Malaysian Journal of Civil Engineering 28(1):50-58 (2016)

THE CHARACTERISTICS OF BRICK AGGREGATE CONCRETE ON A BASIS OF DRY DENSITY AND DURABILITY

Shohana Iffat*

Department of Civil Engineering, Bangladesh University of Engineering & Technology, BUET, Dhaka-1000, Bangladesh

*Corresponding Author: *shohana.iffat@gmail.com*

Abstract: The most remarkable building material-concrete is generally designed to carry compressive loading. Concrete must be sufficiently durable in order to prevent penetration of corrosive elements through its surface. The mechanical properties of concrete are highly influenced by its density. A denser concrete generally provides higher strength and fewer amount of voids and porosity. Smaller the voids in concrete, it becomes less permeable to water and soluble elements. So water absorption will also be less and better durability is expected from this type of concrete. Water, containing harmful elements leads to corrosion of reinforcement embedded in concrete. Water itself is also vulnerable to embedded steel within concrete. A minimum water cement ratio is desired to maintain appropriate strength and durability of concrete. In this paper an experimental program conducting on compressive strength, density, absorption capacity and percent voids of hardened concrete is described. The variation of these properties with maturity of concrete was main focus of this experiment. Also, water and chloride permeability of commonly practiced concrete mixes are also evaluated through this paper. Comparison is made between two types of concrete's property test results. One of them is lightweight concrete made with crushed brick (BC) as primary coarse aggregate. Crushed brick is a locally available construction material in Indian subcontinent. Another type of concrete is a denser one, made with crushed stone (SC) as primary coarse aggregate. The comparisons on test results are presented with respect to time and water cement ratios. It was observed from the experiment that, strength and density increases with maturity of concrete and percent void and absorption capacity decreases with time. Better results were obtained from stone aggregate concrete than brick aggregate concrete in cases of all of the tests. A minimum water cement ratio is also recommended to ensure minimum level of durability through this paper.

Keywords: *Concrete; density; absorption; void; compressive strength, aggregate; water cement ratio; water permeability; RCPT*

1.0 Introduction

The non-natural conglomerate stone concrete is made essentially of Portland cement, water, and aggregate. Cement enhances the binding property of concrete. A chemical reaction called hydration takes place between the water and cement, and concrete normally changes from a plastic to a solid state. Cement having a smaller spacing between particles, hydration occurs faster. The density and compressive strength of concrete cement paste are affected by several parameters like water cementitious materials ratio, supplementary cementitious materials, use of admixture, curing, cement type, etc. [Rasa *et al.*, 2009]. Curing is the procedure to endorse hydration of cement, and consists of a control of temperature and moisture movement from and into the concrete [Neville, 1996]. Proper curing application has significant impact on density and compressive strength of concrete [Raheem, 2013]. The water-cement ratio (W/C) is defined as the proportion by mass of free water to cementitious material in a concrete mix. Structural lightweight concrete is defined as structural concrete made with low-density aggregate that has an air-dry density of not more than 1840 kg/m3 and a 28-day compressive strength of around 17.25 MPa [Ozyildirim, 2009]. Generally, lightweight aggregate concrete absorbs more impact energy than normal weight concrete [Ravindrarajah & Lyte, 2003]. The density of normal weight concrete lies within the range of 2,200 to 2,600 Kg/m3 [Neville, 2000]. The primary purpose of lightweight concrete is to reduce the dead load of a concrete structure [Technical Bulletin-CIP-36, 2003]. Also, this type of concrete is used to improve buoyancy of the structures. But introducing lightweight aggregate in concrete construction often results poor strength and durability performance of concrete, if proper quality control protocol is not maintained. So, instead of using lightweight aggregate, air entraining admixture can be used to reduce density of concrete. The optimization of concrete density to improve structural efficiency (the strength to density ratio), reduce transportation costs, and also enhance the hydration is accomplished by replacing part of the normal-density aggregates (coarse aggregate, fine aggregate, or both) with comparable amounts of low-density aggregate [Hoff, 2002]. Using this approach, concrete densities from 1,842 to 2,370 kg/m3 can be produced to meet specific project requirements [Hoff, 2002]. The uncertainties associated with the parameters affecting the density and compressive strength of cement paste makes it difficult to exactly estimate such properties [Neville & Brooks, 1987; Haykin, 1994]. Also, no definite conclusion can be drawn in terms of the effect of the density and surface texture of lightweight aggregate on the durability of concrete [Kho, 2003].

