Iranica Journal of Energy & Environment 4 {(3) Geo-hazards and Civil Engineering)}: 295-299, 2013
ISSN 2079-2115
IJEE an Official Peer Reviewed Journal of Babol Noshirvani University of Technology
DOI: 10.5829/idosi.ijee.2013.04.03.18

BUT

Effect of Different Curing Conditions on the Mechanical Properties of UHPFC

[1]Lawend K. Askar, [2]Bassam A. Tayeh and [1]B.H. Abu Bakar

[1]School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, Penang Malaysia
[2]The Islamic University of Gaza, Gaza, Palestine

(Received: Match 20, 2013; Accepted in Revised Form: June 22, 2013)

Abstract: Ultra-High Performance Fiber Concrete (UHPFC) is a new class of concrete. Because of its distinguished mechanical properties, UHPFC is considered as an ideal alternative material for use in developing new structural solutions. This paper discusses on influence of different curing conditions on mechanical properties of UHPFC. An experimental program was performed to study the mechanical properties of UHPFC which were cured under six different curing conditions. Test results indicated that steam and boil curing methods showed a promising performance particularly at early age of curing compared to other type of curing.

Key words: UHPFC · Curing · Compressive strength · Flexure strength · Steam curing

INTRODUCTION

Concrete has occupied an important place among construction materials and is widely used in all types of civil engineering structures ranging from small buildings to huge ones. Advances in the science of concrete materials have led to the development of new class of cementations composites; namely, UHPFC [1]. The mechanical and durability of UHPFC made it an ideal alternative material for use in developing new solutions to pressing concerns about highway infrastructure deterioration, repair and replacement; in particular, when UHPFC became commercially available worldwide. Therefore, many more are actively considering the use of UHPFC [2, 3]. It is defined that "curing is the name given to procedures used for enhance the hydration of cement and consists of a control of temperature and of the moisture movement from and into the concrete" [4]. Barring of any of the moist curing parameters such as humidity or temperature adversely affects the compressive strength of the Portland cement concrete. Although, curing is an important aspect in the production of good concrete, the timing and duration of curing is more important [5, 6]. Curing leads to better strength development because allows more water to be made available for the hydration reaction of the concrete's cement paste. It is also to improve the ultimate compressive strength improves resistance to abrasion and reduces surface dusting [6]. The objective of this study is to determine the mechanical properties of Ultra-High Performance Fiber Concrete due to different curing condition and also to identify appropriate curing condition of UHPFC.

Experimental Details

UHPFC Mix: A typical UHPFC mix contains cement, sand, silica fume, steel fiber, super-plasticizer and water in the ranges shown in Table 1. Mix compositions of materials which were used in this experiment reported in terms of weight per unit volume. The function of these fibers within UHPFC is to enhance tensile strength of concrete. Superplasticizers (high range water reducers) was used as chemical admixtures which can maintain the workability required. This mix was obtained by using DOE program.

Preparation of Concrete Mixture and Samples: A mechanical mixer with capacity of 0.25 m^3 operated by electrical power was used in preparing samples. The procedure of mixing was as follows; prepare the required sand in terms of weighing and sieving, silica fume and cement placed in the mixer in a sequence manner, in other words, sand is first put in the mixer followed by the silica fume and finally the cement. Then, the dry materials were well-mixed to obtain a uniformed mixture and before

Corresponding Author: Bassam A. Tayeh, The Islamic University of Gaza, Gaza, Palestine.
E-mail: btayeh@iugaza.edu; cebad@eng.usm.my.

Table 1: UHPFC mix proportion of materials

Material	Amount (Kg/m^3)	Percent by weight
Portland cement	825	33.60
Fine Sand	1140	46.43
Silica Fume	181	7.37
Superplasticizer	45	1.83
Steel Fibers	90	3.66
Water	174	7.08
Water/binder ratio	174/1006	0.17

adding water, superplasticizer was added to a mixture. Finally, steel fiber was added to the mixture; afterwards, the whole ingredients of the mixture were mixed to obtain a homogenous mixture with reduction in binder ratio equal to 0.17.

In preparation of specimens, there were 72 cubes (100mm x 100mm x 100mm) and 72 beams (280mm x 70mm x 70mm), including controlled specimens. The moulds were cleaned and the internal surface was oiled to prevent the adhesion of concrete after hardening. UHPFC casting was carried out in three layers. Each layer was compacted by using a vibrating table until no air bubbles emerged from the surface of the concrete. Then, the concrete was levelled off smoothly to the top of moulds. Moreover, the specimens were covered with polyethylene sheet in the laboratory for about 24 hours and the specimens were then remolded carefully and cured by different methods.

