QUALITY ASSESSMENT OF SELECTED CEMENT BRANDS IN BANGLADESH

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DEDICATED TO

This study is dedicated to our beloved parents, who have been our source of inspiration, guide and give us strength, when we thought of giving up, who continually provide their moral, spiritual, emotional and financial support.

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ABSTRACT

The increased demand of Bangladeshi cement in construction industry has gained attention of researchers, engineers and practitioners to understand the quality of cements. A number of industries produce cement not only to meet the local demand but also export cement abroad.

The research aims to investigate the physical qualities of cements of different brands of Bangladesh using experimental investigations. The physical properties of cement include normal consistency, initial and final setting time, compressive strength of cube, compressive strength of cylindrical concrete, specific gravity of cement.

Standard tests were performed on cements manufactured by five different industries of Bangladesh. A total 70 tests samples on CEM II/B-M type representative cement samples were prepared to conduct tests on those physical parameters as per ASTM specifications.

The experimental results obtained from this study were also analyzed to investigate the statistical parameters. The results are compared with the ASTM guideline values and previously available study. In addition, correlations are also developed to find relationships between compressive strength of concrete and their age of curing. The influence of initial setting times on concrete strength are also investigated. The experimental result shows that almost all the samples meet the ASTM requirement that ultimately proves the good quality of Bangladeshi Cements. Moreover, the results are compared with an existing study for some cases. The comparison reveals that the quality of Bangladeshi cements has improved in last decade quite significantly in terms of mechanical strength of concrete.

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List of Abbreviation

ASTM → American Society for Testing and Materials

OPC → Ordinary Portland Cement

PCC → Portland Composite Cement

PLC → Portland Limestone Cement

CEM I → Ordinary Portland Cement (without supplementary materials)

CEM II/B-M → Portland Composite Cement with supplementary materials (fly ash, slag, silica fume, pozzolana, etc.)

CEM II/B-M → 21-35% Mixed Materials (Slag+fly ash+etc)

CEM II/A-M → 6-20% Mixed Materials (Slag+fly ash+etc)

CEM II/A-S → 6-20% Slag

CEM II/A-S → 6-20% Limestone

SCM → Supplementary Cementitious Materials

BSTI → Bangladesh Standards and Testing Institution

GGBS → Ground Granulated Blast Furnace Slag

PCE → Polycarboxylate Ether (superplasticizer/admixture)

MT → Metric Ton

FY → Fiscal Year

USD → United States Dollar

BDT → Bangladeshi Taka

VRM → Vertical Roller Mill

CAGR → Compound Annual Growth Rate

MPa → Mega Pascal

psi → Pound per Square Inch

CCBL → CEMEX Cement Bangladesh Ltd.

CCL → Confidence Cement Ltd.

XRD → X-Ray Diffraction

SEM → Scanning Electron Microscope / Scanning Electron Microscopy

CHAPTER-1

INTRODUCTION

1.1 General Remarks:

Cement is one of the most essential construction materials in Bangladesh, widely used in housing, infrastructure, industrial projects, and urban development. With rapid urbanization and the growing demand for durable structures, the quality of cement has become a critical factor in ensuring safety, strength, and sustainability of construction works. Quality assessment of cement refers to the process of evaluating its physical, chemical, and mechanical properties to determine whether it meets national and international standards. In Bangladesh, the Bangladesh Standards and Testing Institution (BSTI) plays a key role in regulating cement quality by setting specifications based on international benchmarks such as ASTM and EN standards.

The assessment usually covers important parameters such as fineness, setting time, consistency, compressive strength, soundness, and chemical composition. These tests ensure that cement maintains the required performance in terms of durability and load-bearing capacity under local climatic and environmental conditions.

Since Bangladesh has both local producers and imports cement from international markets, proper quality assessment is vital to prevent substandard materials from being used in construction. High-quality cement not only ensures the structural integrity of buildings and infrastructure but also supports long-term economic growth by reducing maintenance costs and extending service life.

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 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 cement could be made which set under water and this was used for the construction of harbors. 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 cementations materials for specific applications and situations.

1.3 Cement Industry in Bangladesh

In Bangladesh, relative rapid growth of cement industry has been observed since mid-80s. At present, the cement industry of the country is the 40th largest market in the world. Primarily five types of Portland cement are used worldwide. However, in Bangladesh two types of cement are produced known as CEM I and CEM II. CEM I is Ordinary Portland cement (OPC) with no SCM (Supplementary Siliceous Materials such as fly ash, slag, silica fume etc.). CEM II is the Portland Composite Cement (PCC) where SCM or pozzolana is added by replacing the clinker. In areas of durability problem such as sulphate or chloride attack, PCC performs better. Before 2003, mainly OPC was used in Bangladesh. From 2003, production of Portland Composite Cement (PCC) has started in the country following the European Standard Methods (ESM). PCC gives comparable strength and durability like OPC. As a result, PCC is gaining popularity worldwide due to its environmental significance **[1].** At present Lafarge Holcim cement company is producing PLC (Portland Limestone Cement) type cement. PLC is a slightly modified version of portland cement that improves both the environmental footprint and potentially the basic performances in concrete. It can be made at any portland cement manufacturing plant. While ordinary Portland cement (OPC) may contain up to 5% limestone, PLC contains between 5% and 15% limestone. Clinker plays the most vital role for ensuring the strength and quality of cement. Most of the clinker used for cement production in Bangladesh is imported. Only two manufacturers produce clinker at their own plant. One is Chhatak Cement Factory Ltd a government owned company with a limited production

capacity. Another one is Lafarge Surma Cement Ltd, which is situated at Chhatak, Sunamganj and produces approximate 10% of total clinker required for Bangladesh **[1].** Currently the industry is experiencing overcapacity of cement production. In a recently surveyed report by Cement Manufacturer's Association, it has been found that there is production capacity of 40 million tons, whereas actual production is hovering around 32 million tons. On an average the utilization rate of cement manufacturing companies is currently around 75-80%. There are currently 37 companies who are operating as cement producer. Present installed capacity of the industry is 40 million MT. Presently, the actual production of all plants in Bangladesh is roughly 32 million MT which means that the sector is now utilizing roughly 80% of the total industry capacity. At present the demand side of the market is mainly dominated by Government's infrastructure development projects, industrial constructions and real estate companies and independent home builders. Export revenue from Cement has dropped significantly in recent period. In the FY2015-16, the export of cement from Bangladesh amounted to USD 1.71 million (BDT 133.6 million) which was USD 3.94 million (BDT 307.8 million) in FY 2014-15, representing 43.4% plunge in export sales. Bangladesh started exporting cement from 2003. M.I. Cement Factory Limited was the pioneer in cement export from Bangladesh. Cement export data presents that Crown Cement (a brand of M.I. Cement) accounts for 37% of the total export volume in cement **[2].** Cement industry in Bangladesh is currently in a growing phase as the consumption of cement has steadily been rising. Till now, strength is the main focus of quality related issues of cement in the country and overall quality of cement production is quite satisfactory. However, in order to ensure overall sustainability, other durability issues dependent on cement properties need to be considered.

1.4 Research Objectives:

The main objectives of this project work are

(i) To study physical properties of representative cement brands of Bangladesh.

(ii) To conduct experimental investigations on representative cements as per ASTM guideline and hence determine their comparative performance in

concrete for last two decades. Firstly, the main outcome of this study is to identify the ingredients of representative cement brands of Bangladesh and hence to compare their deviation from the standard range. Secondly, the performance of different cements is investigated in concrete construction in terms of setting time, consistency and mechanical strength enhancement. Finally, regression analyses are also performed with the experimental results to understand concrete strength at different ages and hence predict relationship between concrete of different ages and their dependence on mechanical strength.

CHAPTER -2

LITERATURE REVIEW

2.1 Introduction

Due to a massive demand of cement in concrete structures, huge growth of the cement industry is noticed in last two decades. Although the cement demand in both local and international market is quite high, quality of cement still an issue mainly because not much research work has been conducted on Bangladeshi cements. Concrete strength is a very important factor in the construction of concrete structure and cement plays a major role there.

This chapter includes the literature of local cement quality assessments, global and regional demand, production, utilization, major manufacturers, market demand of cement.

2.2 Experimental Study

A number of studies have been carried out on cement testing in various aspects by different researches. But very few studies have been carried out on strength of concrete due to quality control in Bangladesh. Present study will be carried out for a comparative study on strength of concrete at various ages in Bangladesh will be followed by ASTM codes. Very limited of studies have been done on this aspect. It is helpful to an engineer to know the concrete strength in difference ages. Various researches carried out on concrete strength are given below:

Kozul and Darwin **[3]** published a research paper on effects of aggregate type, size and content on concrete strength and fracture energy. The objective of this study was the effects of aggregate type, size and content on the behavior of normal and high-strength concrete and the relationships between compressive strength, flexural strength and fracture energy.

Monzon **[4]** carried out a research on maturity of concrete-strength development. The maturity method was investigated in this thesis to determine (a) how well field cast concrete strengths can be predicted from generated strength-maturity curves and (b) what effects different wet mat curing

durations have on strength development and overall strength. The objective of this thesis was to compare the compressive strengths of in-situ four-inch diameter cores taken from bridge decks with predicted strengths based on (a) strength-maturity curves developed from six-inch diameter field-cast cylinders and (b) strength-maturity curves developed from six-inch diameter lab-cast cylinders.

Abdullahi **[5]** published a journal on characteristics of wood ASH/OPC concrete. The study was presented the behavior of wood ash / OPC concrete. Chemical analysis of wood ash, bulk density, sieve analysis and specific gravity of wood ash and aggregates, consistency, setting time and slump test of the fresh paste were conducted to determine the suitability of the materials for concrete making. Test result indicated that the wood ash was slightly pozzolanic, water demand was increased as the ash content increased and the setting time of the paste increased as the ash content increased. Compressive strength of wood ash/OPC concrete it increased with age at curing with optimum replacement of cement by wood ash of 20%.

Samuel and Anthony **[6]** carried out a research on comparing the compressive strength of concrete utilizing natural pozzolana as a partial replacement of ordinary Portland cement in concrete production. The aim of the study was to compare the strength of concrete using a mixture of pozzolana and Ordinary Portland Cement (OPC) as a binder to that of OPC only in concrete production. The objective of this study was to investigate the performance of locally available natural pozzolanic material in the republic of Ghana and to investigate the influence of the pozzolan on the properties of fresh concrete and compressive strength development.

Anitha et Al **[7].** published an international journal on influence of admixtures on behavior of concrete. In this investigation on performance of concrete with GGBS and different PCE based water reducing admixture the tests on compressive strength and workability of the concrete with Ordinary Portland cement and Portland pozzolana cement with GGBS and admixture are carried out at different curing periods for M45 grade of concrete to conclude its behavior. Compressive

strength at 1 day, 3 days, 7 days and 28 days of PCE based concrete is higher than these collected in the case of normal concrete, independent of the cement type and admixture.

Part researches are reviewed here elaborately and divided into several parts. According to EBL Securities Ltd. **[2, 8]** research report, present situation of Bangladesh cement industry is described mainly in this chapter. On the basis of huge demand of cement, a comparative study on strength of concrete at various ages in Bangladesh is highlighted in this research.

2.3 Development of Cement Industry in Bangladesh

The development of cement industry in Bangladesh dates back to the early-fifties. Till 1990 about 95% of the country's demand for cement had been met through import. Some enthusiastic entrepreneurs ventured into setting up cement plants during 1997 to 2000 which opened a new era in this sector. Prior to inception, Bangladesh used to import cement from global market. As new players entered into the market with no participants, they tapped into the already existing huge demand for cement. The dependency on import lowered in the following years. Currently local producers and multinational companies have engaged in cement production to fulfill the local demand. Fueled by the extensive growth of Chinese cement market and cement markets of developing countries, the global cement market has experienced a massive growth. According to IMARC group, the global market rose to volume of around 5.0 billion tons in 2016 which was around 3.7 billion tons in the year 2012.

From 2016 to 2025, Bangladesh's cement industry saw significant growth, driven by government infrastructure projects, rapid urbanization, and private sector real estate development, leading to increased demand and investment. While facing disruptions like the COVID-19 pandemic, the industry recovered and is projected to continue expanding, with industry experts forecasting steady demand driven by mega-projects, new housing, and the promotion of local and regional export markets. The period also saw efforts in increasing production capacity, adopting more energy-efficient mills, and focusing on improving port infrastructure to boost competitiveness Although the growth in the demand of cement has been increasing in Bangladesh, it is far below than that of many developing countries. So, there is a broader scope of growth for cement sector of Bangladesh. The ongoing construction projects are contributing towards the growing demand of cement but

delaying in the implementation of projects are curtailing the full potential and speed of the consumption growth of cement. Bangladesh is one of the lowest consumers of cement products in the world **[2].**

Table 2.1: Per Capita Cement Consumption (kg) in 2022

Sl no	Name of country	Consumption (KG)
1	China	1700
2	South Korea	961
3	Malaysia	800
4	Thailand	447
5	India	280
6	Myanmar	270
7	Bangladesh	230
8	Pakistan	182
7	Global	563