The W/C ratio has an important influence on the quality of concrete produced. A lower water-cement ratio directed to higher strength and durability. But it may create segregation and other complexities. Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, abrasion or any process of deterioration while maintaining its desired engineering properties. The movement of water through concrete may carry aggressive agents with water [Naik *et al.*, 1996]. As a result, various types of chemical reactions occur between harmful elements and cementitious compounds within concrete and deterioration starts. Among the detrimental agents, sulphate and chloride are most vulnerable which mainly leads to expansion of concrete and corrosion in embedded steel, respectively. The effective concentrations of the corrosive substances in the surface layer are the true boundary conditions for the transport of them in concrete [Liu *et al.*, 2014]. The durability of concrete structures is unarguably a foremost challenge facing the concrete community today. Often, high strength concrete show poor durability performances. In most cases, unskilled and uneducated local contractors and labourers pay no heed to appropriate compaction process and as a result, porous concrete is produced. In this paper, relation between commonly practiced water cement ratio and durability is discussed. Water permeability and chloride permeability of dense and lightweight concrete are tested for different water cement ratios. A comparative study is made among the test results from different mix and different methods. Also, influence of time on concrete's compressive strength, density, voids and absorption capacity are discussed.

2.0 Materials and Methods

2.1 Concrete Preparation

Mix proportion of cement, fine aggregate and coarse aggregate was kept as 1:1.5:3 (Volume basis) in this study. Water cement ratio was kept constant as 0.5 as the main concern was to evaluate effect of time on density and compressive strength. Two types of mix designs were conducted. One of them was prepared with 3/4 inch downgraded crushed stone and 3/8 inch downgraded crushed stone (Figure 1a, 1b) those were mixed together in a ratio of 1:1 and used as coarse aggregate. Another set of concrete utilizing 3/4 inch downgraded crushed brick and 3/8 inch downgraded crushed brick (Figure 1c) in a ratio of 1:1. Sieve analysis was conducted for crushed brick along with crushed stone and sand according to ASTM C136 method [ASTM C136, 2006]. Sylhet sand (sand found in North East part of Bangladesh which is cheap, easily available and used in general construction cases) was used as fine aggregate and OPC (Ordinary Portland Cement) was used as binding material in this study. All necessary properties of the ingredients were tested in laboratory. Bulk specific gravity and absorption capacity of aggregates were obtained according to ASTM C128 [ASTM C128, 2012]. Densities of coarse and fine aggregates were found according to ASTM C29 [ASTM C29, 2009]. From aggregate density test results shown in Table 1, it can say that, SC is denser than BC.

From each type of samples (SC and BC), thirty cylindrical (100mmx200mm) concrete specimens were prepared for 7, 21, 28, 42, and 56 day test. Fifteen of these cylinders were made for density test and rest fifteen cylinders were prepared for compressive strength test. Another set of six cylinders (three with SC, three with BC) were made for RCPT test. Also six cube samples (150mmx150mm) were also prepared for water permeability test. All samples kept fully submerged under saturated lime water up to 28 days to ensure curing.


(a)


(b)


(c)

Figure1: (a) 3/4 inch downgraded crushed stone (SC) (b) 3/8 inch downgraded crushed stone (SC) (c) 3/4 inch and 3/8 inch downgraded crushed brick mixed together (BC)

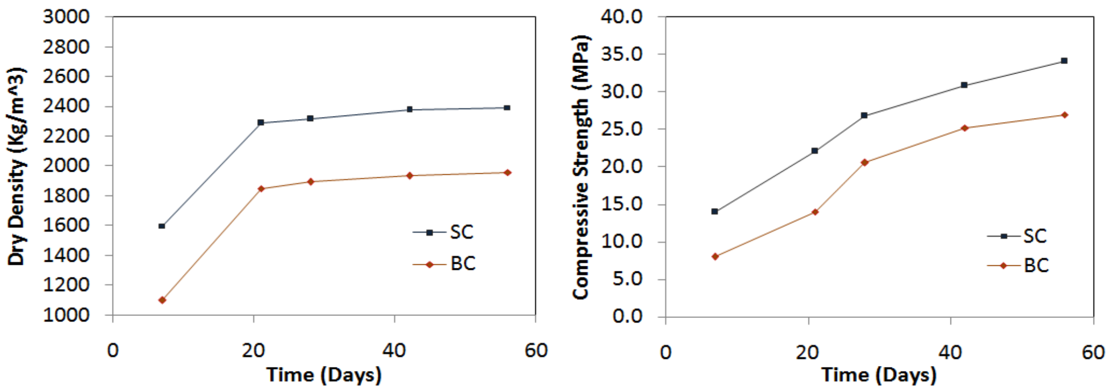
Table1: Coarse aggregate's density test results

