Sustainable Alternatives to Concrete applied in South America

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Table of Contents

Abstract

This research explores the feasibility of green materials and technologies in San Juan de Lurigancho (SJL), in Lima, Peru. The district is threatened by pollution caused by city factories, affecting citizens' health. There is a need to improve the neighborhood's safety and quality of life, summed up with a positive outlook on building sustainably, expressed by neighbors through surveys and by other authors in Latin America. The research shows how through architecture and alternatives to traditional materials like sustainable concrete and cement, the neighborhood's quality of life could be improved by constructing buildings from these materials. Doing so would improve the air quality, address seismic concerns, and create a safe space for the community to learn, grow, and develop. An investment is needed for the project to be executed, considering the cost of implementation and the machines to produce the materials. However, it will also rely on the use of local resources, and overall, will improve resident's lives.

Introduction

Previous research focused on sustainable alternatives to concrete, specifically LC3 and Solidia cement, and their implementation in Peru. Based on their history, current studies about pollution and contamination from the building industry, and the growth in consciousness about sustainability, it is important to research, develop, and implement alternatives for common/traditional building materials. It is essential to find alternatives for traditional building materials like cement and concrete, which have more acceptance and better seismic performance and are also one of the most global and increasingly in demand materials that generate greenhouse gas emissions (Kajaste, R., Hurme, M., 2016).

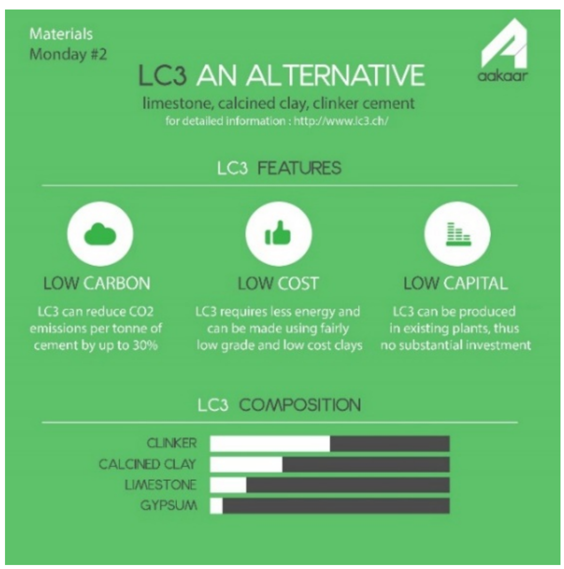
The decision to choose sustainable alternatives for cement and concrete is due to the accessibility and approval of the material in a seismic location like Peru. The intention is to associate other Latin American countries' characteristics with the Peruvian context and make relations that will show the benefits of alternatives to concrete that will reduce pollution compared to Portland cement. Specifically, in Lima, the country capital, and the district chosen for the proposal, the CO2 growing emissions are alarming. Will sustainable alternatives to concrete in Peru be a feasible solution to reduce the pollution levels compared to common concrete and, consequently, improve the quality of life of the neighbors?

Green building technologies and materials have been studied due to their benefits (Wu, X., et al., 2011). However, can this new development on materials and building technologies be implemented in Peru? The study will be based on previous research on Limestone Calcined Clay and Solidia cement (Meyer, V. et al., 2018) and research on Latin American opportunities for these concrete alternatives to be implemented from the 3rd International Conference on Calcined Clays for Sustainable Concrete (Bishnoi, 2020). Based on previous studies and experiments, both alternatives are born as solutions to mitigate the current crisis on climate change and the negative effects that human evolution has had on the environment, specifically to diminish the impact of the building industry, one of the most pollutant ones.

Literature Review

Many engineers around the globe have researched alternative materials and methods for sustainable building. For example, Tom Schuler, with his company Solidia, is working on an easy and profitable cement curating process with Co2 negative emissions. Also, Karen Scrivener has developed a new kind of cement called LC3 or Limestone Calcined Clay Cement, which could reduce carbon emissions by 40 percent. The problem is that not everyone in the industry is willing to trust newer technologies, and with the doubt, time passes, and contamination increases. In Peru, these green developments could be implemented to reduce pollution, reduce the building sector's negative impact on the environment, and reduce production costs compared to other alternatives like Portland cement (Scrivener, K. et al., 2018). Another great benefit is the intention behind the new proposed building, reconnecting communities that have been affected due to the pollution caused by closeness to contaminate industries.

