Republic of Yemen
Ministry of Higher Education and Scientific Research

Emirates international University
Faculty of Engineering & Information Technology

Production of Portland Limestone Cement (PLC)

(LOW COST CEMENT)

A PROJECT SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE BACHELOR DEGREE CHEMICAL ENGINEERING

Done by

AHMED NASSER AL-SAYARI
HAZEM MOHAMMED AL-MATHHJI
OSAMA BASHEER AL-MAQTRI
MOHAMMED ABDUL-AZIZ QASEM
MOHAMMED ANWER OTHMAN
ABDULLATIF JAMIL AL-GAFARI

Supervised by

Dr. Ahmed Al-Anweh

Eng. Jamal Saeed

2023-2022

Abstract:

The cement industry, a driving force behind modern construction and infrastructure, has long been recognized for its significant contributions to the global economy. However, rising costs and environmental concerns have illuminated the need for innovative solutions that prioritize affordability and sustainability.

This graduation project not only delves into the potential of a low-cost cement industry but also explores the possibility of implementing the project as a third production line in the Amran Cement Factory. By doing so, it aims to produce a product that covers the local market's need for finishing materials, in addition to addressing global concerns.

The primary goal of this endeavor is to explore cost-effective and sustainable alternatives to traditional cement production methods, highlighting the potential benefits of implementing such solutions on a global scale and locally within the Amran Cement Factory. By analyzing the factors that contribute to the high costs of cement production, this research will identify potential avenues to reduce expenses and enhance the accessibility of this vital construction material.

Furthermore, this graduation project will investigate the environmental impact of the cement industry and the importance of incorporating sustainable practices into low-cost production methods, aligning with both global and local environmental considerations. By examining cutting-edge technologies, innovative materials, and energy-efficient processes, the project will showcase the potential for creating a greener, more affordable cement industry that caters to the local market's needs.

Through a comprehensive analysis of the low-cost cement industry's challenges and opportunities, this graduation project aims to contribute to a more equitable and eco-conscious future for construction and infrastructure development, with a focus on addressing both global and local market demands. By delving into the potential of low-cost cement production in the context of the Amran Cement Factory, this research seeks to pave the way for a more inclusive and sustainable built environment, empowering communities worldwide and locally to thrive and prosper.

DEDICATION

TO

OUR PARENTS

OUR BROTHERS AND SISTERS

OUR FRINDS AND COLLEAGUES

WITH LOVE

Acknowledgement

I would like to extend our heartfelt gratitude to our supervisor **Dr. Ahmed Al-nweh & Eng. Jamal Saeed** for their invaluable guidance, unwavering support, and unwavering belief in the success of this project. Their insightful feedback and constant encouragement have been instrumental in shaping this work.

I am also deeply thankful to our family for their incessant support throughout this endeavor. Their love, understanding, and encouragement provided the bedrock upon which this project stands.

The collective efforts have played an integral role in the success of this project, and for that, we are truly grateful."

Above that, we would like to thank Almighty Allah for his enduring grace, guidance, and protection that he has bestowed upon us during this research work.

We thank you ...

Supervisor Certification

I certify that the preparation of this project entitled

…………………………………………………………………………………………….,

prepared by ……………………………………………………………………………...

…………………………………………………………………..………………………

Was mad under my supervision at ……………….. department as partial fulfillment of the requirements of bachelor degree in ………………………………………………………….

Supervisor Name:

Signature:

Date:

Examiner Committee

Project Title:…………………………………………………………………..

Supervisor

No	Name	Position	Signature
1			
2			

Examiner Committee

No	Name	Position	Signature
1			
2			
3			
4			

Department Head

…………………..

Table of contents:

List of Tables:

List of Figures:

Shortcuts:

1.PLC: Portland limestone cement
2.OPC: Ordinary Portland cement
3.PPC: Portland Pozzolana cement
4.CEM II/B-32.5 N:
5.C_3S: Alite (Tricalcium silicate)
6.C_2S: Belite (Dicalcium silicate)
7.C_3A: Aluminate (Tricalcium aluminate)
8.C_4AF: Ferrite (Tetracalcium alumionoferrite)
9.SCM_S: Supplementary cementitious materials
10.P. lime: Pure limestone
11.A0: Cement with zero percent pure limestone
12.A10: Cement with ten percent pure limestone
13.A20: Cement with twenty percent pure limestone
14.A30: Cement with thirty percent pure limestone
15.A40: Cement with forty percent pure limestone
16.A50: Cement with fifty percent pure limestone
17.PPE: Personal protective equipment
18.NOX: Nitrogen oxide
19.SOX: Sulphur oxide
20.VOC: Volatile organic compound
21.SCR: Selective catalytic reduction
22.HVAC: Heating ventilation and air conditioning
23.ESP: Electrostatic precipitators

CHAPTER 1

INTRODUCTION

1.1 Cement definition:

Cement is a binder substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together.

Cement is an extremely fine material having adhesive and cohesive properties which provides a binding medium for the discrete ingredients, also cement is a product obtained by pulverizing clinker formed by calcinating raw-materials primarily consisting of lime (CaO), silicate (SiO_2), Alumina (Al_2O_3), and Iron oxide (Fe_2O_3).

Cement industry is considered of strategic industries. However, it is a simple industry compared to the major industries and depends on the availability of raw materials for that.

1.2 History of Cement:

Throughout history, cementing materials have played a vital role and were used widely in the ancient world. The Egyptians used calcined gypsum as a cement and the Greeks and Romans used lime made by heating limestone and added sand to make mortar, with coarser stones for concrete. The Romans found that a cement could be made which set under water and this was used for the construction of harbours. This cement was made by adding crushed volcanic ash to lime and was later called a "pozzolanic" cement named after the village of Pozzuoli near Vesuvius. In places where volcanic ash was scarce, such as Britain crushed brick or tile was used instead. The Romans were therefore probably the first to manipulate systematically the properties of cementitious materials for specific applications and situations.

Marcus Vitruvius Pollio, a Roman architect and engineer in the 1st century BCE wrote his "Ten books of Architecture" a revealing historical insight into ancient technology. Writing about concrete floors, for example: "First I shall begin with the concrete flooring, which is the most important of the polished finishing, observing that great pains and the utmost precaution must be taken to ensure its durability".

The reality of the cement industry:

The consumption of cement in any society is one of the most important economic indicators associated with the level of development of national income, and therefore studies indicate and international statistics that the average global production of cement reaches 3580 million tons, and other statistics indicate double this number in all cases China ranks first with a monopoly on more than half of the world's production and the fourth the countries that follow in an estimated estimate are India with a production capacity of 219 million tons, Iran 72 million tons, The United States of America 69 million tons, and Turkey 64 million tons, while the production of Arab countries is (300 million) and higher than the Arab countries production is Egypt, followed by Saudi Arabia then the Emirates. While Yemen's cement production is approximately 6-7 million tons. It is estimated that its imports of cement amount to about 5 million tons. Through the above, observed that the gap in numbers between Yemen on the one hand and the mentioned countries according to a specific and clear national vision. The above on the one hand shows the urgent need for investment in the establishment of cement factories.

• The history of cement in Yemen

The cement industry began in Yemen in 1973, through Bajil cement factory, followed by the establishment of many factories, although all of these factories produce. However, its production does not meet the needs of the local market, and this is covered the need by importing cement from abroad, and studies indicate that the growth rate the demand for cement in Yemen exceeds 13% annually, and thus the percentage is decreasing local coverage of demand and the increase in the import rate, which means that there is a growing need for this goods in the internal and external market.

Advantages of the cement industry in Yemen:

- The abundance of raw materials necessary for the production of cement of various types and in quantities sufficient to create a leading industry that covers the needs of the local market with great potential to be one of the important exportable goods.
- The geographical distribution of raw materials in the various regions of the Republic of Yemen in order to enable its raw materials contribute to the development of different regions through the cement industry in them or the production of some of different types of the cement.
- The presence of large quantities of additives used in the cement industry, which give Provided by the advantage of reducing the costs of the cement industry and helps in the distinction and quality of the cement product and its diversity.
- Having good technical expertise, an abundance of labor force, and a comparative advantage in the level of hands wages working.
- The rapid growth of the demand for cement in the Yemeni market with the acceleration of the development movement and the growth prospects of the per capita share of cement.

1.3 Description of Raw Materials:

Cement is a highly versatile and widely used building material that is essential for all types of construction work. The production of high-quality cement requires the careful selection and use of various raw materials that are combined in precise proportions. Limestone, clay, shale, sand, iron ore, and gypsum are the primary raw materials used in cement manufacturing. The percentage of each raw material used is essential to ensuring the successful production of high-quality and consistent cement.

1. Limestone

Limestone is the primary raw material used in the production of cement. It comprises calcium carbonate, which reacts with water to produce calcium silicates and calcium aluminates, essential components of cement. Limestone accounts for up to 80% of the raw materials used in cement manufacturing. The quality of limestone used for cement production is critical.

Limestone must contain the right amount of calcium carbonate and other minerals, such as silica, alumina, and iron oxide, to ensure the final product's quality.

The percentage of limestone used in cement production varies depending on the type of cement being produced. For example, the production of Portland cement requires between 60% and 70% limestone.

2. Clay

Clay is another essential raw material used in cement production and accounts for about 15-25% of the total raw materials used. Clay is extracted from quarries and mines and consists of aluminium and silica. When mixed with limestone and iron ore, clay reacts with calcium and alumina to form calcium silicates and calcium aluminates, crucial components of cement. Clay's quality is also critical in cement production, and the percentage used varies depending on the type of cement being produced.

The production of Portland cement, for example, requires a blend of limestone, clay, and other minerals. The percentage of clay used in the production of Portland cement varies between 15 and 25%.

3. Shale

Shale is a sedimentary rock that contains a high percentage of silica and aluminium and is used as a raw material in cement production. Shale can contain up to 10% of iron oxide, which enables it to act as a feedstock for the production of cement clinker. Shale is ground and combined with limestone and clay to form a raw mix, which is then heated in a kiln to produce cement clinker.

The percentage of shale used in cement production varies between 3-5% and is added to provide additional silica and aluminium. Shale's use is beneficial in cement production where it enables producers to regulate the final product's chemistry, contributing to the product's strength, durability, and workability.

4. Sand

Sand is another raw material used in cement production that is available in abundant supply worldwide. The quality and chemical composition of sand used in concrete production are critical. Sands from different sources have different shapes and sizes. It is important to use sand with a particular particle size distribution, coarse enough to prevent the concrete from becoming too brittle, and fine enough to fill the gaps between the coarse aggregate particles properly.

The percentage of sand used in cement production varies between 10 and 20% and depends on several factors, including the required consistency and final product characteristics.

5. Iron Ore

Iron ore is used in cement production to provide the necessary iron for the production of cement clinker. It is usually introduced in small quantities of between 0.5 and 7%. Iron ore provides the necessary iron for the production of cement clinker, and the percentage used must be carefully monitored to ensure that the optimal amount is used. Using too much or too little iron can affect the product's quality and performance.

6. Gypsum

Gypsum is the final raw material used in cement production. Gypsum is added to the cement clinker during the final grinding stage and acts as an inert material, slowing down the hardening process, and regulating the cement's setting time. It also improves the workability of the cement and its ability to flow freely.

The percentage of gypsum used in cement production is between 2 and 10% and varies depending on the specific application and the required final product characteristics.

1.4 Physical and Chemical Properties of raw materials:

Table 1.1 Physical &Chemeical Properties of Raw Materials

Material	Physical Properties	Chemical Properties
Limestone	-Hard, sedimentary rock. -Color can vary from white to dark gray. -Composed mainly of calcium carbonate crystals. -Density: 2410kg/m³	-Reacts with acids to produce carbon dioxide (CO2) -Decomposes to calcium oxide (CaO) and carbon dioxide (CO2) when heated. -M.wt: 100g/mol
Clay	-Fine-grained, soft, and sticky. -Hardens when dried or heated. -Can vary in color (white, gray, brown, or red). -Density: 2080kg/m³	-Composed mainly of alumina and silica compounds. -Reacts with water to form a plastic mass.
Sand	-Fine-grained, granular material. -Typically light-colored (white, tan, or gray). -Composed mainly of quartz (SiO2). -Density: 1602kg/m³	-Highly resistant to chemical attacks. -Insoluble in water.
Iron oxide	-Fine-grained, reddish -brown to black powder. -Hard and dense. -Density: 4800kg/m³	-Insoluble in water. -Reacts with oxygen at high temperatures, forming various iron oxide compounds. -M.wt: 159.69g/mol

1.5 Types of Cement:

1- Ordinary Portland Cement (OPC)

Benefits: OPC is known for its strength, durability, and affordability. It is widely used in general. construction projects where special properties are not required.
Comparison: While OPC provides good strength, it lacks the enhanced resistance to chemicals and aggressive environments that some specialized cements offer.

2- Portland Pozzolana Cement (PPC)

Benefits: PPC offers better resistance to chemicals and reduces the rate of corrosion in steel reinforcements. making it suitable for structures exposed to harsh environments.
Comparison: Although OPC and PPC are both types of Portland cement, PPC is more environmentally friendly due to its lower energy consumption and CO2 emissions.

3- Rapid Hardening Cement

Benefits: Rapid hardening cement achieves strength more quickly than OPC, making it perfect for fast-paced construction projects.
Comparison: While this cement type is advantageous for urgent projects, it may not be suitable for projects where more time is needed for shaping and finishing the concrete.

4- Quick Setting Cement

Benefits: Quick setting cement sets faster than ordinary cement, making it ideal for underwater construction and repair works.
Comparison: While rapid hardening cement achieves strength more quickly, quick setting cement is more focused on setting time and reducing the effects of water.

5- Low Heat Cement

Benefits: Low heat cement produces less heat during hydration, which makes it suitable for use in massive. concrete structures like dams.
Comparison: Although low heat cement is beneficial for large structures, it may not be necessary for smaller projects where heat production is not a significant concern.

6- Sulfates Resisting Cement

Benefits: Sulfates resisting cement is specifically designed to resist sulfate attack, making it an excellent choice for structures exposed to sulfate-rich environments.
Comparison: While PPC also offers resistance to aggressive environments, sulfates resisting cement is specifically designed to combat sulfate-related issues.

7- White Cement

Benefits: White cement provides a smooth and bright finish to surfaces, making it ideal for decorative purposes.
Comparison: In terms of strength, white cement is similar to OPC, but its primary purpose is aesthetics rather than structural integrity.

8- Water Repellent Cement

Benefits: Water repellent cement is resistant to water penetration, making it suitable for use in damp environments or structures that require waterproofing.

Comparison: While hydraulic cement also protects against water, water repellent cement focuses on reducing water absorption rather than setting and hardening in the presence of water.

9- High Alumina Cement

Benefits: High alumina cement is known for its high resistance to chemical attacks, making it perfect for use in areas exposed to corrosive substances.

Comparison: While PPC resists chemicals, high alumina cement has a higher resistance to aggressive chemicals, making it suitable for more extreme environments.

10- Hydraulic Cement

Benefits: Hydraulic cement can set and harden even when exposed to water, making it ideal for construction projects where water exposure is a concern.

Comparison: While water repellent cement reduces water absorption, hydraulic cement is specifically designed to set and harden in the presence of water.

1.6 Method of producing:

Cement production has evolved over time, with more efficient and environmentally friendly methods being developed. Here's a comparison of the old and new methods of producing cement, along with their benefits, harms, economic, and environmental implications.

