LAFARGE-HOLCIM DESIGN AND INNOVATION CHALLENGE REPORT

Exploring novel, sustainable, innovative, and financially viable ways in which Lafarge-Holcim could exploit fly ash for the South African market

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For the attention of:
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AshResources
Fly ash products

In partnership with:
Africa Careers Network

African Leadership Academy
Developing the next generation of African leaders

19/04/2022

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1 Executive Summary

The Lafarge Innovation Challenge was conducted in partnership with Africa Career Network (a department within The African Leadership Academy). The aim of the challenge was for the selected participants to identify new ways that coal fly ash can be used with the focus on the South African Market. The identified and proposed solutions were such that they need not be just innovative but also financially viable for the client (Lafarge Ash Resources) and sustainable with an element of environmental friendliness

Over the course of the program, group one has identified different innovative ways to use the aforementioned coal fly ash (referred to herein as CFA). Through scientific method and financial analysis, the most plausible idea was identified.

The use of fly ash in Ceramics was identified to be the best idea among the seven proposed through initial stages of the program.

2 Introduction

Technological advances have come with a lot of benefits to human life but it also carries some challenges. One of those is the increased energy consumption. Many countries are getting more interested in changing the way energy is produced. For many years, the world has relied on fossil fuels to satisfy energy needs, however, the dangers associated with climate change are more imminent than ever before, as a result there is a need to mitigate environmental issues associated with fossil fuel. However, the energy demand is still higher than what renewable energy sources can supply, in that regard, there will be many years that some countries will still rely on fossil fuel such as coal to provide energy. Coal is one of the oldest fossil fuels that has contributed largely to the industrial development we enjoy today, however, there is a cost that comes with the use of coal, that is the waste produced. Apart from air emissions that contribute to air pollution, there is also ash produced that disposal has proven a major challenge. There are many ways that have emerged from research in ways coal ash can be reused. There are many sectors where coal ash is being used such as : Construction, agriculture, and water purification. There are many opportunities to use coal ash and solve the issue of waste storage and disposal. At the same time , in some instances , the use of coal ash has proven to improve the quality of existing products while also significantly reducing the production cost.

This report will summarize the findings that group one put together over the course of ten (10) weeks, exploring ways that fly ash has been used and selecting one idea that could make a business case.

3 Project Overview

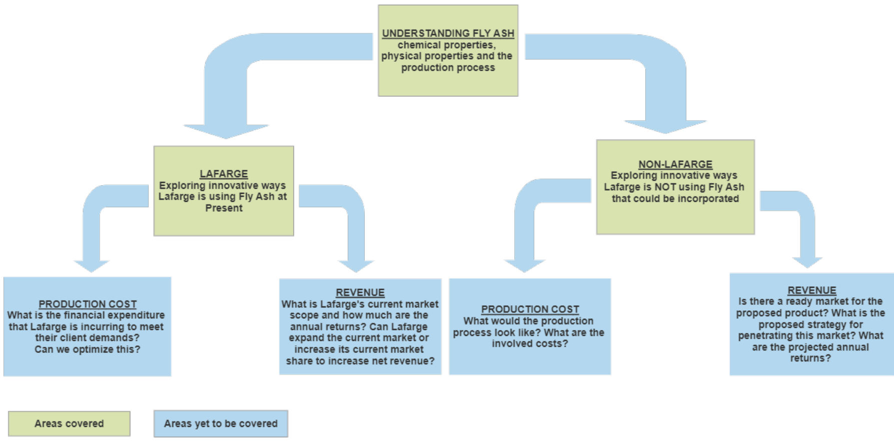

Figure 1: Chart indicating the overall steps taken to cover the relevant project scope

