Effect Of Nano-silica On Mechanical Properties Of Recycled Aggregate Concrete

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ABSTRACT

The present experimental work deals with the effect of colloidal nano-silica on mechanical properties of concrete containing recycled coarse aggregate using five series of concrete mixes: the first is the control mix, containing of natural aggregates with no nano silica. In second, third , fourth and fifth series containing 20%, 40%, 60% and 100% (by weight) natural coarse aggregate are replaced by RCA with 2% and 4% nano-silica repectively. Compressive strength and split tensile strength of all concrete mixes are evaluated after 7 and 28 days of water curing. Addition of nano-silica is found to significantly improve mechanical properties of concrete mixes as compared with control mix.

Keyword : - *colloidal nano-silica , recycled aggregate , mechanical properties.*

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1. INTRODUCTION

1.1. Current Scenario Of Construction Industry:

The generation of construction and demolition waste is increasing all over the world. The construction industry in India generated huge quantities of construction and demolition waste from construction, demolition and renovation activities in every year. The waste arising from demolitions is estimated to be close to 100 million tonnes every year in the developed countries a similar estimate for India. The disposal of these waste material are one of the main problem in construction industry due to lack of sufficient space for dumping of these waste material. In recent decades, these waste materials are collected and reuse it as aggregates in concrete. These recycled aggregate can be use as replacement of natural aggregate as we know that extensively use of concrete causes depletion of natural resources such as natural aggregates. Therefore, the utilization of these recycled aggregate with replacement of natural aggregate is one of the best solution to a number of problem faced by construction industry as its useful for preservation of natural resources, decreasing the cost of waste disposal treatment and reducing enviromental pollution.

The advantages of recycling construction and demolition waste are:

- Reduces the amount of construction and demolition waste entering landfill sites.
- Reduces the use of natural resources in construction and contributes to the environmental protection.
- Provides a renewable source of construction material.
- If used in situ, reduces haulage costs

1.2 Recycled Aggregate:

In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. The coarse aggregate manufactured by crushing and screening of waste concrete is termed as Recycled coarse aggregate (RCA).The concrete manufactured with partially and fully replacement of natural coarse aggregate is generally known as recycled aggregate concrete.

Sources of weakness of recycled aggregate:

- Impurities from construction
- Old cement paste adhered to aggregates.
- Higher porosity and water absorption.
- Rough surfaces and angularity
- Other impurities

The drawback exhibited by recycled aggregate is the attached old mortar that distinguishes these aggregate from natural aggregate. This residual mortar content varies from 23 to55 percent, depending on the size of the RCA. Smaller grain size show higher residual mortar content. Recycled aggregate possesses higher porosity and hence higher water absorption ,lower mechanical strengths, residual impurities on the surface of the recycled aggregate creating weaker bond between cement paste and aggregate.

1.3. Nano-silica:

The reduction of mechanical strengths can be improved with use of nano- technology applied to concrete includes the use of nano materials. Nanomaterials refer to materials that at least, one of its dimensions is less than 100 nm. With regard to issues such as strength, resistance, durability, and high performance, the construction industry is one of the important users of nanomaterials. By adding the nano materials, concrete composites with superior properties can be produced. Nano silica is one of the most applied nanoparticles in concrete. It is a new pozzolanic material which is in water in a solid or liquid form. In the concrete industry. Addition of nano silica (NS) in concretes and mortars results in more efficient hydration of cement. Due to the pozzolonic activity, additional calcium silicate hydrates are formed to generate more strength and to reduce free calcium hydroxide. This also helps in reducing the cement requirement, NS improves the microstructure and reduces the water permeability of concrete thus making it more durable. The addition of nana-silica made microstructure of recycled aggregate cement (RCA) mix dense, uniform and free from small voids. But higher dosages of the nano-silica influenced workability due to dispersion problem and congolomeration of particales[1]. It was found that the replacing cement by 3% of NS in the concrete made with 100% RCA produced strength more that of NAC[3].

Therefore in present research focuses on the detailed experimental study of recycled aggregate concrete with use of suitable dosage of collidal nanosilica.

