Sustainability of Cuban Construction Supply Chain by Means of LC^3 Cement: Case Studies in Villa Clara Province

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Abstract. This paper aims at assessing the implications of using Limestone Calcined Clay Cement (LC^3) in the Cuban construction sector from a sustainability viewpoint. By means of combining Life Cycle Assessment (LCA), economic cost analysis and eco-efficiency approach, two construction techniques have been compared, taking as a functional unit one square meter of usable area. In spite of the inverse correlation between economic efficiency and ecological impact for all confronted techniques, complementary indicators showed some trade-offs at social level. The economic-ecological efficiency of LC^3 potential use is linked to two different sources: the construction method and the cement type itself. Relevant decision-making considerations could support economic policy in the domain of construction industry in Cuba, if taking into consideration the eco-efficiency portfolio provided by this study. Authors conclude that no one construction method is superior *per se* from a sustainability viewpoint, but it rather requires major rethinking beyond economy and environment to embrace social indicators.

1 Introduction

Housing affordability has long been a pressing and challenging issue in Cuba. Alternative solutions need to be rooted under the sustainability umbrella, for at least three reasons: (i) building materials have to be cheaper than usually, (ii) global warming potential should be ameliorated and (iii) social indicators claim for appropriate balance with the economy and the environment. As in most developing countries, housing provision largely relies on concrete. Overall, the production of cement and concrete is estimated to account for around 5–8% of man-made CO_2 emissions [1]. Limestone Calcined Clay Cement (LC^3) is a technological innovation proposed by an international scientific team, led by EPFL-Lausanne, Switzerland. The new product lies on the domain of using supplementary cementitious materials (SCM) to partially replace clinker in the cement content. The cost-effectiveness and environmental advantages of LC^3 have extensively been published in [2–5]. This paper aims at assessing the sustainability of

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using LC3 within Cuban construction supply chain, by taking into consideration a case study approach. Two storey-buildings constructed in the city of Santa Clara by employing Grand Panel and Concrete block techniques, respectively, are analysed.

2 Methodology

The used conducted case studies followed a combination of methods. The methodology Life Cycle Assessment (LCA) was employed to determine the environmental impact of LC3 in alternative construction techniques. LCA is well documented in the international standard 14040 and 14044, dated back to 2006 [6]. Figure 1 shows the system boundaries of the LCA conducted in this research (highlighted in dotted lines), which refers to the material phase of buildings under analysis. The functional unit employed for comparability purposes is one squared meter of usable floor area. Two case studies were conducted: (1) first one is a two-storey building with Grand Panel technique and (2) second, two-storey building constructed using traditional concrete block method. The economic dimension of sustainability was covered by means of an economic cost analysis. Some social indicators such as employment have been also discussed within the sustainability approach.

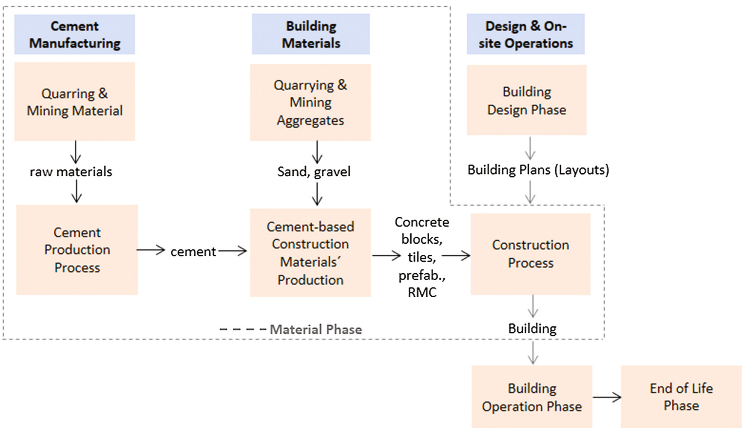

Fig. 1. System boundaries for LCA and economic cost analysis

Table 1 summarizes the data inventory required for LCA as well as for economic assessment. The usable floor area was 168.64 m^2 for Grand Panel building and 161.42 m^2 for concrete blocks building. The column referred to cement entails the amount of cement needed to produce the building materials presented in column 1, whose quantities are shown in the columns labelled “amount”.

The environmental impact factor of OPC, PPC and LC3 cements as well as its productions costs in order to determine the impacts at the level of building construction, were taken from previous research of LC3 Project team. Detailed figures are shown in [7], and authors elaborated on its foundations. Economic and ecological impacts are combined into "an eco-efficiency portfolio", as proposed by Schaltegger [8].

Table 1. Data inventory

Material	Unit	Gran Panel building		Concrete blocks building	
		Amount	Cement	Amount	Cement
Ready-Mix Concrete	m^3	24.9	11.95	40.6	19.49
Prefabricated Concrete	m^3	52	20.02	18.46	7.11
Hollow concrete blocks	u	770	1.32	4460	7.67
Mortar	m^3	20.97	6	59.33	16.97
Total	t		39.29		51.23

3 Results

Main results are intended to show the economic and environmental implications of using LC3 in different construction techniques schemes, given the case studies conducted in Santa Clara, Cuba. As can be seen from Fig. 2, the environmental impact of Grand Panel technology is 22% smaller than traditional concrete block method. This green contribution is associated with the shorter amount of material consumed in Grand Panel compared to block's technique. Replacing traditional cements (OPC+PPC) by LC3 leads to lessen the CO_2 emissions along the life cycle of building materials (within system boundaries specified above), in about 28% for Grand Panel buildings and 30% for concrete ones.

