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Comparative study of the economic-environmental performance of activated alkali cement and Portland cement using LCA and LCC

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INTRODUCTION

Growing demand of the housing and infrastructure sector in Brazil, as already observed in other countries, inflated the economic sector.

Is came the environmental impacts, due to a large amount of waste, energy consumption, and CO_2 emissions.

The production of one ton of Portland cement, one ton of CO_2 is emitted into the atmosphere and 1.15 tonnes of limestone are extracted.

An alternative in the use of mineral additions to partially replace clinker. Other studies are advancing the development of eco-efficient cement.

INTRODUCTION

These types of cement do not have clinker in their composition, which reduces the amount of CO_2 emissions into the atmosphere . Among these binders, it is worth mentioning the activated Alkali Cement.

Activated alkali cement they consist basically of industrial residues, such as fly ash and blast furnace slag.

Every product, however eco-efficient, causes damage to the environment.

OBJECTIVES OF THE PAPER

It is necessary to carry out more research related to its life cycle, to have a broader view of the process production and its true environmental and economic gains when compared to Portland cement.

APPROACH USED

The definition of the methods to be used in the present study followed the procedures indicated by ISSO 14040 and are described in the course of the work.

The life cycle analysis has four stages, the definition of objective and scope, , inventory analysis (ICV)), impact assessment (AICV), and finally, we have the interpretation phase.

APPROACH USED

Definition of objective and scope

The objective of this work is to analyze the life cycle of alternative clinker (activated alkaline cement) in comparison with Portland cement.

APPROACH USED

Determination of functional unit and boundaries

As a functional unit of the study, the production of one cubic meter of concrete was considered, so that it is made up of equal materials and mix.

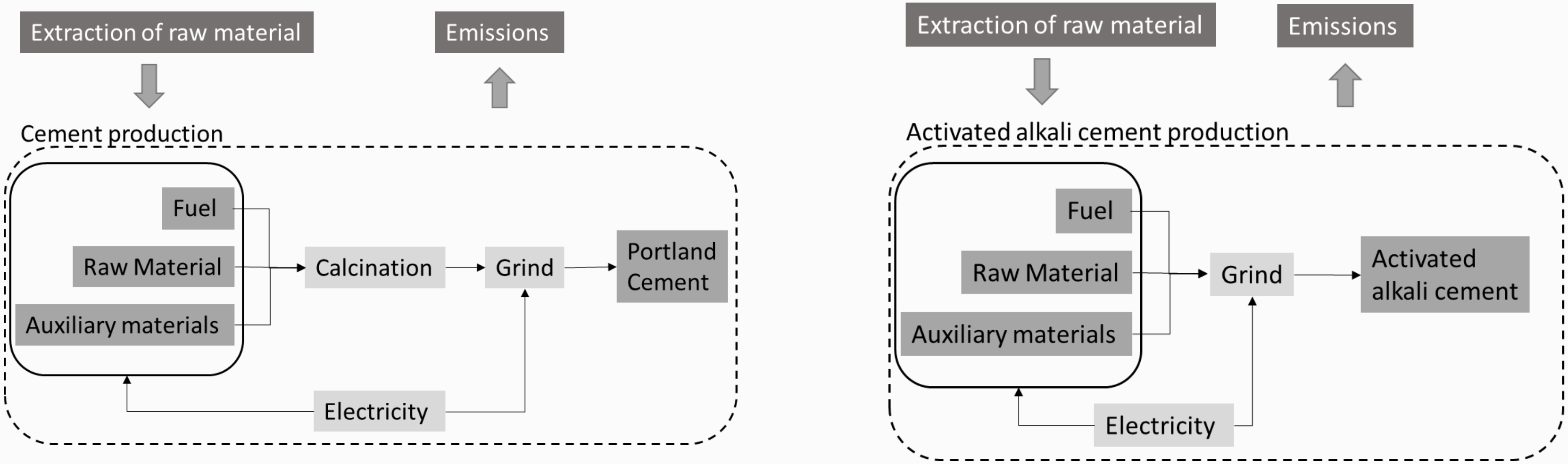
To quantify the environmental impacts managed by the two types of binders, a reference flow of one ton of material produced was used.

The scope considered only from the extraction of the raw material to the final product.

In the case of different types of cement such as this work, the analysis also assumes that both have durability over the years.

