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 cement mortar by controlling the chemical parameter of nano silica by the Taguchi statistical method

Hamid Eskandari-Naddaf[1,*] - Ali Bashtani[2]
[1] Department of Civil Engineering, Hakim Sabzevari University, Sabzevar, Iran
Email address: hamidsttu@yahoo.com, telephone number: 0910 510 2012
[1] Department of Civil Engineering, Hakim Sabzevari University, Sabzevar, Iran
Ali.bashtani1996@gmail.com

ABSTRACT

Concrete compressive strength is one of the most important criteria affecting various parameters. Therefore, changing or optimizing the effective parameters in the manufacture of cement mortar can lead to lower costs and increase compressive strength. In this research, the effect of each compressive strength parameter has been studied considering three factors: water to cement ratio, Fine grained to cement ratio and the amount of nano silica used in cement mortar. In this method, using 18 laboratory samples, the effect of the three parameters mentioned at the following levels with Taguchi optimization in relation to cement: the ratio of water to cement at 35, 0, 4, 5 to cement at 2, 2, 5 and the amount From Nanosilica at levels 4.5, 9 and 13.5. By examining the interactive behavior of the three parameters provided by the Taguchi method, it has been found that the optimal amount of water to cement ratio is 0.35, cement is to cement ratio 2, and the amount of nano silica used in cement mortar 13.5. Finally, considering the scope of this method in previous research and results, the Taguchi statistical method can be used as a reliable method.

Keywords: Nano Silica - Grain to Cement ratio - Water to cement ratio - Compressive strength

1. INTRODUCTION

Various factors influence the prediction of the compressive strength of the cement mortar; this effect can impose an additional cost on the mortar and also fail to achieve the desired resistance in the event of a calculation error. Therefore, it is important to identify the extent of the impact of each agent and its control[1]. With these interpretations, mastering the effect of aggregation has been used, as well as the ratio of water to cement used in the manufacture of cement mortar in order to obtain the desired compressive strength[2, 3]. By examining two samples of cement mortar, it was obtained that a mortar with a high water / cement ratio in comparison to a mortar with a less water / cement ratio was found to be less brittle .Also, the proportion of Fine-Aggregate to cement has the ability to influence the properties of fresh and hardened concrete; thus, it is clear that choosing the correct water-to-cement ratio and fine-grained to cement is important for making a suitable mortar[4]. By comparing the compressive strength of the two modified and unmodified mortar, it was observed that only by reducing the water-to-cement ratio in the modified mortar; the compressive strength, durability and quality, which is part of the engineering properties of the cement mortar, have been improved, with these interpretations affecting The ratio of water to cement is clearly visible in the compressive strength category[5-11]. In the last decade, with the introduction of the use of nanoparticles in improving the compressive strength of concrete, the use of this material has increased due to the positive effects on the physical and chemical properties of the concrete as well as its final compressive strength[3, 12, 13]. In a study conducted on the behavior of nanoparticles, it was found that these materials were able to modify the properties of fresh and even hardened concrete, in a way that calls the use of Nano silica in concrete mortar as a way to increase mechanical properties[4, 9, 10]. The presence of Nano silica in cement mortar used in concrete production has the ability to increase the final compressive strength of concrete[14-16]. In this research, we analyze the effects of three factors of water to cement, fine grained cement and Nano-silica on the resistance parameter of the Taguchi statistical method.

1. Materials and preparation specimens

The data used to investigate the effect of Nano silica particles on the properties of cement mortar applied to the spring elements of the paper by the researcher Boushehrian and Hosseini have been used[17]. In this research, typical

Portland cement (type 425-1), which conforms to the national standards of Iran 389, has been used. Colloidal Nanos silica (with a solid content of 30%) was used. Normal natural sand washed with a soft modulus of 3.2, a specific gravity of 2.74 g / cm3, and a 1% water absorption with good granulation.

