A Study on High Strength Concrete Incorporated with Micro and Nano Silica

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Abstract- Concrete is a key component of both the current and the future's building materials. Increasing concrete's strength and durability is critical, given the world's population growth and the development of technologies to meet those needs. Therefore, the humidification mechanism of cement should be thoroughly explored, and better alternatives should be suggested to produce high-strength concrete (HSC). Hence, current study focuses on the design and development of HSC of strength M60 and M80 using micro and Nano-silica. This study involved using 40-60nm Nano-silica and 0.15 µm silica-fumes to surge the strength in compression of concrete. Experimental studies carried out on HSC are discussed in this paper with critical observations and take always. The paper also elaborates the future direction of research in HSC.

Keywords- High Strength Concrete, Nano silica, Micro silica / Silica fume, Fly ash, Mechanical Characteristic.

INTRODUCTION

The HSC is often due to the formation no structural linkages between the calcium silicate hydrates during the hydration procedure. To manufacture HSC, cement particles must be kept in the micro/nana scale values to improve the behaviour in engineering properties. Investigating the physiochemical composition of typical cement-based materials is challenging because studying behaviour at the nana scale is so complicated. Concrete can be nano-engineered by attaching molecules to the cement particles or by adding nano-sized components, such as nanoparticles, nano-admixtures, and nanotubes, to modify the behaviour of the material and add new properties.

OBJECTIVE OF STUDY

To investigate the characteristic strength in M60 and M80 High strength concrete, including micro and Nano-silica without varying the water cement ratio.

LITERATURE REVIEW

LGLietal. (2018) studied at how Micro Silica (M.S.) and Nano Silica (N.S.) collaborated to affect the concrete's compressive behavior. They examined effectiveness of M.S. and N.S. by combining cement. Using the formula, the synergistic impact of combining the use of M.S. and N.S. was also assessed. As a result of the combined addition, the compressive strength surged. However, the M.S. and N.S. combined addition, had no synergistic discernible effect on elastic modulus. They came to the conclusion that N.S. should not be added separately from M.S., but rather should be used together to maximize the performance of the concrete created.

S.Tanveer Husain and K.V.S. Gopala Krishna Sastry (2014) carried out experimental tests for evaluating the properties i.e. mechanical with M40 of HSC and M50 concrete grade which also includes the strength in compression, split as well as in flexure. In this study, 53 grade's several replacement levels of OPC: Ordinary Portland Cement along Nano silica & silica fume & discovered that SF (7.5%) and NS (2%) were the best replacement levels. It was investigated with conventional concrete and the outcomes demonstrated a percentage improvement in split, compressive, flexural and tensile strength, using a 7.5% and 2% mixture of SF and NS respectively for M40 and M50 concrete grade.

A. Siva Sai et al. (2013) investigated characteristics strength of the concrete mixes high-strength grades of M60 & M70 with partially replaced using the triple blending cement concept of Condensed Silica Fume & Nano-silica. Primary goal is to contrast the properties of concrete (hardening) in this respective study which is produced using cement's triple blend, Nano-silica and Condensed Silica Fume. It was observed that the concrete's compressive strength had surged along with the quantity of CSF, but trend stopped when the NS was over 2% and the CSF was above 10%. Comparing CSF at 10% and NS at 2% respectively so that the concrete control can be offered, there was only 2% increase in flexural strength was observed and compared to concrete control, the compressive and split tensile strengths increased by 14%.

Absar Yousuf Wani and Dr Mohit Bhandari (2021) An assessment of GGBS which stands for Ground Granulated Blast-furnace Slag, usage along with SF & NS is Materialistic for changing the Aspects of Conventional Concrete determination was undertaken. This study's primary objective was to estimate the impacts of GGBS, SF-NS on concrete strength. The effects are so additional cementitious materials were discussed on compressive, flexural strength, permeability, hydration characteristics and shrinkage properties. Additionally, it is conceivable that the self-compressing complexes achieve their maximum compressive strength when the particle sizes continuously range from the smallest to the greatest. The study also emphasizes the improvement in mechanical behavior to the refinement of the pore structure made possible by NS and connected by the pozzolanic reaction and packing consequence.

Dhana singh Sivalinga Vijayan et al. (2023) evaluated nanotechnology applications to show how conventional cement materials are being replaced. In the construction sector, blending traditional cement with nanomaterial slower costs and improves the technical availability of traditional cement components. The paper suggested that, after this review the structural modes with aggregates recycling should be developed that make the strength and durability performance as a major propriety, given that NS and SF can reduce the adverse consequences of some industrial waste by-products and aggregates recycling. Although strength requirements to determine how much heat is emitted, how resistant the material is to corrosion, and what problems may arise with these se tests specimens are employed in crucial structural components. Moreover, a significant conflict was seen between laboratory findings, academics, and Nano materials manufacturers.

