# Combined effect of nano silica and nano alumina on the durability properties of HPC



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## *Abstract*

This study presents the durability properties of high performance blended concrete containing micro silica 10%, nano silica 3% and nano alumina 1%. Use of nano materials is becoming more popular due to its good mechanical and durability properties. A lot of research is going on to know mechanical behavior and durability behavior of concrete containing nano materials and also the optimal amount of nano concentration in concrete. Acid resistance, water absorption, porosity and RCPTof concrete has been tested. The results revealed that binary addition of nano silica and nano alumina improved the durability properties nano silica and nano alumina consumed more $Ca(OH)_2$ and produced more number of C-S-H gel.

**Key words:** Micro silica, Nano-Silica, Nano-Alumina, water absorption, porosity, RCPT.
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## INTRODUCTION

Nanotechnology has been progressing noticeably in recent years. There is a wide interest in studying the impact of nano-particles in construction materials, particularly mortar and concrete studies, because of the new potential uses for nanoparticles. Most of the research that are currently available have concentrated on how hardened cement paste, cement mortar, or concrete's properties are affected by single nano materials.

[1]studied the effect of nano alumina on compressive strength in different curing conditions. They noticed that lime water curing resulted in better compressive strength for special mixes containing nano alumina when compared to normal water curing. Furthermore, the optimum % replacement of nano alumina is found to be 1%. [2]investigated the combined usage of micro silica and nano silica and noticed that sp demand is more for concrete containing nano silica as it reduced workability. They also observed that addition of micro silica and nano silica improved compressive strength and elastic modulus significantly. [3]studied many durability properties containing nano silica and steel fibers. They noticed that including nano silica in concrete improved the permeability, increased freezing and thawing resistance and carbonation. Moreover, adding steel fibers along with nano silica improved the durability significantly.

[4]explored the usage of silica nano particles and high volume fly ash on high strength sustainable concrete at different w/b ratios and observed that adding nano silica improved the strength by 25% at 28 days and durability properties enhanced by 25% - 40%. S. [5]investigated the effect of colloidal nano silica on workability, mechanical and durability properties of HPC they observed that nano silica act as filler which improves microstructure, strength and durability properties. Furthermore, workability has been hugely affected by inclusion of nano silica, super


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plasticizer plays an important role to improve the workability.

Binary addition of nano materials has been rarely investigated. In this paper influence of nano silica and nano alumina on durability properties of high performance binary blended concrete are explored. Acid resistance, water absorption, Porosity and RCPT tests are conducted for 28 days of curing.

## EXPERIMENTAL STUDIES

### *2.1 Materials*

In this study KCP cement 53 grade was used. Its specific gravity is 3.10, fineness of cement is 6% and consistency is 34%. Coarse aggregate of specific gravity 2.6 and maximum size of 20mm was used. locally available river sand of specific gravity 2.65 and fineness modulus of 2.59 was used as fine aggregate. BASF master ease 3709 admixture was used. Its specific gravity is specified by BASF as 1.1. water cement ratio of 0.21 is used. In this study nano silica, nano alumina and micro silica is used in powder form with an average particle size of 17nm, 20nm and 25 microns respectively. Chemical composition of nano silica, nano alumina and micro silica are shown in table 1. Mix proportions for control concrete designated as $M_1$ and blended concrete designated as NSA are shown in table 2. After trails micro silica was fixed at 10%, nano silica was fixed at 3% and nano alumina was fixed at 1%. So, in this study blended concrete of micro silica, nano silica and nano alumina is compared with reference control mix.

**Fig 1 (a)** - Nano silica **Fig. 1 (b)** - Micro silica **Fig. 1 (c)** - Nano alumina

**Table 1**Chemical composition of micro silica, nano silica and nano alumina.

| Item | $SiO_2$ (%) | $Al_2O_3$ (%) | $Fe_2O_3$ (%) | MgO (%) | $TiO_2$ (%) | Particle size |
|---|---|---|---|---|---|---|
| **Micro silica** | 92.24 | 0.39 | 0.24 | 0.75 | - | 25 microns |
| **Nano silica** | 99.88 | 0.005 | 0.001 | - | 0.004 | 17 nm |
| **Nano alumina** | 0.05 | 99.8 | 0.04 | 0.03 | 0.02 | 20 nm |

**Table 2**Mix design.

| Mix. No | Cement ($kg/m^3$) | Fine aggregate ($kg/m^3$) | Coarse aggregate ($kg/m^3$) | water cement ratio | Micro silica ($kg/m^3$) | Nano silica ($kg/m^3$) | Nano alumina ($kg/m^3$) | Super plasticizer % |
|---|---|---|---|---|---|---|---|---|
| $M_1$ | 550 | 555 | 1146 | 0.21 | - | - | - | 0.25 |
| NSA | 475 | 555 | 1146 | 0.21 | 55 | 15 | 4.8 | 2% |



