iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VIII **Month of publication:** August 2017

DOI: http://doi.org/10.22214/ijraset.2017.8257

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

Optimum Usage of Nano Silica and Silica Fume for Increasing the Strength of Concrete

Aravinthan. K[1], Dr. Venkatasubramani R[2], Dr. Srisanthi V. G.[3], Ajith Kumar K[4], Eeshwaran R[5], Sarupriya. S[6], Vanmathi. V[7]
[1234567]Civil Engineering Department, Anna University

Abstract: The optimum content of nanomaterials in the literature varies widely. And the percentage using silica fume (SF) and nano silica (NS) are varying from 0% to 15 % in literature studies. But most of the paper concludes up to 2 % of nano silica with silica fume increases compressive strength more beyond that the compressive strength seems to be decreases and few kinds of the literature concluded that adding 10 % of nano silica increases more strength. So, we are interested to find the optimum percentage of nano silica for increasing high strength of concrete. An experimental investigation has been carried out by adding the cement with constantly 10 % by weight of cement (b.w.c) silica fume (SF) and nano silica (NS) as 2, 4% and 6% b.w.c. The M20 grade concrete is used at w/c 0.45. The compressive test tensile test and Young's modulus test are conducted for finding the optimum strength of concrete.

I. INTRODUCTION

The increased use of cement is essential in attaining a higher compressive strength. But, cement is a major source of pollution. The use of Nanomaterials by replacement or adding of a proportion of cement can lead to a rise in the compressive strength of the concrete as well as to ensure the pollution reduction. Since the use of a very small proportion of Nanomaterial can affect the properties of concrete largely, a proper study of its microstructure is essential in understanding the reactions and the effect of the Nanoparticles. This study is an attempt to explain the impact of a Nanomaterial on the compressive strength, tensile strength, and modulus of elasticity of concrete. A great number of researches have been performed to understand the nature of Nanomaterials and their effect on the properties of concrete. A various number of Research & Development work dealing with the use of Nanomaterials like Nano silica, Silica fume (SF), Al_2O_3, TiO_2, ZrO_2, Fe_2O_3, carbon nanotubes (CNT) are carried out in cement-based materials for blended cement. The pozzolanic activity of the material is essential in forming the C-S-H gel and hence the CH crystals are prevented from growing and their number reduces. A comparative analysis of this work has been presented in the summary of this paper which will highlight the significance of each work.

Akkineni Surgateja et, al (2016). studied that the compressive strength and tensile strength is increased 35% and 45% from control concrete when the Nano silica dioxide (1.5%) b.w.c has been replaced in cement. Use coarse aggregate as crushed granite, OPC 43 grade cement, M_{20} grade concrete, w/c ratio 1.5% and adding superplasticizer for reducing water content. Satyajit Parida (2015) replaced Nano silica in the cement of size 236 nm to improve the compressive strength of concrete. An experimental investigation has been carried out by replacing the cement with Nano silica of 0.3%, 0.6% and 1% b.w.c. From the compressive strength results, it can be observed that increase in compressive strength of concrete is observed on addition of a certain minimum quantity of Nano SiO_2. The increase in strength is maximum up to 10 to 12% in NS 1% by weight of cement (b.w.c) and least for Nano silica(NS) 0.3% b.w.c. with the use of M_{25} grade concrete (1:1.4:2.75) and w/c ratio is 0.43% and using superplasticizers for reducing water content and easy compaction. Dr. D. V. Prasada Rao et, al(2016) investigates the use of Metakaolin (MK) and Nano-Silica (NS) on various properties of concrete are presented. Metakaolin and Nano-Silica are used as partial replacement of cement for the preparation of concrete. In the present investigation initially, cement is partially replaced by Metakaolin 5% and 10% by weight. Further investigation is carried out by combined replacement of Metakaolin at 5% and 10% with Nano-Silica at 1%, 2% and 3% by weight of cement. For structural applications the various properties, such as compressive strength, split tensile strength, modulus of elasticity and flexural strength of M25 grade concrete containing MK and NS are evaluated and the results are compared with the controlled concrete. Based on the test results, it can be observed that concrete prepared with a combination of 5% MK and 2% NS indicated increased strength compared to the controlled concrete. Hence, it can be concluded that concrete prepared with 5% MK and 2% NS combination can be recommended for the structural applications. The increase in the strength properties of concrete is due to the availability of additional binder in the presence of MK and NS. The compressive strength of concrete with 2% Nano-Silica and 5% Metakaolin combination is 9.34% and 8.90% respectively. The split tensile strength of 5% Metakaolin concrete containing 2% Nano-Silica compared with conventional concrete is 8.44%. increasing. Flexural strength of M25 grade concrete with 2% Nano-Silica and 5% Metakaolin combination is 7.54% compared to that of controlled concrete. The increase in Modulus of Elasticity of Concrete with 5% Metakaolin and 2% Nano-Silica compared with conventional concrete is 7.80%.

