FINENESS OF INDIGENOUS CEMENTS OF BANGLADESH AND ITS EFFECTS ON INITIAL AND FINAL SETTINGS

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ABSTRACT

Cement is the most common construction materials. It is expected that finer cement provides larger surface area for hydration thus sets early. But, due to other contents like fillers, gypsum etc. this phenomenon can be different. Non-structural cracks usually form on a mortar-plastered surface due to a number of different causes. Bangladesh being a developing country, construction industries are booming in the recent years. Thus, cement property tests have become an important quality control measure for concrete production. This paper will provide guidance to ensure cement quality by observing the general value of fineness of local cement brands and effect of fineness on consistency, initial and final setting times. Cracks developed on plastered surfaces under different curing conditions are also studied. It is found that consistency increases with increased fineness whereas setting times decreases. Insufficient curing leads to more cracks than prolonged curing (up to 7 days) aided low crack formation. Results suggested requirement of extended curing for at least 7 days and more.

KEY WORDS: Fineness, curing, hydration, gradation, setting time, consistency, cracks.

1.0 INTRODUCTION

Cement is the most widely used binder for civil constructions all over the world. The quality of cement is great concern for the engineers, contractors, owners. A band of composite cement has been introduced in our country in recent time. To improve cement performance, these cements are introduced with a range of fillers (i.e. fly ash, pozzolana, slag etc.). However, due to mixture of these materials with different proportions, total surface area taking part in hydration may vary and eventually govern ultimate product; concrete quality. Non-structural cracks usually form on a mortar-plastered surface due to a series of causes i.e. cement content, water content, curing condition, aging, hydration rate etc. As cement occupies a significant volume of mortar for plastering work, its setting and hardening behavior is expected to affect crack generation. Thus, it is important to get a relation between setting time and fineness to picture the cement quality and crack generation on plastered surface. Bangladesh is growing with its construction industry in the recent years. Cement consumption is effective parameter to indicate growth of concrete industry. Bangladesh produced more than 5.1 million metric tons of cement every year. Thus, cement property tests have become an important quality control measure for concrete production. The result of the research will guide engineers and contractors to ensure cement quality.

2.0 OBJECTIVE

The objectives of this paper are given as follows:

- To determine fineness of cements of indigenous cement brands.
- To establish a relation between setting time and fineness of those local cements.
- Finally, to investigate the crack scenario on cement mortar prepared by various cements with varied fineness.

3.0 LITERATURE REVIEW

Fineness is one of the major physical properties of cement affecting the rate of hydration. It is the total surface area of cement that represents the material available for hydration. Thus, the rate of hydration depends on the fineness of the cement particles and for rapid development of strength, high fineness is necessary; the long term strength is not affected.

A higher early rate of hydration means, of course, also a higher rate of early heat evolution. Greater fineness increases the surface available for hydration, causing greater early strength and more rapid generation of heat. An increase in fineness increases the amount of gypsum required for proper retardation as in finer cement, more C_3A is available for early hydration (Neville, 2000). The water content of a paste of standard consistence is greater the finer cement, but conversely an increase in fineness of cement slightly improves the workability of a concrete mix. Higher grinding leads to higher strength concrete. But energy consumption is a determining factor. Thus fineness is a vital property of cement and has to be carefully controlled.

Higginson (1970) summarized major findings of research by Bureau of Reclamation that was incorporated by American Society for Testing and Materials (ASTM). The relation between fineness and bleeding along with time is shown in **Figure 1** and **Figure 2**. This trend indicates that bleeding reduces exponentially with fineness of cement. **Figure 3** shows effect of fineness on compressive strength and indicate that increased fineness have a beneficial effect on non-air- and air-entrained concrete.

