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PORTLAND CEMENT PRODUCTION FROM RAW MATERIALS

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Abstract: In the production of third-type cement, a mixture of limestone and clay was replaced with Recycled Concrete Aggregates (RCA) at 24%, 49%, 74%, and 86% by mass. The klinkerization was carried out at temperatures of 1450°C, 1400°C, 1350°C, and 1300°C. The produced cements were analyzed in terms of physical-mechanical properties, expansion ability, hydration (calorimetry), and phase formation (XRD and thermogravimetry). Compared to the reference cement, the amount of alite (C3S) increased in the cements produced with Ground Granulated Blast Furnace Slag (GRF). For cements with 50% and 100% GRF in the clinker, similar mechanical strength values to the reference cement were observed, although there was no impact on CO_2 emissions. It was also found that cements produced at 1350°C with 74% clay-limestone mixtures replaced by ACW had mechanical strength comparable to the reference cement without ACW, contributing to the reduction of CO_2 emissions and energy consumption.
Keywords: Portland cement, Portland clinker, granite rocks, asbestos-cement waste.

INTRODUCTION

As shown in Figure 1, the global cement production forecast up to 2050 suggests that production growth will be similar to the increase in the population. From 1950 to 2015, the demand increased tenfold, and in the future, production may exceed these values, which is even socially acceptable. Nearly 90% of cement is produced in countries that are not members of the Organisation for Economic Co-operation and Development (OECD). China's share in global production has already peaked, and by 2050, it is expected to decrease from 50% to 30%.

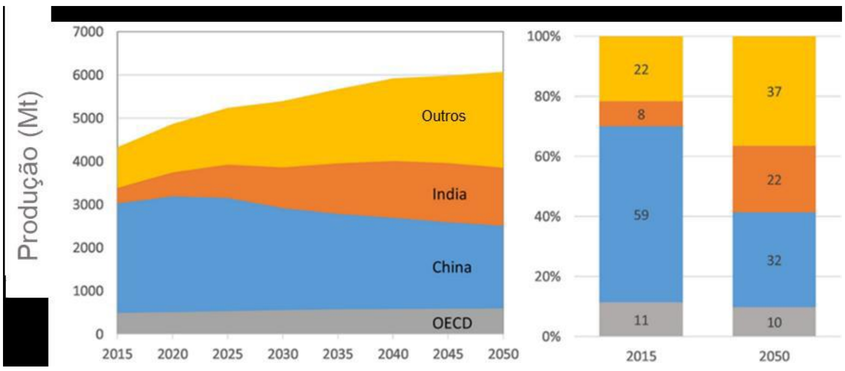

Figure 1. A scenario showing the high consumption of Portland cement worldwide.

MATERIALS AND METHODS

In this study, third-type cement was produced by replacing a mixture of limestone and clay with Recycled Concrete Aggregates (RCA) in proportions of 24%, 49%, 74%, and 86% by mass. The clinkerization process was carried out at temperatures of 1450°C, 1400°C, 1350°C, and 1300°C. The physical-mechanical properties of the produced cements were analyzed, including their expansion ability, hydration rates (calorimetry), and phase formation using X-ray diffraction (XRD) and thermogravimetry.

In addition to RCA, Ground Granulated Blast Furnace Slag (GRF) was also incorporated into some cement mixtures. The cement samples produced were compared to the reference cement for mechanical strength, CO2 emissions, and energy consumption.

RESULTS

The study revealed that the amount of alite (C3S) increased in cements produced with GRF compared to the reference cement. For cements containing 50% and 100% GRF, similar mechanical strength to the reference cement was observed, even though CO_2 emissions remained unaffected. Moreover, cements produced at 1350°C with 74% clay-limestone mixtures replaced by ACW showed similar mechanical resistance to the reference cement. This substitution led to a decrease in CO_2 emissions and overall energy consumption during production.

$CaCO_3 \rightarrow CaO + CO_2(g)$

The energy consumption for clinker production was found to be substantial, with approximately 40% of the energy used for grinding the raw materials, 25% for grinding the clinker, and 20% for operating rotary kilns. The study also examined the impact of using different types of fuels (mainly petroleum coke) on energy consumption, with the process consuming about 4.07 MJ/kg of clinker in 2015.

DISCUSSION

The results of this study show that the substitution of RCA and GRF in Portland cement production can effectively maintain the physical and mechanical properties of the cement while reducing CO_2 emissions. Although the increase in the alite phase (C3S) is beneficial for the mechanical strength of the cement, the reduction of CO_2 emissions remains a crucial factor for sustainable cement production.

One of the critical findings was that using RCA in cement production at temperatures of 1350°C resulted in mechanical properties similar to those of the reference cement. Furthermore, the substitution of ACW with clay-limestone mixtures led to a decrease in CO_2 emissions without compromising the cement's strength, highlighting the potential for reducing environmental impact.

In terms of energy consumption, the production process still relies heavily on fossil fuels, particularly petroleum coke, which accounts for the majority of the energy input. Future advancements in cement production technology could focus on improving energy efficiency, using alternative fuels, and optimizing clinker production processes to reduce energy consumption and emissions further.

CONCLUSION

This study concludes that the substitution of RCA and GRF in cement production does not negatively affect the mechanical properties of the cement and can significantly

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reduce CO_2 emissions and energy consumption. The findings suggest that incorporating sustainable practices, such as the use of recycled materials and optimizing energy use, could play a crucial role in making cement production more environmentally friendly and energy-efficient. Further research is needed to explore the long-term durability and performance of these alternative cements in practical applications.

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