Aggregate	Dry rodded unit weight (kg/m^3)
Crushed stone	1590
Crushed brick	1170

2.2 Density Test and Compressive Strength Test

Up to required days curing, one set (3 cylinders) of concrete specimen were taken out from storage for density test according to ASTM C 642 [ASTM C 642, 2013], for testing at particular day. These specimens were turned to SSD (Saturated Surface Dry) condition by removing water from the surfaces. Then SSD weight of samples in air was measured. Next the specimens were placed in oven at a temperature of 100 to 110°C for 24 h. After that weight of the specimen was measured. Then density was calculated according to ASTM C 642. Density test results are shown in Figure 2a. From this test results, it can easily be said that density increases with days. But rate of density change is low. Concrete with SC shows more density values than concrete with BC.

Similar to density test, after 28 days curing, one set (3 cylinders) of concrete specimen were made ready for compressive strength test at required age according to ASTM C 39 [ASTM C 39, 2005]. Universal testing machine was used to apply compressive load on specimens at a required loading rate. The cylinders were placed within the bearing blocks, the axis of the specimens were aligned properly and compression was applied and compressive strength was calculated. Compressive strength test results are shown in Figure 2b. Compressive strength increases with days. More compressive strength is found from SC concrete than BC concrete. When compressive loading is applied to BC concrete, mortar and aggregate fails together. As brick aggregate has lower compressive strength than stone, brick start to fail earlier than similar type of SC aggregate concrete. So, compressive strength of BC concrete is also found much lower than SC concrete.

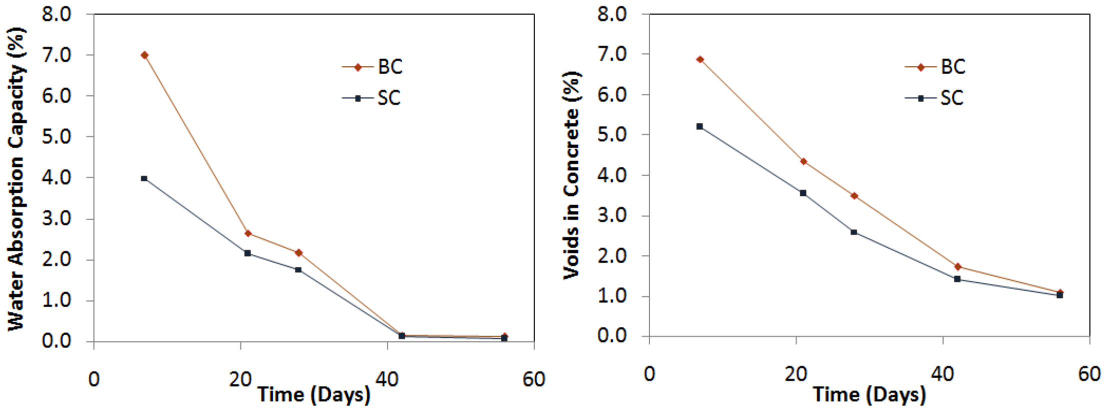


(a) (b)

Figure 2: Effect of time on (a) dry density (b) compressive strength of concrete

2.3 *Absorption Capacity and Percent Void Test*

Absorption capacity of concrete was estimated according to ASTM C642 [ASTM C 642, 2013]. The absorption test results are shown in Figure 3a. From Figure 3a, it is observed that, absorption capacity decreases with time. BC concrete absorbs more water than SC concrete. As the experiment was performed of hardened concrete, so less water absorption is experienced in cases of brick concrete. Otherwise higher rate of water absorption would be found. Hydration in concrete occurs mainly within first seven days, and water absorption capacity and permeability of concrete start to reduce after that time. Percent void in concrete was calculated according to ASTM C642 [ASTM C 642, 2013]. The void test results are shown in Figure 3b. From this test results, it is found that, percent void in concrete reduces with time. Similar to absorption capacity test of concrete, fewer amounts of voids were found in cases of SC concrete than BC concrete.