2. Analysis and discussion

By analyzing Fig. 1, it is considered that the optimum ratio for fine-grained to cement ratio in the ratio of 2.0, for the ratio of water to cement in the ratio of 0.35 and for a nano-silica in the ratio of 13.5, occurs. This occurs while increasing the ratio of fine-grained to cement to a ratio of 2.5 to a decrease in the final strength, as well as a change in the ratio of water to cement from a ratio of 0.35 to 0.4, leads to a decrease in the final strength to below the main line, and at a later stage with Increasing the ratio of water to cement to 0.5% is the lowest level of resistance. The change in the nano-silica ratio, in contrast to the two ratios mentioned above, increases the residual strength in such a way that the use of the nano-silica ratio of 13.5 causes a large change and increased resistance. With this explanation, the use of nano-silica improves the final compressive strength of concrete, which is considered an important goal.

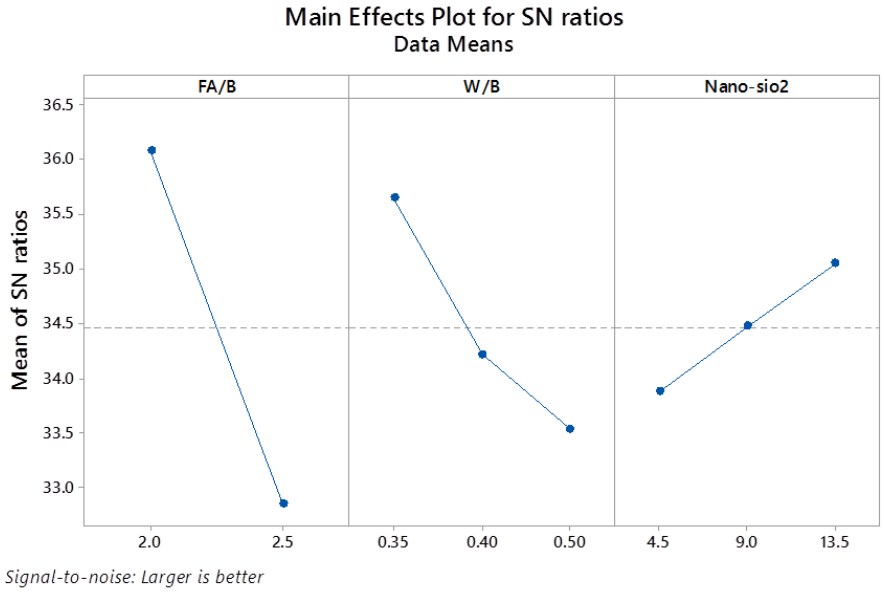

Fig. 1. *Signal to Noise FA / B, W / B, Nano-silica*

According Fig 2, interconnecting canton, the ratio of fine aggregate to cement and the water-to-cement ratio shows that the highest resistance is obtained from the interaction of the water-to-cement ratio of 0.35 and the ratio of fine-grained to cement 2.0 and by increasing each ratio in each of the two As opposed to the loss of ultimate compression strength. The least resistance is obtained from the ratio of water to cement ratio 0.5 to a fine grain to cement ratio of 2.5, which is not recommended for interaction.