The above chart provides an aerial view of the step-by-step process undertaken in the research whose findings are presented herein. Given the team's little initial experience with industry, it became obvious that the beginning step was to understand fly ash as a product – its production process, physical properties, standard classification methods and the chemical components present in a given unit of fly ash. Upon gaining a thorough understanding of fly ash, the research broke down its usage into two broad buckets – the ways in which Lafarge/Ash Resources has been using fly ash thus far and the novel ways in which Lafarge could use fly ash. With the ways in which Lafarge has been using fly ash, the research's focus was to identify if there are ways in which either the production process could be optimised or the demand for fly ash as a product in those respective fields could be amplified in such a way that in the end, Lafarge would enjoy increased returns while still using fly ash sustainably. For the novel ways that Lafarge is not using fly ash, the research's aim was twofold: to identify the tried and tested ways in which other countries have been using fly ash, explore the relevance of the process to the South African market and identify the possibility of not just replicating these processes but also improving on them with the intention of advocating for innovative use of fly ash while at the same time, maximising on the financial returns enjoyed by Lafarge Ash Resources specifically in South Africa. Initially, this research identified seven plausible ways in which Lafarge Ash Resources could exploit fly ash within the context of South Africa. These are as follows:

1. Geopolymers manufacturing [3]
2. Highway engineering [6]
3. Soil Stabilization in Agriculture[7] , [1]
4. Precast manufacturing [4],
5. Asphalt Road Paving [5]
6. Concrete making [6]
7. Structural Fills [9]
8. Ceramic production as a cement alternative [2]

These processes were tried and tested first using scientific methods then through financial projections to establish the monetary return to Lafarge if they were to take up on any of the suggested solutions. Due to the research team's lack of access to laboratory facilities, the scientific methods used herein were based off secondary material i.e., secondary research conducted by accredited professionals. Additionally, due to the scarcity of financial data specifically for the South African market, the research team extrapolated upon global financial data to predict what the South African market might look like. With these two key research criteria, the team was able to whittle the seven ideas down to one which the rest of this report shall lay heavy emphasis on – the use of fly ash in the ceramic production process. The proposal herein is such that there is enough scientific and financial data to back the fact that fly ash can be used as a replacement for cement in the cement-Kaolin mixture as used in the traditional ceramic-production process.

Note: *The above chart is an extract from the ongoing innovation process. At the time of compilation and submission of this report, all the steps indicated in the chart had been exhaustively explored.*

4 Fly Ash Use in Ceramics

4.1 Scientific Testing/Analysis

A secondary scientific test was conducted to ascertain the feasibility of the proposed solution as outlined below:

4.1.1 Methodology

1. The received coal fly ash (CFA) is fired at 10000 C for 2 hours to burn and remove any unwanted chemical substances such as carbon (which would release gases and cause bloating in the ceramic product particularly at high temperatures), stabilise the resulting CFA and reduce its firing shrinkage
2. The resulting CFA is loosened with a hand mortar and mixed with Kaolin in different mixing ratios to establish the optimal mixing point
3. The mixture is then pressed under 141MPa compression pressure then fired at 12000C for four hours resulting in the Kaolin-CFA ceramic product
4. The cast ceramic product is, then, left to cool and its resulting properties carefully analysed

   Note that in the below graphs, KC refers to the Kaolin-CFA mixture. The number after the C refers to the percentage of CFA making up the resulting ceramic mixture under test