S Sanju et, al (2016). focuses on the effect of incorporating nanoparticles such as Nano Al_2O_3, Nano Fe_2O_3 and Nano SiO_2 on mechanical and durability properties of concrete. Nanoparticles were added in three different dosages of 0.5%, 1% and 1.5% by weight of the cementitious material into the concrete mixture. Experimental investigations on Nano-modified concrete were conducted after 28 days of water curing to obtain the mechanical properties such as compressive strength and split tensile strength of specimen. Also, Rapid Chloride Penetration Test (RCPT) and water absorption test were investigated for obtaining the durability properties of a concrete specimen. Binary combination of Nano Al_2O_3 + Nano SiO_2 and Nano SiO_2 + Nano Fe_2O_3 were also considered to study the combined effect of the Nanoparticles. The compressive strength increased to a maximum value of 54.6% and 57.6% with 1.5% addition of Nano SiO_2 and binary combination NSF respectively with respect to control specimen. The split tensile strength increased to a maximum value of 76.8% for NSF and 58.8% for NS3 with respect to control mix. There is a 64.2% reduction in water absorption for a specimen with the addition of 1% of binary combination NSF as compared to control specimens based on 24 hours water absorption test thus showing better resistance to water absorption. RCPT results suggest that control specimen and Nano-modified concrete specimens are under low chloride permeability. But there was up to 60.4% reduction in the current passage for the addition of nanoSiO_2 and Nano Fe_2O_3 particles in concrete specimens as compared to control specimen which reveals improved durability.
Hasan Biricika et, al (2014) studied that the comparison of Nano silica, silica fume and fly ash of weight 5% & 10% are equally taken for each sample By contacting further test Nano silica 10% attain compressive strength of 84% when compare to the control concrete fly ash 10% and silica fume 10% attain compressive strength of 44% and 18% respectively. The material has been used such as superplasticizer Nano silica, silica fume, fly ash and w/c ratio 0.5%. Superplasticizer used for decreasing fluidity. Davoud Tavakoli et, al (2013) investigates the simultaneous use of nano-SiO_2 and silica fume in concrete. In order to such a purpose, silica fume in measures of 5 and 10 percent and nano-SiO_2 in measures of 0.5 and 1 percent were replaced with cement and totally eight mixture plans for doing the compressive strength and water absorption experiments. Finally, the results showed that using such materials improves the qualities of concrete. Using both 10% silica fume and 1% Nano SiO_2, as a cement replacement, resulted in 42.2% increase in compressive strength in comparison to control sample, to gain a consistency defined by slump values of between 4 and 5.5 cm, a super Plasticisers was used and easy compaction.

