THE STUDY OF CEMENT PROPERTIES WITH CERAMIC WASTE FILLERS

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THE STUDY OF CEMENT PROPERTIES WITH CERAMIC WASTE FILLERS

by

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled “The Study of Cement Properties with Ceramic Waste Fillers”. I also declare that it has not been previously submitted for the award of any degree or diploma or other similar title of this for any aother examining body or University.

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LIST OF ABBREVIATIONS

CW	Ceramic Waste
SCM	Supplementary Cementious Material
CO_2	Carbon Dioxide
GHG	Greenhouse Gases
OPC	Ordinary Portland Cement
ASTM C150	American Standard Specification for Portland Cement
ACI	American Concrete Institute
GP	Granite Powder
EGP	Eggshell Powder
IP	Iron Powder
MP	Marble Powder
RCA	Recycling Coarse Aggregate
NCA	Natural Coarse Aggregate
NAC	Natural Aggregate Concrete
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescene
SEM	Scanning Electron Microscopy
PSA	Particle Size Analysis
RHA	Rice Husk Ash
RCPT	Rapid Chloride ion Penetration Test
SHS	Self-propagated Synthesis at High temperature

LIST OF SYMBOLS

℃	Celcius
Ɵ	Theta
g	Gram
%	Percent
°F	Fahrenheit
X	Times, multiple
°	Degree
µm	Micrometer
m^2	Meter square
GJ	Giga Joule

KAJIAN SIFAT SIMEN DENGAN PENGISI SISA SERAMIK

ABSTRAK

Disebabkan populasi global yang terus berkembang dan kehendak untuk memenuhi permintaan pengguna, tapak pelupusan sampah akan terus menerima kuantiti sisa yang banyak. Mengubah kuantiti sisa pepejal yang banyak kepada sumber alternatif boleh membantu memulihara bekalan bahan tidak boleh diperbaharui yang semakin berkurangan, mengekalkan tenaga penting dan mengurangkan isu alam sekitar dan tapak pelupusan. Sisa seramik (CW) berpotensi untuk digunakan sebagai bahan bersimen tambahan (SCM) yang berkesan dalam bahan berasaskan simen kerana kandungan silika-alumina yang tinggi. Menggunakan CW sebagai bahan simen alternatif akan memberi kesan positif kepada alam sekitar. Walau bagaimanapun, masih terdapat kekurangan maklumat mengenai penggunaan CW sebagai bahan mentah dalam pengeluaran simen mesra alam. Matlamat penyelidikan ini adalah untuk mencirikan sampel sisa seramik untuk menentukan kesesuaiannya sebagai penggantian separa dalam Simen Portland Biasa (OPC) dan untuk mengetahui keadaan terbaik untuk mensintesis simen mesra alam menggunakan CW. CW akan dicirikan menggunakan Scanning Electron Microscopy (SEM), X-Ray Fluorescence (XRF), X-Ray Difraction (XRD) dan Analisis Saiz Zarah (PSA). Simen mesra alam kemudiannya dibakar pada pelbagai jenis suhu selepas dihasilkan mingikut komposisi mineralogi tertentu. Penambahan gipsum akan ditambah kepada campuran simen untuk melambatkan penghidratan. Prosedur analisis seperti XRF, SEM dan PSA akan digunakan untuk mencirikan sampel akhir. Oleh kerana sebatian utama telah bertindak balas sepenuhnya dan bahan kimia aktif hidraulik didominasi dalam produk, didapati suhu pensinteran yang ideal untuk simen mesra alam adalah 1100°C. Penemuan ini disokong oleh analisis XRD, XRF, dan SEM. Hasilnya, kajian menunjukkan bahawa sisa seramik boleh digunakan sebagai bahan mentah untuk membuat simen mesra alam.

THE STUDY OF CEMENT PROPERTIES WITH CERAMIC WASTE FILLERS

ABSTRACT

Due to a continuously expanding global population and the desire to satisfy consumer demands, landfills will continue to receive vast quantities of waste. Changing a substantial quantity of solid waste into an alternative resource can assist conserve diminishing non-renewable material supplies, sustain essential energy, and alleviate environmental and landfill issues. Ceramic waste (CW) has the potential to be employed as an effective supplementary cementitious material (SCM) in cement-based materials due to its high silica-alumina content. Utilizing CW as an alternative concrete ingredient will positively affect the environment. However, there is still a paucity of knowledge about using CW as a raw material in the production of eco-friendly cement. The aim of the research is to characterize the ceramic sample to determine its suitability as partial replacement in Ordinary Portland Cement (OPC) and to figure out the best conditions for synthesizing an eco-friendly cement using CW. The OPC and CW will be characterised using Scanning Electron Microscopy (SEM), X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD) and Particle Size Analysis (PSA) investigations preliminary to sample preparation. The eco-friendly cement is then sintered at various temperatures after being produced to a specific mineralogical composition. The gypsum addition will be added to cement mixtures to delay hydration. Analytical procedures such as XRF, SEM, and PSA will be used to characterise the final sample. Because the primary compounds were fully reacted and hydraulic active chemicals predominated in the products, 1100°C was revealed to be the ideal sintering temperature for eco-friendly cement. These findings were backed up by XRD, XRF, and SEM analysis. As a result, study reveals that ceramic waste can be used as raw materials to make ecologically friendly cements.

