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Application of three different CSIR 'green' cement blends for plastering, binding mortar and stock bricks.

GIVING THE MARKET A COMPETITIVELY PRICED, SUSTAINABLE CEMENT ALTERNATIVE

Technology to affordably produce 'green' cement

Addressing a problem and responding to market demand

Finding an affordable alternative to cement, a carbon dioxide culprit

Globally, the cement industry faces mounting pressure to address the issue of carbon dioxide (CO_2) emission and seek solutions for its mitigation. Cement production is a significant emitter, releasing as much as 1 000 kg of CO_2 for every ton of cement manufactured, thus accounting for approximately 5–7% of the world's anthropogenic CO_2 emissions.

One approach to mitigate these emissions involves the increased use of supplementary cementitious materials such as fly ash, slag and silica fume, to partially substitute Ordinary Portland Cement (hereinafter referred to as ordinary cement) clinker. However, a notable challenge arises due to the geographical limitations of these materials. Fly ash, for example, is predominantly found in Mpumalanga, while slags and silica fume are primarily available at smelters located in Gauteng and North West. Consequently, there is a critical need to identify alternative cementitious materials that are abundantly accessible, capable of meeting demand, and competitively priced.

The technology on offer

Processes, equipment and mix formulations to produce competitively priced metakaolin-based cement

The CSIR has developed a cost-effective process for beneficiating South Africa's extensive reserves of kaolinitic clays to produce metakaolin

(calcined clay) through the use of vertical shaft kiln technology. The CSIR has protected its intellectual property concerning optimised processes, production equipment, mix formulations, as well as specialised applications and products.

Kaolinitic clay deposits, used in metakaolin production, are abundant and ubiquitously available across at least six of the country's provinces, including the Eastern Cape, Gauteng, Limpopo, North West, KwaZulu-Natal, Mpumalanga and the Western Cape. This widespread availability of kaolinitic clays renders metakaolin an accessible and viable choice for cement production.

Metakaolin-based cement blends offer several advantages, including significantly reduced carbon footprints, cost-effectiveness, enhanced durability, greater strength and improved reliability of strength, often featuring faster setting times compared to most available cement products. Remarkably, metakaolin-based cement blends can be produced at a mere 45–50% of the cost of ordinary cement with a similar strength rating. Metakaolin can replace up to 70% of ordinary cement, resulting in the elimination of up to 40% of CO_2 emissions while maintaining cement quality. Furthermore, the application process for metakaolin-based cement blends mirrors that of ordinary cement, ensuring a seamless transition to this more sustainable and cost-efficient option.

Despite its potential as a cement extender or supplementary cementitious material, metakaolin has struggled to gain market traction due to its high market price. Conventionally, metakaolin is manufactured on an industrial scale using processes such as rotary kilns, flash calciners and multiple hearth furnaces. These methods entail substantial capacity demands, substantial capital investments and intricate operational procedures.

The core of cost-effective metakaolin production for green, affordable metakaolin/cement blends revolves around the design and operation of the vertical shaft kiln. The use of a vertical shaft kiln for metakaolin production represents an innovative approach.

Value proposition and competitive advantage

Simple, low capital expenditure, close-to-market green cement production

The production of metakaolin from South Africa's huge reserves of kaolinitic clays located near user markets, holds immense market potential. The employment of vertical shaft kiln technology for calcination consumes significantly less fuel compared to ordinary cement production methods. This not only reduces production costs but also plays a pivotal role in reducing environmental impact.

Consequently, metakaolin-based cement blends, which are not only greener but also more economical and high-performing than ordinary cement, can be introduced to the market at exceptionally competitive prices.

Furthermore, a mini-cement business model will be adopted. It offers several advantages, including reduced capital expenditure (capex) and simplified plant operations. This model creates opportunities for emerging broad-based black economic empowerment entrepreneurs to venture into the cement industry by establishing mini plants. By setting up the mini plants in proximity to abundant sources of kaolinitic clays and target markets, transportation costs are minimised, ensuring that metakaolin-based cement blends can be delivered to the market at highly competitive prices.