Fig. 1

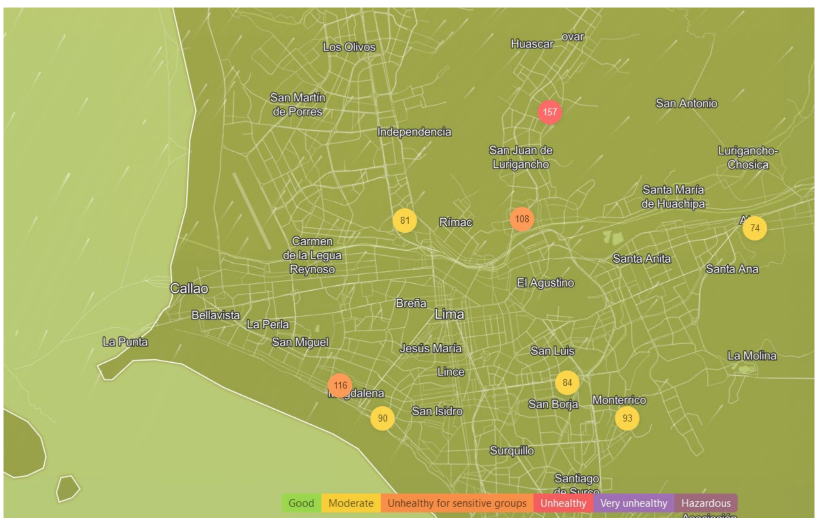


Source: LC3 cement infographic, by Akshar.

With the correct analysis of the environment, this could become a reality and benefit the country as well as set the mark for many others to trust new methods. Studies like "Calcinated Clays for Sustainable" (Scrivener, K., & Favier, A., 2015) have shown throughout analysis on alternative cement composition, characteristics, and development in different environments and societies that green alternatives are a feasible solution that can be applied almost anywhere. With the help of more specific studies and experiments done in Cuba, Venezuela, and countries with similar realities, economic, political or environmental, the implementation of these concrete alternatives could be supported in Peru.

For the specific case of San Juan de Lurigancho district, according to IQ Air, the pollution levels are currently at 157 US air quality index. This is an unhealthy level produced by the environmental damage caused by the enterprises surrounding the area and the lack of limits and responsibility they have (Prado, S. & De Jesús, M., 2018) as well as the plants of production, which create heavy CO_2 emissions.

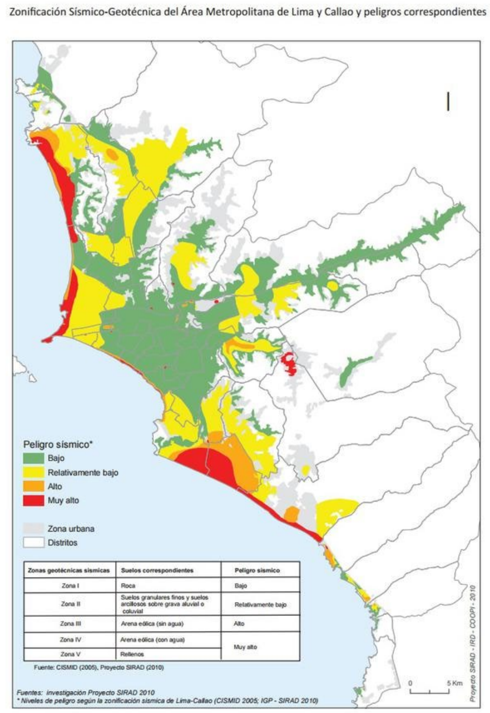
Fig. 2



Pollution air map. Retrieved from [IQ Air Company] 11.05.2021

Also, according to the map presented by the Peruvian-Japanese Center for Seismic Research and Disaster Mitigation, the seismic danger of Peru is mainly focused near the shore, and it affects the district of the area of study.

Fig. 3



CISMID (2005), SIRAD Project (2010)

Materials like concrete and steel are the more popular and of easy access for Latin American countries, which are not the ones that produce most of them. However, the difference between these two is that steel can be reused and recycled for a second use, but its production emits higher CO2 emissions than concrete (Harris, 1999). Compared to wood, and although concrete generates large CO2 emissions on production, it has more carbon sequestration when the use, demolition, and secondary uses are analyzed. Concrete is also a more durable material. Its structural behavior and durability make it one of the most common building materials, and in Peru, one of the most seismically active regions due to the subduction of the oceanic plate under the continental plate; concrete is commonly the preferred material. Therefore, and considering the entire life cycle of the building and material, concrete buildings that repeat the same floor areas have higher carbon benefits than other materials, like wood (Dodoo et al., 2009).

Methodology

The methodology employed to conduct this research is divided into the following sections:

I. Study Area/Site:

The new area of analysis is San Juan de Lurigancho, a district located in Lima, Peru, a poverty zone where most of the city (Lima) plants and industries are located. This generates air pollution and low life quality for the surrounding inhabitants.

A previous study in Cuba and Venezuela shows experiments about concrete alternatives, and the study relates those with the Peruvian territory and microclimates that could match, to make a relation on how the new sustainable materials, especially concrete, are a feasible solution for reducing levels of CO_2 emissions in Peru.

Fig. 4

Map of the San Juan de Lurigancho district in Lima, Peru. Retrieved from Google Maps. 09.24.2021

Fig. 5

Map of factories located in San Juan de Lurigancho district. Adapted from Google Maps. 18.10.2021

II. Research Design

The purpose of the research is to evidence the similarity between the experiments and efficiency of LC3 done in Latin American countries and Peru to recognize concrete sustainable alternatives as a solution for reducing the carbon emissions and contamination that the concrete industry produces. To do so, the characteristics of climate and territory from the studies are compiled from the International Conference on Calcinated Clays for Sustainable Concrete. Specifically, the chapters where topics about technology, production, performance, impact, challenges, and opportunities in Latin American countries are treated. The research also works to identify the green materials and technologies used in developed countries and South America to confirm that they could be implemented in a public building in Peru. This work shows how it will positively impact the community where it is proposed in terms of sustainability and health as well as the positive outcomes of it.

