QUALITY ASSESSMENT OF SELECTED CEMENT BRANDS OF BANGLADESH

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering



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Section: 21A
Summer-2024

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DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted Elsewhere for the award of any degree or diploma.

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Dedicated

to

"Mother"

"Everyone in the world will love you, in that love hides any need. But the one person who will love you unconditionally .She is our mother"

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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 cement mortars, compressive strength of cylindrical concrete, density, specific gravity and fineness of cement. Standard tests were performed on cements manufactured by ten different industries of Bangladesh. A total 300 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 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 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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CHAPTER 1
INTRODUCTION

1.1 Background and Motivations

Cement is a major ingredient of concrete structures and it plays a key role in the construction industry. The extent of use of cement depends on the rate of urbanization and the amount of development projects under taken **[1]**. Cement acts as a binding material which forms a matrix in the presence of water and fine aggregates which holds the coarse aggregates together. Hence, it becomes necessary to test cement to know its physical, chemical and mechanical properties for concrete construction works. Due to a huge demand of cement in concrete structures, enormous growth of the cement industry can be noticed in the last two decades. Consequently, concrete strength is a very important factor in construction **[2-4]**. So, it is required to investigate the quality of cement in Bangladesh. The quality assessment of some cement brands of Bangladesh has been described in the following chapters.

1.2 Research Objectives and Overview

The main objectives of this project work are

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

(ii) To conduct experimental investigations on selected cements as per ASTM guideline and hence determine their comparative performance in concrete for last two decades.

1.3 Organization of the thesis

The report is organized into five chapters. The general background, objective of the study and methodology of the work are presented.

Chapter 1: Introduction and Objective. This Chapter provide fundamental idea of the work being done under the study.

Chapter 2: Literature Review. This Chapter deals with the literature review which includes previous similar studies. In view of the Global and regional demand, production, utilization, major manufacturers, market demand are described in Chapter 2.

Chapter 3: Methodology. This Chapter all experimental procedures test set-up, testing plan and finally test matrix are presented in detail.

Chapter 4: Results and Discussion. This Chapter is composed of all experimental results, graphical presentation and discussion of the research work. The chapter also includes, their parameter and also the prediction of concrete strength at different ages.

Chapter 5: Conclusions and Future Work. This Chapter draws conclusions by summarizing the outcome of the research and new directions for further research and developments.

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 **[4]**. 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 or segmentation, pricing and export of cement.

2.2 Experimental Study

A number 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 **[7]** 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.

Swamy **[8]** published a paper on sustainable concrete for the 21st century concept of strength through durability. The objective of this paper was to show that the current emphasis on high strength and very high strength and the design philosophy of Durability through Strength for concrete materials and concrete structures is fundamentally flawed. To avoid the lack of durable performance of concrete in real life, the concrete materials must be manufactured for durability and not for strength. This study showed that the concept of Strength through

Durability can be achieved through careful design of the cement matrix and its microstructure.

Hasan and Kabir **[9]** presented a paper on prediction of compressive strength of concrete from early age test result. Objective of all studies that have been carried out was to make the concrete strength predictable and increase the efficiency of the prediction. In this paper, an attempt was made to develop a relation between concrete strength and its age.

Amudhavalli and Mathew **[10]** published a journal on effect of silica fume on strength and durability parameters of concrete. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology was led to researchers to use industrial by products as supplementary cementations material in making concrete. The main parameter investigated in this study was M35 grade concrete with partial replacement of cement by silica fume by 0%, 5%, 10%, 15% and 20%. This paper was presented a detailed experimental study on compressive strength, split tensile strength, flexural strength at age of 7 and 28 days. Durability study on acid attack was also studied and percentage of weight loss was compared with normal concrete. Test results indicated that use of silica fume in concrete had improved the performance of concrete in strength as well as in durability aspect.

Mohammed **[4]** carried out a research on Investigation of different cement brands commonly used in Bangladesh. The objective of the research work was common causes of deterioration of concrete structures in Bangladesh, common problems at construction sites that cause early deterioration of concrete structures in Bangladesh, mechanical properties of concrete made with different aggregates available in Bangladesh, investigation on different cement brands available in the market in Bangladesh, recycling of demolished concrete as coarse aggregate for new construction works and recycling of demolished concrete as fine aggregate for new construction works and making blocks.

EBL Securities Ltd. **[1, 6]** published a research on comprehensive review on Bangladesh cement industry. They focused global and regional demand of cement, production, utilization, export, major manufacturers, market demand or segmentation and pricing of cement.

According to Mohammed **[4]** a comparative study on quality assessment of cement, their physical properties and strength of concrete are described in this study. Due to conduct the research of Mohammed **[4]**, a total of 30 cement bags of different brands collected from various local dealers. After collection, each cement bag kept in an air-tight plastic bag to prevent unwanted hydration with the moisture present in air. Ingredients of cement printed on the collected cement bags were recorded. No further test conducted to re-check the composition of cement printed on the cement bags. Immediately after collection of the cement bags from the market, cement samples tested in the laboratory for normal consistency (ASTM C187), compressive strength (ASTM C109), for testing compressive strength, instead of Ottawa sand, standard graded locally available sand used. Compressive strength of cement tested at the age of 7 and 28 days. Out of the four cement bags collected from the market. Part researches are reviewed here elaborately and divided into several parts.

EBL Securities Ltd. [1, 16] 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

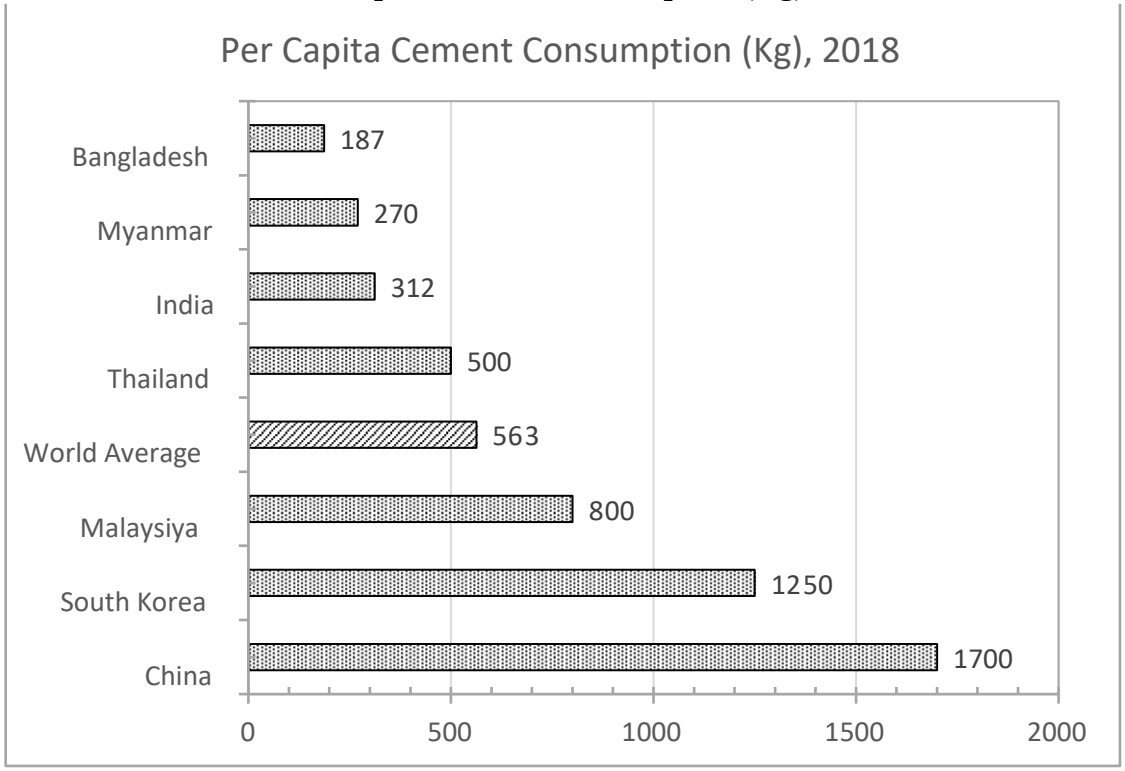
The development of cement industry in Bangladesh dates back to the early-fifties. Till 1990 about 95% of the country's demand for cement had been met through import. Some enthusiastic entrepreneurs ventured into setting up cement plants during 1997 to 2000 which opened a new era in this sector. Prior 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. 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 **[1].**

