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Characteristics of Nano-Silica Concrete with Macro-Fiber Reinforcement

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Abstract: In this study, an experimental investigation on the use of nano silica using the macro-fiber reinforcement on the compressive and tensile strength. The percent of nano silica is 3% from the cement content and the weight of macro-fiber reinforcement were zero, 3 and 5 kg m^{-3}. All tests were performed at 28 and 56 days. Nano-silica is used as partial replacement of cement. Further investigation was carried out by addition of macro-fiber reinforcement for the same percentage of nano silica (3%) of cement in the same mix. Compressive and split tensile strength of these mixes were measured and compared with the control concrete specimens. The experimental test results showed that concrete prepared with (3%) nano silica showed a good comparable strength (either compressive or splitting tensile) than the other two concrete mixes of 10% of silica fume or combined nano silica concrete. The test results showed also that there is a decrease in ratio of tensile to compressive strength as cement content increased for both 10% silica fume concrete and 1% nano silica concrete due to the more increase in compressive strength gain.

INTRODUCTION

High strength concrete and mortar with high strength and durability properties offer many advantages. Sadrmomtazi *et al*.[1] they have been gradually replacing normal strength concrete due to their improved mechanical characteristics and low permeability. With such outstanding characteristics they can be utilized in structure, exposed to severe loading or influenced by environmental conditions, for instance large bridges and offshore constructions.

SCC is a new generation of concrete that can exhibit high deformability and can flow into place under its own weight without any external or internal consolidation and with limited signs of segregation. Maghsoudi *et al*.[2] said the design concept of SCC is mainly based on the combination of high deformability and segregation resistance to achieve self-consolidating, facilitate casting and improve in-situ performance.

Recently, applicable discussion in concrete technology is one of the nanotechnology applications in concrete design. Visual examination, optical microscopy and Scanning Electron Microscopy (SEM) have been extensively used in microstructure research of hardened cement paste and concrete, providing additional understanding of macroscopically properties

Now a day’s use different type of blending material to improve the performance of cement concrete and nano silica powder is one of the blending materials. Rutuja, etc., said the improvement of stability of mixture and it can effectively avoid segregation and secrete water phenomenon, help to improve stress modes of the concrete.

Nanotechnology encompasses main approaches, Jadhav *et al*.[3] the top down" approach, in which larger structures are reduced in size to the nano scale while maintaining their original properties order constructed from larger structures in to their smaller, composite parts and the bottom-up" approach, also called molecular Nanotechnology" or molecular manufacturing," in which materials are engineered from atoms or molecular components through a process of assembly or self-traditionally nano technology has been concerned with developments in the fields of microelectronics, medicine and material sciences. However, the potential for applications of many developments in the nanotechnology field in the area of construction engineering is growing[4].

In this study, nano silica has added. In 3% from the cement content and the weight of macro-fiber reinforcement were zero, 3 and 5 kg m^{-3}. The Compressive strength of respective specimens was tested after 7 and 28 days of curing. Then obtained results compared with traditional concrete. Addition of nano silica and micro-fiber reinforcement in concrete improves the properties of materials which results dandifying the nano structures. Thus, nanopartials act as a filler of pores in concrete which influences the results[5, 6].

MATERIALS AND METHODS

Experimental program

Nano-silica: Nano silica particles is concrete made by filling the pores in conventional concrete using nanopartials of size <00 mm. Currently, cement particle sizes range from a few nano-meters to a maximum of about 100 µm. Nanotechnology generated products have unique characteristics and can significantly fix current construction problems and may change their organization of construction process. The recent developments in the study and manipulation of materials and processes at the nano scale offer the great prospect of producing new macro materials, properties and products. The chemical composition of the nano-silica is shown in Table 1[7].

Macro-fiber reinforcement: SikaFiber® T-48 SL is a macro reinforcement fibers made of polyolefin as shown in Fig. 1. The product has a very high capacity and it has been developed as an alternative to traditional construction reinforcement with a specific use in shot crete and casted concrete. SikaFiber® T-48 SL improve flexural strength and cracking behavior, cohesion and reduced risk for segregation and physical shock resistance. The mechanical properties of macro reinforcement fibers is shown in Table 2[8].

Aggregates: Coarse aggregate has maximum nominal size 10 mm. The used coarse aggregate is clean, free of impurities and with no organic compounds. Testing was carried out according to Egyptian Standards 1109/2002. Fine aggregate is natural sand composed of siliceous materials. The used fine aggregates were clean, free of impurities and with no organic compounds. Testing was carried out according to the same code of coarse aggregate[9].