III. Data and Measures:

The data obtained for this study comes from a compilation of the 1st and 3rd International Conference on Calcinated Clays for Sustainable Concrete. Specifically, the chapters with Cuban and Venezuelan experiments to compare the performance of LC3 in Latin America. Likewise, interviews and publications on the LC3 and Solidia Cement web pages were used to give comparative statistics on how these alternatives are beneficial compared to common cement.

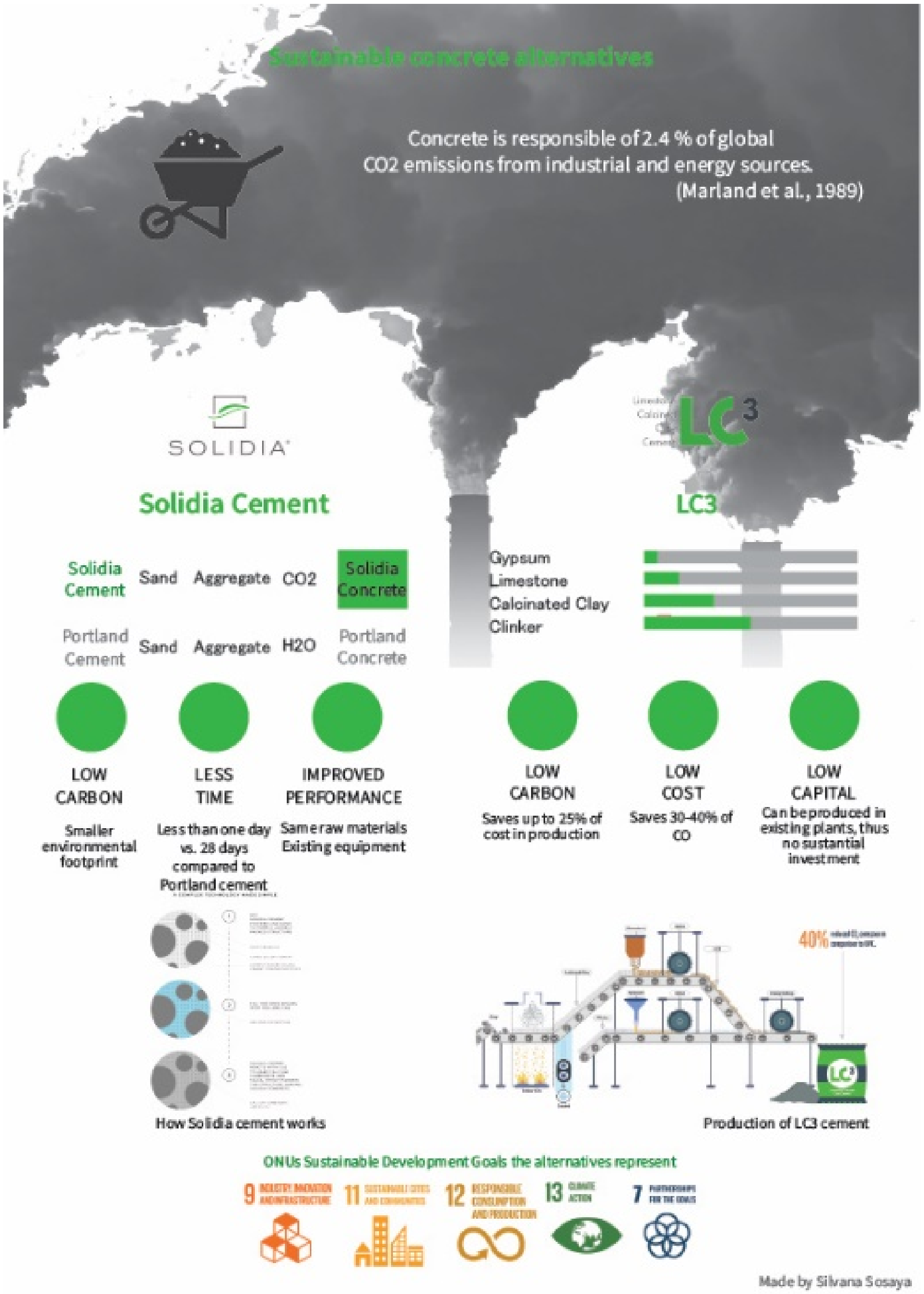
Other data sources for this study include a census made by the National Institute of Statistics and Informatics (INEI), providing information on housing material in the area, and an online survey sent to SJL neighbors via Facebook groups. The survey helped understand people's needs, how the proposed design can meet them (in order to make a beneficial intervention), and their knowledge of the pollution.