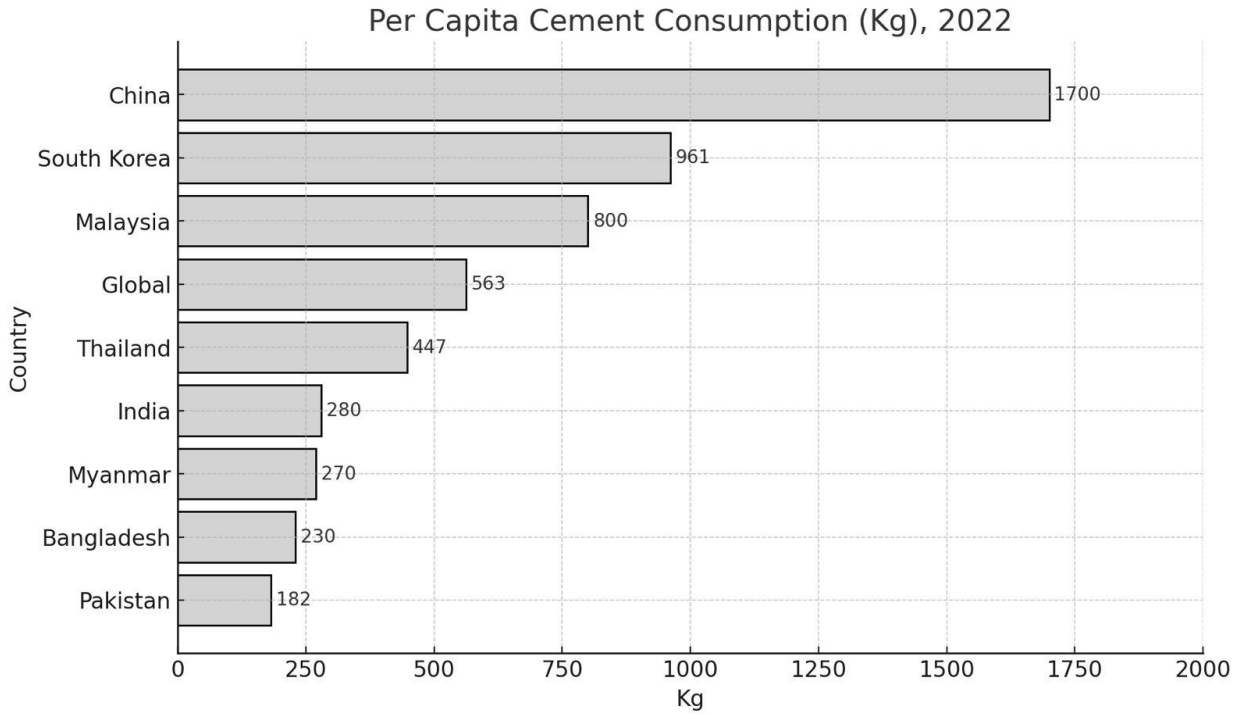


figure: 2.1: Per capita Cement consumption (kg),2022

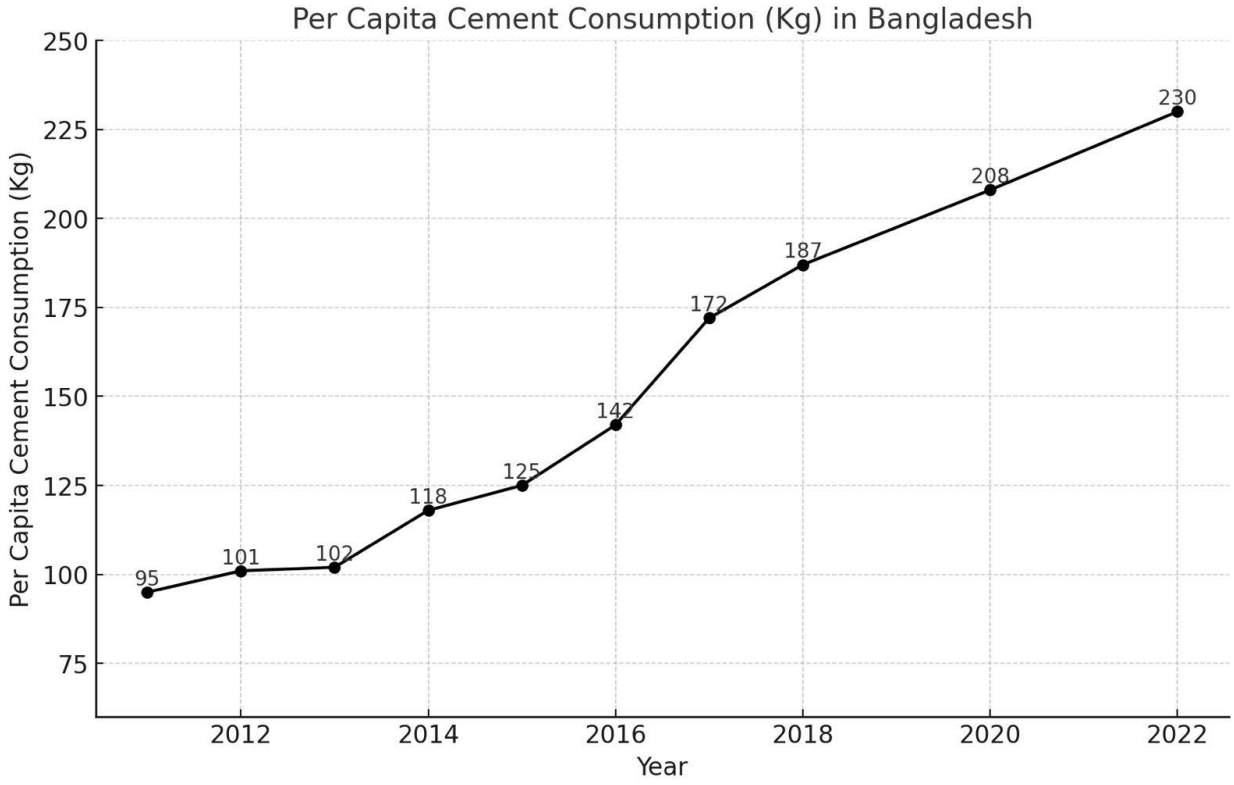


figure: 2.2: Per capita Cement consumption (kg) in Bangladesh

2.4 Major Manufacturers of cement in Bangladesh

There are 37 cement companies currently operating in Bangladesh, producing various brands of cement. While there may be more registered companies, these 37 are the ones actively manufacturing and selling cement, according to the Bangladesh Cement Manufacturers Association.

2.4.1 Bangladesh cement manufacturers list and there brand:

1) Alhaj Mostafa-Hakim Cement Industries Limited-

i). Tajmahal Brand Cement.

2) Premier Cement Mills Limited (T.K. Group)

i). Premier Cement.

3) Shah Cement Industries Ltd (Abul Khayer Group)

i). Shah Cement.

4) Mir Cement Ltd.

i). Mir Cement.

5) Madina Cement Industries Ltd.

i). Tiger Cement.

ii). Three Rings Cement.

6) Mongla Cement Factory (Sena Kalyan Songstha)

i). Elephant Brand Cement.

ii). Sena Cement.

7) M. I. Cement Factory Ltd

i). Crown Cement.

8) Siam City Cement Bangladesh Ltd

i). Insee Cement.

9) Lafarge Holcim Bangladesh Ltd.

i). Holcim Cement.

ii). Supercrete Cement.

10) Aman Cement Mills Ltd.

i). Aman Cement.

11) Olympic Cement Ltd. (OCL).

i). Anchor Cement.

12) Noapara Cement Mills Ltd.

i). Himaloy Cement.

13) Dubai Bangladesh Cement Mills Ltd (A Hossain Group)

i). Five Rings Cement.

ii). VRM Gold Cement,

14) Meghna Cement Mills Ltd (Bashundhara Group)

i). King Brand Cement.

ii). BIR Cement.

15) Bashundhara Industrial Complex Ltd (Bashundhara Group).

i). Bashundhara Cement.

16) Confidence Cement Limited. (CCL)

i). Confidence Cement.

17) S. Alam Cement Limited.

i). S.Alam Cement.

18) NGS Cement Industries Limited.

i). NGS Cement.

19) Royal Cement Limited (KSRM & BSRM Group)

i). Royal Cement.

20) Diamond Cement Ltd.

i). Diamond Cement.

21) Aramit Cement Limited.

i). Camal Brand Aramit Cement.

22) Heidelberg Cement Bangladesh Ltd.

i). Scan Cement.

ii). Rubi Cement.

23) Emirates Cement Bangladesh Ltd.

i). Emirates Cement.

24) Metrocem Cement Ltd.

i). Metrocem Cement.

25) Akij Cement Company Ltd.

i). Akij Cement.

26) Eastern Cement Industries Ltd.

i). Eastern Cement.

ii). Seven Horse Cement.

27) Anwar Cement Limited (Anwar Group)

i). Anwar Cement.

28) CEMEX Cement Bangladesh Ltd. (CCBL)

i). CEMEX Cement.

29) Unique Cement Industries Ltd (Meghna Group)

i). Fresh Cement.

ii). Meghnacem Deluxe Cement.

iii). Dhalai Special Cement.

30) Seven Circle (BD) Ltd.

i). Seven Rings Cement.

31) Bengal Tiger Cement Industries Ltd.

i). Japan Bangla Cement

32) MTC Cement Industries Ltd.

i). Buffelo Head Cement.

33) Chhatak Cement CO Ltd (BCIC)

i). Chattak Cement.

34) Ahad Cement Factory Ltd.

i) Ahad Cement.

35) Asha Cement Ltd (Abul Khayer Group).

i) Asha Cement.

36) Bengal Cement Ltd.

i) Bengal Cement.

37.Olimpia Cement Ltd.

i) Olympia Cement.

Multinational cement companies are –

1.HeidelbergCement Bangladesh Ltd.

i). Scan Cement.

ii). Rubi Cement.

2.Lafarge Surma Cement Ltd. / Lafarge Holcim Bangladesh Limited.

i). Holcim Cement.

ii). Supercrete Cement.

3.CEMEX Cement Bangladesh Ltd. (CCBL)

i). CEMEX Cement

4.Emirates Cement Bangladesh Ltd.

i). Emirates Cement.

5.Seven Circle (BD) Ltd

i). Seven Rings Cement.

2.4.2 Top Cement Companies in Bangladesh by Volume (2023–2024 Estimate)

Serial by most usages cement volume:

Company Name	Estimated Annual Volume (Million Metric Tons)	Market Share (%)	Notes
Shah Cement	6.0 – 6.5	~16–18%	Operates the world's largest vertical roller mill (VRM)
LafargeHolcim Bangladesh	4.2 – 4.5	~12–13%	Uses limestone from its own quarry in Meghalaya, India
Crown Cement	3.5 – 4.0	~10–11%	Known for quality and consistent export volume
Bashundhara Cement	3.5 – 4.0	~10–11%	Part of Bashundhara Group, supplies major projects
Premier Cement	2.8 – 3.2	~8–9%	Strong in domestic distribution
HeidelbergCement (ScanCement)	2.5 – 3.0	~7–8%	German multinational, known for high-quality clinker
Akij Cement	2.2 – 2.8	~6–7%	Fast-growing company with strong brand presence
Fresh Cement (Meghna Group)	2.0 – 2.5	~5–6%	Popular in rural and semi-urban areas
Mir Cement	1.0 – 1.5	~3–4%	Moderate local demand, niche focus
Seven Rings Cement	2.5 – 3.0	~7–8%	One of the top-tier producers with wide distribution

Table 2.2: Top Cement Companies in Bangladesh by Volume

Summary:

Bangladesh cement industry is one of the fastest growing cement markets in the world. Its growth is approximately 11.5% CAGR over the last eleven years. The demand is doubled from 14.6 million MT per year to around 31.3 million MT per year. Per capita cement consumption in Bangladesh almost doubled from 95 kg in 2011 to 230 kg in 2022. Due to a huge demand of cement in concrete structures, huge growth of the cement industry is found last two decades. However, research work on Bangladeshi cements is very limited and still there is a big scope to work particularly on physical and chemical properties of cements as they produced in local factory and local raw materials.

Therefore, it is required to investigate the quality of cement so that sustainability in construction work can be ensured in Bangladesh. This research work has been planned to enrich knowledge on the quality assessment of local cements that may be helpful for both researchers and engineers.

CHAPTER - 3

METHODOLOGY

3.1 Introduction

The main objective of this research is to investigate the physical properties of representative cements of Bangladesh by means of experimental investigations. In order to determine the physical properties of cement such as specific gravity, normal consistency, initial and final setting time, compressive strength of cement cube and compressive strength (cylindrical) of cement, standard tests were performed on the representative cements as per ASTM specifications. Based on the cement production, 5 different cements manufactured by 5 different industries were collected from the market to prepare 70 samples to conduct those tests. This chapter includes sample collection, major composition, test plan, test set-up, sample preparation and experimental procedure.

3.2 Representative Sample Collection

According to Bangladesh Standard, BDS EN 197-1:2003, cements are mainly classified into five major categories according to their composition, namely CEM-I, CEM-II, CEMIII, CEM-IV and CEM-V. CEM-II is basically Portland Composite Cement (PCC). CEMII cement is sub-divided into different groups depending on the contents of mineral admixture and limestone powder, i.e., CEM II/A-M, CEM II/B-M, CEM II/A-S, CEM II/A-L **[9].** Quality assessment of CEM II/B-M type cement is justified in this analysis. There are currently 37 active and recognized companies who are operating as cement manufacturer in Bangladesh **[2].** Among them, samples of 5 major cement brands from CEM II/B-M category were collected from the market as experimental sample. These cement industries are considered the main stake holder of the current cement industries of Bangladesh based on the production capacities. It is important to highlight that all the cement industries have already started their product in the global market here quality of cement as per standard is a vital issue. During collection the samples, the manufacturing and expiry date were observed very carefully so that the date of manufacturing and expiry are nearly same for all cements (± 3 days). Each cement bag was kept in an air-tight plastic bag to prevent unwanted hydration with the moisture which is normally prominent in local weather condition.

3.3 Composition of Different Cements

According to BDS EN 197-1:2003, CEM-II is Portland Composite Cement. CEM-II cement is sub-divided into different groups depending on the contents of mineral admixture and limestone powder, i.e., CEM II/A-M, CEM II/B-M, CEM II/A-S, CEM II/A-L. Quality assessment of CEM II/B-M type cement is used as sample in this analysis. Ingredients of cement printed on the collected cement bags were recorded. As per BDS EN 197- 1 :2003, CEM II/B-M type cement contains clinker 65% - 79%, blast furnace slag, fly ash and lime stone 21% - 35% and minor additional constituents 0% - 5%. Strength class of this cement is 42.5N. All the representative cement brands contain clinker 65% - 79%, blast furnace slag, fly ash and lime stone 21% - 35% and minor additional constituents 0% - 5%. All cement bags levelled approximately same ingredient as they maintained BDS. Since the variation of the ingredients contains wide rage, there is a chance to possess different physical properties even the different industries keep them in the range value.

3.4 Testing Procedures of Cement

In this study, normal consistency, initial and final setting time, cement mortar, compressive strength by cylinder, specific gravity and fineness, density tests are conducted to investigate the physical properties of cement. Generally, those tests are conducted as per specific guideline of ASTM. Test name and their specifications are shown in Table 3.1. Test procedures, test set-up and sample preparation are described one by one in the next sections.

Sl No	Name of test	Test Method & Specification
1	Specific Gravity	ASTM C 188-95
2	Normal Consistency	ASTM C 187-04
3	Initial and Final Setting Time	ASTM C 191-04
4	Compressive Strength (Cylindrical)	ASTM C 39-09a
5	Compressive Strength (Cube)	ASTM C 109-07

Table: 3.1

3.4.1 Specific Gravity

Based on the moisture content present in the cement, the specific gravity can either increase or decrease. The cement particles have pores or particles that can contain water within it. A nominal mix is prepared with a cement of specific gravity. Any change in this value of specific gravity will affect the mix design. Hence, it is necessary to test the specific gravity of the cement procured before mixing process **[10]**. Cement reacts with water as process of hydration. Therefore, in order to prevent this reaction kerosene is used to mix with cement.

Two samples from each cement manufacturing industry were prepared. Therefore, a total of 5 samples were prepared for Specific Gravity test for representative cement sample. Specific Gravity test procedure of cement is shown in Figure 3.2 according to ASTM C 188-95.

