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GREEN CEMENT VALUATION: AN OPTIMISTIC APPROACH TO CARBON DIOXIDE REDUCTION

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Abstract:

This article discusses a variety of more recent alternatives to Portland cement (OPC) that can lower energy consumption and greenhouse gas emissions. Some of these new binders can be made utilizing fuels and low-grade industrial waste. Only after thorough examination of various physico-mechanical, microstructural, and durability properties can the practical viability of these alternative binders be substantiated .In this review paper seven important alternative cementitious binder systems i.e. Supplemental cementitious in place of OPC in some cases , Industrial By-Products , Alternative cements , Concrete Made Using Garbage as Aggregate , Carbona table Calcium Silicate Cement , Cements With a Calcium Hydro silicate Base, Eggshell waste for sustainable construction materials are discussed. It was deduced that all of the more recent cementitious binders could be created utilizing industrial wastes such as low-grade limestone or clay, fly ash, and slags. This would result in the achievement of the desired physico-mechanical and durability properties, as well as a decrease in cost and energy consumption of between 20 and 58 percent. In addition, the creation of the aforementioned alternative binder results in a reduction of greenhouse gases that is anywhere from 15–55%.

1. INTRODUCTION

The manufacturing of concrete, a fundamental component of a building, requires a number of key ingredients, one of which is cement. It is very difficult to imagine what life would be like in today's world without cement and concrete, two essential building materials. The cement of the ordinary Portland variety is a versatile and important construction material(Imbabi, Carrigan, & McKenna, 2012).Therefore the construction sector's continued heavy reliance on cement, the annual global production of ordinary Portland cement is currently three point six billion metric tons (MT), and it is anticipated that this figure would rise to more than 5 billion MT by the year 2030(Danish, Salim, Ahmed, & Materials, 2019).

The construction sector is currently experiencing a number of issues as a result of the toxic effect of cement due to the cumulative effects of carbon dioxide emissions, depleting supplies of organic natural resources, and environmentally friendly products. the price of making cement rises as a result of an increase in the green tax as well as a shortage of supplies. Even with all of the efforts that have been done by various organizations across the globe over the past several decades to reduce CO2 emissions, the production of OPC still accounts for 6% from all CO2 emissions worldwide (Danish et al., 2019).Nowadays, China holds a commanding lead in the cement industry, manufacturing more than 50% percent of the total amount consumed worldwide(Summaries, 2018).Around three point six billion tons of cement are made yearly, and about 900 grams of carbon dioxide are released every tonne during the manufacturing process. (Hasanbeigi, Price, Lu, & Lan, 2010).Not only do emissions of carbon dioxide from cement factories contribute to global warming and acid rain, but so do emissions of sulfur dioxide and nitrous oxides as well(Valipour, Yekkalar, Shekarchi, & Panahi, 2014).Hence, the Cement Market faces several difficulties, including the loss of natural resources, the rising prices of power supplies, requirements reduce CO2 emissions, and the need to guarantee an adequate supply of raw materials to meet the continuously growing demand(Energy; Lund, 2007).As a result of this, it is necessary to look for an alternative that can partially or completely alternate cement to an ecologically favorable cementitious mixture in order to lessen negative influence that the manufacturing of concrete has on the surrounding environment. An effective strategy for lowering pollution levels is to replace some cement with by-products like slag, fly ash, and other waste items. (Crossin, 2015; Kartini, Hamidah, Norhana, Nur Hanani, & Technology, 2014; Yang, Jung, Cho, & Tae, 2015). The other possibility is to replace traditional cement with new types of cement that are more resource efficient. These cements will produce less greenhouse gas emissions and will use less energy, but they will not

compromise the binder's effectiveness or quality(Li, Sun, Li, & research, 2010; Ojan, Montenegro, Borsa, Altert, & Fielding, 2016; Pacheco-Torgal, Castro-Gomes, Jalali, & Materials, 2008). This technique was utilized in the construction of an actual building using coal fly ash, which acts as a substitute for Portland cement in some cases (Bontempi & Bontempi, 2017). The current study explores a wide range of feasible alternates with the goal of decreasing carbon dioxide emissions resulting from binder phase production. They range from using alternative cementitious materials like sulfoaluminate cements and magnesia cements in place of Portland cement's typical raw ingredients and fuels to completely switching to cement cementitious materials as a whole. Another instance would be the manufacturing of masonry cements using alternative raw materials and energy. In addition to discussing the chemical characteristics of OPC, this article is overview about production of CO_2 and some green cement that reduce emission of CO_2 and environment friendly.