Table 1: Composition of nano-silica

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	L.O.I
90.90	0.17	0.07	0.09	0.01	0.19	8.31

Table 2: Mechanical properties of SikaFiber® T-48 SL

Length of fiber	Diameter	Tensile density	Tensile strength	E-module
48 mm	0.9 mm	0.91 kg dm^{-3}	500 MPa	20 MPa

Fig. 1: Shape of macro reinforcement fibers

Superplasticizer: Superplasticizers are high water reducers. It was added to concrete to improve its workability and converse its compactness without water content increase. It makes it possible to produce self-compacting concrete. The implemented super-plasticizer trade name is VISCOCONCRETE# 3425, according to ASTM C494, 2001 of type V. It reduces 30% of water content in mixtures[10].

Mixing, casting: For the present study, the nano silica was first prepared with cement, then add coarse and fine aggregates in saturated surface dry condition were well mixed in a pan mixture. Then add macro reinforcement fiber and finally add water and superplasticizer.

A trial mixes, has been found suitable in this study. Specimens such as cubes dimension 150×150×150 mm, cylinder of diameter 150 mm and height 300 mm and beams with dimension 600×100×50 mm were cast using standard steel moulds and compacted with steel bar, as shown in Fig. 2. The mix the required quantities are listed in Table 3.

Table 3: Mix properties (kg m^{-3})

Mix	Nano-silica wt.%	Macro-fiber R.F.T (kg m^{-3})	Cement (kg)	W/C ratio	Coarse Agg. (kg)	Fine Agg. (kg)	Super-plasticizer (Lit.)
M0/0	-	-	388	0.44	1110	700	3
M3/0	3	-	388	0.44	1110	700	3
M3/3	3	3	388	0.44	1110	700	3
M3/5	3	5	388	0.44	1110	700	3

Fig. 2: Preparation of cylindrical and cubes

Curing of concrete specimen: The concrete specimens were cured in the environmental conditions up to the completion of curing time. After the curing period, the test specimens left in the laboratory until the day of the testing[11].

RESULTS AND DISCUSSION

Each value of the test results discussed and presented in tables and bar charts is the mean of 3 test results. Individual strength test results were well within the range of 7.5% difference of the mean value; crushing machine used in this research shown in Fig. 3, Slump test result off different mixes is equal to 3 cm from top as shown in Fig. 4, crushing of different mix cubes for compressive strength and beams for flexural strength are shown in Fig. 5 and 6, respectively. Mechanical properties of mixes are presented in Table 4.

The addition of nano silica has been able to improve the compressive strength of cubes, adding macro reinforcement fiber improve flexural strength and tensile strength of mixes and reduced hardened unit weight.

On the other hand, adding nano silica in concrete mix (M3/0) has resulted to increase of the unit weight compared to the ordinary concrete (M0/0) by 2.7%. The compressive strength of nano silica concrete mix (M3/0) at 7 days is higher than the ordinary concrete (M0/0) with 15.6%, The compressive strength of nano silica in concrete mix (M3/0) at 28 days is higher than the ordinary concrete (M0/0) with 13.4%. The tensile strength of nano silica concrete mix (M3/0) is higher than the ordinary concrete (M0/0) with 15% and the flexural strength of nano silica concrete mix (M3/0) is the same of ordinary concrete (M0/0) but not improve compressive, tensile and flexural cracks.

Fig. 3: Crushing machine used

Fig. 4: Sample of Slump test for different mixes

Fig. 5: Crushing of cubes of different mixes; M0/0M3/0M3/3M3/5

The addition of macro reinforcement fiber resulted to reduce hardened unit weight for mix (M3/3) and mix (M3/5) compared to mix (M3/0) by 1.6 and 3.2%, respectively. The addition of macro reinforcement fiber resulted to increase compressive strength at 7 days for mix (M3/3) and mix (M3/5) compared to mix (M3/0) by 2 and 2.5%, respectively. The addition of macro reinforcement fiber resulted to increase compressive strength at 28 days for mix (M3/3) and mix (M3/5)

Table 4: Mechanical properties of mixes

Mix	Unit weight (kN m^{-3})	Tensile strength (MPa)	Flexural strength (MPa)	Compressive strength at 7 days (MPa)	Compressive strength at 28 days (MPa)
(M0/0)					
1	24.35		2.141	23.19	30.92
2	24.24		2.123	22.88	30.51
3	24.26		2.135	23.01	30.69
Average (M0/0)	24.28	100 kg	2.133	23.03	30.71
M3/0					
1	24.95		2.207	27.39	35.82
2	24.36		2.147	25.76	33.68
3	25.50		2.052	26.72	34.94
Average (M3/0)	24.94	115	2.135	26.62	34.81
M3/3					
1	24.50		2.179	27.25	35.64
2	24.44		2.164	26.16	34.21
3	24.68		2.199	28.08	36.72
Average (M3/3)	24.54	200	2.181	27.16	35.52
M3/5					
1	23.70		2.341	28.20	36.91
2	24.50		2.298	27.49	35.98
3	24.21		2.236	26.20	34.27
Average (M3/5)	24.14	225	2.292	27.29	35.72