Determination of Specific Gravity

Weigh a clean and dry Le Chatelier Flask or Specific Gravity Bottle with its stopper (Wl). Place a sample of cement up to half of the flask (about 50 gm.) and weight with its stopper (W2). Add kerosene (polar liquid) to cement in flask till it is about half full. Mix thoroughly with glass rod to remove entrapped air. Continue stirring and add more kerosene till it is flush with the graduated mark. Dry the outside and weigh (W3). Entrapped air may be removed by vacuum pump, if available. Empty the flask, clean it refills with clean kerosene

Calculation:

Specific Gravity of Cement = $\frac{(w2-w1)}{(w2-w1)-(w3-w4)*Specific\ gravity\ of\ kerosene}$



Fig 3.1: photograph sample test of set up for specific gravity

3.4.2 Normal consistency test of cement

This test method covers the determination of the normal consistency of hydraulic cement paste with Vicat's apparatus (Shown Figure 3.2). The amount of water content that brings the cement paste to a standard condition of wetness is called "normal consistency". It has a marked effect-upon the time of set as well as upon other properties of cement. The paste at normal consistency is fairly stiff and is used only for the determination of time of set and soundness of cement **[11].** It is necessary to fix the quantity of water to be mixed in cement while experimenting on it. The test setup is shown in Figure 3.2. The normal consistency of a cement paste is defined as that consistency i.e. percentage (%) of water which will permit the vicat's plunger (Shown Figure 3.2) to penetrate to a point 10 mm from the top of the vicat mold (Shown Figure 3.2). This test method conforms to the ASTM standard requirements of specification C187-04. In this study, a total of 15 samples were prepared for normal consistency test of 5 different representative cement brands of Bangladesh. Normal consistency test procedure of cement is shown in table according to ASTM C 187-04.

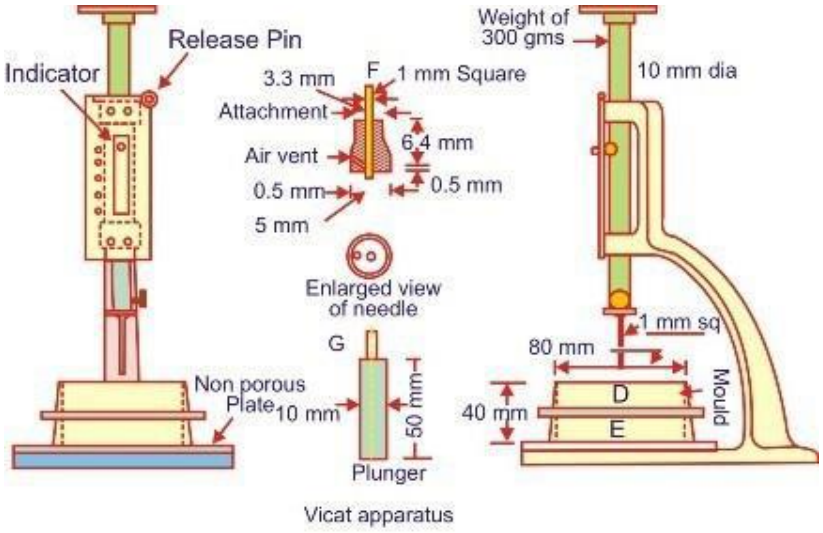


Figure 3.2: Vicat apparatus [12].

Sample preparation for normal consistency test and normal consistency determination photographs are shown in Figure 3.3. Before starting the cement paste preparation, 650 gm cement have to weigh for each sample preparation [Shown Figure 3.3 (a)]. Before mixing water to cement [Shown Figure 3.3 (b)], 24%, 26%, 28%, 30% and 32% or 156 gm, 169 gm, 182 gm, 195 gm and 208 gm have to measure respectively. Figure 3.3 (c) shows the cement mortar mixing for sample preparation and Figure 3.3 (d) shows the normal consistency determination procedure.

Normal consistency test procedure

Preparation of cement paste

First 650 gm cement were added to the water. As per test specification, water is required 24%, 26%, 28%, 30% and 32% of cement respectively. 30s time was allowed for the absorption of the water [56] and mixed the cement with water properly or complete the operation by continuous, vigorous mixing, squeezing and kneading with the hands for 1.5 min

Molding test specimens

The mold was kept on the glass plate and filled the mold with cement paste. Then top of the specimen was made smooth with one or two light touches of the pointed end of the trowel. During the operation of cutting and smoothing, care was taken so that the paste was not compressed.

Normal consistency determination

In the test program, the paste resting on the plate was centered and confined in the ring, under the rod. The plunger end was brought in contact with the surface of the paste. Tightening the set-screw, the rod was to set the movable indicator to the upper zero mark of the scale. Then, the rod was released immediately. This must not exceed 30s after completion of mixing. The paste was to be of normal consistency when the rod settles to a point 10±1 mm below the original surface in 30s after being released. Finally, trial pastes were made with varying percentages of water.



a) Weighing cement



b) Pouring water



c) Mixing cement paste



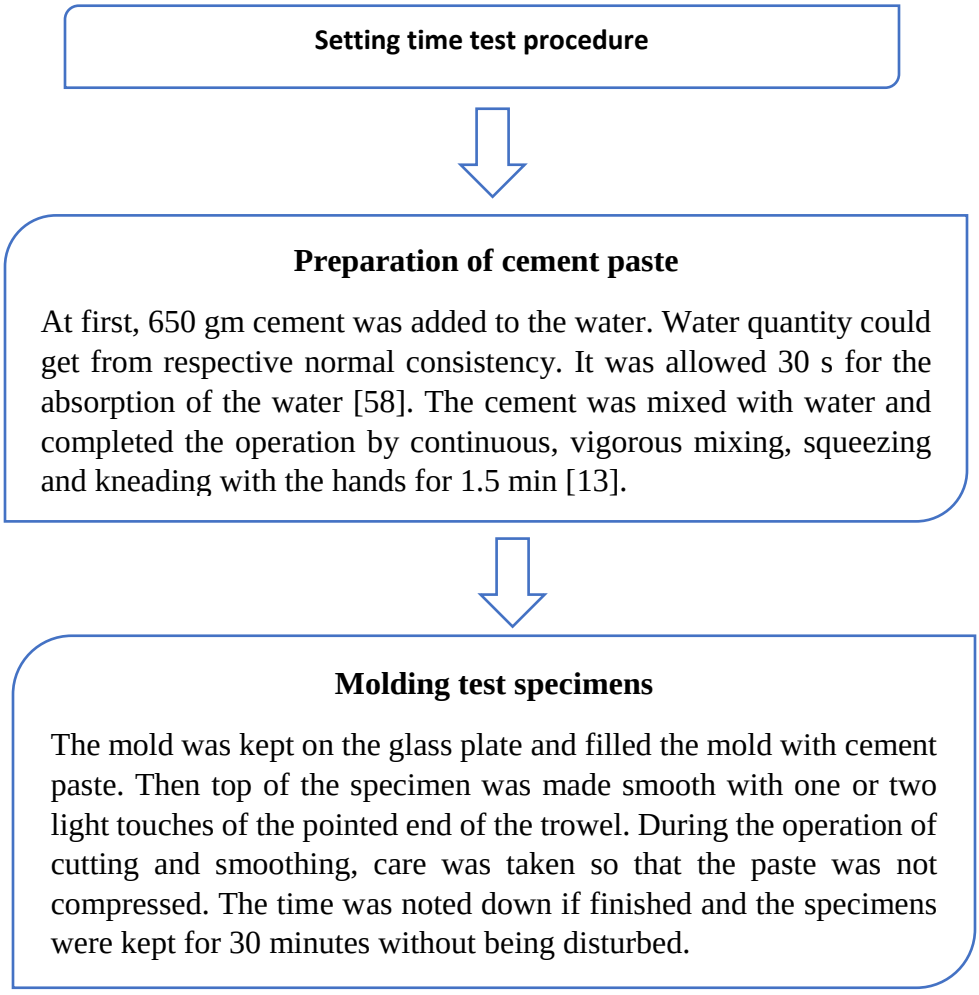
d) Test set-up

Figure 3.3: Photographs of sample preparation (a,b and c) and test set-up (d) for normal consistency test

3.4.3 Setting time test of cement

The objective of this experiment is to determine the initial and final setting time of cement. Cement, when mixed with water, forms slurry which gradually becomes less plastic with the passage of time and finally a hard mass is obtained to form concrete. In this process, a stage is reached when the cement paste is sufficiently rigid to withstand a definite amount of pressure. The time required for cement to reach this stage is termed “Setting time”. The term ‘‘Setting” is used to describe the stiffening of the cement paste. Setting of cement refers to changes of cement paste from a semi-liquid to rigid state.

Setting differs from hardening of cement which refers to the gain of strength of a set of cement paste; although during setting the cement paste acquires some strength **[11].** This test method conforms to the ASTM standard requirements of specification C191. A total of 10 samples were prepared for setting time test of representative cement. Setting time test procedure of cement is shown in table according to ASTM C 191-04.



Time of setting determination

Tightening the set screw and the indicator was set at the upper end of the scale and released the rod quickly by releasing the set screw. The needle was allowed to settle after molding for 30 s. The reading taken to determine the penetration. It was made each penetration test at least 5 mm away from any previous penetration and at least 10 mm away from the inner side of the mold. The penetration was determined [14]

Above Table represents test set-up of the samples for setting time test of cement. It is shows that total 10 samples are prepared for setting time test. For taking penetration reading, paper is kept beside the sample. After finishing the molding, it was kept the specimen for 30 minutes without being disturbed and first penetration reading was taken after 45 minutes serially. 25 mm penetration is the initial setting time and 0.50 mm penetration is the final setting time. After 15 min penetration readings were taken and noted and this procedure was repeated until final setting time or 0.50 mm penetration was obtained.



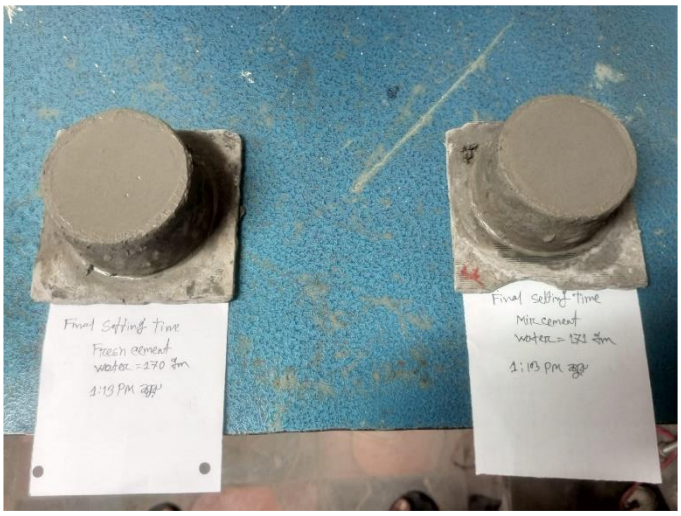




Figure 3.4: Photographs of sample test set-up for setting time test

3.4.4 Compressive strength of Cube

The objective of this experiment is to determine the compressive strength of cement mortars using cube specimens. The samples are 2 inch square sized. Test for structural strength is not made on a neat cement paste because of difficulties in molding and testing with consequent large variations in results. This test is carried out to find out the compressive strength of cement paste indirectly. As shrinkage cracks are formed in dried cement paste, test can't be properly carried out on a block of cement paste **[11].** Therefore, the test is carried out on blocks of mortars made of cement, sand and water, cured for 28 days. For the preparation of cement mortar samples, graded standard sand was mixed with cement. A total of 15 samples were prepared for compressive strength test of representative cement is shown in table according to ASTM C 109-07.

Table 3.2: Quantities of cement, sand and water **[15]**.

Per Sample	If no. of specimens 3
Cement, g	250
Sand, g	687.5
Water, ml for Portland (0.485)	121

Molding Test Specimens:

1	2	3	4
8	7	6	5

Round 1

1	2	3	4
8	7	6	5

Round 3

4	5
3	6
2	7
1	8

Round 2

4	5
3	6
2	7
1	8

Round 4

Figure 3.5: Order of tamping in molding of test specimens **[15].**

Compressive strength test procedure of cube

Preparation of cement mortar

As per specification, cement: sand: water = 1: 2.75: 0.485. Therefore, cement= 250 gm, Ottawa sand= 687.5 gm and water= 121 gm as shown in Table 3.2. The dry paddle and the dry bowl were placed in the mixing position in the mixer. The cement was added to the water. Starting the mixing **[13].**

As per Molding Test Specimens

Molding of the specimens was started within 2.5 min after completion of the mixing. At first, the mold was filled with mortar about 1 depth. Tamping the mortar in each cube compartment 32 times in about 10 s in 4 rounds which is shown in figure 3.5. During tamping of the second layer, bringing in the mortar was forced out onto the tops of the molds and cut off the mortar to a plane with the top

Storage of test specimens

After molding, immediately the specimens were kept in the moist room. After 24 h the specimens were removed from the mould and kept the storage water for curing.

Compressive strength determination

Before starting the test, the specimens were removed from the water not more than 15 min before the test was carried out. Then the cross-sectional area was checked of the specimens. The load rate was 200 to 400 lbs/s (900 to 1800 N/s).









Figure 3.6: Compressive strength test procedure of cement mortar

3.4.6 Compressive strength of cylindrical concrete specimens

The objective of this experiment is to determine the compressive strength of cement concrete specimens. The compressive strength of concrete is one of the most important and useful properties of concrete. In reinforced concrete structures, concrete is employed bn primarily to resist compressive stresses. Nevertheless, strength of any structure usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste **[11]**. The test method conforms to the ASTM standard requirements of specification ASTM C39-09a. Composition of mortars are- Cement: Sand: Coarse aggregate = 1: 1.5: 3 (by weight) and Water Cement ratio = 0.45. As per composition of mortar, 28-days compressive strength 17-32MPa (2500-4700 psi) is considered. Sylhet (FM ≥ 2.50) sand as fine aggregates and 20 mm down-graded boulder stone chips (Dubai LC) as coarse aggregates are used for testing compressive strength of cylindrical concrete specimens. In this part of the experimental investigation, 25 samples were prepared to investigate for 28 days of compressive strength of representative cement sample of cylindrical concrete specimens. Compressive strength test procedure of cylindrical concrete specimens is shown in table according to ASTM C 39-09a. Therefore, a total of 25 samples were prepared for compressive strength test of cylindrical concrete specimens of representative cement sample.

Below Figure represents the sample preparation for compressive strength of cylindrical specimens. It shows that after filling the mold with mortar, smoothing the top of the specimen with one or two light touches of the pointed end of the trowel. Each mold was filled with concrete in three layers and tamping each layer 25 times with 16mm (5/8 in.) steel tamping rod and placed in the moist storage for 24±8 hours at a temperature of 23±1.7°C.

Compressive strength test procedure of cylindrical specimens

Preparation of cement mortar

Cement: Sand: Coarse aggregate = 1: 1.5: 3 (by weight) and Water-Cement ratio = 0.45. The dry paddle and the dry bowl were placed in the mixing position in the mixer. The cement was added to the water. Starting the mixer, it was mixed at the slow speed (140±5 r/min) for 30 s. Then the entire quantity of sand was added slowly over a 30 s and the mixer was changed to medium speed (285±10 r/min) and mixed for 30 s. Mixer was stopped and mortar was stood for 90 s. It was finished by mixing for 60 s at medium speed **[13].**

Preparation of cylindrical specimens

Each mold was filled with concrete in three layers and tamping each layer 25 times with 16mm (5/8 in.) steel tamping rod. The 2nd and 3rd layer of the mold were filled accordingly. The tops of the mold were smoothed off evenly.