Table 1.2 Comparison Between Wet & Dry Method

Comparison	**Old Method: (Wet Process)**	**New Method: (Dry Process)**
Benefits	-Better homogenization of raw materials, resulting in a more consistent cement product. -Easier handling and grinding of raw materials due to the fluid nature of the slurry.	-Lower energy consumption since there is no need for water evaporation. -Simpler and more cost-effective equipment. -Preheater and precalciner systems improve fuel efficiency and reduce emissions.
Drawbacks	-Higher fuel consumption because of water evaporation. -More complex and expensive equipment required for handling slurry.	-Less homogenization of raw materials, which may affect product consistency. -More difficult handling of raw materials in their dry state.
Economic implications	-Higher production costs due to increased energy consumption and complex equipment. -The higher quality of the cement product might command a higher market price.	-Lower production costs due to reduced energy consumption and simpler equipment. -Competitive market pricing due to improved fuel efficiency and emissions reduction.
Environmental implications	-Lower production costs due to reduced energy consumption and simpler equipment. -Competitive market pricing due to improved fuel efficiency and emissions reduction.	-Reduced greenhouse gas emissions because of lower energy consumption and more efficient processes. -Potential air pollution from dust emissions during the handling and grinding of raw materials; however, modern dust collection systems can mitigate this issue.

1.7 Flow sheet:

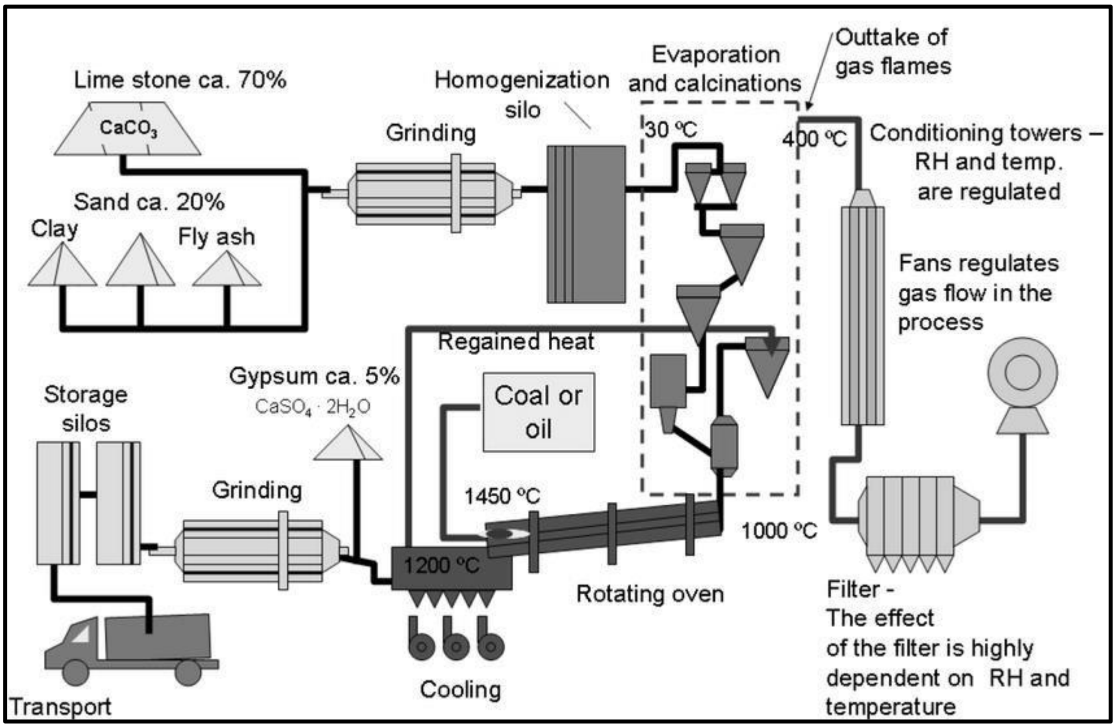

Figure 1.1 Process Flow Sheet

1.8 Description of clinker production process:

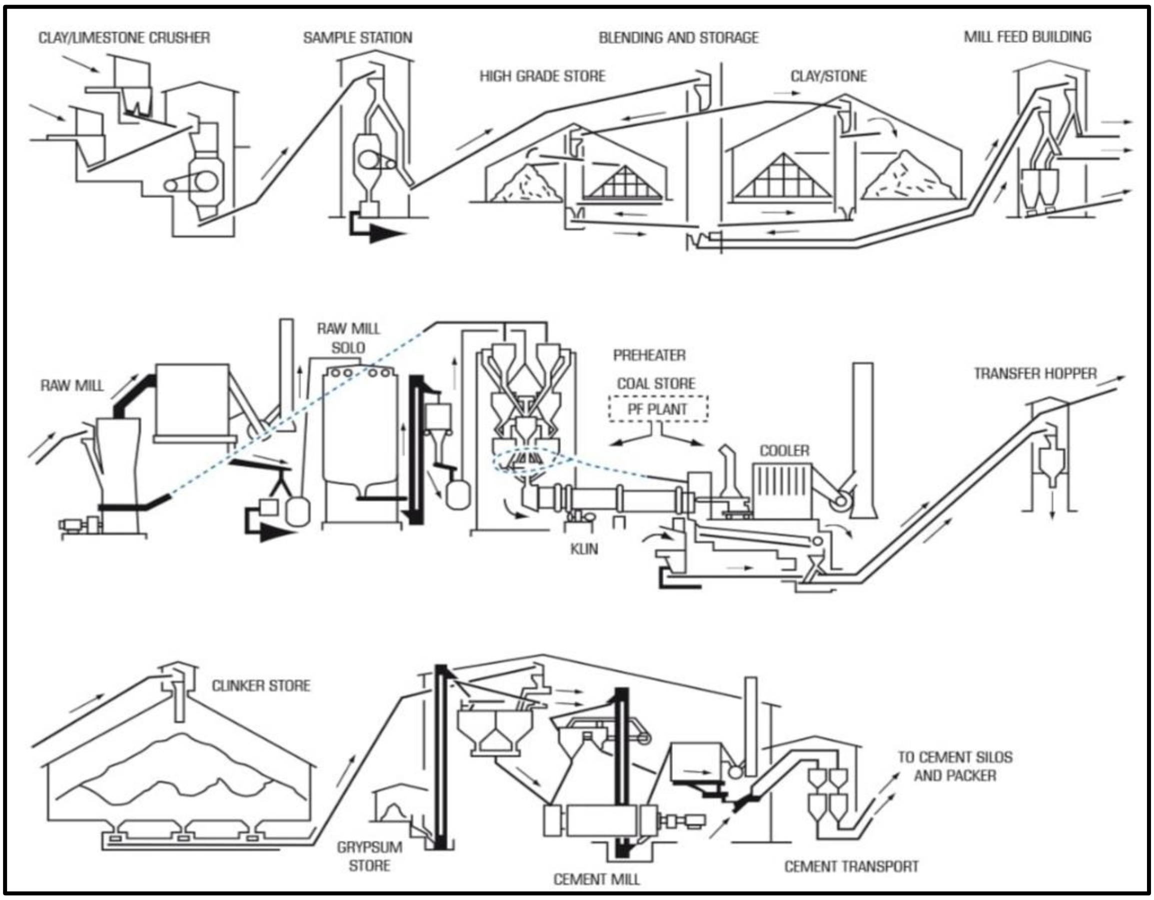

Figure 1.2 Process Flow Diagram of Clinker Production

Step 1 - Quarrying

The raw material for cement manufacture is a rock mixture which is about 80% limestone which is rich in (CaCO3) and 20% clay or shale (a source of silica, alumina and Fe2O3). These are quarried and stored separately. The lime and silica provide the main strength of the cement, while the iron reduces the reaction temperature and gives the cement its characteristic grey color.

Step 2 - Raw material preparation

The steps involved here depend on the process used.

The dry process:

The quarried clay and limestone are crushed separately until nothing bigger than a tennis ball remains. Samples of both rocks are then sent off to the laboratory for mineral analysis. If necessary, minerals are then added to either the clay or the limestone to ensure that the correct amounts of aluminum, iron etc. are present. The clay and limestone are then fed together into a mill where the rock is ground until more than 85% of the material is less than 90μm in diameter.

Step 3 – Clinkering

This is the step which is characteristic of Portland cement. The finely ground material is dried, heated (to enable the sintering reactions to take place) and then cooled down again.

While it is being heated various chemical reactions take place to form the major mineral constituents of Portland cement. The powder from the dry process doesn't contain much moisture so, can be dried in a preheater tower. As it falls through the tower (which takes 30 seconds) it is heated from 70 to 800oC. The moisture evaporates, up to 20% of the DE carbonation (loss of CO_2 occurs and some intermediate phases such as $CaO•Al_2O_3$ begin to appear. The mixture is then fed into the kiln.

The slurry from the wet process contains too much moisture to be successfully dried in a preheater tower. Instead, the slurry is fed directly into the kiln where it is formed into dry balls by the heat and rotation of the kiln. Because of this extra role of the kiln, wet process kilns are generally longer than dry process kilns. The kilns used in both processes are inclined on a shallow angle and lined with heat-resistant bricks.

The reaction processes occurring within the kiln are not easily understood due to the wide variations in raw-mix chemistry, raw-mix physical properties and kiln operating conditions, and the physical difficulties of extracting hot materials from the process for investigation before they cool.

Breaking the reaction processes into a number of simple zones means that can make some approximations about the cement formation process.

Zone 1: 0 - 35 min, 800 - 1100C

DE carbonation. Formation of $3CaO•Al_2O_3$ above 900oC. Melting of fluxing compounds Al_2O_3 and Fe_2O_3.

heat

$CaCO_3$ $CaO + CO_2$

Zone 2: 35 - 40 min, 1100 - 1300C

Exothermic reactions and the formation of secondary silicate phases as follows:

Heat

$2CaO + SiO_2$ $2CaO•SiO_2$

Zone 3: 40 - 50 min, 1300 - 1450 - 1300C

Sintering and reaction within the melt to form ternary silicates and tetracalcium aluminoferrates:

heat + time

$2CaO \cdot SiO_2 + CaO$ $3CaO \cdot SiO_2$

heat + time

$3CaO \cdot Al_2O_3 + CaO + Fe_2O_3$ $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$

Zone 4: 50 - 60 min, 1300 - 1000C

Cooling and crystallization of the various mineral phases formed in the kiln and storage in silos.

CHAPTER 2

PRODUCTION of PORTLAND LIMESTONE CEMENT

2.1 Portland limestone cement:

Portland limestone cement (PLC)is a type of cement that is made by blending Portland cement with limestone. The limestone used in PLC production typically contains higher levels of calcium carbonate than the limestone used in traditional Portland cement production. This higher calcium carbonate content means that less energy is required to produce PLC, resulting in a lower carbon footprint compared to traditional Portland cement.

The use of PLC is becoming increasingly popular in many parts of the world due to its sustainability and environmental benefits. PLC has similar properties to traditional Portland cement and can be used in construction applications, including decoration, mortar, and grout. PLC is also known for its improved durability and reduced susceptibility to sulfate attack and alkali-silica reaction.

The Portland limestone cement industry has been growing in recent years, with more and more cement producers adding PLC to their product portfolios. The use of PLC is also being encouraged by governments and industry associations as part of efforts to reduce carbon emissions and promote sustainable construction practices.

Why Portland limestone cement?

Portland limestone cement (PLC)is a popular choice in the construction industry for several reasons. The primary benefits of using PLC over traditional Portland cement are its environmental and sustainability advantages, as well as its comparable performance in various applications. Here are some key reasons why PLC is preferred:

1- Lower Carbon Footprint: The production of PLC requires less energy and produces fewer carbon emissions compared to traditional Portland cement. This is due to the higher calcium carbonate content of the limestone used in PLC, which reduces the amount of clinker needed in the cement manufacturing process. As a result, PLC has a lower carbon footprint, making it a more environmentally friendly option.

2- Improved Durability: PLC has been shown to exhibit better durability in comparison to traditional Portland cement. This is because PLC has a lower susceptibility to sulfate attack and alkali-silica reaction, which can cause premature deterioration of concrete structures. The improved durability of PLC can lead to longer-lasting structures and reduced maintenance costs.

3- Resource Conservation: The use of PLC reduces the demand for clinker, a primary component of traditional Portland cement. By using a higher percentage of limestone in the cement blend, the overall consumption of non-renewable resources is decreased, promoting resource conservation and sustainability.

4- Cost-Effectiveness: In some cases, PLC can be more cost-effective than traditional Portland cement due to the reduced clinker content. This can result in lower production costs, which can be passed on to the end-users in the form of lower prices for cement and concrete products.

5- Applications: PLC can be used in a variety of construction applications, including mortar, decoration and grout. Its performance is comparable to that of traditional Portland cement, making it suitable for use in various projects without sacrificing quality or performance.

Previous studies about increase the percentage of limestone in Portland limestone cement:

Several previous studies have focused on the effects of increasing the percentage of limestone in Portland limestone cement (PLC). Here are some of those studies:

1."Influence of limestone content, gypsum content and fineness on early-age properties of Portland limestone cement produced by inter-grinding" (2012) by H.Hebhoub et al. This study examined the influence of limestone content, gypsum content, and fineness on the early-age properties of PLC produced by inter-grinding. The results showed that increasing limestone content could enhance the early-age properties of PLC, such as hydration heat, setting time, and strength development.

2."Performance of Portland limestone cements: Cements designed to be more sustainable that maintain performance"(2010) by T. Tennis and M.Thomas
- This study evaluated the performance of PLC and compared it to ordinary Portland cement (OPC). The results demonstrated that PLC, with an increased limestone content, could exhibit similar or better performance than OPC in terms of strength development, durability, and resistance to aggressive environments.

3."Use of high limestone content cement in concrete for sustainable construction"(2012) by F. Debieb et al. This study investigated the effects of using high-limestone-content cement in concrete for sustainable construction. The results showed that concretes made with high-limestone content cement exhibited good mechanical properties and durability, despite the increased limestone content.

4."Effects of limestone addition on the physical and mechanical properties of Portland cement"(2014) by M. Soroka et al.- This study examined the effects of limestone addition on the physical and mechanical properties of Portland cement. The results showed that increasing limestone content could improve the workability, compressive strength, and flexural strength of cement-based materials.

5."Mechanical properties and durability of concrete made with high-volume fly ash blended cements using a coarse fly ash"(2011) by M. Safiuddin et al.- This study investigated the mechanical properties and durability of concrete made with high-volume fly ash blended cements using a coarse fly ash and an increased percentage of limestone. The results indicated that such concrete mixtures could achieve comparable strength and durability to those made with OPC.

These studies demonstrate that increasing the percentage of limestone in PLC can lead to improvements in early-age properties, mechanical performance, and durability. However, the specific effects may depend on factors such as the type of cement, mix components, and environmental conditions.

Percentage of adding limestone in cement over the years:

The proportion of limestone in Portland limestone cement (PLC) has gradually increased overtime as research and technological advancements have demonstrated the benefits of incorporating limestone into cement. The progression of limestone content in PLC can be summarized as follows:

1. Early usage (pre-20th century): Lime-based cement binders, such as lime putty, were often used along with other hydraulic cements, including calcium aluminate cement. Limestone content in these early cementitious materials varied, but it was generally a significant component.

2. Mid-20th century: The development of Ordinary Portland Cement (OPC)reduced the limestone content in cement, focusing more on the clinker component. At this time, the limestone content in cement was typically under 5%.

3. Late 20th century to early 21stcentury: Research and technological advancements demonstrated the benefits of incorporating limestone into cement. Standard specifications for PLC began allowing up to 15% limestone content in the United States (according to ASTMC595 and AASHTOM240) and up to 20% in some European countries.

