Compressive Strength of Nano-Silica Incorporated Recycled Aggregate Concrete

Bibhuti Bhusan Mukharjee[1], Sudhirkumar V Barai[2]

Research scholar, Department of Civil Engineering, IIT Kharagpur, India[1].
Professor, Department of Civil Engineering, IIT Kharagpur, India[2].
bibhuti.2222@gmail.com[1] , skbarai@civil.iitkgp.ernet.in [2]

ABSTRACT-*The present work is based on analysis of the influence of incorporation of Nano-Silica on compressive strength of recycled aggregate concrete using two factorial designs. In this study, recycled coarse aggregate (%), Nano-silica (%) and Specimen Type are selected as factors and each having two levels. Four numbers of mixes with three replicates are designed and compressive strength at seven and 28 days are selected as responses. Analyses of Variance (ANOVA) of experimental results are carried out to study the influence of factors and various plots are used to demonstrate the results of the analysis. The outcome of the study depicts that the selected factors are significantly affecting the compressive strength of concrete. However, the analysis indicates that interaction of factors has no substantial influence on compressive strength of concrete.*

Keywords-recycled aggregate concrete, nano-silica, compressive strength, ANOVA.

1, INTRODUCTION

Recycling of waste concrete for production of aggregates can be helpful in solving problems like depletion of natural resources, scarcity of land for waste disposal, and growing costs of waste treatment prior to disposal [1]. Several studies have been conducted in area of application Recycled Coarse Aggregates (RCA) as a fractional or entire substitution of Natural Coarse Aggregates (NCA) for production of new concrete. The major negative aspect of application of RCA is related its quality as RCA have higher water absorption, more porosity and lesser density than that of NCA. [2]. Previous studies confirmed that compressive strength (CS) of the concrete made with 100% RCA was 25 % lower than that of Natural Aggregate Concrete (NAC) [3, 4]. Moreover, supplementary cementious materials like fly ash, silica fume, ground granulated blast furnace slag, and metakaolin were added in RAC to enhance its CS and significant improvement was observed [6,7]. The significant developments in the field of nanotechnology in recent times lead to the production of novel materials in the nano-meter scale range for application in cement and concrete. Among all available nano-particles, Nano-Silica (NS) could be quite useful as it increases rate of cement hydration and reduces porosity of cement paste and concrete by filling the voids [8]. Increase in strength and improvement of microstructure of cement paste and mortar was reported with the addition of NS [9, 10]. The incorporation of 3% NS in 100% RAC mixes enhanced CS along with improvement of other mechanical properties [11].

Several investigations based on utilization of RCA in concrete mixes and their improvement techniques with addition of various pozzolanic materials are available in literature. However, studies related to the application of NS in RAC mixes are rarely available in previous studies. Therefore, this research work is based on the application two factorial design to analyze the influence of the factors RCA(%), NS(%) and Specimen Type on CS of concrete.

2, EXPERIMENTAL PROGRAMME

The present work comprises of determination compressive strength of two different type specimens of four different types of concrete mixtures developed using 2^3 factorial designs. The level of factor was fixed at 0% and 100% and for NS(%), it was kept at 0% and 3%. The levels of factor "Specimen Type" were Type 1 (150 mm cubes) and Type 2 (100 mm cubes). The experimental results were analyzed using ANOVA and expressed using various plots. Ordinary Portland cement of 43 grade, having consistency 32%, specific gravity and specific gravity 3.12 was used for preparation of concrete mixes. Commercially available colloidal NS having specific gravity 1.12, pH value 10.11 and solid content 39% was used in this study. The Transmission Electron Microscope (TEM) picture taken in bright field mode is shown in Fig. 1.