A. Summary

The review of the amount of literature shows the importance of this field of research. The findings show that a number of Nanomaterials like SiO_2, TiO_2, Al_2O_3, silica fume, metakaolin, and others can be incorporated to improve the properties of concrete. The results show the characteristics of the blended concrete in terms of compressive, tensile and flexural strength. Apart from that the permeability of the specimen can also be decreased by adding a small percentage of the nanomaterials. The SEM, XRD and other analysis show an improved microstructure with reduced number of pores. The optimum content of Nanomaterials in the literature varies widely. And the percentage using silica fume (SF) and Nano silica (NS) are varying from 0% to 15 % in literature study. But most of the paper concludes up to 2 % of Nano silica with silica fume increases compressive strength more beyond that the compressive strength seems to be decreases and few literature concluded that adding 10 % of Nano silica increases more strength so we are interested to find the optimum percentage of Nano silica to increasing high strength of concrete. The current study is concerned with the incorporation of combined with silica fume and Nano-Silica (sio_2) in various proportion(silica fume(SF) 10% + Nano silica(NS) 2% , silica fume(SF) 10% + Nano silica(NS) 4% and silica fume(SF) 10% + Nano silica(NS) 6% . using M_{20} grade concrete(1:1.5:3) and water-cement (w/c) ratio 0.45. The compressive test tensile test and Young's modulus test are conducted for finding its strength of concrete.

II. MATERIALS AND MIX DESIGN

The materials used to design the mix for an M20 grade of concrete are Cement, Fine aggregate, Coarse aggregate, Water, Silica fume, Nano SiO_2, and Superplasticizer.
The properties of these materials are presented below.

A. Properties of Cement

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

The ordinary Portland cement of 43 grade conforming to IS: 455-1989 is used for preparing concrete specimens. The properties of cement used are given in Table 2.1

Table 2.1: Properties of Ordinary Portland cement

SPECIFIC GRAVITY	SETTING TIME (min) (hr)		NORMAL CONSISTENCY (%)
	INITIAL	FINAL	
3.15	29.10	9.45	56

B. Properties of Fine and Coarse Aggregate

The M- Sand is added as fine aggregates and collected from the locally available quarry. The sieve analysis of the samples is done. It is found that the sand collected is conforming to IS 383-1970. For coarse aggregate, the parent concrete is crushed through mini jaw crusher. During crushing it is tried to maintain to produce the maximum size of aggregate in between 20mm to 4.75mm.

The physical properties of both fine aggregate and recycled coarse aggregate are evaluated as per IS: 2386 (Part III)-1963 and given in Table 2.2.

Table 2.2: Properties of coarse aggregate and fine aggregate

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.86	2.79
Sieve analysis	Satisfy the IS383:1970	Satisfy the IS383:1970
Flakiness & Elongation (%)	Nil	_
Water Absorption (%)	0.9%	
Impact Value (%)	14%	_

C. Properties of Nano SiO_2

The average size of Nano-silica was found to be 17 Nano from the chart is given by the supplier. The properties of the material are shown in Table 2.3. Fig 2.1 shows the nano- silica used in this experiment.

Table 2.3: Properties of Nano SiO_2.

Test Item	Standard Requirements	Test Results
Specific surface area	200+20	202
ph value	3.7-4.5	4.12
Loss on drying@105 Degree ºC (5)	$\leq$1.5	0.47
Loss on ignition @1000 Degree ºC (%)	$\leq$ 2.0	0.66
Sieve residue(5)	$\leq$ 0.04	0.02
Tamped density g/l	40-60	44
SiO_2 content (%)	$\geq$99.8	99.88
Carbon content (%)	$\leq$0.15	0.06
Chloride content (%)	$\leq$0.0202	0.009
Al_2O_3	$\leq$0.03	0.005
TiO_2	$\leq$0.02	0.004
Fe_2O_3	$\leq$0.003	0.001
Specific gravity	2.2-2.4(GENERALISED)	
Particle size	17 ANO	

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

D. Properties of Silica Fume

The average size of silica fume was found to be 800 microns is taken from the prescribed chart is given by shop. The properties of the material are shown in table 2.4. Fig 2.2 shows the silica fume used in this experiment.

Table2.4: Properties of Silica Fume.