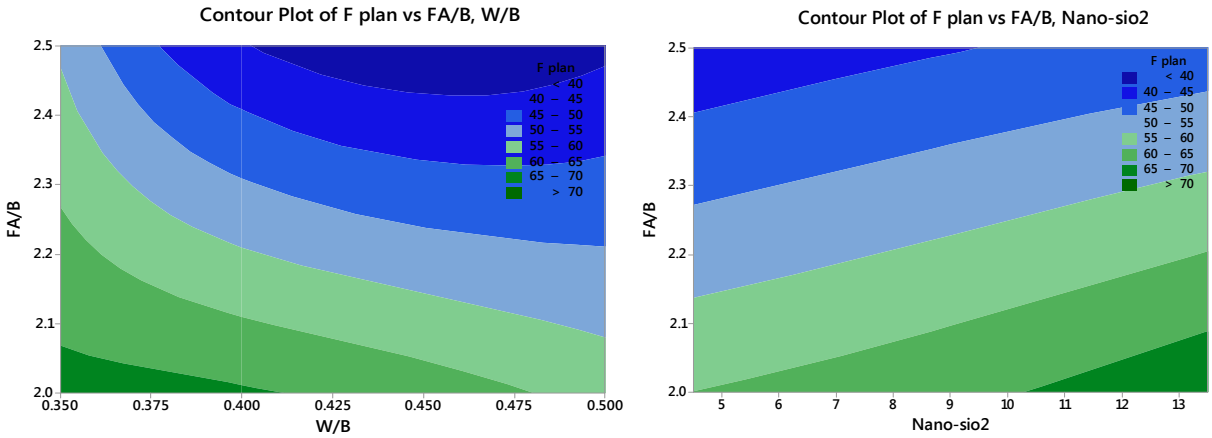

Fig. 2. *Interactive contour W / B, FA / B and FA / B, Nano silica*

Also the ratio of fine-grained to cement with the ratio of Nano-silica used in cement mortar is shown in fig 1. So that any increase in the ratio of Nano-silica leads to an increase in the compressive strength of the final sample, so that the interaction of the smallest proportion of fine grains The cement with the highest proportion of Nano-silica gives the highest possible resistance, while the lower the amount of Nano-silica, while the ratio of fine-grained to cement is constant, the resistance drop. In Fig 3, the fine aggregate, cement plant and the water-to-cement ratio; the water-to-cement ratio of 0.35 represents the highest final strength that can be obtained by interacting with each of the two fine-grained cement ratios. The ratio of 0.35 water to cement in comparison to the two 0.4 and 0.5 ratios is less affected by the change in fine-grained to cement ratio, which shows some kind of stability in maintaining the final strength due to the decrease due to the increased proportion of fine-grained cement to cement. In this regard, the ratio of water to cement 0.4 due to the high drop due to the increase of the ratio of fine-grained to cement is the least stable ratio, and in the use of the maximum should be carefully selected in the selection of fine grain to cement ratio. In the fine-grained cement proportion of cement, the compressive strength of the sample shows a rise in the compressive strength so that the highest compressive strength in the water-to-cement ratio is 0.35 and increases with decreases of 0.4 and 0.5 To make Finally, the interaction of fine grains to cement 2.0 and water-to-cement ratio of 0.35 is chosen as the interactive state of these two factors.