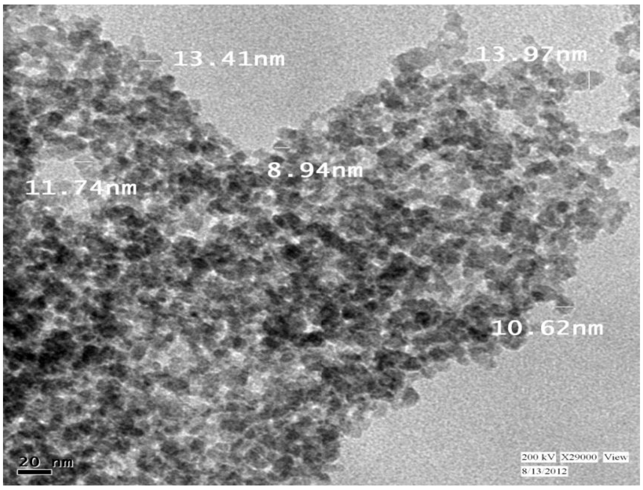


Figure.1 TEM picture of NS

Local river sand was used as Natural fine aggregate (NFA) and crushed dolerite of 20 mm nominal size was used as Natural Coarse Aggregate (NCA). The Recycled Coarse Aggregates (RCA) were retrieved from the waste concrete collected from 30 years old demolished building of Jhargram, West Bengal. The standard tests have been performed for characterization of aggregates and results of those tests are presented in Table 1.

Table 1. Physical and mechanical Properties of Aggregates

Type of aggregate	Bulk density		Specific gravity	Impact value (%)	Loss angels value (%)	Crushing value (%)
	Loose	compact				
NFA	1525	1698	2.62	-	-	-
NCA	1504	1654	2.72	15.35	19.72	15.11
RCA	1321	1418	2.46	34.85	36.56	31.52

Details of mix proportions of concrete considering two factors RCA(%) and NS(%) is shown in Table 2. The CS of 100 and 150 mm cubes was performed after 7 and 28 days using compressive testing machine of 3000 kN capacity in accordance specifications of BIS (IS: 516, 1959).

Table 2. Mix Proportions of concrete mixtures (kg/m^3)

RCA (%)	NS (%)	Mix No.	Cement (kg)	NCA (kg)	RCA (kg)	NFA (kg)	NS (kg)	Water (kg)
0	0	NAC 1	450.000	1180	-	640	-	180
0	3	NAC 2	436.500	1180	-	640	13.500	180
100	0	RAC 1	450.000	-	1067	640	-	180
100	3	RAC 2	436.500	-	1067	640	13.500	180

3, RESULTS AND DISCUSSION

Fig. 2 shows cubic plots of mean of CS of concrete mixes after 7 and 28 days with respect to the factors. The plots systematically represent the CS at different levels of selected factors.

