Thesis Paper

on

Optimization of The Cement Manufacturing Process in Bangladesh

Submitted by:

Md. Mahmudul Hassan Mozumder

ID: EMBA2401031005

Program: EMBA

Major: Management

Department of Business Administration

Sonargaon University (SU)

Submitted to:

Department of Business Administration

Faculty of Business

Sonargaon University (SU)

Submitted for the partial fulfillment of the degree of

Executive Master of Business Administration

Sonargaon University (SU)

Date of Submission: April 28, 2025

Thesis Paper

on

Optimization of The Cement Manufacturing Process in Bangladesh

Submitted by:

Md. Mahmudul Hassan Mozumder
ID: EMBA2401031005
Program: EMBA
Major: Management
Department of Business Administration
Sonargaon University (SU)

Supervised by:

Shahnaz Sharmin
Lecturer
Department of Business Administration
Faculty of Business
Sonargaon University (SU)

Submitted for the partial fulfillment of the degree of
Executive Master of Business Administration

Sonargaon University (SU)

Date of Submission: April 28, 2025

Letter of Transmittal

April 28, 2025

Shahnaz Sharmin

Lecturer

Department of Business Administration

Faculty of Business

Sonargaon University (SU)

Subject: Submission of Thesis Report Titled "Optimization of The Cement Manufacturing Process in Bangladesh"

Dear Madam,

With most respectfully to state that I am pleased to submit my thesis report titled **"Optimization of The Cement Manufacturing Process in Bangladesh"**. This report is an essential part of my EMBA degree requirements and I had the privilege of completing my Thesis at Optimization of The Cement Manufacturing Process in Bangladesh.

This research was conducted under your valuable guidance and includes insights from relevant literature, data gathered through company records, and analyses of the industry specific challenges faced in cement manufacturing process. I hope this report meets your expectations and contributes meaningfully to the field of cement manufacturing.

I would really be grateful if you share your precious thoughts regarding the report. Also, if you wish to have further clarification about any aspect of my report, I would gladly answer your queries with further explanation. Thank you again for your support and patience.

Yours Sincerely

Md. Mahmudul Hassan Mozumder

ID: EMBA2401031005

Program: Executive Master of Business Administration (EMBA)

Major: Management

Sonargaon University (SU)

Declaration of Student

I am Md. Mahmudul Hasssan Mozumder, a student in the Executive Master of Business Administration program with ID: EMBA2401031005 at Sonargaon University. I want to sincerely state that the report titled **"Optimization of The Cement Manufacturing Process in Bangladesh"** has been genuinely created by me. During the preparation of this report, I ensured full compliance with international copyright regulations. I also want to clarify that this report has not been submitted anywhere else for the purpose of obtaining a degree.

Yours Sincerely

Md. Mahmudul Hassan Mozumder
ID: EMBA2401031005
Program: Executive Master of Business Administration (EMBA)
Major: Management
Sonargaon University (SU)

Letter of Authorization

I hereby confirm that the project report titled **"Optimization of The Cement Manufacturing Process in Bangladesh"** is a genuine effort by Md. Mahmudul Hassan Mozumder. The research was conducted under my guidance. I also affirm that, to the best of my knowledge, the content presented in this report has not been included in any other project report or dissertation that led to the award of a degree to any candidate earlier, whether in the same context or a different one.

Shahnaz Sharmin
Lecturer
Department of Business Administration
Faculty of Business
Sonargaon University (SU)

Acknowledgement

I would like to express my heartfelt gratitude to all those who have supported me throughout the journey of this thesis on **"Optimization of The Cement Manufacturing Process in Bangladesh"**

First and foremost, I extend my sincere appreciation to my advisor, **Shahnaz Sharmin** for her invaluable guidance, support, and encouragement. Their expertise and insightful feedback have been instrumental in shaping this research and ensuring its quality.

I am also grateful to the faculty members of **Department of Business Administration** at Sonargaon University for their continuous support and for providing a conducive environment for academic growth. Their encouragement and dedication to teaching have greatly inspired me.

Special thanks to the professionals and managers in the cement industries of Bangladesh who generously shared their time, insights, and experiences during the interviews and data collection process. Their willingness to provide information and perspectives on Cement Manufacturing Process has enriched this study and contributed to a deeper understanding of the industry's challenges and opportunities.

I would like to acknowledge my fellow classmates and friends for their camaraderie, encouragement, and constructive discussions throughout this research. Their support has made this journey more enjoyable and fulfilling.

Lastly, I wish to express my deepest appreciation to my family for their unwavering support and belief in my abilities. Their encouragement and understanding during the demanding phases of this research have been my greatest motivation.

Thank you all for your contribution to this thesis and for being a part of my academic journey.

Abstract

This thesis presents a comprehensive framework for **"Optimization of The Cement Manufacturing Process in Bangladesh"** addressing inefficiencies and proposing strategic improvements through lean manufacturing, automation and sustainable practices. The focus is on enhancing productivity, reducing costs, and minimizing environmental impacts within the rapidly growing cement industry, which has expanded significantly over the last two decades due to urbanization and infrastructure development.

The analysis shows that the industry is predominantly controlled by ten major players, including multinational corporations, which collectively hold approximately 75% of the market share. Additionally, significant attention is given to optimizing production processes, highlighting the importance of automation, energy efficiency, alternative fuels, waste heat recovery, and enhancements in the supply chain. The results suggest that aligning the cement sector with national development goals, particularly in power generation and infrastructure projects, is crucial for its sustainability.

By addressing existing challenges through foresight and collaborative efforts, this study concludes that Bangladesh's cement industry has the potential not only to thrive but also to contribute substantially to the nation's economic prosperity. The findings provide valuable insights into market shares of leading companies, investment activities, regional consumption patterns, and the social and environmental impacts associated with the sector.

List of Acronyms

- Bangladesh Cement Manufacturers Association (BCMA)
- Multinational Corporations (MNCs)
- Ordinary Portland Cement (OPC)
- Portland Composite Cement (PCC)
- Portland Pozzolana Cement (PPC)
- Vertical Roller Mill (VRM)
- Waste Heat Recovery Systems (WHRS)
- Advanced Process Control (APC)
- Corporate Social Responsibility (CSR)
- Key Performance Indicator (KPI)
- Mean Time Between Failures (MTBF)
- Life Cycle Assessment (LCA)
- Energy Efficiency Ratio (EER)
- Material Utilization Ratio (MUR)
- Return on Investment (ROI)
- Carbon Capture and Storage (CCS)
- Just-in-Time (JIT)
- Science-Based Targets Initiative (SBTi)
- Environmental Product Declarations (EPDs)
- Carbon Capture, Utilization, and Storage (CCUS)
- Refuse-Derived Fuel (RDF)

Table of Contents

Cover Page i

Inner Cover Page ii

Letter of Transmittal iii

Declaration of Student iv

Letter of Authorization v

Acknowledgement vi

Abstract vii

List of Acronyms viii

Table of Contents ix

Chapter 01 1

Introduction 1

1.1 Introduction 2

1.2 Background of the Study 2

1.3 Objectives of the Study 5

1.4 Scope of the Study 6

1.5 Limitations of the study 7

Chapter 2 9

Literature Review 9

2.1 Global Trends in Cement Manufacturing Optimization 10

2.2 Previous Studies on Process Optimization 12

2.2.1 Grinding Operation in Ball Mills 12

2.2.2 Operation and Elements of a Closed-Circuit Ball Mill System 13

2.2.3 Auditing Operation 15

2.2.4 Results of Optimization 16

2.2.5 Roller Press Mill working principle and performance evaluation parameters . 18

2.2.6 Optimization results analysis and validation 20

2.2.7 VRM Operation 21

Chapter 3 23

Overview of Cement Manufacturing Industry 23

3.1 Overview of Cement Manufacturing Process 24
3.1.1 Raw Material Extraction 24
3.1.2 Raw Meal Preparation 24
3.1.3 Clinker Production 24
3.1.4 Cement Grinding 25
3.1.5 Packing and Distribution 25
3.2 Types of Cement Produced 25
3.3 Source of Raw Materials 27
3.4 List of the Cement industries of Bangladesh 27
3.5 Representative Organization 28
3.6 Vision 28
3.7 Mission 29
3.8 Operational Structure 29
3.9 Commitment to Sustainability 29
3.10 Board of Directors 30
3.11 Chairmans Message 31
Chapter 4 33
Data Analysis and Results 33
4.1 Introduction 34
4.2 Manufacturing Technology 34
4.3 Operational Challenges in Cement Manufacturing 35
4.4 Process Optimization Techniques 36
4.6 Forecasting and Planning 38
4.8 Key Performance Indicator (KPI) in cement production 38
4.9 Reduction in energy and material wastage 41
Chapter 5 43
Recommendations 43
5.1 Recommended Strategies for Process Optimization 44
5.2 Immediate Investment in Modern Technology and Energy Recovery Systems ... 45
5.3 Development of Local Clinker Manufacturing to Reduce Import Dependence ... 46

5.4 Training Programs for Staff on Energy-Efficient Practices 46

5.5 Government Support in the Form of Tax Incentives for Green Technologies..... 47

Chapter 6 48

Conclusion 48

6.1 Conclusion 49

Bibliography 50

Chapter 01

Introduction

1.1 Introduction

The cement industry is a cornerstone of economic development in Bangladesh, underpinning the nation's rapid infrastructural growth and urbanization. As one of the largest sectors contributing to the construction industry, cement manufacturing not only supports domestic needs but also opens avenues for export, thus enhancing foreign exchange revenues. Despite being self-sufficient in production, the industry faces significant challenges, including inefficient production processes, dependency on imported raw materials, and environmental concerns associated with cement manufacturing.