IV. Methods

First, climate comparisons between Venezuelan and Colombian climates with Peruvian had to be made. Afterward, a contrast between the obtained results and how accurate those results will be in Peru. In total, two surveys were realized. The first one, sent to 23 professionals and students related to the building sector, was about finding out their expectations of concrete sustainable alternatives. The second survey was sent to 24 San Juan de Lurigancho district neighbors. It focused on the reality and experience of the residents relating pollution and quality of public spaces in their neighbor. After reading the research and proposals, studies made from these materials were analyzed to design a program on how a public space like these should be made to best meet the needs of SJL neighbors with low cost and impact on the environment.

Preliminary research results

Fig. 6



Infographic on Sustainable Concrete Alternatives, by Silvana Sosaya 2021

The data exposes the benefits of the concrete alternatives, and why they are a better option compared to common Portland cement, related in economic, environmental, and effectivity aspects. It shows the feasibility of being implemented in Peru and in which zones due to the similarity in climate and topography with previous research.

According to Table 1 from "Solidia Cement an Example of Carbon Capture and Utilization," the Co2 emissions are considerably lower with the alternative concrete, making it a better material for the building to have a less negative impact on an area that is already damaged by pollution.

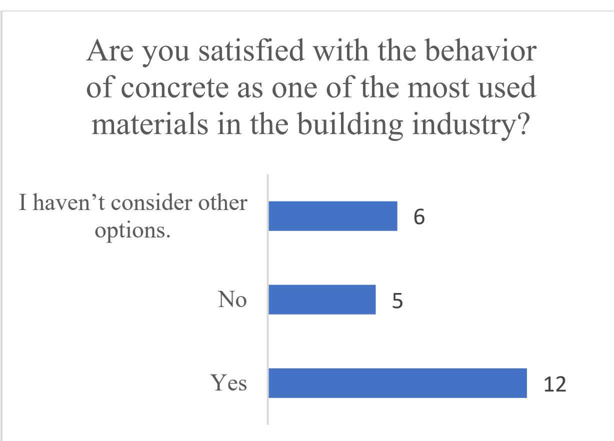
Table 1

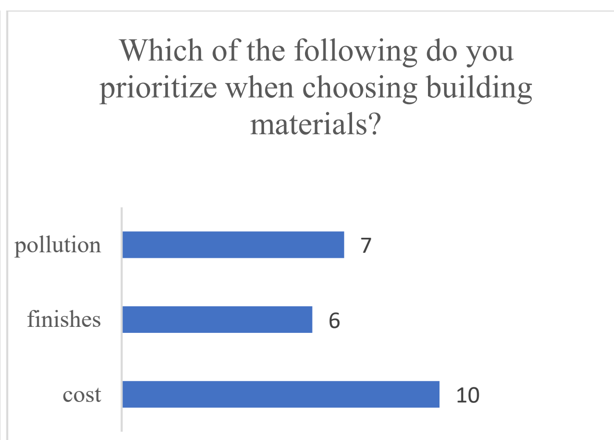
Table 1: CO_2 emissions during the production of PC and CSC clinker (Note: The CO_2 associated with the electrical energy usage in the cement making process is not considered)

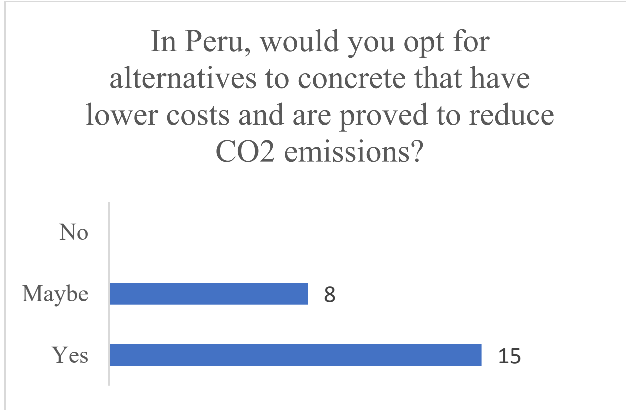
CO_2 emissions from:	Per ton of PC clinker	Per ton of CSC clinker
Limestone decomposition	540 kg	375 kg
Fossil fuel combustion	270 kg	190 kg
Total CO_2 emissions	810 kg	565 kg

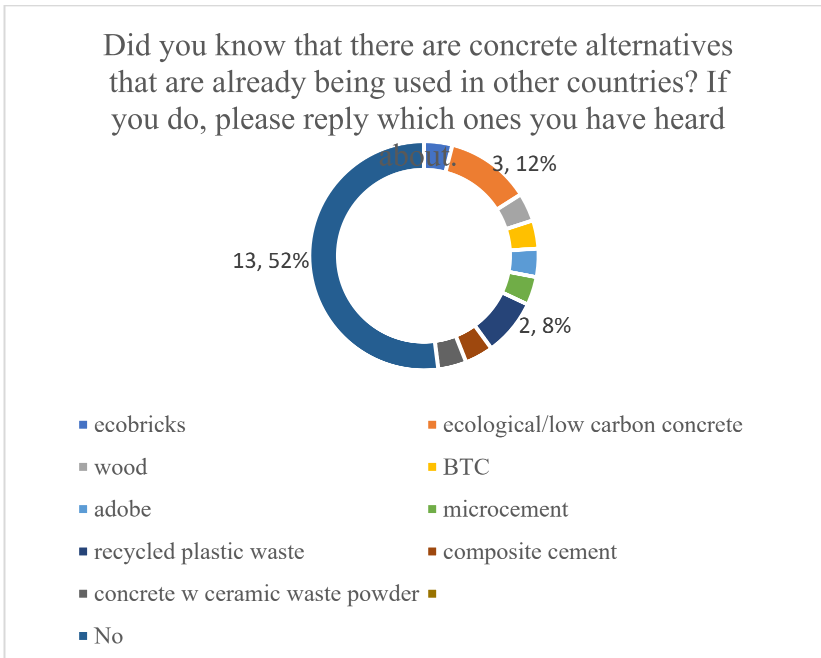
Retrieved from "Solidia Cement an Example of Carbon Capture and Utilization"