CHAPTER 1 : INTRODUCTION

1.1 Background to Cement Production

Cement manufacturing is one of the most essential industries for sustainable growth. It can be regarded the development's backbone. Cement is widely recognised as one of the most fundamental construction materials in the world. It is predominantly employed in the production of concrete. Concrete consists of inert mineral aggregates like sand, gravel, crushed stone, and cement. Consumption and production of cement are intrinsically linked to the construction industry and, by extension, to overall economic activity. Due to its importance as a building material and the geographical availability of its primary raw material, namely limestone, cement is produced in practically every country (Potgeiter, 2012). Cement plays a significant role in terms of economic and social value since it is essential for the development and improvement of infrastructure. It employs a big number of people directly and indirectly and contributes significantly to the Gross Domestic Product (GDP) (Pandey, 2017). It is impossible to imagine modern life without cement. This inorganic binder serves as the adhesive for concrete in the construction of buildings, roads, dams, and bridges, making contemporary infrastructure not only feasible but also economical. Moreover, cement production and the concrete industry, where it is ultimately used and consumed, are vital and dynamic sectors of the global economy and of every nation. It is responsible for the development of jobs and various cascading economic advantages in secondary connected industries, and it is a significant contributor to the global improvement of living standards (Potgeiter, 2012).

Cement has been used in concrete for a very long time, but industrial cement production didn't start until the middle of the 19th century. At first, shaft kilns were used to make cement, but rotary kilns are now used everywhere. Today, the world makes 2.8 billion tonnes of cement every year, and that number is expected to rise to 4 billion tonnes per year. About 1.6 billion tonnes of cement as well as 10 billion tonnes of sand, crushed rock, and gravel are used each year in the global cement technology (Mehta, 2001). It is estimated that producing one tonne of Portland cement requires about 4 GJ of energy, emitting 1.25 tonnes of carbon dioxide (CO_2) into the atmosphere (Wilson, 1993). Governments and businesses are behind the push to reduce CO_2 emissions around the world. They know that the current rate of putting greenhouse gases into the environment is a serious risk to life and well-being on the world in the future. Due to the rapid growth of industry and the steep increase in both public and private transportation, greenhouse gas emissions have reached an alarming level and are expected to grow even faster. It is anticipated that by 2050, cement plants around the world would produce around 5 billion tonnes of carbon dioxide (Potgieter, 2012).

Ordinary Portland Cement (OPC), the most common type of cement, is used in all standard concrete structures. Cement is the most often used cement in the world, since it is manufactured at a rate of approximately 3.8 million cubic metres per year. It is prudent to utilise this cement in all concrete projects (Imbabi et al., 2012). Table 1.1 lists the chemical ingredients of ordinary Portland cement (OPC) (Ali et al., 2008).

Table 1.1 Chemical constituents of Ordinary Portland Cement (OPC) (Ali et al., 2008)

COMPONENT	**AMOUNT (%)**
Lime (CaO)	60.0 - 67.0
Silica (SiO_2)	17.0 - 25.0
Alumina (Al_2O_3)	3.0 - 8.0
Iron Oxide (Fe_2O_3)	0.5 - 6.0
Magnesia (MgO)	0.1 - 4.0
Sulphur Trioxide (SO_3)	1.0 - 3.0
Soda and/or Potash ($Na_2O + K_2O$)	0.5 - 1.3

1.2 Overview of Cement Production in Malaysia

Malaysia is one of the countries in southeast Asia that is the largest consumer of cement on a per capita basis. Consumption of cement per person in Malaysia is roughly 600 kilograms, which is far more than the amount consumed in developed economies like the United States and Australia, or even in regional Southeast Asian cement heavyweights like Vietnam and Thailand (Tamotia, 2020). In the same way that urban growth and infrastructure development are driving the cement industry in most developing countries, they are also influencing the cement industry in Malaysia. Since the late 1980s, the nation has been seeing a surge in demand for cement as a direct result of steps taken by the government to modernize infrastructure in rural areas and establish free trade zones. Aside from a slump that occurred in the wake of the Asian financial crisis that occurred in 1997, the industry had been reaping the benefits of ever-increasing demand brought about by the construction of residential and public infrastructure.

From 1850 to 2000, the World Resources Institute (2003) provides global data on CO_2 emissions from energy usage and cement production. Total CO_2 emissions (excluding land use) are expressed as follows: thousands of tonnes of CO_2 per capita, expressed per one thousand persons. Malaysia's total CO_2 emissions from the cement sector are lower than those of Qatar, the United States, and Australia, which emit 40.6735, 19.4839, and 16.5444 per 1,000 people, respectively, according to the World Resources Institute (2003). Even Japan, which is considered to be an energy-efficient nation, has a greater CO_2 emission rate of 9.61204 per 1,000 inhabitants. Malaysian cement companies emit only slightly more CO_2 than the weighted average of 4.2 per 1,000 individuals.

