COMPARISON OF CEM I AND CEM II CEMENT CONCRETES IN TERMS OF WATER PERMEABILITY

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ABSTRACT

Concrete is the most widely used construction material in Bangladesh. Concrete durability is of utmost importance since each concrete structure has design life of at least 50 years. Strength is the only parameter used in this country for quality assurance of concrete; however, depending on the exposure condition concrete requires different degrees of durability. For example some concrete structures are exposed to weathering action and some are prone to chemical attack or even just water in case of structures that are situated on river banks. Bangladesh being a riverine country faces a challenge in case of water permeability of those structures. Impermeability is the main condition of durable concrete. Water ingress causes corrosion of reinforcement which can lead to weakening of structural member or even to failure. In this study water permeability test has been performed on concretes made with both Ordinary Portland Cement (CEM I) and Portland Composite Cement (CEM II) to observe the effect of water penetration on them. The samples were tested for their durability as per EN 12390-8 "Depth of Penetration of Water under Pressure" after 28, 56 and 91 days. The depth of water absorption was measured and from the results it was observed that CEM II cement concretes showed lower permeability than CEM I cement concretes even though CEM I cement is still the most popularly used cement in concreting works here. Thus it can be concluded that the less widely used CEM II concrete was found to perform better in the long run.

Keywords: *Concrete, durability, permeability, CEM I, CEM II*

1. INTRODUCTION

Excellent long-term performance of concrete structures is associated with both concrete strength and durability properties. Permeability is a governing property to estimate durability of a concrete structure. In terms of deterioration of concrete due to physical or chemical causes, the mobility of fluids or gases through the concrete are nearly always involved. That is why Roy (2012) referred to permeability of concrete as a silent killer. Water is a necessary ingredient for the cement hydration reactions in concrete. Water facilitates the mixing of the components of concrete hence it is present from the beginning. Gradually, most of the evaporable water in concrete is lost, leaving the pores empty or unsaturated. Resaturation of pores due to exposure of concrete to the environment is a destructive phenomenon that causes corrosion of steel embedment and reinforcements (Mehta & Monteiro, 2013).

In Bangladesh, there are more than 60 cement companies those are producing cements with different composition and supplying to the market with different brand names (Mohammed et al, 2012). Among all the different brands, the most popularly used cement type in concreting works is the Ordinary Portland Cement or CEM I cement and which was the only cement available in this country until 2002 (Nahar, 2011). From the year 2003 CEM II cement has been available in the local market and is being used in construction work in the country since then (Nahar, 2011). Compressive strength test is the only test carried out in determining concrete quality. Durability of concrete, although being the most important criteria for long term performance, is ignored in concrete quality control. In this work, water permeability characteristics of concrete made with both CEM I and CEM II cement were observed and comparative study was done between the types. From the observed results it could be noted that the yet not so popular CEM II cement that contains supplementary cementing materials performs better in terms of durability.

2. EXPERIMENTAL SETUP

2.1 Materials and Mix Proportions

Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC) were used as binder material in this study. 20 mm downgrade and 10 mm downgrade stone chips in the ratio of 60:40 were used as coarse aggregate (gradation curve shown in Figure 1) and Sylhet sand (FM 2.73) was used as fine aggregate for preparing the test specimens. Sieve analysis of the aggregates was done according to the specifications of ASTM (C 136). Although the gradation curve of combined aggregate is non uniform, this ratio of 20 mm and 10 mm downgrade coarse aggregates was used in order to represent the usual concreting work of Bangladesh. Concrete mixes were produced using four different target strengths for both of the cement types in order to compare their properties. Table 1 shows the mix designs used for both the CEM I and CEM II cement concrete specimens.