The survey to professionals and students in the building industry provided interesting results, as shown in the following graphics. For example, respondents are willing to consider alternatives if they provide lower emissions.

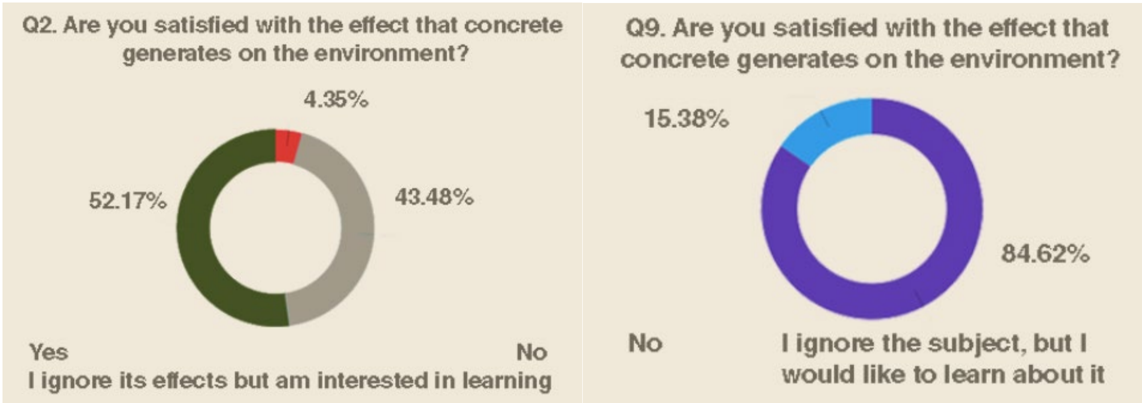








The second survey, sent to San Juan de Lurigancho neighbors aging from 18-50 through Facebook, groups (https://uarizona.co1.qualtrics.com/jfe/form/SV_5uxlhnxWqNjQpfw) shows:



It has also been expressed the need to produce and maintain better public spaces, which will consequently aid in the community's sense of security. It has been expressed how PG&E Energy Centers can serve as a source of education and make a bookmark for these types of spaces in South America.

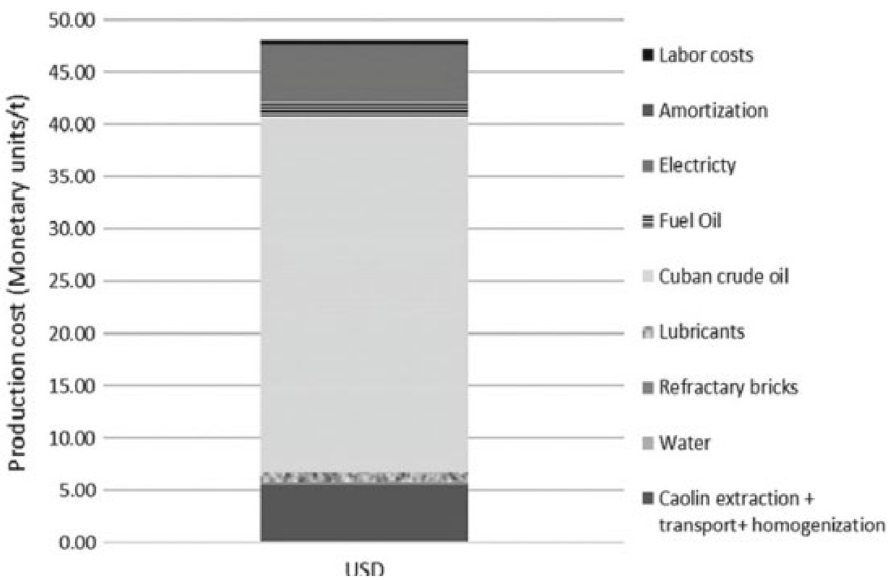
Discussion and Conclusion

After recollecting the data from previous research done in Latin American countries and the United States, some connections could be made relating to the purpose of the study, which is to determine if sustainable alternatives to common concrete could be implemented in Peru.