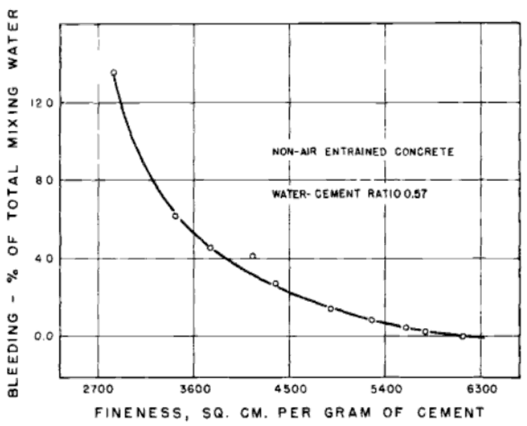

Figure 1: Effect of cement fineness on bleeding of concrete

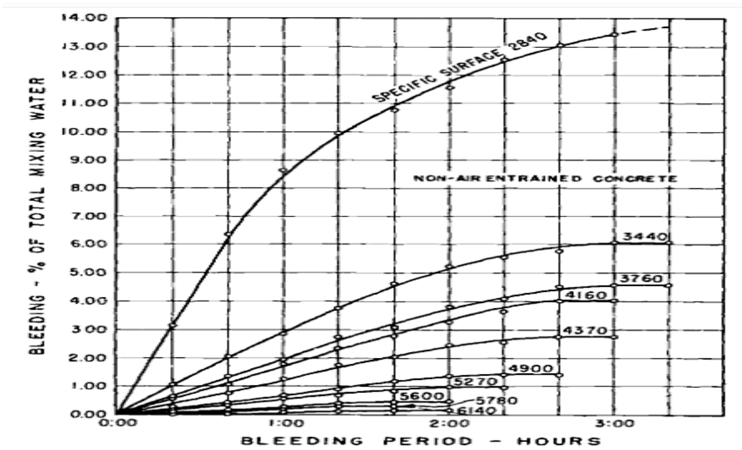

Figure 2: Effect of fineness on rate of bleeding of concrete

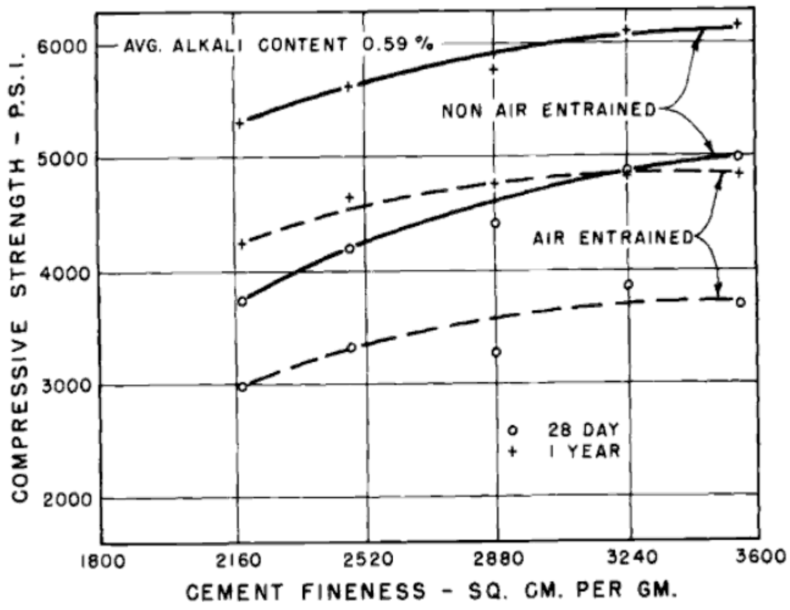

Figure 3: Effect of cement fineness on compressive strength of concrete

When the specific surface area is the same, the more homogeneous the particle size distribution of cement, the more rapid its hydration and the higher the strength of cement paste. The conclusion was drawn by Zhongzi (1986) that with any particle size distribution. Study by Alexander (1972), Data from new experiments and from work published during the last 40 years are subjected to regression analysis to determine the relationship between strength and composition and fineness of cement. This opinion may be differed on the relative importance of C_3S and C_3A and is examined against a background of experience with a group of materials that are representative of Portland cement in general, and in terms of an analysis based on a model in which, during the first weeks of hardening, the strength developed by C_3S depends on the proportion of C_3A in the cement.