1.4. Objective of work:

The objective of this work is to analyse and propose technical guidelines on mechanical properties, performance criteria and behaviour of concrete made with recycled aggregates using nano-silica. For recycled aggregates to be used in structural concrete, it is necessary to carry out an in depth study of their material properties and analyse how these properties in turn affect the quality of the second-generation concrete in presence of nano material like nano-silica

Therefore following objectives of present work-

1) To characterize the recycled aggregates in terms of physical and chemical properties and also to study the properties of concrete made with recycled aggregates

2) To analyze the structural behaviour of concrete made with different percentages of recycled coarse aggregates.

3)To analyze the option for the use of recycled aggregate in concrete in main stream construction rather than using it as an infill material.

2. EXPERIMENTAL WORK

2.1. Materials:

Cement: In this experimental study, ordinary Portland cement (OPC) 53 grade, used which satisfies the requirements of IS: 12269-2013.The specific gravity of cemet was found to 3.15.

Nano-silica: commercially available nano-silica was used as 2% replacement of cement in this work.

Table no.2.1. Properties of colloidal Nano-silica

Colour	Specific gravity	SiO2 content	Particle size	pH value	Surface area
Translucent white liquid	1.201	30.1%	9.5mu	9.5	319 sq.m/gm

Fig.No.2.1.Collidal Nano-Silica

Fine aggregates :Locally available river sand was used as fine aggregates. Sand used confirmed to grading zone – II as per IS: 383-1970 specification.Standard tests have been performed on fine aggregate to characterised physical properties.

Natural coarse aggregates: The natural coarse aggregates were crushed stone from a local quarry of Basaltic rock. Coarse aggregates used in the experimental study were 20 mm down size and tested as per IS: 2386-1963 and confirmed as per IS: 383-1970 specifications.

Recycled coarse aggregates :Since the objective of the present study is to assess the suitability of coarse aggregates derived from field demolished concrete. The 20mm RCA were prepared from the waste concrete collected from a 10 years old demolished bunglow of Pune (Maharashtra).

Table No.2.2.Physical Properties of Aggregate

Properties of aggregate	NCA	RCA	NFA
Size of aggregate	20mm	20mm	-
Specific gravity	3.27	2.81	2.69
Water absorption (%)	1	2.8	1.6
Bulk density			
a)Compacted(kg/m^3)	1764.48	1638.83	-
b)Loose (kg/m^3)	1523.18	1328.16	-

Water : The normal drinking water was used for concrete mixes.

2.2. Mix design

The experimental investigation is based on a reference concrete mix of grade M20 using natural aggregate and recycled aggregate. On the basis of the material properties, the proportioning of concrete mix is carried out in accordance to IS 456-2000 and as per the guidelines of IS 10262:2009 (draft 2007). The process of determining an appropriate mix proportion involved a number of trial casting and testing. The detailed design description of the final mix proportion is presented here.

Table no.2.3. Mix proportion per cubic meter of concrete with 2% NS.

Series of samples	Cement (kg)	NCA (Kg)	RCA (kg)	NFA (kg)	NS (kg)	Water (kg)
Control	349	1462.86	------	676.91	----	191.58
R20	342	1163.59	250.15	673.03	7	191.58
R40	342	872.69	500.31	673.03	7	191.58
R60	342	581.79	750.46	673.03	7	191.58
R100	342	------	1250.7	673.03	7	191.58

Table no.2.4.Mix proportion per cubic meter of concrete with 4% NS

Series of samples	Cement (kg)	NCA (Kg)	RCA (kg)	NFA (kg)	NS (kg)	Water (kg)
Control	349	1462.86	------	676.91	----	191.58
R20	335	1156.89	248.71	669.16	14	191.58
R40	335	867.67	497.43	669.16	14	191.58
R60	335	578.44	746.14	669.16	14	191.58
R100	335	-------	1244.21	669.16	14	191.58

2.3. Methodology

For present work , initially colloidal nanosilica was mixed with water and stirred properly so that uniform dispersion of nano particles of silica could be achieved[1]. After that cement ,sand and aggregates are mixed as per mix design in concrete mixture. All the dry ingredients were placed into a pan mixer and then required quantity of water and 2% and 4% nanosilica mixtures was added and mixed thoroughly in a pan for respective mixes.

Fig No.2.2.Casting of specimens

The different specimens cast were cube specimens of size 150 x 150 x 150 mm for compressive strength test and cylinder of size 150mm diameter and 300 mm height for tensile strength test. The fresh concrete was placed into the moulds with the help of scoop. The moulds were filled with concrete in workable condition in three layers, each layer being compacted by using standard tamping rod and vibrated using table vibrator to achieve an adequate compaction. After adequate compaction, the specimens were finished smooth and left under wet gunny bags. After 24 hours the specimens were demoulded and transferred to curing tank where in they were allowed to cure for 7 and 28 days. The compressive strength and split tensile strength test was conducted after the concrete specimens were cured for 7 and 28 days on compression testing machine. The testing on machine was carried out in accordance with IS specification.