Table 2.1: Per Capita Cement Consumption (Kg) in 2016 [1].

Sl. No.	**Name of Country**	**Consumption, Kg**
1	China	1700
2	South Korea	1250
3	Malaysia	800
4	Thailand	500
5	India	312
6	Myanmar	270
7	Bangladesh	187
8	World Average	563

Table 2.2: Per Capita Cement Consumption (Kg) in 2018



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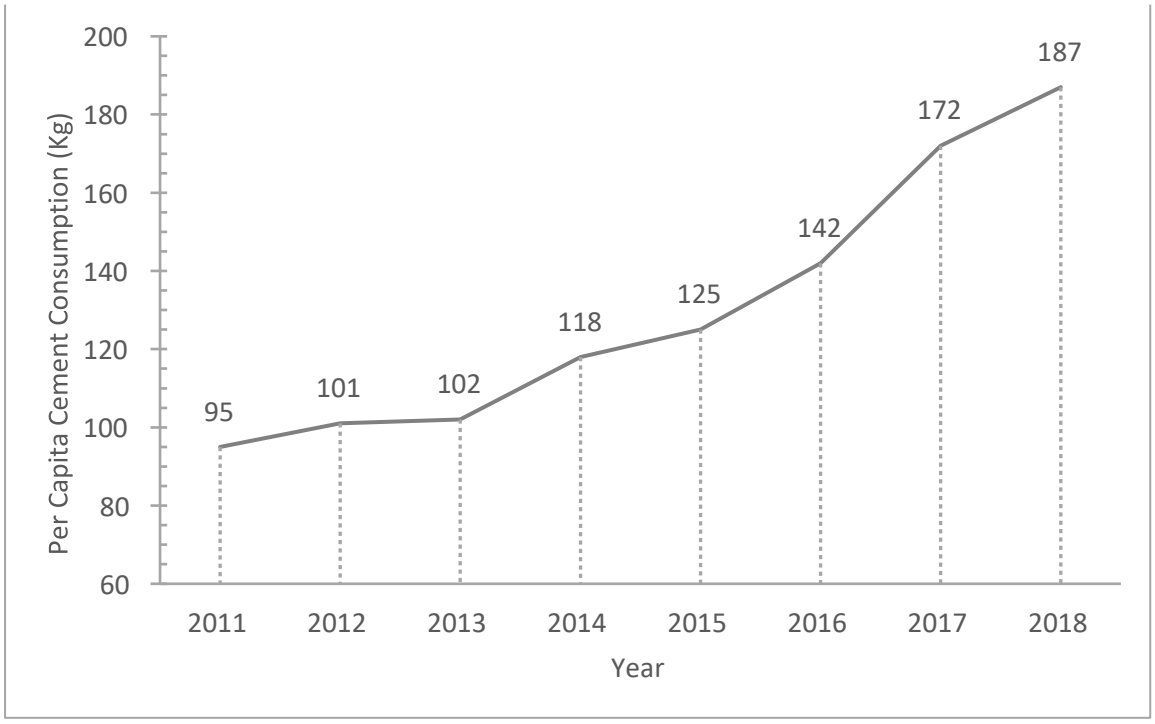


Figure 2.1: Per Capita Cement Consumption (Kg) in Bangladesh.

2.4 Use of Cement in Bangladesh

In Bangladesh, relative rapid growth of cement industry has been observed in 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. According to BDS EN 197-1 :2003, cements are mainly classified into five categories according to their composition, namely CEM-I, CEM-II, CEM-III, CEM-IV, and CEM-V. 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. 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. CEM II/A-M cement with less amount of mineral admixture (<20%) is commonly available in the market compared to CEM II/B-M which contains more amount of mineral admixture (21~35%). Cement type is Portland Composite Cement; BDS EN-197-1:2003, CEM II/B-M, strength class 42.5N, clinker 65% - 79% and lime stone 21% - 35% **[2-4]**. 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. The basic difference between them is in the manufacturing technology. Only 65% to 80% of clinker is required to produce PCC while 95% of clinker is required to produce OPC. As a result, PCC is gaining popularity worldwide due to its environmental significance **[15]**. 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.

2.5 Major Manufacturers of Cement in Bangladesh

Currently, only 34 factories are in operation, including four multinational companies. At present, 81% of the total market share is held by top ten manufacturers. Among the top 10 cement market manufacturers in Bangladesh, 8 are local and 2 are multinational. Multinational cement companies are facing intensive competition with local companies

which are grabbing the top slot of the industry by operating in economy of scale and with deft marketing strategy. MNCs now hold only 25-30% of the total market share. As a result of failure to penetrate market, two of the global cement group, UAE based Emirates Cement and Mexico-based cement manufacturer Cemex has recently divested their Bangladesh operations. However, completion of acquisition of Holcim by Lafarge Surma will reshape the industry dominance in Bangladesh as both the companies already operates own business here. After the completion of acquisition, Lafarge-Holcim has the 2nd place in terms of market share **[1, 6]**.

Table 2.3: Installed and expansion capacity of cement companies [1].