The fraction of cement retained on a 45µm (No. 325 ASTM) test sieve can be determined using ASTM 430-92. This would ensure that the cement does not contain an excess of large grains which, because of their comparatively small surface area per unit mass, would play only a small role in the process of hydration and development of strength. Sieve test gives no information on the size of grains smaller than 45 µm sieve, and it is the finer particles that play the greatest part in the early hydration. The specific surface area can be determined by the air permeability method, using an apparatus developed by Lea and Nurse. Modification of this of the Lea and Nurse Method was given by Blaine, the method is prescribed by ASTM C 204-94. Modern specification no longer lay down minimum values of the specific of Portland cement, this being indirectly controlled by the early strength requirement where appropriate. Average Blaine fineness of modern cement ranges from 3,000 to 5,000 cm^2/g (300 to 500 m^2/kg). Standard fineness guideline is more than 280 m^2/kg followed in our country.

Setting of cement is the process of changing from a fluid to a rigid stage. Among four major compounds of cement, C_3A and C_3S react the fastest in setting. Setting times and consistency of cement paste are determined by Vicat's apparatus by penetration method. ASTM C 150 is the most widely used setting time test procedure suggesting 45 minutes for initial setting. Although no specification is given for final setting time rather by observation, it can be taken as 90+1.2 X initial setting time (min).

Crack formation on freshly plastered surface is a very common phenomenon in Bangladesh. This type of crack allows seepage of moisture and future deterioration of wall coating thereby high maintenance and repair cost. Whittmann (2002) showed that larger aggregate in concrete increases fracture energy thus reduces crack. Sand-cement mortar being originated from fine sand is prone to cracking.

An interesting and reliable experimental process, along with a rigorous and innovative data analysis, has been performed by Colina and Acker (2000). Cracking caused by desiccation shrinkage has been reproduced in the laboratory using a micro-concrete block, which has allowed us to study the cracking network evolution at different ages of drying. Interesting observations about shrinkage and water content variation during drying have also been obtained: we were able to separate the autogenously shrinkage from the desiccation shrinkage. The scale effect on drying cracks also had been studied using a model material made with a mixture of clay and sand, obtaining, notably, two predictive curves: the geometrical cracking ratio as a function of the initial geometrical slenderness, and the curve of the weight loss per unit of volume as a function of time normalized by the initial thickness. Recently, research (Colina and Nelson, 1998) on mortar has been performed in order to study the influence of sample dimensions with a material closest to concrete.

4.0 METHODOLOGY

Cement samples were collected by random sampling from market. Samples were then tested for fineness by Blaine's Apparatus conforming ASTM C 204. Consistency and setting time of cement were determined for respective fineness according to ASTM C 191. Effect of fineness of initial and final settings was investigated. A particular cement brand was used to prepare uniform coat of cement: sand: water (1:2:0.5) plaster on a wall and allowed to cure under four different curing conditions: no curing, moist cured for 1 day, moist cured for 3 days and moist cured for 7 days. Fineness, consistency, initial and final setting times of used cement were 320 m2/kg, 27%, 135 minutes and 195 minutes respectively. Fineness modulus, specific gravity (SSD) and absorption capacity of local sand were 1.02, 2.33 and 8.67 respectively. Gradation of used local sand is given in **Figure 4**.