Fig No.2.3.Testing of Cube

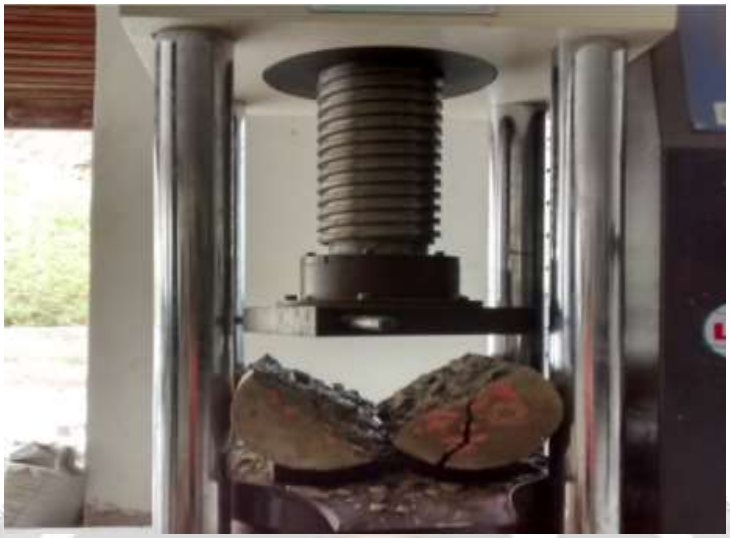
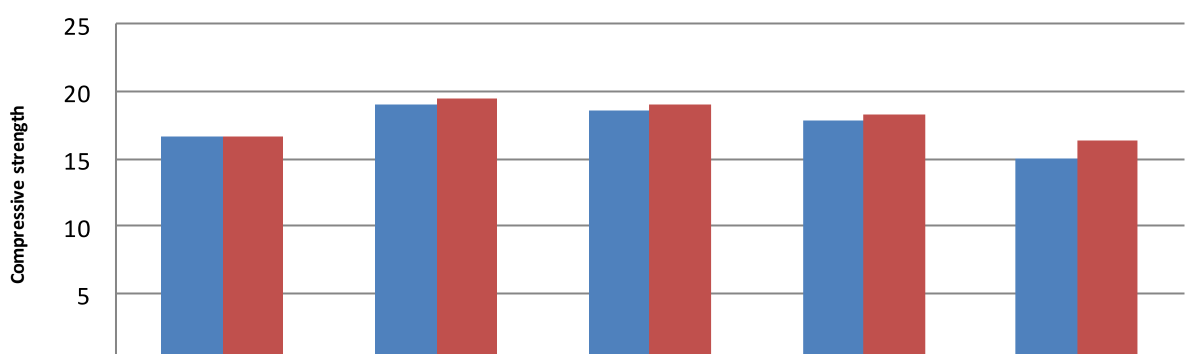