2. METHODOLOGY

The methodological approach for the review paper titled "Lowering of Carbon Dioxide through the Valuation of Green Cement" entails doing a complete literature search with specific keywords linked to green cement and CO2 emissions reduction. Studies that are relevant to the topic will be chosen based on the inclusion criteria, and then data will be retrieved and examined to look for recurring themes and conclusions. The assessment will conduct an in-depth analysis of how successful green cement is at lowering CO2 emissions, and it will make recommendations for further research and potential applications of the material.

3. RESULTS & DISCUSSIONS

3.1 Global output of Portland cement

The availability of raw materials drives a significant amount of variation in cement production from one country to the next. If a nation's production is unable to meet the demand for its goods, that nation has the option to satisfy its requirements through imports. According to an analysis that looks at the most recent developments in the cement industry worldwide, the amount of cement that was manufactured all over the world is projected to be 360 crores tones mention in Fig.1 that indicates the domination of China over the market of Asia (Imbabi et al., 2012). The worldwide cement production is shows steadily increase through 1990 to 2050 in Figure 2. This is to be noted that, after water, it is the product that is the second most utilized on the entire globe. Developing nations like China and India , which is having a strong need for the both housing and infrastructure, are driving the industry's rapid expansion, particularly in recent years (Council & Right, 2009).

