4th International Conference on Applied Research in
Chemistry Science and Biology
With license No. 16/49457 from the Ministry of Science, Research and Technology
September 2017, Tehran, Iran

Optimization of compressive strength of concrete containing Nano silica and polypropylene fibers and variable water to cement ratio using edge design

Hamid Eskandari-Naddaf[*,*] Fatemeh Zahiri and Mohammad Darghadami
[1]Department of Civil Engineering, Hakim Sabsevari University, Sabsevar, Iran
*corresponding author : Hamidsttu@yahoo.com

ABSTRACT

Research has shown that the use of Nano scale has led to increased quality and strength of concrete. Given the fact that researchers are paying particular attention to the use of nanotechnology in the concrete industry they have taken a new approach to the construction industry. In this regard 12 mixing designs with different amounts of these additives with three types of cement strength classes (525, 425 and 325) and 9 cubic samples (10×10×10) were designed and tested for compressive strength. The purpose of this paper is to investigate and compare the compressive strength of samples containing Nano silica and polypropylene fibers and the ratio of water to cement ratio to each other in order to achieve maximum strength by checking the vertex method and its ability to find the highest compressive strength has been evaluated. The results show that Nano silica particles have a greater effect on compressive strength compared to fibers. In this study for the production of high strength concrete the use of Nano silica is due to the positive interaction that occurs between the cement pulp and its beads. The findings also show that using higher resistivity cements could result in better strength results especially in designs involving Nano silica particles.

Keywords: Compressive Strength, Nano silica, Fiber, Vertex Method

1. INTRODUCTION

Factors that can have a significant impact on the compressive strength of concrete include the ratio of water to cement the type and amount of pozzolanium materials and aggregates consumed [1]. Today new types of concrete have been produced to improve the strength and durability of concrete [2, 3]. To improve the strength of concrete structures against continuous the combination of fibers in concrete is used [4-8]. Among the fibers used in concrete, polypropylene fibers as synthetic fibers have attracted the attention of many researchers because of reduced cost and weight, Inertness, corrosion strength and acid, increased strength to cracking [9-14]. There are important factors that are effective on the strength of the mortar. Early on the impact of the ratio of water to cement has been researched [15]. Subsequently various investigations were carried out and according to a study it was found that the compressive strength of the concrete varies greatly with the change in the ratio of water to cement and the subsequent amount of cement [16]. Following the advent of nanotechnology, nanotechnology is used to improve the properties of cement used in concrete [17-21]. This is currently developing at an upside. Cement has the role of adhesive in concrete and nanotechnology has increased the mechanical properties of cement which increases cement bonding strength and thus increases compressive strength of concrete [22]. Increasing short-term strength and increasing long-term strength to high-strength concrete with Nano-silica is possible [23]. Strength to water penetration and 28-day compressive strength of concrete is improved by using Nano silica [24]. Improving microstructures, reducing permeability, reducing porosity, and increasing the compressive strength resulting from the use of Nano-silica in concrete can be concluded that the use of Nano silica is valuable that Collapardi and colleagues approve of this issue [25].

Optimizing using a pilot scheme may be helpful in shortening the experience time [26]. Test design is a statistical method that can significantly reduce the number of tests and conclusions in the high standard. To solve this problem and to obtain the optimum test design (DOE) it provides a better alternative to study the effects of its variables and responses with a minimum number of tests [27, 28]. In this designed study a mixing test is used. Identify the best invoice settings for optimizing concrete properties since the mixing test is easily used in concrete industry. The usefulness of this method for optimizing the properties of concrete has been investigated [29]. In this paper the effect of factors such as polypropylene fibers, Nano silica and water to cement ratio on mechanical properties of concrete has been attempted. For example the compressive strength of concrete made with strength class325, 425 and 525 in 28 days with 9 samples in 12 the mixing scheme has been investigated by the mixing optimization method.

