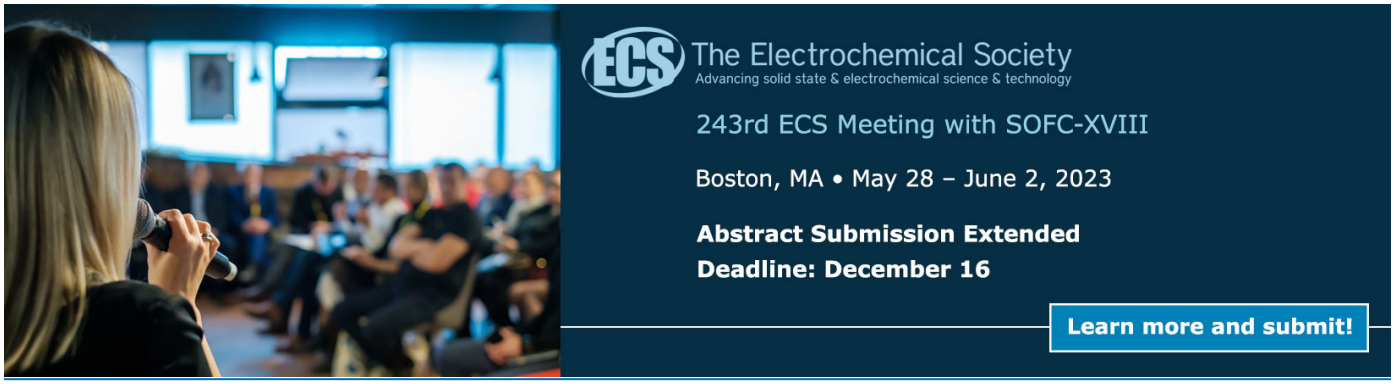
Compressive Strength of a Prescribed Control Mix for High Performance Self-compacting Concrete



Compressive Strength of a Prescribed Control Mix for High Performance Self-compacting Concrete

O G Mark[1,3], A N Ede[1], C Arum[2], G O Bamigboye[1], S O Oyebisi[1] and K J Jolayemi[1]

[1]Civil Engineering Department, Covenant University, PMB 1023, Ota, Nigeria
[2] Civil Engineering Department, Federal University of Technology, PMB 704, Akure, Ondo State, Nigeria

[3]E mail oluwaseun.mark@covenantuniversity.edu.ng

Abstract- Another way of improving concrete production involves incorporating the unique features of high performance concrete with the special properties of self- compacting concrete, resulting in another type of concrete called high performance self-compacting concrete (HPSCC). Many researchers have developed diverse designed control mix for HPSCC which were obtained through several and rigorous designed trial mixes. Yet, little work has been done on prescribed control mix for HPSCC. The purpose of this paper is to establish a prescribed control mix ratio for HPSCC and to test by conducting compressive strength test. Review of the various designed control mix ratios is done in this paper. A logical prescribed control mix ratio of 1:1.02:0.95 has been established for an HPSCC with 0.36 w/c proportion, 0.02 superplasticizer/cement proportion. The compressive strength gave 36.10 MPa at 7 days curing age, 41.76 MPa at 14 days curing age and 57.29 MPa at 28 days curing age. This strength result satisfied the strength criteriaa of HPSCC, according to EFNARC It is therefore recommended that a prescribed control mix of 1:1.02:0.95 be used if the minimum crushing strength value expected at 28 days is 40 N/mm^2 for an HPSCC.

Keywords: high performance self-compacting concrete (HPSCC), self-compacting concrete (SCC), high performance concrete (HPC), compressive strength, prescribed control mix, ordinary Portland cement, superplasticizer.