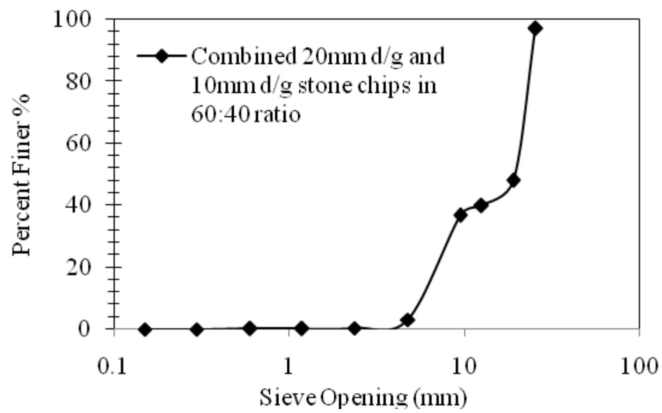

Figure 1: Grain size distribution of coarse aggregates (combined 60:40 stone chips)

Table 1: Mix designs used for preparing sample

Mix No	Characteristic Strength (MPa)	Coarse Aggregate (kg)	Fine Aggregate (kg)	Cement (kg)	Water (kg)	W/C Ratio
1	20	1313	649	340	170	0.5
2	30	1242	613	400	188	0.47
3	40	1225	605	450	180	0.4
4	50	1289	637	450	157.5	0.35

2.2 Water Permeability Test

2.2.1 Test Specimens

To carry out the water permeability test, 6 inch concrete cubes having 4 different characteristic strengths (20 MPa, 30 MPa, 40 MPa and 50MPa) were prepared using CEM I and CEM II cements. The specimens were kept in a dry place to bring them in air dry condition before they could be tested for water permeability as per EN 12390-8 “Depth of Penetration of Water under Pressure” (2009) after 28, 56 and 91 days.

2.2.2 Test Procedure

The air dry specimens were placed in the water permeability apparatus (Figure 2). The specimens are clamped between the two flanges with special circular gaskets. Water was applied from the bottom to the surface of the concrete specimens under controlled pressure of 5 bars for 72±2 hours.

Figure 2: Placing the specimens on the permeability apparatus

Figure 3: Splitting the specimen in half

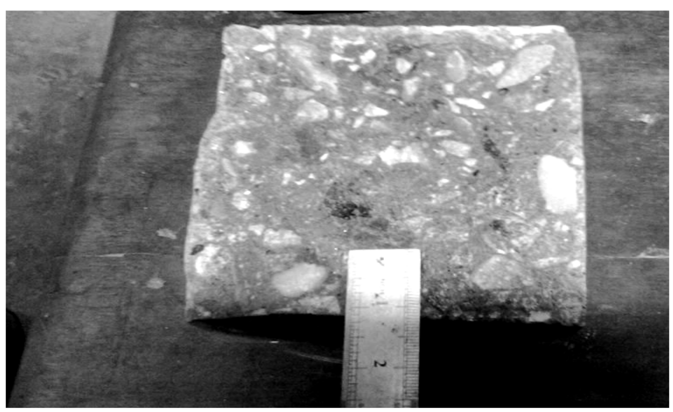

Figure 4: Measurement of depth of penetration

After that, the face on which water pressure was applied was wiped to remove excess of water. Then the specimens were split in half (Figure 3), perpendicularly to the face on which water pressure was applied. As soon as the split face had dried to such an extent that water penetration front could be clearly seen, the water front on the specimen were marked. Then the maximum depth of penetration under the test area was measured and recorded to the nearest millimeter (Figure 4).

2.3 Compressive Strength of Cylindrical Concrete Specimens

Compressive strength test on concrete specimens was done according to the specifications of ASTM test method for Compressive Strength of Cylindrical Concrete Specimens (ASTM C39).

2.3.1 Test Specimens

Concrete cylinders were made with diameters 4 inches and height 8 inches. In order to compare the compressive strength test results with the water permeability results, the specimens were tested on 28, 56 and 91 days of age.

2.3.2 Test Procedure

Tests of the moist-cured specimens were done as soon as practicable after removal from curing chamber at specific age. Load from the compression machine was applied continuously and without shock until the specimen failed and the maximum load carried by the specimen was recorded. Type of failure was also noted. This procedure is shown in Figure 5. Compressive strength of each cylinder was calculated by dividing the maximum load carried by the specimen during the test by the average cross-sectional area.