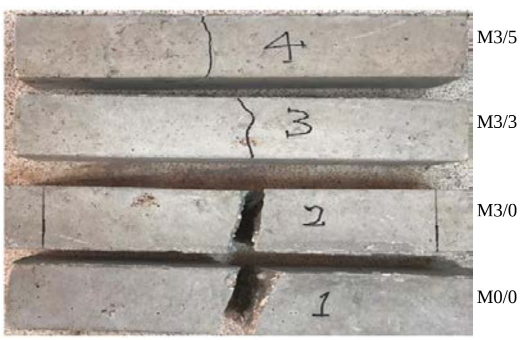

Fig. 6: Crushing of beams to find flexural strength for different mixes; M3/5, M3/3, M3/0 and M0/0

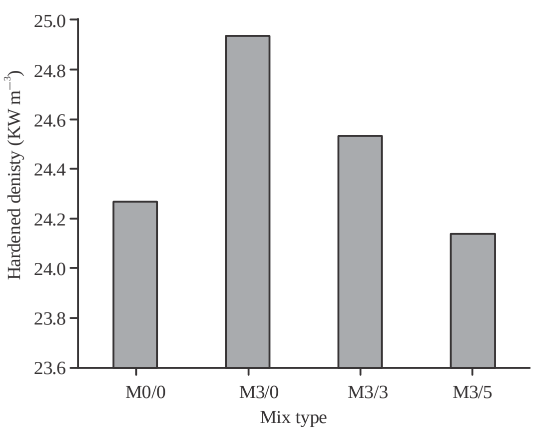

Fig. 7: Unit weight for different mixes

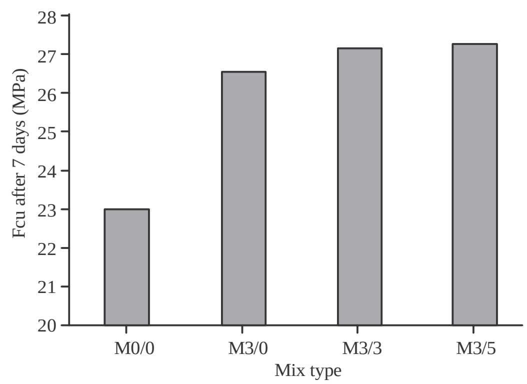

Fig. 8: Compressive strength at 7 days for different mixes

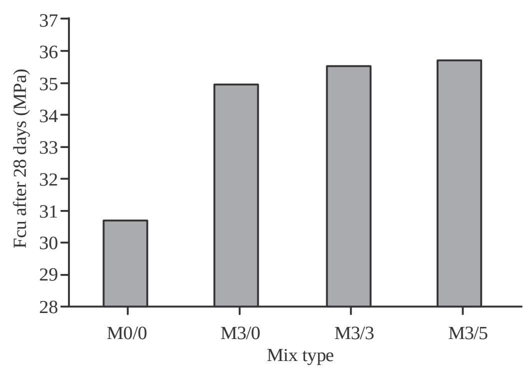

Fig. 9: Compressive strength at 28 days for different mixes

compared to mix (M3/0) by 2.1 and 2.6%, respectively. The addition of macro reinforcement fiber resulted to increase tensile strength for mix (M3/3) and mix (M3/5) compared to mix (M3/0) by 73.9 and 95.7%, respectively and addition of macro reinforcement fiber resulted to increase flexural strength for mix (M3/3) and mix (M3/5) compared to mix (M3/0) by 2.15 and 7.3%, respectively (Fig. 6- 9).

