Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

REVISITING HIGH STRENGTH CONCRETE USING COMMON ADMIXTURES

N. M. Nor*, M. A. A. Ghazali, M. Z. Ahmad, M. A. Yusof, M. Vikneswaran and M. A. Yahya

Faculty of Engineering, National Defence University of Malaysia, 57000 Kuala Lumpur, Malaysia

Published online: 10 September 2017

ABSTRACT

This research revisits on high strength concrete (HSC) using common admixtures, looking at the fundamental requirement to achieve the HSC. Basic requirement of HSC is low water-cement (w/c) ratio. In this project, silica fume (SF) is the mineral admixtures chosen to be applied in the mix, and Super plasticizer (SP) is the chemical admixtures used to enhance workability while reducing water content. The SP and SF portions influence on compressive strength are studied. Concrete cubes size 100 x 100 x 100 mm are casted and tested for compressive strength. The highest average 7 days' compressive strength achieved is about 49 MPa. Thus, the expected strength after 28 days is 70 MPa, equivalent to concrete grade C70. In this study, the mix with 10% of silica fume to cement content, and 0.04 liter of super plasticizer to one m^3 concrete mix seems to produce the best result.

Keywords: Carbon Fiber;High Performance Concrete (HPC); Silica Fume (SF); Super plasticizers (SP); Water-cement ratio (w/c).

Author Correspondence, e-mail: azman@upnm.edu.my

doi: http://dx.doi.org/10.4314/jfas.v9i3s.42

1. INTRODUCTION

High strength concrete (HSC) is a concrete mixture for high durability and high compressive strength (more than 50 MPa) when compared to common conventional concrete (20 to 40 MPa) [4]. The product can be more economical even though its initial cost can be higher compared to the common conventional concrete. This is because the used of HSC will generate a lighter structure, more long lasting structure and the service life of the structure can be extended. Due to this condition, the structure can resist damage and this will decrease overall cost for maintenances. Proper design and production are the main factor that will influence the quality of the HSC [10-22].

This research will revisit the development of HSC. The used of HSC in the construction industry, especially in the construction of bridges, skyscrapers, mega structures and many other type of structures that demand the used of high strength concrete is the main motivation for this technology [3]. The used of the HSC will be very beneficial since it will reduce the size and weight of the structure and consequently will reduce the size of the foundation. Besides that, the usage of HSC will be more economical for life-cycle cost performance. Further, it will reduce the use of natural resources such as cement and aggregates due to smaller structural elements.The objectives of this research are to design and test HSC mix using state-of-the-art technique in order to achieve mean compressive strength of 40 MPa or more in 7 days, and to investigate the effects of using silica fume (SF) and super plasticizers (SP) on compressive strength of concrete [1].Finally, the effect of carbon fiber in concrete mix will be tested.

Based on the literature, the pillars of practical mix design for HSC are low water-cement ratio, used of super plasticizers, application of cement with a high strength [6] potential and application of pozzolans and in particular silica fumes [14, 21]. HSC can be produced with water-cement ratios in the range of 0.22-0.40 and the resulting 28-days compressive strength are in the range of 60 to 130 MPa. The maximum size of coarse aggregates should be kept to a minimum at 9-12 mm in order to achieve optimum compressive strength with high cement content and low water-cement ratio. According to [8] to make the concrete mix design for high performance concrete (HPC), the aggregates size used in the matrix should be less than 2.5mm and the water cement ratio should be less than 0.24 [2]. The usage of the SP is highly recommended because of the high fines [5] requirements for cohesiveness of the mixed and rapid slump loss. The SF plays the roles of filler due to its fine particle size and pozzolanicmaterial, its ability to react with free lime and leading to formation of hydro silicates. SF plays a positive part up to approximately 20% content and has the most important effect when reaching 10 to 15% content, regardless of water-cementitious material ratio [9].

2. METHODOLOGY AND RESULTS

2.1. Effect of Silica Fume and Superplastisizer on Concrete Strength

In revisiting the HSC, the experimental works begin with the trial mix. As shown on Table 1, the trial mixes involve using simple HSC mix of 1:1:2 (Cement: Sand: Aggregate ratio) with 0.5 w/c ratio. Second mix will reduce w/c ratio to 0.25 and to use super plasticizer (SP). While, the third mix is to add silica fumes (SF) to the second mix. The results are as shown on the same table. Mix 2 shows direct impact of reducing the water ratio by half will double up the strength, provided SP is added to help on workability. While, adding 10% SF in Mix 3 do not show any strength improvement.