The survey done with students and professionals shows that 21,74% are not satisfied with the performance of concrete in the building industry. 26,09% of the population sample had not considered other alternatives. More than half (52,17%) are not satisfied with the effect that concrete generates on the environment, and everyone who ignores those effects (43,48% of the sample) is interested in learning about them. Amongst these and all the results, it is correct to say that people are interested in learning from concrete alternatives that could reduce the cost and reduce negative environmental impacts such as pollution compared to Portland concrete. There is a strong belief (95,65%) in implementing the presented alternatives in Peru and a great willingness to collaborate in that process (100%).

According to Sánchez-Berriel et Al. on "Impacts Assessment of Local and Industrial LC3 in Cuban Context: Challenges and Opportunities", in Cuba, where "(…) measurement of the reserves conclude that there are enough resources to guarantee more than 25 years of production." (p. 264) cement-based on LC2 showed economic advantages compared to other cements, such as industrial LC3, OPC, and PPC. It also has environmental advantages for both local and industrial LC3, due to a significant reduction in emissions and energy demand versus OPC and PPC. Among these benefits, relating to local production, the calcination of clay done in Cuba, carried in a wet process rotary clinker kiln, reduced 40% of the energy used on the clinkerization process. Also, in Table 1, the monetary benefits of the local production and transportation are shown in USD. (Bishnoi, S, 2020)

Table 2



Source: Life cycle costing of calcined clay in Siguaney. Costs in USD. Made by Sánchez-Berriel et Al., Impacts Assessment of Local and Industrial LC3 in Cuban Context: Challenges and Opportunities 2020

It is important to recognize that commonly used cement such as OPC and PPC showed greater negative environmental impact due to emissions and greater economic impact, as explained in the following Table 2.

Table 3

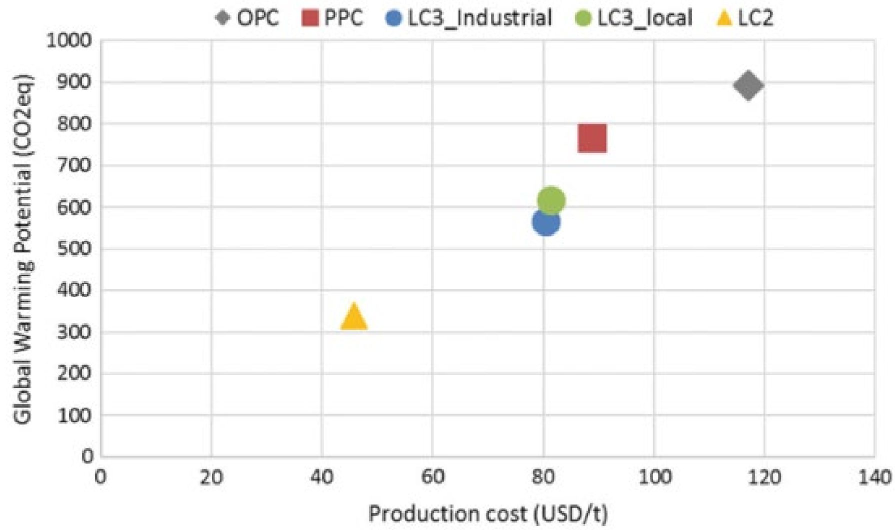


Fig. 4 Environmental versus economic impact. OPC, PPC, LC3 industrial and local

Martirena & Alujas found that “Cement demand in Latin America(South America, including Brazil, Central Americ and the Caribbean) exceeds 250 million tonnes per year; this demand is planned to grow to 350–400 million in 2050” (p. 778). Specifically, in the local context, mining represents 10% of Peruvian GDP, 60% of exports, 16% of private investment, and 19% of taxes paid by companies (Gestión, 2020). The relation and possibility to achieve even greater results if industrializing LC3 locally from Peru is most likely to be beneficial for the building industry, due to its improvement in efficiency and reduction of costs compared to common concrete. This also allows Peruvian society to have more affordable housing and for the environment due to the proven reduction of Co2 emissions and higher chances to have general approval from the economic representatives in Peru.

For that purpose, it is important to determine a variety of factors, such as the type of clay deposits and their accessibility to the cement plants, as well as the minerals that may come with it and their effect on the activated clay performance, the methodology and technology for the clay calcination as well as the grinding strategy and the strategy for the other components such as ternary cements. For that reason, results of research done alongside the Cuban Technical Resource Center showed that the combination in use of calcinated clays and limestone could achieve the decreasing demands in clinker as a component in cement, since there are more reserves of kaolinitic clays in the Latin American Region (Bishnoi, S, 2020). This is the case of Llanacora district on Cajamarca located in Peruvian north (Vergara, B., 2017), as well as having similar performance to type I Portland cement.

From the “Survey for neighbors of San Juan de Lurigancho,” it was found that neighbors are not satisfied with the levels of pollution in the district nor with the negative effects concrete has on the environment. It was also found that following the insecurity, the second most important problem is pollution and its damage to their quality of life. Among the required public spaces were libraries, cinemas, recreational games, and parks.

The terrain, located in the district of San Juan de Lurigancho in Lima, Peru, has an area of 2100 square meters and the building consists of two floors. The design features proposed in the building reduce pollution levels and increase life quality from cleaner air, energy, and money savings. The proposed building also serves as a commentary space for the community to grow and develop safely and with environmental values. The proposal also considers the location’s opportunities, climate conditions, soil, and other resources to define the green technologies applied. According to the Peruvian Association of Renewable Energies, Lima city has privileged access to wind and solar power; these two green materials, such as LC3 concrete, will also be applied in the project.