In recent years, researchers and industry professionals have continued to explore the effects of higher limestone content in PLC, with some studies using up to 30% limestone.

Project of production of Portland limestone cement in Yemen:

Yemen has a significant cement industry, with several cement plants operating in the country. The main cement producers include the Amran Cement Plant, Bajil Cement Plant, and Al-Barh Cement Plant. These plants produce various types of cement, including ordinary Portland cement (OPC) and blended cements.

As the global construction industry moves towards more sustainable practices, there is potential for the use of PLC in Yemen. The limestone required for PLC production is available in various regions of the country, which could help in reducing the carbon footprint associated with cement production.

Furthermore, some of the existing cement plants in Yemen may have the capacity to produce PLC, either by modifying their current production processes or by adding additional production lines.

In order to promote the use of PLC in Yemen, it would be essential for the local cement industry, government, and construction stakeholders to collaborate and create a supportive regulatory environment. This could include updating building standards and codes to recognize the use of PLC, encouraging the use of PLC in public projects, and providing incentives for cement producers to invest in the technology and infrastructure required to produce PLC.

The availability of limestone resources and the global trend towards sustainable construction practices make PLC a viable option for the Yemeni cement industry. However, this would require cooperation among various stakeholders, including cement producers, government authorities, and the construction sector.

Through conducting preliminary studies and fieldwork, it has become clear that most types of various cement are not produced in the local market, despite the abundance of raw materials.

Therefore, in our current study, we aim to conducting a study to establish a third production line at AMRAN CEMENT PLANT site to produce low-cost cement (PLC)with specifications that meet the needs of finishing and decoration work, as well as block factories (finishing cement) (CEMll/B-L32.5N) with a production capacity of 30000 ton/year.

2.2 Raw Material:

1- Clinker: from AMRAN CEMENT PLANT clinker silos.
2- Pure Limestone: from the quarries that contain pure calcium carbonate.
3- Gypsum

2.3 Chemical and Physical Properties for raw materials of PLC:

Table 2.1 Chemical & Physical Properties for Raw Material of PLC

Material	Physical Properties	Chemical Properties
Clinker	-Color: dark gray or black in color. -Hardness: quite hard and can resist scratching. -Porosity: relatively low in porosity -Shape: Irregularly shaped. -Density: 3170kg/m^3	-Chemical Composition: consists of C3S, C2S, C3A, C4AF. -Reactivity: highly reactive when mixed with water to form cement paste. -Heat Generation: generates significant heat during the hydration process. -Strength: impacts the final concrete's compressive strength and durability.
Gypsum	-It is a hygroscopic compound, which means that it can absorb moisture from the air and become damp.	-It has a neutral pH of 7 and is non-toxic. -Is an important source of calcium and sulphur, which are essential nutrients for plant growth.
Pure Limestone	-Color: white, gray, beige, and even black, depending on impurities and geological factors. -Hardness: relatively soft compared to other rocks. -Porosity: It can be porous, with variable porosity depending on factors such as compaction and cementation. -Density:2130kg/m^3.	-Chemical Composition: composed of calcium carbonate (CaCO3), typically accounting for over 90% of its composition. -Solubility: slightly soluble in water. -Reactivity: It reacts with acids, effervescing or bubbling when exposed to strong acids like hydrochloric acid (HCl), due to the release of carbon dioxide (CO2).

2.4 Compression between OPC & PLC:

Table 2.2 Compression Between OPC & PLC

	Ordinary cement	**Portland lime cement**
Raw materials	Primarily made from limestone, clay, and iron ore. It contains a higher percentage of clinker, which is responsible for its strength.	Blend and varying amounts of limestone. It typically contains25-40% limestone, which reduces the carbon footprint.
Strength	Higher early strength, making it suitable for applications where quick setting and strength gain are critical.	Have slightly lower early strength but can develop comparable or even higher ultimate strength over time.
Durability	More resistant to harsh environmental conditions due to its higher clinker content.	Better durability in the long term due to reduced heat generation during production and improved resistance to sulfate attacks.
Environmental Impact	Higher carbon footprint due to the energy-intensive clinker manufacturing process.	More environmentally friendly because it incorporates supplementary cementitious materials (SCMs) like limestone, reducing CO2 emissions.
Cost	High purchasing cost.	Cheaper.
Power consumption	High.	Low.

2.5 Laboratory and fieldworks and their results:

1-Field trip:

Figure 2.1 Section of Raw Materials In The Quarries of Amran Cement Plant

During the operation, a visit was made to the quarries of the Amran Cement Factory, with the aim of examining the different rock sections and dividing them according to their chemical composition and the proportions of raw materials in each section. During the visit, samples of pure white limestone were taken for chemical tests using x-rays to determine the chemical properties of this type of stone. Advanced X-rays were used to analyze the microscopic composition of the samples and to measure the different chemical compositions and proportions of the raw materials. According to the test results, pure white limestone has been selected for use in the production of low-cost cement. This stone is suitable for efficient and economical manufacture of low-cost cement, as it has suitable chemical properties.

2-Preparation of raw materials:

After taking a sample of the White pure limestone and conducting chemical analyzes on it and making sure that it meets the required specifications according to the 25kg of the White pure limestone was taken for laboratory experiments.

Also, a quantity of clinker and gypsum material was taken from the adjacent yard of the clinker silos and chemical analyzes were carried out on it, and the results were as follows:

Table 2.3 Chemical Analyzes Compostion of Raw Materials For PLC

	Pure limestone	Clinker	Gypsums
SiO_2	0.09	19.51	0.93
Al_2O_3	0.52	5.54	0.30
Fe_2O_3	1.24	2.91	0.02
CaO	55.31	64.96	30.35
MgO	0.96	2.44	0.40
SO_3	0.19	0.79	43.31
K_2O	0.02	1.14	0
Na_2O	0.02	0.22	0.1
Mn_2O_3	0.05	0.09	0
TiO_2	0.12	0.12	0.02
P_2O_5	0.00	0.10	0
Cl	0.01	0.01	0.01

3-The cracking stage:

Figure 2.2 Crusher Lab

By the mini crusher located in the quality inspection laboratories located in the Amran cement factory, all the quantities of limestone, clinker and gypsum were individually crushed into small parts for easy grinding afterwards in the grinding stage.

4-Grinding stage:

Figure 2.3 Raw Mill Lab

Using disk mill, all quantities of pure limestone, clinker and gypsum were ground separately and prepared for the placement stage.

5-Placement stage:

After the completion of the grinding process of all raw materials, 6 samples were taken, each sample weighing 4kg consisting of clinker, gypsum and pure limestone, and numbered according to the percentage of pure limestone for each sample from 0% to 50% according to the following table:

Table 2.4 Placement of Samples

% / Type	Clinker (g)	Pure Limestone (g)	Gypsum 3% (g)
PLC 0%	3880	——	120
PLC 10%	3480	400	120
PLC 20%	3080	800	120
PLC 30%	2680	1200	120
PLC 40%	2280	1600	120
PLC 50%	1880	2000	120

6-Final smoothing stage:

Figure 2.4 Ball Mill Lab

After the placement stage for each sample the final smoothing stage takes place by using a mini ball mill to soften cement in each sample and access to the required softness.

7-Fineness test:

Figure 2.5 Blaine Air Permeability Apparatus

Blaine Air Permeability Apparatus determines the fineness of Cement by measuring the specific surface area of fine materials in square centimeters per gram of test sample. A quantity of air is drawn through a bed of definite porosity, and the rate of airflow is determined by the pore volume in the bed, a function of the size of particles. The components of the apparatus are a stainless-steel test cell, plunger, perforated disc, calibrated U-tube manometer, and rubber aspirator and bulb, all mounted on a sturdy wood panel with a base. An 8oz bottle of red spirit manometer fluid, a package of filter paper, and a woodblock for holding the cell during filling are also included.
Results of Blaine test:

Table 2.5 Results of Blain Test

Name	Blain (cm^2/g)
A0	4048
A10	4194
A20	4181
A30	4128
A40	4115
A50	4181

According to previous results observed that the blain of cement increases with the addition of P. Lime, usually caused by the specific surface of P. Lime. However, the value of blain in old samples was fixed to a value higher than 4000 cm^2/g because it is advisable for finishing cement to be higher fineness than ordinary cement to fill voids, and with increased the fineness the pressure resistance increased.

8-Sieves test:

Figure 2.6 Partical Size Measuring Equipment

The fineness of cement is a measurement of the size of the cement particles and is represented in terms of the cement's specific surface area.

Aim:

To evaluate the fineness of cement utilising an IS sieves with a 90 and 45 micron opening in accordance with the requirements of IS.

The fineness test of cement involves passing samples of cement through a standard IS sieve. This is how the test is performed. The weight of a cement particle is calculated, and the size of the particle must be more than 90 microns. After that, the proportion of cement particles that have been kept is computed.

Apparatus:

- 90 and 45 µm IS Sieve.
- Weight Balance has a capacity of 10 mg to 100 g.
- Nylon or pure bristle brush.

Results:

Table 2.6 Particle Size Result

Name	Fineness	
	45UR	90UR
A0	1.5	0.36
A10	2	0.37
A20	2.5	0.7
A30	2.8	0.9
A40	3.5	1.6
A50	3.8	1.8

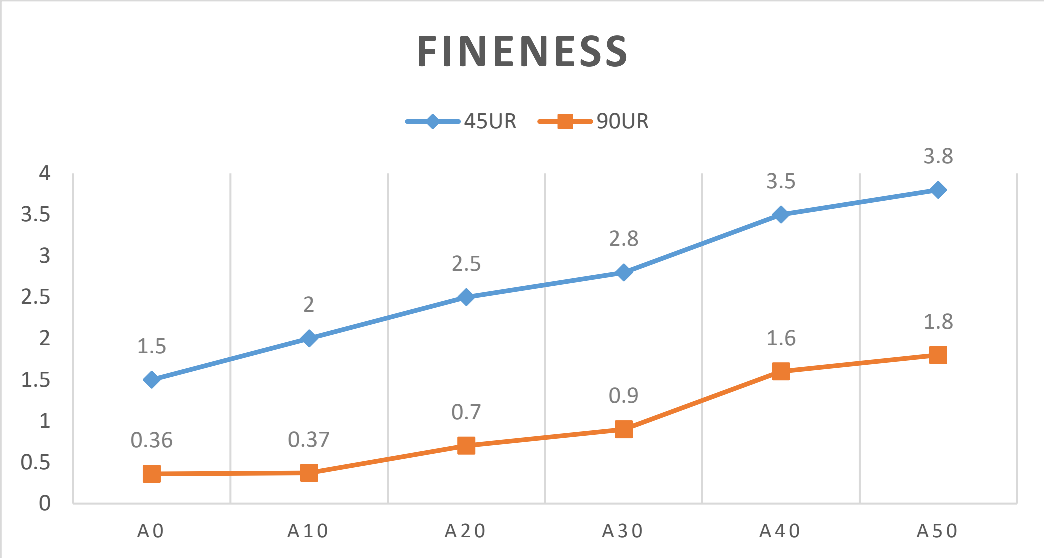

Figure 2.7 Fineness Chart

9-Setting time test:

Figure 2.8 Vicat Device

The initial setting time of concrete is the time when cement paste starts hardening while the final setting time is the time when cement paste has hardened.

Apparatus Required:
Vicat's apparatus, Balance, Measuring cylinder, Stop watch, Glass plate, Enamel tray, and Trowel.

Initial Preparation:
- Consistency test to be done before starting the test procedure to find out the water required to give the paste normal consistency (P).
- Take 400 g of cement and prepare a neat cement paste with 0.85P of water by weight of cement.
- Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time (T1).
- Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block.

Test for Initial Setting Time:
- Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle.
- Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block.
- In the beginning the needle completely pierces the test block. Repeat this procedure i.e., quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (T2).

Test for Final Setting Time:
-For determining the final setting time, replace the needle of the Vicat's apparatus by the needle with an annular attachment.
-The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so. Record this time (T3).

Calculations:

Initial setting time=T2-T1

Results:

Table 2.7 Setting Time Results

Name	Setting time		
	Consistency water (%)	Initial	Final
A0	27.8	1:10	2:40
A10	27.2	1:00	2:50
A20	25.4	1:00	2:40
A30	25.2	1:00	2:50
A40	24	1:00	2:50
A50	23.2	1:00	2:50

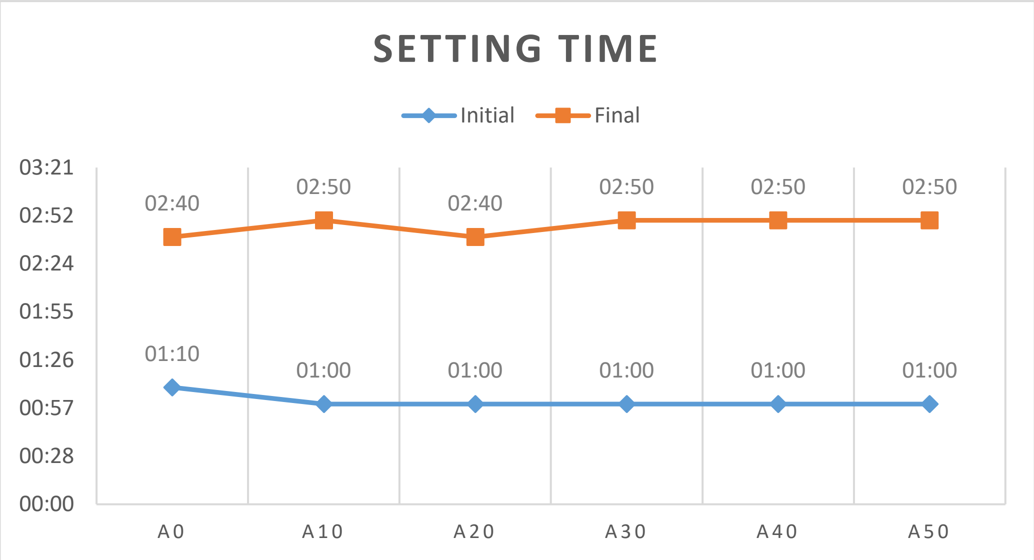

Figure 2.9 Setting Time Chart

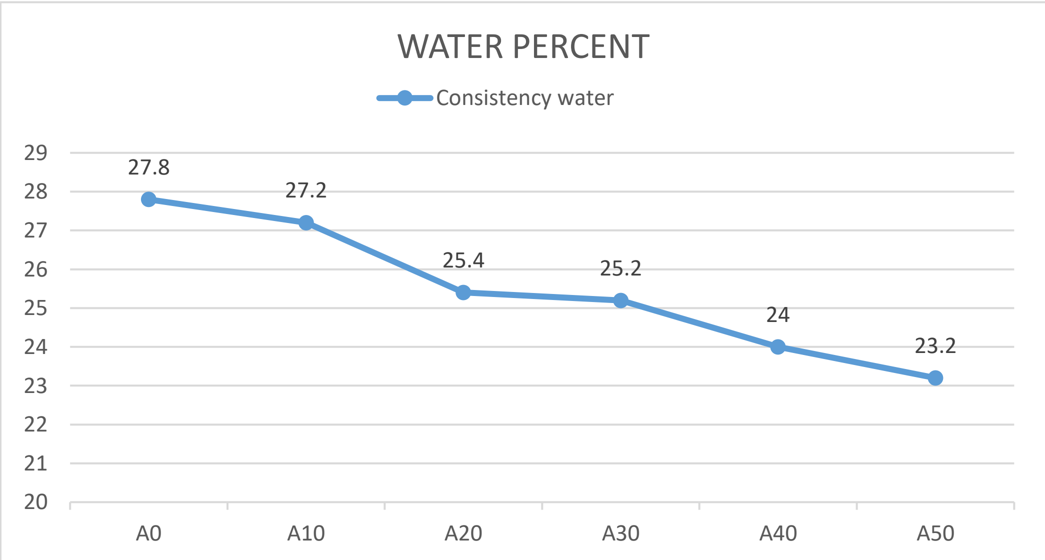

Figure 2.10 Water Percent Chart

According to figure (2.10) observed the percent of water decrease with the addition of P.Lim because of :

Dilution Effect: Pure limestone, when added to the cement mixture, acts as a filler material. It dilutes the clinker content in the cement. Clinker is the main component in traditional Portland cement, and it requires more water for proper hydration. When you reduce the clinker content with limestone, less water is needed for the same level of hydration

Chemical Interaction: Limestone contains calcium carbonate (CaCO3), which can chemically react with water during the cement hydration process to produce calcium hydroxide (Ca (OH)2) and carbon dioxide (CO2). This reaction can consume some of the water initially present in the mixture, reducing the overall water demand

Particle Packing: Limestone particles can enhance the packing density of the cementitious materials. This improved particle packing reduces the void spaces between particles, allowing for more efficient water distribution. As a result, the mixture may require less water to achieve the desired workability

10-Compressive strength:

Objective:

to determine the concrete pressure resistance as a measure to control the quality of cement production.