2. LABORATORY MATERIALS

In this research three types of strength class of Portland cement type 325-1 and 425-1 and 525-2 have been used. In the manufacture of these samples fine-grained and silica-shaped quaternary aggregates were used according to the grain size curve in accordance with the ASTM regulations regarding the application of aggregates in concrete. It should be noted that the percentage of fine grained material was 50% compared to the fine grained and grated aggregate. Silica soot was used as a powder and in gray added to it during the mixing operation. Nano silica used as a nourishing liquid is based on nanotechnology with a very impressive effect and low consumption. Polymer fibers (polypropylene) are used as secondary reinforcement of concrete or mortar to reduce shrinkage and cracking control and increase the durability of concrete in the long run. The fibers are added to the mixed dry or fresh mixture in accordance with the manufacturer's instructions at the time of construction and mixing of concrete with other materials. Consumption varies between 0.5 and 2 kg per cubic meter depending on expected performance. Another way is to mix the fibers in the water before adding it to the dry mix. In these experiments the fibers were mixed in the first method. Poly carboxylate (PCE) based super-lubricant was also used and 0.2 to 1.2% cement weight added (depending on the slump) to the material. In this research the experimental samples 10×10×10 cubic meters for determination of compressive strength were constructed in 12 mixing plans and 3 cement resistant grades listed in Table 1 in which a total number of samples of 9 cubic meters were obtained. The mixing plan for the sample of concrete is weighted in the table. It should be noted that as shown in the mixing table the mixing plan 1 is as a control and without any other fibers or additives. Mixing scheme 2 to 6 with fiber and water to cement ratio 0.5 and mixing scheme 7 to 12 with Nano silica and water to cement ratio 0.4 were constructed.

Table 1. *Concrete Mixing Design*

Aggregate (gr)	Super lubricant (gr)	fibers (gr)	Nano silica (gr)	Micro silica (gr)	cement (gr)	water (gr)	
3600	18	0	0	0	1330	665	1
3600	18	6	0	0	1330	665	2
3600	18	12	0	0	1330	665	3
3600	18	18	0	0	1330	665	4
3600	18	24	0	0	1330	665	5
3600	18	30	0	0	1330	665	6
3600	19	0	0	133	1197	532	7
3600	19	0	38	95	1197	532	8
3600	19	0	95	38	1197	532	9
3600	19	0	66/5	66/5	1197	532	10
3600	19	0	19	114	1197	532	11
3600	19	0	133	0	1197	532	12

3. ANALYZE THE RESULTS

In the Response Trace design the effect of changing variables on the response can be seen. In this chart the predictions made from the fitted model. The response tracking plan shows the effect of each element in the central point of the experimental region on the relative response value. When multiple responses differ from one system to another in order to get a fair result we should use the response tracking graph. In this graph the vertical column shows the strength value with regard to the effect of the factors [30]. The horizontal column represents the deviation from the reference relative to the composition. In this chart finding optimal solutions for different responses is shown. This chart cannot provide us with a useful demonstration of the level of response. Because the three-dimensional response pattern of the image is better than the surface and therefore the basis for optimization is better. Since the amount of water to cement is less than the range of numbers inside the graph therefore the curve does not appear among the curves of other factors.

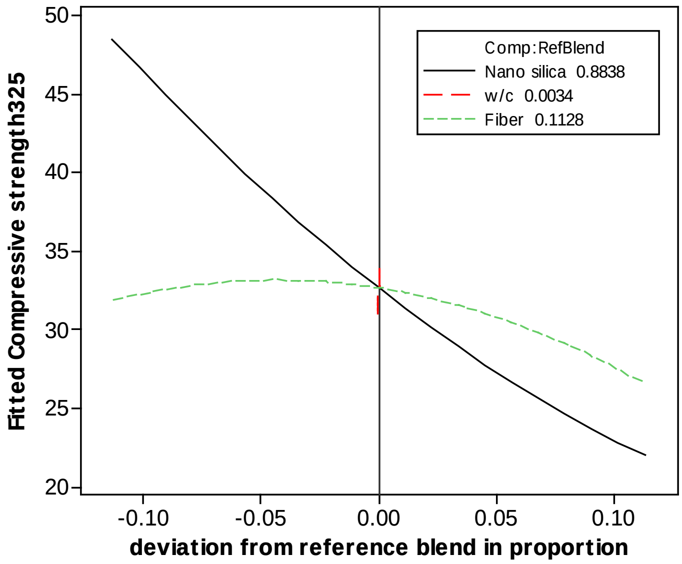

Fig. 1. *Cox response trace. Compressive strength of cement category 325*

In Fig.1 it can be seen that by decreasing the amount of Nano silica the compressive strength of the concrete decreased by 325 cement but increased with increasing the amount of compressive strength of the fiber and then decreases and strength decreases.