1.3 Cement Production Environmental Impact

Due to concrete's large consumption, the demand for cement production has also increased. Cement is made from a large number of raw materials that are produced and reacted at high temperatures and pressures. Large-scale extraction of raw minerals such as limestone and clay, as well as fossil fuels such as coal, frequently leads in considerable deforestation and soil erosion. When raw materials are heated to high temperatures for solid-state reactions to happen, this is called pyro processing. Natural gas, coal, fuel oil, tyres, hazardous waste, petroleum coke, and pretty much anything else that can be burned is used as a fuel source. The production of one tonne of Portland cement consumes around 4 GJ of energy and releases approximately 1 tonne of carbon dioxide into the atmosphere (Mehta, 2001). The cement industry is one of the largest contributors to greenhouse gas (GHG) emissions, specifically CO_2 emission, as well as one of the largest emitters of particles, NOx, and SO_2. The cement industry is responsible for approximately 6–8% of total carbon emissions, and the cement subsector consumes approximately 12–15% of the total industrial energy (Ali MB, 2011), making it the second largest CO_2 emitter after the power industry. Therefore, even small reductions in greenhouse gas emissions per ton of cement production can make a significant global impact.

Air pollution is the biggest environmental problem caused by the cement industry. The main pollutions caused by making cement are air pollution, cement dust, solid waste pollution, water pollution, ground vibration, noise pollution, and the depletion of resources caused by getting raw materials. Gases from both the kiln and the preheating process are used to dry and heat the raw materials. Components of fuel gases include CO_2, N_2, O_2, $S0_2$, water vapor, and micro components such as CO and NOx production. Emissions of gases occur in two stages:

(a) Calcinations: CaO production will release CO_2 and water vapour at elevated temperatures.

(b) Combustion of fuel: The successful operation of a rotary kiln necessitates an adequate source of heat that first raises to the desired operating temperature and then maintains it.

By burning fuel, carbon, hydrogen, sulfur, and nitrogen in fuel combine with oxygen in the air to produce the necessary heat. Dust pollution is also caused by making cement, which can hurt your eyesight and air quality. The Centers for Disease Control and Prevention make it clear that once the dust has been drained, it can get into the water and endanger the health of people and animals. The discharge of wastewater into the atmosphere is responsible for the contamination of river and groundwater supplies (Ding L., 2015). In regions with an increasing population, construction, and urbanization, as well as land human activities, degrade the soil. Poor land management can also cause soil to break down and water to run off the land instead of seeping into it. Both of these things contribute to erosion. Also, the majority of noise pollution comes from the process of making cement. Noise pollution was caused by the preparatory work of raw materials, the combustion of clinker, the storage of materials, and the usage of heavy machinery. Based on how the noise is made, industrial noise is divided into three types:

complicated gas noise, electrical and magnetic noise, and mechanical noise (Gao Hongwu, 2003). The main noisemakers in cement plants are the blowers, which make gas-dynamic noise, the milling machines and crushers, which make mechanical noise, and the electric engines, which make electromagnetic noise. Noise pollution has serious effects on the anatomy and physiology of human body systems such as the neurological, digestive, and cardiovascular systems (Gao Hongwu, 2003). Long-term exposure to high noise cement mill environments makes it more likely that someone will develop symptoms of neurasthenia syndrome, such as memory loss, high blood pressure, trouble sleeping, dizziness, headaches, and tiredness.

Rubber, sludge, waste oil, and waste fuel that have been recycled can be used as renewable fuel in the cement industry. This cuts down on the use of nonrenewable resources for energy production (Imbabi, 2012). In addition to making cement plant operations more environmentally friendly, researchers look into whether waste materials could be used to replace some cement in concrete. Hamidian et al. said that growing concern about the damage the cement industry does to the environment has led to a need for cement that are less harmful to the environment and cost less. As people try to use less limestone, they have made it possible to study the use of waste materials like eggshell, oyster shell, and cockle shell as partial cement replacements. Waste industrial byproducts like palm oil fuel ash, slag, fly ash, rice husk ash, and waste ceramic powder have been used as cementitious materials because of their pozzolanic properties.

1.4 Problem Statement

A million tonnes of ceramic by-product are currently stored in landfill sites. As a result, landfills will continue receiving vast quantities of waste and badly affect the environment. Ceramic has been used as a partial replacement in cement, however the information about using ceramic waste as a partial replacement in cement is still scarce. Using ceramic waste as an alternative ingredient in cement is expected to have a positive environmental impact and need to be further investigated

During the cement production process, unoptimized operating conditions will lead to higher energy consumptions and higher net CO_2 emissions. The same amount of CO_2 is produced by the production of cement, but 1.5 times as much limestone is required. Optimized operating conditions need to be determined in synthesizing the eco-friendly cement using ceramic in order to lower the energy consumption as well as reducing the CO_2 emission while enhancing or maintaining the properties of the cement.

1.5 Research Question

1. What properties of the ceramic waste samples make it appropriate for use as a partial replacement in cement, and how may these properties be determined?