Curing Regimes: After the casting process was completed, the concrete should be prevented from premature drying and avoid the varying in temperature. These precautions are necessary in order to protect the concrete from a negative impact on methods of curing. In this study, six curing methods were used as follows:

- Spraying specimens with water (fog room).
- Immersing specimens in water.
- Normal curing.
- Boiling water curing method.
- Steam cured after one day casting.
- Steam cured after two days casting.

In fog room curing method, the specimens were tested after 3, 7, 14 and 28 days. However, concrete should first be kept in the cube for 24 hours before curing. UHPFC specimens were placed in the fog room along the process of curing. The specimens in the immersing water method placed in the lab for 24 hours to complete process of hardening. The specimens were demolding carefully. The specimens were immersing in water until the finishing operation complete within ages.

The third method was normal curing method, after complete the 24 hours. UHPFC specimens were placed in ambient weather with temperature nearly to, 28°C. This type of curing has four ages for specimens; 3 days, 7days, 14days and the final age were 28 days.

Another method of curing was referred to as boiling water curing method; the specimens were moist-cured in the laboratory for 23 hours. After elapsing the 23 hours, the specimens were lowered into the boiling curing tank for 3.5 hours with a 100°C temperature. The total time for cooling the specimens was 28.5 hours, then immersed in water until completing the ages test for specimens.

In steam cured, casting specimens were left for one day after casting without curing, apply curing treatment includes steaming the UHPFC at 90°C for 60 hours (Including 6 hour ramp up and 6 hour ramp down times) [7, 8]. All specimens were removed after the 60 hour cure process after this stage.

The last method of curing is steam cured after two days, it is very similar to the process conducted in one-day steam cured; however, the delay with this method is extended into two days instead of one which is the only difference with the pre-mentioned one-day approach.

Compressive Strength Test: A machine with a capacity of 1000 kN was utilized and the load was applied at a rate of 0.3 KN/s. The specimens of concrete were (100 x 100 x 100) mm cubs that have three cubes per age. A total of three specimens were tested in compression at 3, 7, 14 and 28 days of curing. The maximum Compressive strengths recorded from each of these tests were averaged for each testing day, according to B.S. EN 12390 [9].

Flexure Strength: Flexure strength represent one of the most important mechanical properties of concrete which have been tested after 3, 7, 14 and 28 days of curing. the machine for testing flexure strength has four rollers: the distance between two above rollers was third of the depth specimen, the distance between the two bottom rollers was three times of depth specimen according to ASTM C 78 [10]. The dimension of the specimens was (70x70x280) mm. The two Prism specimens are tested for each age with following periods 3, 7, 14 and 28 days of curing.

RESULTS AND DISCUSSION

Compressive Strength: The results of compressive strength tests for all specimens and at all conditions are demonstrated in Table 2, Figures 1 and 2. Each value represents the average of three specimens.