The optimization of the cement manufacturing process is essential to enhance productivity, reduce operational costs, and minimize environmental impacts. Current practices often rely on traditional methodologies that can lead to inefficiencies, high energy consumption, and waste generation. By exploring innovative technologies and process improvements, there exists an opportunity to streamline operations and achieve sustainable growth within this vital sector.

This thesis aims to investigate and propose strategies for optimizing the cement manufacturing process in Bangladesh. It will explore factors such as raw material utilization, energy efficiency, advanced manufacturing technologies, and waste management practices. By focusing on these areas, the research will provide actionable insights and recommendations that can significantly enhance the competitiveness and sustainability of the cement industry in Bangladesh, ensuring that it meets both current demands and future challenges. Through this study, we aspire to contribute to a more efficient, economically viable, and environmentally responsible cement production landscape in the country.

1.2 Background of the Study

The cement industry in Bangladesh has a relatively short history compared to other countries, beginning in 1941 with the establishment of Chattak Cement Factory Ltd in Sylhet. Following the country’s independence in 1971, the second factory, Chittagong Cement Clinker and Grinding Factory Ltd, was established in 1973. Although cement

demand grew significantly from the early 1970s to the 1990s, the lack of local limestone hindered domestic production, leading to a reliance on imports.

The early 1990s marked a pivotal moment as local entrepreneurs began investing in cement production, ushering in what is known as the Nascent Stage of the Bangladesh Cement Industry. Companies such as Confidence Cement Ltd, Meghna Cement Mills Ltd, and others emerged during this period. In the mid-1990s, the Bangladesh Cement Manufacturers Association (BCMA) was formed to support businesses in the industry and address government-related issues.

Following the footsteps of Hyundai Cement, large multinational corporations (MNCs) including Heidelberg, Lafarge, Holcim, Cemex, Teiheiyo, and Ultratech entered the market in phases, further reshaping the industry and decreasing reliance on imports. Between 2008 and 2018, production quadrupled, and the number of registered companies grew to 76, though only 42 are currently operational. Among these, seven are listed on the stock market, enhancing their visibility and potential for investment. The total effective yearly capacity across these companies is about 58 million tons, compared to a demand of approximately 33 million tons. The market is dominated by about ten companies, including two multinationals, which hold around 75% of the market share.

Cement grinding facilities are primarily located in five key areas: Mukterpur, Narayanganj, Meghnaghat, Chittagong, and Mongla, with most being grinding plants rather than clinkerization facilities. In recent years, the industry has also started exploring export opportunities, particularly to northeast India, though this segment remains relatively small. Significant innovations in product offerings have occurred, transitioning from the traditional Ordinary Portland Cement (OPC) to various types, with Portland Composite Cement (PCC) now making up about 95% of production.

Additionally, production methods have modernized, with traditional Ball Mills being supplemented by advanced technologies such as Polycom and Vertical Roller Mill (VRM), the latter setting a Guinness World Record for Shah Cement Industries.

The cement industry has become increasingly influential in advertising and public engagement, reflecting its growth and importance in the economy. Currently, per capita cement consumption is around 182 kg, with expectations of increased growth to 250 kg by 2022, supported by a projected annual growth rate of 10% over the next five years.

However, challenges persist, including market saturation and oversupply as major players pursue expansion projects. The industry may require several years to effectively utilize this surplus capacity.

Table 1. Bangladesh Leading Cement Industry

Market Share	Leading Position Shah Cement Industries Ltd.
Consumption	Public Sector:45% Real Estate 30% Individual 25%
Total Revenue (Listed Companies)	BDT 80,272 Million
Export	USD 9.57 Million

Table 2. Share Holding Pattern of the cement industry

Company	**Sponsor**	**Govt.**	**Institute**	**Foreign**	**Public**
LHBL	64.68%	0%	16.89%	0.63%	17.80%
Heidelberg	60.67%	0%	26.61%	0.43%	12.29%
Confidence Cement	30.03%	0%	35.43%	0%	34.54%
Crown Cement	67.08%	0%	17.70%	0.05%	15.17%
Premier Cement	47.15%	0%	21.31%	0.03%	31.51%
Meghna Cement	49.76%	0%	33.50%	0%	16.74%
Aramit Cement	45.92%	0%	10.02%	0%	44.06%

1.3 Objectives of the Study

The primary objective of this study is to identify and implement strategies to optimize the cement manufacturing process in Bangladesh for improved operational efficiency, cost-effectiveness, and environmental sustainability.

The specific objectives are as follows:

- To Analyze the Current Production Processes to establish a baseline for identifying inefficiencies and areas for improvement.
- To Identify Key Bottlenecks and Inefficiencies to detect major technical and operational challenges such as high energy consumption, equipment wear, and under-utilized automation tools.
- To Propose Process Optimization Strategies to recommend feasible technological interventions such as energy-efficient equipment, waste heat recovery systems, alternative fuels and digital control systems tailored to the Bangladesh.
- Evaluate methods for maximizing resource utilization, including raw materials and energy to reduce waste and enhance productivity.
- Recommend systems for continuous quality monitoring and testing to ensure the consistency and reliability of cement products.
- To Assess the Environmental and Economic Impacts to quantify the potential reduction in CO_2 emissions and cost savings achievable through the proposed optimization measures.
- To Encourage Sustainable Industrial Practices the integration of cleaner production technologies and resource-efficient operations in alignment with national and international sustainability goals.
- Promote collaboration among stakeholders, including manufacturers, government bodies, and research institutions, to share best practices and align on sustainability goals.
- Analyze how optimized cement manufacturing processes can contribute to economic development and job creation in Bangladesh.

By addressing these objectives, the study aims to support the cement industry in enhancing productivity while reducing its environmental footprint and reliance on imported raw materials.

1.4 Scope of the Study

This study focuses on analyzing and optimizing the cement manufacturing processes within the industrial context of Bangladesh. It aims to provide a comprehensive framework for improving operational efficiency, reducing environmental impact, and enhancing cost-effectiveness in both large and medium-scale cement plants operating in the country.

The research primarily covers the following areas:

1. Assessment of Current Manufacturing Practices: The study evaluates the existing production processes adopted by major cement manufacturers in Bangladesh, such as rotary kiln operations, clinker production, grinding systems, and packaging. It identifies bottlenecks and inefficiencies, particularly in terms of energy consumption and equipment performance.

2. Energy and Resource Utilization: A significant focus is placed on the consumption of thermal and electrical energy across different stages of production. The study explores strategies for reducing energy intensity through modern technologies such as vertical roller mills (VRM), waste heat recovery systems (WHRS), and energy-efficient motor drives

3. Environmental Sustainability: Given the global emphasis on reducing carbon emissions, the study includes an analysis of CO_2 emissions and particulate matter released from cement production. It evaluates the potential for adopting low-carbon technologies, alternative fuels (e.g., biomass, RDF), and carbon capture mechanisms in the local context

4. Supply Chain and Logistics Optimization: The research covers the optimization of the supply chain, from raw material procurement (mainly imported clinker and gypsum) to distribution logistics. It looks into challenges such as port delays, poor transportation infrastructure, and inventory management inefficiencies.

5. Financial and Technical Feasibility: The study includes a cost-benefit analysis of proposed optimization interventions to ensure that recommendations are economically viable for manufacturers of varying sizes.

6. Policy and Regulatory Alignment: It also considers the alignment of process optimization with government policies on industrial development, energy conservation, and environmental protection.

The scope is limited to cement factories operating in Bangladesh, but draws on global best practices to propose feasible solutions. Field data is collected from selected major cement producers, industry experts, and published reports.

1.5 Limitations of the study

While this study aims to provide comprehensive insights into optimizing cement manufacturing in Bangladesh, certain limitations were encountered that may affect the generalizability and scope of the findings:

Here are some of the critical challenges facing the cement industry in Bangladesh:

- **Overcapacity:** The cement industry in Bangladesh is facing overcapacity, with a production capacity much higher than the current demand. This has led to lower prices and lower profits for cement manufacturers.
- **Raw material shortages:** The cement industry in Bangladesh is facing raw material shortages, mainly sufficient reserves of high-quality limestone suitable for clinker production, the key ingredient in cement. This necessitates importing clinker, which can affect cost-effectiveness and production efficiency
- **High energy costs:** Bangladesh's cement industry faces high energy costs, which is a significant factor in the high cost of cement.
- **Focus on Selected Plants:** Due to time and resource constraints, the study primarily focuses on a few major cement manufacturers. This limits the representation of small or regional producers who may face different operational challenges

- **Technological Variation:** Cement plants in Bangladesh differ in age, capacity, and technology adoption. Standardizing recommendations across such a diverse landscape was challenging, and proposed solutions may not be uniformly applicable
- **Lack of Long-Term Environmental Data:** Due to limited environmental monitoring in many plants, it was difficult to conduct a detailed assessment of emissions or long-term ecological impacts. Some findings are based on estimations or global averages
- **Dynamic Market Conditions:** The cement industry is influenced by fluctuating fuel prices, foreign exchange rates, and regulatory changes. These external factors were beyond the control of the study and may affect the practical implementation of proposed strategies.
- **Supply Chain Disruptions:** Fluctuations in raw material availability and transportation issues can affect production schedules.