APPROACH USED

Determination of functional unit and boundaries



Product system for clinker and activated alkali cement production

APPROACH USED

Choice of compared cements

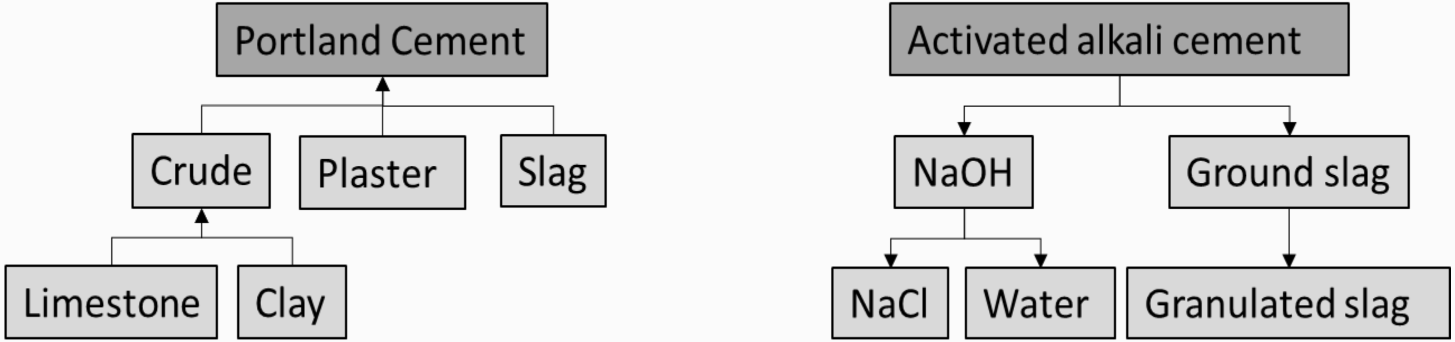
The cement used for the LCA was Portland cement type PC II - E which contains up to 34% of blast furnace slag in its composition.

In comparison, activated alkali cement consisting only of blast furnace slag and activated by 5% sodium hydroxide was used, a composition indicated by Langaro (2017).

APPROACH USED

Data inventory analysis

The process that precedes the inventory analysis for the insertion of data in the LCA software is the development of a product tree



APPROACH USED

Data inventory analysis

Portland Cement Production (34% Slag)		
Raw material	Amount (kg / ton. of cement)	
Limestone	1.650	BGS (BRITISH GEOLOGIAL SURVEY, 2005)
Clay	400	
Plaster	40	SIGNORETTI (2008)
Slag	340	Addition 34%
Electricity	Amount (kJ / ton. of cement)	
Limestone crushing	9.309,67	PAULA (2009)
Clay grinding	2276,64	
Raw grinding	74.959,49	
Homogenization	10.713,60	
Supply and exhaustion of the rotary kiln	39.506,40	
Operating the oven	6.696	
Activation of the primary air blower	2.151,65	
Clinker cooler	14.508	
Clinker cooler	5.624,64	
Clinker grinding	99.819,50	
Electrostatic precipitator	1.450,80	
Production of activated alkali cement		
Raw material	Amount (kg / ton of cement)	
Slag	1000	BORGES et al., (2014)
Slag grinding	Amount (kJ / ton of slag)	
Energy consumption - vertical mill	210.312	BORGES et al., (2014)
Production of Sodium Hydroxide	Amount (kg / ton of hydroxide)	
Water	450	BORGES et al., (2014)
Sodium Chloride	1.462,50	
Electrolysis energy	10800 kJ/ ton. of hydroxide	PACHECO (2012)

APPROACH USED

Cost cycle analysis

A cost study was carried out, which identifies the product costs at each stage of the product's life cycle.

The cost analysis will count only as of the stages of material extraction and production of the Cement, without taking into account their durability during their useful life.