Cement Company	Promoter	Products	Brand	Installed Capacity (Million MT/Yr.)	Post Expansion Capacity (Million MT/Yr.)
Shah Cement	Abul Khair Group	OPC & PCC	Shah Cement	5.20	-
Bashundhara Group	Bashundhara Group	OPC & PCC	Bashundhara Cement & King Brand Cement	5.05	7.05
Lafarge Holcim Cement	Lafarge Holcim	Clinker, OPC, PCC & PLC	Power crete+, Super crete and Holcim	Cement: 3.40 Clinker: 1.15	-
Aman Cement	Aman Group	OPC	Aman cem.	3.75	-
Unique Cement (Fresh)	Meghna Group	OPC, PCC & Portland Pozzolana Cement	Fresh Cement	3.60	-
Seven Rings Cement	Shun Shine Group International Ltd.	OPC & PCC	Seven Rings Cement	3.50	4.40
Premier Cement	Premier Cement	OPC & PCC	Premier Cement	2.80	5.80
Heidelberg Cement	HC Netherlands Holding B.V (39.8%), HC Asia Holding GmbH, Germany (20.86%)	OPC & PCC	Scan Cement & Ruby Cement	2.38	-
Crown Cement	M.I. Cement Mills Ltd.	OPC & PCC	Crown Cement	1.74	3.50

Madina (Tiger) Cement	Madina Cement Industries Ltd.	OPC & PCC	Tiger Cement	1.69	-
Akij Cement	Akij Group	Fly-Ash Free Cement	Akij Cement	1.20	-
Royal Cement	Kabir Steel Group & BSA Group	OPC & PCC	Royal Cement	1.00	-
Anwar Cement	Anwar Group	OPC, and Portland Pozzolana Cement	Anwar Cement	1.00	-
Confidence Cement	Confidence Group	OPC & PCC	Confidence Cement	0.75	1.50
Eastern Cement	Doreen Group	OPC & PCC	Seven Horse Cement and Seven Horse Supreme	0.45	-
Mongla Cement	Sena Kalyan Sangstha	PCC	Elephant Brand Cement	0.39	-
S. Alam Cement	S.Alam Group	PCC	Minar Brand	0.36	-
Aramit Cement	Aramit Group	PCC	Camel	0.20	0.70
Mir Cement	Mir Group	OPC & PCC	Mir Cement	0.20	-
Mostafa-Hakim Cement	Mostafa-Hakim Family	OPC	Taj Mahal Cement	0.17	-

2.6 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 seven 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 2013 to 187 kg in 2018 **[6].** 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, compressive strength of cement mortars and compressive strength (cylindrical) of cement, standard tests were performed on the representative cements as per ASTM specifications. Based on the cement production, 4 different cements manufactured by 4 different industries were collected from the market to prepare 20 samples to conduct those tests. This chapter includes sample collection, major composition, test plan, test set-up, sample preparation and experimental procedure.

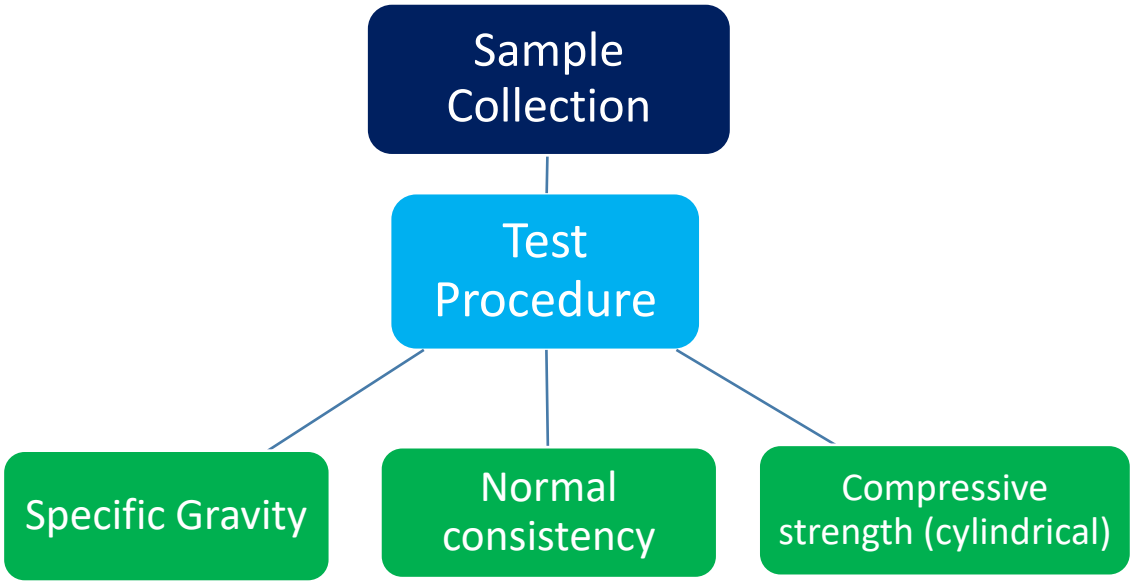


Figure3.1: Overview of Methodology

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 **[4]..** Quality assessment of CEM II/B-M type cement is justified in this analysis. There are currently 34 active and recognized companies who are operating as cement manufacturer in Bangladesh **[1]**. Among them, samples of 4 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 **[1]** 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 1971 : 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 test 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	Compressive strength (cylindrical)	ASTM C 39-04

Table 3.1. Test name and ASTM codes

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 3.15. 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 **[11]**. 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 4 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.

Specific Gravity test procedure of cement

Determination of Specific Gravity

Weigh a clean and dry Le Chatelier Flask or Specific Gravity Bottle with its stopper (W1). 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

$$\boldsymbol{Specific\ Gravity\ of\ Cement} = \frac{(\mathbf{W2-W1})}{(\mathbf{W2-W1})-(\mathbf{W3-W4})*\mathbf{Specific\ Gravity\ of\ kerosene}}$$



Figure 3.3: Photographs of sample Specific Gravity test.

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 3.4)**. 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 . 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 3.4**. 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 3.4)** to penetrate to a point 10 mm from the top of the vicat mold **(Shown Figure 3.4)**. This test method conforms to the ASTM standard requirements of specification C187-04. In this study, a total of 50 samples were prepared for normal consistency test of ten different representative cement brands of Bangladesh. Total 5 sample were prepared for each representative cement sample for normal consistency test. Normal consistency test procedure of cement is shown in **Figure 3.5** according to ASTM C 187-04.