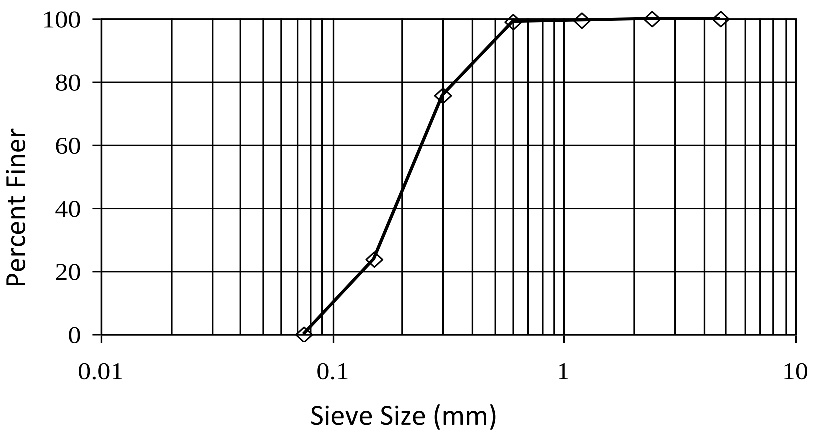

Figure 4: Gradation of sand

The amount of crack formed per unit area was measured in terms of length for all four curing conditions after 28 days. Statistical software SPSS version 16.0 was used to compare the variation of crack formation. SPSS is a strong statistical software for analyzing data and used intensively for numerical comparison. Determination of fineness is shown in **Figure 5**. Plastering work on walls is shown in **Figure 6**. The cracks were marked by markers and number and lengths were measured using scale.

Figure 5: Determination of fineness by Blaine's apparatus

Figure 6: Crack formation on plastered surface

5.0 RESULTS

Randomly collected eleven common cement brands were tested for fineness, consistency, initial and final consistency in the laboratory. The results are tabulated in Table 1.

Table 1: Variation of cement properties with fineness

Serial No.	Fineness (m^2/kg)	Consistency (%)	Initial Setting Time (minutes)	Final Setting Time (minutes)
1.	378	28	87	129
2.	421	31	113	168
3.	319	29	134	197
4.	324	25	106	173
5.	361	27	97	150
6.	354	28	121	176
7.	335	26	91	138
8.	340	28	125	180
9.	317	26	144	229
10.	305	28	105	167
11.	320	27	135	195

Results obtained from laboratory test were plotted in Microsoft Excel software to achieve general trend among fineness, consistency, initial and final setting times. The plotted graphs are shown in **Figure 7, Figure 8 and Figure 9**.