Test Item	Test Result
Silica(SiO_2)	99.77%
Alumina(Al_2O_3)	0.10%
Ferric Oxide(Fe_2O_3)	0.06%
Titania(TiO_2)	0.006%
Calcium Oxide(CaO)	0.00%
Magnesium Oxide(MgO)	0.00%
Potash(K_2O)	0.005%
Soda(Na_2O)	0.009%
Loss on Ignition	0.05%

Fig. 2.1. Image of the Nano SiO_2

Fig. 2.2. Image of the Silica Fume

E. Properties of Superplasticizer

The Conplast SP430 has been used as a superplasticizer in this experiment. It has the specific gravity 1.225. It doesn't have the presence of chloride content as mentioned by IS456 and its main advantage is a reduction of water & early strength is increased up to 20%.

III. EXPERIMENTAL TECHNIQUES AND RESULT ANALYSIS

A. Fresh Concrete Test

1) *Slump Test:* The concrete *slump test* measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. Slump value=200mm

Fig 3.1 Slump cone test.

Fig 3.2 Flow table test.

2) *Flow Table Test:* The flow table test or flow test, also known as the slump flow test, is a method to determine the consistency of fresh concrete. Flow table test is also used to identify transportable moisture limit of solid bulk cargoes. It is used primarily for assessing concrete that is too fluid (workable) to be measured using the slump test because the concrete will not retain its shape when the cone is removed.

$$\text{Flow index} = \frac{(25\text{-spread diameter})}{25}$$

$$= \frac{(25-10.34) \times 100}{25}$$

$$= 58.64\%.$$

B. Hardened Concrete Test

1) *Compressive Strength Test:* The compressive strength of specimens is determined after 7 and 28 days of curing with surface dried condition as per Indian Standard IS 516-1959. Two specimens are tested for typical category and the mean compressive strength of two specimens is considered as the compressive strength of the specified category. Fig 3.4 shows compressive strength test results for a specimen for 7 days, & Fig 3.5 shows compressive strength test results for a specimen for 28 days.

Fig. 3.3. Compressive Strength Test.

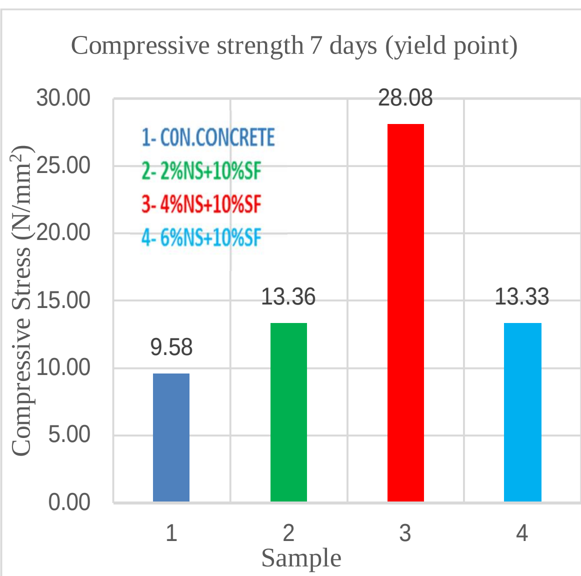


Fig3.4: Compressive strength Test for 7 days.

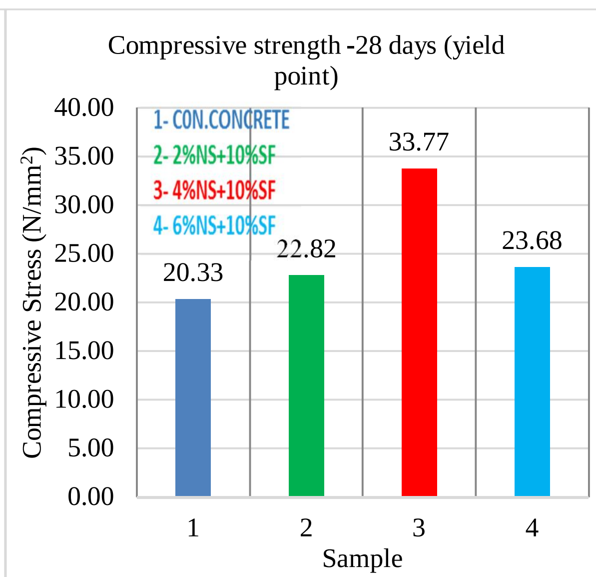


Fig3.5: Compressive strength Test for 28 days.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