Figure 5: Determination of compressive strength of concrete

3. RESULT AND DISCUSSION

3.1 Variation of Compressive Strength versus Age

Compressive strength test was done on cylinders of the same mixes that were used in water permeability test. Figures 6, 7, 8 and 9 below show the variation of compressive strength test results between CEM I and CEM II cement concrete for characteristic strength of 20 MPa, 30 MPa, 40 MPa and 50 MPa respectively. The values in brackets show the obtained compressive strength values at 28 days of age. All of the graphs show that long term strength of CEM II concretes are higher than CEM I concretes although up to 28 days of age, both the strength results are comparable. Strength gain is higher in CEM I cement concretes at early ages, but later CEM II takes over. This occurs because, although concrete mixtures containing fly ash tend to gain strength at a slower rate than concrete without fly ash, the long-term strength is usually higher.

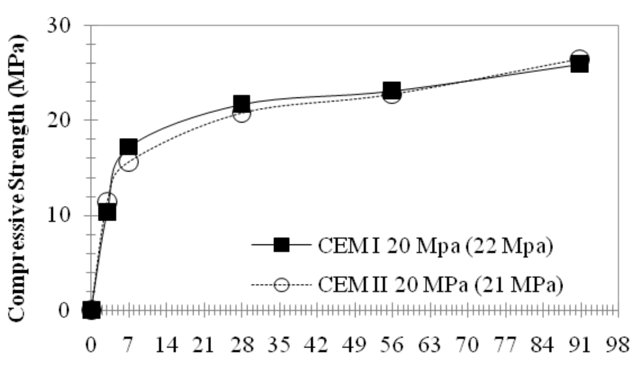

Figure 6: Variation of compressive strength with age for concrete of characteristic strength 20 MPa

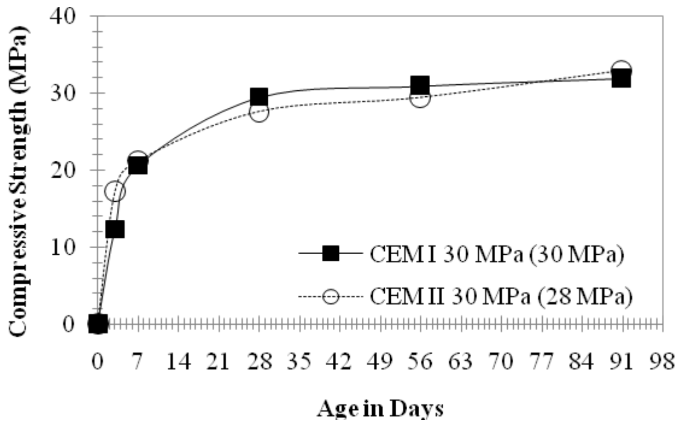

Figure 7: Variation of compressive strength with age for concrete of characteristic strength 30 MPa

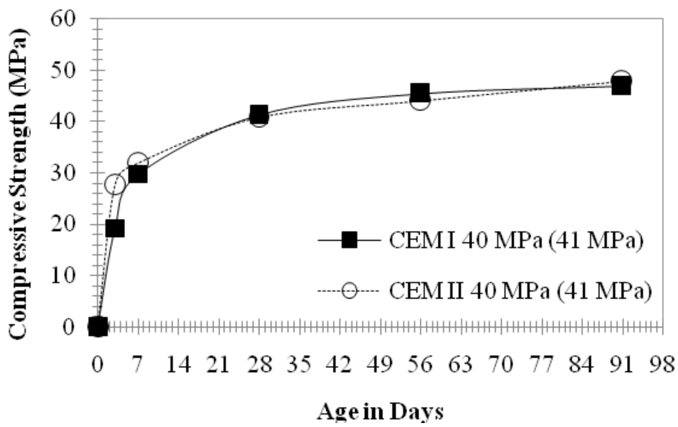

Figure 8: Variation of compressive strength with age for concrete of characteristic strength 40 MPa