2. What kind of an impact will it have if we use some of the ceramic waste samples in place of some of the cement?

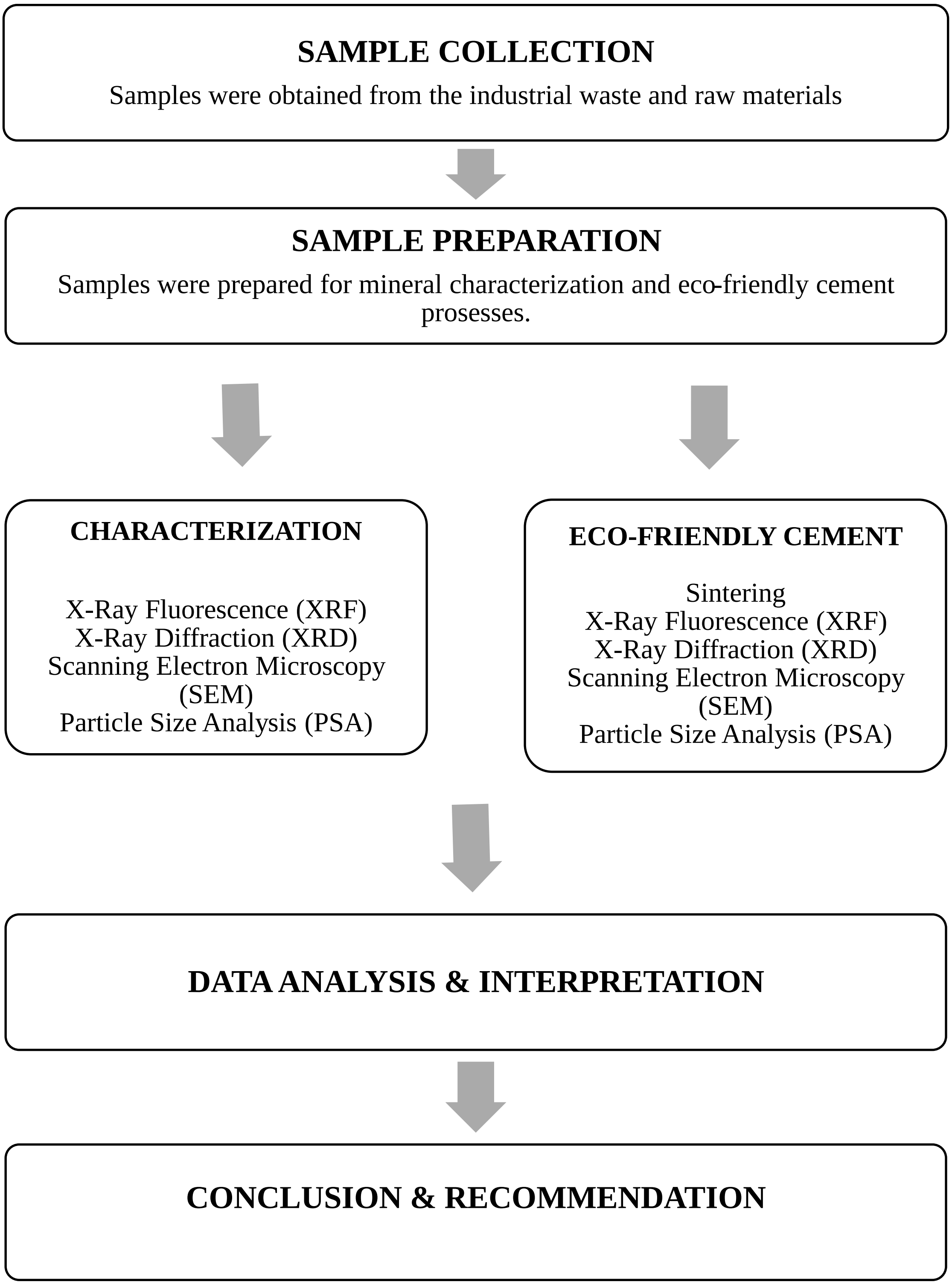
3. What are the optimal conditions for producing eco-friendly cement out of ceramic waste, and how may they be achieved?

1.6 Objectives of Research

- The main objective of this research is to characterize the ceramic sample to determine its suitability as partial replacement in Portland cement.

- To establish the optimal conditions for synthesizing the eco-friendly cement using ceramic.

1.7 Scope of Study



CHAPTER 2 : LITERATURE REVIEW

2.1 Cement Manufacturing Process

2.1.1 The basics of cement manufacture

Portland cement is manufactured in a series of processes, as shown in Figure 2.1.