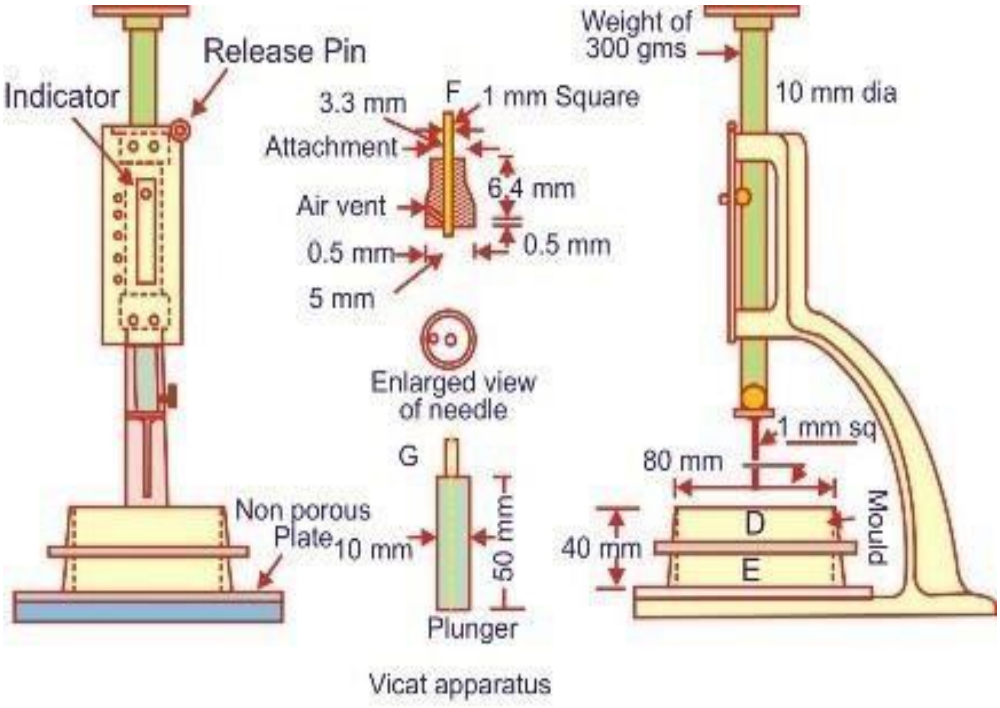


Figure 3.4: Vicat apparatus [13].

Sample preparation for normal consistency test and normal consistency determination photographs are shown in **Figure 3.5**. Before starting the cement paste preparation, 650 gm. cement have to weigh for each sample preparation **[Shown Figure 3.6 (a)]**. Before mixing water to cement **[Shown Figure 3.6 (b)]**, 24%, 26%, 28%, 30% and 32% or 156 gm. 169 gm. 182 gm. 195 gm. and 208 gm. have to measure respectively. **Figure 3.6 (c)** shows the

cement mortar mixing for sample preparation and **Figure 3.6 (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%, 25%, 26% and 27% of cement respectively. 30s time was allowed for the absorption of the water **[14]** 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 **[15].**

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 centerd 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.



Figure 3.6: Photographs of sample preparation (a, b and c) and test set-up (d) for normal consistency test

3.4.3 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 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 **[12].**

The test method conforms to the ASTM standard requirements of specification ASTM C39. 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 20 MPA (3000 psi) is considered .Sylhet (FM ≥ 2.50) sand as fine aggregates and 20 mm down-bricks chips as coarse aggregates are used for testing compressive strength of cylindrical concrete specimens. In this part of the experimental investigation, 6 samples were prepared

to investigate for each age (7and 28) days of compressive strength of representative cement sample of cylindrical concrete specimens. Compressive strength test procedure of cylindrical concrete specimens is shown in **Figure 3.7** according to ASTM C 39-04. Therefore, a total of 24 samples were prepared for compressive strength test of cylindrical concrete specimens of representative cement sample.

Figure 3.9 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

Preparation of cylindrical specimens

Each mold was filled with concrete in three layers and tamping each layer 25 times with 16 mm (5/8 in.) steel tamping rod. The 2^{nd} and 3^{rd} 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 min. before the test was carried out. Then the cross-sectional area was checked of the specimens.

The load rate was 35±7 psi/s. Fracture types were observed very carefully (Shown in **Figure 3.7**).

Figure 3.7: Compressive strength test procedure of cylindrical specimens [15, 16].

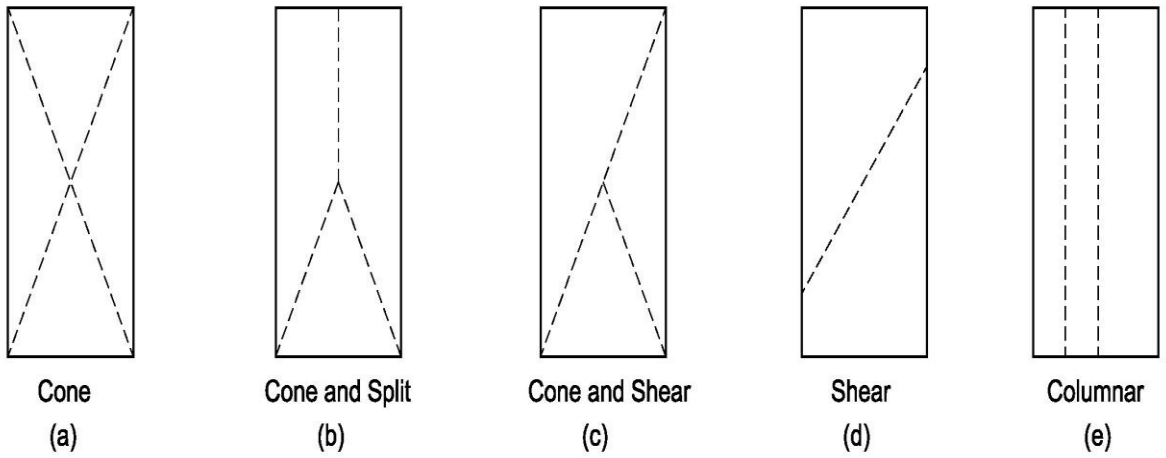


Figure 3.8: Sketches of types of fracture [16].

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 3.9: 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 (cylindrical) 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 four cement

brands of Bangladesh that makes a total 40 numbers of samples. Detail sample numbers of different tests and category are presented in Table 3.2.

Table 3.2. Test Name and Sample Quantity

Sample No. for the Test of Cement					
Seleted Cement Sample	Specific Gravity	Normal Consistency Test	Compressive strength of cylindrical concrete Test		
			7 days	28 days	Total Test Sample
Holcim	1	3	3	3	**10**
Shah	1	3	3	3	**10**
Fresh	1	3	3	3	**10**
Seven Horse	1	3	3	3	**10**
G. Total	**4**	12	**12**	**12**	**40**

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

Based on the experimental set-up and test procedure as presented in Chapter 3, Tests are conducted on 40 samples to obtain the physical properties of four 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 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 previous available study.

4.2 Specific Gravity of Cements

Specific gravity test of cement samples was conducted as per ASTM C 188-95.

The specific gravity of cement of all four manufacturers is shown in **Figure 4.1.** It is observed from the figure that the specific gravity of Bangladeshi cement varies in a range of 2.91 to 3.15. According to the ASTM standard, the specific gravity of cement is generally about 3.12-3.19. The mean value 3.082 is very close to the ASTM standard.