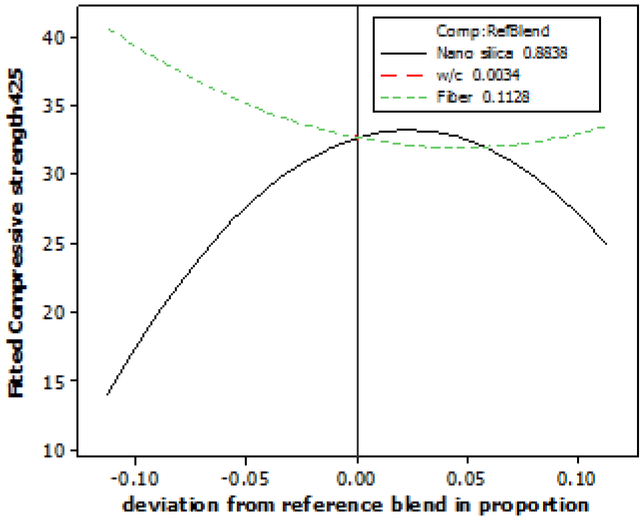

Fig. 2. *Cox response trace. Compressive strength of cement category 425*

But according to the diagram initially Nano-silica has increased strength and its strength is less than the effect of the fiber but in the second part the reduction of Nano-silica has a greater effect on the reduction of strength to fibers and the fiber reduces the strength level. With the simultaneous impact of these three factors the water content of cement was not affected.

It is shown in Fig.2 that initially had the greatest effect on fiber strength and with decreasing fiber content the amount of compressive strength decreased and then again increased slightly. In this type of cement class Nano-silica has a lesser effect on the amount of strength to fibers and with increasing Nano-silica content the compressive strength increased and in the short run its increase increased the fiber content and then again reduced the strength.

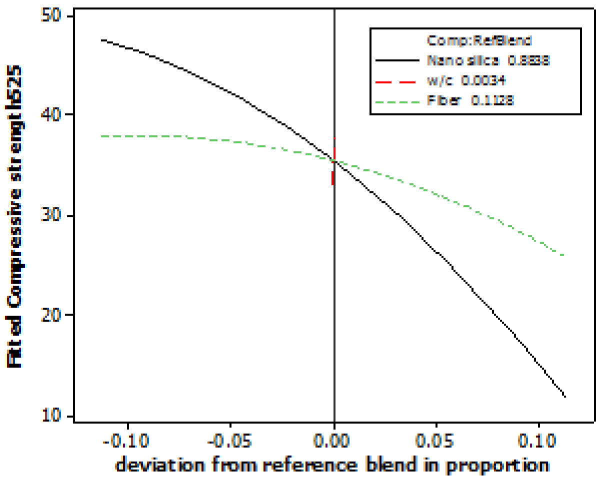

Fig. 3. *Cox response trace. Compressive strength of cement category 525*

In Fig.3 we see that as the amount of cement class increases the compressive strength of the Nano silica increases. Initially the Nano silica was the most effective in increasing the resistivity and as the Nano silica increased the amount of strength decreased but at the same time the amount of strength increased with increasing fiber content and in one part of the path to increase its strength to the Nano silica. And the ratio of water to cement has not been affected.

4. CONCLUSION

In this research the relationship between Nano silica and fiber and water-to-cement ratio with concrete compressive strength has been investigated. One of the important activities in this study was the use of the DOE methodology which uses a mixing optimization method under the finite vertex sub-set to find the optimal level of factors and determine the effect of each factor. The use of polypropylene fibers does not have a significant effect on compressive strength and only affects cracking and permeability. In spite of the fact that the results of using higher strength class in samples did not follow a certain trend they were almost effective in samples containing nano-silica materials so that increasing the cement strength category resulted in increased compressive strength.