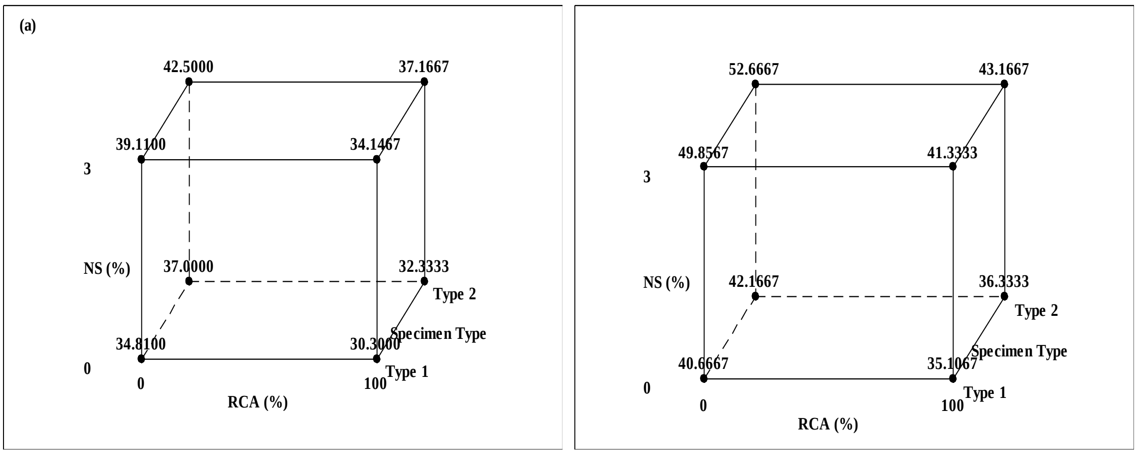


Figure.2 Cubic plots of CS after (a) 7 (b) 28 days

The ANOVA results for seven and 28 days CS of concrete mixes are presented in Table 3 and 4 respectively. It can be seen that main effects such as RCA(%), NS(%), and Specimen Type are significantly affecting the test results as p-value less than 0.05. However, the terms consisting of 2-Way and 3-Way interactions are not found to be significant. The CS of concrete mixes decreases with substation of NCA with RCA owing to the inferior properties of RCA and development of weak bonding between the aggregates and cement mortar [3, 4]. However, addition of NS improves CS of concrete due to the filling of voids present in cement mortar matrix, and subsequently Interfacial Transition Zone (ITZ) of concrete is improved. The CS of 100 mm cubes are slightly higher than 150 mm cubes, which is related to size effect of specimens. Therefore, the factors RCA(%), NS(%) and Specimen Type have substantial influence on CS of concrete.

Table 3. Analysis of Variance for 7 Days CS

Source	DF	SS	MS	F	P
RCA (%)	1	142.204	142.204	46.64	0.000
NS (%)	1	128.066	128.066	42.00	0.000
Specimen Type	1	42.400	42.400	13.91	0.002
RCA (%)*NS (%)	1	0.470	0.470	0.15	0.700
RCA (%)*Specimen Type	1	0.104	0.104	0.03	0.856
NS (%)*Specimen Type	1	1.793	1.793	0.59	0.454
RCA (%)*NS (%)*Specimen Type	1	0.017	0.017	0.01	0.941
Residual Error	16	48.783	3.049		
Pure Error	16	48.783	3.049		
Total	23	363.839			

Table 4. Analysis of Variance for 28 Days CS

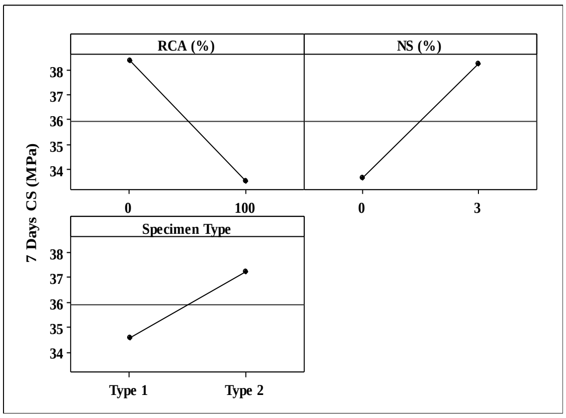
Source	DF	SS	MS	F	P
RCA (%)	1	324.503	324.503	135.39	0.000
NS (%)	1	402.211	402.211	167.82	0.000
Specimen Type	1	20.369	20.369	8.50	0.010
RCA (%)*NS (%)	1	16.484	16.484	6.88	0.018
RCA (%)*Specimen Type	1	0.586	0.586	0.24	0.628
NS (%)*Specimen Type	1	1.378	1.378	0.57	0.459
RCA (%)*NS (%)*Specimen Type	1	0.186	0.186	0.08	0.784
Residual Error	16	38.348	2.397		
Pure Error	16	38.348	2.397		
Total	23	804.063			

The equations relating the factors with 7 and 28 days CS are stated in Eqn. 1and 2, which are linear in nature and indicate about the absence of higher order terms as these terms are insigificant.

7 Days CS = 35.905-0.045× RCA(%) +1.634× NS (%) + 1.095× Specimen Type (1)

28 Days CS = 41.417+ 0.057× RCA(%) +3.282× NS (%) + 0.75× Specimen Type (2)

The main effect plots for seven and 28 days CS is shown in fig. 3, which indicates that CS reduces with increase in RCA(%) from 0% to 100%. This reduction of CS is mainly due to the inferior quality of RCA as compared to that of NCA. However, CS increased significantly with the increase in level of the factor NS(%) from 0% to 3%, as addition of NS improves microstructure of concrete by filling voids present in it. Moreover, CS increases with change of level of factor Specimen Type as CS of 100 mm cubes is higher than that of 150 mm cubes. However, the effect of this factor as less significant as compared to the other factors RCA(%) and NS(%), which can be confirmed from the difference in F-value presented in ANOVA table.