Chander Mohan Kansal and Rajesh Goyal (2021) compared differences in the characteristic so concrete made of NS, SF, and SS for the concrete's performance when aggregates are replaced with aggregate coarser or the finer in properties in concretes for the high-performance. As a result, this analysis aims to comprehend the potential for using SS, NS, and SF produced in India to replace cement and finer aggregate. Six samples were created using various ratios of the selected admixtures, including steel slag along with Nano-silica & the silica fume. The outcomes indicate that the strength was slightly increased by the regulated incorporation of these admixtures, i.e., fixing their content percentages up to a point beyond which it decelerated.

Sandeep Salhotra & Arun Nishchal Guleria (2016) focused on concrete's mechanical properties using SF. According to this study, for creating high-performance concrete (HPC) silica fume acts as an excellent pozzolanic component. This article's quantify the impact on properties concerning their varying percentages as per micro-nano silica in different concrete grades. It was observed that using MS and NS together as pozzolanic can result in improved characteristics. According to the literature research, silica fume can be added to cement or replaced to enhance the mechanical qualities of concrete. Yet, the strength of concrete can be weakened by the excessive inclusion of SF. Hence, SF can be increased or subtracted using a calculated proportion. It can be concluded that using micro silica in place of 7.5% of the cement will give typical concrete more substantial characteristics.

LGLietal. (2017) examined on various mortar mixtures with varying contents and the mortar's durability using various tests including chloride, water, sulphate, carbonation and strength. The super plasticizer dosage was adjusted for each mortar mix to get workability which stays constant throughout. Adding MS-NS alone & MS-NS combination has various consequences which may be analysed based on outcome. The combining of MS-NS are potential synergistic consequences are investigated. It is concluded that adding MS-NS may boost the mortar SP's while managing the workability required. To improve the mortar's sulphate, carbonation resistance and cube strength by the addition of M.S. or N.S. In short, adding 1% NS is about equivalent to adding 10% MS. Adding both MS and NS, on the other hand, may have synergistic benefits because their combined effects are greater than their individual totals.

Abhilash P. P. et al. (2021) The effects of NS when added to concrete as an additive or used to partially replace cement on the characteristics of freshly poured and hardened concrete were demonstrated. Based on prior research, this study indicated that the NS's consequences on concrete is dependent on the size of the particle as well as the surface, dosage, Kind (colloidal) and ratio of w/c. According to the study, 2 to 3% doses of N.S. rang could manage to better the durability as well as the mechanical properties. This might contribute to the pozzolanics activity or the pore's structure. If the 3% or higher dosage of NS is used than, major strength reduction may be observed. Engineering properties may change with a elevated dosages which maybe 3% or more as required, due to the NS particles adhering together and causing high porosity, micro cracking, decreased compressive strength, etc. If the NS particles were evenly spread, their addition would improve the concrete's microstructure.

LG Li et al. (2017) conducted experimental studies on various mortar mixtures with Water-cemet ratios and various other parameters including MS-NS percentages and SP dosages. Also, the workability (similar) was made at different times as 7, 28 and 56-days to measure the cube strength and flows spread as well as the micro structure imaging using the slump, SEM tests and strength of cube. The work ability would diminish with the addition of MS and NS, but the loss in work ability might be made up by increasing the required dosages. NS has an even larger requirement for SP than MS does. The 7, 28 and 56-days strength of cube would dramatically surge with the MS-NS incorporation. Comparatively, adding NS increases strength more effectively than adding MS. A quantitative analysis of the MS as well as NS on strength has effect which are synergistic of has revealed a general tendency of a more substantial these effect with larger Water with Cement ratio and a reduced effect at a later stage. However, at increased NS content, the synergistic effect is more significant. Similarly, it was researched that synergistic combination of MS as well as NS results in densification of micro structure of the cured cement paste.

EXPERIMENTAL PROGRAM

High-strength concrete development requires appropriate materials and methods to satisfy the objectives. Thus, description of the materials used, their properties, and the methodologies adopted for the study are given below.

- CEMENT–OPC

Ultratech 43 and 53 ordinary grade Portland cement which confirming to the IS 8112-1989 and 12269-1987, readily available in the market. The tests result to find out the basic characteristics of cement which are used in this study are given in table below:

METHDOLOGY

Design mix for HSC was done with reference to IS 10262-2019.

1. Determine the concrete's mean target strength which is generally based on the design requirements.
2. Select the water and cement ratio based on the maximum size of aggregate and the concrete's exposure conditions.
3. Determine the cement's content of mix based on the water-cement ratio and the target strength of the concrete.
4. Determine the coarse aggregate content using the last size of aggregate and the cement content, the fine aggregate content using the water and coarse aggregate content, and the add mixture content using the initial trial mixes.
5. Calculate the proportions of each ingredient in the mix based on the desired batch size.
6. Verify the mix proportions through trial batches, adjusting the proportions as necessary to get the required work ability and strength.

RESULTS AND DISCUSSION

The outcomes of tests described in the previous section are discussed in this section. The characteristics of mortar cubes, HSC mixes and other mechanical behavior is compared.