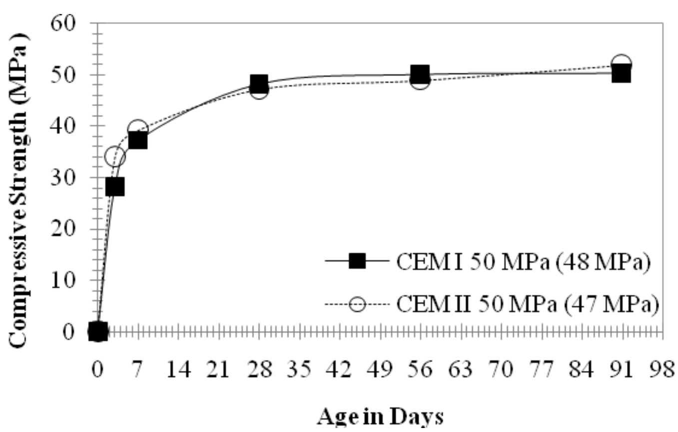

Figure 9: Variation of compressive strength with age for concrete of characteristic strength 50 MPa

3.2 Comparison of Water Permeability between CEM I and CEM II cement

On each graph, both CEM I and CEM II water penetration depth values were plotted corresponding to concrete age in days. Comparison was done between the two types of cement concretes having same characteristic strength.

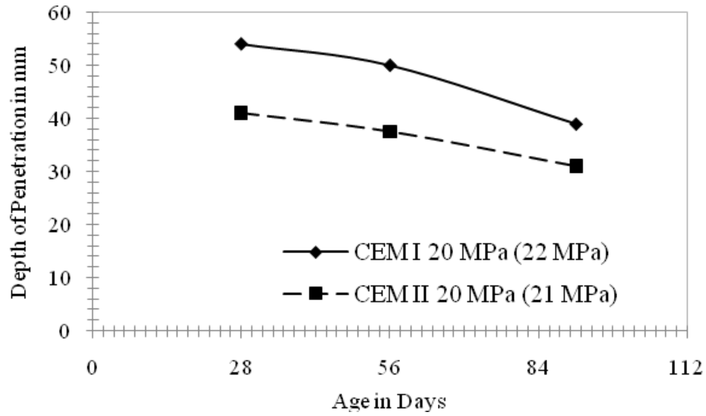

Figure 10: Variation of water permeability with age for characteristic strength 20 MPa

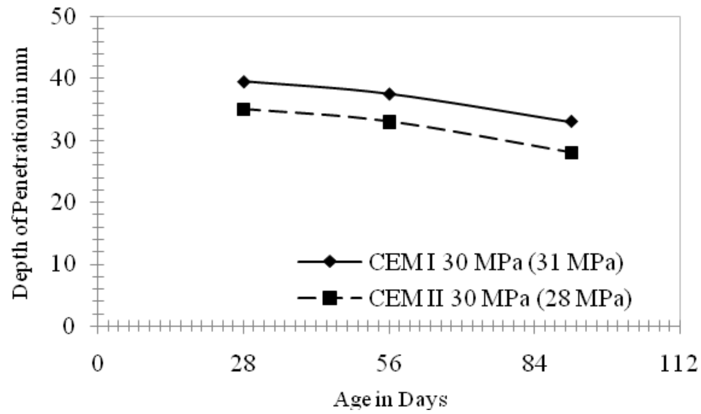

Figure 11: Variation of water permeability with age for characteristic strength 30 MPa

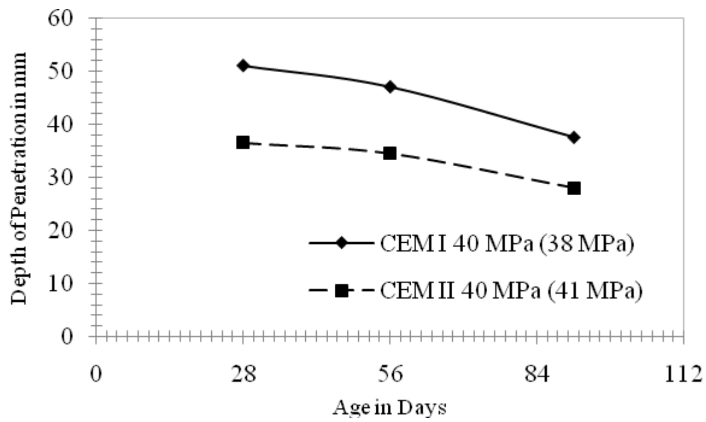

Figure 12: Variation of water permeability with age for characteristic strength 40 MPa