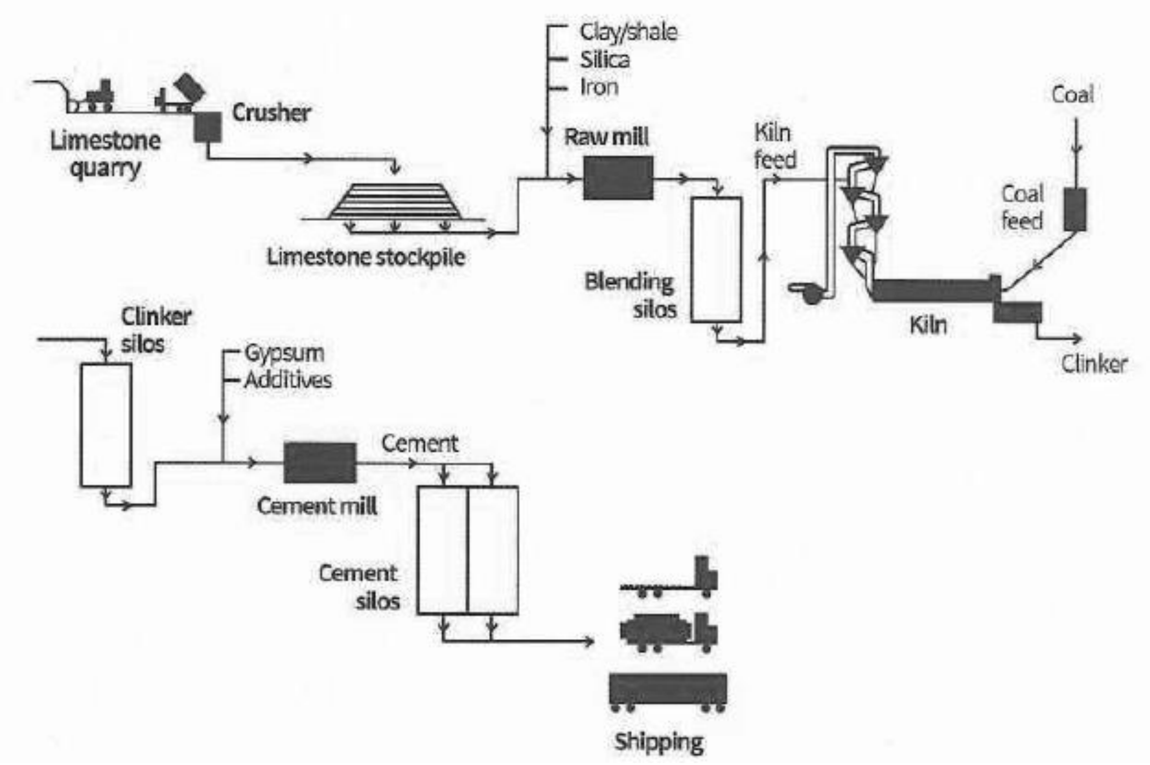


Figure 2. 1 Cement plant schematic process

Source: Alsop, P.A., 2019. *Cement plant operations handbook: for dry process plants*. Tradeship Publications Ltd.

In order to make Portland cement, there are four steps: (1) Crushing and grinding the raw materials. (2) Mixing the ingredients in the right amounts. (3) Burning the prepared mix in a kiln. (4) Grinding the burned product, called "clinker," with about 5% gypsum (to control the time of set of the cement). The wet, dry, and semidry processes are when the raw materials are ground wet and fed to the kiln as a slurry, ground dry and fed as a dry powder, or ground dry and then moistened to form nodules that are fed to the kiln.

All materials, except soft ones, are first crushed, frequently in two stages, and then ground, typically in revolving, cylindrical ball or tube mills with a charge of steel grinding balls. Depending on the operation, this grinding can be done wet or dry, however for dry grinding, the raw materials may first need to be dried in cylindrical, rotating dryers. By vigorously swirling soft materials with water in wash mills, a thin slurry is produced, which is then passed through screens to remove larger particles. Limestone (calcium carbonate) and other materials with suitable proportions of calcium, silicon, aluminium, and iron oxides are crushed and processed to produce a fine flour-like unprocessed meal.

By selective quarrying and controlling the raw material fed to the crushing and grinding mill, a preliminary approximation of the chemical composition necessary for a specific cement is obtained. By extracting material from two or more batches containing slightly different raw mixtures, finer control is achieved. In the dry process, these mixtures are held in silos, whereas in the wet process, slurry tanks are utilised. By inducing agitation and rapid circulation with compressed air, the dry materials in the silos are thoroughly blended. In the wet process, the slurry tanks are either mechanically or pneumatically (or both) agitated. Occasionally, the slurry, which includes 35-45% water, is filtered to reduce the water content to 20-30%, and the filter cake is then fed to the kiln. This minimises the amount of fuel required for combustion.

The feed of raw materials is inserted at the higher end of the kiln and steadily flows to the lower, or fire, end. The fuel for combustion may be injected powdered coal, oil, or natural gas. Depending on the raw materials being burned, the temperature at the end of the firing ranges from around 1350-1550°C. Usually, a heat exchanger is put at the back of the kiln to make sure that as much heat as possible gets to the raw materials going in and as little heat as possible gets lost in the waste gases. Small clinker nodules are what comes out of the kiln with the burned product. The heat is given to the air that comes in, which cools the product. Dark clinker grains are what occurs out of the kiln as a result of the reaction. Clinker can be turned into cement right away, or it can be stored for later use.

Clinker and the right amount of gypsum are ground into a powder form in horizontal mills, just like the raw materials were. Material can go straight through the mill (open-circuit grinding), or coarser material can be distinguished from the ground product and sent back to the mill for more grinding (closed-circuit grinding). The feed material is sometimes given a small amount of a grinding aid. In the same way, an air-entraining agent is added to air-entraining cements. Cement is pneumatically pumped into storage silos, from where it is pulled to be packaged in paper bags or shipped in bulk containers.

2.1.2 Raw Materials

The first thing that needs to be done to make cement is to mix a number of different raw materials such as shown in Table 2.1. This is to ensure that the cement produced have the specific chemical that is required set by the industries. These raw materials are ground into finer particles, which makes them more reactive. The mixed raw materials are then fed into a cement kiln, which expose them to extremely high temperatures (Kosmatka et.al, 2002).

Although it is essential to have the right ratios of calcium, silicon, aluminium, and iron, the overall chemical composition and structure of the various raw components might differ from one another. This is due to the extremely high temperatures present in the kiln, which cause many of the chemical components included in the raw ingredients to be burned away and replaced with oxygen from the surrounding air (Kosmatka et.al, 2002). The primary raw materials that can be utilised to produce each of the primary cement constituents are broken down into their respective categories and are listed in Table 2.1.