Storage of test specimens

After molding, all specimens were placed in the moist storage for 24±8 hours at a temperature of 23±1.7°C. Then the specimens were removed from the mold and immersed in saturated lime water until testing.

Compressive strength determination

Before starting the test, the specimens were removed from the water not more than 15 minbefore the test was carried out. Then the cross-sectional area was checked of the specimens.

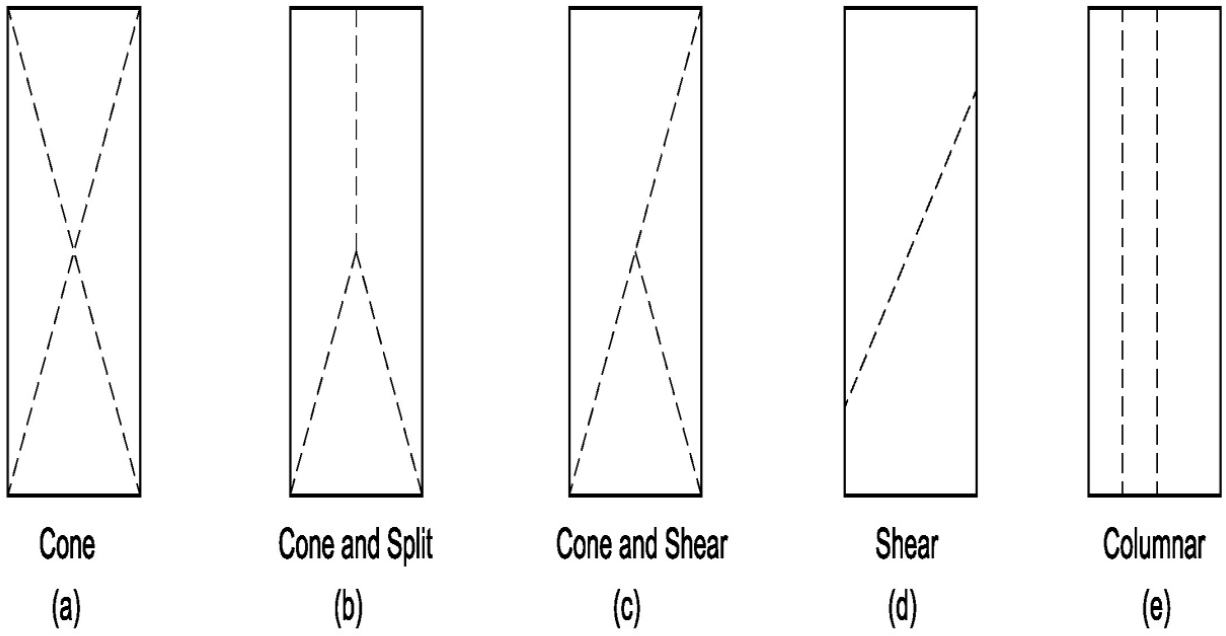


Figure 3.7: Sketches of types of fracture **[16]**.

Type of failure and the appearance of the concrete are shown in **Figure 3.7**. According to failure mode, a short description is given below.

(a) Cone type- A cone failure results lateral expansion of the concrete is restrained as the vertical compressive force is applied. Fairly typical fracture types for normal concrete.

(b) Cone and Split type- Fairly typical fracture types for normal concrete.

(c) Cone and Shear type- Fairly typical fracture types for normal concrete.

(d) Shear type- This type of fracture generally indicates the cylinder failed prematurely, yielding results lower than the actual strength of the concrete. Concretes with high sand contents may fail in the shear mode.

(e) Columnar type- When the cylinder is allowed to expand more laterally and exhibit a splitting failure. This reduces the lateral confining pressure that's usually present and thus reduce the apparent strength.



Figure 3.8: Photographs of sample preparation for compressive strength of cylindrical concrete specimens.

3.5 Summary

This chapter highlights the testing procedures, test setup and sample preparation of normal consistency, initial and final setting time, compressive strength of cement mortars, compressive strength (cylindrical), density, specific gravity and fineness of cement as per ASTM standards. To investigate physical properties of overall cements of Bangladesh, representative cement samples are collected from the leading ten cement manufacturers of the country. In view of maintaining similar age of the cements, manufacturing and expiry date of each cement are checked. All test procedures are highlighted in this chapter. Test samples were prepared as ASTM guideline. Each set of samples contains all five cement brands of Bangladesh that makes a total 70 numbers of samples.

Table: 3.3 Test Name and sample quantity.

Sample for the test of cement							
Selected cement sample	Sp. Gravity	Normal Consistency	Initial Setting Time	Final Setting Time	Compressive Strength of Cube	Compressive Strength of Cylinder	Total Test Sample
Shah	1	2	1	1	3	5	13
Crown	1	3	1	1	3	5	14
Scan	1	3	1	1	3	5	14
Fresh	1	3	1	1	3	5	14
Mir	1	4	1	1	3	5	15
Grand Total	5	15	5	5	15	25	70

CHAPTER - 4

EXPERIMENTAL RESULTS AND DISCUSSIONS

4.1 General Remarks

Based on the experimental set-up and test procedure as presented in Chapter 3, Tests are conducted on 70 samples to obtain the physical properties of five representative cement industries of Bangladesh. As test procedure, relevant ASTM guidelines are followed to assess the physical quality assessment of CEM II/B-M type cements. The physical properties of cements incudes specific gravity, normal consistency, setting time and compressive strength of cement. The experimental results obtained from this study are also analyzed to investigate the statistical parameters. The results are compared with the ASTM guideline values and previously available study.

4.2 Specific Gravity of Cements

Specific gravity test of cement samples was conducted as per ASTM C 188-95. The detail test procedure is presented in chapter 3 Section 3.4.1. It is observed from the figure that the specific gravity of Bangladeshi cement varies in a range of 2.31 to 2.97. According to the ASTM standard, the specific gravity of cement is generally about 3.12-3.19. The mean value 2.67 is lower than the ASTM standard and one of the samples (Scan) is very low. That is 2.31

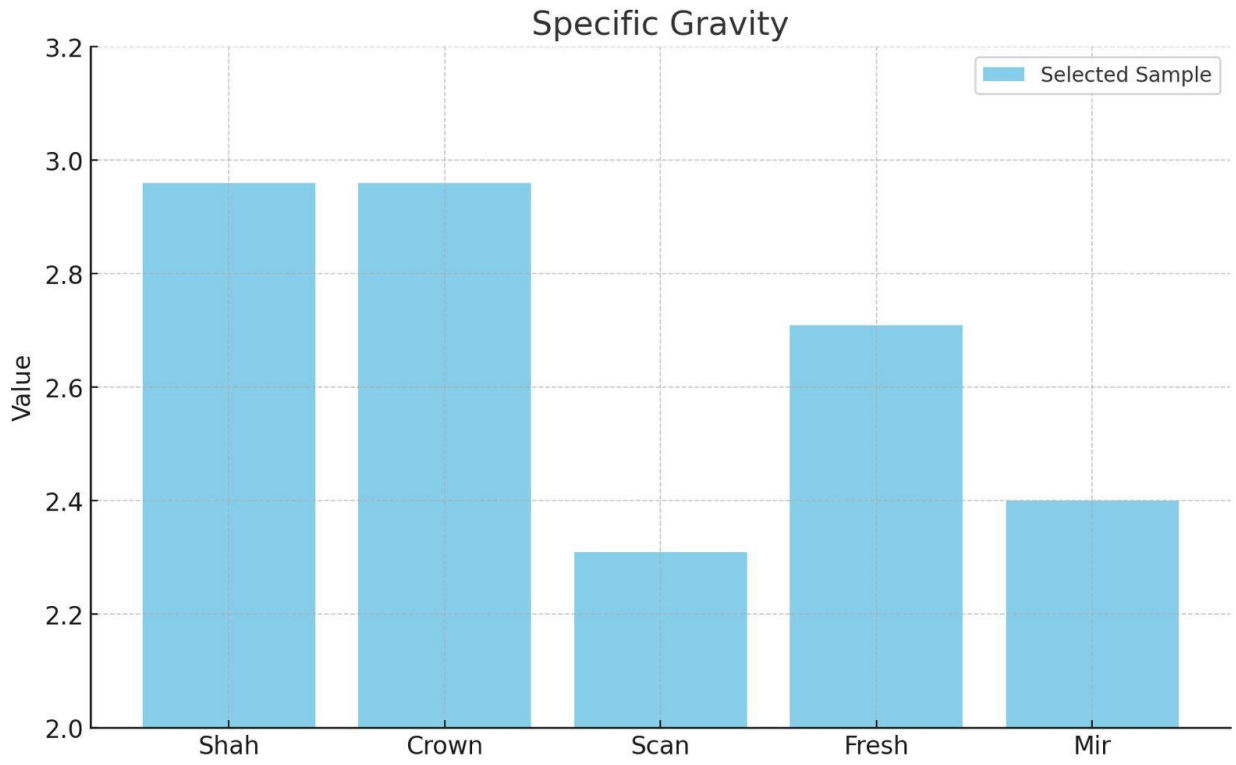


Fig 4.1: Specific Gravity of selected cement samples

4.3 Normal Consistency Test Results

Normal consistency test of cement samples was conducted as per ASTM C 187-04. The detailed test procedure is presented in Chapter 3, Section 3.4.2. The variation of penetration with water content of 5 representative cement samples for the normal consistency test is shown in Figure 4.2. It is found that the penetrations of four representative cement samples (out of five) are almost the same because their trend lines pass very closely. The variation of the normal consistency of the representative cement sample with the mean value is shown in Figure 4.2. According to ASTM C 187, the normal consistency of cement is 22~30%. The result shows that almost 100% of the representative cement samples are very close to the ASTM limit of normal consistency. Instead of falling within the consistency of cement in a range of 22-30%, all Bangladeshi cements maintain cement's consistency within 26 % - 27% which are very close to the ASTM range (22-30%). From Figure 4.2, it can be seen that the mean value of normal consistency is 26.37%. It represents that normal consistency is very closer to the ASTM range

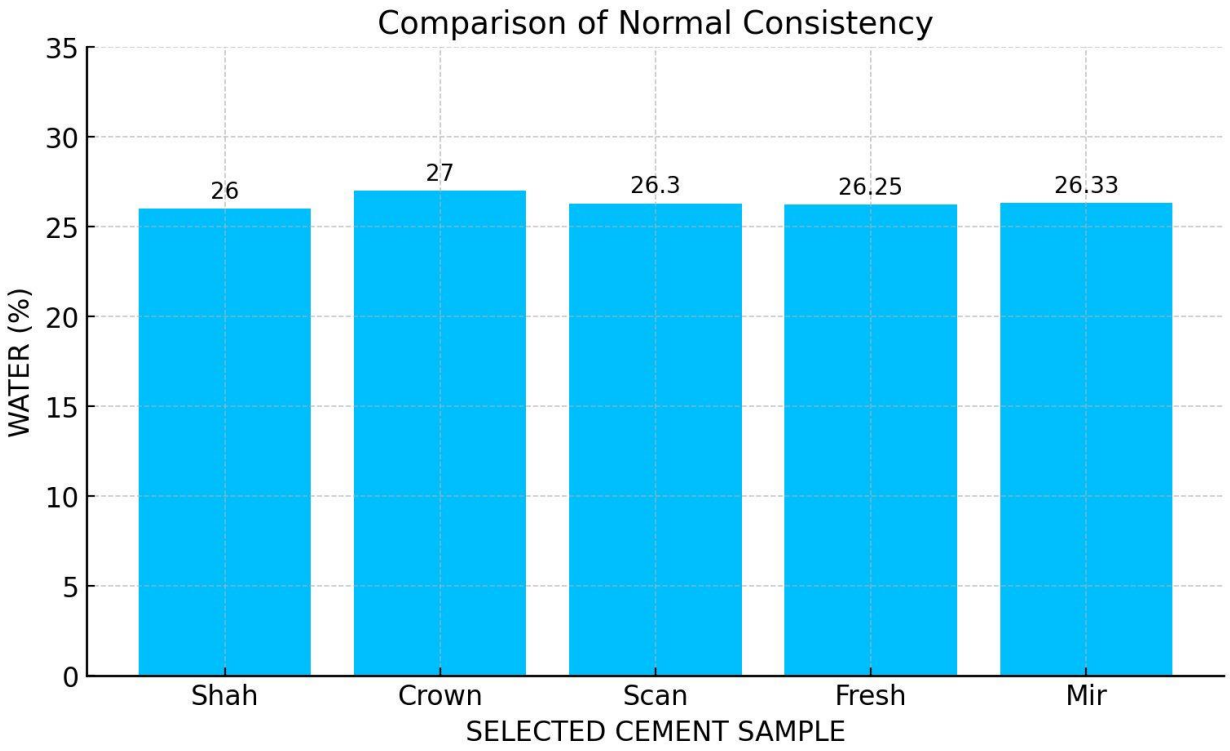


Fig 4.2: Normal Consistency of Selected Cement samples

4.4 Setting Time Test Results

Setting time test of cement samples were conducted as per ASTM C 191-04. The detail test procedure is presented in Chapter 3 Section 3.4.3. This section includes the experimental results of both initial setting time and final setting time. Figure 4.3 represents the variation of penetrations with setting time of representative cement samples 5 different manufacturer of Bangladesh. It is observed from the results that minimum and maximum setting time are 45 minutes and 90 minutes, respectively at 25 mm penetration. Therefore, it can be realized that 80% initial setting time of cement is 75 minutes to 90 minutes. Only one cement's (Fresh) initial setting time is 45 min. That's reacts too early than others 4 cement. In Fig 4 the results final setting time of selected sample minimum is 179 min and maximum is 227. According to ASTM C 150, standard requirements of initial setting time is not less than 45 minutes and final setting time is not more than 375 minutes. Initial and final setting time of all representative cement samples are observed to be satisfactory as per ASTM requirements. Mean value of initial setting time is 75 minutes and 203 minutes for final setting time. Overall that which satisfies by ASTM