The average results obtained from the sample compression tests, broken at 7 and 28days, are shown in Fig 3.4 & 3.5. The compressive strength developed in concretes containing nano-SiO_2 and silica fume particles was higher than that of the control sample in every case. Although nano-SiO_2 is used in modicum amounts in concrete, its impact is somehow similar to silica fume with high consumption measures. This fact, in turn, indicates the high pozzolanic activity of nano-SiO_2. The simultaneous impact of nano-SiO2 and silica fume is more than that of each one. It can be due to either the size of particles that given the different grading of nano-SiO_2 and silica fume fills up

All the concrete pores and results a condensed concrete, and the simultaneous pozzolanic influence of the two materials, adjacent to each other, which shows a better result. The most compressive strength was related to the samples possessing 10 percent of silica fume and 4 percent of nano-SiO_2 (SF10N4) in which about 66.10 percent of increase had in its strength. The pozzolanic impact of nano-SiO_2 on the compressive strength was more effective at early curing ages (7 days); while the pozzolanic properties of silica fume are more vivid in 28 days curing age. Which in turn causes the defect of concrete in all ages to be completely covered in the case of simultaneous use of the two materials?

2) *Modulus Elasticity:* The variation of Modulus of Elasticity of M20 grade concrete containing Silica Fume with an increase in Nano-Silica is shown in Fig.3.7& 3.8. The Modulus of Elasticity of M20 grade of controlled concrete is 27967 N/mm^2.The Modulus of Elasticity of concrete with further increase in the Nano-Silica content the Modulus of Elasticity increases. A similar trend is observed with the concrete containing 2%Nano-Silica+10%Silica Fume, 4%Nano-Silica+10%Silica Fume, 6%Nano-Silica+10%Silica Fume increase in Modulus of Elasticity of Concrete compared with conventional concrete is 14.49%.

Fig. 3.6. Modulus of elasticity Test.

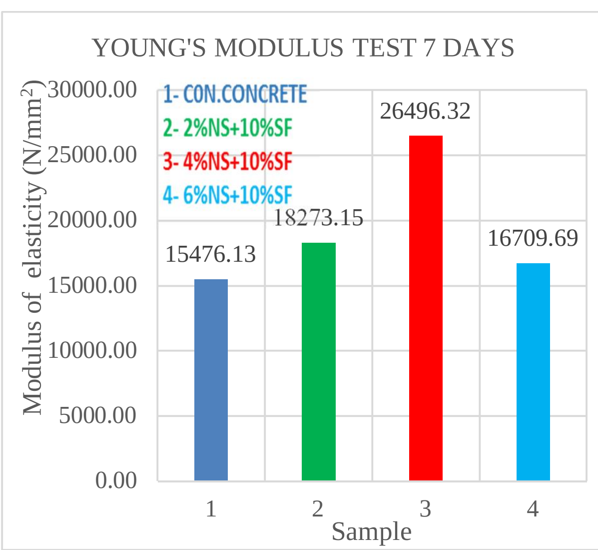


Fig3.7: Young's modulus Test for 7 days.