4.1.2 Observation and analysis

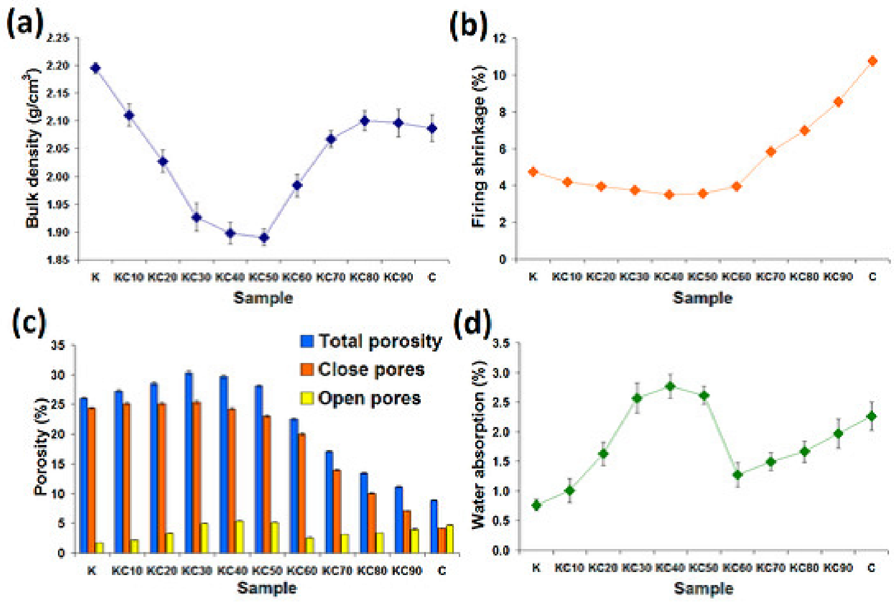

Figure 2: Graphs showing relevant analysis for the above experimental process

1. An increase in the amount of CFA (up to 50% of mixture) in the Kaolin mixture results into an observed decrease in the ceramic product's bulk density which can be attributed to CFA's porosity. However, beyond 50% CFA, the bulk density of the resulting ceramic product begins to increase as the CFA particles tend to agglomerate more

2. For so long as CFA forms 60% or less of the ceramic product, an increase in CFA results into an observed decrease the ceramic's firing shrinkage. This refers to the tendency of the ceramic product to reduce in size upon heating and cooling (as outlined in step 3 of methodology). The Kaolin shrinking happens because of the conversion of Kaolinite into metakaolinite. However, adding CFA (which has already been preheated) reduces this hence improves on the product quality.

3. An increase in the amount of CFA results into an observed increase in the ceramic's water absorption capacity until when CFA is 60% of the mixture where a significant dip in absorption is observed after which the rising trend repeats itself. The ceramic's tendency to absorb water is a reflection of its strength in that the lower the absorption rate, the lower its bulk density/ probability to expand and crack hence a more durable product

4. The optimal mixing ration is 2:3 – 2 parts Kaolin and 3 parts CFA for every unit ceramic product

4.2 Lafarge-specific Implementation Mapping

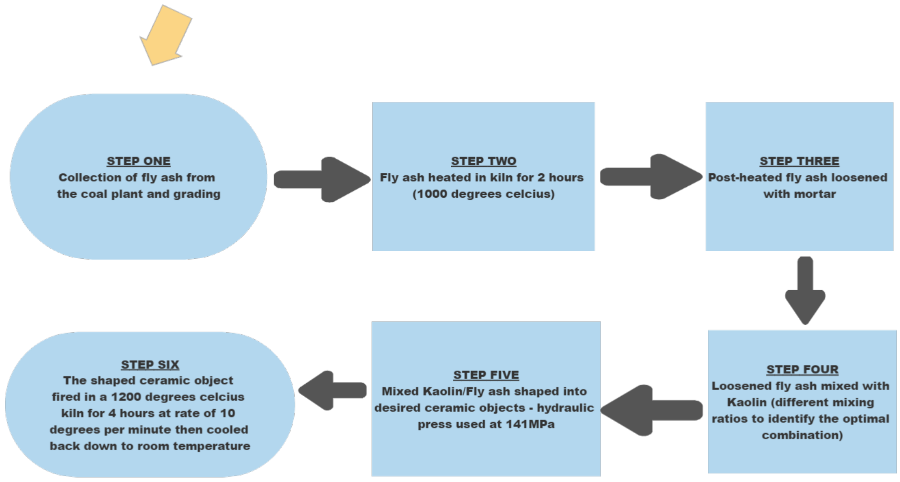

Figure 3: Flow chart outlining the proposed implementation process

The above table outlines the overall step-by-step approach that Lafarge is to implement in the event that they choose to venture into the South African ceramic market. The options outlined herein are twofold:

1. That Lafarge could explore the ceramic market purely as a fly ash supplier to the companies that are involved in the production of ceramic material. This would mean that Lafarge focuses on occupying the first three steps highlighted in the above table i.e., processing fly ash to the required standard then delivering the resulting fly ash to partner companies that will use it in ceramic production.
2. That Lafarge occupies the entire value chain from collection of fly ash to the eventual production and distribution of the ceramic product to the entire South African market.