Table 1. The trial mix for 28th days compressive strength

Mix	Materials in 1 m^{3}Concrete Batch, kg/m^3						Super-Plasticizers	w/c Ratio	Average Compressive Strength
	Cementitious Material		Total	Water	Fine Agg.	Coarse Agg.			
	Cement	SF					L/m^3	by wt.	MPa
1	1.5	-	1.5	0.75	1.5	3.0	-	0.5	36.13
2	1.5		1.5	0.37	1.5	3.0	0.15	0.25	75.89
3	1.5	0.15	1.65	0.37	1.5	3.0	0.15	0.25	71.96

Further, we formulate another mix and test for silica fume optimum content. The amount of silica fume used in the mix was 30, 20 and 10% of cement weight. The mix design which obtained the optimum compressive strength will be selected to test the effect of super plasticizer on the mix. The results are as shown on Table 2. Mix 1 with 10% silica fume to cement content tends to give the best result. While, adding more SF in Mix 2 and 3 do not show much strength improvement.

Table 2. Mix design of HSC with various percentages of silica fumes

Mix	Materials in 1 m^3Concrete Batch, kg/m^3						Super-Plasticizers	w/c Ratio	Average 7 Days Compressive Strength
	Cementitious Material		Total	Water	Fine Agg.	Coarse Agg.			
	Cement	SF					L/m^3	by wt.	MPa
Control 1	1.95	-	1.95	0.76	2.6	4.45	0.01	0.39	26.65
1	1.95	0.20	2.15	0.76	2.6	4.45	0.01	0.39	35.76
2	1.95	0.39	2.34	0.76	2.6	4.45	0.01	0.39	28.12
3	1.95	0.58	2.53	0.76	2.6	4.45	0.01	0.39	25.55

Next, we formulate another mix and test for super plasticizer optimum content. The amount of super plasticizer used to test the effect on compressive strength was 0.10 L, 0.08 L and 0.06 L, all for per m^3 of concrete mix. The SF content is fixed at 10% of cement content. The results are as shown on Table 3 and Fig. 1. Mix 4 with 0.04 L SP per m^3 of concrete gives the best result.

Table 3. Mix design of HSC with various volumes of super plasticizers

Mix	Materials in 1 m^3Concrete Batch, kg/m^3						Super-Plasticizers	w/c Ratio	Average 7 Days Compressive Strength
	Cementitious Material		Total	Water	Fine Agg.	Coarse Agg.			
	Cement	SF					L/m^3	by wt.	MPa
Control 1	1.95	0.2	2.15	0.56	2.6	4.45	-	0.29	41.30
1	1.95	0.2	2.15	0.56	2.6	4.45	0.10	0.29	42.64
2	1.95	0.2	2.15	0.56	2.6	4.45	0.08	0.29	44.73
3	1.95	0.2	2.15	0.56	2.6	4.45	0.06	0.29	44.84
4	1.95	0.2	2.15	0.56	2.6	4.45	0.04	0.29	48.77