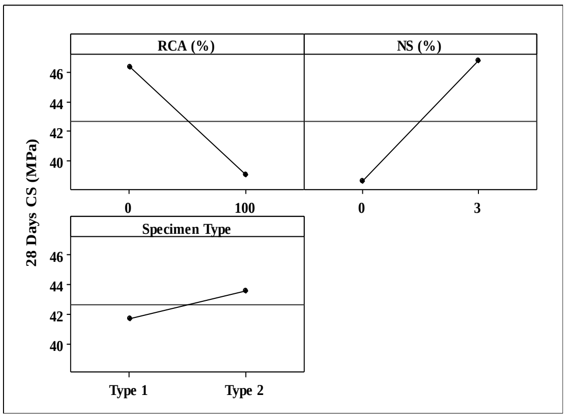


Figure.3 Main effects plots for CS after (a) 7 (b) 28 days

Fig. 4 shows interaction plots for CS at 7 and 28 considering the selected factors RCA(%), NS(%), and specimen type.

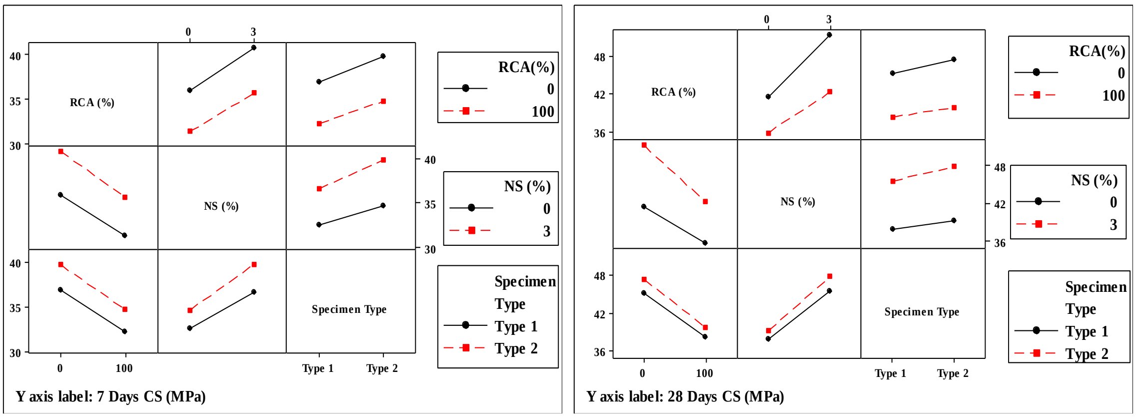


Figure.4 Interaction plots for CS after (a) 7 (b) 28 days

It can be seen from these plots that interactions between the factors have no significant effect on the selected responses. Interaction of effects are said to be significant when plots intersect with each other and in other way, the influence of one factor on the selected response is modified with the alteration of the level of another factor.

V. CONCLUSION AND FUTURE WORK

The influence of colloidal NS on the compressive strength of concrete considering factors RCA(%), NS(%), and Specimen Type has been investigated using Two Factorial design. The experimental results are analyzed using ANOVA and the conclusions of the study are stated as follows:

- The CS of concrete specimens reduces significantly with the incorporation of RCA in place of NCA, as RCA are having higher water absorption and more porous in nature as compared NCA, which leads to weaker ITZ of RAC as compared to that of NAC. Therefore, the factor RCA(%) significantly affects the CS of concrete.
- The influence of the factor NS(%) is found to be significant as CS of the concrete with colloidal NS is more than that of concrete made without NS, as silica nano-particles increase rates hydration and fill the voids of the C-S-H structure leading to a dense concrete.
- The significance of Specimen Type on CS of concrete could be understood as CS of 100 mm cube is having higher value than that of 150 mm cube.
- From analysis of results of the study, the factors RCA(%), NS(%) and Specimen Type are found to be significantly affecting the CS of concrete. However, the interactions between these factors have no significant effect on CS of concrete.

- Application of other factorial designs considering more factors for analysis of various properties of concrete could be treated as future scope of this work.

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