1. Introduction

In the construction industry, concrete remains very important and unique. As written by Copeland and Brunauer [1] in 2004 wrote that water is the only product that human uses more than concrete. For this reason, as modernization continues, concrete dominates. Nonetheless, recent concrete production poses

several challenges which include environmental contamination, by product disposal, release of harmful carbon dioxide, exhaustion of raw materials and so on.
Khayat [2] defined self-compacting concrete as a flowing concrete which has the ability to flow across congested reinforcements, fill all the corners of the form work and compacted under its own weight. The requirements for self-compacting concrete include; ability to spread through and entirely fills complex formworks under its self-weight (good filling ability); ability to pass through congested reinforcements under its self-weight (excellent passing ability); adequate resistance to segregation of aggregates. On the other hand, high performance concrete is a concrete that is specially mixed, placed and cured to produce high strength, high durability, high modulus of elasticity, low permeability and high resistance to chemical attack. Concrete that conforms to the requirements of both high performance concrete (HPC) and self-compacting concrete (SCC) is regarded as HPSCC. Okamura in his designed mix methods [3], [4] set the total content of the coarse aggregate as half the

HPSCC solid content and set the content of the fines to be 0.4 of the total content of the mortar. Water/cement ratio was initially obtained starting with slump flow measurement of the concrete paste. Afterwards, the w/c proportion together with the superplasticizer was gotten out of the slump flow measurement of the concrete mortar. Lastly, the water/cement ratio as well as the superplasticizer content was obtained through several trial mixes of HPSCC, in order to achieve good results. The method designed by Peterson et al [5], [6] determined the optimum volume of both coarse and fine aggregates, in order to achieve excellent flowability using CBI technique. Likewise, the binder volume, w/c proportion together with the superplasticizer was achieved using the rheometer. Su et al designed mix method [7], [8]. They did theirs based on aggregate compacting ratio. Also, coarse aggregate volume was half the whole aggregate volume of HPSCC, while the total volume was taken as 57% of the whole solid volume of HPSCC. Likewise, OPC content was obtained from the desired crushing strength per kilogram of the OPC. The w/c proportion together with the superplasticizer was gotten through several trial and error to achieve the desired fresh properties.

Thanh et al [9] designed an HPSCC mix based on the SCM binding potentials together with specifications for rationing normally vibrated concrete. Statistical method of designing concrete mix has also been used to produce HPSCC whereby, rather than choosing an initial concrete mix and continuing through trial mixes to get the best concrete mix, series of trial mixes encompassing a selected set of ratios of each concrete mix contents are being clearly stated [10]. Although all these designed mix methods gave appreciably higher compressive strength values, the methods showed how complex they are in practicality. This article intends to prescribe an HPSCC control mix ratio as well as to verify it by conducting compressive strength test.

2 Materials and Methods

2.1 Materials

2.1.1 Ordinary Portland cement. The binder utilized was Dangote Portland cement and gotten from a retail outlet in Ota, Ogun State, Nigeria, in compliance with ASTM Type I cement specification [11].

2.1.2 Granite. Locally available granite was used for this mix and was locally purchased at a quarry site in Abeokuta, Ogun State, Nigeria. 12.5 mm size of granite was used and was spherical in shape, according to EFNARC guidelines [12].

2.1.3 River sand. Locally available river sand was used for this study and was also locally obtained from a river bank in Ota, Ogun State, Nigeria. The maximum size of the river sand was 4.75 mm according to EFNARC guidelines [12].

2.1.4 Superplasticizer. For the required flowing ability to be achieved, the superplasticizer utilized was Complast SP 430. It was available in dark liquid form.

2.1.5 Potable water. The potable water utilized was clean and free from silt, organic matter and harmful impurities such as oil, alkaline and acid.

2.2 Methods

Nine (9) cubic moulds with 150 mm length on each side were prepared, properly greased and made ready for the casting. Batching was done by weight and a digital weighing balance was used for this purpose. 33400 g of ordinary Portland cement (prescribed) was weighed and poured on a steel plate, 34068 g of river sand (prescribed) was also weighed and thoroughly mixed with the OPC on the plate, using a hand trowel until a uniform blend was achieved. 31730 g of granite was added to the uniform blend and also thoroughly mixed to achieve a uniform blend as well. This gave a mix ratio of 1:1.02:0.95 (prescribed). Water/cement ratio used was 0.36 (prescribed), which means that 12024 g of water was weighed and kept aside. Superplasticizer/cement ratio used was 0.02, which means that 668 g of superplasticizer was weighed, added and properly mixed with the already weighed water. The liquid mixture was poured to the already blended concrete constituents and final thorough mixing was done. Observations showed a flowable concrete.