The proposed program is not only sustainably built and powered, but it also has common areas, such as workshops, multipurpose rooms, Learning and Research Resource Center (CRAI), green areas, play areas for children, a vegetable garden, and an amphitheater. This will increase the value of the project and will be a milestone for the community and the city in general, as a demonstration of the benefits that this type of architecture can bring. It is also an innovation that the building will follow the model of the PG&E Energy Centers, being an educational space that will explain how sustainable concrete is applied to the building while upskilling young people who want to work in the sustainable building industry.

Conclusion

The research explored how using sustainable concrete methods could improve the quality of life and reduce pollution in SLJ. It did so through case studies and surveys of professionals and residents. The survey sent to the SJL neighbors explained their expectations. It showed their problems, which were mainly interpreted as insecurity and the need for adequate common spaces and their preservation. Other data also exposed the increasing and alarming levels of pollution in the SJL district in Lima, Peru, mainly from the industries there. From the second survey, the main concern that the neighbors had was the insecurity and need for adequate common spaces that can reinforce the community and their preservation. The appliance of this design will mean great benefit for the communities of San Juan de Lurigancho. The proposed program will be a bookmark for sustainability and for public buildings in the region from air quality, sense of community, security, and the generation of jobs.

Even though the plants of production for these concrete alternatives are not yet available in South America, specifically for the case of Peru, there is the presence of Kaolinitic clays, used for sustainable concrete, at the Llanacora district in Cajamarca. Moreover, the production of the material can be implemented in existing plants, generating local production, reducing transportation costs and emissions, and generating industrialization possibilities for the green building industry.

Other data from news have confirmed that these problems are persistent in the area of analysis and will try to solve them through the design and functionality of the building. In search of proposing a green building that will also reduce the needs of SJL, it was found that it is possible to execute a building that implements technologies as solar panels and Eolic energy, as well as the use of lc3 concrete for its construction. Studies in South American and Caribbean countries, such as Cuba and Venezuela, have shown that it is doable.

However, the application cost could reduce the approval and time of execution, considering that there are no providers in South America, and machines and training would be essential. For future research, it would be beneficial to know from the experts in the new material (LC3), their thoughts on expanding their range of commerce and their perspective and techniques to reduce costs for projects proposed in under-developed countries. Doing so could provide better techniques, and job opportunities would appear and make a greater impact.

Appendix

1. Survey "**Green/alternative building materials and their implementation in Peru**", made by Silvana Sosaya

Green/alternative building materials and their implementation in Peru

The following survey is directed to engineers, architects and/or professionals related to the construction industry. The intention of the survey is to understand the current general knowledge, thoughts, and tendencies on changing traditional building materials for green alternatives in Peruvian culture.

Please copy the following URL to access the survey:

https://uarizona.co1.qualtrics.com/jfe/form/SV_38ENL9SLJSyys6i

Q1. Are you satisfied with the behavior of concrete as one of the most used materials in the building industry?

-Yes

-No

-I haven't consider other options.

Q2. Are you satisfied with the effect that concrete generates on the environment?

-Yes

-I ignore its effects and am not interested in learning them.

-I ignore its effects but am interested in learning them.

-No

Q3. Which of the following do you prioritize when choosing building materials?

-Finishes

-Cost

-Pollution generation

-Time

Q4. Did you know that there are concrete alternatives that are already being used in other countries? If you do, please reply which ones you have heard about.

-________________

-No

Q5. Do you recognize these alternatives as a positive evolution on the building industry?

-Yes

-No

Q6. In Peru, would you opt for alternatives to concrete that have lower costs and are proved to reduce CO2 emissions?

-Yes

-Maybe

-No

Q7. Do you think concrete alternatives could be implemented in Peru? If not, please explain why.

-Yes

-No, because of __________

Q8. Would you be willing to collaborate on projects for the implementation of concrete alternatives in Peru?

-Yes

-No

2. "**Survey for neighbors of San Juan de Lurigancho**", made by Silvana Sosaya

Survey for neighbors of San Juan de Lurigancho

This survey focused on the reality and experience of the residents of San Juan de Lurigancho will be used for academic purposes. Please answer each question honestly for the best result. Thank you.

Please copy the following URL to access the survey:

https://uarizona.co1.qualtrics.com/jfe/form/SV_5uxlhnxWqNjQpfw

Q1. Do you currently live in San Juan de Lurigancho?

-Yes

-No

Q2. For how long have you been a neighbor?

-1-3 years

-3-5 years

-5-10 years

-10+ years

Q3. What would you say is the biggest problem the district is facing?

-Delinquency/ Insecurity

-Pollution

-Other: _______

Q4. Which activities do you do when you are in SJL?

-Tourism

-Shopping

-Work

-Family visiting

Q5. Which of the following do you use more frequently?