Experiment tools:

- The test template is a cube with a side length of 15 cm and a surface area of 225 cm²according to British specifications.

-The pressure Rod is a steel rod weighing 1.82 kg pressure device.

Figure 2.11 Experiment Tools of Cubes

The samples are weighed separately as follows:

-Cement in the amount of 195 g.

-Sand 585g.

-Water 80 ml.

- mix cement and sand with the addition of water until the dough forms.

- pour the dough into the mold and put it in a vibrating device to discharge it from the air and to ensure the -distribution of the dough in each mold.

-write down the date of pouring the sample and how long it will take in the water.

-The samples (cubes) are placed in water for 3, 7, 28 days.

-The sample is placed in the pressure device.

-The cube is compressed until the fracture to determine and record the pressure applied to it at the moment of its fracture.

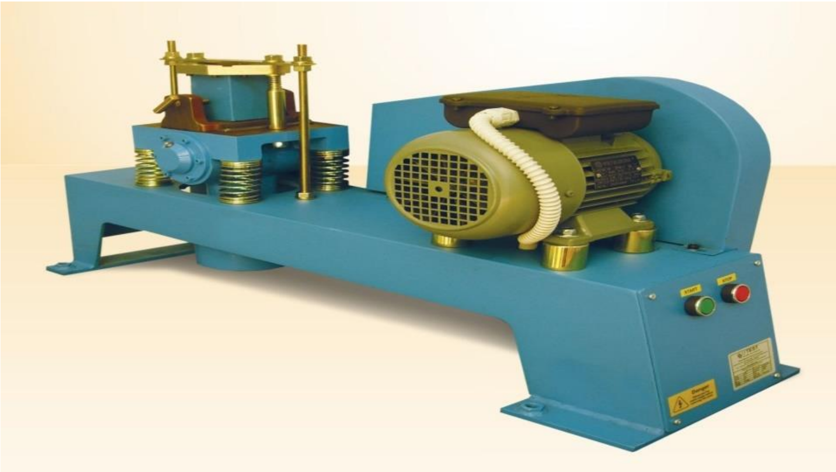

Figure 2.12 Vibrating Device

(a)

(b)

(c)

(d)

(e)

Figure 2.13 (a, b, c, d, e) Samples Cubes & Compressive strength

Figure 2.14 Compressive Measuring device

Results:

Table 2.8 Compressive Strength Results

Name	Compressive strength (N/mm²)		
	3d	7d	28d
A0	30.1	39.8	51.7
A10	30.06	39.9	51.7
A20	26.6	34.9	47.1
A30	21.7	28.3	39.7
A40	15.1	21	32.3
A50	9.6	13.2	21.1

Compressive Strength Chart:

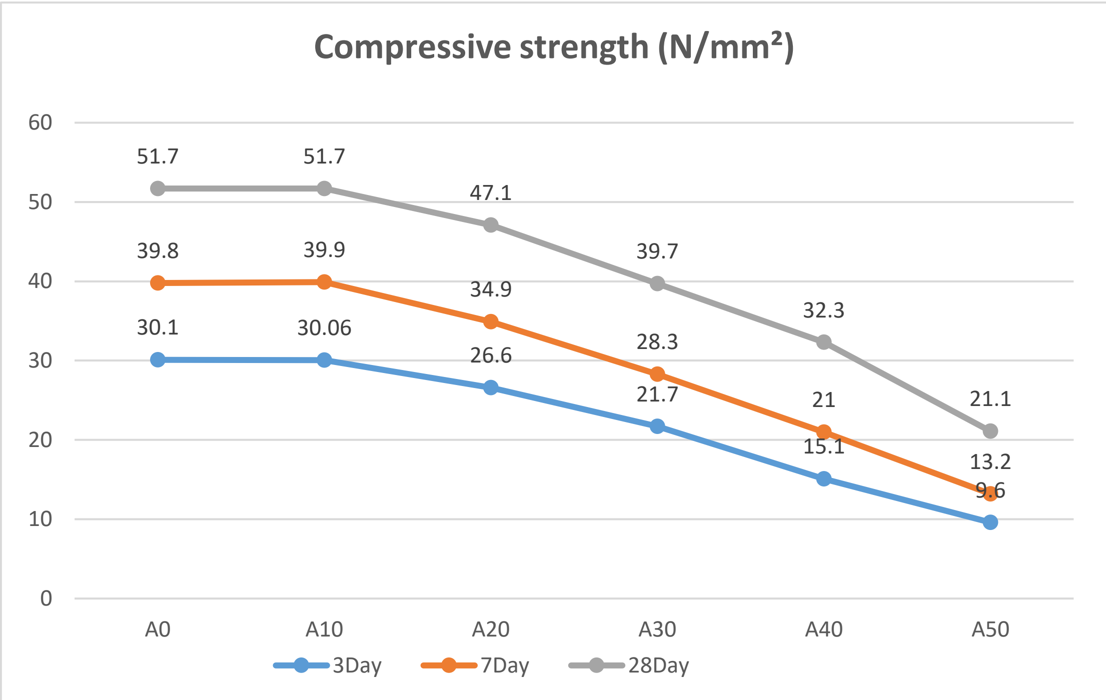

Figure 2.15 Compressive Strength Chart

According to figure (2.15) the compression strength decreases significantly with the increase in the percentage of the adding of P. Lime 2, 7 and 28 days. Because of the decrease in clinker percent

Laboratory Result:

Table 2.9 All Laboratory Result

%	Name	Clinker	Gypsum	P. lime	Fineness			Setting time			Compressive strength(N/mm²)		
					Blain (cm^2/g)	45UR	90UR	Consistency water (%)	Initial	Final	3d	7d	28d
0%	A0	3880	120	-	4048	1.50	0.36	27.80	1:10	2:40	30.10	39.80	51.70
10%	A10	3480	120	400	4194	2.00	0.37	27.20	1:00	2:50	30.06	39.90	51.70
20%	A20	3080	120	800	4181	2.50	0.70	25.40	1:00	2:40	26.60	34.90	47.10
30%	A30	2680	120	1200	4128	2.80	0.90	25.20	1:00	2:50	21.70	28.30	39.70
40%	A40	2280	120	1600	4115	3.50	1.60	24.00	1:10	2:50	15.10	21.00	32.3
50%	A50	1880	120	2000	4181	3.80	1.80	23.20	1:00	2:50	9.60	13.20	21.10

The Chemical Analyzes for each Sample:

Table 2.10 The Chemical Analyzes for Each Sample

	A0	A10	A20	A30	A40	A50
SiO_2	19.01	16.17	13.82	11.33	8.62	6.10
Al_2O_3	5.41	4.70	4.16	4.16	3.04	2.53
Fe_2O_3	2.83	2.54	2.26	1.97	1.66	1.35
CaO	63.96	64.98	66.72	68.12	69.77	71.54
MgO	2.40	2.16	1.99	1.80	1.61	1.45
SO_3	2.19	2.23	2.20	2.18	2.17	2.16
K_2O	1.10	1.04	0.96	0.88	0.78	0.69
Na_2O	0.22	0.18	0.17	0.16	0.15	0.14
Mn_2O_3	0.09	0.09	0.09	0.09	0.10	0.10
TiO_2	0.12	0.09	0.08	0.06	0.05	0.04
P_2O_5	0.10	0.08	0.07	0.06	0.04	0.03
Cl	0.01	0.01	0.01	0.01	0.01	0.01

2.6 Description of (PLC) production process:

Raw materials are taken from the hopper and clinker silos in certain proportions according to the laboratory results that were previously conducted, which are as follows: clinker 57%, pure limestone 40%, gypsum 3%, and then transported through conveyor belts to the cement mill, which in turn mixes, homogenizes and finalizes the cement. The cement is transported from the mill to the air separator via the elevator, which passes the materials to storage and packaging and returns the materials that are not well ground to the mill. The bag filter receives the air loaded with fine particles coming from the mill and the air separator to separate the fine particles and return them to the storage silos.

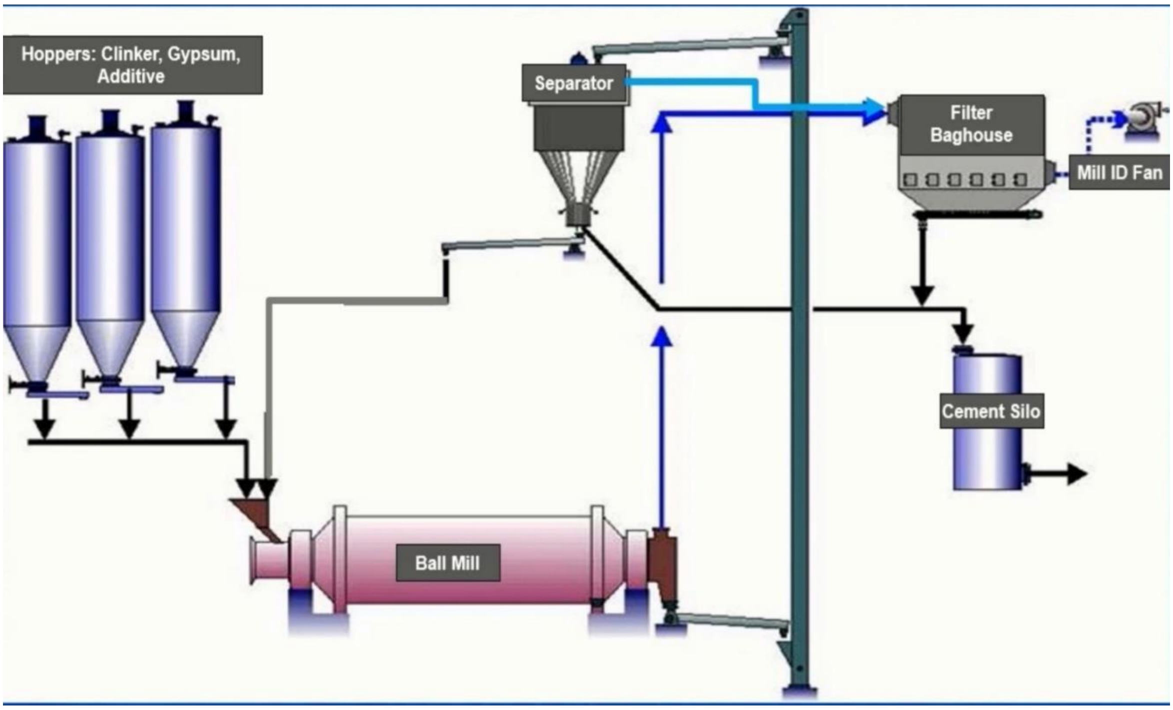

Figure 2.16 Process Flow Sheet of PLC Production

2.7 Applications of PLC:

-All types and activities of finishing works.
-Plastering and restoration.
-Architectural concrete.
-Cement bricks.
-Paving and flooring works.
-Construction, repairs and restoration works.
-Making concrete blocks.
-Lining floors before tiling work.

2.8 Advantages & Disadvantages of PLC:

Table 2.11 Advantages & Disadvantages of PLC

Advantages	Disadvantages
It has an environmental benefit as it reduces carbon emissions, unlike ordinary cement	Not suitable for all applications and requirements for durability, strength and performance
The production cost is low, which is reflected in the purchasing cost of the consumer	It does not achieve the same ultimate strength as ordinary Portland cement.
Lowest cost for cement finishing works	
Faster adhesion of cement finishes	
Reduces cracks and fills voids	

2.9 Chemical & Physical properties of PLC:

Table 2.12 Chemical & Physical Properties of PLC

Chemical	Physical
Contain a significant amount of calcium carbonate	Density: 2733.9kg/ m^3
Typically has similar Almunia and silica content to OPC	Strength: 32.5N
	Color: light gray

CHAPTER 3

MATERIAL
&
ENERGY BALANCE

Data Considered:

-basis:30000 ton per year
-1 year =150 days of working
-Recycle (R) =20% w/w of F

Calculation of Basis:

30000 ton	1 year	1 day
Year	150 days	24 hr

=8.33 ton/hr

8.33 ton	1000 kg
Hr	1 ton

=8330 kg/hr

8330 kg	1 Ibm
Hr	0.453592 kg

=18364.52142 Ibm/hr

Quantity (ton/year)	**Units**		
30000	**Ton/hr**	**Kg/hr**	**Ibm/hr**
	8.33	8330	18364.52142

3.1 Process block diagram:

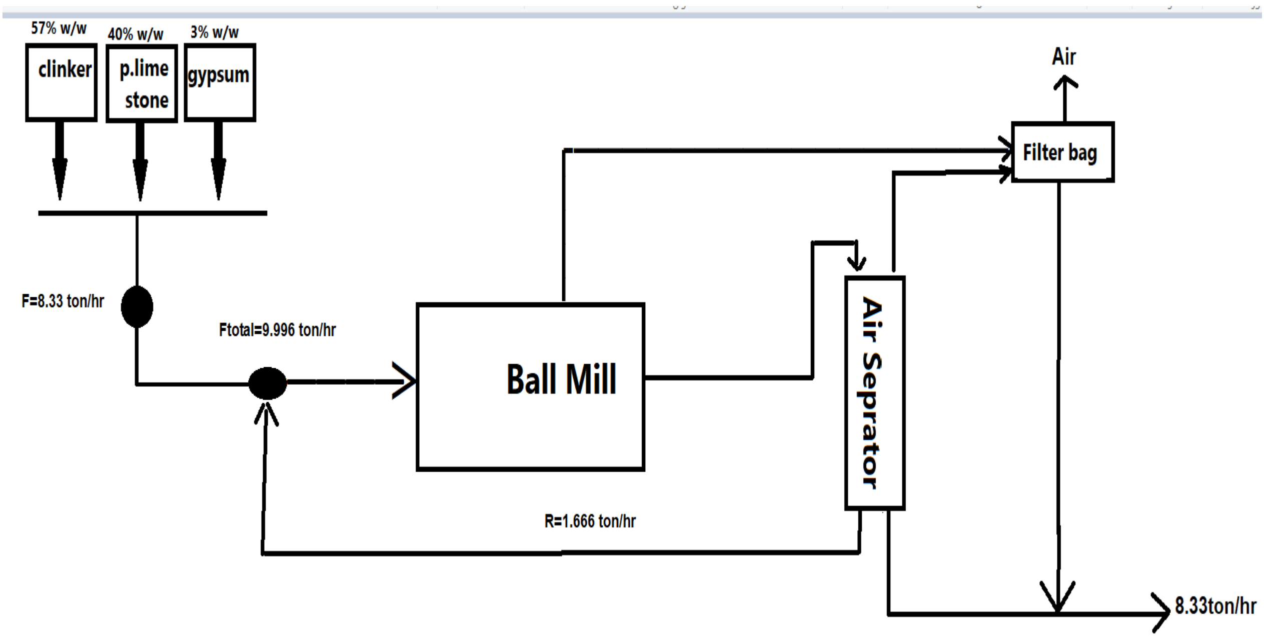

Figure 3.1 Process Block Diagram of PLC Material Balance

3.2 Material Balance:

Overall material balance
Input=output
8.33 ton/hr=8.33 ton/hr

Calculation of Raw Material:

-clinker entering:
57% w/w of F=0.57*8.33 ton/hr=4.7481 ton/hr

4.7481 ton	1000 kg
Hr	1 ton

=4748.1 kg/hr

4748.1 kg	1 Ibm
hr	0.453592 kg

=10467.77721 Ibm/hr

Material	Units		
Clinker	Ton/hr	Kg/hr	Ibm/hr
	4.7481	4748.1	10467.77721

-P. limestone entering:
40% w/w of F=0.4*8.33 ton/hr=3.332 ton/hr

3.332 ton	1000 kg
hr	1 ton

=3332 kg/hr

3332 kg	1 Ibm
hr	0.453592 kg

=7345.808568 Ibm/hr

Material	**Units**		
P. Limestone	**Ton/hr**	**Kg/hr**	**Ibm/hr**
	3.332	3332	7345.808568

-Gypsum entering:
3% w/w of F=0.03*8.33 ton/hr=0.2499 ton/hr

0.2499 ton	1000 kg
hr	1 ton

=249.9 kg/hr

249.9 kg	1 Ibm
hr	0.453592 kg

=550.9356426 Ibm/hr

Material	**Units**		
Gypsum	**Ton/hr**	**Kg/hr**	**Ibm/hr**
	0.2499	249.9	550.9356426

3.3 Energy Calculation:

According to AMRAN CEMENT PLANT, they produce 1500000 ton/year so, the power consumption for (mill, fan, air separator) is 172.5 MWh as shown in the table below:

Table 3.1 AMRAN CEMENT PLANT Cement Mill Datasheet

CEMENT MILL

MILL RUNNING HOUR	24.0 hour
CLINKER FEED	4036 ton
GYPSUM FEED	162.9 ton
POZZOLANA FEED	413 ton
ADDITIVE FEED	0 ton
BY PASS DUST FEED	0.0 ton
CEMENT PRODUCTION	4612 ton
CEMENT MILL WATER CONSUMPTION	48 m3
AVERAGE PRODUCTION	192.2 ton/h
POWER CONSUMPTION (MILL, EX.FAN, SEPARATOR)	172.5 MWh
AVERAGE POWER CONSUMPTION (MILL, EX.FAN, SEPARATOR)	37.4 kWh/ton
CEMENT MILL SECTION POWER CONSUMPTION	194.9 MWh

-basis: production capacity of 10 ton/hr

Energy of ball mill:

Table 3.2 Specification of Ball Mill

Specification (m)	Capacity (ton/hr)	Rotating speed(r/min)	Grinding body(ton)	Motor model	Power (kw)	Weight (ton)
Φ2*9	9.5-10	23.88	31	JR138-8	380	58.4

This type is suitable at capacity (9.996 ≈10 ton/hr).as shown in the table above the power required for 10 ton/hr is 380 kw

Energy balance for air separator:

Table 3.3 Specification of Air Separator

Type	Amount supplied(ton/hr)	Motor power(kw)
VTP600	10	11

This type (VTP600) is suitable at capacity (9.996 ≈10 ton/hr).as shown in the table above the power required for 10 ton/hr is 11 kw.

And from the data of air separator design calculation the power of air separator from this equation:

P=ΔP*Q

Where,

P=Power required (kw)
ΔP=Pressure drop (pa)
Q=Volumetric flow rate(m^3/s)

Given:
ΔP=7.49 mbar, Q=1.5566 m^3/s

ΔP=

7.49 mbar	Pa
	0.01 mbar

=749 pa

So
P=749*1.5566=1165.89W =1.17 kw (for 1 ton/hr)
So, for 10 ton
P=1.17*10=11.7 kw

Thus

Power consumption for (mill, fan, air separator) is:
380 kw+11.7 kw=391.7 kw

CHAPTER 4

PLANT LAYOUT
&
EQUPMENT DESIGN

4.1Plant layout:

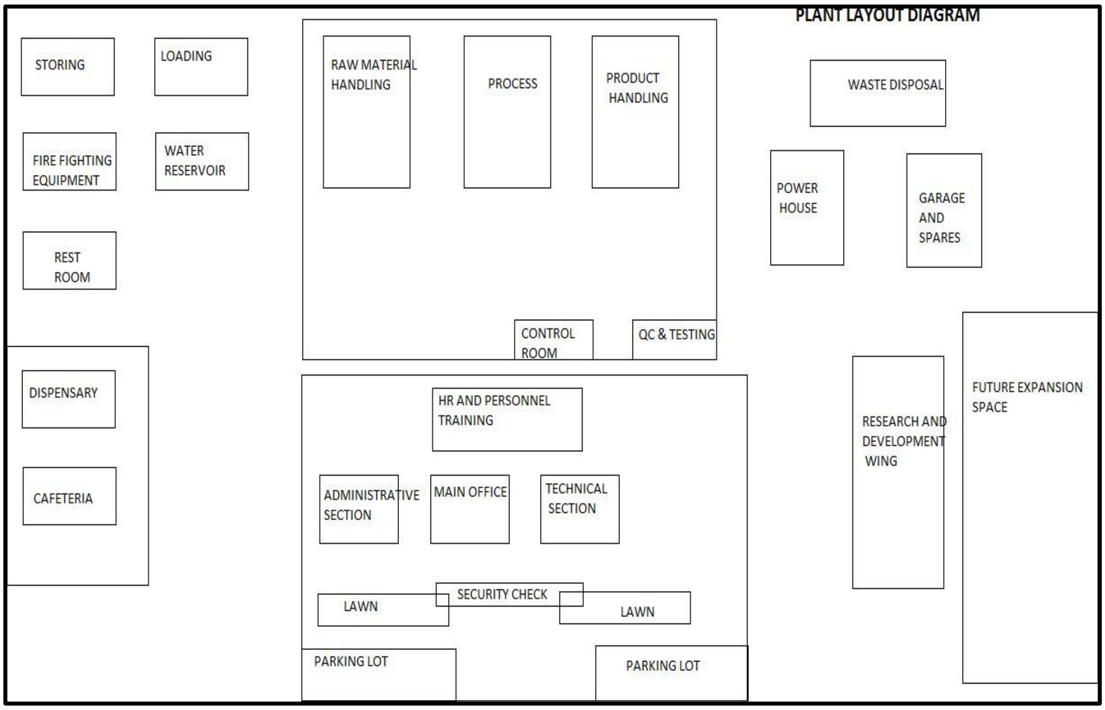

Figure 4.1 Plant Layout of Cement Plant

4.1.1 Plant Location:

The planning of the factory or factory site depends to a large extent on experience combined with the expectations of the human elements in terms of operation and maintenance. One of the most important factors in the factory operation is the accurate establishment and reasonable arrangement of devices, buildings and pipeline networks, as they are the key to economic construction and safety operation, Therefore, the old design of factories is no longer in line with the rapid development of production processes at the present time. Therefore, the factory must be designed to suit industrial conditions at the present time and in the future, and facilitate making the necessary adjustments to suit the changes that are added in the production process in the future.

Among the reasons that require making modifications in building the factory from time to time are:

-The occurrence of fundamental changes in the industrial process as a result of scientific progress, which requires replacing old machines with modern ones in order to face the intense competition in the market.

-The occurrence of fundamental changes in the product market, such as the lack of consumer interest in buying the factory's products, forcing the factory management to make adjustments in the production process.

4.1.2 Site Selection:

Choosing a factory location is one of the most important decisions, because such a decision is not made from time to time, but only once, due to the high cost of a mistake in this decision, which cannot be reversed after its implementation. The most important factors that are taken into consideration when choosing a factory location are the following:

1. Raw materials.
2. Manpower.
3. Energy.
4. Transportation and communications.
5. Environmental conditions.
6. Abundance of land.
7. Waste disposal.
8. Water needed for the industrial process.

The following is a brief explanation of the above factors:

First: raw material

Availability of raw materials: Ensure continuous and reliable supply of raw materials, especially limestone, clay and gypsum, which are the basic ingredients for cement production. Evaluate the proximity of these resources to the factory and conclude supply agreements with reliable suppliers

Second: Manpower :

The largest part of the factory cost is the cost of labor, and therefore the selection of the factory location depends on the availability of labor from engineers, technicians, administrators, and highly qualified workers, because labor is considered an essential factor in the production process.

Third: Energy:

Many industrial processes require electrical power and other types of energy for the purpose of carrying out industrial operations. Therefore, it is necessary to know the amount of energy required for the industrial process, and to study the costs of obtaining all types of energy.

Fourth: Transportation:

Providing various means of transportation is one of the basic factors that must be taken into consideration when choosing a factory location, because the process of transporting materials and energy from their sources to their places of consumption, and the process of transporting products to their places of consumption also represents a high cost.

Fifth: Disposal of waste and rubbish:

The process of disposing of waste and residues resulting from the industrial process is one of the problems facing the factory management, especially since Laws and most countries in the world prohibit throwing this waste into wells and rivers or burying it in the ground.

Sixth:

An important factor in choosing the factory location is establishing the necessary infrastructure for the cement factory, including buildings, production facilities, storage areas, and administrative offices, and providing a good drainage network.

Seventh: Land and location:

Obtaining suitable land with sufficient area to establish a cement factory. Consider factors such as proximity to limestone deposits (a key raw material for cement production), transportation infrastructure, access to utilities such as water and electricity, and environmental regulations.

4.2 Main Equipment List:

4.2.1 BALL MILL:

The cement ball mill is a kind of cement grinding mill. It is mainly used for grinding the clinker and raw materials of the cement plant, and also for grinding various ores in metallurgical.

Figure 4.2 Ball Mill

4.2.2 AIR SEPRATOR:

Cement mill separator, or cement separator, is a type of equipment that was widely used in the cement grinding system and raw mill system of cement plants. The function of the separator is to separate the fine-sized particles from the coarse-sized particles.

Figure 4.3 AIR SEPRATOR

4.2.3 FILTER BAGHOUSE:

The Filter Baghouse is a dust control device whose purpose is removing the dust contained in the exhaust gases from industrial process.

Figure 4.4 Filter Baghouse

4.3 Equipment Design:

4.3.1 Air separator (Cyclone) Design:

These curves can be transformed to other cyclone sizes and operating conditions by use of the following scaling equation for a given separating efficiency:

$$d_2 = d_1 \left[\left(\frac{D_{c2}}{D_{c1}} \right)^3 \times \frac{Q_1}{Q_2} \times \frac{\Delta\rho_1}{\Delta\rho_2} \times \frac{\mu_2}{\mu_1} \right]^{1/2} \qquad (4.1)$$

Where,

d_1= mean diameter of particle separated at the standard conditions, at the chosen separating efficiency, as shown in Figures

d_2=mean diameter of the particle separated in the proposed design, at the same separating efficiency;

D_{c1}=diameter of the standard cyclone=8 inches (203 mm);

D_{c2}=diameter of proposed cyclone, mm;

Q_1=standard flow rate:

for high efficiency design=223 m^3/h;

for high throughput design=669 m^3/h;

Q_2=proposed flow rate, m^3 /h;

$\Delta\rho_1$=solid-fluid density difference in standard conditions=2000 kg/m^3;

$\Delta\rho_2$=density difference, proposed design;

μ_1=test fluid viscosity (air at 1 atm, 20C) =0.018 mN s/m^2;

μ_2=viscosity, proposed fluid.

Pressure Drop:

The pressure drop in a cyclone will be due to the entry and exit losses and to friction and kinetic energy losses in the cyclone. The empirical equation given by Stairmand (1949) can be used to estimate the pressure drop.

$$\Delta P = \frac{\rho_f}{203} \left\{ u_1^2 \left[1 + 2\emptyset^2 \left(\frac{2r_t}{r_e} - 1 \right) \right] + 2u_2^2 \right\} \qquad (4.2)$$

Where,

ΔP=cyclone pressure drop, millibars;

ρ_f=gas density, kg/m^3;

u_1=inlet duct velocity, m/s;

u_2=exit duct velocity, m/s;

r_t=radius of circle to which the center line of the inlet is tangential, m;

r_e=radius of exit pipe, m;

ø=factor from Figure 10.47;

ψ=parameter in Figure 10.47, given by

$$\psi = f_c \frac{A_s}{A_1}$$

Where,

f_c=friction factor, taken as 0.005 for gases;

A_s=surface area of cyclone exposed to the spinning fluid, m^2. For design purposes this can be taken as equal to the surface area of a cylinder with the same diameter as the cyclone and length equal to the total height of the cyclone (barrel plus cone);

A_1=area of inlet duct, m^2

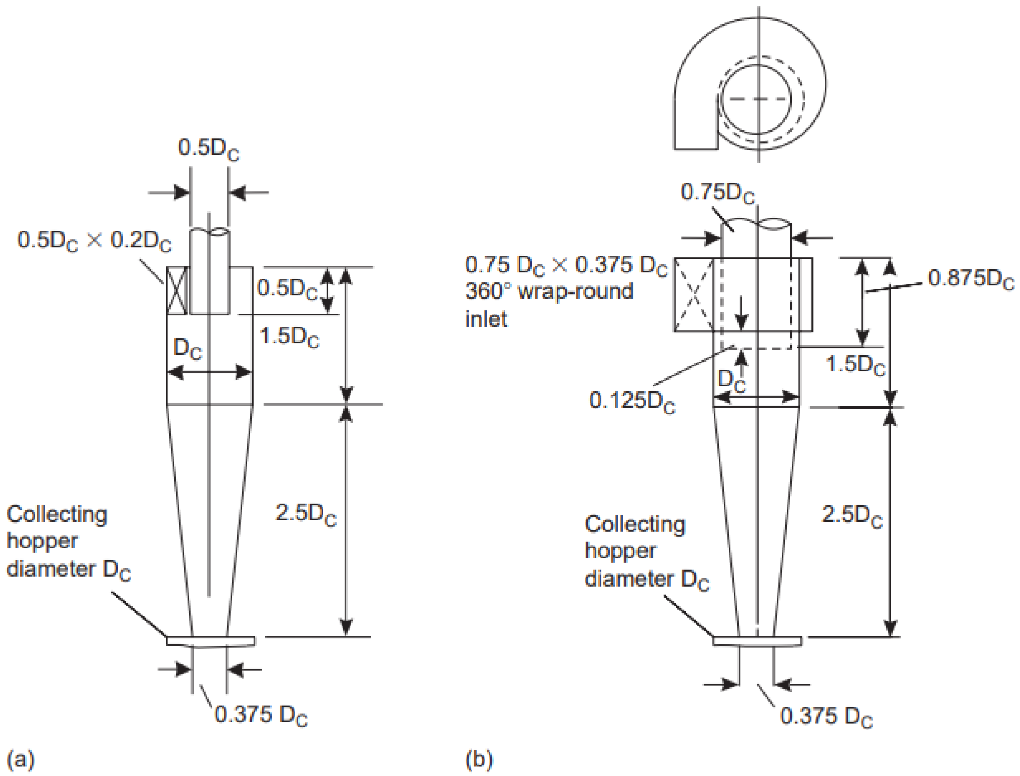

Figure 4.5 Standard Cyclone Dimension. (a) High-Efficiency Cyclone. (b) High Gas-Rate Cyclone.