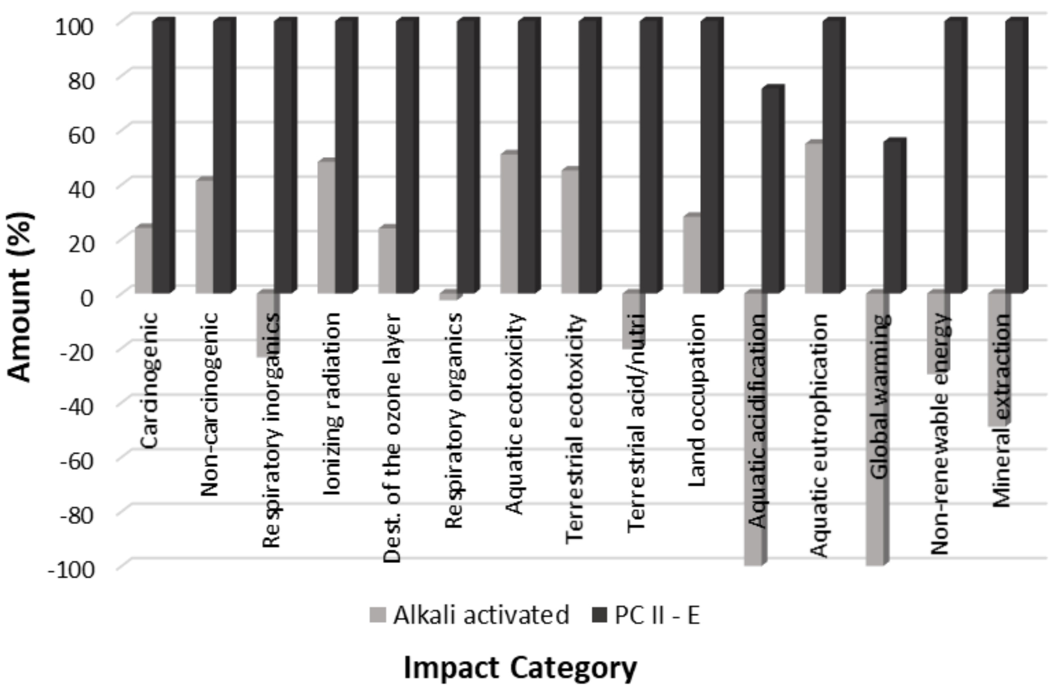
Produção de Cimento Portland (34% de Escória)		
Raw material	Amount (kg / ton. of cement)	Costs
Limestone	1.650	R$ 363,00
Clay	400	R$ 88,00
Plaster	40	-
Slag	340	-
Electricity	Amount (kJ / ton. of cement)	
Limestone crushing	9.309,67	R$ 1,49
Clay grinding	2276,64	R$ 0,36
Raw grinding	74.959,49	R$ 11,99
Homogenization	10.713,60	R$ 1,71
Supply and exhaustion of the rotary kiln	39.506,40	R$ 6,32
Operating the oven	6.696	R$ 1,07
Activation of the primary air blower	2.151,65	R$ 0,34
Clinker cooler	14.508	R$ 2,32
Clinker cooler	5.624,64	R$ 0,90
Clinker grinding	99.819,50	R$ 15,97
Electrostatic precipitator	1.450,80	R$ 0,23
Production of activated alkali cement		R$ 493,72
Production of activated alkali cement		
Raw material		
Slag	Amount (kg / ton of cement)	
Slag grinding	1000	R$ 0,00
Energy consumption - vertical mill	Amount (kJ / ton of slag)	
Production of Sodium Hydroxide	210.312	R$ 33,65
Water	Amount (kg / ton of hydroxide)	
Sodium Chloride	450	R$ 0,00
Electrolysis energy	1.462,50	R$ 146,25
Raw material	10800 kJ/ ton. hydroxide	R$ 1,73
Limestone		R$ 181,63

KEY RESULTS

The characterization of the environmental impacts caused by the two compared types of cement.

The alkali-activated cement had noticeably smaller impacts than the Portland cement in all categories.

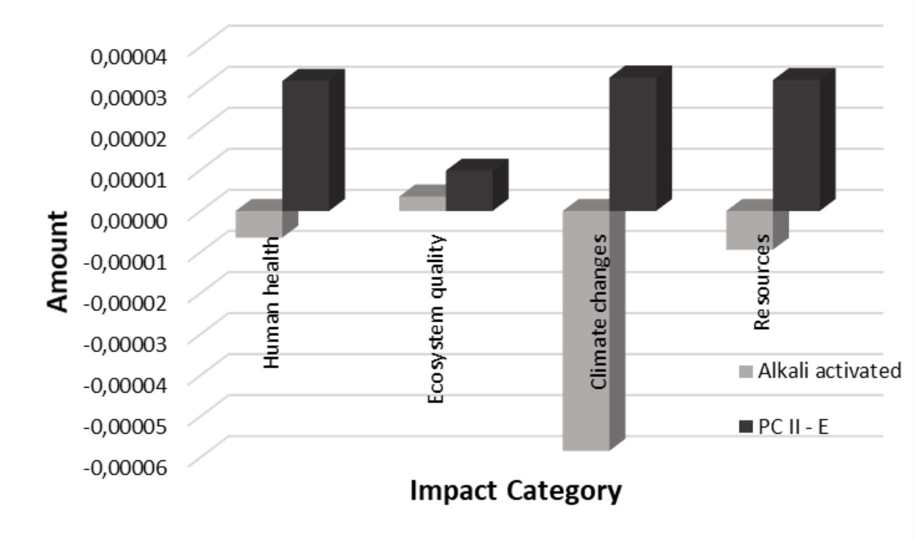
The categories of aquatic acidification, global warming, and mineral extraction were the categories with the greatest discrepancy between the two types of cement compared, with a difference of 175.3%, 155.7%, and 148.9% respectively.