Fig No.2.4.Testing of Cylinder

3. RESULTS AND DISCUSSIONS

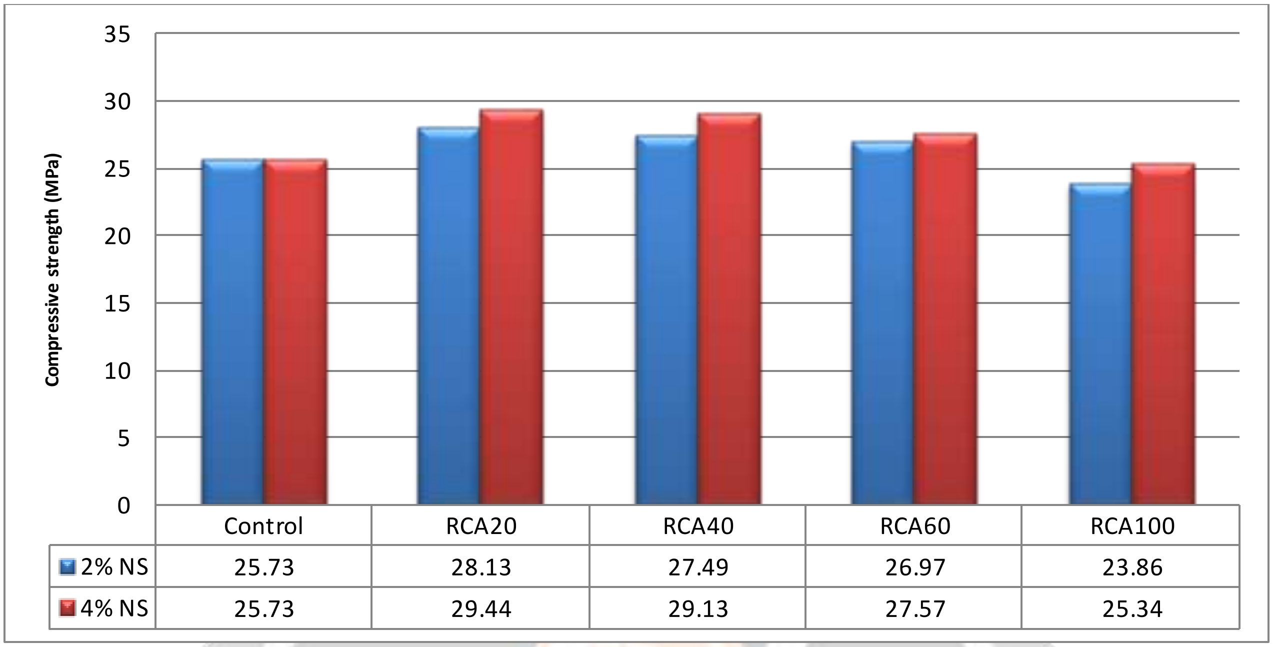
3.1. Compressive strength

The following charts 3.1 and 3.2 represent the compressive strength of five different type of concrete mixes at 7 and 28 days curing. The chart shows the effect 20%, 40%, 60% and 100% replacement of natural aggregate with recycled aggregate with addition of 2% and 4% nanosilica. It can be seen that in concrete containing 20% RCA, addition of 2% and 4% nanosilica significantly increased the compressive strength at all ages. It is also observed that the 4% nanosilica performed slightly better than 2% nanosilica in concrete containing 20% RCA. The results of concrete containing 40% and 60% RCA, addition of 2% and 4% nanosilica gives satisfactory results as compared with control mixes where as the results of concretes containing 100% RCA , it gives marginal results as compared with control mix.



	Control	RCA20	RCA40	RCA60	RCA100
2%NS	16.68	19.09	18.53	17.83	15.11
4%NS	16.68	19.5	19.05	18.23	16.38