The cyclone should be designed to give an inlet velocity of between 9 and 27 m/s (30 to 90 ft/s); the optimum inlet velocity has been found to be 15 m/s (50 ft/s).

Data:

Particle size (μm)	50	40	30	20	10	5	2
Percentage by wight less than	70	65	55	45	40	10	4

Air at 25°C ,$\mathbf{Q_{air}}$=5600 m^3/hr at the $\dot{m}_{cement}$=mass flow rate of cement=9996 kg/hr
ρ_{cement}=density of cement=2733.9 kg/m^3

Solution:

$\mathbf{Q_{cement}}=\frac{\dot{m}_{cement}}{\rho_{cement}}=\frac{9996}{2733.9}=3.656\ m^3/hr$

$\mathbf{Q_{totoal}}=Q_{cement}+Q_{air}=3.656+5600=5603.656\ m^3/hr$

Flow rate=$\frac{5603.656}{3600}$=1.5566 m^3/s

Area of inlet duct, at 15 m/s=$\frac{1.5566}{15}=0.104\ m^2$

From figure1, area of inlet duct=$0.5D_c*0.2D_c$=0.104 m^2

So, D_c=1.0198 m

This is clearly too large compared with the standard design diameter of 0.203 m. Try four cyclones in parallel, D_c=0.51 m.

Flow rate of cyclone =$\frac{5603.656}{4}=1400.914\ m^3/hr$

Density of Air at 25°C =$\frac{28.96}{22.4}\times\frac{273}{298}=1.1844kg/m^3$

negligible compared with the solid's density.

Kinematic viscosity of air at 25°C =15.575 m^2/s

So,
Dynamic viscosity of air at 25°C :

$\mu=\rho*\upsilon=1.1844*15.575=0.01845$ cp(mNs/m^2)

from equation 4.1:

$$Scaling\ factor=\left[\left(\frac{D_{c2}}{D_{c1}}\right)^3\times\frac{Q_1}{Q_2}\times\frac{\Delta\rho_1}{\Delta\rho_2}\times\frac{\mu_2}{\mu_1}\right]^{1/2}$$

$$Scaling\ factor=\left[\left(\frac{0.51}{0.203}\right)^3\times\frac{223}{1400.914}\times\frac{2000}{2733.9}\times\frac{0.01845}{0.018}\right]^{1/2}=1.376$$

The performance calculations, using this scaling factor and Figure 4.6, are set out in Table 4.1 The collection efficiencies shown in column 4 of the table were read from Figure 4.6 at the scaled particle size, column 3. The overall collection efficiency satisfies the specified solids recovery. The proposed design with dimensions in the proportions given in Figure 4.5a is shown in Figure 4.7.

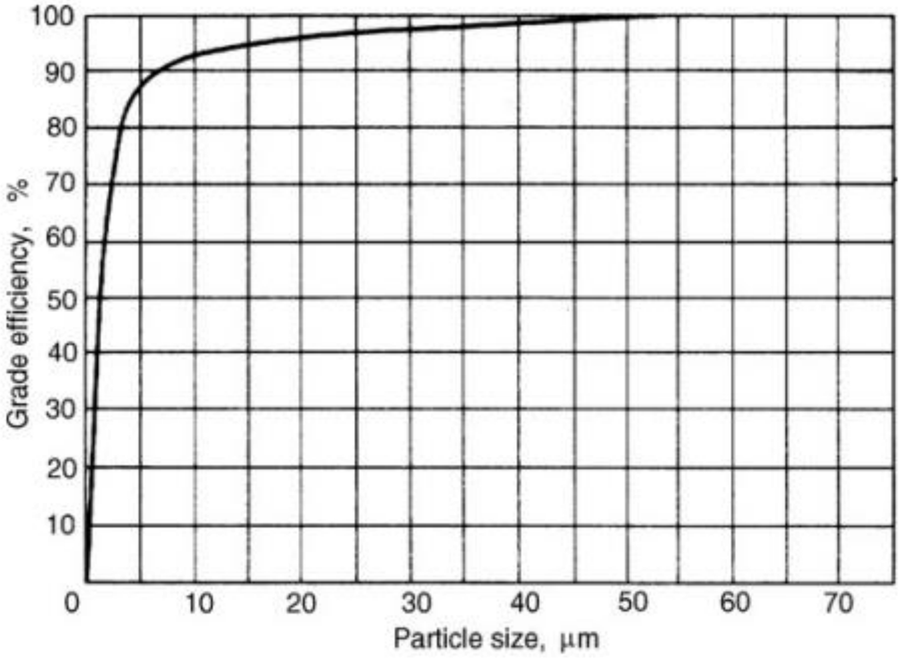

Figure 4.6 High-Efficiency Cyclone Performance

Table 4.1 Calculated Performance of Cyclone Design

Particle size (µm)	**Percent in range**	**Mean particle ÷ Scaling factor**	**Efficiency at scaled size %**	**Collected 2*4/100**	**Granding exit 2-5**	**Percent at exit**
>50	30	36	98	29.4	0.6	5.2
50-40	5	33	97	4.9	0.1	0.9
40-30	10	25	96	9.6	0.4	3.5
30-20	10	18	94	9.4	0.6	5.2
20-10	5	11	93	4.7	0.3	2.6
10-5	30	5	86	25.8	4.2	36.5
5-2	6	3	72	4.3	1.7	14.8
2-0	4	1	10	0.4	3.6	31.3
	100			88.5	11.5	100

Table 4.2 Proposed Cyclone Design, All Dimensions

Air separator dimension			
Parameters	**Dimension**	**Ratio**	**Value (m)**
Body diameter	D_c	D_c	0.51
Length of cylinder	L_b	$2.5D_c$	1.3
Length of cone	L_c	$1.5D_c$	0.77
Inlet height	H	$D_c/2$	0.26
Inlet width	W	$0.2D_c$	0.1
Gas exit dia	D_e	$D_c/2$	0.26
Dust outlet dia	D_d	$0.375D_c$	0.2

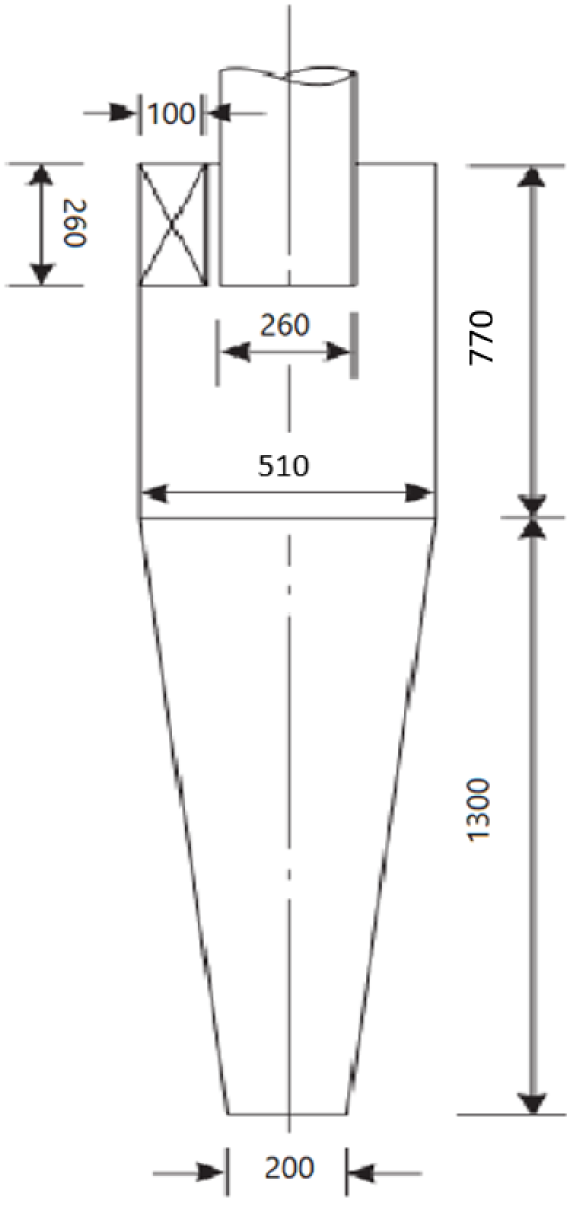

Figure 4.7 Proposed Cyclone Design, All Dimensions mm

Pressure drop calculation:

From equation 4.2:

$$\Delta P = \frac{\rho_f}{203}\left\{u_1^2\left[1 + 2\emptyset^2\left(\frac{2r_t}{r_e} - 1\right)\right] + 2u_2^2\right\}$$

Area of inlet duct A_1=0.026 m^2

Cyclone surface area A_s=π*0.51*(4*0.51) =3.269 m^2

f_c taken as 0.005

$$\psi = f_c\frac{A_s}{A_1} = \frac{(0.005) \times (3.269)}{0.026} = 0.63$$

$$\frac{r_t}{r_e} = \frac{0.51 - \left(\frac{0.2 \times 0.51}{2}\right)}{0.5 \times 0.51} = 1.8$$

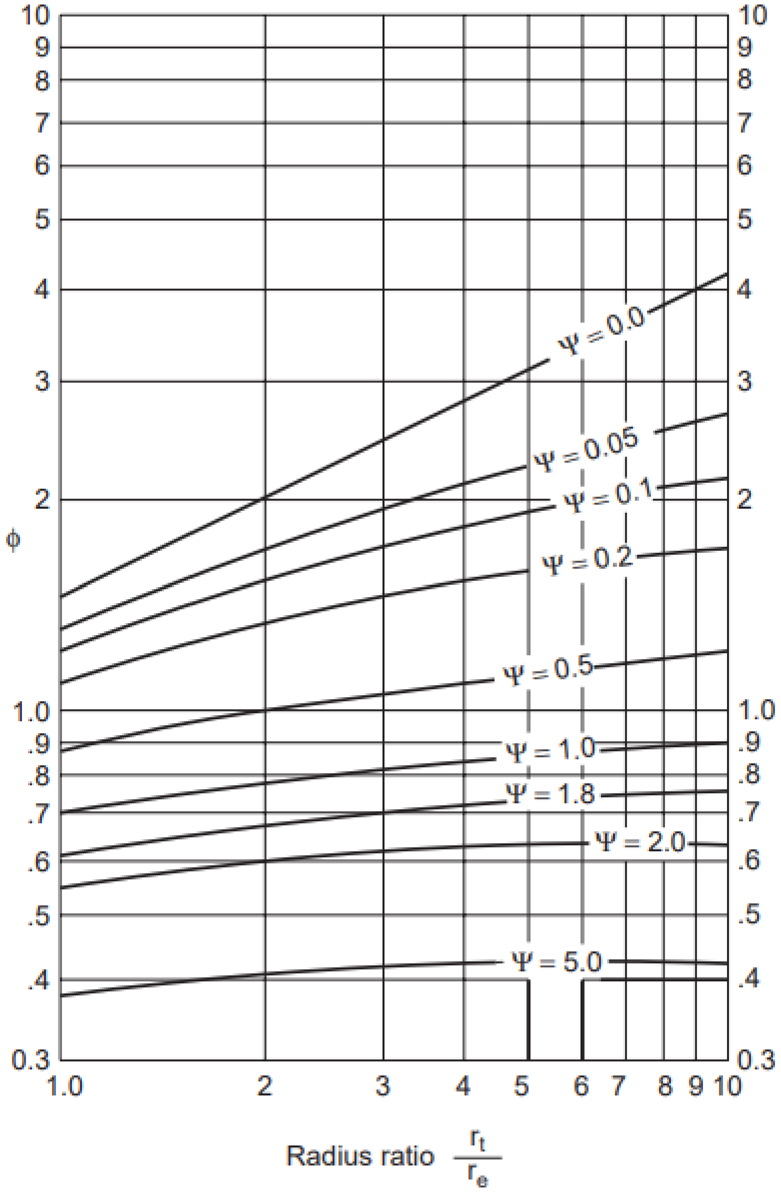

Figure 4.8 Cyclone Pressure Drop Factor

From figure 4.4. at Ψ=0.63, $\frac{r_t}{r_e} = 1.8$, the Ø=0.9

$u_1 = \frac{1400.914}{3600 \times 0.026} = 14.97$ m/s

Area of exit pipe= $\frac{\pi(0.5 \times 0.51)^2}{4} = 0.051\ m^2$

$u_2 = \frac{1400.914}{3600 \times 0.051} = 7.63$ m/s

$$\Delta P = \frac{1.1844}{203}\{14.97^2[1 + 2 \times 0.9^2(2 \times 1.8 - 1)] + 2 \times 7.63^2\} = 7.49\ mbar$$

4.4 Cost estimation:

$$C_2 = C_1 \left(\frac{I_2}{I_1}\right) \qquad (4.3)$$

C_1=Estimated cost at previous time

C_2=Cost at expected time

I_1=Index value at previous time

I_2=Index value at expected time

Table 4.4 M&S Index Value

Year	Index M&S
1990	941.4
2023	2261.3

4.4.1 Ball mill cost estimates:

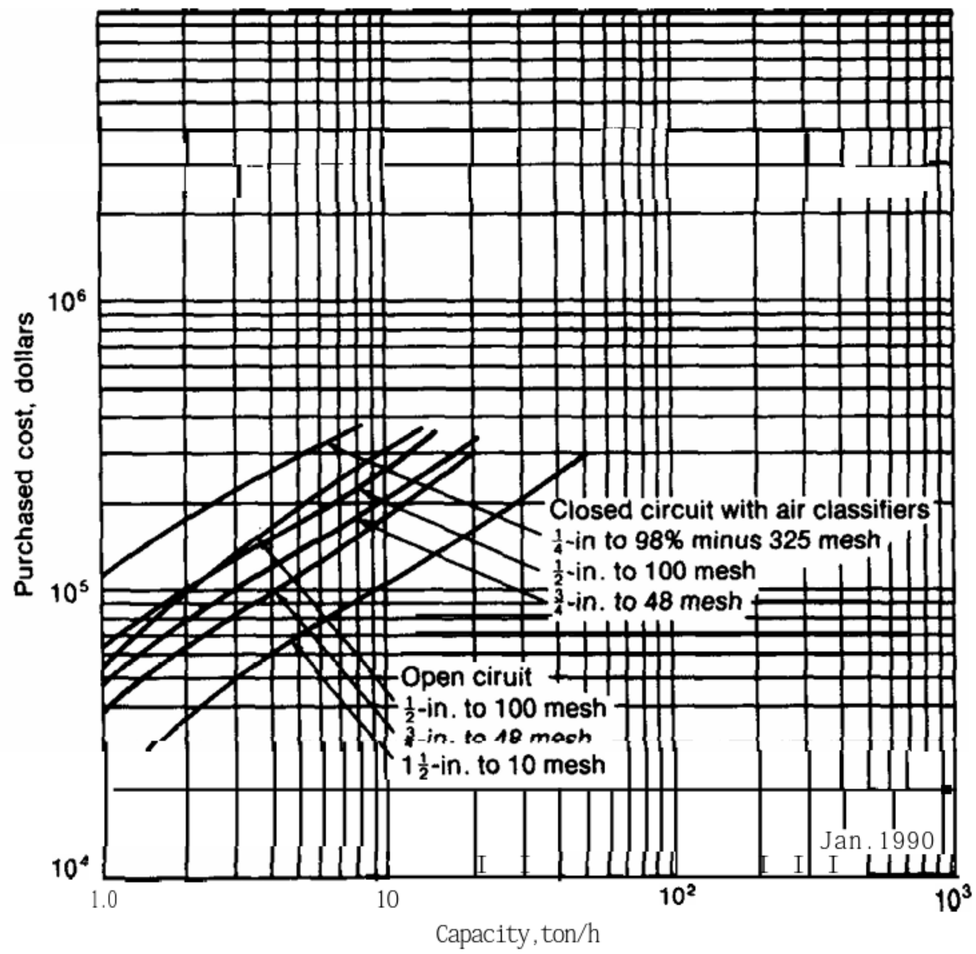

Figure 4.9 Ball Mill Cost Chart

From figure (4.9) at capacity 9.996 ton/h and closed-circuit system the cost of ball mill is $200,000 in 1990, the price includes installation, classifier, motors, drives, and an average allowance for foundations and erection.