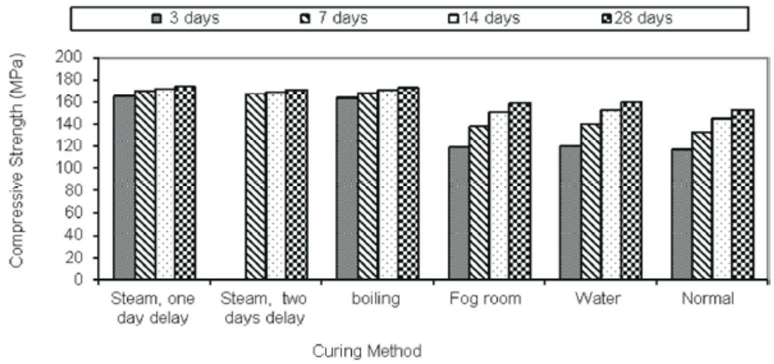

Fig. 1: Relationship between compressive strength and curing condition

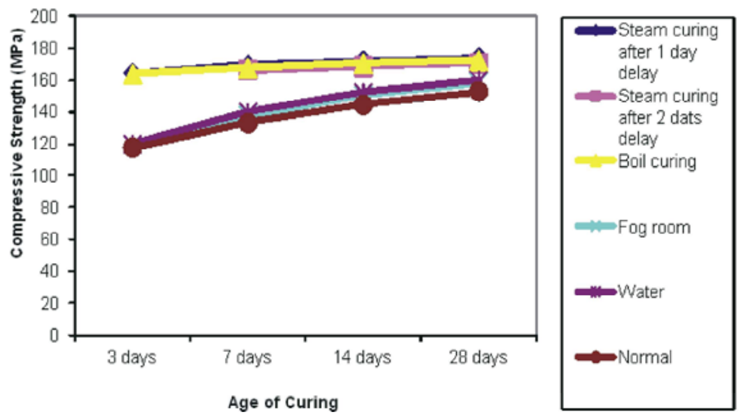

Fig. 2: Relationship between compressive strength and age for curing

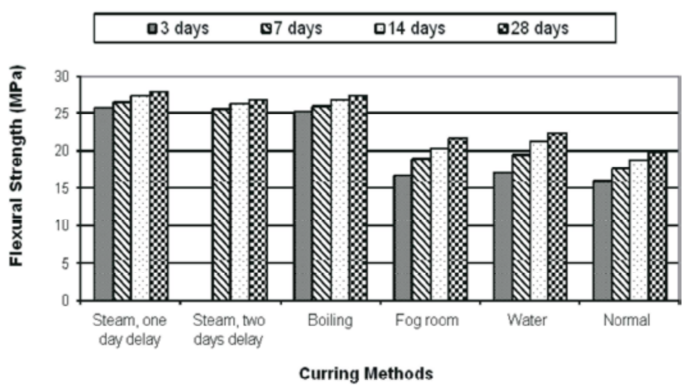

Fig. 3: Relationship between flexure strength and curing condition

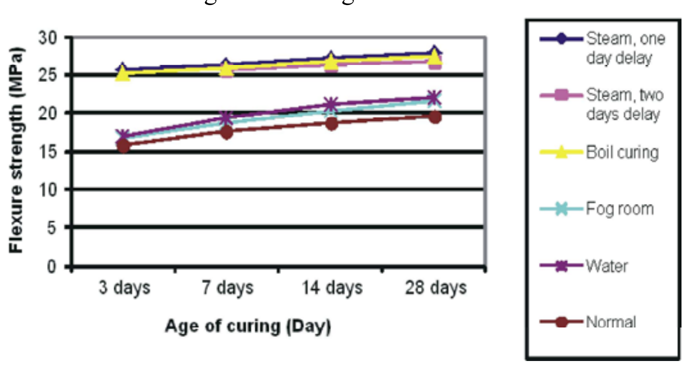

Fig. 4: Relationship between flexural strength and age for curing

Table 2: Compressive strength test

	Compressive strength (MPa)			
Curing condition	3 days	7 days	14 days	28 days
Steam Curing one day delay	164.45	169.59	171.86	173.6
Steam Curing two days delay		166.35	168.58	170.54
boiling Curing	163.63	167.74	170.39	172.48
Fog room Curing	119.31	137.62	150.49	158.28
Water Curing	119.86	139.74	152.36	159.86
Normal Curing	117.17	132.93	144.67	152.63

Table 3: Flexure strength test

	Flexure strength (Mpa)			
Curing condition	3 days	7 days	14 days	28 days
Steam Curing one day delay	25.72	26.43	27.32	27.92
Steam Curing two days delay		25.64	26.32	26.86
boiling Curing	25.27	25.83	26.76	27.42
Fog room Curing	16.68	18.75	20.34	21.64
Water Curing	16.95	19.31	21.16	22.21
Normal Curing	15.93	17.62	18.71	19.69

The results in Figures 1 and 2 indicate that with all types of curing methods the compressive strength is proportionally increase with curing ages. In steam curing method, UHPFC has a relatively higher compressive strength with 28 days. The compressive strength on the 28^{th} day for UHPFC is 173.60 MPa. In terms of strength development, it is shown that UHPFC has a gradually increased strength development. In other words, the UHPFC strength increased regularly day by day until the 28th day. Steam curing two-day delay and boiling curing obtained a compressive strength of 170.54 and 172.84 MPa, respectively by the 28th day. The result shows that steam curing and boil curing methods increase the compressive strength in the first age of curing [11, 12] and improves the microstructure of the concrete [13-15]. Steam curing and boil curing is a methods used to accelerate the rate of strength development of concrete. In the case of curing of concrete by fog are the same conditions surrounding the concrete as in the case of curing by water curing method and the results obtained were very little different from those obtained with a fog method. The compressive strength at the 28th day the fog room curing and immersion water curing are 161.28 and 162.86 MPa, respectively. In normal curing the compressive strength in 28 days was 155.63 MPa this value is the lowest result in different curing regimes in 28 days. Increased strength development in normal curing method slower than fog, water, steam and boil curing method due to that slower hydration process occurs because of the lack of water.

Flexure Strength: The effect of different curing methods on the flexure strength of UHPFC could be notice as depicted in Table 3, Figures 3 and 4.

Flexural testing was conducted at 28 days on prisms that underwent six curing regimes. A total of 72 prisms were test. The flexure strength on the 28th day for UHPFC is 27.92 Mpa in the case of steam curing one day delay. At the 28th day, steam curing two days delay and boil curing obtained flexure strength of 26.68 and 27.42MPa, respectively. In the case of curing of concrete by fog are the same conditions surrounding the concrete as in the case of curing by water curing method and the results obtained were very little different from those obtained with a fog method. The flexure strength at the 28th day the fog room curing and immersion water curing are 21.64 and 22.21 MPa, respectively. In normal curing the flexure strength in 28 days was 19.69 MPa, this value is the lowest result in flexure strength under different curing regimes in 28 days. This result indicates that the UHPFC mechanical properties gradually increased until the 28^{th} day. Also the first three methods used to accelerate the rate of flexure strength of UHPFC in the first age of curing. However, increased flexural strength in natural weather curing method slower than other methods due to slower hydration process occurs.

CONCLUSION

As a result, steam and boiling methods proportionally increases the mechanical properties of UHPFC, in the first ages of curing. This means that both curing methods accelerating the rate of compressive strength and flexure strength of UHPFC, it was noticed that curing was accelerated by retaining heat of hydration or by the addition of heat via steam or boil method. Increase of temperature method effect on the microstructure and mechanical properties of UHPFC at an early age of curing. Mechanical properties in fog curing method is slightly different from the water curing method while the normal curing method gave the lowest values in mechanical properties because dry curing resulted in a lower mechanical properties compared to other curing methods.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Universiti Sains Malaysia for providing the financial support for the present resaerch.

REFERENCES

1. Fehling, E., M. Schmidt, K. Bunje and W. Schreiber, 2008. Design of first hybrid UHPC-steel bridge across the river Fulda in Kassel, Germany., in Second International Symposium on Ultra High Performance Concrete, 05-07 March 2008: Kassel University, Kassel, Germany, pp: 581-588.
2. Tayeh, B.A., B.H. Abu Bakar and M.A. Megat Johari, 2012. Mechanical properties of old concrete - UHPFC interface., in International Conference on Concrete Repair, Rehabilitation and Retrofitting III (ICCRRR 2012), 02-05 September 2012: Cape Town, South Africa, pp: 1035-1040.
3. Nematollahi, B., M.R. Raizal Saifulnaz, M.S. Jaafar and Y.L. Voo, 2012. A review on ultra high performance 'ductile'concrete (UHPdC) technology. International Journal of Civil and Structural Engineering, 2(3): 1003-1018.
4. Neville, A.M., 1995. Properties of Concrete, Longman Group Limited, England.
5. Haque, M.N., 1990. Some concretes need 7 days initial curing, in Concr. Int., pp: 42-46.
6. Austin, S.A., P.J. Robins and A. Issaad, 1992. Influence of curing methods on the strength and permeability of GGBFS concrete in a simulated arid climate. Cement and Concrete Composites, 14(3): 157-167.
7. Tayeh, B.A., B.H. Abu Bakar and M.A. Megat Johari, 2013. Characterization of the interfacial bond between old concrete substrate and ultra high performance fiber concrete repair composite. Materials and Structures, 46(5): 743-753.
8. Tayeh, B.A., B.H. Abu Bakar, M.A. Megat Johari and M.M. Ratnam, 2013. The Relationship between substrate roughness parameters and bond strength of ultra high- performance fiber concrete. Journal of adhesion science and technology, http://dx.doi.org/10.1080/01694243.2012.761543.
9. B.S., E.N., BS EN 12390-3:2002. Testing hardened concrete-Compressive strength of test specimens, in British European Standard 2002: London, United Kindom.
10. ASTM, C., 78, Standard Test Method for Flexural Strength of Concrete, in Annual Book of ASTM Standart, 4.022004.
11. Tayeh, B.A., B.H. Abu Bakar, M.A. Megat Johari and Y.L. Voo, 2012. Mechanical and permeability properties of the interface between normal concrete substrate and ultra high performance fiber concrete overlay. Construction and Building Materials, 36: 538-548.
12. Tayeh, B.A., B.H. Abu Bakar, M.A. Megat Johari and A.M. Zeyad, 2013. The role of silica fume in the adhesion of concrete restoration systems. Advanced Materials Research, 626: 265-269.
13. Erdem, T., L. Turanli and T. Erdogan, 2003. Setting time: An important criterion to determine the length of the delay period before steam curing of concrete. Cement and Concrete Research, 33(5): 741-5.
14. Gesoğlu, M., 2010. Influence of steam curing on the properties of concretes incorporating metakaolin and silica fume. Materials and Structures, 43(8): 1123-34.
15. Kjellsen, K.O., 1996. Heat curing and post-heat curing regimes of high-performance concrete: influence on microstructure and CSH composition. Cement and Concrete Research, 26(2): 295-307.