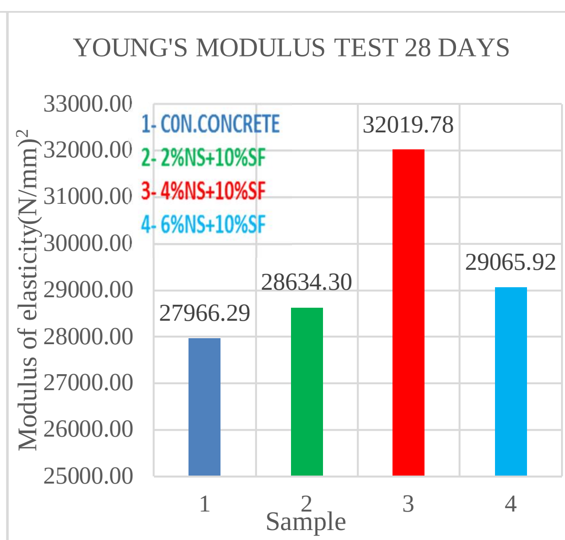


Fig3.8: Young's modulus Test for 28 days.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

3) *Flexural Strength Test Results:* The flexural strengths test of the specimens are given in Figure 3.10 & 3.11, were in the range of 2.5 Mpa–3.6 Mpa, which was the specimen NS4+SF10 slightly higher than that of OPC (2.5MPa) after 7 days of curing. On the other hand, after 28 days, the flexural strength of NS4+SF10, increased to 5.34 Mpa, while the flexural strengths of NS2+SF10 and NS6+SF10 with 10 additives were measured as 4.5 Mpa and 3.94 Mpa, respectively. The flexural strength of NS4+SF10 was the highest across all the specimens and 35.53% higher than that of OPC at standard age.

Fig. 3.9. Flexural Strength Test.

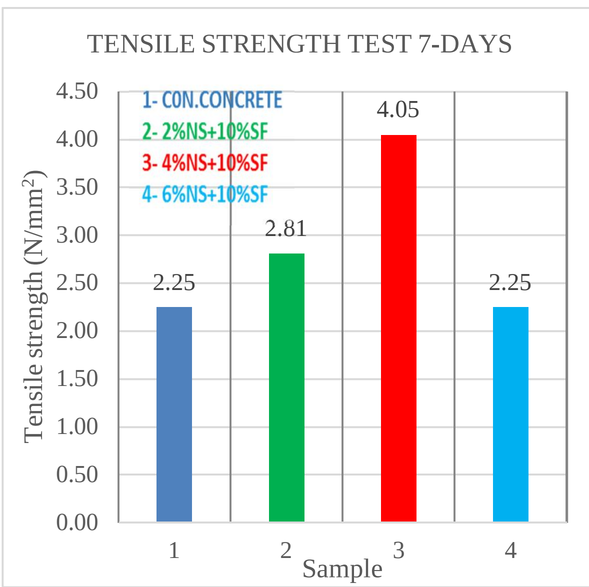


Fig 3.10: Flexural Strength Test for 7 days.

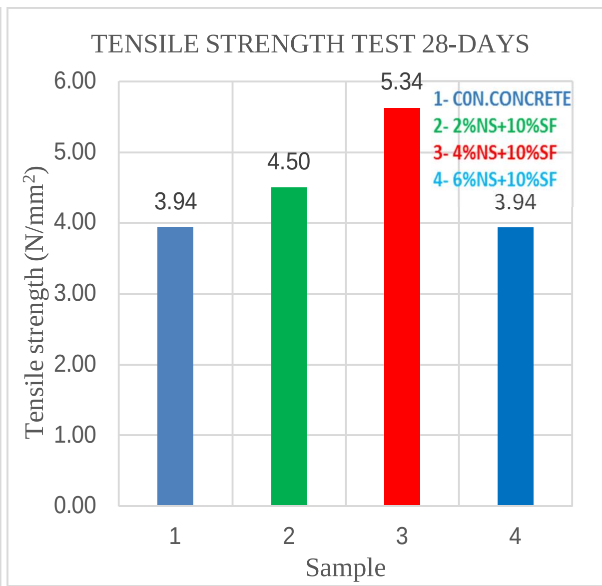


Fig 3.11: Flexural Strength Test for 28 days.

