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Light Steel Framing and Structural Concrete Walls: Sustainable Perspectives for Affordable Housing

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Abstract
The emerging countries' society has demanded an increase on investments for affordable housing to long forgotten communities with low income – along, customarily, with the mind-set of sustainable development. In the past years, Brazil, for instance, has had an expansion on government programs that subsidize low-cost housing and, thus, studies on this area become more needed. In this paper, the sustainable aspects of two construction methods (Light Steel Framing and Structural Concrete Walls) are reviewed. The theories involving both methods and their practical approach are compared to their economical, ecological and social standards – aiming to identify the more sustainable one. Local aspects such as the supplying of materials, the work force expertise and the possible social obsolesce projections are fairly granted for both techniques. Hence, it was possible to track one construction site of the extension of approximately 1600 houses on Structure Concrete Walls and another one of a single house on Light Steel Frame, which is then extrapolated to an extent of several houses for comparison. Furthermore, based on the sustainable standards (economical, ecological and social), the Light Steel Frame mechanism has demonstrated to be superior in all standards when applied to the geographic conditions.

Keywords: Light Steel Frame, Structural Concrete Walls, Sustainability

1. Introduction

The civil construction business act directly on the environment, changing and shaping the interactions of those who live in it. The construction takes part on consuming 4 to 7 ton of material for each world's habitant annually (Agopyan et al., 2008). Therefore, building interferes directly with the natural resources and the community's lives – ergo, sustainable manners must take hand in the conception of projects and communities interference.

Locally, Brazil has a deficit in affordable housing and for that reason; the government is encouraging contractor to invest in parks of affordable housing for low-income families. With that said, big horizontal sites are growing vastly in Brazil and it is ideal and necessary to conduct this growing by applying sustainable manners.

Having in mind this growing scenario, two construction practices were counterweighted, not only by its productivity and by profits, but also by its sustainable practices and outcomes: Light Steel Framing and Structural Concrete Walls construction's methods were evaluated by its influence on ecology effect, economically viability and social impact practices in an affordable housing context.

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2. Sustainability

One civilization is sustainable when holds the ability of endurance and conservation for several generations – this happens through a combination of long-term vision and prudence that ceases the deterioration of natural resources and human lives (Brown, 1981; Meadows et al., 2007).
Ecologically speaking, constructions with longer lifespan presents a lower demand for repairs in the near future and it tends to take longer to be converted in rubble, as a result it decreases the total volume of materials involved (Agopyan et al., 2011).
For instance, if takes longer for a building to be demolished, then less row materials are extracted from the nature and less waste is disposed in the environment. Thus, having a longer lifespan result directly in wasting (Borges, 2010; Agopyan et al., 2011).
Evaluation sustainability is not straightforward, whereas defining the concept is a start. Therefore, sustainability three E's approach define three sustainable areas: Ecology, Economics and Equity – where each one has importance on the global analysis (Basu et al., 2014; Slaper and Hall, 2011).

3. Affordable Housing for Low-income Families

Affordable housing is aimed for low-income families that are not able to afford a house at minimal conditions for living. Usually build or financed by the government, vast social projects unite several groups and culture references that outstands the complexity of implementing one project in a region (Bonduki, 1998).
The fundamental goal of a housing is to shelter: to protect the inhabitant from external threats and this concept has sustained from time, even with the technology advances (Brandão et al., 2003, apud Lawrence, 1990; Larcher, 2005, apud Abiko, 1995). However, according with Lacher (2005), social housing has much more obligation then just sheltering only, it should provide a good and sustainable environment.

4. Structural Concrete Walls

The construction system of Structural Concrete Walls is a methodology based in the concepts of scale production and increase in productivity. By using this method, the structure's and the acoustic-thermal's system is the concatenated in one. The walls are made of concrete and the complementary systems, as hydraulics and electrical, are put together before dumping concrete (Misurelli et al., 2009).
The main characteristic of the system is the replacement of the traditional masonry system with structural concrete pillars and beans for a single wall filled with reinforced structural concrete. This method is based on systemic construction method, which ensures an increased quality and industrialization – ergo more control of wasting and velocity of production (Parede de Concreto, 2008).
In order to evaluate consistently the method, a local project for affordable housing to low-income families was studied extensively according to its sustainable practices. Jardins Mangueral (Image 1) is a PPP development – private-public partnership – projected for approximately 10 thousand housing. The architectural assemble is composed by

apartments with two rooms (46 m²), houses with three rooms (68 m²) and twined houses with two rooms (52 m²). The last served as object of study for this research.
The budget shown subsequently in the analysis part consists of the gross building cost for 1602 residences, discounting the indirect costs, benefits and profits.