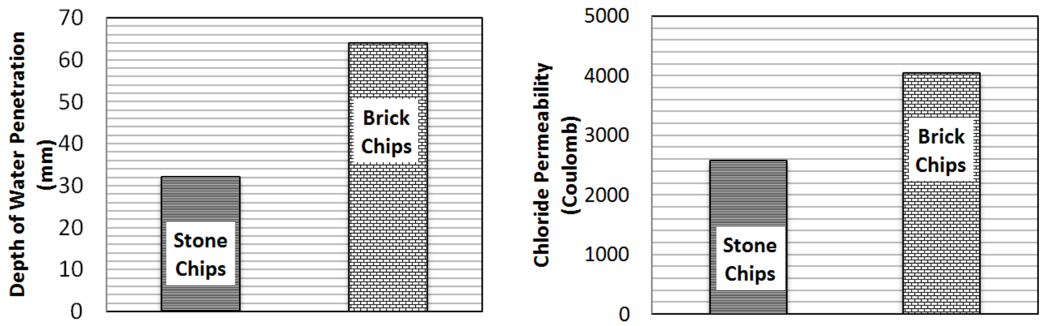
(a) (b)

Figure 3: Effect of time on (a) absorption capacity (b) percent void of concrete

2.4 Water Permeability and Chloride Permeability Test

Water permeability of 28 day aged concrete samples was tested according to BS EN 12390-8 [BS EN 12390-8, 2009] method which is a stressed procedure. Depth of water penetrated through concrete surface is displayed in Figure 4a. Average depth of water penetration through stone aggregate concrete cubes surface was found around 32 mm when water cement ratio was 0.45. In case of brick concrete, 64 mm water penetration was recorded (Figure 4a). With the purpose of avoiding corrosion of embedded steel within concrete member, minimum 25 mm cover depth is required for slab. For beam and column this requisite depth is 37.5 mm. Minimum cover depth mandatory to obstruct the penetration of water and corrosive elements those are liable for corrosion. From Figure 4a, it is evidently observed that, for stone aggregate concrete, less amount of water penetration occurs than that for brick aggregate concrete.

The electrical conductance of 28 day old concrete was determined by ASTM 1202 [ASTM C 1202, 2012; Iffat, 2015; Iffat *et al.*, 2014; Manzur *et al.*, 2015] test method to provide a rapid indication of its resistance to the penetration of chloride ions. Electrical conductance of the concrete is measured by the total charge passed during the period of the test according to ASTM C1202. According to ASTM C 1202 [ASTM C 1202, 2012], if more than 4000 coulomb charge passes through a concrete sample, it is recommended as high chloride permeable. If the passed charge is within 2000 to 4000 coulomb, it is suggested as moderate chloride permeable which is recommended for design. In Figure 4b, results of chloride permeability test (average value) is presented for both stone and brick aggregate concrete specimens. It is clearly observed that, more charge passed in cases of brick aggregate concrete samples. It means, lightweight aggregate is more permeable than dense concrete. For water cement ratio 0.45, moderate chloride permeability is noticed for stone aggregate concrete. In case of brick aggregate concrete, high chloride permeability is noted for same case which is not recommended.



(a) (b)

Figure 4: Durability test results (a) depth of water penetration inside concrete specimen (b) chloride permeability of concrete specimens

3.0 Conclusions

It is important to ensure structural safety through utilizing proper construction materials. In order to guarantee safety, concrete must have to assure adequate compressive strength, density, a minimum percent of void and minimum water absorption through the surface. Adequate strength and density is required to sustain a certain loading. Minimum void and absorption capacity reduce water permeability of concrete. From this experiment it is observed that, compressive strength and density increases with time and void and absorption capacity reduces with time. Mainly hydration process leads to strength gaining and attaining a certain level of durability. Concrete with SC yielded more compressive strength and density than concrete with BC. Also, it is observed that BC concrete is more permeable (having more amount of voids) than SC concrete.