IV. CONCLUSION

The combination of silica fume with nano-SiO_2 as a replacement for cement has been investigated in this study. The silica fume was used in quantities of 10 percent and nano-SiO_2 was 2, 4 and 6 percent of the cement. The following conclusions were drawn from the study.

The Silica fume and nano-SiO_2 lead to the improvement of concrete strength and it is determined by compressive strength, Modulus of elasticity, flexural strength test results of using these two Nanomaterials. Nano-silica has extensive filler effect due to its Nano level fineness. The pour filling effect of Nano-silica has a more specific surface area as compared to cement which leads to decrease in workability as fine particles demand more water. It was observed that Nano-silica initiate as well as accelerate pozzolanic activity in the mortar which results in the formation of C-S-H gel in a good amount that steers towards an increase in compressive strength. It was observed that high specific surface area of Nano-silica particles affect the workability as we got true slump for all the mix ratios except 6%NS &10% SF which gives 200mm slump. As fineness of particles increase, demand for water is attracted towards the formation of concrete. So, use of superplasticizer in this situation is of key demand. Throughout the study, it was observed that impact of Nano-silica towards hydration activities is noticeable. Nano-silica initiates formation of hydrated products at a good rate which leads to high early strength 28Mpa In 7 days which is 2.8 times higher than normal concrete. But it should be keenly noted down that overall effect of Nano-silica on compressive is 2.8 times higher in 7 days and 1.6 times higher in 28 days than control mix. Flexural strength is 1.8 times higher in 7 days and 1.35 times higher in 28 days than control mix which is used to eliminate the tensile cracks in concrete due to tensile stress, shrinkage, environmental effects etc. The modulus of elasticity is for control mix is 15476.13Mpa and for 4%NS &10%, SF is 26496.32Mpa. Eventually, this is 1.71 times higher in 7 days. In the case of 28 days modulus of elasticity the value of control mix is 27966.29Mpa and for 4%NS &10% SF is 32019.78Mpa and it is 1.14 times higher than control mix. The simultaneous use of silica fume and nano-SiO_2 increase noticeably the strength of concrete compared with conventional concrete, besides, in view of the two materials, influence process in the case of their simultaneous use in concrete, all defects of concrete in all ages will be covered and caused them to strengthen each other.

REFERENCES

[1] Akkineni Surya Teja, Rajkumar R, Ramya Sajeevan. (2016), “Experimental Study on the Strength and Durability of Nano Concrete”, International Journal of Applied Engineering Research, ISSN 0973-4562 Volume 11, Number 4, pp 2854-2858.

[2] Dr. D. V. Prasada Rao, S. Venkata Maruthi, (2016), “Effect Of Nano-Silica On Concrete Containing Metakaolin”, International Journal of Civil Engineering and Technology, Volume 7, Issue 1, Jan-Feb 2016, pp. 104-112.

[3] S Sanju, S Sharadha and J Revathy (2016), “Performance on the Study of Nano Materials for the Development of Sustainable Concrete”, International Journal of Earth Sciences and Engineering. vol. (09), No. 03.

[4] Hasan Biricik, Nihal Sarier(2014), “Comparative Study of the Characteristics of Nano Silica–, Silica Fume– and Fly Ash–Incorporated Cement Mortars”, Materials Research. Vol. 17(3), pp.- 570-582.