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### *2.2 Test Methods*

#### *2.2.1 Water absorption and porosity*

The most conventional method to determine water penetration is water absorption. Cubes of 100 mm x 100 mm x 100 mm were used. ASTM C642 is used as guide and Specimens were kept in oven at 105°C until their weight reached a stable value, which is then considered to be their oven-dried weight. Now, the specimen's weight in water is measured. The saturated weight of the cubes is then measured after submerging them for at least 48 hours.
Water absorption and porosity can be calculated by following formulas

$$\text{Water absorption} = \frac{saturated\ \ weig\,ht\ of\ cubes\ -oven\ dried\ \ weig\,ht\ of\ cubes}{oven\ dried\ \ weig\,ht\ of\ cubes} \text{ x } 100$$

$$\text{Porosity} = \frac{saturated\ \ weig\,ht\ of\ cubes\ -oven\ dried\ \ weig\,ht\ of\ cubes}{1000-weig\,ht\ of\ specimen\ \ in\ water} \text{ x } 100$$

Note: All units are taken in grams

#### *2.2.2 Rapid Chloride permeability test*

Fig. 2 shows the experimental setup of RCPT done under the guidance of ASTM C1202-12. Concrete specimens of 100 mm x 50 mm cylinder disc specimens were used.First, the disc specimen is inserted between the cell assembly's two compartments and tested for air and water tightness. The cathode compartment is then filled with 3% NaCl solution, while the anode compartment is filled with 0.3 normality NaOH solution. After that, RCPT is applied to the concrete specimens by sending a 60V DC current between the anode and cathode.
The current is measured every 30 minutes for 6 hours. A measurement of the electrical conductance of the concrete over the course of the test is called the cumulative charge passed. The formula below, which is based on ASTM C1202, can be used to determine the overall charge that was passed.

$$Q = 900\ (I_0 + I_{360} + 2I_{30} + 2I_{60} + \ldots\ldots\ 2I_{300} + 2I_{330})$$

Q = Total charge in coulombs

$I_0$ = Current (ampere) immediately after the voltage is applied

$I_t$ = Current (ampere) at t min after the voltage is applied

**Table 3**RCPT values according to ASTM C1202-12

| **Charges passed** | >4000 | 2000 - 4000 | 1000 - 2000 | 100 - 1000 | <100 |
|---|---|---|---|---|---|
| **Chloride ion penetrability** | High | Moderate | Low | Very Low | Negligible |


**Fig. 2** Experimental setup of RCPT



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### *2.2.3 Chemical Resistance*

This is calculated in terms of visual inspections, weight lossand residual compressive strength. 100 mm x 100 mm x 100 mm concrete cube specimens are cast. After 28 days of water curing, the cubes are allowed to dry for one day before weighing.Now, immerse the cubes in 5% concentrations of acids such as H2SO4, HCL, and NA2SO4 for 28 days, as shown in fig. 3. After 28 days remove the cubes from acidsand measure weight loss, and residual compressive strength.



## RESULTS AND DISCUSSION

### *3.1 Water absorption and porosity*

The results of % of water absorption at the age of 28 days are shown in fig. 4. It is clearly visible that the percentage of water absorption decreased significantly for NSA mix when compared to $M_1$ mix. This is due to pore filler effect of both nano silica and nano alumina. Water absorption for NSA mix increased by 52.7% when compared with $M_1$ mix. Porosity also decreased for NSA mix when compared to $M_1$ mix.