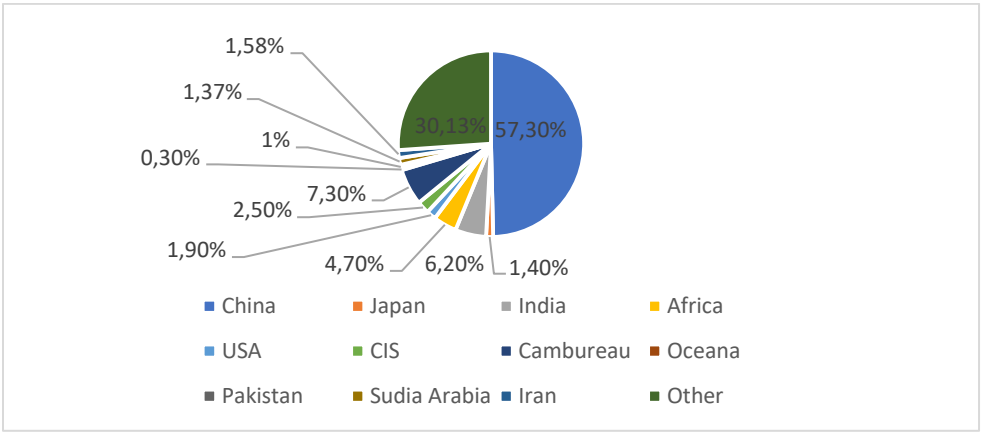


Figure 1. Current global cement production

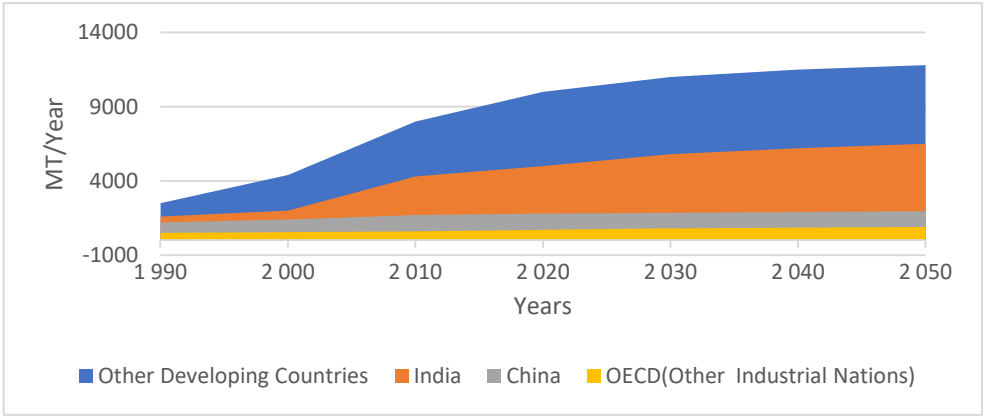


Figure 2. Estimated global cement production 1990-2050

3.2

3.3 CO2 emissions and energy consumption (Present & Future)

An estimated 900 grams of carbon dioxide are released per 1000 grams of cement produced(Hendriks, Worrell, De Jager, Blok, & Riemer, 1998). It produces 3.24 billion tons of carbon dioxide every year from extraction to pyro-processing to grinding to shipping.(Association, P.C. How Cement is made. Available from: https://www.cement.org/cementconcrete-applications/how-cement-is-made). The process of cement making generates a significant amount of carbon dioxide gas, which includes: After a process of carbonization process. Once the cement kiln reaches extremely high temperatures, the ingredients are burned. The amount of carbon dioxide (CO2) released during fuel combustion varies significantly depending on the type of fuel utilized (Table 1). It has been calculated that 1.75 0.1 MJ/kg of heat is needed for the clinker-making process, however because of various disorganization in the process of cement making, real requirements of heat are much higher.

Clinker Ratio (%)	Calcination Process	Dry Kiln Process				Wet Kiln Process			
		Coal	Oil	Gas	Waste	Coal	Oil	Gas	Waste
55	0.275	0.54	0.51	0.45	0.34	0.665	0.54	0.58	0.32
75	0.3	0.71	0.65	0.6	0.48	0.878	0.68	0.74	0.41
Portland 95	0.48	0.48	0.80	0.76	0.51	1.1	0.91	0.94	0.58

Table 1. Emissions of CO2 depends upon used fuel (kg/kg) and kiln process (Crossin, et al., 2015)

The use of rotary kilns in pyro-processing also adds to the release of carbon dioxide. Cement factories utilize a variety of rotary kilns, including:

i. Dry with pre calciner kiln and preheater
ii. Dry with pre calciner kiln and preheater
iii. Dry kiln
iv. Dry kiln/ Half wet
v. Wet Kiln

The Global Cement & Concrete Association (GCCA) has proposed some ways in which the cement industry can advance toward improvement. These include the implementation of new advancements for both existing and newly constructed cement manufacturing plants, as well as the encouragement of major cement manufacturers to adopt environmentally friendly alternatives, such as low carbon fuel and clinker substitution. For the sake of the cement sector and the environment, the government should implement the GCCA's suggestions about green alternatives. If no advancements are achieved in the cement sector, CO2 emissions are projected to increase to five times their 1990 levels by 2050 (as shown in Figure 3). The construction industry ought to follow the global trend toward eco-friendly materials. These measures will not only protect the environment from a variety of threats, but they will also boost economic output. The potential savings from lowering carbon footprints is illustrated in Figure 4.