Chapter 2

Literature Review

2.1 Global Trends in Cement Manufacturing Optimization

Cement manufacturing is one of the most energy-intensive industries globally, responsible for about 7-8% of the world's carbon dioxide emissions (International Energy Agency [IEA], 2020). Due to growing environmental concerns, cost pressures, and the need for greater efficiency, global cement producers are increasingly adopting optimization strategies. These strategies focus on improving energy efficiency, reducing emissions, utilizing alternative raw materials and fuels, and integrating digital technologies into manufacturing processes.

1. Energy Efficiency Improvements

A major focus area for global cement manufacturers has been reducing energy consumption, particularly thermal and electrical energy. Companies are adopting:

Vertical Roller Mills (VRM): These mills consume 20–40% less energy compared to traditional ball mills (Ghosh & Chatterjee, 2019).

Waste Heat Recovery Systems (WHRS): Many plants have installed WHRS to capture heat from kiln gases and convert it into electricity, reducing dependency on grid power (World Cement Association, 2021).

2. Alternative Fuels and Raw Materials (AFR)

Cement plants are increasingly substituting traditional fossil fuels with alternative fuels such as:

- Biomass (e.g., rice husk, wood chips),
- Refuse-Derived Fuel (RDF) from municipal solid waste,
- Tire-derived fuels,
- Industrial by-products like slag, fly ash, and silica fume.

Substituting clinker with supplementary cementitious materials (SCMs) reduces energy consumption and CO_2 emissions significantly (IEA, 2020).

3. Digitalization and Industry 4.0

The application of digital technologies is transforming cement manufacturing:

Advanced Process Control (APC): AI and machine learning models optimize kiln operations, reducing fuel consumption and improving product quality.

Predictive Maintenance: IoT sensors monitor equipment health, preventing unplanned downtimes.

Smart Logistics and Inventory Management: Data analytics optimize raw material and product flow across the supply chain (McKinsey & Company, 2018).

These technologies help plants achieve higher levels of automation, operational efficiency, and cost reduction.

4. Carbon Capture, Utilization, and Storage (CCUS)

Given the pressure to decarbonize, companies are investing in:

Carbon Capture Pilot Projects: Leading firms like Lafarge Holcim and HeidelbergCement are pioneering projects to capture and store CO_2 emissions from cement plants (World Cement Association, 2021).

Green Cement Initiatives: Development of new cement formulations like limestone calcined clay cement (LC3) that produce less CO_2.

5. Sustainability Certifications and Standards

International certifications are driving sustainable manufacturing practices:

- **ISO 50001:** For energy management systems.
- **Environmental Product Declarations (EPDs):** Transparency in environmental performance.
- **Science-Based Targets Initiative (SBTi):** Several cement firms are aligning emissions targets with climate science.

2.2 Previous Studies on Process Optimization

2.2.1 Grinding Operation in Ball Mills

Several energy efficient options for cement grinding are available today such as vertical roller mills, roller presses (typically in combination with a ball mill), and clinker pre grinders with ball mills. Ball mills have been the traditional method of comminution in the mineral processing industries and continue to operate with old generation classifiers, their maintenance sometimes neglected. This in combination with an inefficient operation translates into high energy consumption and low production. The consumption of energy by the cement grinding operation amounts to one third of the total electrical energy used for the production of cement. The optimization of this process would yield substantial benefits in terms of energy savings and capacity increase.

Optimization addresses the grinding process, maintenance and product quality. The objective is to achieve a more efficient operation and increase the production rate as well as improve the run factor. Consistent quality and maximum output with lower specific power consumption results in lower operating costs per unit of production. Optimization can also reduce the cost of liners and grinding media. The cost of optimization is minimal since inspecting the mill and the resulting modifications - such as re-grading the grinding media or moving the diaphragm are labor elements that can be handled by the plant's maintenance crew. Upgrading the classifier and baghouse involves capital expenditure with a high benefit to cost ratio. Optimization is especially important when multiple products are being produced. (PEC Consulting Group/Publication/Cement)



Fig- Ball Mill for Cement Production

2.2.2 Operation and Elements of a Closed-Circuit Ball Mill System

Cement ball mills typically have two grinding chambers. The first chamber is filled with larger diameter grinding media and lined with lifting liners. The first chamber coarse-grinds the feed material and prepares it for the second chamber. The second chamber is the fine grinding chamber. It is lined with classifying-type mill shell liners and provided with finer ball charge. Classifying liners ensure that the ball charge is segregated along the length of the chamber keeping larger grinding media at the beginning of the compartment and smaller media towards the end of the chamber. An intermediate partition, called the central diaphragm, separates the coarse and fine grinding chambers. The purpose of the central diaphragm is to retain the grinding media in their respective chambers, provide adequate opening for the airflow and, in some special types, regulate the feed to the second compartment. The mill is equipped with a discharge diaphragm at the end. This diaphragm

retains the grinding media in the second chamber and allows the discharge of finely ground material.

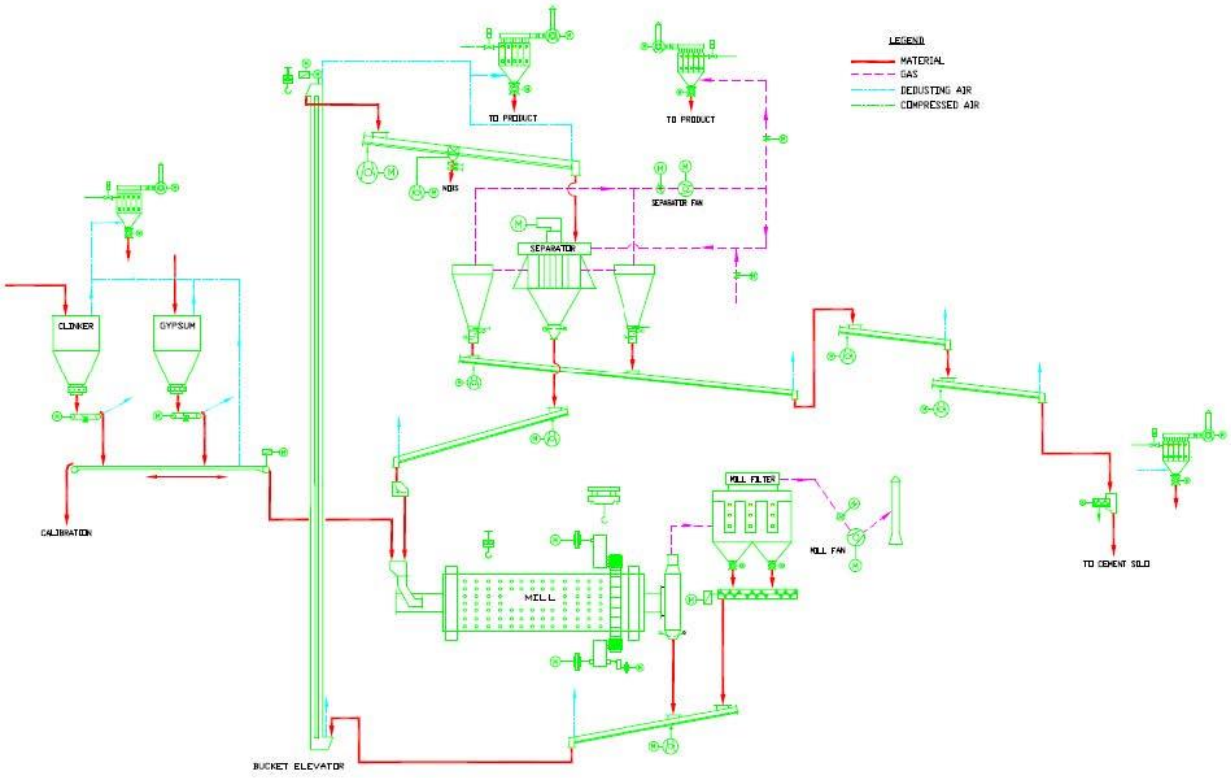


Figure 1. Closed Circuit Ball Mill System

Clinker, Gypsum and other desired additives are fed to the ball mill in specific proportions based on the quality requirement. Feed material is ground in the ball mill, discharged and fed to a classifier with the help of a bucket elevator for classification of the ground cement into two streams – coarse and fines. The coarse fraction is sent back to the mill and the fines are collected in cyclones and / or a baghouse as finished product. The mill is ventilated by an induction fan. The air required for classification is provided by another fan. The fans pull the gases through independent baghouses which clean the vent air and return the cement dust to the system. (PEC Consulting Group/Publication/Cement)

2.2.3 Auditing Operation

The audit of a closed-circuit grinding system focuses on feed material characteristics, grinding progress in the mill, mill ventilation, classification and controls.

Internal inspection of the mill can reveal a lot of important and vital information about the performance of the grinding system such as the separator's behavior, influence of grinding media and the mill ventilation.

Circuit sample analysis and mill chambers sample analysis indicates performance of the separator and progress of the grinding process along the length of the mill.
The separator is expected to perform in a way that a minimum of the fines is carried in the coarse reject fraction and sent to the mill for regrinding. The separator's efficiency is determined by drawing a Tromp curve based on particle size distribution analysis. The separator's performance can be improved by changing the adjustments or replacing worn components. The operational controls are also reviewed for optimized mill operation.
Every element of a closed-circuit ball mill system is evaluated independently to assess its influence on the system.

Figure 2 below is a typical example of inefficient grinding indicated by the analysis of longitudinal samples taken after a crash stop of the mill.