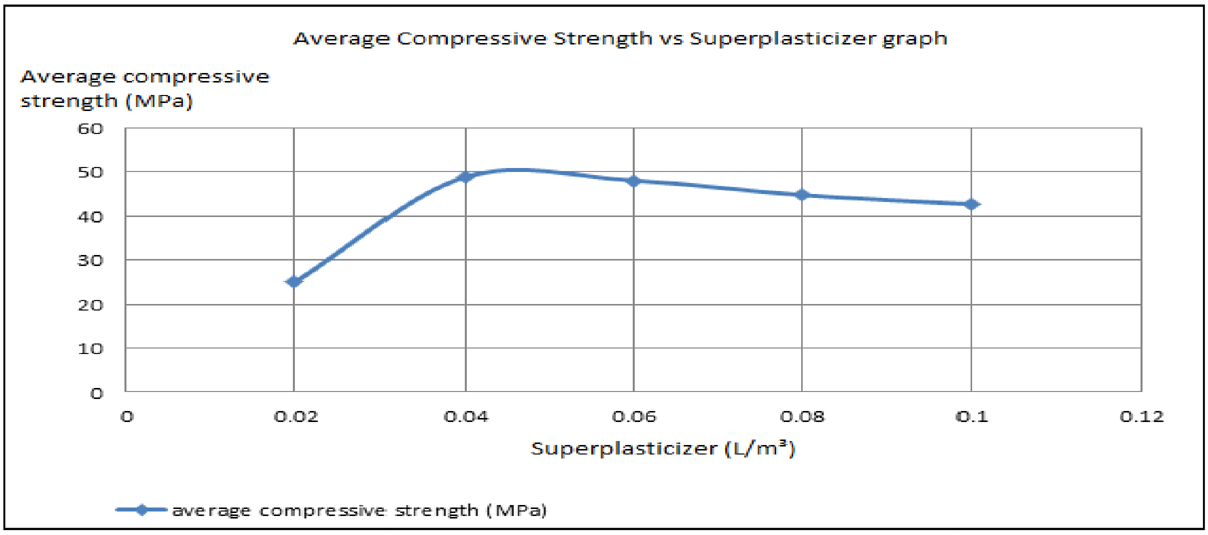

Fig.1. The optimum amount of superplasticizer

2.2.The Effect of Carbon Fiber (CF) in a Concrete Strength

In this research, the variable of the experiment is the amount of short and chopped carbon fiber which are 5g, 10g, 15g and 20g CF per mix which converted into 0.05%, 0.11%, 0.16% and 0.22% of CF respectively by weight of concrete cube.Table 4 shows the result of control mix, Mix 1 that contains 0.05% of CF, Mix 2 contains 0.11% of CF, Mix 3 contains 0.16% of CF and Mix 4 contains 0.22% of CF by weight of the concrete cube. The highest average compressive strength for 7 days is 56.3MPa and the highest average compressive strength for 28 days is 78.33MPa, both from Mix 3.

Table 4. The compressive strength of the CF mix design

Age of Concrete Cube (days)	Research Mix Design								
	Control Mix	Mix1 0.05%	Mix2 0.11%	Mix3 0.16%	Mix4 0.22%	Mix1 0.05%	Mix2 0.11%	Mix3 0.16%	Mix4 0.22%
	Mean Compressive Strength (MPa)					Concrete Strength Difference Compared to Control Mix (%)			
7	44.0	48.7	52.7	56.3	54.8	9.65	16.51	21.85	19.71
28	68.4	67.5	74.83	78.33	71.43	-1.33	8.59	12.67	4.24

3. DISCUSSION AND CONCLUSION

The experimental result shows that, for silica fumes content, the highest strength is achieved at 10% silica fume relative to cement content by weight. The hydration rate of silica fumes mainly depends on two main parameters, which are the water-cement ratio and the silica fume content. For the low water-cement ratio, silica fume particles absorbed the water content available for cement hydration, resulting in less water directly contributing to the hydration process of the cement [6]. The slowing down of the hydration process diminishes the early age compressive strength before the pozzolanic reaction contributes to the resistances [9]. The total heat of hydration in the first 10 days depends on the amount of silica fume added to the mix. The highest strength achieved with 10% of silica because it increases heat of hydration due to the pozzolanic effects. When the silica fume was increased to 30% of cement content, the compressive strength decreased because the hydration rate of cement slows down and there is less water to react with cement. Since reaction is slow, the reaction may not be completely done in 7 days, therefore reduced the early strength of the concrete. In this research, results show that silica fume did not produce an immediate strength enhancement. Higher strength was not achieved in early age, probably due to the dilution effect of the pozzolan and as well as the slow nature of pozzolanic reaction [18]. Based on that reason, the silica fumes can be beneficial to increase the compressive strength of the concrete in the later stage while controlling the heat of hydration.

Further, as for the super plasticizer, the highest strength is achieved at 0.04 L of SP content per m^3 of cement mix. Study shows that super plasticizer will slow down the hydration process. The higher the volume of super plasticizer, the slower the hydration process will be. Though, increment in the dosage of the admixture will enhance the compressive strength, there is still an optimum limit for the usage of admixture. Over dosage of SP will cause bleeding and segregation, which will affect the cohesiveness and uniformity of the concrete. As a result, compressive strength will be decreased if the used dosage is beyond the optimum dosage, this is inline with statement by [16].As for the use of Carbon Fiber (CF) as admixture, the highest average 28 days'compressive strength is 78.33 MPa which contains of 0.16% CF by weight of the concrete. This is the optimum strength achieved in the research. The improve in strength is 12.67% relative to the control mix [7].