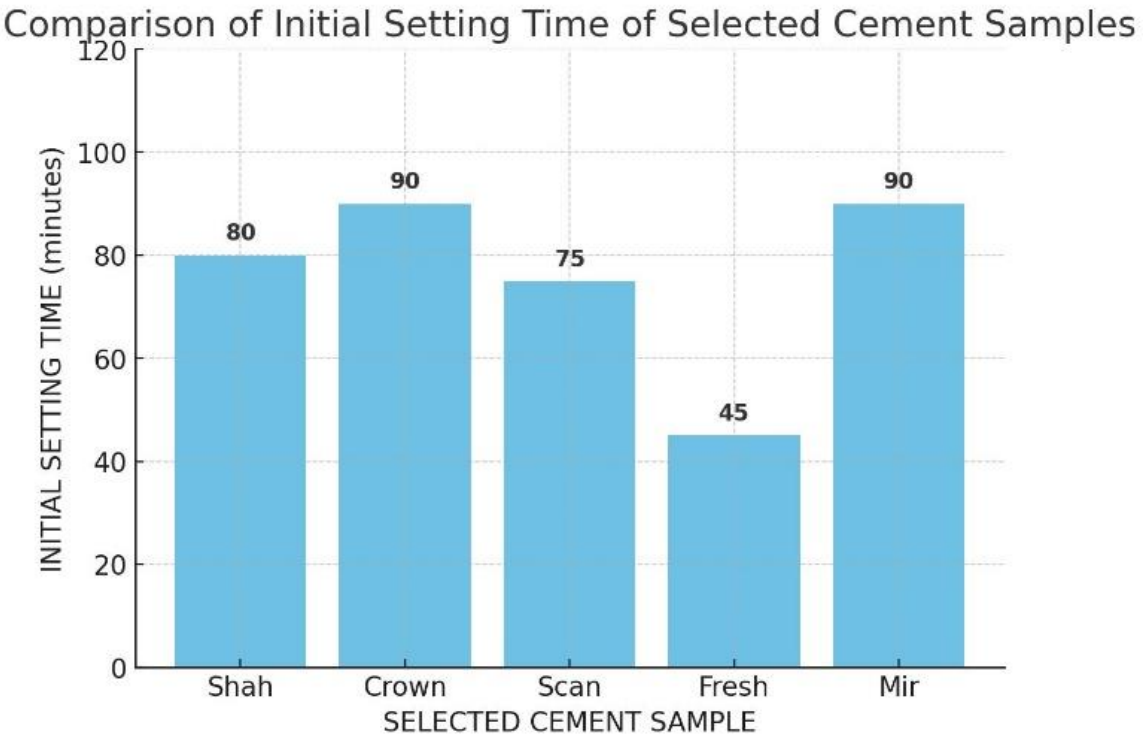


Fig 4.3: Comparison of Initial Setting Time of representative cement samples

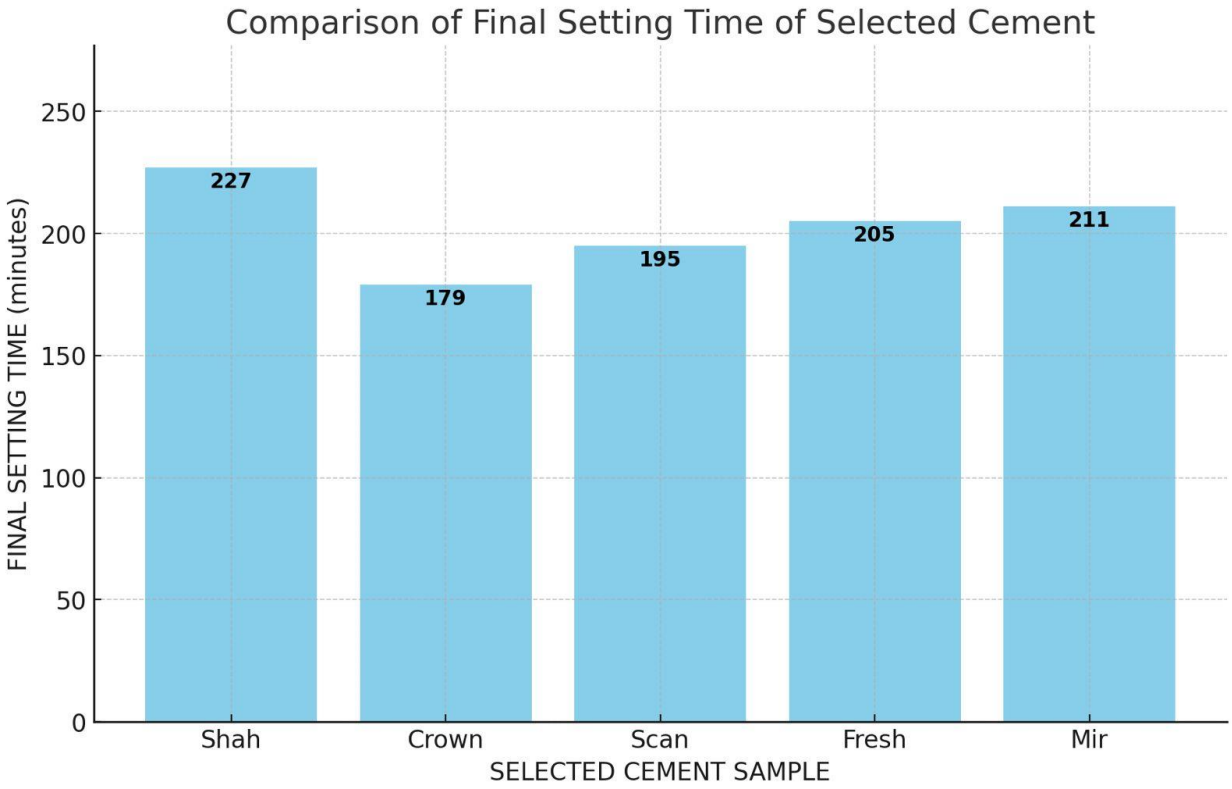


Fig -4.4: Comparison of Final Setting Time of representative cement samples

4.5 Compressive Strength of Cube

Tests on compressive strength of cement mortar were conducted as per ASTM C 109-07. The detail test procedure is presented in Chapter 3 Section 3.4.4. The compressive strength of cement mortar made with different representative cement samples at 28 days are presented on Figure 4.10. It can be seen that compressive strength of cement is increased with the age of the sample. According to ASTM C 595-12, standard requirements of compressive strength is 25 MPa (3620 psi) at 28 days. It is found that five representative cement samples meet the 28-days requirement. The mean values of compressive strength are found to be 27.77 MPa (4027.6 psi) for 28-days. And only Crown cement doesn't follow this ASTM code value which are presented on Figure 4.10.

This result highlights that the quality of Bangladeshi cement in terms of compressive strength improves significantly over the last decade.

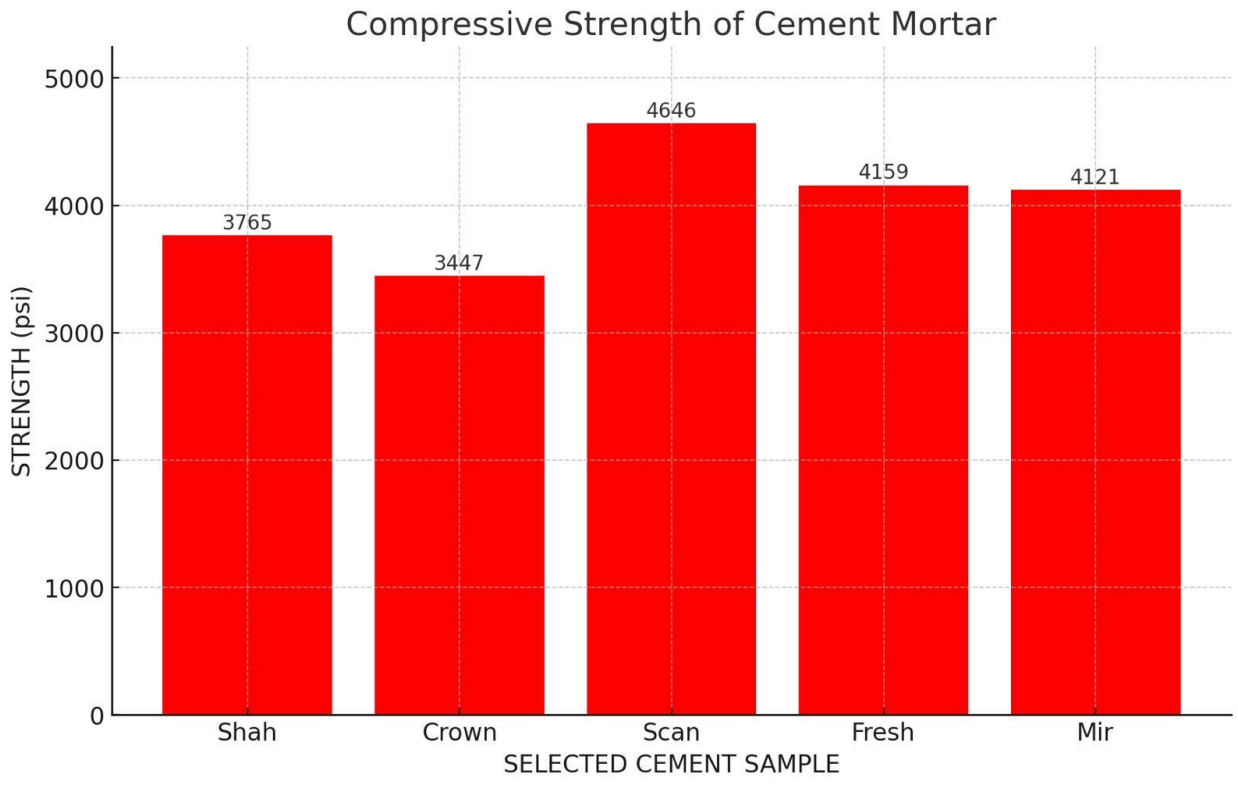


Fig -4.5: Comparison of compressive strength test of cement mortar

4.6 Compressive Strength of Cylindrical Concrete Specimens

Tests on compressive strength of cylindrical concrete specimens were conducted as per ASTM C 39-09a. The detail test procedure and test mechanism are presented in Chapter 3, Section 3.4.5. The variation of compressive strength of cylindrical concrete specimens is shown in Figure 4.18. Composition of mortars are- Cement: Sand: Coarse aggregate = 1: 1.5: 3 and Water–Cement ratio = 0.45. As per composition of mortar, by using 100mm by 200 mm cylinder and after 28-days compressive strength is 17 to 32 MPa (2500 to 4700 psi) is considered. And 1:1.5:3 mix ratio is considered for M20 grade (2900 psi) concrete. According to the ASTM standard, the minimum strength to achieve at 28 days are 99%, respectively. However, all representative cement samples satisfy the 28-days ASTM requirement of strength. Mean value 21.18 MPa (3071.6psi) for 28-days is satisfactory. It is important to highlight that the scan cement is achieve highest value and crown is achieve lowest value.

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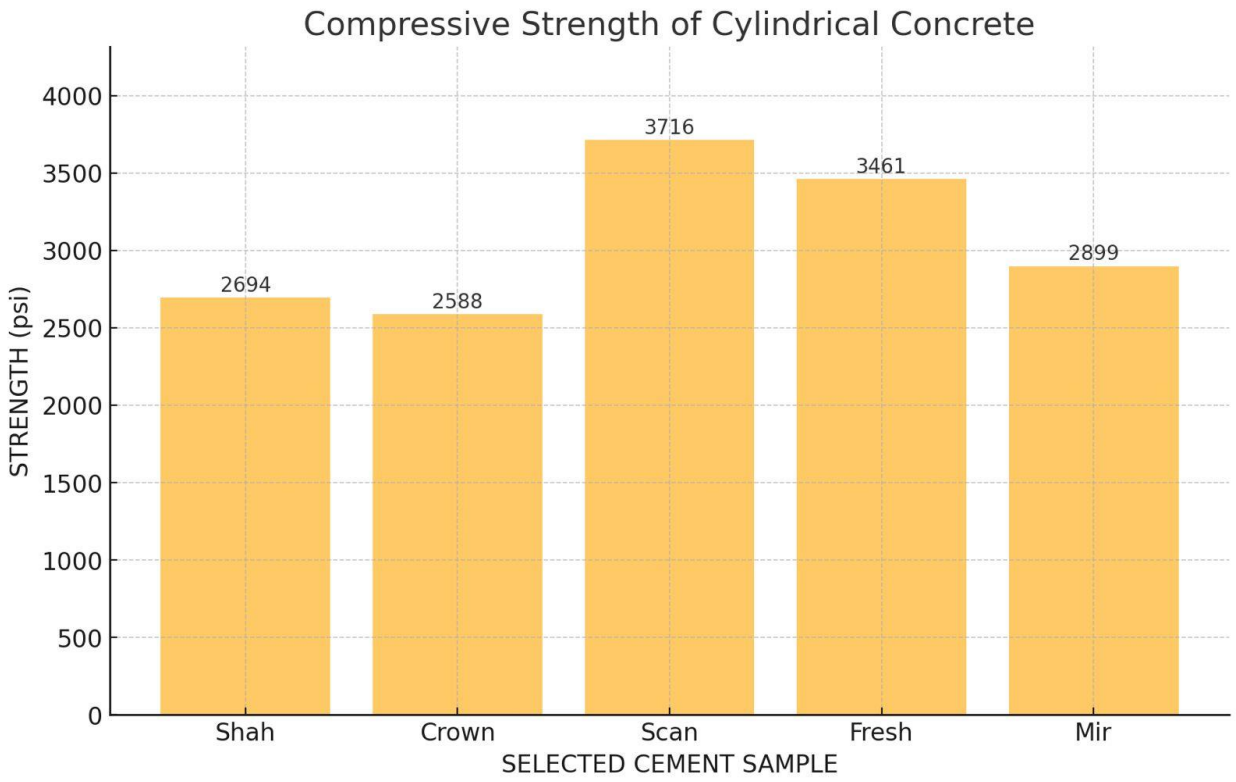


Fig -4.6: Comparison of compressive strength test of cement samples (cylinder)

4.7 Summary of Findings

In this study, a total 70 numbers of representative Bangladeshi cement samples are\ tested to obtain the physical properties. The test results provide an overview of quality of Bangladeshi cements. In addition, Regression analysis are conducted using the tested results. The key findings from this study can be summarized as follows:

i) The experimental results on the specific gravity showed that the mean density of all tested samples is 2.67 whereas the ASTM range of specific gravity of such type cements varies in the range of 3.12-3.19. Since the mean value is lower than ASTM range, it can be concluded that specific gravity of Bangladeshi cements doesn't follows the guideline quite accurately.

ii) According to the ASTM C 187, normal consistency of cement is 22~30%. However, it interesting to note that the Bangladeshi cements showed very closer consistency to the ASTM range. 100% of the representative cement samples showed quite similar behavior. Consistency of those samples just higher than the ASTM guideline. All the samples showed consistency in the range of 26-27% rather (22-30%) with a mean value of normal consistency is 26.27%.

iii) All representative cement samples satisfy the ASTM C 595-12 requirements of the limit of initial setting time and final setting time. The mean values of both initial and final setting time are also in the range. It is found that there is a tendency of achieving lower strength for the representative cement samples with longer initial setting time and higher level of strength for the cement with longer final setting time.

iv) The result showed that compressive strength of cube increases with age as expected. According to ASTM C 595-12, standard requirements of compressive strength of cement mortars is 25 MPa (3620 psi) in 28 days. It is found that 80% representative cement samples satisfy the 28-days requirement. Mean values of compressive strength at different age satisfy the ASTM requirements.

v) The compressive strength of cylindrical concrete specimens was tested following ASTM C39-09a standards. Mortar composition used was cement, sand, and coarse aggregate in a 1:1.5:3 ratio with a water–cement ratio of 0.45. Cylindrical specimens of 100mm × 200mm were prepared, and the 28-day compressive strength ranged from 17 to 32 MPa (2500–4700 psi). ASTM requires at least 99% of samples to meet strength criteria at 28 days, and all tested samples satisfied this requirement. The mean compressive strength recorded was 21.18 MPa (3071.6 psi). Among the tested samples, Scan cement achieved the highest strength, while Crown cement showed the lowest.