KEY RESULTS

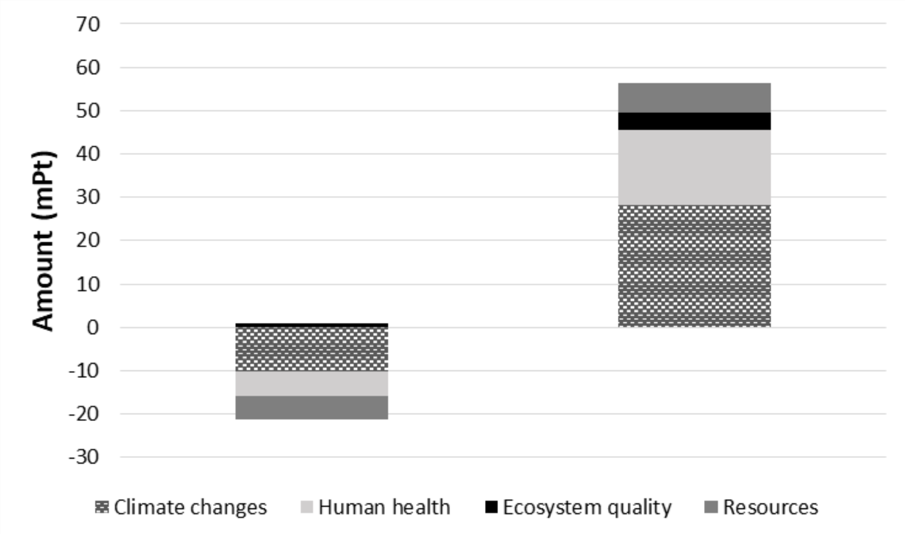
The normalization of data in the Simapro software, shows the most relevant impact categories.

As evidenced in the characterization of impacts, alkali-activated cement has less damage than Portland cement in all categories. The most significant difference is related to climate change. Another indication that the inexistence of the calcination process in the development of alkali-activated cement influences CO_2 emissions.



KEY RESULTS

The impact categories are presented uniquely, to observe in general the comparison between the two types of cement.



KEY RESULTS

Considering the cost analysis

Stage	Portland Cement	Activated Alkali Cement
Production costs	R$ 493,72/ton	R$181,63/ton
Operating costs	-	-
Maintenance costs	-	-
End-of-life costs	-	-

Note that the production cost for activated alkali cement is lower, around 33.78% of the production cost of portland cement.

Considering only the raw material extraction process until it leaves the factory. Thus, studies on the durability of materials must be improved so that we can accurately quantify the life cycle until the end of its useful life and the costs of repairs and maintenance of materials, especially alkali-activated cement.

MAIN CONCLUSIONS

LCA is an important tool for analyzing environmental impacts caused by different materials, from which it is possible to make decisions and analyze which are the main categories responsible for the degradation of the environment.

The Simapro software makes it possible to evaluate the main impact categories of different binding materials in a comparative way and assists in the choice of less harmful materials.

Knowing the stages of production of the materials and correctly quantifying the necessary raw material and energy consumption for product development, in addition to establishing the limits for this assessment is essential for a good LCA.

MAIN CONCLUSIONS

Activated alkali cement presented itself as a less harmful binder when compared to PC II - E, especially with regard to greenhouse gas emissions, due to the fact that the calcination process is not necessary in its production.

Considering the production costs of the binders, it is identified that the activated alkali cement remains with a better performance, with a cost of approximately 33.78% of the cost of the PCII, which is also crucial for the definition of the economic viability of the processes .

MAIN CONCLUSIONS

It is worth remembering that the study encompasses only the production process of the binders, without considering the durability of the material after mixing and more detailed studies on LCA may include this parameter.

More detailed analyzes, which consider durability and social impacts of the two materials, still need to be developed and studied to prove the real attractiveness of activated alkali cement.

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