Table 2. 1 Raw ingredients used to provide each of the main cement elements

Calcium	**Silicon**	**Aluminium**	**Iron**
Limestone	Clay	Clay	Clay
Marl	Marl	Shale	Iron Ore
Calcite	Sand	Fly Ash	Mill Scale
Aragonite	Shale	Aluminium	Shale
Shale	Fly Ash		Blast Furnace Dust
Seashells	Rice Hull Ash		
Cement Kiln Dust	Slag		

Function of the constituents of raw materials

Lime

It is the primary ingredient used in the production of cement. It is responsible for giving cement its cementing property. An excessive amount of lime causes cement to expand and disintegrate. A lack of lime reduces cement's strength and accelerates its setting time. In the correct proportions, it strengthens and stabilises cement. Therefore, lime can significantly alter the characteristics of cement.

Silica

This contributes significantly to the strength of concrete. Calcium reacts chemically with silica to produce dicalcium silicate (C_2S) and tricalcium silicates (C_3S). Excess silica strengthens cement, but delays its setting time.

Alumina

This makes more complicated compounds with the silica and calcium that help the cement set faster. It acts as a flux and brings down the clinkering temperature. Using too much alumina speeds up the curing time of cement, but it also makes it weaker.

Iron Oxide

This is mostly what gives cement its colour. Some of the hardness and strength of the cement are also increased. During the process of making cement, it makes it easier for the raw materials to mix together.

Magnesium Oxide

A tiny amount provides strength to the cement; nevertheless, an excessive amount renders the cement unsound.

2.1.3 Raw Materials Processing

The production of cement can be broken down into two main stages. In the beginning, clinker is manufactured from the raw ingredients. Cement is created from cement clinker in the second step of the process. Depending on the condition of the raw material, the first step of the process could involve a dry, wet, semi-dry, or semi-wet procedure. After being supplied in bulk, the raw materials are crushed and homogenised to create a mixture before being introduced into a rotary kiln. This is a massive rotating pipe that may be up to 6 metres in diameter and can be up 60 to 90 metres in length (Hahn, et.al 1997). A flame reaching temperatures of 2,000℃ burns inside of this huge kiln. The kiln is tilted at an angle to facilitate the materials' slowdown journey to the opposite end, where they are rapidly cooled to temperatures between 100 and 200℃.

Four basic oxides in the exact quantities create cement clinker: calcium oxide (65%), silicon oxide (20%), alumina oxide (10%) and iron oxide (5%). When heated by the flame to a temperature of approximately 1450℃, these elements will mix and combined (referred to as "raw meal" or slurry). New compounds are formed: silicates, aluminates, and ferrites of calcium. The hydration of these chemicals is responsible for the hydraulic hardening that occurs in cement (Hahn, et.al 1997). Clinker is the name given to the product produced at the end of this step. These solid grains are eventually stored in huge silos.

The cement grinding mill, which may be in the same location as the clinker plant, is where the second phase of production takes place. Gypsum (calcium sulfates), as well as other cementing materials (such as coal fly ash, blast furnace slag, natural pozzolanas, etc.) or inorganic matter (limestone), are added to the clinker. All of the ingredients are ground together to make a fine, even powder. The cement is then stored in silos until it is moved in bulk or put into packages.

2.2 Type of Cement

The properties of cement during hydration are vary according to:

- Chemical composition
- Degree of fineness

Different varieties of cement can be produced by varying the amounts of their primary elements. Based on the composition materials used in its manufacture, each variety of cement has unique properties, uses, and advantages.

Types of Cement

- Portland cement
- High-alumina cement
- Natural cement
- Expansive cement

2.2.1 Ordinary Portland Cement (OPC)

Ordinary Portland cement is the most popular type of cement, and it may be used in all types of normal concrete construction. This form of cement is the most widely produced and utilised in the world, accounting for an average of 3.8 million cubic metres per year. This cement can be utilised for any concrete construction job.

Types of Portland Cement

- Ordinary Portland cement – Type I
- Modified cement - Type II
- Rapid-hardening Portland cement – Type III
- Low heat Portland cement – Type IV
- Sulfate-resisting Portland cement – Type V

It is possible to add some additive to Portland cement to produce the following types:

- Portland blast furnace cement – Type IS
- Pozzolanic cement - Type IP
- Air-entrained cement - Type IA
- White Portland cement
- Coloured Portland cement

2.2.1 High-Alumina Cement

Due to its large-scale features, high alumina refractory cement concrete provides various benefits. In addition, its resistance to heat is advantageous for sectors working with high temperatures or even direct fire. In additionally, it possesses a high compressive strength and is highly reactive. Also noteworthy is its minimal frost action, as more heat is generated during the setting process. The production of alumina refractory cement is fundamentally distinct from the production of portland cement.

This is because its primary raw materials are bauxite and lime. They are combined according to the specified quantities, which will be ground into 100mm fragments. The fragments are then placed in a kiln and heated to their fusing point (1600°C). The molten material is then moved down a steel plate and into a rotary kiln to cool. The material is then coarsely milled in tube mills till it reaches 2250cm^2/gram.