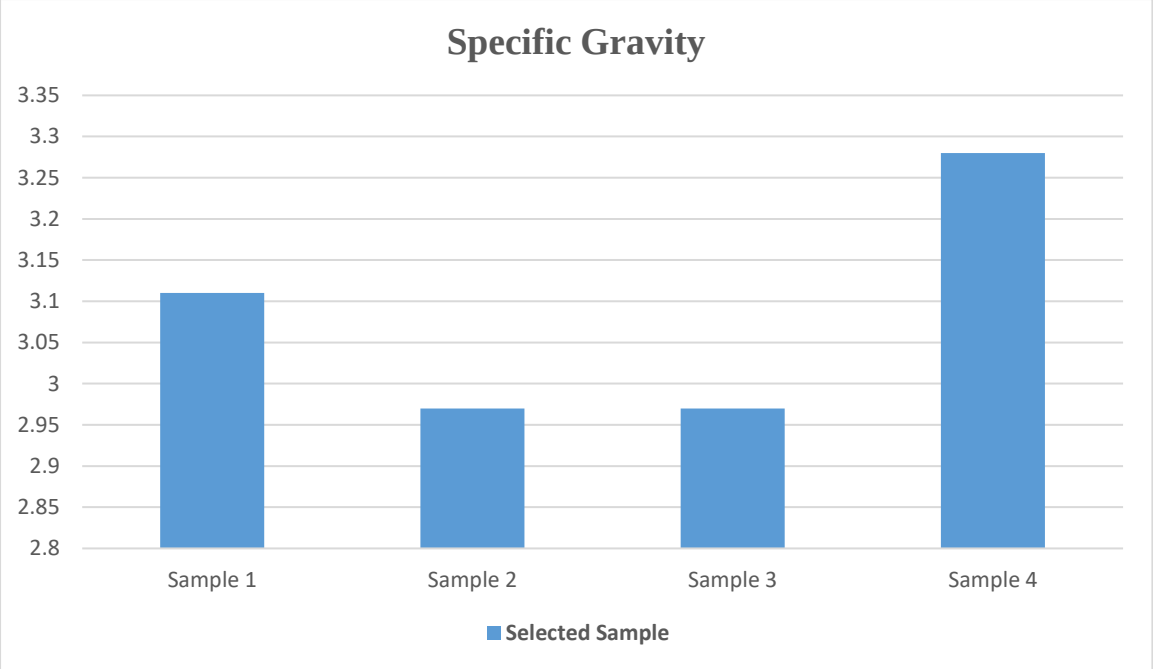


Figure 4.1: Specific Gravity of Selected cement samples

4.3 Normal Consistency Test Results

Normal consistency test of cement samples was conducted as per ASTM C 187-04. The variation of penetration with water content of 4 selected cement samples for normal consistency test is shown in **Figure 4.2**. It is found that the penetrations of three selected cement samples (out of four) are almost same because their trend lines pass very closely. The penetrations of 1 cement sample 4 are different from the others. Therefore, Seven Horse does not follow ASTM guidelines. The figure shows that with the increase of penetration depth, normal consistency of cement decreases. The variation of normal consistency of representative cement sample with mean value is shown in **Figure 4.3**. According to the ASTM C 187, normal consistency of cement is 22~30%. The result shows that almost 75% of the representative cement samples are very close to the ASTM limit of normal consistency. Instead of falling the consistence of cement in a range of 22-30%, From **Figure 4.2**, it can be seen that the mean value of normal consistency is 27.73%. It represents that normal consistency is just higher than the ASTM range **[4]**..

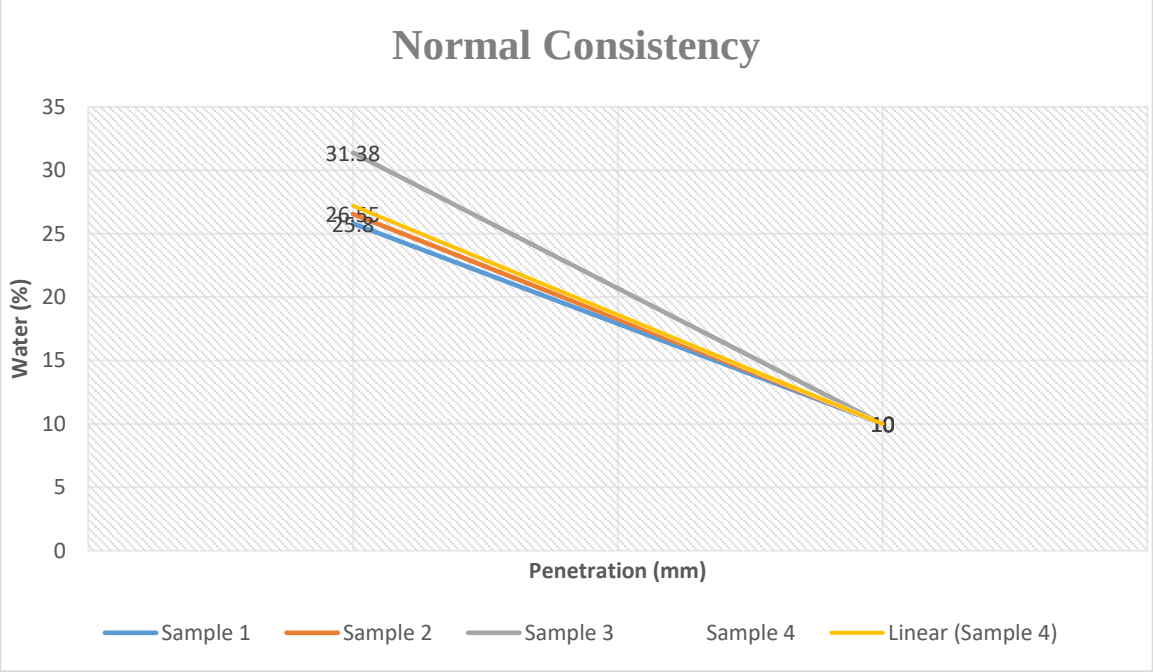


Figure 4.2: Normal consistency of Sample 1-4.

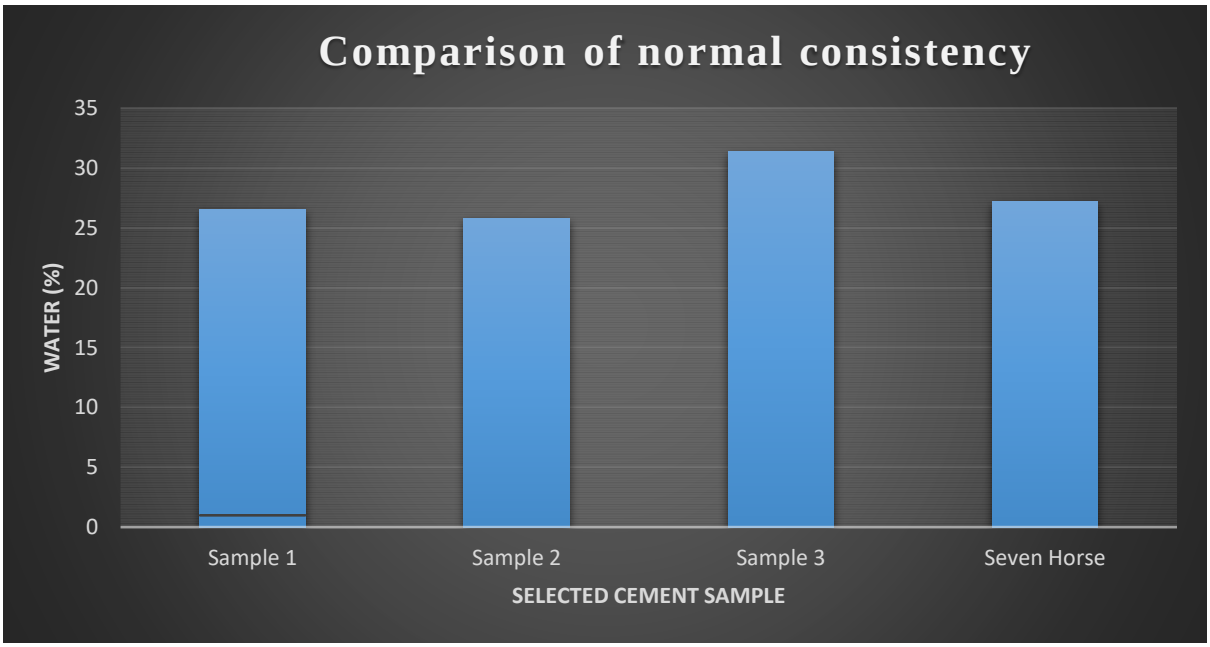


Figure 4.3: Normal consistency of selected cement samples

4.4 Compressive Strength of Cylindrical Concrete Specimens

Tests on compressive strength of cylindrical concrete specimens were conducted as per