5. REFERENCES

1. Goodspeed, C.H., S. Vanikar, and R. Cook, *High-performance concrete defined for highway structures.* Concrete International, 1996. **18**(2): p. 62-67.
2. Farnam, Y., S. Mohammadi, and M. Shekarchi, *Experimental and numerical investigations of low velocity impact behavior of high-performance fiber-reinforced cement based composite.* International Journal of Impact Engineering, 2010. **37**(2): p. 220-229.
3. Breitenbiicher, R. *High Performance Fibre Concrete SIFCON for repairing environmental structures', in'High Performance Fiber Reinforced Cement Composites (HPFRCC3)'.* in *Proceedings of the 3rd International Workshop, Eds. HW Reinhardt and AE Naaman (R1LEM Publications sarl, Cachan, 1999).* 1999.
4. Banthia, N., C. Yan, and K. Sakai, *Impact strength of fiber reinforced concrete at subnorma temperatures.* Cement and Concrete Composites, 1998. **20**(5): p. 393-404.
5. Toutanji, H., S. McNeil, and Z. Bayasi, *Chloride permeability and impact strength of polypropylene-fiber-reinforced silica fume concrete.* Cement and Concrete Research, 1998. **28**(7): p. 961-968.
6. Song, P., S. Hwang, and B. Sheu, *Strength properties of nylon-and polypropylene-fiber-reinforced concretes.* Cement and Concrete Research, 2005. **35**(8): p. 1546-1550.
7. Nataraja, M., N. Dhang, and A. Gupta, *Statistical variations in impact strength of steel fiber-reinforced concrete subjected to drop weight test.* Cement and Concrete Research, 1999. **29**(7): p. 989-995.
8. Aruntaş, H.Y., et al., *Effects of super plasticizer and curing conditions on properties of concrete with and without fiber.* Materials Letters, 2008. **62**(19): p. 3441-3443.
9. Banthia, N. and R. Gupta, *Influence of polypropylene fiber geometry on plastic shrinkage cracking in concrete.* Cement and Concrete Research, 2006. **36**(7): p. 1263-1267.
10. Alhozaimy, A., P. Soroushian, and F. Mirza, *Mechanical properties of polypropylene fiber reinforced concrete and the effects of pozzolanic materials.* Cement and Concrete Composites, 1996. **18**(2): p. 85-92.
11. Ghavami, K., *Bamboo as reinforcement in structural concrete elements.* Cement and concrete composites, 2005. **27**(6): p. 637-649.
12. Qian, C. and P. Stroeven, *Development of hybrid polypropylene-steel fibre-reinforced concrete.* Cement and Concrete Research, 2000. **30**(1): p. 63-69.
13. Toutanji, H.A., *Properties of polypropylene fiber reinforced silica fume expansive-cement concrete.* Construction and Building Materials, 1999. **13**(4): p. 171-177.
14. Yao, W., J. Li, and K. Wu, *Mechanical properties of hybrid fiber-reinforced concrete at low fiber volume fraction.* Cement and concrete research, 2003. **33**(1): p. 27-30.
15. Feret, R., *Essais de divers sables et mortiers hydrauliques.* Ann. Ponts Chauss. Mémoires et Documents, 1896. **7**: p. 174-197.
16. Montgomery Douglas, C., *Design and analysis of experiments.–5th edition by Wiley & Sons.* Inc., New York, 2001.
17. Farzadnia, N., A.A.A. Ali, and R. Demirboga, *Characterization of high strength mortars with nano alumina at elevated temperatures.* Cement and Concrete Research, 2013. **54**: p. 43-54.
18. Farzadnia, N., et al., *Characterization of high strength mortars with nano Titania at elevated temperatures.* Construction and Building Materials, 2013. **43**: p. 469-479.
19. Farzadnia, N., et al., *Effect of halloysite nanoclay on mechanical properties, thermal behavior and microstructure of cement mortars.* Cement and Concrete Research, 2013. **48**: p. 97-104.

20. Jo, B.-W., et al., *Characteristics of cement mortar with nano-SiO 2 particles.* Construction and building materials, 2007. **21**(6): p. 1351-1355.

21. Berra, M., et al., *Effects of nanosilica addition on workability and compressive strength of Portland cement pastes.* Construction and Building Materials, 2012. **35**: p. 666-675.

22. Scrivener, K.L. and R.J. Kirkpatrick, *Innovation in use and research on cementitious material.* Cement and Concrete Research, 2008. **38**(2): p. 128-136.

23. Li, G., *Properties of high-volume fly ash concrete incorporating nano-SiO 2.* Cement and Concrete research, 2004. **34**(6): p. 1043-1049.

24. Ji, T., *Preliminary study on the water permeability and microstructure of concrete incorporating nano-SiO 2.* Cement and Concrete Research, 2005. **35**(10): p. 1943-1947.

25. Collepardi, M., et al. *Optimization of silica fume, fly ash and amorphous nano-silica in superplasticized high-performance concretes*. in *Proceedings of 8th CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, SP-221, Las Vegas, USA*. 2004.

26. Huisman, R., et al., *Development and optimization of pharmaceutical formulations using a simplex lattice design.* Pharmaceutisch Weekblad, 1984. **6**(5): p. 185-194.

27. Montgomery, D.C., *Design and Analysis of Experiments, John Wiley & Sons.* New York, 2001: p. 64-65.

28. Giovanilton, F., L. Fernando, and L. Andrea, *Application of Surface Methodology for Optimization of Biodiesel Production by Transesterification of Soybean Oil with Ethanol.* Fuel Processing Technology, 2011. **92**: p. 407-413.

29. Simon, M.J., E.S. Lagergren, and K.A. Snyder. *Concrete mixture optimization using statistical mixture design methods*. in *Proceedings of the PCI/FHWA international symposium on high performance concrete*. 1997.

30. Cleland, D. and A. McCluskey, *An extreme vertices mixture design approach to the optimisation of 1, 2, 3-trichlorobenzene specific molecularly imprinted polymers.* Organic & biomolecular chemistry, 2013. **11**(28): p. 4672-4679.