The concrete mix was cast into each of the already oiled concrete cubes in one layer only, with no compaction at all. The surface was smoothly dressed and allowed to stay for 24 hours. De-moulding and water-curing of the concrete cubes were performed at the end of 24±4 hours under ambient temperature towards 7 days, 14 days and 28 days.

After 7 days, removal of three (3) cubes out of water was done and dried prior to crushing, using a digital crushing machine at the Structures Laboratory of Covenant University, Ota, Ogun State, Nigeria. This was also done at the end of 14 and 28 days.

Crushing loads at failure were noted and recorded. Average value of the three (3) samples of each of the curing days were taken and further calculations were done to determine the average 7,14 and 28 days crushing strength values.

2.3 Results and discussion

From table 1 and figure 1, 7 days compressive/crushing strength gave 36.10 N/mm^2. 14 days compressive/crushing strength gave 41.76 N/mm^2 and 28 days compressive/crushing strength gave 57.29 N/mm^2. Comparing these values to the performance criteria of HPSCC, given by EFNARC [12] that the minimum early-age strength of HPSCC should be 20 N/mm^2 and 28 days strength of HPSCC should be at least 40 N/mm^2. It can be said that the prescribed control mix ratio of 1:1.02:0.95 is okay. Also from the above result, as the curing age increased, the compressive strength increased, which was far above that for normally vibrated concrete. The high strength was achieved because the basic principles of obtaining high performance self-compacting concrete as discussed by Dehn, Holschemacher and Weiber [13]; Okamura and Ouchi [3] were strictly followed. They wrote that the optimum flowing ability and high strength of HPSCC can be obtained by using HRWR, limited volume of coarse aggregate together with increased binder volume with reduced water/binder proportion.

Table 1. Compressive Strength Test Result.

Trials	Crushing value (kN)	Cube size (mm^2)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
7 days				
A	628.20	150 x 150	27.92	36.10
B	980.10	150 x 150	43.56	
C	828.45	150 x 150	36.82	
14 days				
A	782.78	150 x 150	34.79	41.76
B	1075.95	150 x 150	47.82	
C	960.30	150 x 150	42.68	
28 days				
A	1701.23	150 x 150	75.61	57.29
B	849.15	150 x 150	37.74	
C	1316.48	150 x 150	58.51	