Table 2. 2 Composition of High Alumia Refactory Cement

Composition	**Percentage**
Silica	3-8%
Alumina	37-41%
Lime	36-40%
Iron Oxide	9-10%
Titanium	1.5-2%
Magnesium	1%
Insoluble Residue	1%

2.2.2 Natural Cement

The word "natural" means that the raw material, a type of clayey limestone called "clayey marl," is dug up and burned without being changed in any way. On the other hand, Portland cement and other "artificial" cements are made from a mixture of pure limestone, silicates, and clays that are chemically similar to or different from marls in a controlled and repeatable way. Over the course of geologic time, certain impurities have gotten deep into the limestone, making natural cement. But the limestones that are used to make natural hydraulic lime and natural cement both have amorphous silica, but the limestones that are used to make natural cement have a lot of finely formed alumina.

clayey marls are the name for these unique natural limestones that are used to make cement. (Webb, 2020).

Due to the small amounts of silicates and alumina that are naturally found in the limestone, marl can be burned at temperatures less than 2200° F. So, all of the CO_2 that was in the limestone part of the marl is let out. Some of the leftover "quicklime," or CaO, combines with the silica to make belite, which is a calcium silicate complex that helps natural hydraulic limes take a long time to harden when they are mixed with water. At these high temperatures, the remaining quicklime also fuses with the alumina to make a large group of calcium-alumina compounds (Webb, 2020). Burned materials, called "clinker," are ground into a fine powder. This makes the natural cement ready to be mixed with rocks and water.

Because of these alumina reactions, natural cements are very different from hydraulic limes in the way that they set. In contrast to pure lime, which must reabsorb CO_2 from the air to slowly set over months, and hydraulic limes, whose initial setting with water can take from hours to days, the hydraulic reaction of aluminates with water, which is typical of natural cements, happens almost quickly, in a matter of minutes. Even though they are made of different chemicals, natural cements and gypsum plasters both set quickly. In the same way, natural cements have a very strong ability to hold things together. This means that the amount and type of aggregates used can be more flexible than with other limes.

2.2.3 Expansive Cement

Generally, expansive cement is composed of Portland cement with an expansive additive. Expansive cement, when combined with water, produces a paste that, after setting, expands in volume substantially more than Portland cement paste. The primary constituents of expansive cement include silicate-type, aluminate-type, sulphoaluminate-type, and calcium aluminoferrite-type compounds. The expansion mechanism involves ettringite formed in cement paste expanding. And the setting and hardening of expansive silicate cement is rather stagnant, but that of expansive aluminate cement is rapid.

Silicate Expansive Cement

It is the expansive cement produced by combining Portland cement with aluminate cement and gypsum. By adjusting the amount of aluminate cement and gypsum, the value of its expansion can be altered. Replace the aluminate cement in silicate expansive cement with alunite to get alunite expansive cement. Alunite is composed of [K_2SO_4•$Al_2(SO_4)_3$•4Al(OH)] and may produce ettringite, the best expansive cement currently available. Alunite expansive agent and aluminate expansive agent used to Portland cement will also result in cement expansion.

Aluminate Expansive Cement

Grinding aluminate cement clinker and dihydrate gypsum or combining their ground particles produces aluminate expansive cement. It has excellent self-strengthening and airtightness.

Aluminoferrite Expansive Cement

It is constituted of anhydrous calcium sulphoaluminate, dicalcium silicate, and gypsum.

Sulphoaluminate Expansive Cement

It is composed of gypsum, iron phase, anhydrous calcium sulphoaluminate, and dicalcium silicate.

By altering the proportions of the above mentioned four categories, it is possible to produce expansive cement with varying expansion ratios. Depending on the expansion ratio, expansive cement can be separated into expansive cement and self-stressing cement. This cement is utilised in huge, continuous floor slabs. It is effective for filling foundation holes and producing concrete that is stronger than regular Portland cement concrete. This material is used to manufacture bridge and building components made of prestressed concrete. It can also be used to construct water-retention structures, repair damaged concrete surfaces, and grout anchor bolts.

2.3 Introduction to Ceramics

Ceramics are inorganic materials that are made up of both metal and non-metal parts. Their properties depend on how these parts are joined together (Hare, 1984). Ceramic materials can be used for almost anything. Because most of its bonds are strong ionic and covalent connections in different amounts, they are able to adapt to different situations. The bonds determine many of the properties of ceramic materials, such as their relatively high fusion temperatures, high modulus, high wear strength, poor thermal properties, high hardness, fragility paired with tenacity, and low ductility. Since they are joined to make chemical bonds, they are good electrical insulators and don't have any electrons that can move. (Freiman, 1991).

Traditional ceramics and technological or advanced ceramics are the two broad categories of ceramic materials. Traditional ceramics are made from silicates, which include cement, refractories, and clay products. Traditional ceramics are made in large quantities and are in high demand. Clay and other natural materials, like sand, are used to make the raw materials for traditional ceramics. Technical or advanced ceramics are made from man-made raw materials that have been through a lot of chemical processing to make them pure and improve their physical properties. Because of this, they are made with more modern and complicated tools. They include carbides, nitrides, borides, pure oxides, and a wide variety of ceramics that can be used in magnetic, ferroelectric, piezoelectric, and superconducting ways. (Cranmer, 1991).