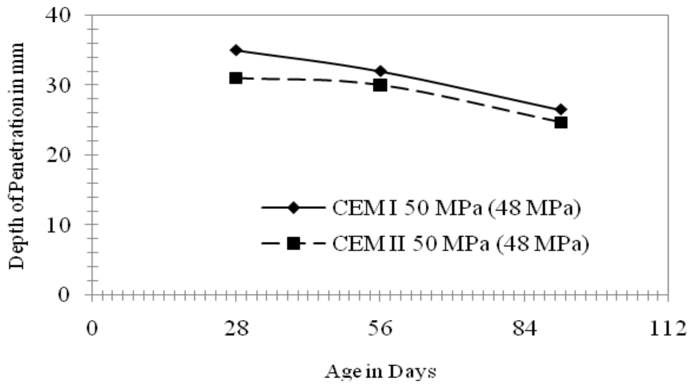

Figure 13: Variation of water permeability with age for characteristic strength 50 MPa

Water penetration versus age plot gave a decreasing trend which indicates that water penetration depth decreases with the passage of time. Since water permeability of concrete is proportional to this depth of penetration, it signifies that concrete permeability decreases with age.

All of these four graphs (Figures 10, 11, 12 and 13) show that depth of penetration of water is higher for CEM I cement concretes; which implies that permeability of CEM I concrete is more than the CEM II concrete specimens at all ages. CEM II cement contains supplementary cementing materials such as fly ash, silica fume, natural pozzolana etc. Lower permeability of cement paste containing supplementary cementing materials is attributed to the slow pozzolanic reaction of the pozzolans and disconnection of the channels between large pores (Ramezanianpour, 2014) hence making CEM II cement concretes more durable than CEM I.

4. CONCLUSIONS

By inspection of trends of the graphs drawn, it can be stated that although the compressive strength results of both the cement concretes were comparable, CEM II concretes showed better performance in terms of durability. Fineness of the supplementary cementing materials and their slow pozzolanic activity are the reason behind concrete being less permeable with age. Moreover, only 65-80% clinker is required to produce CEM II cement whereas 95% is needed to produce CEM I. This huge reduction in clinker content reduces energy consumption as well as carbon footprint, making this cement very popular worldwide. Since strength of CEM II is not reduced due to reduction of clinker content and it performed better in the long run with respect to water permeability, CEM II cement is suggested for construction work in a country like Bangladesh whose geography is dominated by at least 700 rivers flowing through it.

REFERENCES

ASTM Standard C136/C136M-14, 2015, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, ASTM International, West Conshohocken, PA, 2014, DOI: 10.1520/C0136_C0136M-14, www.astm.org

ASTM Standard C39/C39M-15a, 2015, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*, ASTM International, West Conshohocken, PA, 2015, DOI: 10.1520/C0039_C 0039M - 15A, www.astm.org

British Standard Institution (2009) *BS EN 12390-8:2009 Testing hardened concrete. Depth of penetration of water under pressure.* London, British Standard Institution.

Mehta, P.K., & Monteiro, P.J.M. (2013). *Concrete: Microstructure, Properties, and Materials* (4th ed.). New York, NY: McGraw-Hill.

Mohammed, T.U., Hasan, P., Islam, B.K.M.A, Hasnat, A. & Sharkia, S. (2012). *Investigation on Different Cement Brands Commonly Used in Bangladesh*. Paper presented at the Third International Conference on Construction In Developing Countries (ICCIDC–III) "Advancing and Integrating Construction Education, Research & Practice", Bangkok, Thailand.

Nahar, Z. (2011). *Cement Sector of Bangladesh.* Retrieved from IDLC Finance Limited, http://www.idlc.com/

Ramezanianpour, A.A. (2014). *Cement Replacement Materials: Properties, Durability, Sustainability,* New York, NY: Springer.

Roy, J.B. (2012, March). Permeability of Concrete – A "Silent Killer". *NBMCW*