4. ACKNOWLEDGEMENTS

The author extends his utmost gratitude to the Ministry of Higher Education Malaysia and the National Defence University of Malaysia for funding this research.

5. REFERENCES

[1] Ali H H. The effects of curing condition on compressive strength in high strength concrete.Diyala Journal of Engineering Sciences, 2009, 2(1):35-48

[2] Aïtcin P. C. High performance concrete. Florida: CRC Press, 2011

[3] Behzad N, Raizal S M R, MohdSalleh J, Yen L V. A review on ultra high performance 'ductile' concrete (UHPdC) technology. International Journal of Civil and Structural Engineering, 2012, 2(3):994-1009

[4] Caldarone M. A. High strength concrete: A practical guide.Abingdon: Taylor and Francis, 2009

[5] Rokugo K, Kanda T, Yokota H, Sakata N. Applications and recommendations of high performance fiber reinforced cement composites with multiple fine cracking (HPFRCC) in Japan. Materials and Structures, 2009, 42(9):1197-1208

[6] Demirboga R, Gul R. Production of high strength concrete by use of industrial by-products. Building and Environment, 2006, 41(8):1124-1127

[7] El-Hadj K, Roger D, Salima A, Said K. Silica fume effect on hydration heat and compressive strength of high performance concrete. ACI Material Journal, 2009, 106(2):107-113

[8] Uchida Y, Niwa J, Tanaka Y, Katagiri M. Outlines of 'Recommendations for design and construction of ultra high strength fiber reinforced concrete structures' by JSCE. In International Workshop on High Performance Fiber Reinforced Cementitious Composites in Structural Applications, 2005, pp. 1-8

[9] Kadri EH, Duval R. Hydration heat kinetics of concrete with silica fumes. Construction and Building Materials, 2009, 23(11):3388-3392

[10] Wille K, Naaman AE, Parra-Montesinos GJ. Ultra high performance concrete with compressive strength exceeding 150 MPa; A simpler way. ACI Materials Journal, 2010, 108(1):46-54

[11] Japan Society of Civil Engineers (JSCE). Recommendations for design and construction of high performance fiber reinforced cement composites with multiple fine cracks. Concrete engineering series 82.Tokyo: JSCE, 2008

[12] Nawy E. G. Fundamentals of high strength high performance concrete.New York: Wiley, 2000

[13] Xincheng P. Super-high-strength high performance concrete. Florida: CRC Press, 2017

[14] Rashid M A, Mansur M A. Considerations in producing high strength concrete. Journal of Civil Engineering, 2009, 37(1):53-63

[15] Russell H G. Mineral admixtures for high performances concrete. Concrete Products, 2002, 105:60-61

[16] Salahaldein A. Influence of superplasticizers on strength of concrete. International Journal of Research in Engineering and Technology, 2012, 1(3):2277-2288

[17] Voo Y L, Foster S J. Characteristics of ultra-high performance ‘ductile’ concrete and its impact on sustainable construction. IES Journal Part A; Civil and Structural Engineering, 2010, 3(3):168-187

[18] Wong H S, Razak H A. Efficiency of calcined kaolin and silica fume as cement replacement material for strength performance.Cement and Concrete Research, 2005, 35(4):696-702

[19] Yusof M A, Nor N M, Zain M F M, Sohaimi R M, Peng N C. Normal strength steel fiber reinforced concrete subjected to explosive loading.International Journal of Sustainable Construction Engineering and Technology, 2010, 1(2):127-136

[20] Yusof M A, Nor N M, Zain M F M, Peng N C, Ismail A, Sohaimi R M, Zaidi A M A. Mechanical properties of hybrid steel fibre reinforced concrete with different aspect ratio. Australian Journal of Basic and Applied Sciences, 2011, 5(7):159-166

[21] Yusof M A, Nor N M, Ismail A, Peng N C, Sohaimi R M, and Yahya M A. Performance of hybrid steel fibres reinforced concrete subjected to air blast loading. Advances in Materials

Science and Engineering, 2013, 2013:1-8

[22] Rana N, Tiwari A, Srivastava A K. High performance concrete and its applications in the field of civil engineering construction. International Journal of Current Engineering and Technology, 2016, 6(3):982-985

How to cite this article:
Nor N M, Ghazali M A A, Ahmad M Z, Yusof M A, Vikneswaran M, Yahya M A. Revisiting high strength concrete using common admixtures. J. Fundam. Appl. Sci., 2017, *9(3S), 546-554*