Because ceramics are so versatile, they can be used for a wide range of end users and applications. For example, in the construction and building industry, they can be used as clay bricks and blocks, sanitary ware, and wall and floor tiles; in the home, they can be used as tableware (porcelain), cooking ware (glass-ceramics), or pottery; in the industrial processing and manufacturing industry, they can be used as refractories, filters, cutting tools, or parts for solid oxide fuel cells; and in high technology, they can be used as components for electronic displays. Because of their unique electrical properties, they have numerous applications in electronics, including capacitors ($BaTiO_3$), high transition temperature superconductors ($YBa_2Cu_2O_7$), piezoelectric and ferroelectric, insulators, varistors (ZnO), and integrated circuit substrates (Borrel, 2018). They are employed in the production of infrared windows, lasers, and high-pressure sodium lights because to their aesthetic qualities. The ferrites are a family of ceramics that stand out because of their magnetic properties. They are normally put into two big groups: soft ferrites (spinels and garnets) and hard ferrites (hexaferrites), such as barium hexaferrite, spinel ferrites of Mn-Zn, or Ni-Zn ferrites doped with ruthenium or lanthanides that have a strong saturation magnetization value and are used in permanent magnets, coloured pigments, and electronics. (such as interference suppressors, electronic amplifiers, or power inductors) (Barry, 2013).

One of the biggest problems with using ceramics as building materials is that they tend to break easily and don't absorb much energy. They also can't be deformed in a plastic way, which is especially important when they are being pulled. This tendency to break easily can be explained to a large extent by the fact that the material has flaws, which are almost impossible to get rid of completely in this type of material. These flaws make the material even weaker since ceramics are much more resistant to forces of compression than forces of tension (Dolores, 2019). This is because the ceramic structures make it hard for the dislocations to move, even when the temperature is high. But one of the uses that is expanding is the use of structural parts that make the mechanical properties better. For these purposes, you need materials that are strong in a variety of environments, can withstand high temperatures, and don't rust or oxidise. Compared to materials like metals, ceramics are also much lighter (Dolores, 2019).

In order to make the ceramic parts, the powder needs to be made, combined, moulded, and then heated. Sintering can happen through either diffusion in the solid stae or the formation of a liquid phase between the grains (Rahaman, 2007). Processes like as sol-gel, self-propagated synthesis at high temperature (SHS), precipitation, etc. can be used in the lab to create ceramic powders, but they can also be formed by processing natural raw materials (minerals from rocks). Particulate systems generated through synthesis are more common in advanced ceramics, where the control of impurities and flaws is more crucial in the end usage of the piece, as this involves a comprehensive control of the purity of the raw materials and their final microstructure. Traditionally, ceramic powders made from minerals have been utilised. To create a finished ceramics product using the traditional methods, one must first begin with raw materials, which must then go through a series of processes designed to remove impurities and create a powder that can be moulded and fired. However, powders used in modern ceramics are often laboratory-created because of their high purity requirements. There are many ways to get ceramic materials, but lab-made powders all have some things in common. For instance, they are free of impurities, have an uniform size and shape, have a high specific surface area, can be ground into finer particles without forming hard clumps or aggregates, and have more consistent qualities overall. (Dolores, 2019).

After the ceramic powder has been cleaned, homogenised, etc., it is compacted and given the desired shape during the shaping stage of processing. However, the resulting material will have poor mechanical qualities and a large number of holes. The main ways to shape something are by axial and isostatic dry pressing, porous mould or tape moulding, extrusion, or injection moulding. The type of piece required for manufacturing as well as the time and resources available in the production system determine which of these shaping methods will be used. Not only should the packaging be well-coordinated, but it should also be as homogenous as possible to prevent microstructural faults that would otherwise reduce the finished material's usefulness. In order to achieve this goal, it is necessary to regulate several factors during the moulding procedure, including particle size and distribution, clumping, and powder flow. (Dolores, 2019).

Once the green piece has the shape you want, it needs to be dried and the organics must be taken out before the material is made denser. Controlling how the green piece dries is done in rooms with a controlled temperature and air flow. In the organic elimination stage, the organic compounds that were used in the processing are removed from the outside to the inside. This means that the thicker the piece is, the harder it is to remove the organic compounds. Organic additives can be removed by evaporation, chemical extraction with solvents, catalytic extraction, or heating until they break down.

Lastly, the sintering process takes place. This is when the compacted material, shown in green, is heated to a high enough temperature for mass to move into the spaces between the particles, making the compact denser. As the sintering process goes on, the porous phase breaks up and disappears, leaving only the pores that are still blocked by the ceramic matrix and can't be removed. Sintering can happen in three ways: in a solid state, in the presence of a liquid phase, or through a chemical reaction.

However, ceramic materials do not degrade, thus their carrying value is typically significantly higher than that of other materials (Dolores, 2019). The same physical qualities that make ceramics among the most long-lasting materials also make them among the most challenging to recycle. Even though it's hard to recycle, there are ways to "revalue" trash, which means to find a new use for it. Bricks, concrete, and bituminous pavements are all recyclable materials that can be broken down into aggregates for use in new concrete or as direct road bases.

Waste may be easily recovered in the ceramics and cement sectors due to their production methods (Perez, 2007). They can utilise the energy released during combustion, for instance, or build the garbage right into the matrix of the material so that it becomes inert. Since these ceramic materials possess characteristics not found in any other substance, they find its applications in a wide range of industries (Dolores, 2019).