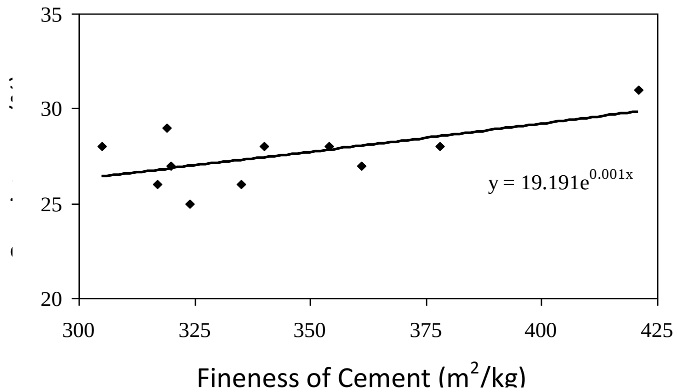

Figure 7: Relationship between fineness and consistency of cement

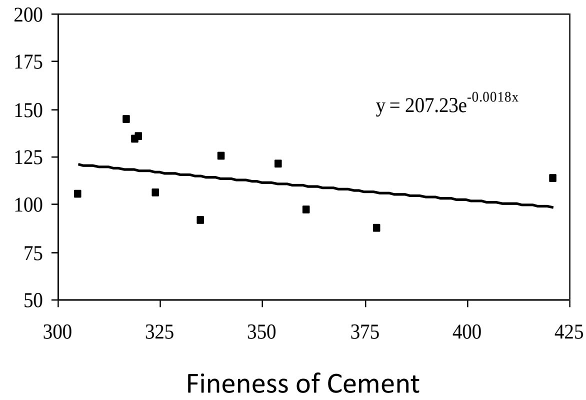

Figure 8: Relationship between fineness and initial setting time of cement

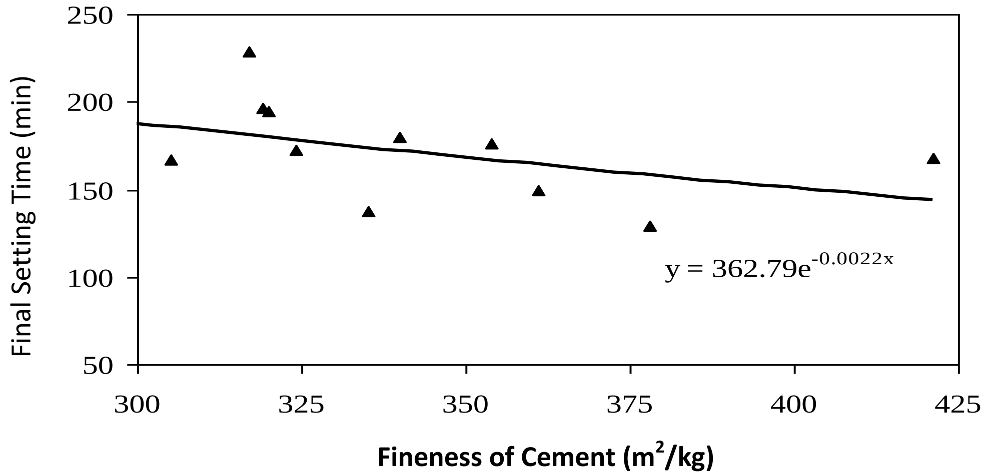

Figure 9: Relationship between fineness and final setting time of cement

Cement sand plastering 0.25 inch was laid on one face of a three feet high brick wall. There were four segments of layering each of size 18 inch wide by 36 inch height. The cracks formed in each segment of different curing condition were manually measured by numbers and lengths. The results are shown in **Table 2.**

Table 2: Details of cracks for different curing conditions

Curing Condition	Number of Cracks	Minimum Length of Crack (cm)	Maximum Length of Crack (cm)	Total Crack Length (cm)	Mean (cm)
No curing	45	2	32	457	10.16
Curing for 1 day	16	3	18	155	9.69
Curing for 3 day	13	2	28	140	10.77
Curing for 7 days	14	2	10	77.5	5.54

Bar charts **Figure 10 and Figure 11** show variation of length and total number of cracks against curing condition.