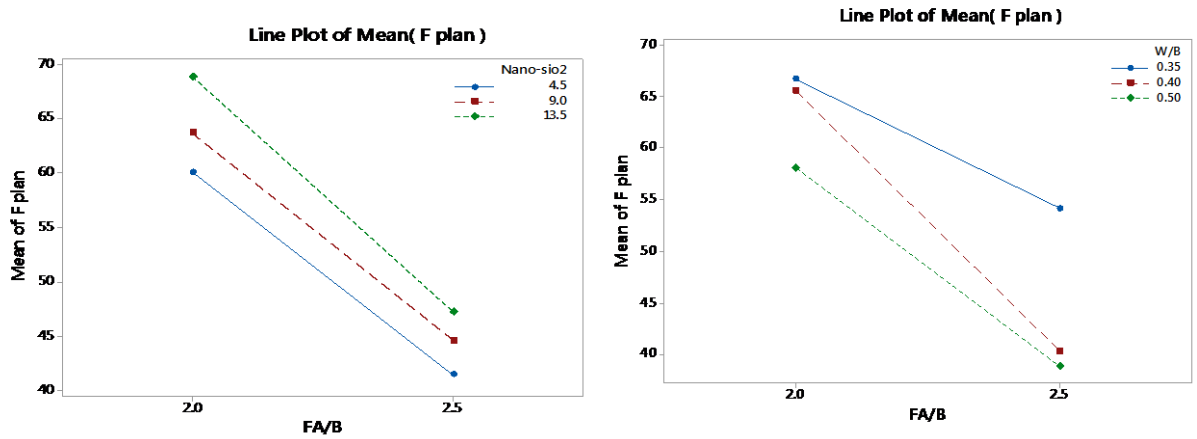

Fig. 3. *Interactive layout FA / B, W / B and FA / B, Nano silica*

3. Tables

Table 1 - Chemical Properties of Cement

Materials	Nano Silica	Ordinary Portland Cement(%)
Sio2	99.7	21.4
Al2o3	-	6
Fe2o3	-	3.4
Cao	-	64
Mgo	-	1.8
So3	-	1.4
K2o+Na2o	-	1
Loi	2.8	3
Special Weight	1.2	3.15
Special level	-	0.37
Average	-	1

Using nano-colloidal particles improves the performance of nanoparticles by increasing the dispersion of nanoparticles in concrete[18]. Natural natural sand washed with a softness modulus of 3.2, a specific gravity of 2.74 g / cm3, and a 1% water absorption with good grains. Finishing grains are considered in accordance with ACI 549R-97[19]. Naphthalene with a solid content of 40% with a water-reducing function improves the dispersion of nanoparticles and the efficiency of the mortar by increasing the viscosity of the mortar[20, 21]. In this research, two parameters are used in three different levels, including a parameter in two levels, which is indicated in Table 2.

Table 2. Test parameters along with each level

parameters	Level 1	Level 2	Level 3
Water to cement ratio	0.35	0.4	0.5
Fine grain to cement ratio	2	2.5	-
Nano Silica	4.5	9	13.5

18 specimens were used to make laboratory samples, so that the three interactions of nano silica 4.5, 9, 13.5 and water-to-cement ratio of 0.35, 0.4 and 0.5 and two interactive levels of fine-grained cement to cements 2 and 2.5 were used. Mix designs are provided in table 3.

Table 3. Mix design of specimens

Mix no	Fine aggregate to binder ration	Water to cement ratio	Nano silica
1	2	0.35	4.5
2	2	0.35	9
3	2	0.35	13.5
4	2	0.4	4.5
5	2	0.4	9
6	2	0.4	13.5
7	2	0.5	4.5
8	2	0.5	9

9	2	0.5	13.5
10	2.5	0.35	4.5
11	2.5	0.35	9
12	2.5	0.35	13.5
13	2.5	0.4	4.5
14	2.5	0.4	9
15	2.5	0.4	13.5
16	2.5	0.5	4.5
17	2.5	0.5	9
18	2.5	0.5	13.5

4. Conclusion

In this research, investigate the effect of fine aggregate to cement ratio, water to cement ratio and Nano-silica content on the compressive strength, so that the results are as follows:

The use of Nano-silica leads to improved compressive strength and produces the highest resistance in a ratio of 13.5. In contrast to the two parameters, fine aggregate to cement and water to cement ratio, which shows a decrease in the compressive strength of the final sample with an increasing proportion of the sample, the use of a higher ratio of Nano-silica has shown an increase in resistance, so that the cost of using more than Nano silica by An increase in the quality of the product is justified. Taguchi's method recognizes the sensitivity of the two water-cement and Nano-silica ratio factors to the interactions of these two factors with the fine aggregate to cement ratio, which indicates that these two parameters are more effective in achieving the ultimate goal of obtaining the highest compressive strength Is. By considering the optimal interactions of both agents with each other, these results can be obtained by interacting fine aggregate to cement ratios 2.0 and water-to-cement ratio of 0.35, fine aggregate -to-cement ratio interaction and Nano-silica 13.5 interactions, and interaction The ratio of water to cement 2.0 with a Nano silica ratio of 13.5 is most optimal and it is possible to combine the results of the statistical method with the optimal possible use of these three parameters from the ratio of fine grained to cement 2.0, water to cement ratio 0.35 With Nano silica 13.5 is possible.