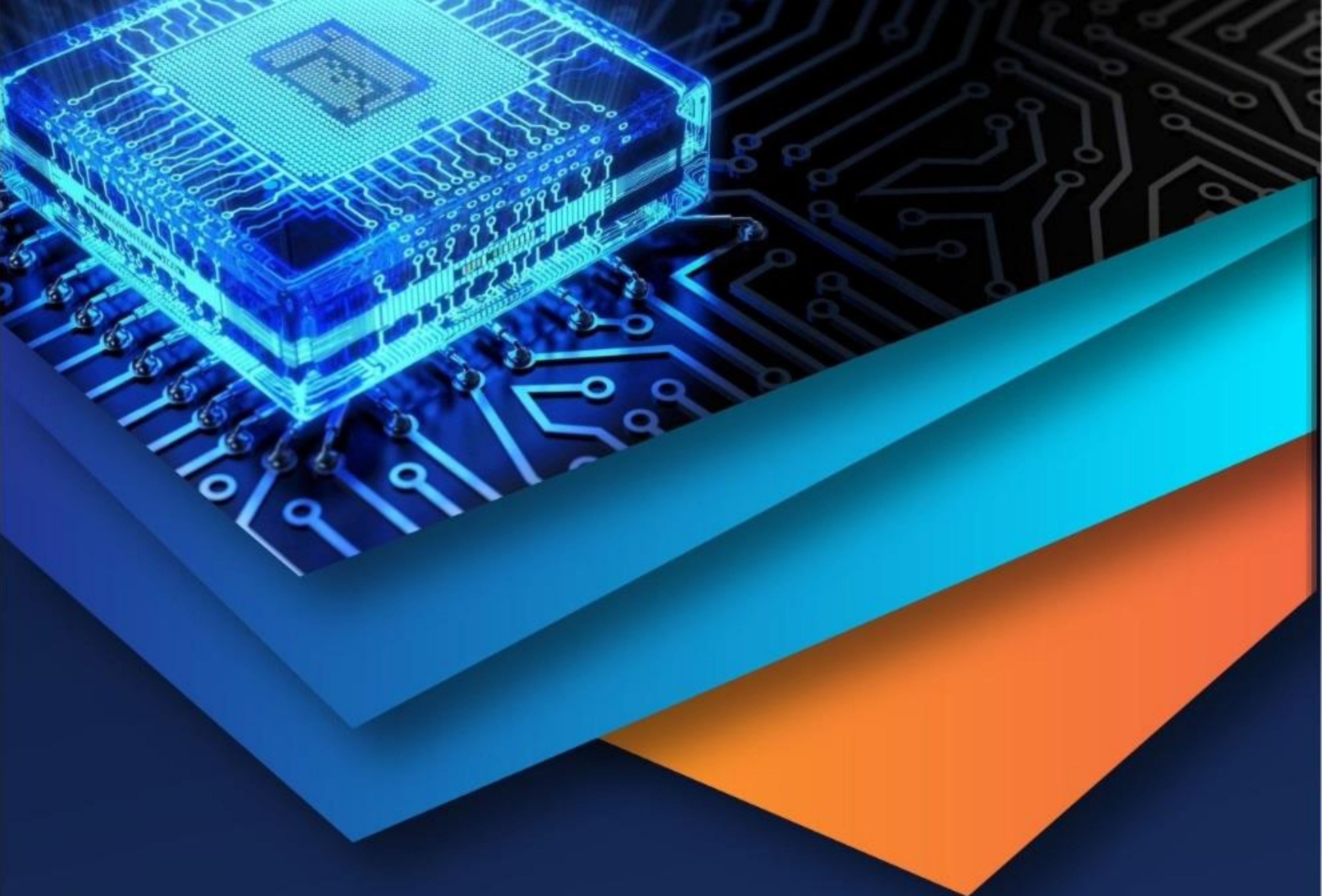
[5] Davoud Tavakoli, Ali Heidari (2013), “Properties of concrete incorporating silica fume and nano-SiO2”, Indian Journal of Science and Technology, vol. -6(1), pp-3946-3950 ·

[6] Satyajit Parida (2015), “Effect of Nano Silica on The Compressive Strength of Concrete”, Satyajit Parida 111CE0045, NIT Rourkela Thesis.

[7] IS 2386-1963 (Part-III). Methods of Test for Aggregates for concrete Part III specific gravity, density, voids, absorption and bulking. Bureau of Indian Standards.

[8] IS 383-1970. Specification for coarse aggregate and fine aggregate from natural sources for concrete. Bureau of Indian Standards.

[9] IS 456-2000. Plain and Reinforced concrete- code of practice (Fourth Revision). Bureau of Indian Standards.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY