Evaluation of Carbonation Resistance in Nanosilica-Modified Concrete for Enhanced Durability of Civil Infrastructure Materials

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ABSTRACT
The use of statistical analysis in this study facilitated in understanding the carbonation behavior of different concrete mixes with nanosilica. In the present work, a factorial analysis of variance (ANOVA) with two different cement types i.e. OPC and PPC and three different water-cement ratios as replicates was carried out. The results of the a fore said analysis with water-cement ratio as replicate showed that the nano silica have significant effecting overning the carbonation depth as compared to that of other above-mentioned variables. Cement types as replicates, nanosilica and water-cement ratio were recognized as the significant factor influencing the carbonation depth

KEYWORDS: AccontTrade, Uniqueness index, MFP, Auctioneer.

1. INTRODUCTION
Concrete is a manmade construction material consists of cementations material, fine aggregate, coarse aggregate and water. The cost of these materials is increasing day by day.Due to the rapid growth of the construction industry, depletion of natural resources and deterioration of concrete structure have caused an unsustainable development of the construction industry [1]. We need to study a way to reduce the cost of building materials, especially cement. A recent advancement in the construction industry has been to replace cement with waste from concrete. This alternative reduces costs, saves energy and protects the environment. In order to preserve natural resources, the reuse of waste materials is being carried out by the engineering fraternity. In view of this, nanosilica as a replacement of cement has become an alternative thereby stimulating sustainable development. One of the areas of research focuses on replacement of cement by pozzolanic materials [2]. Out of these pozzolanic materials, silica fume is one of the extensively used materials nowadays. It is produced as a by-product during production of silicon. Silica fume plays three important roles in concrete. It causes pore size refinement, reacts with free lime and strengthens the transition zone. However, it has been observed that concretes are subject to a number of natural factors and corresponding phenomenon governing their durability and life. The durability of concrete structures depends on countless factors such as its design (water-cement ratio, steel proportion, quality of work) materials used for its fabrication (cement, aggregates, water), fabrication procedures (wet curing time), and the environment under which it will serve (urban, marine, industrial or a combination). Degradation mechanisms and the type of attack observed on concrete structures depend directly on environmental parameters such as relative humidity, temperature, and wind speed and direction [3].

Carbonation of concrete is one such process governing its durability and life in one or the other way. Carbonation occurs in concrete because the free hydroxides (mainly calcium hydroxidein concrete react with carbon- dioxide from air or water to form calcium carbonate. Owing to the consumption of hydroxides the pH value of concrete pore solution reduces to below 9.0[4].Accordingly, the scope of this study was to a) determine the carbonation depth in concrete samples made from two different types of cement i.e. Ordinary Pozzolana Cement (OPC) and Portland pozzolana Cement (PPC) with nanosilica and three water-cement(w/c)ratios(i.e.0.40.0.45and0.50)andb) to identify the significance of different variables influencing and inducing carbonation in the different concrete mixes, through analysis of variance (ANOVA).

2. MATERIALS AND METHODS
In this study ordinary Portland cement (OPC) (Grade 43) and Portland pozzallana cement (PPC) have been used throughout experiment. It is tested as per provision of BIS: 8112[5] and IS 1489 (Part 2) [6]. Nano silica is utilized in this experiment in the dust form. Physical and chemical properties of nano silica are investigated as per ASTM C1240[7]. Nanosilica contains very high amount of amorphous silicon dioxide and very less quantities of iron, magnesium, and alkali oxides. Sand from local river conforming to zone III with a 4.76 mm maximum size was used as fine aggregate. It was tested as per specifications of BIS: 383[8]. Coarse aggregates with maximum size of aggregate (MSA) 20 mm of quartzite origin was used Deep ground water from laboratory tap is used for mixing the concrete mixture. A polycarboxylic ether (Master Glenium ACE 30) based super plasticizer is used in all mixture conforming with ASTM C 494 type F [9] with density around 1.10 and pH almost 5.0 is used for maintaining the workability of fresh concrete.

Concrete cubes were prepared as per requirements of BIS: 10262[10]. Then, cement is partially replaced with five nano silica percentages (1%, 2% 3%, 4%, and 5%) by mass. The water cement ratio of 0.40,0.45 and 0.50 were kept throughout the experiment. First, nano silica is mixed with cement by trowel then all constituents of concrete are mixed in the revolving pan mixer. Before adding water, cement and aggregates were dry mixed. To maintain consistency of concrete super plasticizer is added with water. Before casting the concrete cubes, workability (slump test) is carried to check the laying ease of fresh concrete. After 24 hours cubes were demoulded and kept in the water tank for 28 days moist curing. After moist curing the cubes were kept in the ambient laboratory condition still further processing. These were then conditioned in a laboratory air environment for 14 days. After 14 days, cubes were placed in a storage chamber with active control on carbondioxide(4±0.5)%, temperature (20±2)^{0}C and relative humidity (55±5) % for a period of 70 days [11]. Concrete cubes were crushed in compression testing machine the crushed This powder material was sieved through 150µm and the collected powder was then stored in air tight condition. was then used for pH test.

Anaqueous solution of this powder obtained was then prepared by dissolving it in distilled water1:1 proportion by mass and then properly mixed and stirred for an hour. After that the solution was then heated gently and, allowed to settle and cool. Immediately after preparation of concrete solution, it was put in a sealed container in a desiccatorprior to the pH measurement. The solution was then filtered through What man No. 1 filterpaper. After that the pH value of aqueous solution of concrete was measured using digital pH meter [12].

The pH value of these concrete cubes due to the effect of carbonation tends to get reduced to below 9.0. Correspondingly, the effect of carbonation in this study was ascertained by carrying out pH test for thetwo cement typesi.e.OPCandPPCwithnanosilica,andthreewater-cement(w/c)ratiosi.e.0.40,0.45 and 0.50, as discussed above.

Statistical analysis: Factorial ANOVA

Analysis of variance (ANOVA) was conducted according to the guidelines offered by Hicks(1982). In the first case, two types of cement (OPC and PPC) and the carbonation depth of three different water-cement ratios have been considered as the replicates. Second case, different water-cement ratios and the carbonation depth of two types of cements considered as the replicates. Therefore, the effect of the individual factors on carbonation depth of the concrete mixes was assessed by the analysis of variance (ANOVA), which is the test of null hypothesis or the test at a certain probability level.

3. RESULTS AND DISCUSSION

The pH test results as obtained in this study for different concrete mixes prepared with OPC and PPC cements with nanosilica are shown in Table 1.From the Table 1, it is also observed that during carbonation process, pH of non-carbonated concrete is between 12.15 to12.69. Although, there is no pattern found and it may be deduced that the introduction of nanosilica in concrete by partially replacing cement seems not effecting on pH of the concrete. Further, taking the average of pH values for non-carbonated concrete in view of exposure period 70 days of accelerated carbonation.

Table 1: pH value of concrete mix containing made with nanosilica for different w/c ratios

	pH value					
	OPC			PPC		
NS %	0.40	0.45	0.50	0.40	0.45	0.50
0	12.69	12.55	12.5	12.65	12.52	12.45
1	12.62	12.48	12.39	12.55	12.4	12.3
2	12.5	12.4	12.2	12.47	12.31	12.3
3	12.45	12.26	12.1	12.3	12.28	12.18
4	12.3	12.12	12	12.1	12.2	12.08
5	12.15	11.95	11.94	12	12	11.9

Further the results obtained, signifying the influence of different variables in the carbonation of the different concrete samples, through analysis of variance (ANOVA) with water-cement ratio as replicate and cement types as replicates are given in Table1 and 2.

The calculated F-ratio was compared with the F-value from Fisher's distribution at 99% confidence level. The F-values related to Fisher's distribution depend upon the number of degree of freedom of the individual factors, the residual error and the probability level. F-ratio more than the tabulated F-value indicates that the variance corresponding to the factor is more compared to variance of error thus the factor is relevant and its effect may not be neglected.

Table 2:Results of ANOVA for carbonation depth with water-cement ratios as replicates

Source	Sum of squares	Distribution factor	Mean squares	F-ratio	F from fisher's distribution at 99% Probability
Aggregate	64.954	1	64.954	8.143	6.345
Cementtype	0.110	1	0.110	0.14	6.345
Nanosilica*cementtype	0.651	1	0.631	0.80	6.345
Error	336.340	42	4.650		
Total	4021.357	48			

Table 3: Results of ANOVA for carbonation depth with cement type as replicates

Source	Sum of squares	Distribution factor	Mean squares	F-ratio	F from fisher's distributior at 99% probability
Aggregate	68.451	1	68.451	118.934	7.264
Water-cementratio	309.303	3	102.009	189.777	4.27
Nanosilica*Water-cementratio	17.458	3	6.211	11.556	4.27
Error	19.987	40	0.528		
Total	4021.35	48			

From the results of ANOVA tabulated above Table 2 and 3, it was observed that in the case of water-cement ratio as replicates, the calculated F-ratio of aggregate is higher than the F-value at 99% confidence level. For the other factors like cement types, aggregate and cement types, the calculated F-ratio is smaller than that of the F-value at the same confidence level. It was thus inferred, that nanosilica have significant effecting overning the carbonation depth of concrete samples in the a fore said mixes as compared to that of other above-mentioned variables. On the other hand, in the case of cement type as replicates, it was observed that the calculated F-ratio of nanosilica and water-cement ratio is higher than that of the F-value obtained from Fisher's distribution at 99% confidence level. Accordingly, nanosilica and water-cement ratio were recognized as the significant factor.

4. CONCLUSION

The analysis of variance (ANOVA) based on factorial analysis carried out in this study enabled in identifying the significance of different variables in carbonation of concrete. Accordingly, through this study, the most significant factor amongst all the other variables affecting carbonation was interpreted. Results from this study showed that the most significant effect on the carbonation of concrete made with nanosilica, when water-cement ratio was the replicates and both water-cement ratio and the nanosilica were the significant factors, when cement types were taken as replicates

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