ASTM C 39-04. The detail test procedure and test mechanism are presented in Chapter 3 Section 3.4.3. The variation of compressive strength of cylindrical concrete specimens is shown in **Figure 4.4**. Composition of cylindrical are- Cement: Sand: Bricks aggregate = 1: 1.5: 3 and Water–Cement ratio = 0.50. As per, 28-days compressive strength 24 MPA (2000 psi) is considered. According to the ASTM standard, the minimum strength to achieve at, 7 days and 28 days are 65% and 99%, respectively. In view of that, minimum compressive strength at testing ages of 7 days and 28 days are required to be 8.27 MPA (1200 psi) and 13.78 MPA (2000) psi respectively (for Bricks chips). However, all representative cement samples satisfy the 28-days ASTM requirement of strength. Mean value 9.26 MPA (1344 psi) for 7-days, mean value 14.12 MPA (2049 psi) for 28-days.

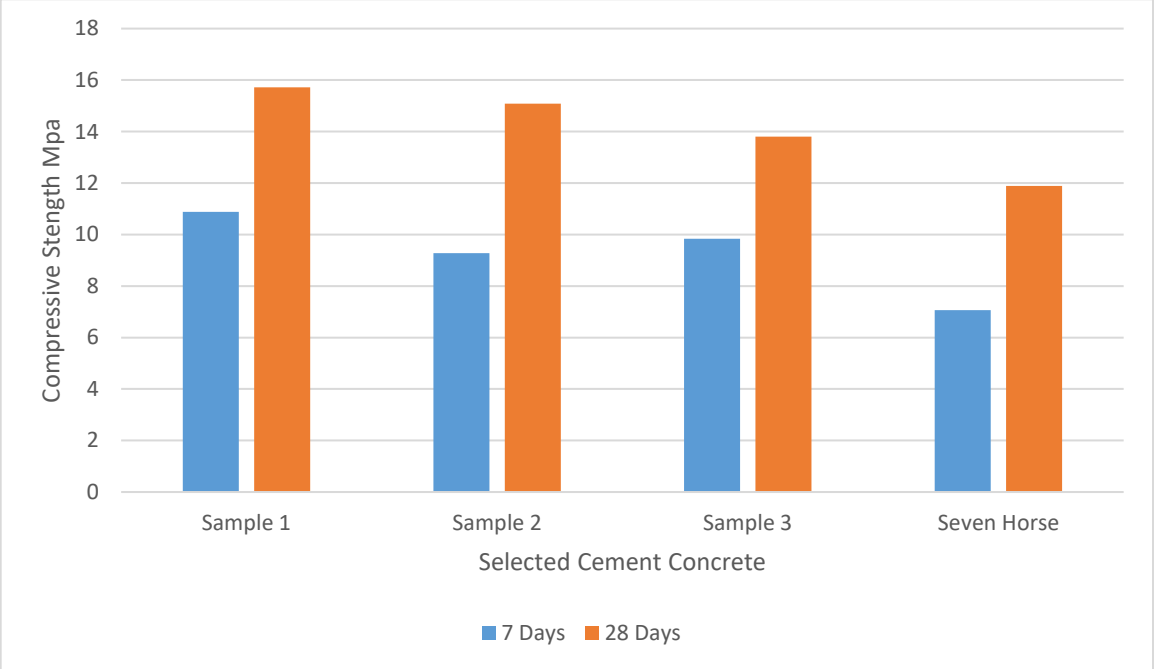


Figure 4.4: Compressive strength(Cylindrical) of selected cement concrete .

4.5 Summary of Findings

In this study, a total 40 numbers of selected 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 specific gravity showed that the mean of all tested samples is 3.082 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 very close to ASTM range, it can be concluded that specific gravity of Bangladeshi cements 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 a bit higher consistency than the ASTM range. 75% 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 28.0~32% rather (22-30%) with a mean value of normal consistency is 27.73 %.

iii. According to the ASTM standard of compressive strength of cylindrical concrete specimens, the minimum rates of strength gaining are 7 days 65% and 28 days 99%. The mean value 9.26 MPA (1344 psi) for 7-days and mean value 14.12 MPA (2049 psi) for 28-days.

CHAPTER 5
CONCLUSIONS AND FUTURE WORKS

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, compressive strength (cylindrical) and specific gravity standard tests were performed on cements manufactured by ten different industries of Bangladesh. A total 44 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.

In addition, Regression analysis are conducted using the tested results. This study also provides the relationship between compressive strength at different ages, between mortar and cylinder strength, fineness and compressive strengths. Moreover, the results are compared with existing study in some cases. The key findings from this study can be summarized as follows:

1. The experimental results on the specific gravity of all representative cement samples are very close and the differences among the specific gravities are very low. The Specific of cement varies in range 2.91 to 3.15 gm. /cm^3 with a mean density of 3.082 gm. /cm^3. Only one out of 2 industries shows a Specific Gravity below 3.0 gm. /. The

range is also very close to the ASTM standard value of 3.15 gm. /cm^3. Therefore, it can be concluded that the density of Bangladeshi cement shows a standard following ASTM guideline.

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. 75% 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 22-30% with a mean value of normal consistency is 27.73 %.
3. According to the ASTM standard of compressive strength of cylindrical concrete specimens, the minimum rates of strength gaining are 7 days 65% and 28 days 99%. The mean value 9.26 MPA (1344 psi) for 7-days, mean value 14.12 MPA (2049 psi) for 28-days.

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.

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 ten different manufacturers are considered as the representative cements.
2. Due to limitations, this study did not consider the Setting time test, fineness Test, Compressive strength of cement mortars, chemical composition tests 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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PA 19428-2959, United States.

Appendix A

1. Specific Gravity test result of representative cement sample-Holcim

$$Sg = \frac{(172-122)}{(172-122)-(372-329)*0.79}$$

$$=3.11$$

2. Specific Gravity test result of representative cement sample-Shah

$$Sg = \frac{(172-122)}{(172-122)-(375-333)*0.79}$$

$$=2.97$$

3. Specific Gravity test result of representative cement sample-Fresh

$$Sg = \frac{(172-122)}{(172-122)-(371-329)*0.79}$$

$$=2.97$$

4. Specific Gravity test result of representative cement sample-Seven Horse

$$Sg = \frac{(172-122)}{(172-122)-(376-331)*0.79}$$

$$=3.28$$

Appendix B

Table D1: Normal consistency test result of representative cement sample-Holcim.