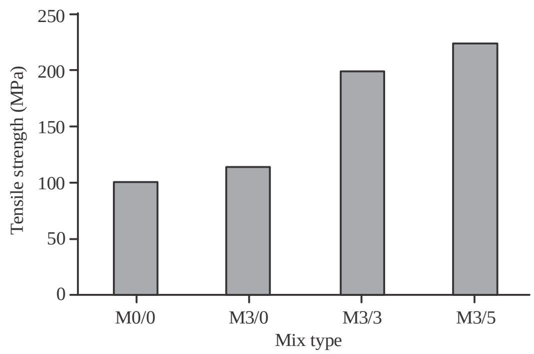

Fig. 10: Tensile strength for different mixes

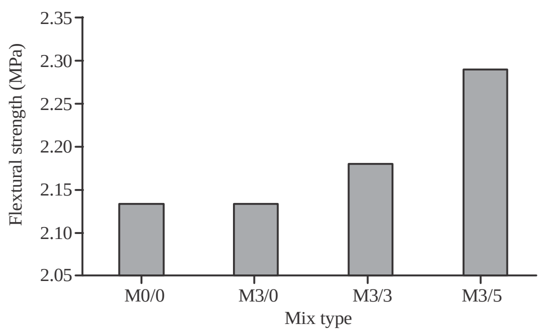

Fig. 11: Flexural strength for different mixes

The most important advantage of adding macro reinforcement fiber it make concrete ductile not brittle as shown in Fig. 10 and 11.

CONCLUSION

Following concluding remarks have been made on basis of the work conducted: the unit weight of nano silica concrete mix higher than ordinary concrete by 2.7% and adding macro reinforcement fiber in this mix reduced unit weight by 2.4% compared to mix without macro reinforcement fiber.

The compressive strength of nano silica concrete mix at 7 days is higher than the ordinary concrete with 15.6% and adding macro reinforcement fiber in this mix increase compressive strength at 7 days by 2.25% compared to mix without macro reinforcement fiber.

The compressive strength nano silica concrete mix at 28 days is lower than the ordinary concrete with 13.4% and adding macro reinforcement fiber in this mix increase compressive strength at 28 days by 2.4% compared to mix without macro reinforcement fiber.

Tensile strength of nano silica concrete mix is higher than the ordinary concrete with 15% and adding macro reinforcement fiber in this mix increase tensile strength by 84.8% compared to mix without macro reinforcement fiber.

Flexural strength of nano silica concrete mix is the same ordinary concrete but when adding macro reinforcement fiber in this mix the flexural strength increases by 4.72% compared to mix without macro reinforcement fiber.

REFERENCES

01. Sadrmomtazi, A., A. Fasihi, F. Balalaei and A.K. Haghi, 2009. Investigation of mechanical and physical properties of mortars containing silica fume and nano-sio2. Proceedings of the 3rd International Conference on Concrete & Development, April 27, 2009, Housing & Urban Development Research, Tehran, Iran, pp: 1153-1161.
02. Maghsoudi, A.A., M.J. Soheil and A. Darbhenz, 2010. Effect of the nano particles in the new generation of concretes, SCC. Int. J. Nanosci. Nanotechnol., 6: 137-143.
03. Jadhav, A.P., A.P. Patil, D.D. Parkhe, S.D. Bhagat and R. Pawar, 2018. Nano concrete and its classified applications in nano technology. Proceedings of the IRAJ International Conference, October 28, 2018, IRAJ, Pune, India, pp: 8-11.
04. Ahmad, S.S.E., H.S. Khalil, A.H. Atia and A. Fawzy, 2017. Mechanical behavior of high strength concrete incorporating silica fume and amorphous nano silica at different cement contents. J. Al Azhar Univ. Eng. Sector, 12: 1295-1303.
05. Aly, M., M.S.J. Hashmi, A.G. Olabi, M. Messeiry and A.I. Hussain, 2011. Effect of nano clay particles on mechanical, thermal and physical behaviours of waste-glass cement mortars. Mater. Sci. Eng. A., 528: 7991-7998.
06. Ghosal, M.G. and A.K. Chakraborty, 2015. A comparative assessment of nano-SiO_2 & Nano-TiO_2 insertion in concrete. Eur. J. Adv. Eng. Technol., 2: 44-48.
07. Mani, M. and G.N. Devi, 2017. Study on behavior of nano concrete. Int. J. Emerging Trends Technol. Comput. Sci., 6: 239-244.
08. Mugilvani, P., S.T. Murugan, B. Kaviya and K. Sathishkumar, 2019. Experimental investigation on nano concrete. Int. J. Civil Eng. Technol., 10: 2938-2943.
09. Supit, S.W. and F.U. Shaikh, 2014. Effect of nano-$CaCO_3$ on compressive strength development of high volume fly ash mortars and concretes. J. Adv. Concrete Technol., 12: 178-186.
10. Vasanthi, P., S. Senthilselvan, D.B. Hexton, M.S.I. Farooq and P. Suresh, 2017. Durability study on nano concrete. Int. J. Chem. Tech. Res., 10: 693-698.
11. Velmurugan, P. and V.R. Sarathy, 2016. A brief review on nano minerals. Int. J. Eng. Manage. Res., 6: 148-150.