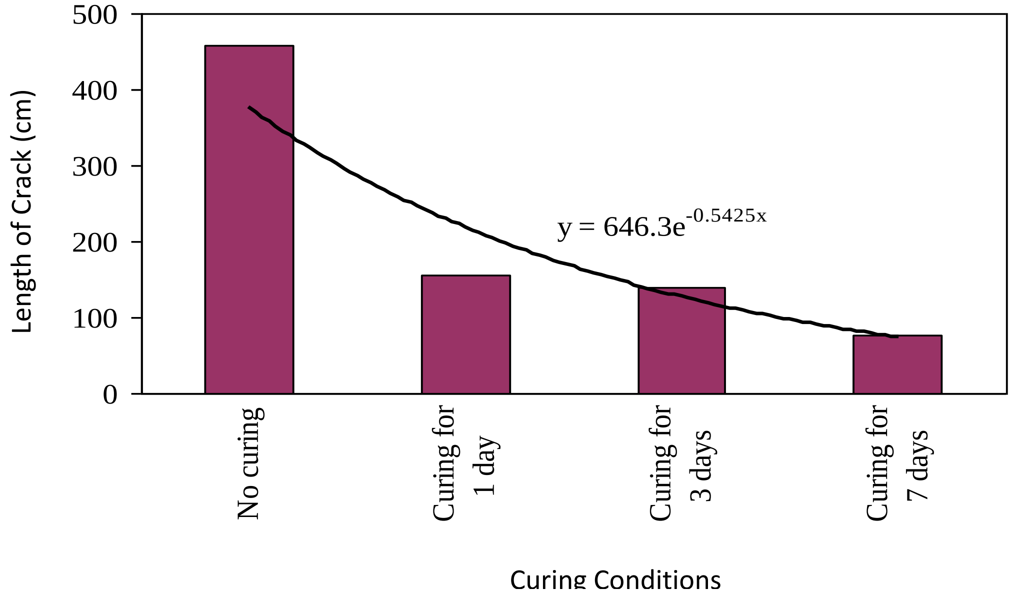

Figure 10: Variation of total crack length with curing conditions

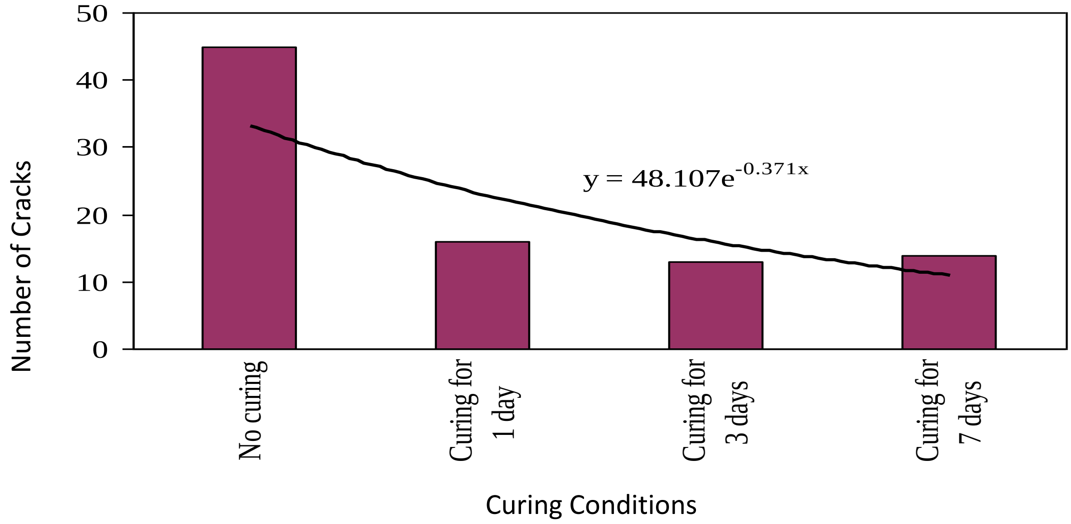

Figure 11: Variation of number of crack with curing conditions

6.0 DISCUSSION

Results of fineness survey suggested upward trend of consistency with increased fineness as seen from **Figure 7**. This data indicated that water requirement increases with increased fineness. However, the increment is marginal. Initial and final setting times were reduced with increment of fineness of cement. Final setting times showed more drastic reduction than that of initial setting times. This phenomenon suggested higher hydration rate of cement after initial setting time.

As expected, low curing time was associated with high crack formation with greater number of cracks. Both the cases of crack formation and crack number, prolonged moist curing condition reduced crack formation at an exponential rate. Average crack length was reported to be about 10 cm for insufficient curing whereas 7-day curing reduced half of the crack length at about 5 cm per crack.

7.0 RECOMMENDATIONS

After the study of indigenous cements and its properties, it can be concluded that present fineness value satisfies the ASTM guideline of 280 m^2/kg. From the obtained results and discussions, following recommendations can be estimated:

Requirement of higher consistency by particular cement leads to higher fineness and subsequently lower initial and final setting times during its hydration.

Formation of crack is influenced by curing condition. Lengthened curing aids lower crack formation.

This study was conducted for constant water-cement ratio. Effect of variable water should be studied further.

Due to time and resource constraint, more extended curing conditions could not be practiced. Effect for 14 and 30 days curing may be studied in future.

8.0 ACKNOWLEDGEMENT

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