Using the equation (4.3) to determine the cost in 2023:

$$C_2 = C_1\left(\frac{I_2}{I_1}\right)$$

And from table (4.3):

$$C_2 = 200{,}000\left(\frac{2261.3}{941.4}\right)$$

So, C_2= $480400 in 2023.

4.4.2 Air separator (Cyclone) cost estimates:

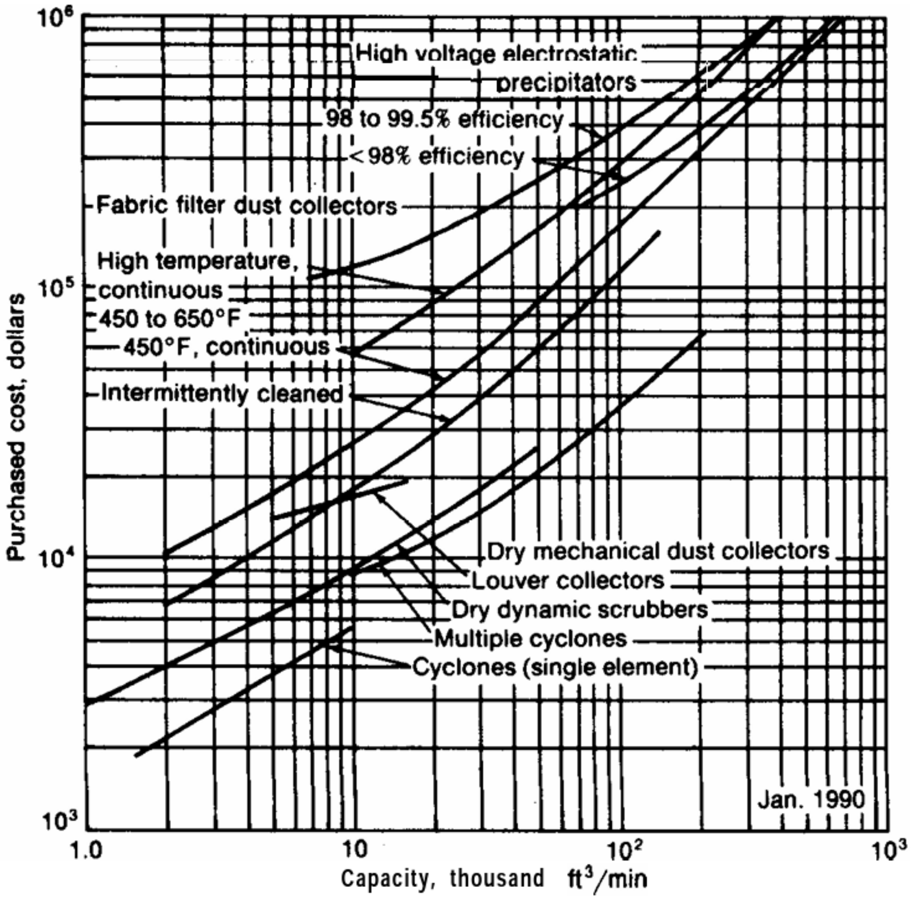

Figure 4.10 Cyclone &Filter Bag Cost Estimates

The capacity of cyclone =5603.656 m^3/h

In ft^3/min capacity=

5603.656 m^3	35.3145 ft^3	1 h
H	1 m^3	60 min

= 3300 ft^3/min

From figure (4.10) at capacity 3300 ft^3/min the cost of air separator (cyclone) is $2,900 in 1990.

Using the equation (4.3) to determine the cost in 2023:

$$C_2 = C_1 \left(\frac{I_2}{I_1}\right)$$

And from table (4.3):

$$C_2 = 2{,}900 \left(\frac{2261.3}{941.4}\right)$$

So, C_2= $6970 in 2023.

4.4.3 Filter bag cost estimates:

From figure (4.10) observed that the fabric filter dust collectors carve started from capacity 7000 ft^3/min because the filter is suitable for large quantity, so the cost value of filter will be taken at the lowest capacity in the carve is 7000 ft^3/min, and from that at capacity 7000 ft^3/min the cost of filter bag is $100,000 in 1990.

Using the equation (4.3) to determine the cost in 2023:

$$C_2 = C_1 \left(\frac{I_2}{I_1}\right)$$

And from table (4.3):

$$C_2 = 100{,}000 \left(\frac{2261.3}{941.4}\right)$$

So, C_2= $240,230 in 2023.

CHAPTER 5

SAFETY
&
ENVIROMENT

5.1 Safety:

Occupational health and safety have become a public health priority in industrialized countries and a primary concern, especially in high-risk industries. Cement manufacturing is one of these industries. Cement is one of the most widely used construction material on earth. Because cement has been used commonly, its health effects have become an important issue both for employees and the environment. In addition to the various health hazards, cement workers are especially exposed to dust which causes lung function impairment, chronic obstructive lung disease, restrictive lung disease, pneumoconiosis and carcinoma of the lungs, stomach and colon at various production process such as quarrying, crushing, raw material grinding, blending, kiln burning, cement grinding and packaging in cement industry. Therefore, ensuring healthy and safe working conditions for employees and contractors is a fundamental key to corporate social responsibility, and is one of the most important issues for the cement industry.

In addition, with the increasing complexity of industrial tissue and with the rapidity that the techniques develop in the big factories, risks assessment becomes a crucial and strategic answer to preserve workers health and safety on the one hand and to maintaining a qualified labor on the other hand.

5.1.1 Industrial safety:

is “a group of preventive measures and precautions that are taken or followed with high efficiency in planning, design, supervision, implementation, operation and maintenance to ensure the safety of the industrial facility and to ensure the proper functioning of the work.

the purpose of safety?

To prevent industrial accidents, most of which were found to be due to errors in the actions of individuals or Error in equipment or its use.

5.1.2 HAZARDS IN CEMENT MANUFACTURING:

Cement manufacturing processes including health and safety risks were classified as follows:

- Quarrying
- Crushing
- Clinker production
- Milling processes at raw mill, cement milling and coal milling
- Material transport
- Filtering
- Storage
- Loading and delivery of final products
- Fuel storage activities
- Use of hazardous material
- Generating units.

In Table (5.1), main hazard factors associated with cement manufacturing processes are presented. As shown from Table (5.1), main hazardous factors in quarrying of raw materials can be defined as dust and noise. Noise emits during blasting, crushing and operation of conveyors in quarrying operations. Noise sources in cement manufacturing plant mainly include milling machines, crushers, electric motors

Table 5.1 Main Hazard Factor

Cement manufacturing process	Main hazard factor
Quarrying	Dust and noise
Raw material preparation	Dust, toxic gases (CO, CO2, NOx, SOx) HEAT POLLUTION
Clinker burning	Dust, toxic gas, high heat radiation, high workload
Clinker cooling and cement milling	Auxiliary material, dust, noise
Lap	Dust, noise, toxic materials, burns, and radiation
Packing and storage	Dust & high workload

Dust emissions are one of the most significant impacts of cement manufacturing and associated with handling and storage of raw materials (including crushing and grinding of raw materials), solid fuels, transportation of materials (e.g., by trucks or conveyor belts), kiln systems, clinker coolers, and mills, including clinker and limestone burning and packaging/bagging activities. Packaging is the most polluting process (in terms of dust) in cement production.

Nitrogen oxide (NOX) emissions are emitted from the high temperature combustion process of the cement kiln. Carbon dioxide defined as greenhouse gas is mainly associated with fuel combustion and with the decarbonation of limestone.

In addition to specific hazards, there are also general hazards in all of the cement manufacturing process such as safe behavior, work equipment, safety labeling, personal protective equipment (PPE), manual load handling.

Typical injury causes in cement plants are defined as slips, trips and falls (29%); falling or moving objects (19%) and lifting, overload and exertion (18%) as shown from Figure (5.1). Fatalities are the most serious tragedy that can happen in the cement Industry. 79% of all fatalities arise from 3 main causes: Traffic & Mobile Plant (43%), Falls from Heights & Items falling (21%) and Caught in Moving/Starting Equipment (15%). It was reported that contractors and young/temporary employees are high risk categories in cement manufacturing plants.

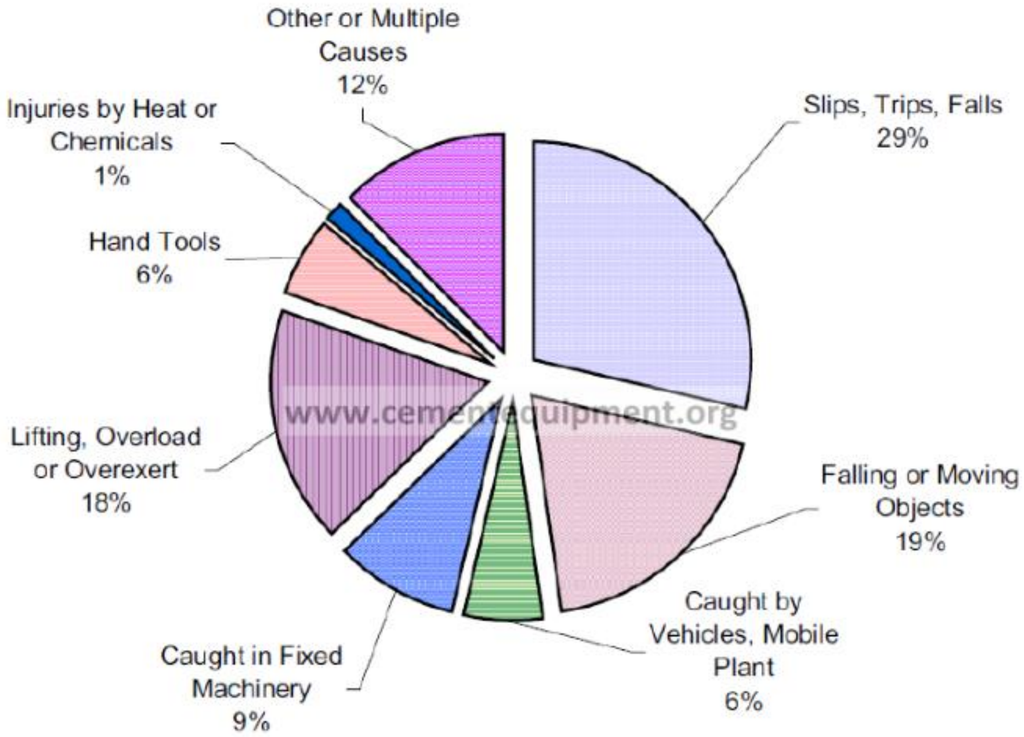

Figure 5.1 Diagram of Injuries

5.1.3 The hazards and solutions related to working with cement:

1. **Exposed to dust:**

Respiratory problems arise from activation and inhalation of cement dust, including irritation and known illnesses such as silicosis.

Solution: Use appropriate personal protective equipment such as dust masks. Implement dust control measures such as humidifying the work area to reduce floating dust.

2. **Skin irritation:**

Direct contact with wet cement can result in skin irritation or chemical burns.

Solution: Wear appropriate personal protective equipment, including gloves, and wash skin quickly if exposed to wet cement. Use protective creams to protect the skin.

3. **Manual handling and musculoskeletal injuries:**

Lifting and moving heavy bags or materials can lead to back strains and other musculoskeletal injuries.

Solution: Training workers on correct lifting techniques and providing mechanical means such as forklifts or conveyor belts.

4. **Crush injuries:**

Heavy equipment and machinery used in cement works can pose a risk of crushing injuries.

Solution: Implement safety protocols, such as proper training and equipment maintenance. Use warning signs and barriers around machines.

5. **Exposure to chemicals:**

Exposure to some chemicals used in cement production can be harmful.

Solution: Providing workers with safety data sheets for the chemicals used. Ensure proper ventilation and use personal protective equipment when handling chemicals.

6. **Fall from high places:**

Working on high places or scaffolding systems can lead to falls.

Solution: Use fall protection equipment, such as guardrails, safety nets, or personal fall protection systems. Inspect scaffolds regularly to ensure safety.

7. **High temperatures:**

Working in high temperature conditions can lead to heat-related illnesses.

Solution: Schedule work during cooler times of the day, provide shade and humidity, and train workers to recognize and prevent heat-related illnesses.

8. **Exposure to noise:**

Cement production and construction can generate high levels of noise, which may lead to hearing damage.

Solution: Use noise protection, implement noise control measures, and conduct regular hearing tests for workers exposed to loud noise.

9. Electrical Hazards:

Electrical equipment and wiring can pose a risk of electric shock and fire.

Solution: Ensure proper maintenance of electrical systems, and use appropriate personal protective equipment, and train workers on electrical safety protocols.

10. Chemical leaks and fires:

Accidental leaks or accidental fires involving cement or related chemicals.

Solution: Having leak response plans and fire safety plans, along with providing appropriate firefighting equipment and training in its use.

5.2 Environment:

The environmental pollution caused by cement factories is a growing concern due to the harmful impact it causes on the environment and public health. Cement factories produce a large amount of carbon dioxide, which is a major contributor to climate change. In addition, cement factories emit a range of other air pollutants such as nitrogen oxides, sulfur dioxide, and particulates, causing negative impacts on the air quality, soil, and water.

Studies conducted by environmental organizations and state agencies indicate that cement production is responsible for a significant portion of global greenhouse gas emissions. In fact, some studies suggest that cement production is responsible for up to 7% of global emissions. Furthermore, cement factories are usually located in areas with a high population density, which exacerbates the impact on local communities.

The pollution generated from cement factories poses significant environmental and health risks. Harmful air pollutants, such as fine dust particles and acidic gases, can lead to respiratory problems and other health issues. Furthermore, pollution from cement factories can contaminate nearby water sources and soil, affecting the food chain, and biodiversity.

Therefore, finding ways to reduce the environmental pollution caused by cement factories is critical. This requires investing in new technologies, and implementing more stringent environmental regulations. A comprehensive approach to addressing the issue of environmental pollution in the cement industry can help mitigate the damage that cement factories pose to the environment and public health.

