chosen section: W150x24 | Chosen section: W150x24 | Chosen section: Pinus taeda L. (25x30) | For wood sections, data validations were performed analytically. |

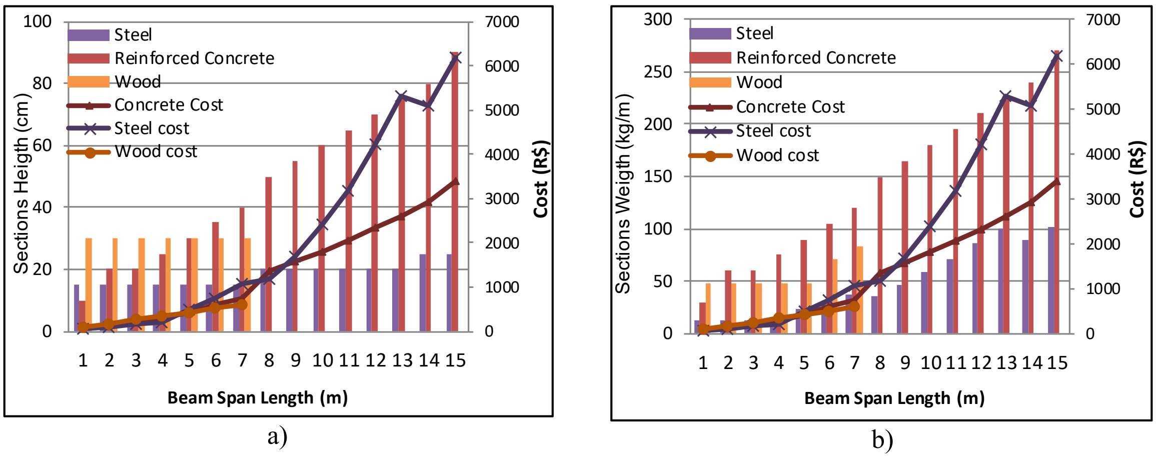


Figure 8. Output stage (schema). a) Materials sections details, b) Final sections dimensioning and costs

From Fig. 8, it was seen that for small spans (up to 6 meters), no large variations were found in the structural materials costs. Above 7 meters, the available sections of wood proved to be insufficient for additional requests (considering the commercial directory); in this sense, the possibility of working with laminated wood is suggested.

How it was not found large variations concerning materials performance for small spans, parameters concerning aesthetics of buildings, construction rationalization, and construction time must be considered during the choice of the material. For spans over 9 meters, considering only the issue cost, the advantage of working with concrete beams was found. However, for the execution of concrete beams in large spans, heights sections, and higher than those of steel are required. About this aspect, when we consider the use of a ceiling height with usual dimensions of 2.60, the use of concrete beams, that demands high section in the face of large spans, does not seem feasible. Considering the weight aspect, above 9 meters span, concrete beams were around 64% heavier than steel beams; this fact should be regarded when analyzing the additional cost of foundations.

In addition, steel structures contribute to the rationalization of constructions because they have part of their elements produced in an industrial environment. However, as it requires a more specialized workforce and greater precision in the projects, these factors can impact the costs involved in the works, and this aspect also needs to be considered when choosing the construction/structural material.

# 3 Conclusions

According to the results shown in this paper, it is possible to conclude that Concremaço® seems to be a viable tool for dimensioning concrete, wood, and steel beam sections. In addition, it can also be used for preliminary cost-benefit analysis. From the cost-benefit analysis, it was observed that for small spans, up to 6 meters, there was practically no variation for the values found, even though the steel beams showed small advantages for the first 4 meters analyzed. Above 9 meters, the benefit of using concrete beams was found if we consider only the cost issue. However, it is worth noting that the steel beams are more advantageous when we relate the height of the beam to the weight of the structural element.

In this way, a more comprehensive study, which addresses, for example, the economy in the time construction, the cost of integrated construction systems, the expenses with the maintenance of the structure, etc., must be developed to achieve the best parameter and adoption the construction system, that fits the requirements of each construction.

.

# References

[1] A. Acheampong, M. Adom-Asamoah, and R. O. Afrifa. "Comparative Study of the Physical Properties of Palm Kernel Shells Concrete and Normal Weight Concrete in Ghana 1 A. Acheampong, 2 M. Adom-Asamoah 3 J. Ayarkwa, and 4 R.O. Afrifa." *J. Sci. Multidiscip. Res.*, vol. 5, no. 1, pp. 129–146, 2013.

[2] F. L. PEDROSO. "Concreto: as origens e a evolução do material construtivo mais utilizado pelo homem," *Revista Concreto & Construções. n. 53.*, pp. 14–19, 2009.

[3] J. . ARAÚJO. Curso de Concreto Armado (Volume 1), 4. Ed. Rio Grande: *Dunas*, 2014.

[4] M. . GUANABARRA, "Dimensionamento de estruturas metálicas: Rotina Computacional para a seleção de perfis metálicos," UFRGS, 2010.

[5] J. PFEIL, W. PFEIL, Estruturas de aço: dimensionamento prático, 8. Ed. Rio de Janeiro: *LTC*, 2009.

[6] I. H. BELLEI, Edifícios Industriais em aço: projeto e cálculo, 5. Ed. São Paulo: *Pini*, 2003.

[7] J. PFEIL, W. PFEIL, Estruturas de Madeira, 6. Ed. Rio de Janeiro: *LTC*, 2003.

[8] A. G. LOPES, Introdução à Programação em Visual Basic 2010, 1. Ed. Lisboa, Portugal: *FCA*, 2010.