Key characteristics and advantages of this technology in contrast to traditional cement production include:

- Adherence to current cement specifications;
- A substantial reduction in carbon emissions by 30%–40%;
- A notable decrease in energy consumption by at least 40%;
- Access to ample and easily obtainable resource materials;
- Lower capex, simple manufacturing processes and reduced production expenses;
- Compatible with existing ordinary cement technology;
- Suitability for small to medium-sized enterprises; and
- Enhanced performance and durability.

Historically, the African cement industry was primarily dominated by large multinational corporations. However, a shift occurred at the beginning of the 21st century with the entry of new players into the market. This influx of fresh competition, combined with expanded production capacities from the newcomers and existing industry players led to intensely competitive markets. With lower prices per ton of cement, lower margins followed. Today, newcomers to the South African market are still operating, market shares have stabilised and cement prices have started to increase.

Given the proportionally small volumes that CSIR C^3 licensees will produce, the impact on market prices will be negligible. The upward price increase over the next few years will therefore be to the licensees' advantage.

Market opportunity

A price-based cement purchase decision with a low-carbon benefit

Every year, approximately four billion tons of cement is produced worldwide, with Africa accounting for 5.1% of the global cement produced. This is projected to grow at a compound annual growth rate (CAGR) of 5.9% by 2029, driven by urbanisation and infrastructural development.

Currently, the South African cement sector produces around 13 million tons of cement annually, with a capacity to produce over 20 million tons per year. The market is projected to grow at a CAGR of 2.5% between 2023 and 2028, reaching a value of around 15.5 million tons. However, due to the influx of low-priced cement imports from China and Vietnam, the industry operates below its full capacity. Consumers have been basing their cement purchasing decisions primarily on price, resulting in an increased demand for cheaper imported blended cements. The CSIR-developed metakaolin-based cement blends can be produced and sold at competitive prices, comparable to imported cement rates – creating jobs and reducing carbon emissions.

Business opportunity

Maximising on mini-cement businesses

A mini-cement business model will be adopted. Prospective non-exclusive licensees can license the technology via CSIR C^3.

CSIR C^3 will also sell a proprietary CSIR-designed and custom-made vertical shaft kiln to primary licensed producers of metakaolin. Primary and secondary licensees will be licensed to blend the metakaolin with ordinary cement (CEM 1) and other additives to produce metakaolin cement blends of desired performance specifications. The primary licensees are those that will be licensed to produce metakaolin and metakaolin-cement blends, while the secondary licensees are those that will be licensed to

blend procured metakaolin and other materials to produce the metakaolin-cement blends.

CSIR researchers with extensive expertise in cement research and product development will assist the primary licensees in setting up plants nationwide for a designated fee. The licensees will distribute the metakaolin-based cement blends to end-users and intermediaries such as retailers, cement blenders, precast producers and specialty cement companies.

A similar mini-cement model is commercially successful in India, the world's second largest producer of cement, behind China.

Investment and return on investment

Invest in a mini-cement business model for South Africa and the rest of Africa

An estimated R10 million is required to meet operating costs associated with pilot production of green cements in collaboration with a pre-selected third-party with future commercial interest. CSIR C^3 may host/incubate several potential licensees at the green cement piloting facility prior to the setting up of a licensee production facility.

An estimated R70 million is required for capital expenditure to set up a 100-ton-per-day green cement plant. Typically, at a discount rate of 10%, for a 100-ton-per-day plant, the net present value exceeds R10 million; the internal rate of return exceeds 20% and the pay-back period is less than five years.

Milestones and timelines

The CSIR is establishing a pilot plant for scaling up operations, which will serve to mitigate risks, conduct market testing and trial collaborations, and scale production to reach an annual output of 18 000 tons of metakaolin cement blends. In year two, CSIR C^3 may host potential licensees at the green cement piloting facility prior to the establishment of licensee production facilities. By year three, small, medium and micro enterprises may be licensed to produce the CSIR-developed cement blends at their own facilities.

A team of multidisciplinary experts

The research and development efforts are supported by a team of researchers and engineers with extensive expertise in various fields, including ceramic engineering, materials science and technology, chemical engineering, civil engineering, mechanical engineering, process engineering, manufacturing and production management.

ENQUIRIES:

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Top: CSIR researchers at an experimental site where the technology was tested. Left: A concrete roofing tile industrially manufactured from a CSIR-developed cement blend. Above: A sample of the CSIR 'green' cement blend. Right: Stock bricks made using CSIR 'green' cement blends and different aggregates.