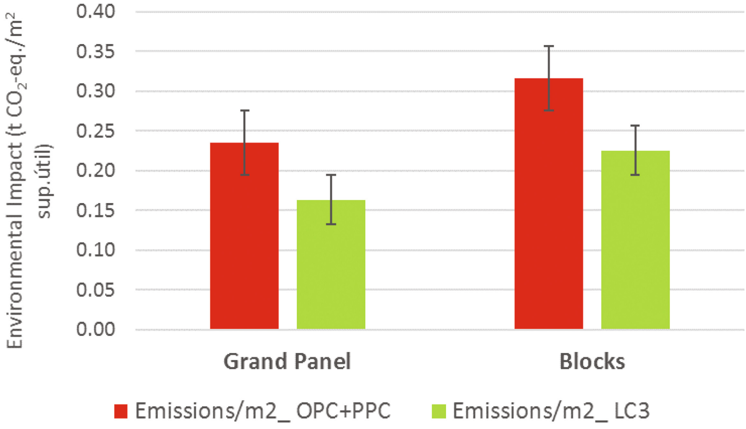

Fig. 2. Environmental impact of cements and construction technologies choices

Figure 3 sheds light on the economic contribution of options under appraisal. Concrete block's technique appears to be 25% less cost-effective than Grand Panel. The introduction of LC^3 in Cuban construction sector might contribute to cost savings of approximately 12% (in concrete blocks houses) and 13% (in Grand Panel ones).

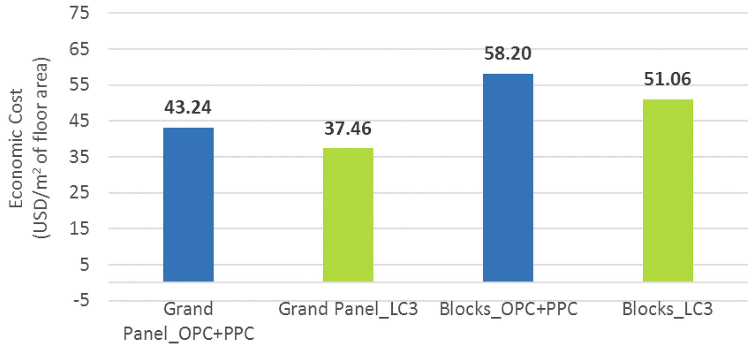

Fig. 3. Economic cost comparison amongst alternative construction techniques and cement types

Figure 4 shows an eco-efficiency portfolio for the conducted case studies. The combination of cost effectiveness and ecological contribution of LC^3 contributes positioning the new cement as an eco-efficient material. It appears to be a positive correlation between economic and environmental achievements for both cement types and construction techniques. This would push some policy decisions in Cuban construction sector if LC^3 is to be implemented at large scale. However, some trade-offs come out when taking into consideration additional indicators. For instance, concrete block construction method is labour-intensive, thus, contributing to employment enhancement in the country. However, Grand Panel, which uses less manpower, is a fast construction process due to the use of prefabricated elements instead of placing the blocks with mortar one by one. These issues provide inputs for policymakers in order to decide which method is more suitable. In authors' viewpoint, despite being proved the eco-efficiency

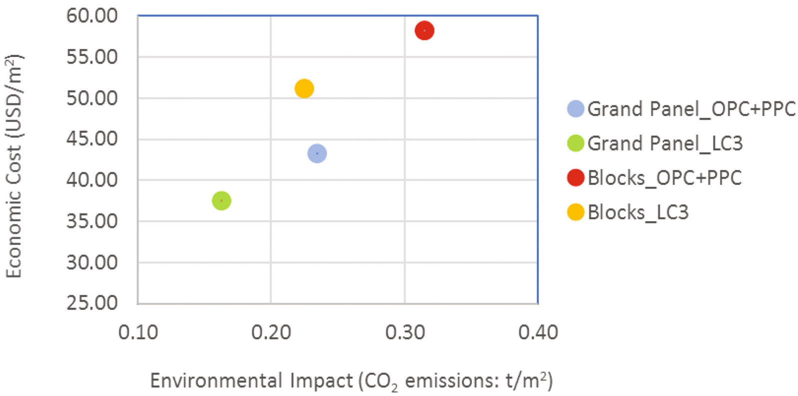

Fig. 4. Eco-efficiency portfolio

profile of Grand Panel versus Blocks, the choices must be tailored in a case-by-case basis, depending on a large number of factors that are underlying.

4 Conclusions

The main purpose of this paper was to assess the implications of using Limestone Calcined Clay Cement (LC^3) in the Cuban construction sector from a sustainability viewpoint. The conducted research has found that implementing housing programs by means of Grand Panel construction technique is rather beneficial than concrete block technique from an economic and environmental viewpoint. However, trade-offs are latent when expanding the system analysis to further consider the social dimension of sustainability. Therefore, decision-making within Cuban construction sector with regards to construction techniques requires a holistic approach which must rely on the specific conditions on a case-by-case basis, rather than concluding that one building method is strictly better than the other one. A sustainability approach must be rooted on an integrative system thinking which should entail discussions beyond the economy and the environment. Moreover, LC^3 has the potentials for affording major sustainability goals even in the wort case scenario.

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