Image 1: Low-cost housing units with 52 m², Jardins Mangueral, Brasília, Brazil (Authors).

5. Light Steel Framing

Light Steel Framing (LSF) is a construction methodology that uses light weighted structural galvanized steel cold formed frames with plywood and pre-fabricated cement boards. The frames are disposed according to the architectural needs and connected by bolts, forming panels and trusses, as shown in Image 2. United, the frames resist to accidental and dead loads, distributing it to a slab foundation. In addition, because the materials are all pre-fabricated, the task on the site is for assemble only – providing a production velocity increase (Santiago et al., 2012).
For the field analysis of the system and through help of a company with heavy participation in executing Light Steel Frame constructions, visitations were conducted to a single house site in a residential townhouse in Brasília, Brazil. Another company with vast participation in designing and building LSF houses complemented observations and provided the budget required for a 52 m² twined house based on the same plants as the executed in Jardins Mangueral's Structural Concrete Walls.

Image 2: Light Steel Framing housing construction site (Authors)

6. Ecology Analysis

The ecology analysis is based on the water consumption, pollution in the

fabrication's process, adoption of non-renewable materials and waste dynamics. Because of the grand-scales constructions sites, housing projects produces massive impact on the environment, therefore, it is important to incorporate the construction's lifespan in the analysis.

In the Structural Concrete Walls, the water consumption is ample needed. Although, this spend less water than the traditional method (Reinforced concrete structure with ceramic masonry), it still uses water on the fabrication of cement, mixing and dumping concrete. In addition, the system require elements like plasters that spends a great amount of water. To produce concrete's Portland cement materials such as clay, sand, gravel, etc., is needed. The base product of cement is clinker that the fabrication in rotary oven pollutes massively the atmosphere disposing heavy amounts of CO_2.

Still, locally, these products are well distributed and transportation impacts are lower. In the Jardins Mangueral construction's site was implemented a concrete temporary fabric that lowered the costs and the burden of transportation, although, the gravel, sand and cement had to be carried from distant regions not reducing completely the transportation impact.

In addition, reducing the volume of the house itself helps to diminish the consumption of materials. The Concrete Walls has a thickness of 12 cm and uses a steel net for the reinforcement, so it does not need beans, pillars and deep foundations – hence the need for heavy ribbon. At last, building concrete structures requires statistical testing for the quality of the concrete, in this way, samples are extracted for each lot produced – increasing therefore the materials waste.

On the Light Steel Framing scenario, as it is a dry construction method, the methodology of construction spend a rate much lower of water in the life cycle, the water is applied only in the fabrication of steel. The structure joins are bolted, not demanding plasters for example.

Manufacturing steel pollutes less then concrete, resulting in less impact. However, the transportation acts heavily in the outcome. In the local region there is none stalled factories producing LSF frames hence the panels must be transported by distant regions – compromising the emission of pollutants in the way.

The main positive aspect of implementing Light Steel Frame in housing projects is the precision of assemble (millimeters). The materials are all pre-fabricated and allocated, as the architectural projects demands. Thus, errors are not permitted and consequently wasting materials are diminished. The gross building part of building in LSF almost does not produces waste, as the image 3 shows.

Image 3: Total waste in a Light Steel Framing construction site (Authors)

7. Equity Analysis

The equity analysis is extended by the social impacts of each construction in the context of affordable housing. The users and the workers point a view are discussed in the act of building itself and the reliability for users in the future. The life quality of the consumer, maintenance and susceptive to pathologies establish important points of comparison for each system.

For concrete walls, the water pipes and electrical conduits are hidden in shafts or are embedded inside the concreted walls. In part, maintenance can be conducted for the hidden pipes in shafts, however, if the systems need repair probably it will affect the parts inside the walls – ergo, making a simple maintenance interfere in the structure of the house. In that way, for consumers the reliability is affected by the rigid composition obsolesce.

In contradiction, the Light Steel Framing system is easy to replace and disassemble, the plywood and cement board can be unscrewed and the electrical or hydraulics systems can be checked and exchanged. On other point, LSF require flexible pipes to adapt in the frames' holes displacement (Image 4), in other to traditional rigid PVC pipes.

For both systems pathologies are critical to well-behavior of the structure, both use the walls as a load`s support. In Light Steel Framing, a cracked plywood or cement board is easily identified and replaced – showing for the user where the pathology that caused the cracking tensile is, because the joins are all less rigid, tensile forces are no well conducted to distant regions. This helps the user to give the appropriate maintenance rapidly.