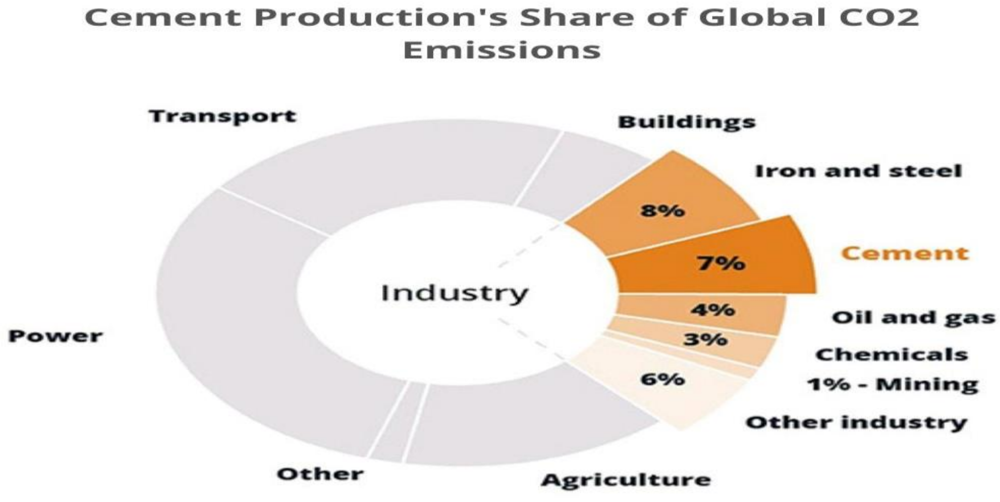

Figure 5.2 Cement Production's Share of Global CO2 Emissions

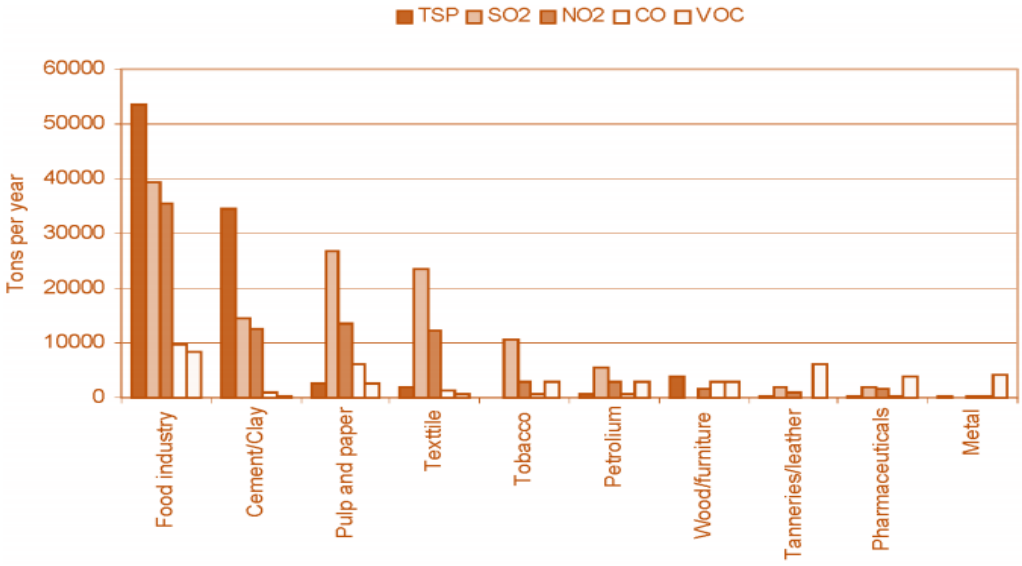

Figure 5.3 Major Pollutants Industries Chart

5.2.1 Major pollutants

- NOx emission
- Sulfur dioxide emission
- VOC
- Dust
- CO_2 & CO
- Heavy metals (Pb, Cd, Ni, Ti)

5.2.2 Source of pollution:

1.Pollution resulting from spillage areas in the cooler.

2.Pollution resulting from the clinker grinding process.

3.Pollution resulting to the raw material crushing process (leads to the emission of dust).

Figure 5.4 Crushing Pollution

4.Pollution resulting to the transport of clinker and raw materials through conveyor belts results in the (emission of dust in spillage areas).

Figure 5.5 emission of dust in spillage areas

5. Emission of gases due to reactions in the furnace (SOx, NOx, CO2).

Figure 5.6 Emission of Cement Industry Gases

6. Emission of gases due to fuel combustion.

Figure 5.7 Emission of Gas Fuel

5.2.3 Solutions of pollution:

Step 1: Use clean fuels and alternative energy sources such as biomass, wind, solar, and hydroelectric power to reduce emissions of greenhouse gases.

Step 2: Install air filtering systems and dust collectors to reduce dust emissions from manufacturing processes.

Step 3: Use advanced technologies like selective catalytic reduction (SCR) and other emission control systems to reduce NOx emissions.

Step 4: Develop and implement strict environmental regulations and enforce them to ensure compliance by cement companies.

Step 5: Promote the use of alternative, eco-friendly building materials like recycled concrete, fly ash, and slag to reduce cement production.

Step 6: Increase public awareness about environmental issues and involve communities in finding solutions to pollution problems in the cement industry.

Step 7: Encourage research and development of new technologies and processes that reduce pollution and improve the environmental performance of the cement industry.

5.2.4 Pollution control equipment:

Filter baghouse:

Figure 5.8 Filter Baghouse

A filter bag: is a filtration device used to remove particles and contaminants from a gas or liquid stream. It consists of a series of fabric bags or tubes that capture and retain particles while allowing the clean gas, or liquid to pass through.

Bag filters are commonly used in industrial processes, HVAC systems, and wastewater treatment to improve air or water quality by removing dust, dirt, and other impurities.

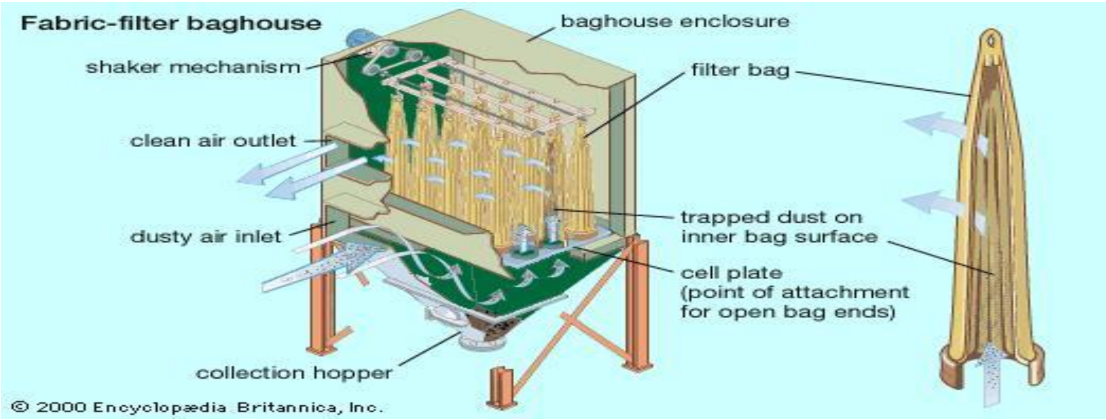

Figure 5.9 Filter Bag

In cement factories, bag filters are commonly used to control air pollution and capture particulate matter generated during various processes. The working principle of bag filters in cement factories involves the following steps:

1.Dust Collection: During different stages of cement production, such as crushing, grinding, and clinker production, fine particles and dust are generated. These particles are carried by the exhaust gases.

2.Inlet: The exhaust gases containing dust and particles enter the bag filter housing through an inlet.

3.Filtration: Inside the bag filter housing, there are numerous fabric bags or tubes made of special filter materials. These bags are positioned vertically, and the exhaust gases pass through them from the outside to the inside.

4.Dust Capture: As the exhaust gases flow through the bags, the fine particles and dust are captured on the outer surface of the bags due to the filtering action. Clean air continues to pass through the bags and exits the filter.

5.Cleaning: Over time, the dust accumulates on the outer surface of the bags, reducing their efficiency. To maintain proper filtration, bag filters have a cleaning mechanism, often using compressed air pulses. These pulses cause the bags to flex and release the collected dust into a hopper at the bottom of the filter.

6.Dust Disposal: The collected dust falls into a hopper at the bottom of the bag filter, where it can be collected and disposed of properly.

7.Clean Air Outlet: After the dust is removed from the bags, clean air exits the bag filter and is released into the atmosphere.

This process ensures that the air emissions from cement factories are cleaner and comply with environmental regulations, as it effectively captures and removes particulate matter and dust before releasing the treated air. Bag filters are an essential component of controlling air quality in cement production facilities.

Electrostatic precipitators (ESP):

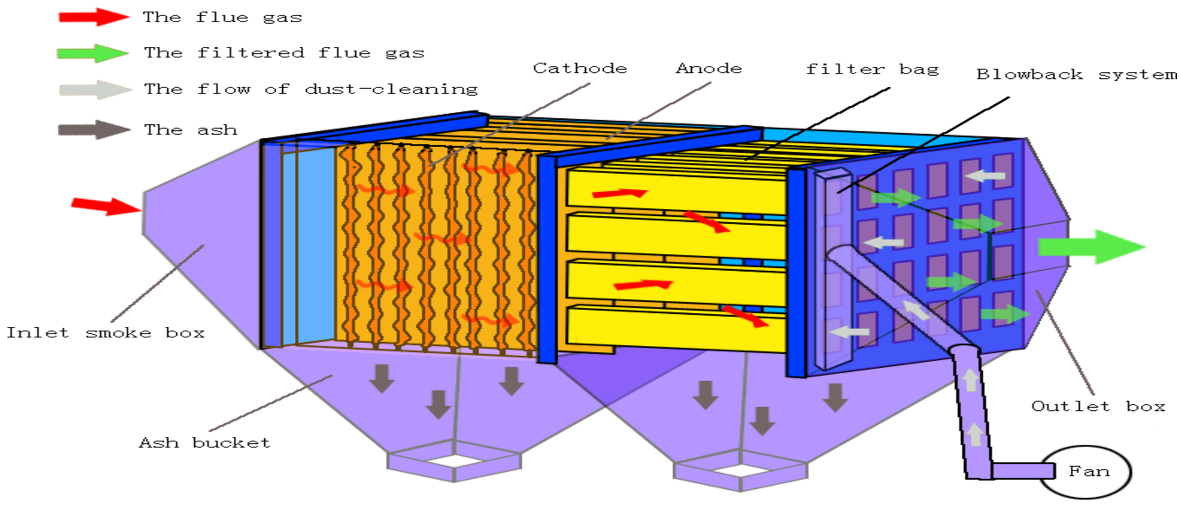

Figure 5.10 Electrostatic Precipitators (ESP)

An electrostatic precipitator: often called an ESP, is a device used to remove fine particles, like dust and smoke, from industrial exhaust gases. It works by using an electric charge to attract and collect these particles onto charged plates or electrodes. This process helps improve air quality and reduces pollution from various industrial processes.

In the cement industry, electrostatic precipitators (ESPs) are commonly used to control air pollution and capture particulate matter produced during various manufacturing processes. Here's how ESPs work in the cement industry:

1.Raw Material Preparation: Cement production involves crushing, grinding, and heating raw materials like limestone, clay, and shale. These processes generate dust and particulate matter.

2.Kiln Emissions: The most critical stage in cement production is the clinker kiln, where raw materials are heated to very high temperatures. This process also generates significant emissions, including fine particulate matter and gases like sulfur dioxide (SO2).

3.ESPs Installation: ESPs are installed in the exhaust systems of cement kilns and other dust-producing equipment. These devices are strategically placed to capture dust and particulates before they are released into the atmosphere.

4.Charging and Collection: As explained earlier, in the ESP, the dirty air from the cement production process passes through ionization wires where particles become charged. These charged particles are then collected on electrically charged plates, effectively removing them from the exhaust gas.

5.Periodic Cleaning: Over time, the collected dust and particulates build up on the collection plates. To maintain efficiency, the plates are periodically cleaned by rapping or vibrating the plates, causing the collected material to fall into a hopper for disposal.

6.Emission Control: The cleaned exhaust air, now significantly reduced in particulate matter, can be released into the atmosphere or further processed to remove any remaining pollutants, such as SO2, through additional air pollution control devices like scrubbers.

The use of electrostatic precipitators in the cement industry helps to reduce air pollution, meet environmental regulations, and ensure cleaner emissions. It also contributes to improved air quality in the surrounding areas, making it an essential part of sustainable cement manufacturing.

Recommendations:

1- Study the possibility of benefiting from the carbon dioxide emitted from the current coal-fired power generation unit, by establishing a miniature gas production unit and thus reducing gas emissions to preserve the environment and obtain a side economic return.

2- Conducting tests on the possibility of adding specific percentages of ash (resulting from the coal power generation unit) to cement to obtain the best percentage to reduce the cost and obtain better durability and quality.

3- The grinding process consumes high energy in the cement industry. Grinding and production efficiency can be improved, as well as energy consumption reduced by adopting modern grinding techniques.

4- The possibility of using the cement kiln to treat hazardous waste from sites outside the factory, thus obtaining additional financial returns for the factory.

5- The possibility of reusing the wasted heat energy from the rotary kiln in processes that require heating for the purpose of saving the consumed energy.

6- Reducing energy consumption in manufacturing processes at every stage and monitoring the energy performance of the factory.

References:

[1] British Standards Institution, E.N.196-1: methods of testing cement-part1: determination of compressive strenghth, (2005).

[2] Cement chemistry, Harold F, W. Taylor (1990).

[3] Cement Formulae Handbook, May (2010).

[4] Cement and Concrete 24. An Analysis of The Properties of Portland Limestone Cement and Concrete (2002) 371-378.

[5] CSI. Environmental and Social Assessment Guidelines (2005).

[6] CSI. Progress Report, Geneva: WBCSD (2005).

[7] Handbook for designing cement plants,B.S. publi cations.Deolalkar S.

[8] "Effects of limestone addition on the physical and mechanical properties of Portland cement" by M. Soroka et al (2014).

[9] European Standard. Composition, Specifications, and Conformity Criteria for Common Cements.

[10] Gavin Towler & Ray Sinnott-chemical engineering.

[11] Harry Zivl -Grinding & Separating Technology Systems.

[12] Index Marshall & Swift Equipment Cost Index.

[13] "Influence of limestone content, gypsum content and fineness on early-age properties of Portland limestone cement produced by inter-grinding" by H. Hebhoub et al (2012).

[14] "Mechanical properties and durability of concrete made with high-volume fly ash blended cements using a coarse fly ash" by M. Safiuddin et al (2011).

[15] New Types of Low Carbon Cements with Reduced Portland Clinker Content.

[16] Cem-concr.Res.34. P. Arjunan, A. Kumar (2004) 1161-1165.

[17] Lea's Chemistry of Cement and Concrete.Peter Hewlett; Martin Liska (2019).

[18] "Performance of Portland limestone cements: Cements designed to be more sustainable that maintain performance" by T. Tennis and M.Thomas et al (2010).

[19] PLANT DESIGN AND ECONOMICS FOR CHEMICAL ENGINEERS, Max S. Peters, Klaus D. Timmerhaus, 4^{th} edition.

[20] Portland Limestone Cement. Preparation of Cements. Digest 2009, December (2009) 1337-1355.

[21] Chemical engineers Handbook, 7^{th} edition, Robert H Perry & Don Green-Perry's, McGraw Hill (1996).

[22] Cem-concr.Compos. S. Tsivilisa, E. chaniontakisb, G. Kakalia, G. batisa (2002) 371-378.

[23] "Use of high limestone content cement in concrete for sustainable construction"by F. Debieb (2012).