Chart No.3.1.Variation in compressive strength at 7 days

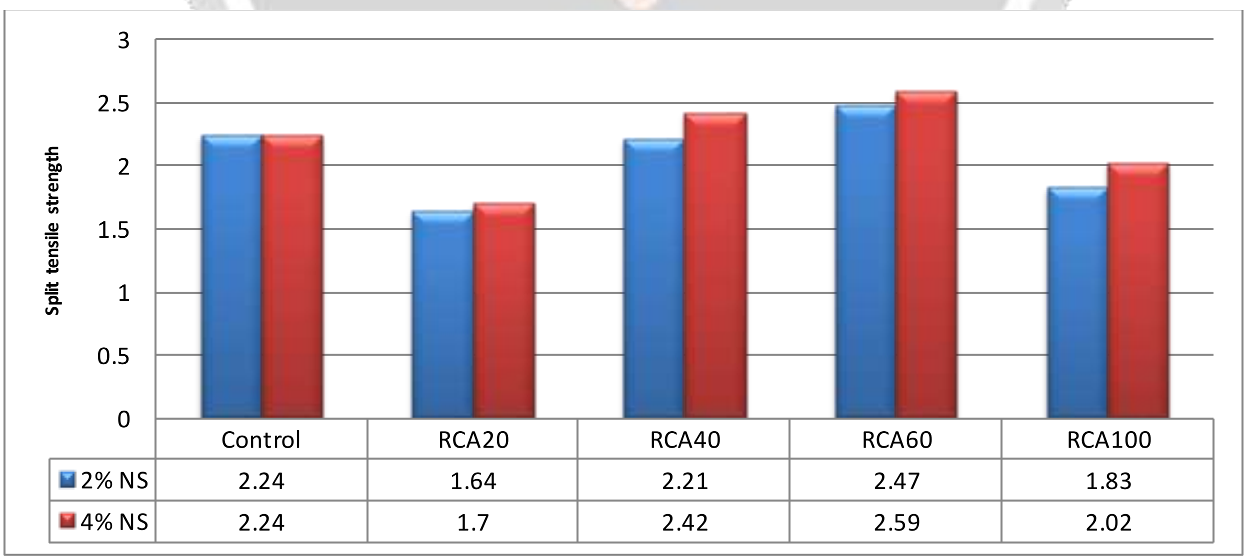


	Control	RCA20	RCA40	RCA60	RCA100
2% NS	25.73	28.13	27.49	26.97	23.86
4% NS	25.73	29.44	29.13	27.57	25.34

Chart No.3.2.Variation of compressive strength at 28 days

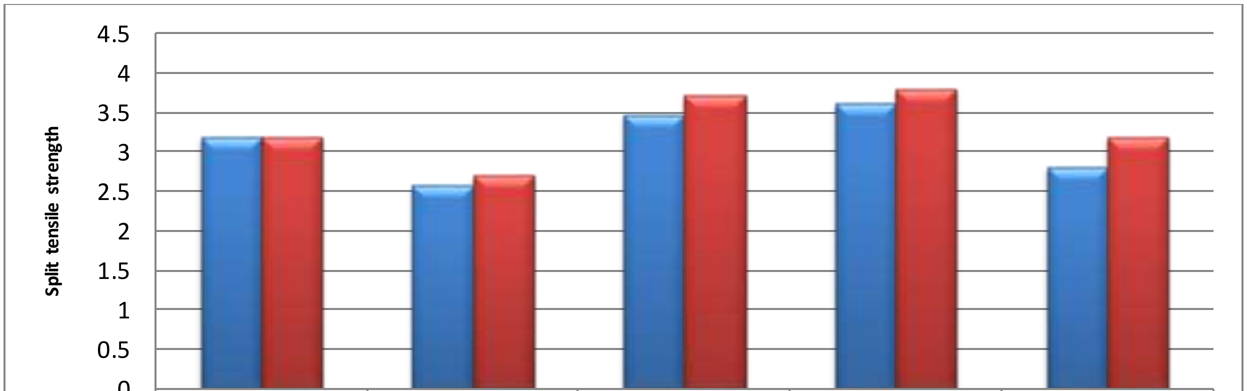
3.2. Split tensile strength

The following charts shows the variation of split tensile strength (STS) with respect to percentage of NS. It can be seen that the split tensile strength of concrete increases with increasing percentage of recycled aggregate with incorporation of nanosilica at 2% and 4%. When comparing the effect of nanosilica addition to the concrete containing 20% RCA get decreased as compared with control mix. In case of concrete containing 40% and 60% RCA, samples with the addition of 2% and 4% nanosilica surprisingly performed better than concrete containing 20% RCA and control mix. The Optimum result of split tensile strength get at 60% RCA with incorporation of 2% and 4% nanoslica. However ,concrete containing 100% RCA with 4% nanosilica gives almost equal value of split tensile strength with the control mix at 28 days.



	Control	RCA20	RCA40	RCA60	RCA100
2% NS	2.24	1.64	2.21	2.47	1.83
4% NS	2.24	1.7	2.42	2.59	2.02

Chart No.3.3.Variation in split tensile strength at 7 days



	Control	RCA20	RCA40	RCA60	RCA100
2% NS	3.2	2.59	3.48	3.62	2.82
4%NS	3.2	2.7	3.72	3.81	3.19

Chart No.3.4.Variation in split tensile strength at 28 days

4. CONCLUSIONS

- Concrete produced by incorporating nano-silica as a partial replacement of cement by 2% and 4%, can replace natural aggregate by recycled aggregate up to 60% gives increasing compressive and spilt tensile strength as compared with control mix.
- Concrete mixes with 4% nanosilica gives increasing compressive and split tensile strength as compared with concrete mixes containing 2% nanosilica.
- The enrichment of compressive and tensile strength of concrete was achieved by addition of nanosilica as nano particles of silica act as filler material to fill the void in recycled aggregate and making concrete stronger and denser.
- In general conclusion, recycled aggregate from demolished concrete blended with natural aggregate, along with 2% and 4% nanosilica can be an useful component in making concrete for structural applications

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