Sl. No	Cement (gm.)	Water (%)	Water (gm.)	Penetration (mm)	Time (s)	Required Water for 10mm Penetration
1	650	24	156	4	30	26.55% OR 172.57 gm.
2	650	25	162	7	30	
3	650	26	169	8	30	
4	650	27	175.5	14	30	

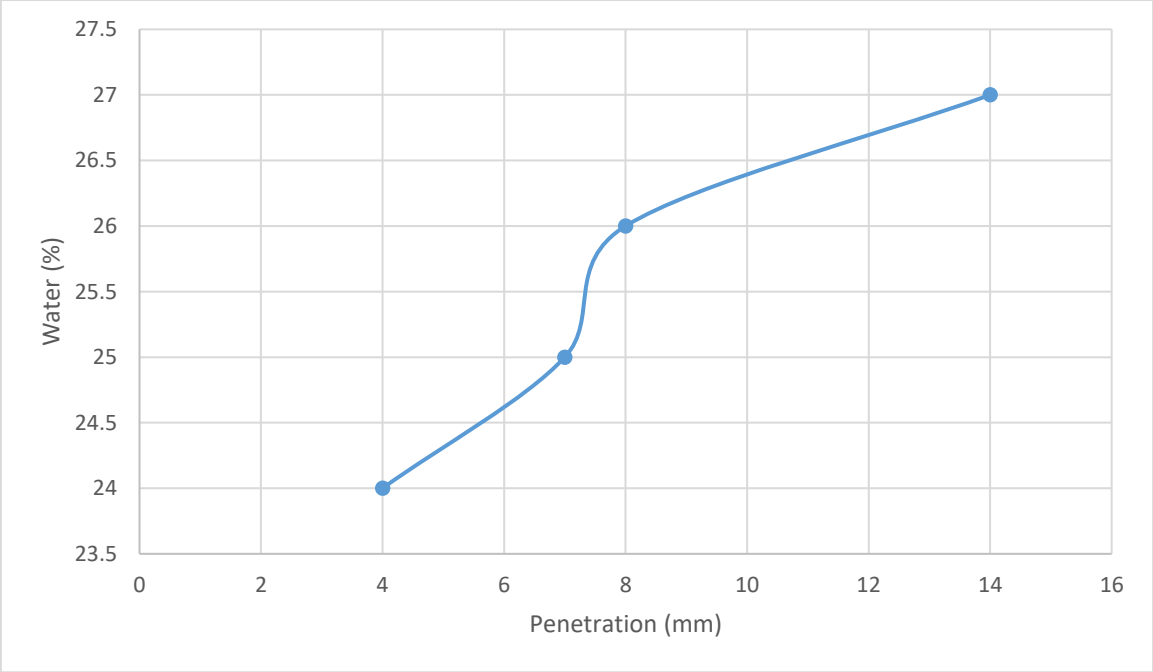


Figure D1: Normal consistency of representative cement sample-Holcim

Table D2: Normal consistency test result of representative cement sample shah

Sl. No	Cement (gm.)	Water (%)	Water (gm.)	Penetration (mm)	Time (s)	Required Water for 10mm Penetration
1	650	24	156	5	30	25.80 OR 167.7 gm.
2	650	25	162.5	7	30	
3	650	26	169	12	30	
4	650	25.80	167.7	10	30	

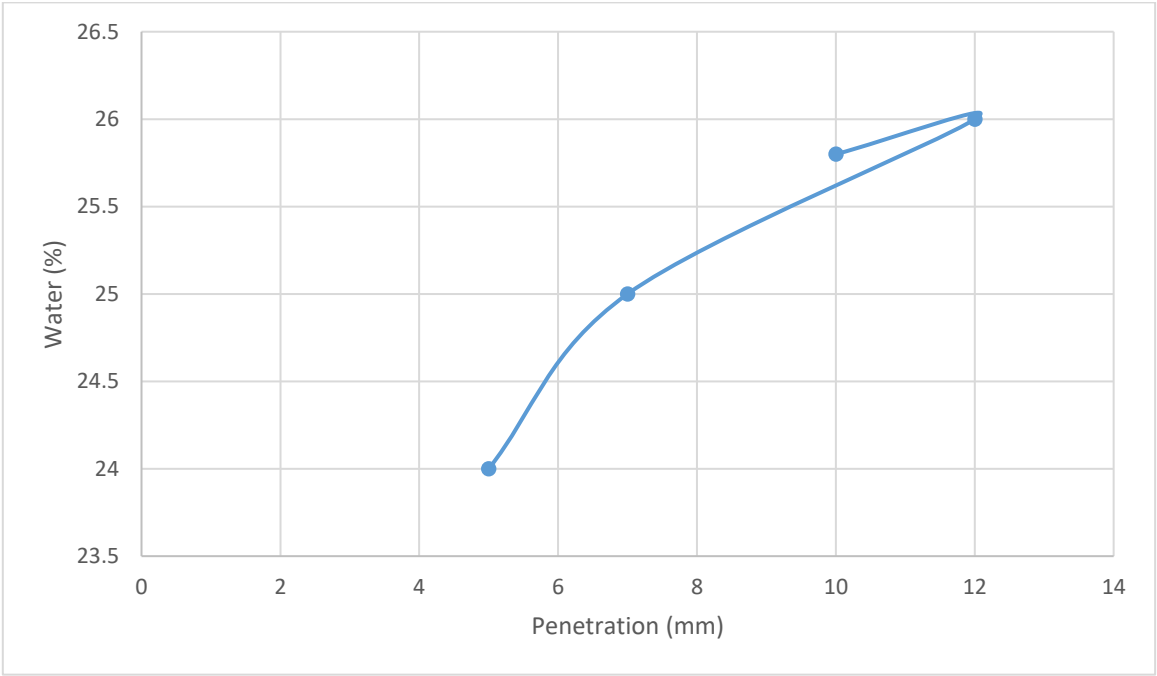


Figure D2: Normal consistency of representative cement sample-Shah

Table D3: Normal consistency test result of representative cement sample-Fresh

Sl. No	Cement (gm.)	Water (%)	Water (gm.)	Penetration (mm)	Time (s)	Required Water for 10mm Penetration
1	650	24	156	.5	30	31.38% OR 203.97 gm.
2	650	25	162	6.5	30	
3	650	26	169	9	30	
4	650	27	175.5	12	30	