Water absorption and corrosive material carrying capacity of a concrete surface is largely dependent on many factors. In most of the cases, properly cured concrete, become progressively and significantly less permeable with time. Excessive water cement ratio leads to porous concrete allowing water to penetrate through its surface. In many locations, especially in coastal areas, water contains corrosive elements like chloride, responsible for corrosion in embedded steel. So durability of concrete in that structure may be affected due to this fact. Another observation from this paper is that, more water and chloride permeability were found from all durability tests for lightweight concrete with brick aggregate, than normal stone aggregate concrete. So, brick aggregate concrete should be avoided in construction of structural members those exposed to an environment having extreme moisture content such as foundation, retaining wall, marine structures like pier etc. Furthermore, it is recommended to maintain a lower water cement ratio to guarantee apposite durability of concrete mainly, in cases of lightweight aggregate concrete consist of crushed brick.

4.0 Acknowledgements

The author wishes to pay her considerate thanks to Concrete Laboratory, Department of Civil Engineering, Bangladesh University of Engineering & Technology, BUET, for their assistance in this research work.

References

ASTM C 1202 – 12 (2012), "*Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration."* West Conshohocken, PA.

ASTM C 642 – 13 (2013), *Standard Test Method for Density, Absorption, and Voids in Hardened Concretes*, ASTM International, West Conshohocken, PA.

ASTM C128–12 (2012), *Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate*, ASTM International, West Conshohocken, PA.

ASTM C136 –06 (2006), *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, ASTM International, West Conshohocken, PA.

ASTM C29 – 09 (2009), *Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate*, ASTM International, West Conshohocken, PA.

ASTM C39–14a (2005), "*Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*." ASTM International, West Conshohocken, PA.

BS EN 12390-8-2009 (2009), "*Testing Hardened Concrete: Part 8, Depth of Penetration of Water Under Pressure*." British Standards Institution, London, UK, BSI.

Haykin, S. (1994), Neural Networks: A Comprehensive Foundation, MacMillan, New York.

Hoff G.C. (2002), "Guide for the Use of Low-Density Concrete in Civil Works Projects", *Innovations for Navigation Projects Research Program*, U.S. Army Corps of Engineers Washington, DC.

Iffat S. (2015), "Relation between Density and Compressive Strength of Hardened Concrete", Concrete Research Letters, Vol. 6 (4) , pp 182-189.

Iffat, S., Emon, A. B., Manzur, T., and Ahmad S.I. (2014), "An Experiment on Durability Test (RCPT) of Concrete According to ASTM Standard Method using Low-Cost Equipments." Advanced Materials Research Vol. 974, pp. 335-340, Switzerland.

Kho C.C. (2003), "Water Permeability and Chloride Penetrability of Lightweight Aggregate Concrete", *Proceedings of 9th NUROP Congress*, Nanyang Technological University, Singapore.

Liu J., Xing F., Dong B., Ma H. and Pan D., (2014) "Study on Surface Permeability of Concrete under Immersion", Materials — Open Access Materials Science Journal, pp 876-886.

Manzur T., Iffat S., Noor M.A. (2015), "Relation between Properties of Internally Cured Concrete and Water Cement Ratio", International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, Vol. 9, No. 9, pp 973-976.

Naik T.R., Singh S.S. & Hossain M.M., "Permeability of High Strength Concrete Containing Low Cement Factor" Journal of Energy Engineering, Vol. 122, No 1, (1996).

Neville A.M. (1996), *Properties of Concrete*, 4th ed., USA, New York: John Wiley and Sons, (1996).

Neville A.M. (2000), Properties of Concrete, 4th ed., England: Longman.

Neville, A.M. and Brooks, J.J (1987). Concrete Technology, Longman Scientific & Technical.

Ozyildirim C. (2009), "Durability of Structural Lightweight Concrete" *LWC Bridges Workshop,* IBC.

Raheem A.A. (2013) , "Effect of Curing Methods on Density and Compressive Strength of Concrete", *International Journal of Applied Science and Technology*, Vol. 3 No. 4.

Rasa E., Ketabchi H. and Afshar M.H. (2009), "Predicting Density and Compressive Strength of Concrete Cement Paste Containing Silica Fume Using Artificial Neural Networks", *Transaction A: Civil Engineering*, Vol. 16, No. 1, pp. 33(42).

Ravindrarajah R.S. & Lyte M.C. (2003), "Properties of adjusted density high-performance concrete", ADVANCES IN STRUCTURES: Steel, Concrete, Composite and Aluminium, ASSCCA '2003 Conference Sydney, Australia.

Technical Bulletin-CIP-36 (2003), Structural Lightweight Concrete", *National Ready Mix Concrete Association*.