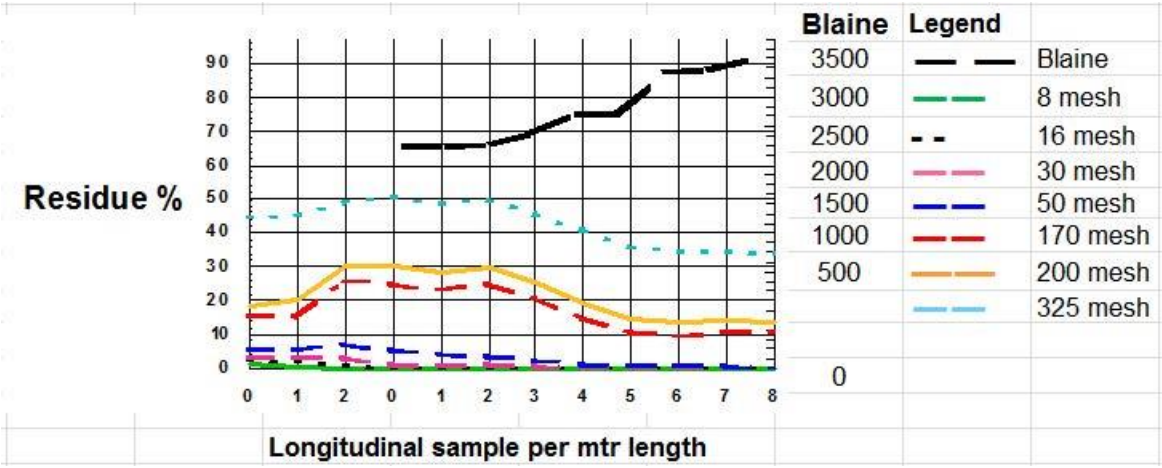


Figure 2. Analysis of Longitudinal Samples

The graphical analysis in Figure 2 represents the progress of the grinding process along the length of the mill. In a correct operation the residue will be high initially, falling

gradually as grinding progresses, which is not the case in the above graph. Compare this with the milling progress as presented in Figure 4 after optimization.

The following picture shows the condition of the grinding media and the material in one of the grinding chambers of the mill. These observations provide a clear idea of internal conditions — such as a clogged diaphragm or incorrect material level — and present the potential steps for optimization. (PEC Consulting Group/Publication/Cement)



Figure 3. Internal condition of Ball Mill.

2.2.4 Results of Optimization

The graphical analysis presented in Figure 4 represents progress of grinding along the length of the mill after optimizing the grinding process. Desired progress of grinding is clearly visible in the graphs.

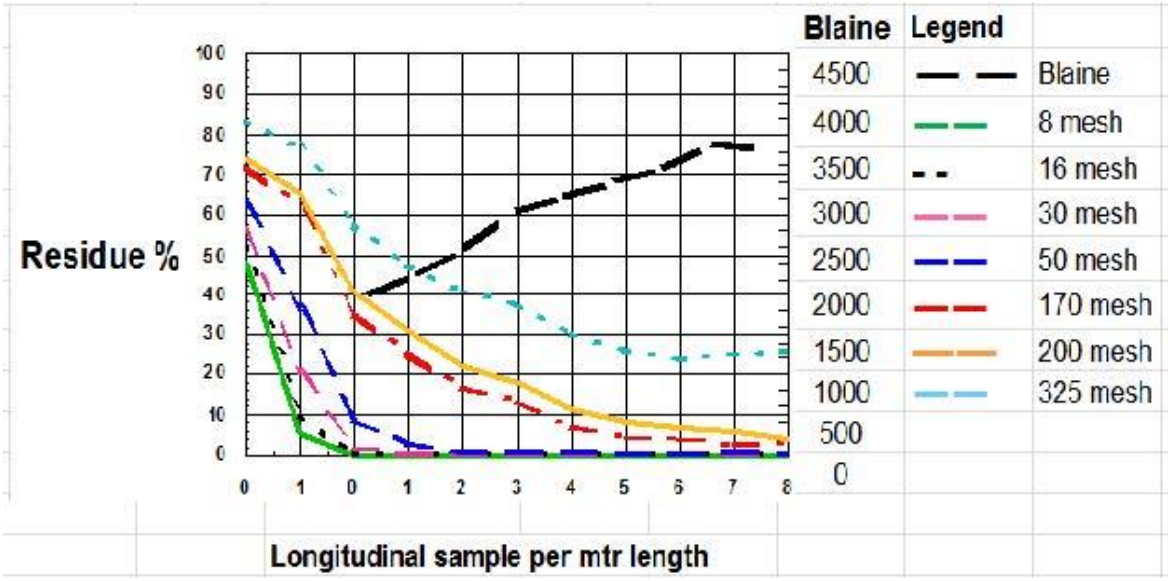


Figure 4. Analysis of Longitudinal Samples

Use of suitable grinding aids also is recommended to improve grinding. However, it is important to mention that grinding aids should not be considered as optimization tools. It is recommended that all operational and process deficiencies be eliminated and that the system be optimized before considering use of a grinding aid to further improve the process.

Results of the optimization can be measured by multiple parameters such as separator efficiency, specific power consumption, system throughput, and wear rate of grinding media and liners.

Changing the separator to a high efficiency type brings about better residue value (on 45 micron) for the same Blaine. Alternatively, the cement can be ground to a lower Blaine with the same residue, which determines the strength of cement. In most cases the layout permits replacing the separator to a high efficiency type.

An evaluation of the grinding system and operation includes meaningful and critical inspection of all equipment, components and the process parameters by experts (PEC Consulting Group/Publication/Cement)

2.2.5 Roller Press Mill working principle and performance evaluation parameters

Working principle:

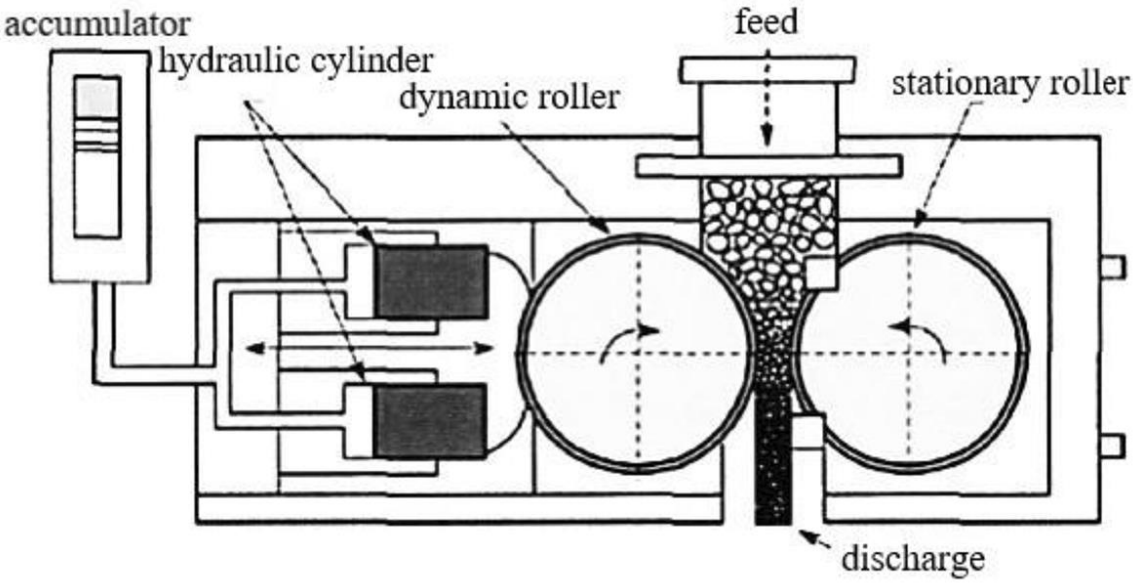


Fig. 1: Schematic diagram of high-pressure roller mill structure.

The main structure of the high-pressure roller mill is shown in Fig. 1, which mainly includes the frame, hydraulic system, guide trough, pressure roller and other devices. The two pressure rollers of the high-pressure roller mill are called fixed roller and dynamic roller. The fixed roller is fixed on a fixed shaft and rotates on the fixed shaft by means of a drive unit, and the movable roller is fixed on a floating shaft and is driven to rotate by another drive unit, which will move in the horizontal direction under the pressure generated by the hydraulic unit. The working gap between the movable and fixed rollers is called the roller gap. During the working process of the high-pressure roller mill, the material enters into the guide chute, fed by the top of the pressure roller, and discharged from the bottom of the pressure roller after crushed by the roller pressure.

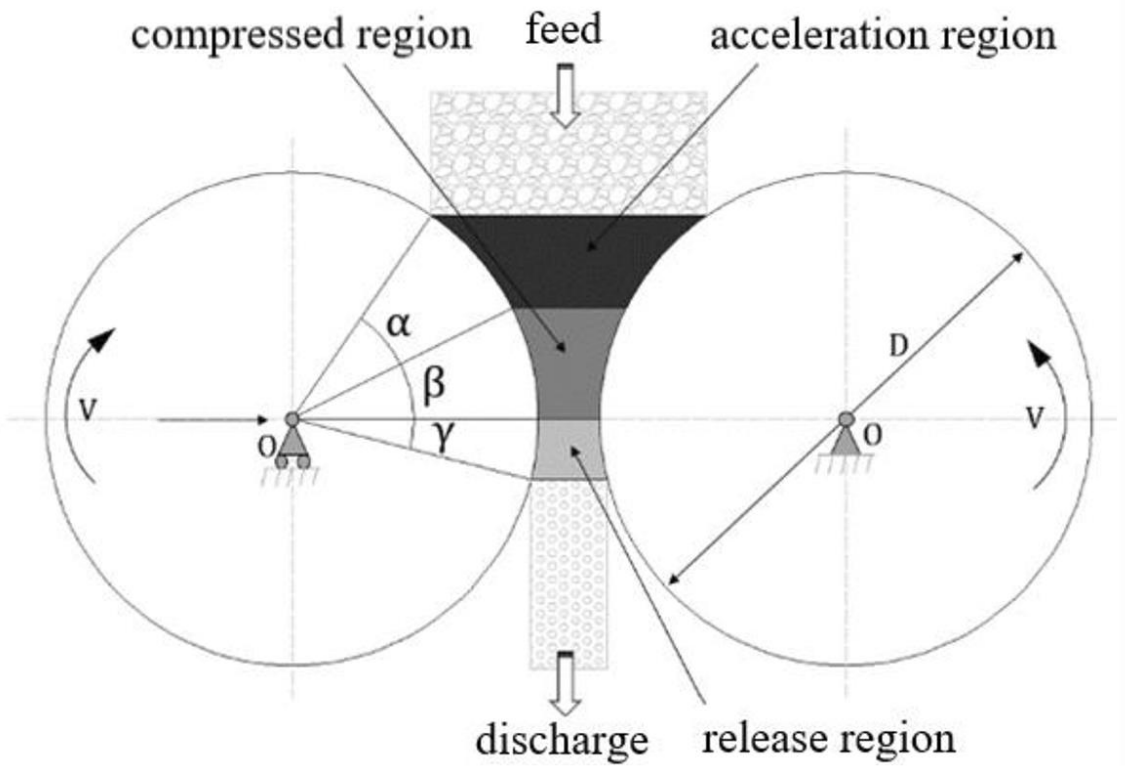


Fig. 2: Working principle diagram of high-pressure roller mill.

1. The principle of material crushing is shown in Fig. 2. The material pulverization interval is divided into three region, which are the acceleration region (the region corresponding to the rounding angle α), the compression region (the region corresponding to the rounding angle β) and the release region (the region corresponding to the rounding angle γ). In the material particles roll pressure process, the material first in the acceleration region above the contact with the two rollers, due to the existence of friction between the two, the material is therefore accelerated with the rollers for the accelerated movement, when the movement to the compression region, the speed of the material and roller surface speed is basically the same (assuming that there is no sliding between the material and the rollers), at this time the material began to be crushed by the two rollers squeezed and crushed, and always arrived at the smallest gap rollers, as the rollers gap increases. With the increase of roller gap, the compressed crushed material will rebound in the release region, and released to the end of the release region to the

loose state or discharged in the form of material cake.(https://www.nature.com/articles/)

2.2.6 Optimization results analysis and validation

The optimal combinations obtained from the two optimization methods are simulated and verified and the results are shown in Table 1:

Optimization Method	Roll surface pressure(N)	Productivity (Tph)	Particle diameter proportion (%)
Response surface method	150450.00	1268.00	58.14
Orthogonal Test	204540.00	1237.00	49.52

Table 1. Simulation verification results.

Comparing the simulation data after the optimization of response surface method with the prediction data after the optimization of the previous paper, the errors between the predicted values and the simulation values can be obtained, which are 3.6% of the roll surface pressure, 6.8% of the productivity, and 4.7% of the proportion of discharge particle diameter, which proves the accuracy of the optimization model of the response surface method.

Table 1 in the response surface optimization combination of simulation results and orthogonal test optimization results for comparison, it can be concluded that the integrated weighted optimization of the roll surface pressure, productivity and the proportion of discharge particle diameter are not as good as the response surface optimization. The main reason for this result is that only the weights are considered, the interaction between the factors is not considered, and the entropy weighting method can only be optimized on the existing data, which leads to bias in the interpretation and prediction of the experimental results. In contrast, the response surface is first optimized by designing reasonable experiments and then fitting the equations based on the experimental data, the fitted

equations are continuous and the interaction between factors is considered, so that the global optimization can be achieved.(https://www.nature.com/articles/)

2.2.7 VRM Operation

The operation procedure of a Vertical Roller Mill (VRM) for cement grinding involves several critical steps to ensure efficient and effective processing of materials. Initially, the grinding table is rotated, which, aided by centrifugal force, evenly distributes the material into the crushing zone between the rollers. As the rollers engage with the grinding table, the materials are subjected to pressure and friction, resulting in crushing and fine grinding. Key parameters such as the inlet and outlet air valve settings must be carefully monitored and adjusted to maintain a balanced air volume in the system, which is crucial for optimizing the grinding process.



Fig.- Vertical Roller Mill (VRM)

The hydraulic system is activated to apply consistent pressure to the rollers, ensuring they remain firmly against the grinding bed. This pressure is critical for achieving the desired fineness of the cement. The specific grinding occurs in a high-pressure zone beneath the outer lobe of the rollers, with a special groove design that aids in de-aerating the material. Overall, VRMs are known to consume approximately 50% less power than traditional ball mills when processing equivalent quantities of clinker, making them a more energy-efficient choice for cement production. The operation of a VRM requires continuous monitoring and adjustment of various process parameters to adapt to changing conditions and maintain operational stability.

Chapter 3

Overview of Cement Manufacturing Industry

3.1 Overview of Cement Manufacturing Process

The cement manufacturing process is a complex and energy-intensive operation that transforms raw materials into one of the most essential construction materials. This process typically involves several key stages, each contributing critically to the production of high-quality cement.

3.1.1 Raw Material Extraction

The first stage of cement manufacturing is the extraction of raw materials.

Limestone, the primary raw material for cement, is extracted through mining or quarrying operations. Other essential materials such as clay, silica, iron ore, and alumina are also sourced to adjust the chemical composition of the final product. Extraction techniques may include blasting, drilling, and mechanical excavation, ensuring that the materials meet the required chemical specifications (International Energy Agency [IEA], 2020).

3.1.2 Raw Meal Preparation

After extraction, the raw materials undergo several processes to prepare the raw meal:

Crushing: The mined materials are crushed to reduce their size for further processing. Homogenization: The crushed materials are blended thoroughly to ensure a uniform chemical composition. Drying and Grinding: In modern dry process plants, raw materials are dried using hot gases and ground into fine powder using vertical roller mills or ball mills. This step is crucial because the quality of the raw meal affects the efficiency of subsequent stages (CEMBUREAU, 2021).

3.1.3 Clinker Production

The homogenized raw meal is then fed into a rotary kiln—a large, rotating cylindrical vessel: The kiln operates at extremely high temperatures, reaching up to 1450°C. During this stage, a series of chemical reactions occur, known as calcination and clinkerization. The result is the formation of clinker—small, dark grey nodules composed mainly of calcium silicates. This stage is the most energy-intensive in the entire process and a major

source of carbon dioxide emissions due to fuel combustion and raw material decarbonation (Ghosh & Chatterjee, 2019).

3.1.4 Cement Grinding

After cooling, clinker is mixed with a small amount of gypsum (to control setting time) and other possible additives like fly ash, slag, or limestone. The mixture is finely ground in cement mills to produce the final cement product. The fineness of grinding directly influences the strength and setting characteristics of cement. Advanced grinding technologies such as Vertical Roller Mills (VRMs) help improve energy efficiency at this stage (Hasan et al., 2020).

3.1.5 Packing and Distribution

Finally, the finished cement is stored in silos to ensure uniform quality before being packed. Cement is packed into bags (commonly 50 kg) or supplied in bulk, depending on market requirements. It is then distributed to retailers, construction sites, or exported internationally. Efficient logistics and transportation management are critical to maintaining the quality of cement during distribution.

3.2 Types of Cement Produced

The cement industry produces various types of cement to meet different structural and architectural needs. Each type has specific chemical compositions and properties suited for particular construction applications. In Bangladesh, as in many other countries, the most common types of cement produced include:

- **Ordinary Portland Cement (OPC):** Ordinary Portland Cement (OPC) is the most widely used cement type for general construction purposes.It consists mainly of clinker (about 95%) and a small proportion of gypsum (about 5%) to regulate setting time. OPC is highly preferred for structures requiring high strength and

quick setting. It is commonly used in building foundations, roads, bridges, and multi-storied buildings.

- **Portland Composite Cement (PCC):** Portland Composite Cement (PCC) is a type of blended cement. It is manufactured by mixing clinker, gypsum, and one or more extenders such as fly ash, slag, or limestone. PCC typically contains 65%-79% clinker, which reduces the carbon footprint compared to OPC. It is widely used in general construction due to better workability, durability, and eco-friendliness. PCC is particularly popular in Bangladesh because it offers an economical and sustainable alternative.
- **Portland Pozzolana Cement (PPC):** Pozzolana Cement, often referred to as Portland Pozzolana Cement (PPC), is a blended cement that combines Ordinary Portland Cement (OPC) with pozzolanic materials like fly ash, volcanic ash, silica fumes, or calcined clay. Pozzolanic materials possess little or no cementing properties themselves but, when finely divided and mixed with water and calcium hydroxide form compounds with cementitious properties. This chemical reaction improves the cement's performance, particularly in durability and resistance to aggressive environments.
- **White Cement:** White Cement is a specialized type of cement that differs from OPC mainly in color. It is produced by controlling the amount of iron oxide and manganese oxide during manufacturing. The raw materials used are pure limestone, clay, and other materials low in iron. White cement is primarily used for architectural projects, decorative works, tiles, flooring, and facade treatments where aesthetic appeal is essential.
- **Blast Furnace Slag Cement:** Blast Furnace Slag Cement is made by mixing Portland clinker with granulated blast furnace slag (a by-product of the steel industry). Typically, slag constitutes up to 70% of the mix. This type of cement offers enhanced durability, resistance to sulfate attack, and low heat of hydration. It is especially suited for marine structures, underground works, and massive construction projects where lower heat generation is crucial.

3.3 Source of Raw Materials

The cement industry relies heavily on imported raw materials like clinker, gypsum, slag, fly ash, and limestone. While some raw materials are sourced domestically, significant portions are imported from countries like India, China, Thailand, Indonesia, Malaysia, Vietnam, Japan and Korea.

Specific Materials:

Clinker: A key ingredient, mainly sourced from Vietnam and other Asian nations.

Gypsum: Sourced from various countries including India, China, Indonesia, and Japan.

Slag: Imported from countries like India, China, Japan, and Vietnam.

Fly ash: Mainly sourced from India and other countries.

Limestone: Extracted domestically, but also imported from India, China, Vietnam, Thailand.

3.4 List of the Cement industries of Bangladesh

Here's a list of some of the prominent cement companies operating in Bangladesh (BCMA, 2023):

1. Shah Cement Industries Limited
2. Seven Circle Bangladesh Limited
3. Premier Cement Mills Limited
4. M.I Cement Factory Limited
5. Lafarge Holcim Ltd
6. Meghna Cement Mills Ltd
7. Unique Cement Industries Limited
8. Akij Cement Company Limited
9. Heidelbarg Cement Industries Ltd
10. Madina Cement Industries Ltd
11. Confidence Cement Ltd
12. Diamond Cement Ltd
13. Royal Cement
14. Ultratech Cement
15. King Cement Ltd
16. Cemex Cement
17. Olympic Cement
18. Mongla Cement Factory
19. Dubai Bangla Cement Ltd
20. Anawar Cement Mills Ltd
21. Eastern Cement Industries Ltd
22. Aramit Cement Ltd
23. Nawapara Cement Ltd
24. MIR Cement Ltd
25. Aman Cement Ltd
26. Metrocem Cement Ltd
27. Dash Bandhu Cement Mills Ltd

28. Chattak Cement Factory Ltd
29. NGS Cement Ltd
30. S.Alam Cement Ltd
31. Al-Haj Mostofa Hakim Cement
32. Ayanpure Cement
33. Bengal Cement Limited

3.5 Representative Organization

For the purpose of this study, Bengal Cement Ltd. has been considered as a representative organization due to its technological advancement and growing market position in Bangladesh's cement industry.

Bengal Group of Industries have successfully diversified their business in at least 32 sectors, where the newest edition to that is the Bengal Cement Limited. In 2018 “Bengal Cement” started its journey with the slogan “Strength with Durability”. A skilled team is associated with the company to reach the customers of home and abroad with quality cement. To produce high quality cement, it is importing world-class raw materials such as grade-one clinkers, quality fly ash, limestone, gypsum etc. from different region of the world including Indonesia, Vietnam and Japan. With hourly 160 Metric Tons production capacity of modern ball mills, the company is able to produce 4,000 Metric Tons of quality cement per day and 1.4 million Metric Tons per year accordingly.

Bengal Cement, consistent to quality, committed to spread its outskirt market by meeting the country’s demand through adequate supply with competitive price. To fulfill the rising demand of cement and as an aim to contribute the growing infrastructure development by providing quality building materials, the brand dreams to provide innovative products and building solutions with a clear commitment to social and environmental sustainability that matches the uplifting of urbanization creating impacts on the people and the planet.

3.6 Vision

Bengal Cement aims to provide safe and reliable products & technologies. We strive to become a company who plays an indispensable role in building a reliable, affordable, sustainable infrastructure & also to be a role model of cement manufacturing company,

benefiting all stakeholders and fulfilling community beliefs, global greenhouse conscious & corporate social responsibilities.

3.7 Mission

Bengal Cement fortifies their purposes by furnishing with local communities and the nation through building. Ensuring a durable future for nation is the most aspiring job for us. Accomplishing indestructible buildings are the main stimulation for our contenders.

3.8 Operational Structure

The organization is structured into several key operational departments:

- Production & Process Control
- Quality Assurance
- Engineering & Maintenance
- Supply Chain & Logistics
- Sales and Marketing
- Finance and Accounting
- Administration and HRD
- Environmental Health & Safety
- Research & Development

3.9 Commitment to Sustainability

Bengal Cement is investing in brand-building, market expansion, and technological advancements to solidify its position as an industry leader. The company prioritizes sustainable practices alongside delivering superior products.

Mr. Abdullah Al Alamin (Brand and Communication Head of Bengal Cement Limited) Says,

"We are not just selling cement; we are building relationships, trust, and the future of our nation. Our commitment to innovation and sustainability ensures that Bengal Cement remains a leader in the industry,"

"Every bag of cement we produce is a step toward a stronger Bangladesh. Our work goes beyond the bottom line—it's about building a legacy of progress and prosperity for generations to come,"(Brand Practitioners 2023). **Here are some key Sustainability Activities:**

Environmental Sustainability:

- Fly Ash Utilization:
- Energy Efficient Technology
- Dust Reduction Technology
- Quality Cement Blending

Social and Economic Sustainability:

- Business Expansion and Job Creation
- Corporate Social Responsibility (CSR)
- Community Building

Other Sustainability Aspects:

- Focus on Quality and Durability
- Innovation and Research
- Brand Reputation

3.10 Board of Directors



Md. Moshed Alam

Chaiman of Bengal Group



Md. Firoz Alam

Managing Director of Bengal Group

3.11 Chairmans Message

We started our journey back in 1969 by establishing country's first plastic processing company- Bengal Plastics Ltd. Today, Bengal Group is one of the largest plastic industries in Bangladesh. However, our activities are not limited to plastics these days. Over the years we have successfully diversified our businesses into electronic media, real estate, food, chemical, paper, garments and renewable energy.

Our employees are the most indispensable saving grace to the success of our business. Solidarity, teamwork, and accountability are the core values, on which we've built our foundation. Superior product quality, strong commitment to our customers, and timely delivery have contributed to the success of our growth.

2012 was a very exciting year for us as that year we've taken two of our companies to public. On April, 2013 we have successfully listed our company, Bengal Windsor Thermoplastics Ltd. on both Dhaka & Chittagong Stock Exchanges.

Bengal group of industries will launch Bengal Cement Ltd. to contribute in fastest growing cement sector and economic growth of Bangladesh.

Initially Bengal Cement Ltd. will produce 4000 MT per day cement by state-of-the-art German technology and within a very short time the production capacity will expand to 8000 MT per day. Bengal Cement plant situated at Baradi, Narayangonj under Dhaka division. The plant is only 35 KM away from Dhaka city beside the river Meghna.

The cement industry is a very energy intensive industry. That's why Bengal Cement introducing less emission and green environment technology to their recent cement plant. It would be the state of art technology which will bring green technology and energy efficient technology all together, to produce high quality and International standard cement for heavy construction work as well as general consumers all over the country around Bangladesh. Bengal Cement Ltd. giving priority in produce quality cement blended through innovative processing, development of using technology which decreased dust to create environment friendly surroundings, research for increased efficiency of finished goods and overall development of cement manufacturing technology.

We will continue to focus on expanding our businesses in order to create more jobs to eliminate poverty in our society. We have also adopted effective CSR programs to make positive impacts on our community whilst maximizing business value of our stakeholders and shareholders.

Thank you

Chapter 4

Data Analysis and Results

4.1 Introduction

The cement industry in Bangladesh has witnessed significant growth over the last few decades, driven by rapid urbanization, infrastructure development, and increased construction activities. This report analyzes the current cement manufacturing process in Bangladesh, highlighting key processes, challenges, and opportunities for increased efficiency and overall development.

The primary objective of this analysis is to identify and recommend strategies for optimizing the cement manufacturing process in Bangladesh. This includes enhancing efficiency, reducing costs, improving product quality, and minimizing environmental impact.

4.2 Manufacturing Technology

1. Ball Mills:

Traditionally, ball mills are the most common equipment used in cement grinding. They consist of a rotating cylinder filled with grinding media (steel balls) that help grind the clinker into fine powder. While effective, ball mills are less energy-efficient compared to newer technologies.

2. Vertical Roller Mill (VRM):

Increasingly, Bangladeshi cement manufacturers are adopting vertical roller mills as a more energy-efficient alternative. VRMs crush and grind the materials through the pressure exerted by rollers on a rotating table, significantly reducing energy consumption and improving product quality due to better particle size distribution.

3. Roller Press and Combination Mill:

Some facilities use Roller Press (or high-pressure grinding rolls) to pre-grind the clinker before it enters the ball mill or VRM. This hybrid approach offers a balance between traditional and modern grinding methods, enabling higher efficiency and lower production costs.

4.3 Operational Challenges in Cement Manufacturing

Cement manufacturing faces numerous operational challenges, including high energy consumption, environmental regulations, raw material availability and cost, maintenance of aging equipment, and the need for skilled labor.

Additionally, carbon capture technologies are still being developed and are complex to implement.

Here's a more detailed look at the challenges:

1. Environmental Regulations and Sustainability:

- Greenhouse Gas Emissions
- Alternative Fuels
- Waste Management

2. Raw Material and Supply Chain Challenges:

- Raw Material Availability and Cost
- Supply Chain Disruptions
- Transportation Costs

3. Operational Efficiency and Maintenance:

- High-Temperature Conditions
- Aging Equipment
- Skilled Labor Shortages
- Maintenance Costs

4. Technological and Innovation Challenges:

- Carbon Capture Technologies
- Digitalization and Automation
- Clinker Substitution

5. Economic and Market Challenges:

- Demand Fluctuations
- Market Competition
- Fuel Prices

- Political Instability and Macroeconomic Challenges:

6. Occupational Health and Safety:

- Dust Exposure:
- Safety Procedures:

4.4 Process Optimization Techniques

Process optimization in cement manufacturing focuses on maximizing efficiency, minimizing waste, and improving product quality. Key areas include optimizing raw material handling, clinker production, grinding, and quality control. This involves utilizing advanced technologies, automation, and data analytics to monitor and adjust process parameters in real-time.

- **Raw Material Handling and Preparation:** Optimizing quarrying, crushing, and storage of raw materials to ensure consistent quality and minimize waste. Using online elemental analyzers and software to accurately proportion raw materials for the raw mill. Ensuring proper blending and homogenization of raw materials.
- **Cement Grinding:** Optimizing grinding efficiency using VRM technology, Roller Press Technology, high-efficiency separators and grinding aids. Utilizing grinding simulation and modeling techniques to optimize mill performance. Exploring the use of cement grinding aids to improve output and quality.
- **Quality Control:** Implementing quality control systems throughout the process to ensure consistent cement quality. Utilizing online elemental analyzers and quality prediction systems to monitor and adjust process parameters in real-time.
- **Digitalization and Automation:** Using Advanced Process Control (APC) systems to monitor and adjust process parameters in real-time. Implementing predictive maintenance systems to reduce downtime and improve energy efficiency. Utilizing data analytics to identify areas for improvement and optimize operations.
- **Energy Optimization:** Optimizing energy consumption throughout the process, including kiln operation, grinding, and other ancillary processes. Implementing waste heat recovery systems to reduce energy costs. Exploring alternative energy sources and fuel mixes.

- **Process Control:** Establishing a real-time link with suppliers and services to ensure efficient resource management and rapid response to demand changes. Utilizing process control systems to monitor and adjust process parameters in real-time.

4.5 Cost-Benefit Analysis of Optimization Strategies

The cost-benefit analysis of optimization highlights that while initial investments may be substantial, the long-term financial and environmental benefits significantly outweigh the costs. The adoption of energy-efficient technologies, sustainable fuel alternatives, and advanced quality control systems all present valuable opportunities for improving operational efficiency, reducing costs, and enhancing profitability. Here are some Optimization Strategies

- **Adoption of Vertical Roller Mill (VRM):** Initial capital investment for purchasing and installing VRMs may be higher than traditional ball mills; however, operational costs are lower due to reduced energy consumption. VRMs offer up to 30-40% energy savings, significantly reducing the overall cost of production.
- **Use of Alternative Fuels:** Transitioning to alternative fuels such as biomass and waste-derived fuels may involve upfront investments in technology and infrastructure. Utilizing alternative fuels can reduce dependency on fossil fuels, leading to a decrease in fuel costs by 20-30% and lower carbon emissions, making operations more sustainable and cost-effective in the long term.
- **Implementation of Advanced Process Control Systems:** Investment in advanced control systems (including sensors and automation technologies) may incur high upfront costs. Improved efficiency results in reduced energy consumption, lower material waste and enhanced product quality, potentially leading to a reduction in variable costs by 10-15%.
- **Quality Control Innovations:** Implementing real-time quality monitoring systems requires investment in technology and training. Enhanced quality leads to reduced rework and rejection rates, and the ability to produce premium products can command higher market prices, thus increasing revenue.

- **Employee Training and Development:** Financial resources must be allocated for employee training programs to improve skills related to new technologies and processes. A well-trained workforce improves operational efficiency, productivity, and safety, potentially reducing operational downtime and maintenance costs by up to 15%.

4.6 Forecasting and Planning

Forecasting and planning are crucial components of strategic decision-making in the cement industry. These processes allow manufacturers in Bangladesh to anticipate demand, manage resources efficiently, and achieve operational goals. Below is an overview of key forecasting methods, planning strategies, and their relevance to the cement manufacturing process.

- Demand Forecasting
- Production Planning
- Resource Management
- Financial Forecasting and Budgeting
- Monitoring and Adjustment

4.8 Key Performance Indicator (KPI) in cement production

Key Performance Indicators (KPIs) in cement production are quantifiable metrics that help assess various aspects of the manufacturing process, from production efficiency to quality control and environmental impact. Here are some essential KPIs relevant to cement production:

1. Production Efficiency

- Capacity Utilization Rate:
  Formula: (Actual Production / Maximum Production Capacity) × 100
  Purpose: Measures how effectively the plant is using its production capacity.
- Production Volume:

Metric: Total tons of cement produced over a specific period (daily, weekly, monthly).

Purpose: Tracks production output to meet demand.

- Cycle Time:

  Metric: Total time taken to produce a batch of cement.

  Purpose: Assesses the time efficiency of production processes.

2. Quality Control

- Compressive Strength:

  Metric: The strength of the cement tested at defined curing times (e.g., 7 days, 28 days).

  Purpose: Ensures the product meets required strength specifications.

- Fineness (Blaine Surface Area):

  Metric: Surface area of the cement powder per gram (often measured in m^2/kg).

  Purpose: Influences hydration rate and strength development of the cement.

- Rejection Rate:

  Formula: (Rejected Product / Total Production) × 100

  Purpose: Indicates the quality control effectiveness by measuring the percentage of cement not meeting standards.

3. Energy Efficiency:

- **Energy Consumption per Ton of Cement:**

  Formula: Total energy consumed (kWh) / Total tons of cement produced.

  Purpose: Helps identify opportunities for energy savings.

- **Fuel Consumption per Ton:**

  Formula: Total fuel used (tons or liters) / Total tons of cement produced.

  Purpose: Evaluates fuel efficiency in the production process.

4. Environmental Sustainability

- **CO_2 Emissions per Ton of Cement:**
  Formula: Total CO2 emissions (in tons) / Total tons of cement produced.
  Purpose: Measures the environmental impact of cement production.
- **Alternative Fuel Usage:**
  Formula: (Amount of alternative fuel used / Total fuel used) × 100
  Purpose: Assesses the extent to which alternative fuels are utilized in the production process.

5. Maintenance and Reliability

- **Mean Time Between Failures (MTBF):**
  Formula: Total Operating Time / Number of Failures
  Purpose: Indicates equipment reliability.
- **Downtime Percentage:**
  Formula: (Total Downtime / Total Scheduled Production Time) × 100
  Purpose: Evaluates the impact of maintenance on production capacity.

6. Cost Management

- **Cost per Ton of Cement:**
  Formula: Total production costs (materials, labor, energy, maintenance) / Total tons of cement produced.
  Purpose: Helps gauge efficiency and identify cost-saving opportunities.
- **Operational Efficiency Ratio:**
  Formula: Total Operating Costs / Total Production Output
  Purpose: Measures the overall efficiency of operations.

7. Human Resource Productivity

- **Labor Productivity:**
  Formula: Total Production / Total Labor Hours
  Purpose: Assesses worker efficiency.

8. Supply Chain Efficiency

- **Inventory Turnover Ratio:**

Formula: Cost of Goods Sold / Average Inventory

Purpose: Indicates how efficiently inventory is managed.

9. Safety Management

- **Incident Rate:**
  Formula: (Number of Incidents / Total Hours Worked) × 1,000,000
  Purpose: Measures workplace safety effectiveness.
- **Compliance Rate with Safety Standards:**
  Formula: (Number of Compliant Activities / Total Activities Assessed) × 100
  Purpose: Evaluates adherence to safety regulations and internal standards.

4.9 Reduction in energy and material wastage

The formulas provided measure various aspects of efficiency, including Energy Efficiency Ratio (EER), Material Utilization Ratio (MUR), waste reduction, ROI for energy projects, energy consumption, and environmental impact through Life Cycle Assessment (LCA).

1. Energy Efficiency Ratio (EER):

Formula: EER = (Cooling or Heating Output (BTU/h)) / (Energy Input (W))

Explanation: EER measures the efficiency of HVAC systems by comparing the cooling or heating output to the energy input. A higher EER indicates better efficiency.

2. Material Utilization Ratio (MUR):

Formula: MUR = (Used Material) / (Total Material Input) * 100

Explanation: MUR quantifies how much of the raw material is converted into usable product, helping to assess waste.

3. Waste Reduction:

Formula: Waste Reduction = ((Initial Waste - Final Waste) / Initial Waste) * 100

Explanation: This formula calculates the percentage reduction in waste over a specific period.

4. Return on Investment (ROI) for Energy Efficiency:

Formula: ROI = (Net Profit from Energy Savings) / (Cost of Investment) * 100

Explanation: ROI evaluates the financial benefits of energy efficiency projects.

5. Energy Consumption:

Formula: Total Energy Consumption (E) = Power (P) * Time (t)

Explanation: This formula calculates the total energy consumed, typically measured in kilowatt-hours (kWh), by multiplying the power usage (kW) by the time (h).

6. Life Cycle Assessment (LCA):

Formula: Total Environmental Impact = Σ (Impact at each life cycle stage)

Explanation: LCA analyzes the environmental impact of a product or process throughout its entire lifecycle, from raw material extraction to disposal.

Chapter 5

Recommendations

5.1 Recommended Strategies for Process Optimization

To optimize cement manufacturing in Bangladesh, a multifaceted approach focusing on efficiency, sustainability, and technology adoption is recommended. This includes optimizing raw material handling, implementing advanced grinding and blending techniques, improving energy efficiency, and exploring alternative clinker materials to reduce carbon emissions.

Here's a more detailed Recommendation:

1. Raw Material Optimization:

- **Bulk Control and Handling:** Implement efficient blending strategies to minimize variability in raw material compositions.
- **Quality Control:** Establish rigorous quality control measures for raw materials to ensure consistent clinker and cement production.
- **Resource Efficiency:** Focus on minimizing waste and maximizing resource utilization throughout the raw material supply chain.

2. Grinding and Blending:

- **Advanced Grinding Technologies:** Adopt high-efficiency grinding mills and optimize grinding parameters to achieve desired fineness and specific surface area.
- **Blending Optimization:** Fine-tune blending processes to achieve desired chemical composition and cement properties.
- **Additions Management:** Carefully manage the addition of blended materials (e.g., fly ash, slag) to optimize performance and sustainability.

3. Energy Efficiency:

- **Waste Heat Recovery:** Explore opportunities for capturing and utilizing waste heat from the kilns and other processes.
- **Process Automation:** Automate key processes to improve operational efficiency and reduce energy waste.

4. Sustainability and Emissions:

- **Alternative Clinker Materials:** Investigate the use of alternative materials like fly ash, metal slag, or calcined clay to reduce clinker content and lower carbon emissions.
- **Emissions Monitoring and Control:** Implement robust emissions monitoring and control systems to comply with environmental regulations and minimize pollution.
- **Circular Economy Practices:** Explore opportunities to integrate waste materials from other industries into the cement manufacturing process, promoting circular economy principles.

5. Technology Adoption:

- **Automation and Robotics:** Implement automation and robotics in areas like raw material handling, grinding, and packaging to improve efficiency and reduce labor costs.
- **Data Analytics:** Leverage data analytics to track production performance, identify areas for improvement, and make data-driven decisions.
- **Digital Platforms:** Utilize digital platforms for order management, real-time tracking, and communication with customers to improve efficiency and customer satisfaction.

6. Specific to Bangladesh:

- **Addressing Infrastructure Challenges:** Work towards improving transportation infrastructure to ensure efficient delivery of raw materials and finished products.
- **Policy and Regulatory Framework:** Advocate for a supportive policy and regulatory framework that encourages innovation and sustainable practices.
- **Capacity Building:** Invest in training and development programs to build a skilled workforce capable of operating and maintaining advanced technologies.

5.2 Immediate Investment in Modern Technology and Energy Recovery Systems

Cement plants in Bangladesh must urgently upgrade their existing production systems by investing in modern technologies. This includes the adoption of Vertical Roller Mills

(VRMs) for energy-efficient grinding, high-efficiency separators to reduce energy consumption, and automated process control systems for better operational precision.

Additionally, the installation of Waste Heat Recovery Systems (WHRS) should be prioritized. WHRS can capture the excess heat generated from kilns and coolers and convert it into electrical energy, thereby reducing dependency on external electricity sources and cutting overall energy costs. Immediate modernization will not only lower operational expenses but also help industries comply with environmental regulations (Ghosh & Chatterjee, 2019).

5.3 Development of Local Clinker Manufacturing to Reduce Import Dependence

Currently, Bangladesh heavily depends on imported clinker, which exposes the industry to global price volatility and supply chain disruptions. To mitigate these risks, investment in local clinker production facilities is essential.

Developing local clinker plants will ensure a more stable and cost-effective supply of the primary raw material needed for cement manufacturing. It will also reduce foreign exchange outflows and strengthen the country's self-reliance. New clinker production units should be designed using energy-efficient kilns and low-carbon technologies to promote sustainable development (BCMA, 2023).

5.4 Training Programs for Staff on Energy-Efficient Practices

Optimization of manufacturing processes also requires a knowledgeable and skilled workforce. Therefore, cement companies should implement regular training programs focused on:

- Energy management systems,
- Efficient kiln operation,
- Maintenance of advanced equipment,
- Best practices for raw material handling and blending.

Through capacity building, employees can operate plants more efficiently, identify energy loss points, and adopt preventive maintenance measures, ultimately improving overall plant performance. A continuous learning culture can significantly contribute to achieving higher productivity and lower emissions

5.5 Government Support in the Form of Tax Incentives for Green Technologies

Policy-level interventions are critical for driving industry-wide improvements. The government of Bangladesh should offer tax incentives, subsidies, or low-interest loans to companies that invest in green technologies such as:

- Waste Heat Recovery Systems,
- Alternative fuels and raw materials infrastructure,
- Carbon capture and storage (CCS) systems
- Energy-efficient machinery.

Chapter 6

Conclusion

6.1 Conclusion

Optimizing the cement manufacturing process is essential for enhancing operational efficiency, reducing costs, improving product quality and meeting sustainability goals in an increasingly competitive market. By implementing a structured approach that encompasses detailed process mapping, data-driven decision-making, energy efficiency initiatives, rigorous quality assurance and employee engagement, cement manufacturers can significantly streamline their operations.

Through continuous monitoring and analysis of production metrics, companies can identify and address inefficiencies, reduce waste and ensure that resources are utilized effectively. Advances in technology, such as automation and data analytics, play a vital role in facilitating these optimizations and enabling predictive maintenance, which further minimizes downtime and enhances productivity.

Moreover, adopting sustainable practices not only helps in reducing environmental impact but also resonates with growing consumer demand for eco-friendly products. As the industry trends move toward a circular economy, exploring alternatives in raw materials and energy sources can provide a competitive edge while supporting global efforts to combat climate change.

In summary, a comprehensive and proactive approach to process optimization in cement manufacturing leads not only to improved financial performance but also positions companies to be leaders in sustainability and corporate responsibility, ensuring long-term success in a dynamic and challenging landscape.

Bibliography

Books and Journals:

1. PEC Consulting Group. (n.d.). Optimization of cement grinding operation in ball mills. Retrieved from https://pecconsultinggroup.com/optimization-of-cement-grinding-operation-in-ball-mills/
2. Zhang, H., Liu, F., & Zhang, H. (2024). Optimization of the cement production process. Scientific Reports, 14(1), 101. Retrieved from https://www.nature.com/articles/s41598-024-79691-7#Sec2
3. Hasan, M., Rahman, M., & Chowdhury, R. (2020). Energy Efficiency Opportunities in Bangladesh's Cement Industry. International Journal of Energy Research, 44(2), 1839–1851. Retrieved from https://www.academia.edu/115396878/Empirical_investigation_of_energy_management_practices_in_cement_industries_of_Bangladesh
4. Emerging Rating. (2023). An overview of the cement industry in Bangladesh. Retrieved from https://emergingrating.com/wp-content/uploads/2023/11/An-Overview-of-the-Cement-Industry-in-Bangladesh.pdf
5. The Daily Star. (2023). Cement sector struggles amid political, economic challenges. Retrieved from https://www.thedailystar.net/business/news/cement-sector-struggles-amid-political-economic-challenges-3804466
6. International Energy Agency. (2023). Technology roadmap: Low-carbon transition in the cement industry. Retrieved from https://www.iea.org/reports/technology-roadmap-low-carbon-transition-in-the-cement-industry
7. Thermo Fisher Scientific. (2021). 6 points in the production process to optimize cement making. Retrieved from https://www.thermofisher.com/blog/mining/6-points-in-the-production-process-to-optimize-cement-making/
8. McKinsey & Company. (2018). The Cement Industry at a Turning Point: A Path Toward Value Creation. Retrieved from https://www.mckinsey.com/industries/chemicals/our-insights/the-cement-industry-at-a-turning-point-a-path-toward-value-creation
9. The World Bank. (2022). Cement Sector Assessment: Energy Efficiency and Sustainability. Retrieved from: https://www.worldbank.org/en/country/bangladesh/publication/cement-sector-assessment

10. Fuji Electric Co., Ltd. (n.d.). Optimizing process control in cement plants. Retrieved from https://www.india.fujielectric.com/blog/optimizing-process-control-in-cement-plants
11. Ghosh, S., & Chatterjee, A. (2019). Energy Optimization in Cement Manufacturing. Journal of Cleaner Production, 223, 475-484

Websites:

12. Bangladesh Cement Manufacturers Association. (n.d.). Cement industry. Retrieved April 22, 2025, from https://www.bcma.com.bd/cement-industry
13. Bengal Cement Limited. (n.d.). Bengal Cement. Retrieved April 23, 2025, from https://www.bengalcement.com.bd/
14. Brand Practitioners. (2023). Bengal Cement: Pioneering Innovation and Sustainability. Retrieved from: https://brandpractitioners.com/bengal-cement-pioneering-innovation-and-sustainability-in-bangladeshs-cement-industry/
15. Business Inspection. (n.d.). Cement industry of Bangladesh. Retrieved from https://businessinspection.com.bd/cement-industry-of-bangladesh/
16. International Cement Review. (2023). Cost Reduction Strategies in the Cement Industry. Retrieved from https://www.cemnet.com/
17. Portland Cement Association (PCA). (2020). What is Portland Cement? Retrieved from https://www.cement.org/cement-concrete-applications/paving/what-is-portland-cement
18. CEMBUREAU. (2021). White Cement Overview. Retrieved from https://cembureau.eu/media/ytphltmf/white-cement.pdf
19. Indian Concrete Institute (ICI). (2022). Slag Cement and Its Applications. Retrieved from https://www.icjonline.com/slag-cement