5. REFERENCES

1. Eskandari, H., *Designing, Proposing and Comparing the Methods Predicting the Compressive Strength of the Ferro cement Mortar.* Concrete Research Letters, 2015. **6**(1): p. 1-10.
2. Haach, V.G., G. Vasconcelos, and P.B. Lourenço, *Influence of aggregates grading and water/cement ratio in workability and hardened properties of mortars.* Construction and building materials, 2011. **25**(6): p. 2980-2987.
3. Sahmaran, M., et al., *Effects of mix composition and water–cement ratio on the sulfate resistance of blended cements.* Cement and Concrete composites, 2007. **29**(3): p. 159-167.
4. Meddah, M.S., S. Zitouni, and S. Belâabes, *Effect of content and particle size distribution of coarse aggregate on the compressive strength of concrete.* Construction and Building Materials, 2010. **24**(4): p. 505-512.
5. Schulze, J., *Influence of water-cement ratio and cement content on the properties of polymer-modified mortars.* Cement and Concrete Research, 1999. **29**(6): p. 909-915.

6. Zhou, J., et al., *Influence of free water content on the compressive mechanical behaviour of cement mortar under high strain rate.* Sadhana, 2011. **36**(3): p. 357-369.
7. Zhou, J.-k. and L.-m. Ge, *Effect of strain rate and water-to-cement ratio on compressive mechanical behavior of cement mortar.* Journal of Central South University, 2015. **22**: p. 1087-1095.
8. Ingram, K.D. and K.E. Daugherty, *A review of limestone additions to Portland cement and concrete.* Cement and concrete composites, 1991. **13**(3): p. 165-170.
9. Pei, M., et al., *Effect of the monomer ratio on the properties of poly (methyl methacrylate butyl acrylate) latex-modified mortars.* Journal of applied polymer science, 2004. **93**(5): p. 2403-2409.
10. Nataraja, M., M. Jayaram, and C. Ravikumar, *Prediction of early strength of concrete: a fuzzy inference system model.* International Journal of Physical Sciences, 2006. **1**(2): p. 47-56.
11. Vralstad, T., et al. *A visual journey into the 3D chemical nanostructure of oilwell cement*. in *SPE International Symposium on Oilfield Chemistry*. 2013. Society of Petroleum Engineers.
12. Donza, H., O. Cabrera, and E. Irassar, *High-strength concrete with different fine aggregate.* Cement and Concrete Research, 2002. **32**(11): p. 1755-1761.
13. Singh, S., P. Munjal, and N. Thammishetti, *Role of water/cement ratio on strength development of cement mortar.* Journal of Building Engineering, 2015. **4**: p. 94-100.
14. Li, H., et al., *Microstructure of cement mortar with nano-particles.* Composites Part B: Engineering, 2004. **35**(2): p. 185-189.
15. 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.
16. Li, H., H.-g. Xiao, and J.-p. Ou, *A study on mechanical and pressure-sensitive properties of cement mortar with nanophase materials.* Cement and Concrete research, 2004. **34**(3): p. 435-438.
17. Booshehrian, A. and P. Hosseini, *Effect of nano-SiO2 particles on properties of cement mortar applicable for ferrocement elements.* Concrete Research Letters, 2011. **2**(1): p. 167-180.
18. Senff, L., et al., *Effect of nano-silica on rheology and fresh properties of cement pastes and mortars.* Construction and Building Materials, 2009. **23**(7): p. 2487-2491.
19. Balaguru, P. and G. Batson, *State-of-the-art Report on Ferrocement.* ACI Committee, 1997. **549**.
20. Hosseini, P., A. Booshehrian, and S. Farshchi, *Influence of nano-SiO2 addition on microstructure and mechanical properties of cement mortars for ferrocement.* Transportation Research Record: Journal of the Transportation Research Board, 2010(2141): p. 15-20.
21. Li, H., M.-h. Zhang, and J.-p. Ou, *Abrasion resistance of concrete containing nano-particles for pavement.* Wear, 2006. **260**(11): p. 1262-1266.