1. SLUMP CONE TEST

The water-cement ratio used for the study is 0.29 for the M60 mix and 0.25 for the M80 mix. The results show that the values are between 65–75 mm, categorized as the medium degree of workability (as per IS 456:2000 (clause7.1)). The results inferred that the absorption of water characteristics of the Nano-silica. The mix incorporated with nano silica showed less slump value than micro silica.

Sample no.	Grade of Concrete	Average Slump Value(mm)
1	M60– I	70
2	M60- II	75
3	M80-I	67
4	M80- II	73

2. COMPRESSIVE STRENGTH OF CUBES

The results showed that both NS and MS incorporated mortar cube gives more strength than the control mix, showing that the binding between these particles is much better. Compared with control mix, the percentage increase in compressive strength of mortar cubes incorporated with NS and MS is plotted against the curing days. Results of the 1-day test showed a 17.8% increase in compressive strength for Nano silica incorporated mortar cubes and only an 8% increase for cubes incorporated with micro silica compared with control cubes when compared with the control specimen. Similarly, on the 3rd day, 24 % increase has observed for Nano silica-incorporated mortar cubes and only about an 8 % increase for cubes incorporated with micro silica when compared with control cubes. The trend for NS incorporated mix continues in 7-day testing, and then declines in 28th day compressive value. A similar kind trend was seen in MS as well.

3. COMPRESSIVE STRENGTH OF HSC

The compressive strength of HSC of mixes M60 and M80 incorporated with NS and MS were tested for 3, 7 and 28 curing days. The water cement ratio used for both NS and MS incorporated mixes were constant, i.e., 0.29 for M60 and 0.25 for M80. To achieve M80 strength apart from these additives, Fly Ash is used.

It was observed that the NS-included mix forM60 achieved the targeted strength on the 28th-day of testing. While the MS mix could not achieve the targeted strength, it achieved an average strength of around 64 N/mm2. In 3rd day test, the average compressive strength of the MS incorporated mix was 6% more than the NS mix, but got reversed in the7th day test.

4. FLEXURAL STRENGTH OF HSC

The results show an average flexural strength of 8.2 and 9.57 N/mm2 for theM60 and M80 design mix, respectively, approximately 30% more than the required strength per IS code.

Sample No:	Flexural Strength (N/mm^2)-M60	Flexural Strength (N/mm^2)-M80
1	7.5	9
2	8.75	9.35
3	8.25	10.35
Avg. Flexural strength	8.2	9.57

CONCLUSION

This study focused on the development of High Strength Concrete with micro and Nano silica. For this laboratory tests for materials were conducted and was analyzed with theoretical values. Based on these values, a mix design for M60 and M80 grades of concrete were prepared and mix proportions for different combinations was obtained. After casting, curing the samples are tested in universal testing machine. The compressive strength, split tensile strength and flexural strength for mixes were studied. Hence, the following points can be concluded from this study:

1. In compares onto control cubes, compressive strength of mortar cubes incorporating Nano silica increased by 17.67% and that of cubes incorporating micro silica by only 8% in the1-day test.
2. Similarly, a 24.08% increase in compressive strength for mortar cubes incorporating Nano silica and 7.71% increase for cubes incorporating micro silica were seen on the third day.
3. The graph displays a declining trend in the 7 and 28-day strength findings on mortar cubes compressive strength.
4. It can be stated that adding Nano silica is more effective in increasing the strength than micro silica. This is mainly because then a nontechnology in mortar makes it less porous due to the smaller particle size.
5. The optimum level of NS-3% was used throughout the study based on the literature review and earlier CSIR-CBRI works, and the findings showed that mixes containing NS attained early strength more quickly than mixes incorporating MS.
6. Strength gain in NS incorporated cubes can be filler and pozzolanic effect of the NS. Particle size has great significance in hydration and strength of hardened paste.
7. Given that NS absorbs more water and influences the workability of concrete, its addition significantly lessened the slump. Concrete's early age strength was

also enhanced by NS, along with its compressive and flexural strengths.

8. In the instance of the M60 grade 3-day compressive strength were exceptional results attained, where MS-incorporated concrete cubes out performed NS cubes. It is necessary to conduct micro structural studies in order to determine the reason.

9. For combinations containing greater doses of silica fume, a higher requirement for superplasticizer is seen.

10. For M60 grade, cement with MS 6% with a w/c ratio of 0.29 resulted in highest compressive strength of 63.42 MPa, split tensile strength of 5.23 MPa, and flexural strength of 8.2 MPa.

11. For M80 grade, cement replacement with fly ash15% and MS 6% with w/c ratio 0.25 resulted in highest compressive strength of 87.77 MPa, split tensile strength of 6.2 MPa, and flexural strength of 9.57 MPa.

FUTURE SCOPE OF WORK

The study suggests that to carry out HSC works with Nano and micro materials; research must be widened in the areas like:

HSC design using various combinations of Nano and micro materials.

Numerical modeling and validation of experimental results.

Durability and the micro structure studies of HSC with NS and MS.

Studies on NS and MS optimization.

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