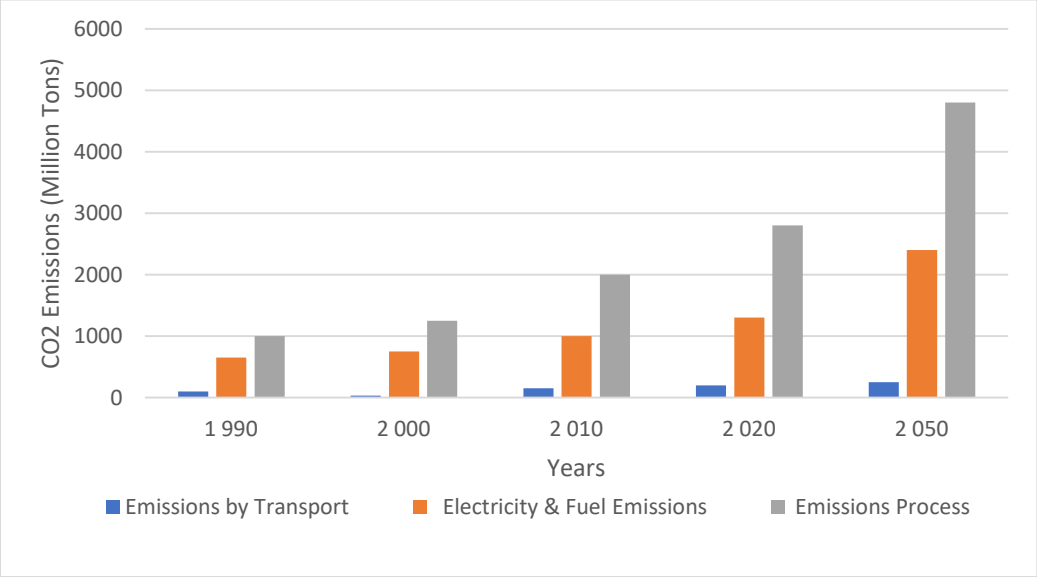


Figure 3. Global emissions of CO2 in production of cement (Araghi, et al., 2015)

"Green cement" describes a variety of cement made in a sustainable and ecologically responsible manner throughout production. Energy consumption is decreased or carbon-neutral materials are employed in its production. Geopolymer cement is one of the most popular eco-friendly options. Rather than using typical cement sources like limestone, geopolymer cement is created from industrial waste items like fly ash. The manufacturing process will produce fewer carbon dioxide emissions as a result of this. Alkali-activated cement is yet another environmentally friendly option. This cement is made from industrial waste products that include blast furnace slag and fly ash (table 2). When these components are combined with an alkaline solution, a chemical reaction takes place, resulting in a cement-like substance. As more and more people

learn about the negative effects that typical cement production has on the environment, green cement is gaining popularity.

Green cement helps lower a building's carbon footprint because it is made using eco-friendlier ingredients and processed in an eco-friendlier way.

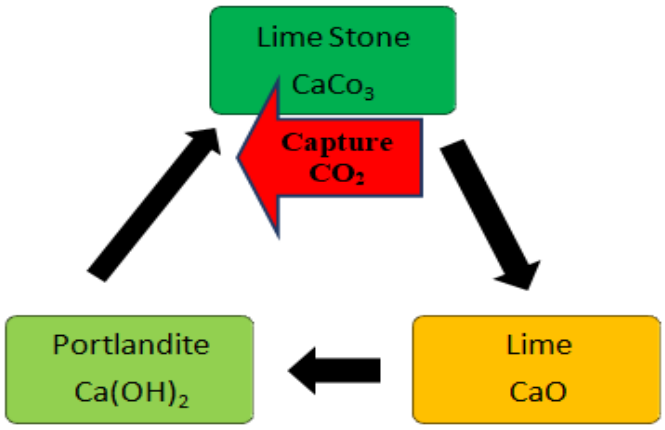


Figure 4. Green Cement production method (Gergely, et al., 2010)

Production	Country	Reference	Unit
19172	China	Dec/22	Ten Thousands of Tones
3743	Pakistan	Jan/23	Thousands of Tones
3665	Japan	Feb/23	Thousands of Tones
2070	Malaysia	Jan/23	Thousands of Tones
1079	Taiwan	Jan/23	Thousands of Tones
3077	Thailand	Jan/23	Thousands of Tones
5685	North Korea	Dec/21	Thousands of Tones

Table 2. Production of cement

3.4 Supplemental cementitious in place of OPC in some cases

The largest energy user and contributor to CO_2 emissions in concrete is the manufacturing of OPC, Concrete's overall CO2 emissions will be significantly reduced by its partial replacement with a sustainable element requiring less energy and carbon. Substitute to OPC as a concrete bonding agent include additional supplementary cementing materials (SCMs), which are more ecologically friendly. With filler and admixtures qualities Concrete's mechanical properties and durability might be enhanced by SCMs. Because SCMs are largely waste byproducts from other industries and its usage in concrete gives a mechanism for effectively handling this waste, they are a green replacement. In addition, their effective use prevents the mining of a number of regions and natural raw material deposits that may have been used for the production of OPCs or their disposal, respectively.