CHAPTER - 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In Bangladesh, due to the huge construction works, the demand of cement is increasing day by day. A number of industries produces cements not only to meet the local demand but also export cement all over the world. At this stage, the quality of Bangladeshi cement has become a burning issue for quality construction and sustainable development of the local market and increasing the national revenue by exporting a large part of cement production. The main objective of this research was to assess physical qualities of cements of Bangladesh using experimental investigations. In order to determine the physical properties cement such as normal consistency, initial and final setting time, compressive strength of cube, compressive strength (cylindrical), specific gravity standard tests were performed on cements manufactured by five different industries of Bangladesh. A total 70 tests samples on CEM II/B-M type representative cement samples were prepared to conduct tests on those physical parameters as per ASTM specifications.

The experimental results obtained from this study are also analyzed to investigate the statistical parameters. The results are compared with the ASTM guideline values and previous available study. In addition, correlations are also developed to find relationships between compressive strength of concrete and their age of curing. The influence of initial and final setting times on concrete strength are also investigated. The relationship between mortar strength and concrete strength from the same batch of cement are also investigated.

The key findings from this study can be summarized as follows:

1. Specific gravity test of cement samples was conducted as per ASTM C 188-95. The detail test procedure is presented in chapter 3 Section 3.4.1. It is observed from the figure that the specific gravity of Bangladeshi cement varies in a range of 2.31 to 2,97. According to the ASTM standard, the specific gravity of cement is generally about 3.12-3.19. The mean value 2.67 is lower than the ASTM standard and one of the samples (Scan) is very low. That is 2.31.

2. According to the ASTM C 187, normal consistency of cement is 22~30%. However, it interesting to note that the Bangladeshi cements showed a bit higher consistency than the ASTM range. 90% of the representative cement samples showed quite similar behavior. Consistency of those samples just higher than the ASTM guideline. All the samples showed consistency in the range of 26-27% rather (22-30%) with a mean value of normal consistency is 26.27 %.

3. All representative cement samples satisfy the ASTM C 595-12 requirements of the limit of initial setting time and final setting time. The mean values of both initial and final setting time are also in the range. It is found that there is a tendency of achieving lower strength for the representative cement samples with longer initial setting time and higher level of strength for the cement with longer final setting time.

4. The result showed that compressive strength of cube increases with age as expected. According to ASTM C 595-12, standard requirements of compressive strength of cement mortars is 25 MPa (3620 psi) in 28 days. It is found that 80% representative cement samples satisfy the 28-days requirement. Mean values of compressive strength at different age satisfy the ASTM requirements.

5. The compressive strength of cylindrical concrete specimens was tested following ASTM C39-09a standards. Mortar composition used was cement, sand, and coarse aggregate in a 1:1.5:3 ratio with a water–cement ratio of 0.45. Cylindrical specimens of 100mm × 200mm were prepared, and the 28-day compressive strength ranged from 17 to 32 MPa (2500–4700 psi). ASTM requires at least 99% of samples to meet strength criteria at 28 days, and all tested samples satisfied this requirement. The mean compressive strength recorded was 21.18 MPa (3071.6 psi). Among the tested samples, Scan cement achieved the highest strength, while Crown cement showed the lowest.

5.2 Limitations of this Study

The study has the following limitations:

1. This research program could not include the chemical composition and soundness test of cements which could improve the content of the research. However, the apparatus for those tests are still not only difficult to avail but also expensive.
2. Source of cement ingredients all brands are still unknown since the manufacturer did not cooperate to provide such information.
3. Fineness and soundness testing equipments are not available in our Sonargaon University laboratory.

5.3 Recommendations for the Future Studies

1. In the present study, experimental investigations are performed for CEM II/B-M type cements. In addition, cements samples from five different manufacturers are considered as the representative cements. As further study, it is recommended to study for CEM II/B-M, CEM II/A-M, CEM II/A-S and CEM II/A-L type cements with more number's representative cements.

2. Due to limitations, this study did not consider the chemical composition tests, fineness and soundness test of the cement samples. In future study, chemical composition test may be conducted by SEM or XRD. In addition, soundness of cement may be tested to learn the physical properties of cement in wide range.

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APPENDICES

Appendix A: Specific Gravity Test Results of Representative Cement Samples

Specific Gravity of Cement:

Here,

Weight of specific gravity bottle/pycnometer (W1) =70 gm

Pycnometer + Kerosene (W4) =140 gm

Pycnometer + Sample Cement(W2) = 120 gm

Pycnometer + Sample Cement + Kerosene = W3

Kerosene specific gravity = 0.79

Specific Gravity of Cement = $\frac{W2-W1}{(W2-W1)-(W3-W4)\times 0.79}$

1. Shah

Pycnometer + Sample Cement + Kerosene(W3)= 182 gm

Specific Gravity = $\frac{120-70}{(120-70)-(182-140)\times 0.79}$

= 2.97

2. Crown

Pycnometer + Sample Cement + Kerosene(W3)= 182 gm

Specific Gravity = $\frac{120-70}{(120-70)-(182-140)\times 0.79}$

= 2.97

3. Scan

Here, W1= 62 gm, W2= 112 gm, W3= 176 gm, W4=140 gm

Specific Gravity = $\frac{112-62}{(112-62)-(176-140)\times 0.79}$

= 2.31

4. Fresh

Pycnometer + Sample Cement + Kerosene(W3) = 180 gm

Specific Gravity = $\frac{120-70}{(120-70)-(180-140)\times 0.79}$

= 2.71

5. Mir

Pycnometer + Sample Cement + Kerosene(W3) = 177 gm

Specific Gravity = $\frac{120-70}{(120-70)-(177-140)\times 0.79}$

= 2.40

Appendix B: Normal Consistency Test Results of Representative Cement Samples

1. Shah

Sl No	Cement (gm)	Water (%)	Water (gm)	Penetration(mm)	Time (sec)	Require water for 10 mm penetration
1	650	25%	162.5	5	30	26% or 169 gm
2	650	26%	169	10	30	

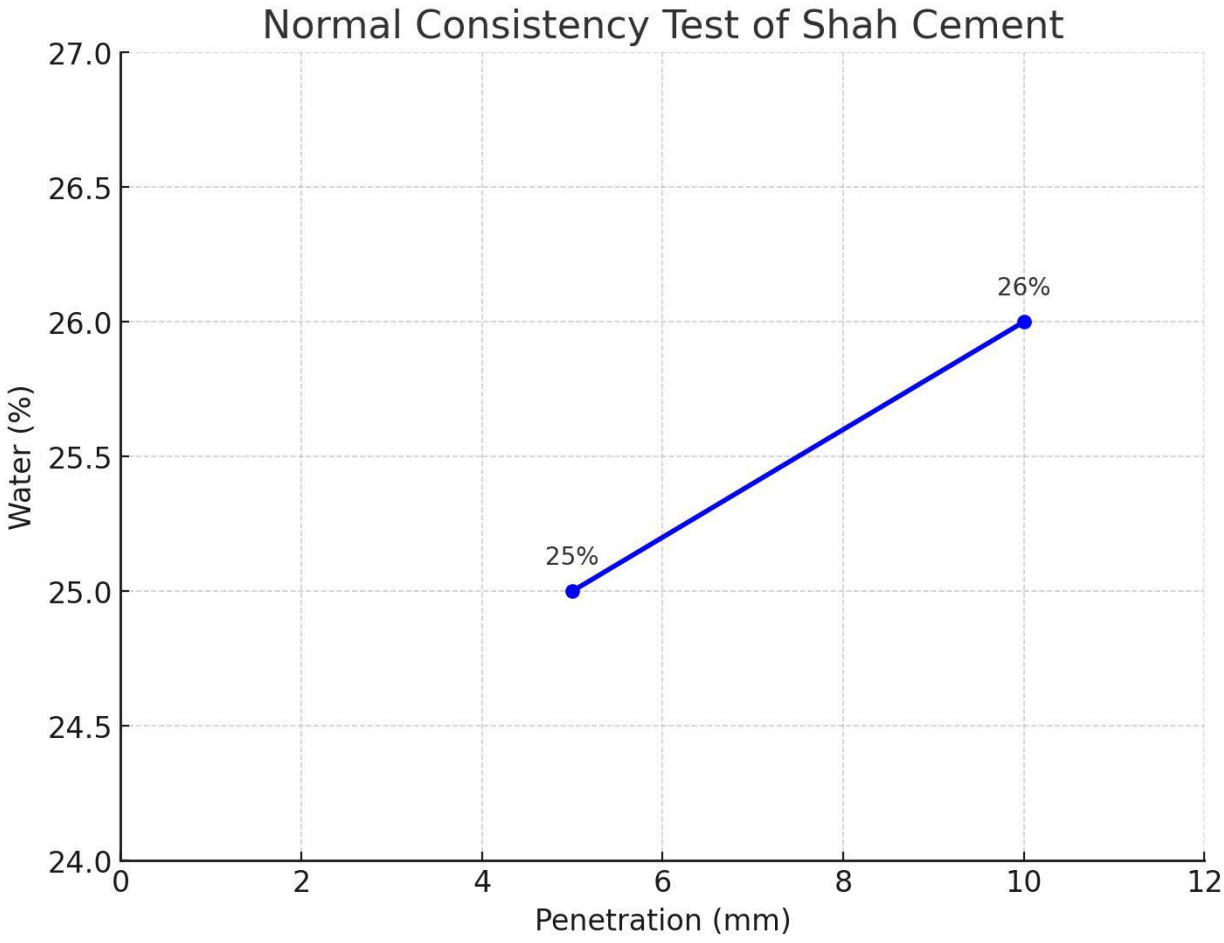


Figure B.1: Normal Consistency test of Shah Cement

2. Crown

Sl No	Cement (gm)	Water (%)	Water (gm)	Penetration(mm)	Time (sec)	Require water for 10 mm penetration
1	650	25%	162.5	1	30	27% or 175.5 gm
2	650	26%	169	4	30	
3	650	27%	175.5	10	30	

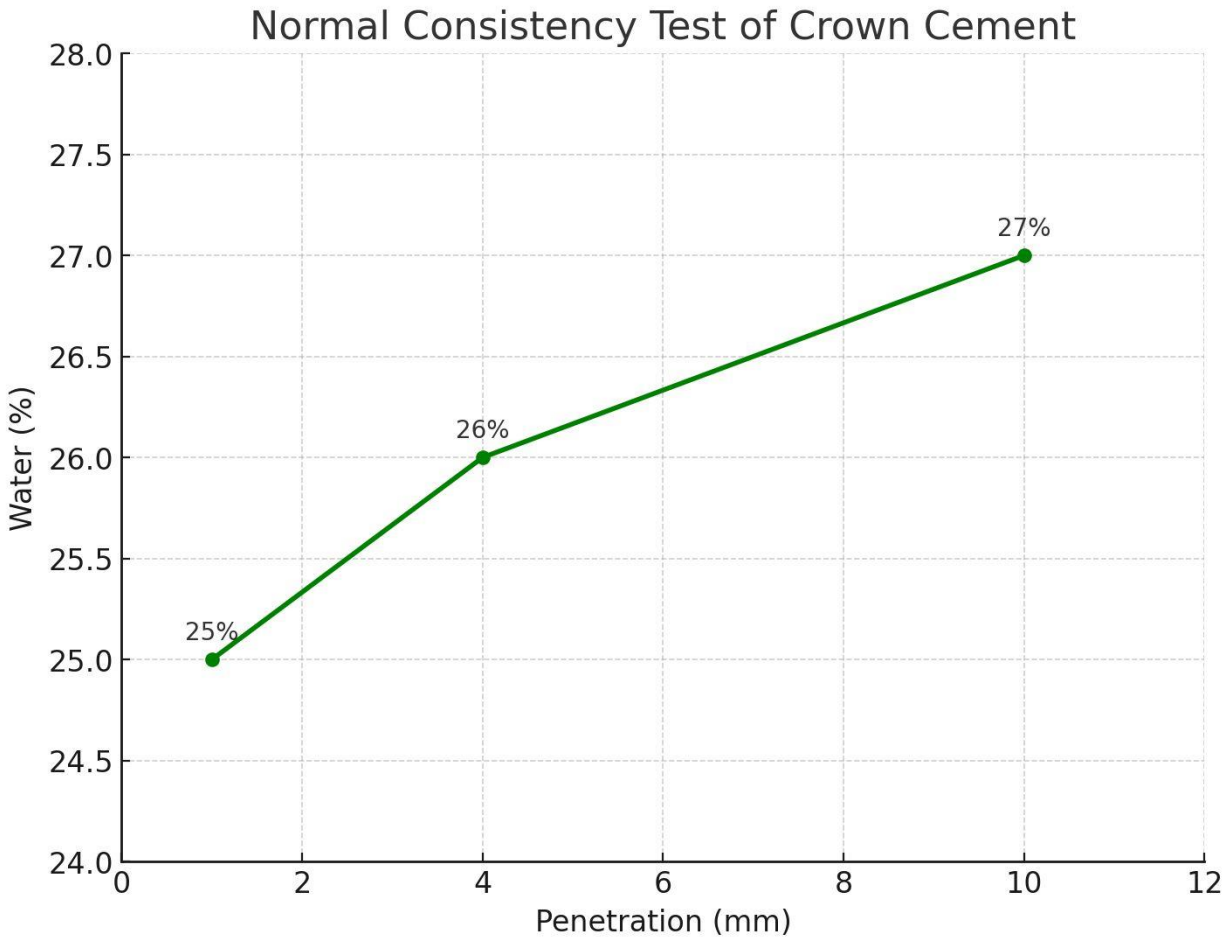


Figure B.2: Normal Consistency test of Crown Cement

3. Scan

Sl No	Cement (gm)	Water (%)	Water (gm)	Penetration(mm)	Time (sec)	Require water for 10 mm penetration
1	650	25%	162.5	5	30	26.3% or 170.95 gm
2	650	26%	169	9	30	
3	650	26.3	170.95	10	30	

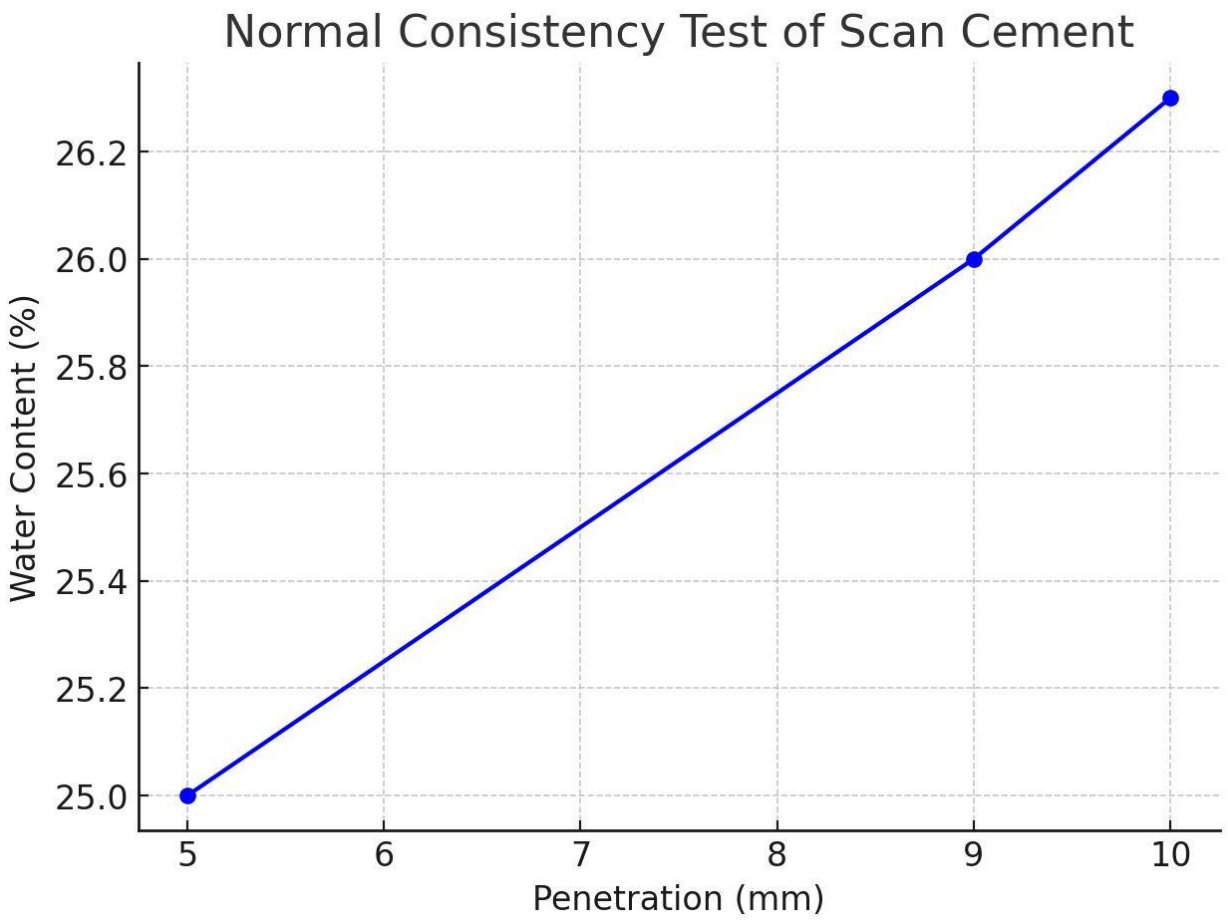


Figure B.3: Normal Consistency test of Scan Cement

4. Fresh

Sl No	Cement (gm)	Water (%)	Water (gm)	Penetration(mm)	Time (sec)	Require water for 10 mm penetration
1	650	25%	162.6	4	30	26.25% or 170.625 gm
2	650	26%	169	8	30	
3	650	26.5%	172.25	12	30	

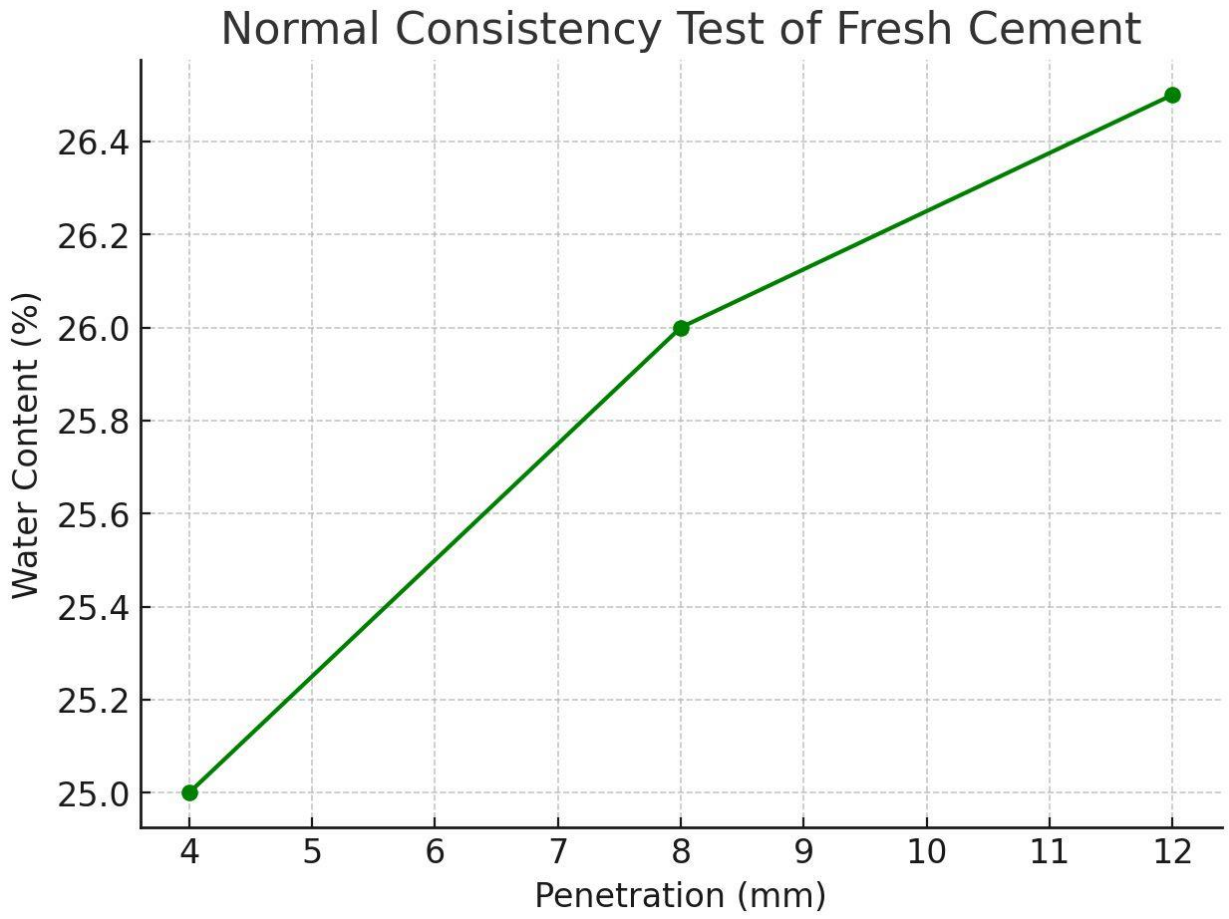


Figure B.4: Normal Consistency test of Fresh Cement

5. Mir

Sl No	Cement (gm)	Water (%)	Water (gm)	Penetration(mm)	Time (sec)	Require water for 10 mm penetration
1	650	24%	156	1.5	30	26.33% or 171.145 gm
2	650	25%	162.6	5	30	
3	650	26%	169	8.5	30	
4	650	27%	175.5	13	30	

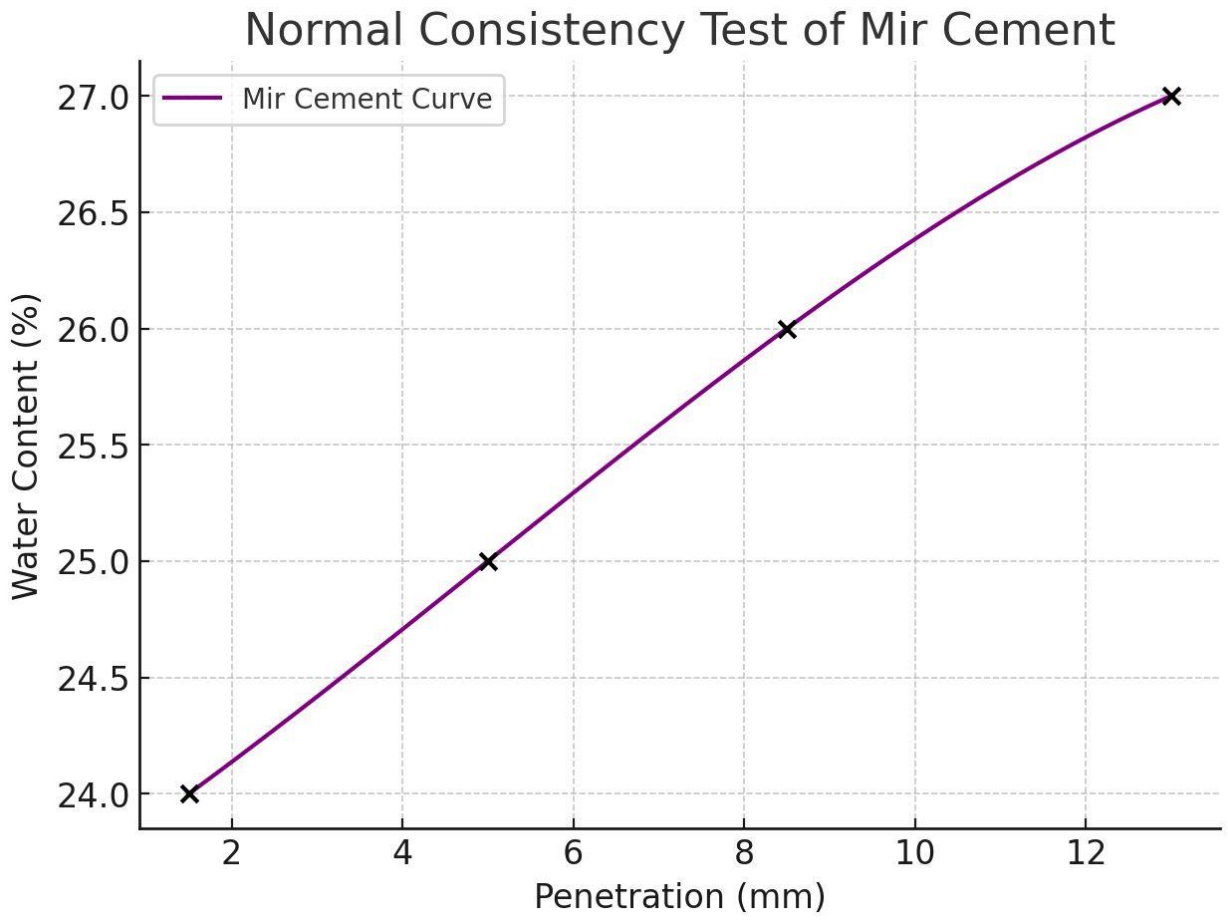


Figure B.5: Normal Consistency test of Mir Cement

Appendix C: Data and Results for Setting Time Test

Table C1: Setting time test result of representative cement sample-1 (Shah Cement)

Time (min)	30	45	60	75	90
Penetration (mm)	40	40	36	30	25
Initial setting time (25 mm)	80 min				
Final setting time (0.5mm)	227 min				

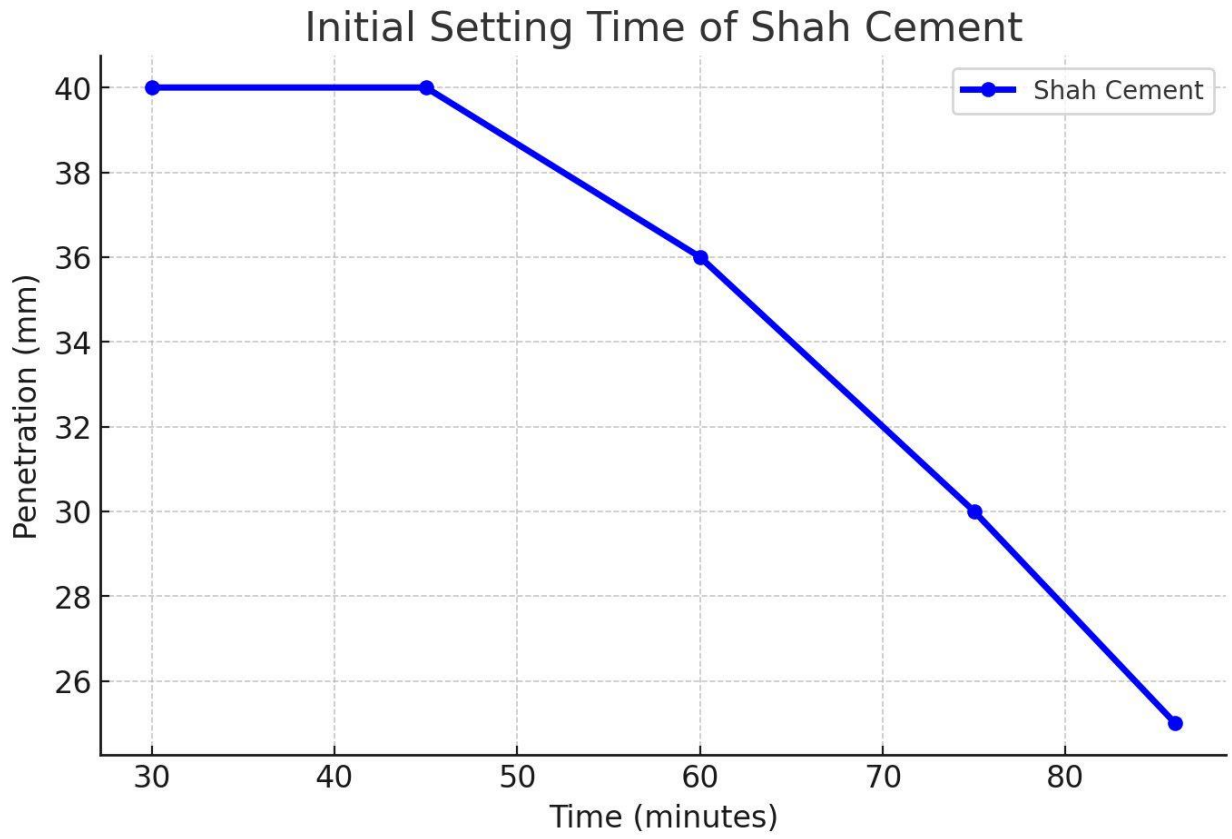


Figure C.1: Initial Setting time of Shah Cement.