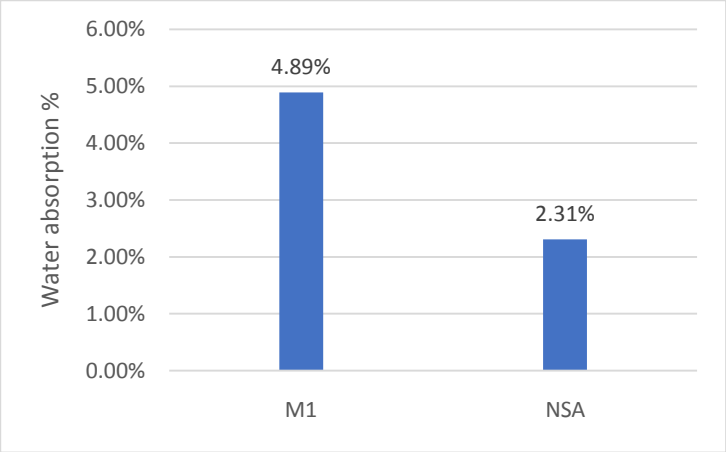



**Fig. 4** Water absorption at 28 days

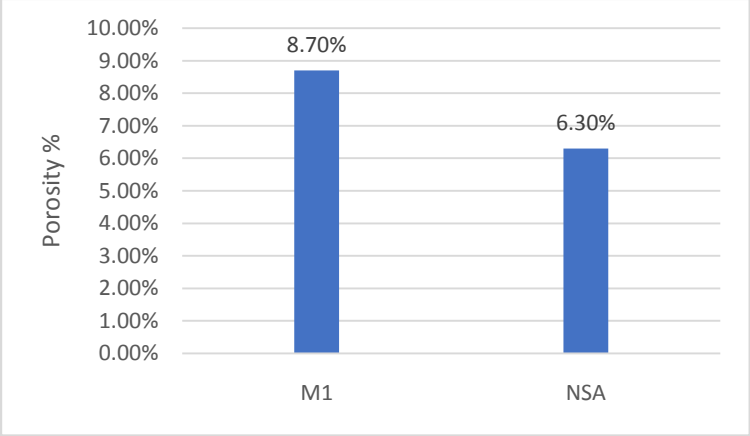



**Fig. 5** Porosity in % at 28 days

Generally higher porosity value means having high permeability thereby decreases its strength and durability properties. Control concrete exhibited higher porosity and water absorption values than nano concrete as seen in fig. 5. Adding nano silica improves pozzolanic activity and making the micro structure dense thereby decreasing the water absorption [6]. when compared with water absorption values of [7] he achieved water absorption percentage of 7.8% at the age of 28 days for 1% nano alumina. In this study water

absorption percentage at 28 days is 2.31%. So, it is clearly evident that combined usage of nano silica and nano alumina is feasible and better than single usage of nano particle.

### *3.2 Rapid Chloride permeability test*

Fig. 6 shows the variation of RCPT of $M_1$ and NSA mix at the age of 28 days. Inclusion of nano silica and nano alumina combinedly reduced the coulomb value, indicating that concrete has become denser. $M_1$mix exhibited low permeability whereas, NSA mix showed very low permeability. Therefore, speed through which chloride ions can travel into concrete is decreased significantly for NSA mix. [8], [9], [10]used nano silica individually in concrete and RCPT values were mostly on par with them and sometimes better than using single nano particle. So combined usage of nano silica and nano alumina exhibited better results for RCPT when compared with single usage of nano particles.



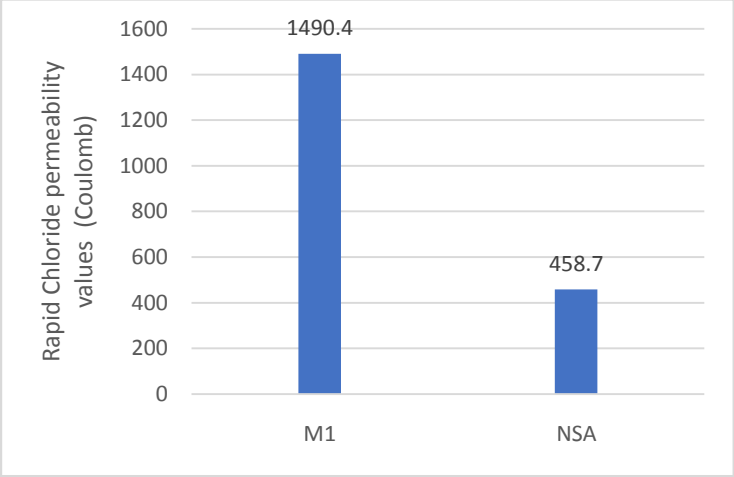



**Fig. 6** Rapid Chloride permeability values at 28 days.

### *3.3 Chemical resistance*

A detailed study about chemical resistance is given below.

#### *3.3.1 Visual observations*

Table 4 shows the physical appearance of cube specimens after being subjected to various chemicals for 28 days. It can be clearly visible that surface of the cubes deteriorated extensively when exposed to 5% H2SO4. Whereas, for 5% HCl, 5% NA2SO4 it is not deteriorated much. Overall, 5% NA2SO4 doesn't get effected much.