In concrete, the percentage of OPC that can be replaced by SCM ranges from 10 to 50 percent (Juenger, Winnefeld, Provis, Ideker, & research, 2011). Yet, depending on the features that are sought after, this range may be expanded. In most cases, the pozzolanic and filler qualities of SCMs are what cause an enhancement in concrete properties. Over the course of several decades, SF known as silica fume, a by product of the manufacturing of ferrosilicon, has been utilized as an SCM in concrete. It has been demonstrated that the addition of SF to concrete in partial substitution for OPC not only lowers the overall greenhouse gas emissions but improves mechanical properties of the concrete. (Behnood, Ziari, & Composites, 2008).

Furthermore, it has been demonstrated that rice husk ash (RHA), which belongs to the SCM family and is a by product of rice production, can improve the initial durability and strength of concrete(Zunino, Lopez, & composites, 2016). Increased density of the ITZ between the paste and aggregate has been hypothesized to account for the beneficial effects of RHA on concrete characteristics when used in partial substitution for OPC. This was accomplished by the improvement of the concrete's microstructure (Hesami, Ahmadi, Nematzadeh, & Materials, 2014; Mohseni, Naseri, Amjadi, Khotbehsara, & Ranjbar, 2016; Zunino et al., 2016). However, it is essential to note which incorporating RHA into concrete results in effects that are detrimental to the completely new properties of concrete. This should be kept in mind.

When OPC is partially swapped out for RHA in concrete, the primary adverse effects that are observed are an increase in the amount of water that is required and a reduction in the concrete's flow ability. In addition, when replacement rates

reach a certain threshold, the material's mechanical and durability attributes might start to deteriorate. For example, its compressive strength could decrease and its permeability could rise. RHA should undergo preliminary testing on a smaller scale before being used for a partial alternative for extensively used ordinary Portland cement in concrete. Moreover, the procedure should be appropriately optimized. Because the qualities of RHA are affected by a wide variety of parameters, like such as location, burning circumstances, fertilizer used, etc. The optimal replacement level that was required varied from study to study. To determine the best replacement rate for OPC in concrete using any SCMs with restricted replacement, it's crucial to carry out preliminary tests.

These tests can be done with any SCM. It has also been reported that using FA from burning coal in energy production being SCM can improve the concrete properties (Mohseni et al., 2016; Tian, Zhang, Ye, Yang, & Materials, 2015). However, to obtain full benefits, such as improved characteristics, one must use the appropriate replacement rate and curing techniques(Chen, Li, Xiang, Li, & Materials, 2016; Shafigh, Nomeli, Alengaram, Mahmud, & Jumaat, 2016). In general, Utilizing SCMs as an alternative for OPC results in improved qualities and a reduction in the general carbon footprint and its content of concrete.

So, the use of Supplementary cementing materials at greater alternate levels results in deleterious impacts on new and hardened characteristics. For example, when the amount of OPC was raised and SCMs were used instead, the slump went down. Because of how well they absorb water and how much surface area they have,, SCMs have been shown to reduce slumping, which has been related to their growing levels(Le, Müller, Siewert, Ludwig, & design, 2015).

3.5 Industrial By-Products

Industrial by-products are among the most favourable environmentally permissible replacement to conventional OPC. That's because alumino-silicate precursors, which are primarily leftovers from various industrial processes, have completely replaced OPC. Concrete's ability to withstand deterioration over time is significantly improved by completely removing OPC from the material.

The use of AABs instead of OPC has been reported in scientific research to reduce carbon dioxide emissions by up to 80% (Duxson & Provis, 2008). Chemical accelerators like the alumino-silicate based accelerator (ASBA) are an illustration of a chemical admixture. As soon as ASBA is added to concrete and mortar, the cement will hydrate more quickly, the concrete will firm up faster, and the pace of stiffening or development of strength will rise(CHAKARTNARODOM et al., 2023).