Locally, works are more adapted with the concrete methodology of construction; executing slabs and concrete shows no problem, but Structural Concrete Walls presents a subtle element that demands qualification. Concrete plates in the site analyzed were composed of aluminum, in difference with the traditional wood plates, and this special plate requires cares that must be informed to works before.

In other hand, to build with Light Steel Frame, it is necessary to train workers with the new tools and methods used in LSF. In the region of studied only two contractors works

and has their own team of trained workers – and as the culture is not yet shaped for the fragilities of LSF, workers must be accompany by their supervisors closely.

Image 4: Light steel frame hole's representation

8. Economic Analysis

By accompanying both sites and enterprises, it could be observed that none sustainable practice is executed without the financial subsidy and in case of affordable housing, the profits is shirked by the necessity to be affordable. Thusly, financial viability is essential for the final product, the analysis was conducted by two budgets for the 52 m² twined house for each system, excluding indirect costs.

Table 1 represents the gross cost for building the object of the study in the Structural Concrete Walls method. It was provided by the company responsible for the Jardins Mangueral project and was based in a dimension of 1602 units. The budget resulted in a price per square meter about R$ 881,56 per square meter.

Naturally, the total cost is affected by the local conditions and dispositions, thus in the timing for building in the Structure Concrete Walls methods is heavily conducted by the concrete curing (almost 30 days). In addition, the workers abilities influences on the outcome cost, in Jardins Mangueral at the start, the productions techniques were primitive and not tested, but in the final stage, the team of workers were producing much faster.

Table 1: Structural Concrete Walls budget (Authors)

2 Rooms unit - 52 m² - Structural Concrete Walls		
Stage	Single cost (R$)	Percentage of the total cost
Infraestructure	7.389,84	16,12%
Superestructure	18.441,02	40,23%
Sealing	412,61	0,90%
Roof	2.257,52	4,92%
Stairs	502,64	1,10%
Eletrical system	2.462,56	5,37%
hydrolical system	728,12	1,59%

Ceramics covering	1.997,87	4,36%
Plaster	228,15	0,50%
Inside painting	3.998,00	8,72%
Outside painting	986,52	2,15%
Doors	1.044,92	2,28%
Windows	2.370,33	5,17%
Visual communications	45,27	0,10%
Fixtures	729,03	1,59%
Final cleaning	324,60	0,71%
External constructions	1.923,31	4,20%
Total cost	45.842,31	

Similarly, to above, equal plans were budget: 52 m² twined house with a dimension of two thousand houses in Light Steel Framing. Table 2 shows the gross building cost for the object of analysis. The budget outcomes a cost for middle twined houses of R$ 699,01 per square meter and of R$ 757,88 per square meter for border houses.
Other factors also could influence the total cost, such as the training difficulties for capacitating the workers and timing. The last, is one of the most advantageous aspects of Light Steel Framing, where the building's duration is decreased and indirect costs not represented in the budged could shrink the total cost for producing the project.

Table 2: Light Steel Framing budget (Authors)

Type	Single house cost (R$)	Cost for m² of construction (R$/m²)
Boarder houses	39.409,99	757,88
Middle houses	36.348,62	699,01

9. Conclusion

In this study, it was acknowledge that affordable housing projects set a great importance for sustainable practices. The large scale interferes directly in the local supplying market and by the presence of government intensifies the need to optimization of costs and productions – ergo these contracts usually are limited to a original budget. Both methodologies furnish the economical low-income family's needs, but the sustainable aspects presets in different ways – having the Light Steel Framing outstanding the Structure Concrete Walls.
Ecologically speaking, although the materials used in the Structural Concrete Walls system affect less in the transportation aspect, the production of it interferes massively polluting the atmosphere, especially the Portland cement fabrication. Further, obsolesce of the materials used does not favor the sustainable aspect of reducing materials' volume in constructions, despite, LSF has shown a possibilities to renew its elements in the future.
Water consumption is a critic aspect for such large scale projects as housing, then, despite Light Steel Frame uses of water in the metal fabrication stage, concrete constructions still waste more water then dry-constructions as LSF.
Analyzing the long term, Light Steel Frame possibilities of maintenance secure a better

live for the future users that cannot be responsible for affording costly repairs due to their social-financial conditions. Structural Concrete Walls tighten the future possibilities and corrections to pathologies that may occur.

Finally, in the economic aspect both systems show adequate solutions for affordable housing projects and by calibrating the indirect costs, velocity of production and quality can make a positive result in sustainable practices. Besides the LSF final unitary cost (R$/m^2) is lower than the Structural Concrete Walls, is recognizable that the LSF budget was conducted with a dimension of more houses. Both systems has shown to be economically competitive.

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