#### *3.3.2 Percentage weight loss*

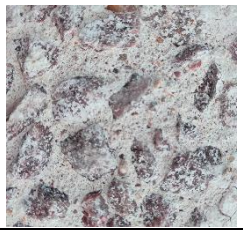
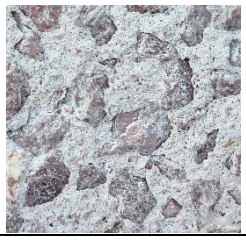
Before immersion of cubes in chemicals initial weight are noted and after 28 days of immersion in acids final weights are taken. Comparing both these weights will give the percentage weight loss. It is clearly indicating that percentage weight loss NSA mix is less when compared to $M_1$ mix. Percentage weight loss values at the age of 28 days is presented in table 5.

#### *3.3.3 Residual compressive strength*

Figure 7 depicts the compressive strength of concrete mixes immersed in water. Table 6 shows the residual compressive strength of cubes immersed in 5% H2SO4, 5% HCl, and 5% NA2SO4. The percentage of compressive strength loss is calculated by comparing these results. When compared to water immersion, the residual compressive strength of cubes immersed in acids decreased.



**Table 4**Physical appearance of cubes immersed in water after 28 days.

| Mix | Chemicals | | |
|---|---|---|---|
| | $H_2SO_4$ | HCL | $NA_2SO_4$ |
| $M_1$ |  |  |  |
| NSA |  |  |  |

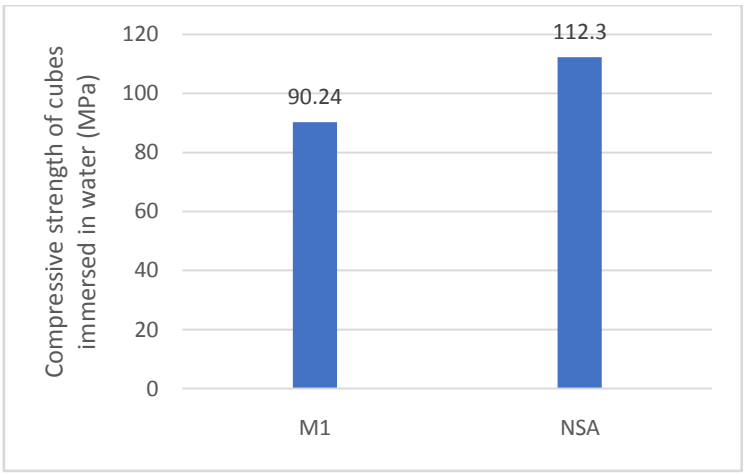



**Fig. 7** 28 days Compressive strength of cubes immersed in water

**Table 5** Percentage weight loss after 28 days of immersion

| **Mix** | **$H_2SO_4$** | **HCL** | **$NA_2SO_4$** |
|---|---|---|---|
| **$M_1$** | 4.74 | 0.08 | 0.051 |
| **NSA** | 3.92 | 0.03 | 0.013 |

**Table 6** Residual Compressive strength of cubes immersed in acids

| **Mix** | **H2SO4** | **HCL** | **NA2SO4** |
|---|---|---|---|
| **$M_1$** | 78.45 | 88.69 | 89.07 |
| **NSA** | 107.32 | 110.68 | 111.54 |



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**Table 7**Percentage loss of compressive strength

| Mix | H2SO4 | HCL | NA2SO4 |
|---|---|---|---|
| $M_1$ | 13.1 | 2.83 | 0.52 |
| NSA | 4.34 | 1.44 | 0.18 |



## CONCLUSIONS

This article presents the experimental study of combined effect of nano silica and nano alumina on durability properties with incorporation of nano silica 3% and nano alumina 1%. The below conclusions are reached

1. When compared to control mix $M_1$, results showed that adding nano silica and nano alumina exhibited better durability characteristics.
2. The hydration reaction and pore filler effect of nano silica and nano alumina improved the concrete matrix and densified the microstructure.
3. Water absorption and porosity has decreased significantly for concrete incorporating nanoparticles.
4. RCPT values reduced by huge percentage of 69.22% when compared with control mix.
5. Cubes immersed in 5% H2SO4 chemical solution deteriorated significantly when compared with cubes immersed in 5% HCl chemical solution and 5% NA2SO4 chemical solution.
6. Percentage weight loss is more for cubes immersed in 5% H2SO4 solution is more when compared with cubes immersed in 5% HCl solution and 5% NA2SO4 solution.
7. Though percentage weight loss is decreasing for both the mixes when immersed in all chemical solution. NSA mix showed better resistance overall and percentage weight loss is less when compared to control mix.

This is the initial study of durability properties using nano silica and nano alumina combinedly. Detailed study on this for 90, 180 days to be done and presented in further work.

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