Additionally, these aluminosilicate precursors' application in concrete makes room for efficient waste management. Waste materials from the steel and iron industries, the power sector, and agriculture, like rice husk trash and fly ash, and other waste products are typical aluminosilicate precursors. To create AAB, the alumino-silicate precursors must first be activated by alkaline medium. Ions dissolve as a result of this activation, and a material is created that stiffens with time. Despite the fact that the use of AABs allows for a substantial increase in the durability of concrete,, the utilization of particular activators may make it impossible to take advantage of this benefit. This is going to happen since the activators have a significant amount of available carbon and carbon in them. Nevertheless, this problem with sustainability may be avoided by employing activators that have low levels of energy inputs and carbon and which, in exchange, have qualities that are equivalent to or superior to those of activators with larger levels of energy inputs and carbon. The characteristics of the AAB are influenced by a number of parameters, the most important of which are the aluminosilicate precursor type and the alkali activator(Duxson & Provis, 2008). One of the most popular forms of activators used in AAB is sodium hydroxide, which also creates a high degree of strength. Sodium silicate is another popular type of activator.

An enormous amount of energy is needed to produce activators like sodium silicate and sodium hydroxide, which also contribute significantly to carbon dioxide emissions in the environment (Habert, De Lacaillerie, & Roussel, 2011; van Deventer, Provis, Duxson, Brice, & Valorization, 2010). The processing of activators that are naturally occurring in the environment, such sodium carbonate, however, uses less energy overall.

3.6 Alternative cements

One of the ways that one can produce environmentally friendly concrete is through the utilization of calcium sulfoaluminate and calcium aluminate cements. In the early 1900s, a Frenchman named Jules Bied invented calcium aluminate. Calcium aluminate cement is primarily composed of monocalcium aluminate, with smaller amounts of other compounds.

Other types of compounds are also present (Scrivener & Capmas, 2003). Because this cement produces less carbon dioxide emissions during manufacture than regular Portland cement (OPC), concrete constructed with it might be seen as being more ecologically friendly.

The major purpose of early calcium aluminate cement manufacture was to protect concrete against sulphate assault. However, because of the long-term advantages it provides, it has been utilized to construct buildings in areas where sulfate resistance is not an issue. Additionally, these cement variants provide increased ability to resist wear and the alkali-silica reaction, both of which are forms of wear. Additionally, some types of building might benefit from employing them because to how rapidly they acquire strength.

Although OPC aids in acquiring green resources, certain other types of cement are costly than ordinary Portland cement , it has constrained their usage (Cather, 1997). There has been some research into the possibility of using fly ash is binder to enhance the hardness and compressive power of cementitious composites, the results have been promising. We have performed these analyses (Golewski, 2018).

3.7 Concrete Made Using Garbage as Aggregate

The bulk of the different solid waste products generated by different industries are dumped in landfills or in unoccupied spaces, where they pose a danger of environmental pollution. This raises the possibility of environmental damage. In contrast, a significant amount of aggregates are used each year in the production of concrete, and It's likely that alternative suppliers of It seems unlikely that aggregate supplies will be able to keep pace with the increasing need for concrete in the near future. As a consequence, in order to supplement the supply from natural sources, additional components from outside sources must be used. Concrete that uses different types of solid waste as aggregate since it won't be required to mine and manage natural aggregates, it will be manufactured in a manner that has a lower impact on the natural environment than current methods (table 3). The following are examples of some of these wastes: plastic (Araghi et al., 2015), discarded materials from building and demolition(Rao, Jha, Misra, & Recycling, 2007), glass, trash from agricultural production(Aliabdo, Abd Elmoaty, Aboshama, & Materials, 2016; Rao et al., 2007) slag, as well as ceramics (Awoyera, Gobinath, Haripriya, & Kulandaisami, 2020; Sivakrishna et al., 2019).

Material	Properties
Rice husk ash	Excellent as an alkali activated binder or cementitious additive (Qin et al., 2019).
Fly ash	Its impact on permeability and compressive strength has been particularly notable (Thorneycroft, Orr, Savoikar, Ball, & Materials, 2018).
Silica fume	Concrete's strength and durability might benefit from a percentage of less than 30 percent cementitious material (Saboo, Shivhare, Kori, Chandrappa, & Materials, 2019).
Polypropylene	Reduce the impact on concrete's bond properties to a minimum. Nonetheless, it helps the concrete's flexural strength (Mohebi, Bahnamiri, Dehestani, & Materials, 2019).

Table 3. Properties of some common materials in green concrete

3.8 Carbonatable Calcium Silicate Cement

Carbonation and also hydration are both valid methods for the hardening of calcium silicates. In the past, atmospheric carbonation was used to harden lime-based binders, but the procedure was exceedingly laborious and time-consuming due to the atmosphere's relatively low carbon dioxide content (440 ppm) of carbon dioxide (ppm CO2), which is an increase of approximately 50 percentage points from its ancient time value but is still less than the value of water vapour (Gartner, Sui, & Research, 2018). If diffusion-induced inward carbonation from the outside results in a non-homogenous hardening profile, this might provide a problem for bulk concretes. Several precast concrete manufacturers are already using the partial carbonation curing method, which increases the strength of the finished product in comparison to the humid curing method. Yet, this approach results in a lower CO2 footprint. The improvement is due to the introduction of specialist carbonatable calcium silicate clinkers (CCSC) technology thanks to improvements made to the carbonation process that did not need the use of an excessive amount of energy (Solidia, USA)(Atakan, Sahu, Quinn, Hu, & DeCristofaro, 2014). Traditional cement kilns may produce CCSC clinkers (CaSiO3, CS) from low-lime calcium silicate minerals like wollastonite. Because these clinkers only need around 45% CaO, whereas OPC needs 70%, CO2 emissions are cut by about 30% during production. Furthermore, heat that must be reached in order to produce these cement clinker is around 1200 degrees Celsius, but the temperature that must be reached in order to sinter OPC is 1450 degrees Celsius. The low temperature in the kiln also results in a decrease of 30% in CO2 emissions(Atakan et al., 2014). The clinker that is formed is nonreactive and will not harden merely by hydration. It is only possible to cure the clinker in reasonably pure CO2 gas, with the relative humidity and temperature under regulated conditions. This necessitates making certain adjustments in the curing chambers, which results in additional expenses related to capital expenditures. The CCSC has demonstrated a considerable strength growth in just 24 hours, in comparison to the OPC strengths attained in 28 days for mixes designed exactly the same way. Because the water that was evaporated CSSC concrete uses a lot less water since water is recycled from fresh concrete during the curing process (Gartner et al., 2018). Nevertheless, as a result of the requirement for a particular curing technique, concretes made with this form of cement are incapable of protecting steel from corrosion (as a result of a low PH of less than 9), which restricts its applicability to only non-reinforced cement products (Environment, Scrivener, John, Gartner, & Research, 2018; Gartner et al., 2018).

3.9 Cements with a Calcium Hydrosilicate Base (Celitement)

Celitement is the name given to a novel class of hydraulic cementitious binders. The Karlsruhe Institute of Technology (KIT) was responsible for developing the parts and overseeing the production process. These binders are identical to conventional cementitious binders in terms of the raw ingredients used, the mixing process, and the setting (Habert, 2014). It is constructed out of amorphous calcium hydrosilicates and hydraulic fluids. Carbonates (like limestone) and silicates are the types of raw materials that are acceptable for use in the creation of celitement e.g., sand, fly ash and slag. Processes are carried out after calcination. The carbonate proportion of raw materials varies from 40 to 50%, as opposed to OPC, where it makes up around 70% of the total. Between 1 and 2 may be found in the CaO to SiO2 ratio. These proportions are indicate to as "complexation of Calcium hydroxide in calcium silicate hydrate," and they found in concrete (P. Stemmermann, Beuchle, Garbev, & Schweike, 2011). There are

two steps involved in the processing of raw materials. The raw materials go through hydrothermal treatment in an autoclave in the first phase of the process at temperatures between 150 and 200 degrees Celsius with saturated steam pressure. A hydrated calcium silicate substance known as (C2SH) is created during this process.

The second step involves mixing and milling the created calcium silicate hydrate together with other silicate components to create amorphous calcium hydrosilicates (Schneider, Romer, Tschudin, Bolio, & research, 2011). The thermal treatment is performed at lower temperatures (150-200 degrees Celsius) than the OPC. Carbon dioxide (CO2) emissions have been cut by as much as half as a result of the lower energy requirements necessitated by the lower carbonate content in mixture. Mortar samples' compressive strength peaked at 80 MPa after 28 days (Peter Stemmermann, Schweike, Garbev, Beuchle, & Möller, 2010). In 2011, with the assistance of the Schwenk group, a prototype manufacturing unit which had a potential of one hundred kg per day was built (P. Stemmermann et al., 2011).