A more in-depth explanation of the above processes is given below:

1. Collection of fly ash from the coal plant and grading. Specifically in the context of Lafarge and South Africa, this would include the collection of fly ash from the different coal plants and bringing them all together in the Ash Resources fly ash site
2. The second step would involve heating the fly ash, as explained in the methodology section, to temperatures of about 10000C to remove unwanted chemical components such as carbon (which would be detrimental to the future steps), stabilise the fly ash and reduce on its firing shrinkage when it is used as a mixture with Kaolin
3. After heating the fly ash for stability and purification, the resulting mass will then be broken down using a standard mortar into the dusty form.

   In the event that Lafarge decides to focus on being the fly ash supplier to the ceramic industry, this report proposes that this should be the end of fly ash processing. The next step from here would be to distribute the fly ash to the already identified partner companies for further use in the production of the ceramic appliances. However, in the event that Lafarge decides to occupy the entire value chain, the remainder of this section explains the key steps involved:
4. 4. This is the first step in the actual ceramic appliance production. Lafarge is to set up equipment to allow for the mixing of fly ash with Kaolin (clay). As established in the scientific method above, the optimal mixing ratio would be 60% fly ash and 40% Kaolin

5. Lafarge would, then, take the resulting mixture and feed it into a hydraulic press which is designed with appropriate shapes for the different products that are to be made at the end of the process. This constrains the resulting Kaolin-fly ash mixture into the right shape before it is moved on to the next step

6. Having been compressed into the appropriate shape, the resulting mixture is to be, then, transferred to a kiln where it is to be heated at 1200 degrees Celcius for four hours then allowed time to cool before packaging and distribution to the target clients.

5 Financial Analysis

[10] [8] The financial analysis has shown financial potential for the ceramics in South Africa. Ceramics are found in household items, construction materials and technical material such as coating materials.In 2009, South Africa imported 183 Mt of ceramic products, worth R2 615 million, while the ceramics exported are 15.2 Mt, worth R408 million. This shows great potential for the ceramic industry which essentially shows an avenue for fly ash use.

6 Implementation Strategy

Having conducted the relevant scientific feasibility studies and established through financial analysis that the South African ceramic industry is worth Lafarge's pursuit, this report proposes an implementation strategy that encapsulates both of the options listed in the Process Mapping section above. The strategy is such that in the beginning, Lafarge should focus on being the leading fly ash supplier to the companies heavily invested in South Africa's ceramic production. However, as time goes by, Lafarge should establish ways to optimise the ceramic production process and, eventually, take up the entire value chain to become the leading ceramic production company in South Africa. Below are some of the key steps that are to be undertaken by Lafarge in both their first and second phase of implementation:

- *Phase One – focus on being the leading fly ash supplier to South Africa's ceramic producing companies:*
  1. Client identification – this would involve conducting preliminary research into ceramic producing companies which are not only leading in South Africa but also champions of sustainability in the production process
  2. Pitching – upon thorough research into the identified clients, this step would involve representatives from Lafarge approaching these companies with a pitch on the environmental and financial importance of substituting cement with fly ash. The second purpose of this step is to get an understanding of the amount of fly ash the proposed partner company would be willing to buy annually and the unit cost at which they would make this purchase hence establish the net annual returns
  3. ROI analysis – having come to an agreed price per unit fly ash, Lafarge's research team will need to go back to the drawing board to strike comparisons between the investment cost (Capital expenditure for upgrading and installing new equipment on site and operational expenditure for maintaining their daily operations) and the projected annual returns. This will inform on how much Ash Resources can make from supplying fly ash on an annual basis
  4. Equipment installation/ upgrade. Having established the presence of reasonable returns, Ash Resources is to install the relevant equipment as highlighted herein in the process mapping section and begin production
  5. Product supply. The returns made from this phase are, as per this report's findings and proposal, to be reinvested in both the maintenance of the production process and in the second phase of the implementation strategy