Table C2: Setting time test result of representative cement sample-1 (Crown Cement)

Time (min)	30	45	60	75	90
Penetration (mm)	40	37	33	30	25
Initial setting time (25 mm)	90 min				
Final setting time (0.5mm)	179 min				

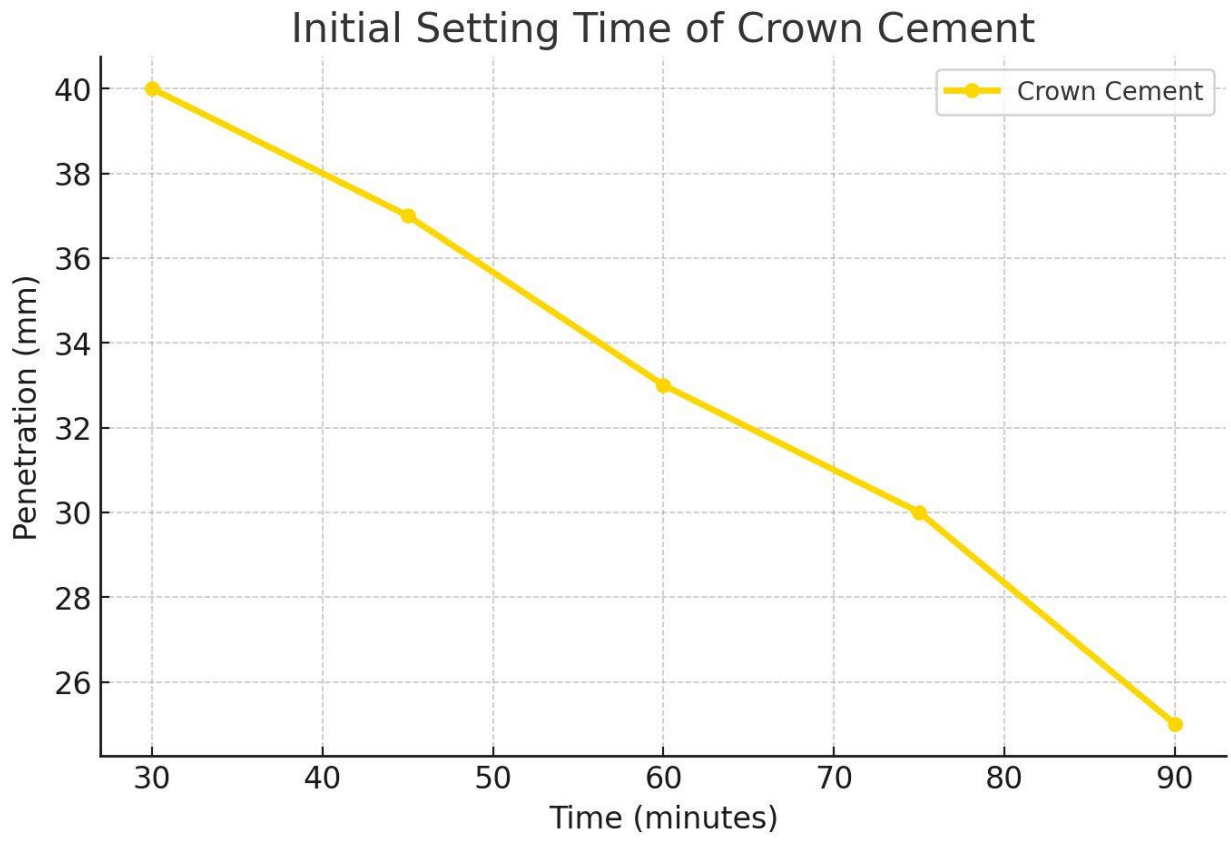


Figure C.2: Initial Setting time of Crown Cement.

Table C3: Setting time test result of representative cement sample-1 (Scan Cement)

Time (min)	30	45	60	75	90
Penetration (mm)	40	34	29	25	-
Initial setting time (25 mm)	75 min				
Final setting time (0.5mm)	195 min				

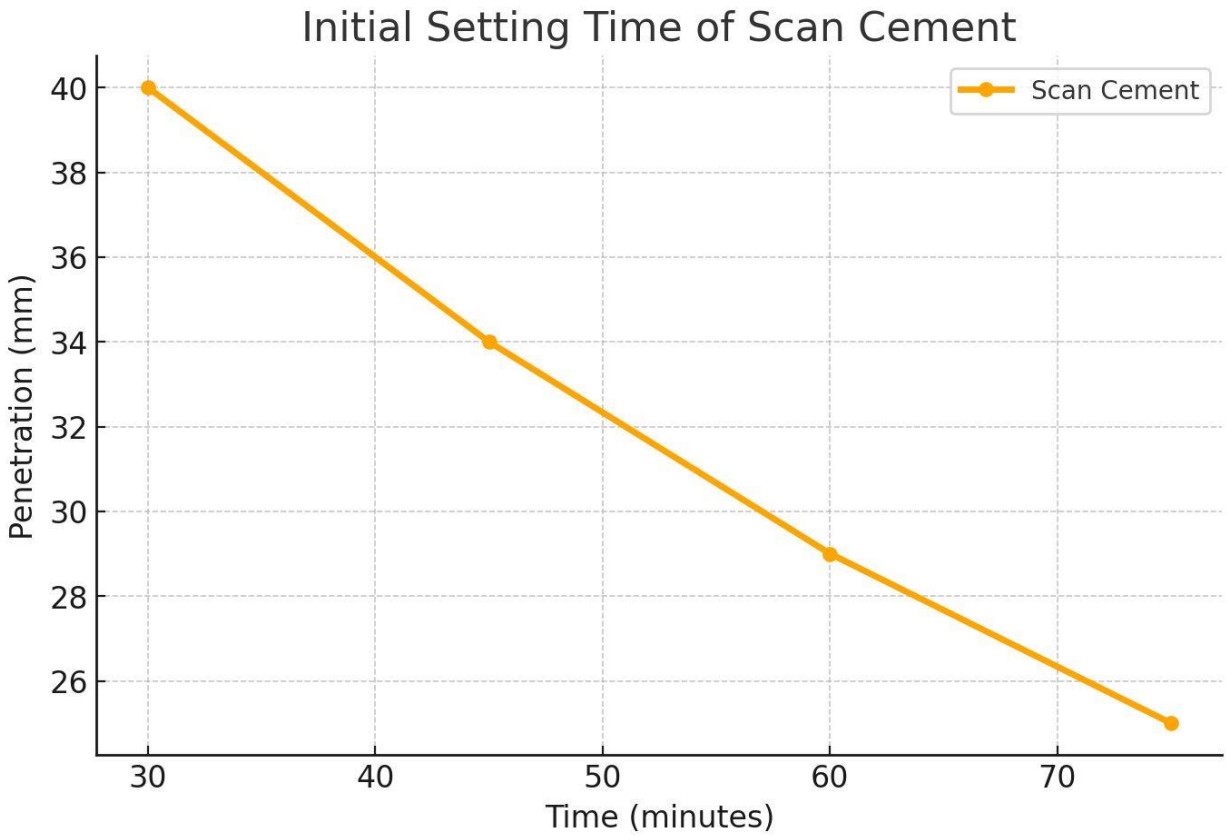


Figure C.3: Initial Setting time of Scan Cement.

Table C4: Setting time test result of representative cement sample-1 (Fresh Cement)

Time (min)	30	45	60	75	90
Penetration (mm)	40	25	-	-	-
Initial setting time (25 mm)	45 min				
Final setting time (0.5mm)	205 min				

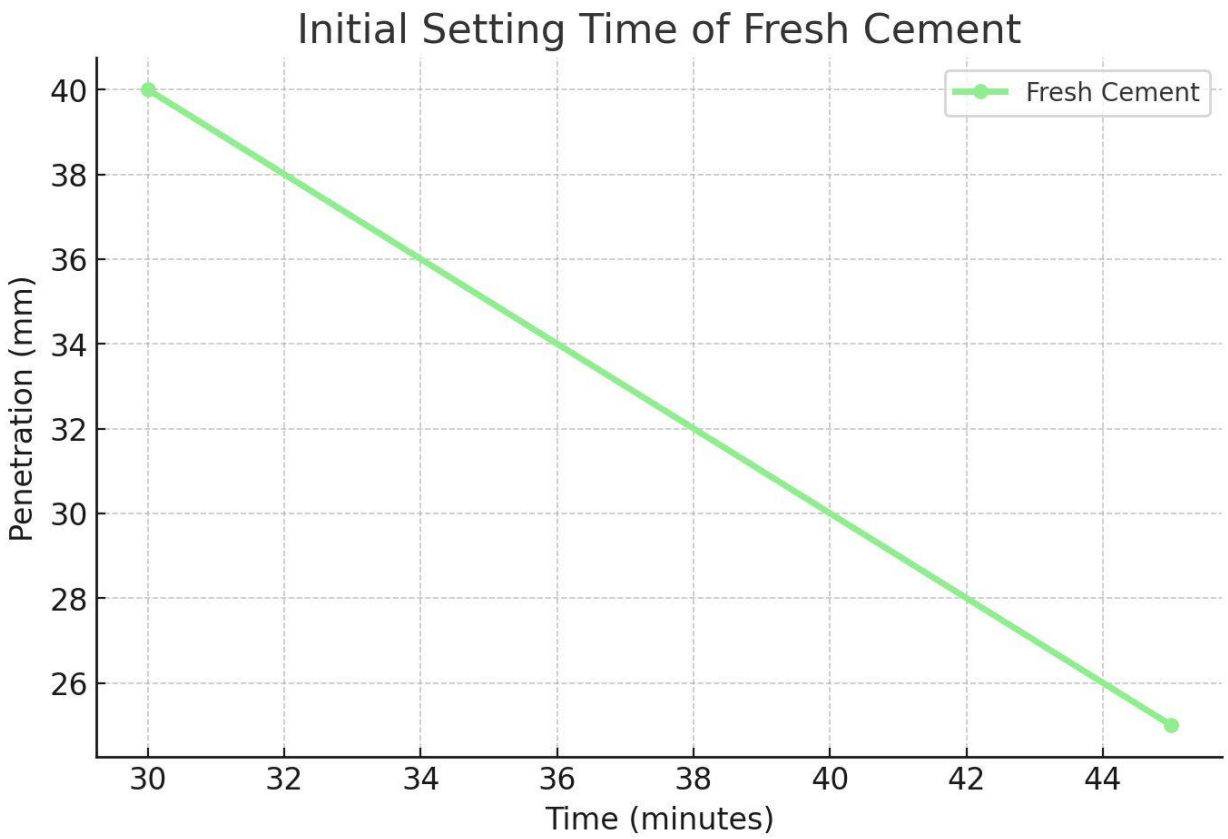


Figure C.4: Initial Setting time of Fresh Cement.

Table C5: Setting time test result of representative cement sample-1 (Mir Cement)

Time (min)	30	45	60	75	80
Penetration (mm)	40	38	33.5	27	25
Initial setting time (25 mm)	80 min				
Final setting time (0.5mm)	211 min				

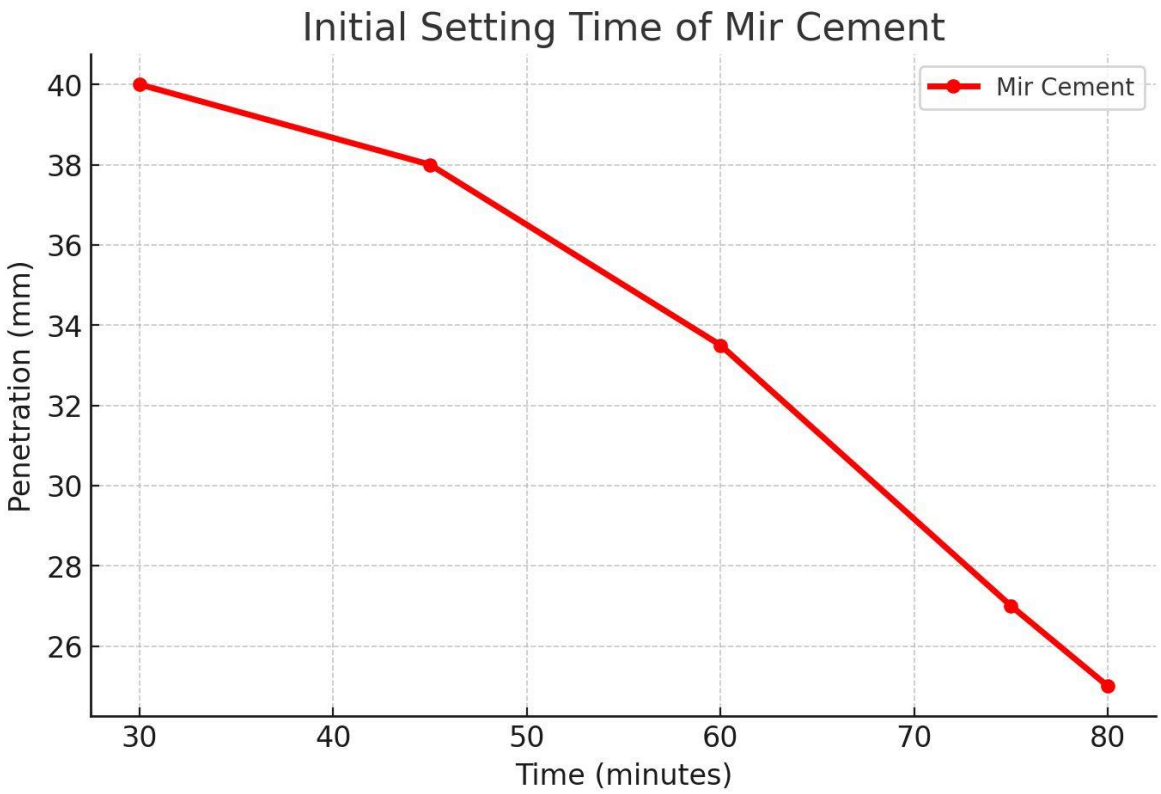


Figure C.5: Initial Setting time of Mir Cement.

Appendix D: Data and Results for Compressive Strength Test of Cement Mortars

Table D: Compressive strength test (cube) result of representative cement sample

Cement Brand	Age (days)	Specimen No.	Compressive Strength (psi)	Average Compressive Strength (psi)	Average Compressive Strength (MPa)
Shah	28 Days	1	3484.4	3765	25.96
		2	3877.8		
		3	3934		
Crown	28 Days	1	3428.2	3447	23.77
		2	3540.6		
		3	3372		
Scan	28 Days	1	4945.6	4646	32.04
		2	4383.6		
		3	4608.4		
Fresh	28 Days	1	4158.8	4159	28.68
		2	4383.6		
		3	3934		
Mir	28 Days	1	3990.2	4121	28.42
		2	4327.4		
		3	4046.4		

Appendix E: Data and Results for Compressive Strength Test of Cylindrical Concrete Specimens

Table E: Comp. strength test (cylindrical) result of representative cement sample-1

Cement Brand	Age (days)	Specimen No.	Compressive Strength (psi)	Average Compressive Strength (psi)	Average Compressive Strength (MPa)
Shah	28 Days	1	2395	2695	18.58
		2	2751		
		3	2826		
		4	2662		
		5	2839		
Crown	28 Days	1	2779	2588	17.84
		2	2251		
		3	2463		
		4	2573		
		5	2873		
Scan	28 Days	1	3125	3716	23.55
		2	3816		
		3	3927		
		4	3803		
		5	3909		
Fresh	28 Days	1	3474	3461	23.86
		2	3030		
		3	3891		
		4	3483		
		5	3427		
Mir	28 Days	1	2944	2899	19.99
		2	2758		
		3	2884		
		4	2928		
		5	2979		