Even so, in comparison to the creation of OPC, the manufacturing method for Celitement is more complicated since it involves a greater number of processing stages (table 4). Because this method is still in the process of being developed in the laboratory, it is not possible to provide a meaningful estimate for carbon dioxide emissions or overall energy efficiency in an industrial setting in the real world (Environment et al., 2018).

Name	Type	CO_2 Reduction	Raw Material	Process Temperature
Geopolymer Approx.	Alkali activated materials	70%	Fly ash, Al/Si wastes, alkaline solutions	Ambient
Sulfolauminate cement		30–40%	Limestone, gypsum, bauxite, sand/clay	1200–1300 ◦C
Magnesia Binder (Novacem)	Magnesium oxide	>100%	Magnesium silicates	200 ◦C (180 bar) + 700 ◦C
Magnesia Binder (TechEco)	Magnesium oxide + OPC + fly ash	>100%	MgCO3	<450 ◦C (Tec-Kiln)
Celitement (KIT) As	Calcium silicate hydrate	Approx. 50%	OPC (Ca/Si ratio 1–2)	150–200 ◦C (hydrothermal)
Carbonatable Calcium Silicate cement (Solidia)	Calcium silicate (wollastonite)	Approx. 70%	As OPC for cement	1200 ◦C

Table 1. The potential of alternative cements in CO2 reduction (Reproduced from Crossin, et al., 2015)

3.10 Eggshell waste for sustainable construction materials

Eggshell waste is increasingly used to make value-added products. Calcium phosphate bio-ceramics contain eggshell waste (Gergely et al., 2010) (Barbara, Marta, Beata, & Florian, 2016; Rivera et al., 1999), calcium supplement (Siemiradzka, Dolinska, & Ryszka, 2018; Tsai et al., 2008), adsorbent material (Salaudeen, Tasnim, Heidari, Acharya, & Dutta, 2018; Witoon, 2011), in the form of a solid catalyst for the manufacture of biodiesel (Gupta & Rathod, 2018; Teo et al., 2017). However, the only application of eggshells in the food and industrial sectors is the production of calcite, which is used in the manufacture of fertilizer, medications, and building materials. In spite of this fact, various applications of eggshell waste that are catalytic and sorptive have been reported (Quina, Soares, Quinta-Ferreira, & Recycling, 2017).

At the moment, there is a growing interest in the potential of eggshell to be used in the development of environmentally friendly building materials (figure 5).

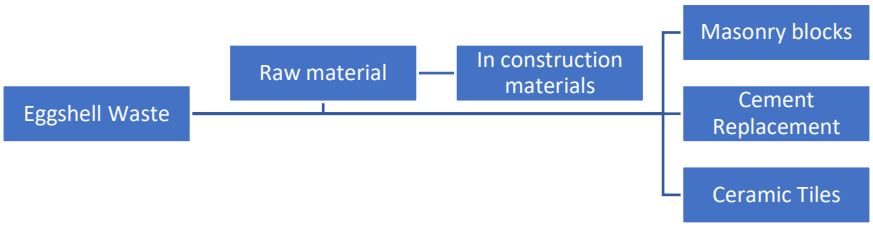


Figure 5. Materials Flow chart

4. CONCLUSION

In this research, a variety of different techniques to reducing carbon dioxide emissions that are associated to the manufacturing of binder phase were investigated and addressed. These range from substituting traditional raw materials and fuels used in the production of Portland cement to the complete replacement of the clinker used in cement manufacturing with new the clinker, like sulfoaluminate cements and magnesia cements. One example of the former is the use of sulfoaluminate cements. In the end, the economic and strategic planning vision of industry owners and the government is what will determine the techniques that may be taken to promote the durability of cement production. With internationally binding agreements, the introduction of incentives for potentially successful solutions (such as a decrease in CO2 emissions) and a change in focus to long term benefits will result in the development of alternative binders and familiarity with those binders.

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