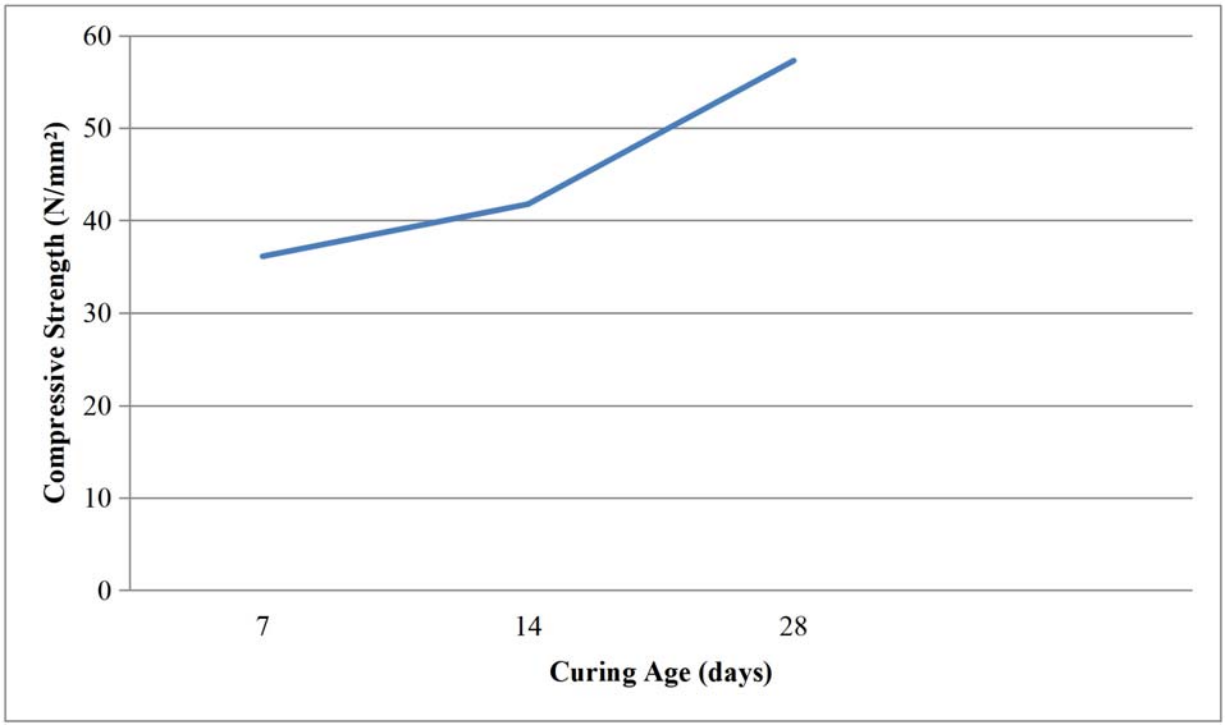


Figure 1. Compressive strength of the prescribed control mix.

2.4 Conclusions

(1) A prescribed control mix of high performance self-compacting concrete is successfully established.
(2) The 7 days compressive/crushing strength gave 36.10 N/mm^2, 14 days compressive/crushing strength gave 41.76 N/mm^2 and 28 days compressive/crushing strength gave 57.29 N/mm^2.
(3) As the curing age of the HPSCC increased, the compressive strength increased.
(4) The compressive/crushing strength obtained for the HPSCC gave more values than the compressive strength of normally vibrated concrete, which is usually 25 N/mm^2 at 28 days.
(5) It is recommended that this prescribed control mix of HPSCC established should be adopted by engineers for further research and also for construction purposes.

Acknowledgement
The authors would like to appreciate Covenant University Centre for Research, Innovation and Discovery for financially supporting.

References

[1] Brunauer S. and Copeland L E 2004 The chemistry of concrete. Scientific American Journal 80-92.
[2] Khayat K H 2009 Workability, testing, and performance of self-consolidating concrete ACI Material Journal **3** 346-53.
[3] Okamura H and Ouchi M 1998 Self-compacting high performance concrete Progress Structural Engineering Material Journal **1** 378–83.
[4] Okamura H and Ozawa K 1995 Mix design for self-compacting concrete. Concrete library JSCE, **25** 107–20.
[5] Petersson O and Billberg P 1999 *Investigation on Blocking of Self-compacting Concrete with Different Maximum Aggregate Size and Use of Viscosity Agent Instead of Filler*. First International RILEM Symposium. on Self-compacting Concrete (Paris: RILEM Publications SARL).
[6] Petersson O, Billberg P and Van B K 1996 *A Model for Self-compacting Concrete*. RILEM Conference Product Methods Workability Concrete (E & FN Spon) 483–92.
[7] Su N and Miao B 2003 A new method for the mix design of medium strength flowing concrete with low cement content. Cement Concrete Composites Journal **25** 215–22.
[8] Su N, Hsu K C and Chai H W 2001 A simple mix design method for self-compacting concrete. Cement. Concrete Research **31** 1799–807.
[9] Thanh H L, Matthias M, Karsten S and Ludwig H 2015 The mix design for self-compacting high performance concrete containing various mineral admixtures. Materials and design Journal **72** 51-62.
[10] Ana M M, Lino M, Sandra N and Paula M 2018 Design of self-compacting high performance concrete: study of mortar phase. Construction and building Journal **167** 617 – 30.
[11] ASTM C 150 2004 *Standard Specification for Portland Cement* Vol.04.01 (American Society for Testing and Materials: Philadephia).
[12] EFNARC 2002 *Specifications and Guidelines for Self-consolidating Concrete*, (European Federation of Suppliers of Specialist Construction Chemicals: Surrey), 32pp.
[13] Dehn F, Holschemacher K. and Weiβe D 2000 *Self-compacting Concrete (SCC) Time Development of the Materials Properties and the Bond Behavior*. (The Leipzig Annual Civil Engineering Report: University of Leipzig) .115-24.