- *Phase Two – Ash Resource Takeover of the Ceramic Product Value Chain*
  Whilst being the first and leading fly ash supplier to the ceramic industry would have Lafarge reap substantial financial returns (given that it is a blue ocean strategy with untapped market potential), the inability to differentiate from other South African fly ash suppliers (excluding the provision of quality service) would see to the emergence of stiff competition hence lowering a significant reduction in the financial returns enjoyed by Lafarge. As such, this report proposes that Lafarge should exploit their short-lived market dominance and substantial returns while at the same time, reinvesting the profits from the above first phase in setting up for the second phase as outlined below:

  1. Scoping of the ceramic product market. The goal herein is for Lafarge to take up the entire ceramic production value chain. As such, a critical understanding of the ceramic market demand (e.g., the highest selling products) would inform on what best Lafarge should focus on once they go into production mode.
  2. Optimisation of the existing ceramic production process. That Lafarge will have been in partnership with ceramic companies (as their fly ash supplier) would provide them with an opportunity to learn the current ways of working and, through research with funding from the profits from phase one, identify ways to optimise the process, reduce the production cost and hence come into the market with far much more competitive prices compared to the pre-existing ceramic producing companies
  3. Equipment Installation. Whereas in phase one, the focus was more on the upgrading of the already existing equipment, new equipment will have to be installed on Lafarge's site to accommodate for steps 4, 5 and 6. This report proposes that part of the installation cost be covered by the profits from the first phase and the remainder be covered by debt/equity from the financial institutions established in South Africa and already in partnership with Lafarge
  4. Product disbursement. Once Lafarge rolls into production, this report proposes that their initial market penetration strategy follows the Business-to-Business model. This is because the pre-existing ceramic companies have a thorough understanding of the Business-to-Customer model due to their presence in the market hence Lafarge competing with them would not yield any positive financial results. This report proposes that it is only after Lafarge's B2B model has been properly established that they should consider venturing into the B2C, equipped with not just market research but also built-in experience from their time in the B2B model.

7 Challenges and Areas of Improvement

Due to time constraints, there was not enough financial data to establish fairly accurately the prices and cost of ceramics partly of fly ash, therefore , it will be necessary to conduct a more focussed market research study to get the real picture.

There will be a need to establish a pilot plant and produce various samples to demonstrate that the properties are not heavily altered when fly ash is used.

Finally, it is to be noted that the proposed solution involves relatively high temperatures particularly in the production process. While there is ongoing research to establish alternative ways for the Kaolin-fly ash mixing process, most of these are still at their early innovation stages. This report proposes that to make the process even more environmental friendly (and financially plausible), it is worthwhile for Lafarge to follow up with further research through companies already working in the aforementioned field.

8 Conclusion

As a conclusion, during this program , it was demonstrated that the use of fly ash to produce useful products is one way to mitigate environmental issues associated with the use of coa to produce energy. Fly ash has interesting properties that make it a good substitute for other products which are more harmful to the environment and which are more expensive. Fly ash has been shown to mix very well with Portland cement and even improve the quality of the final products such as concrete or precast. Fly ash and coal ash usage is one of the ways the coal environmental impact can be tackled. There are many ways that fly ash can be used, many were explored by Group one during this program, and it is recommended to explore the use of fly ash to produce ceramics products and it has proven to be more feasible.

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