-Parks/Playground

-Sport fields

-Cultural activities (concerts, theater)

-Libraries

Q6. Are you satisfied with the public spaces in the district? Briefly explain why.

-Yes

-No, because…

Q7. Which type of public space would you consider the district lacks off?

Q8. Would you consider positive to implement working spaces, such as co-working centers in the district?

-Yes

-I would prefer a space just for students.

-No

Q9. Are you satisfied with the pollution levels on the district?

-Yes

-No

-I ignore the subject, but I would like to learn about it.

Q10. Do you consider as positive the construction of public buildings that implement renewable energies (solar panels, wind energy) on the district?

-Yes

-No

Q11. Considering the benefits that they bring to the environment, would you consider as positive the investment on public buildings made from sustainable materials?

-Yes

-No

Results:

Green/alternative building materials and their implementation in Peru

Interviewee	Q1.	Q2.	Q3.	Q4.	Q4.2	Q5.	Q6.	Q7.	Q7. 3	Q8.
1	I haven't consider other options.	I ignore its effects but am interested in learning them.	Cost	Yes	BTC, adobe, microcement	Yes	Yes	Yes		Yes
2	Yes	I ignore its effects but am interested in learning them.	Pollution generation (Reduction)	Yes	ecobricks	No	Maybe	Yes		Yes
3	Yes	No	Cost	No		Yes	Yes	Yes		Yes
4	Yes	I ignore its effects but am interested in learning them.	Finishes	No		Yes	Yes	Yes		Yes
5	No	No	Pollution generation (Reduction)	No		Yes	Yes	Yes		Yes
6	Yes	I ignore its effects but am interested in learning them.	Pollution generation (Reduction)	No		Yes	Maybe	Yes		Yes
7	Yes	No	Cost	Yes	bricks, wood, etc	No	Maybe	No, because of:	cost/benefits	Yes
8	Yes	Yes	Pollution generation (Reduction)			Yes	Maybe	Yes		Yes
9	Yes	No	Finishes	Yes	Recycled plastic waste, composite cement	Yes	Maybe	Yes		Yes
10	Yes	I ignore its effects but am interested in learning them.	Finishes	No		No	Yes	Yes		Yes
11	Yes	No	Finishes	Yes	Ecological concrete	Yes	Yes	Yes		Yes
12	I haven't consider other options.	I ignore its effects but am interested in learning them.	Pollution generation (Reduction)	No		Yes	Maybe	Yes		Yes
13	Yes	I ignore its effects but am interested in learning them.	Finishes	No		No	Yes	Yes		Yes
14	Yes	No	Cost	No		Yes	Maybe	Yes		Yes
15	I haven't consider other options.	I ignore its effects but am interested in learning them.	Cost	Yes	Low carbon concrete	Yes	Yes	Yes		Yes
16	No	No	Cost	No		Yes	Yes	Yes		Yes
17	I haven't consider other options.	I ignore its effects but am interested in learning them.	Cost	No		No	Yes	Yes		Yes
18	No	No	Pollution generation (Reduction)	Yes	concrete with ceramic waste powder	Yes	Yes	Yes		Yes
19	I haven't consider other options.	No	Cost	No		Yes	Yes	Yes		Yes
20	No	No	Finishes	Yes		Yes	Maybe	Yes		Yes
21	Yes	I ignore its effects but am interested in learning them.	Pollution generation (Reduction)	No		No	Yes	Yes		Yes
22	I haven't consider other options.	No	Cost	Yes	Recycle Plastic	Yes	Yes	Yes		Yes
23	No	No	Cost	No		Yes	Yes	Yes		Yes

Survey for neighbors of San Juan de Lurigancho

Q5. Which of the following do you use more frequently?

-Parks/Playground (50%)

-Sport fields (50%)

-Cultural activities (concerts, theater)

-Libraries

Q6. Are you satisfied with the public spaces in the district? Briefly explain why.

-Yes (30,77%)

-No, because… (69,23%)

Not because at night in most public spaces it is filled with informal or clearings and garbage, etc.

It has no maintenance

There is very little security

The recreation areas need to be maintained.

Most of them are not supervised by the Municipality or are forgotten

It is not safe and is almost never clean.

It does not have green areas

Lack of green areas and aesthetic care

They lack maintenance

Q7. Which type of public space would you consider the district lacks off?

The parks lack more care

Parks

They lack pet parks

Pave the tracks and more green areas.

Libraries, cinemas

Libraries and places for fun

Recreational games park

The signage in the avenues

Parks

Parks, recreation centers

Q8. Would you consider positive to implement working spaces, such as co-working centers in the district?

-Yes	(76,92%)
-I would prefer a space just for students.	(15,38%)
-No	(7,69%)

Q9. Are you satisfied with the pollution levels on the district?

-Yes	(0%)
-No	(84,62%)
-I ignore the subject, but I would like to learn about it.	(15,38%)

Q10. Do you consider as positive the construction of public buildings that implement renewable energies (solar panels, wind energy) on the district?

-Yes	(92,31%)
-No	(7,69%)

Q11. Considering the benefits that they bring to the environment; would you consider as positive the investment on public buildings made from sustainable materials?

-Yes (100%)

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