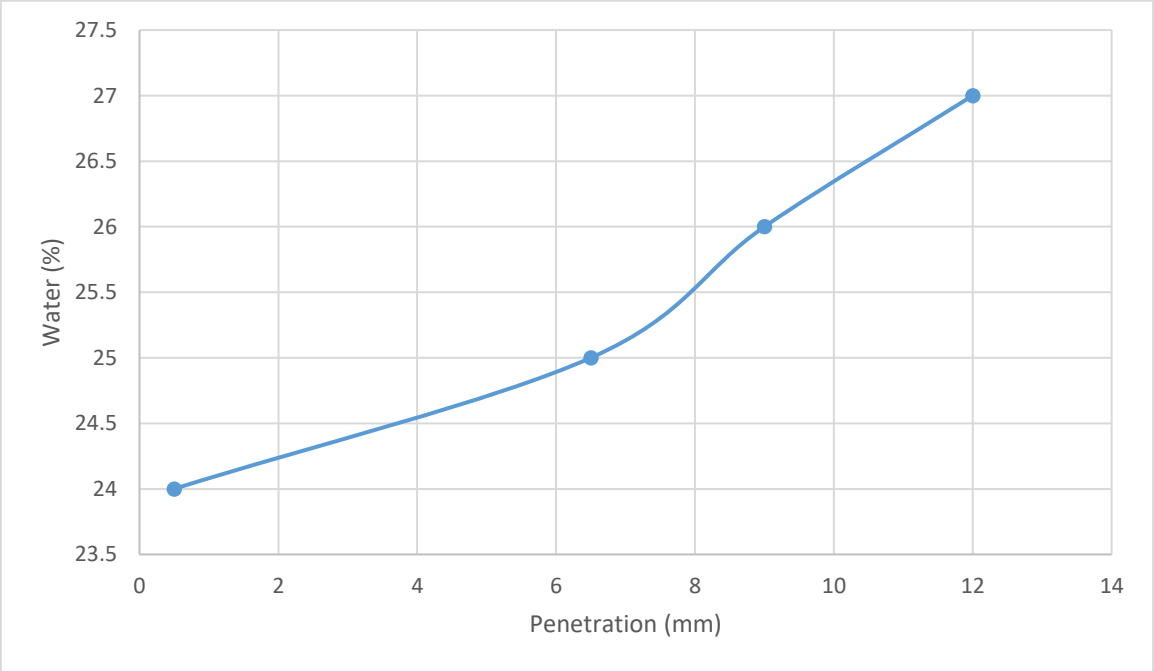


Figure D3: Normal consistency of representative cement sample-Fresh

Table D4: Normal consistency test result of representative cement sample-Seven Horse

Sl. No	Cement (gm.)	Water (%)	Water (gm.)	Penetration (mm)	Time (s)	Required Water for 10mm Penetration	
1	650	24	156	6.5	30	27.2% OR 176.8 gm.	
2	650	25	162.5	8	30		
3	650	26	169	9	30		
4	650	27	175.5	14	30		

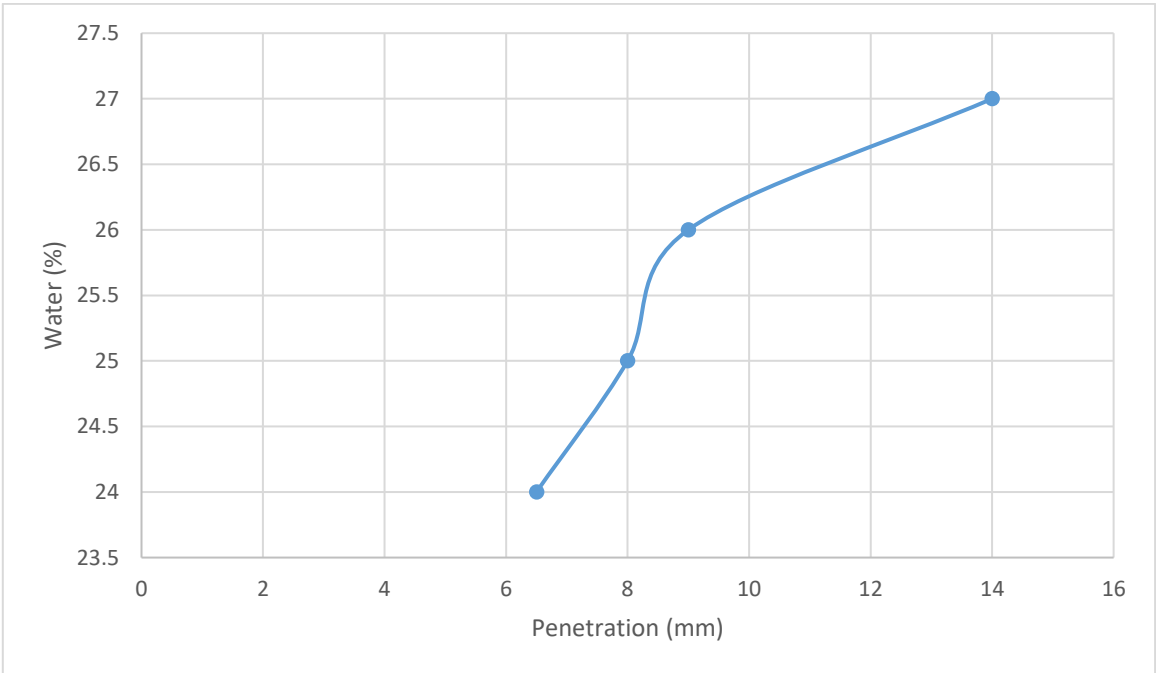


Figure D4: Normal consistency of representative cement sample-Seven Horse

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

Table F1: Compressive strength test (Cylindrical) result of representative cement sample-Holcim.

Age (days)	Date of Testing	Specimen No.	Compressive Strength (MPA)	Average Compressive Strength (MPA)	Average Compressive Strength (psi)
7	29.03.24	1	10.90	10.88	1577.70
		2	11.36		
		3	10.37		
28	19.04.24	1	17.72	15.72	2281.16
		2	15.04		
		3	14.41		

Table F2: Compressive strength test (Cylindrical) result of representative cement sample-Shah

Age (days)	Date of Testing	Specimen No.	Compressive Strength (MPA)	Average Compressive Strength (MPA)	Average Compressive Strength (psi)
7	29.03.24	1	8.99	9.28	1345.13
		2	9.23		
		3	9.60		
28	19.04.24	1	15.80	15.09	2189.17
		2	15.55		
		3	13.91		

Table F3: Compressive strength test (Cylindrical) result of representative cement sample-Fresh

Age (days)	Date of Testing	Specimen No	Compressive Strength (MPA)	Average Compressive Strength (MPA)	Average Compressive Strength (psi)
7	29.03.24	1	10.41	9.84	1427.667
		2	10.54		
		3	8.56		
28	19.04.24	1	14.88	13.81	2003.68
		2	12.61		
		3	13.93		

Table F4: Compressive strength test (Cylindrical) result of representative cement sample -Seven Horse.

Age (days)	Date of Testing	Specimen No	Compressive Strength (MPA)	Average Compressive Strength (MPA)	Average Compressive Strength (psi)
7	29.03.24	1	6.74	7.075	1026.33
		2	7.34		
		3	7.13		
28	19.04.24	1	11.33	11.89	1725.90
		2	12.03		
		3	12.32		