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Non-Destructive Testing on Concrete Subjected to Chemical Condition

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Abstract. Regular in-situ inspection of structures is required for accessing the condition of concrete. In concrete, several unpredicted and uncontrollable factors affect the expected performance and life cycle of the structures. Non-destructive testing can be applied to both new and old structure to monitor infrastructures. This test is better known to assess and evaluate the condition of concrete. In this investigation, the non-destructive testing and destructive testing were used to estimate the strength of concrete cubes of M25 subjected to 28days of curing with acid at varying PH values (1.5, 2.5 and 3.5) and water. The test was used to determine the strength of the cubes. From the result he concluded that cubes cured with water had better strength throughout the test and gradual deterioration was observed in the cube specimen subjected to acid.
Keywords: compressive strength, Rebound hammer, ultra-pulse velocity

1. Introduction

Concrete deterioration in past few decade has been alarming. Chemical attacks are known widely as one of the most significant issues concerning the construction industry. All these chemical attacks deteriorate the properties of cementitious materials. The curing environment of concrete have effect on the strength development of such concrete. Natural environments may also cause acid attack to concrete structures which cause serious damage. Acid rain, acidic soils, chemical factories e.t.c constantly affect concrete work when in contact with them, they negate the durability of structures in such environment. They damage the foundation of the structures which could lead to the failure of the entire structure [1-5]. The condition of the assessment of the deterioration can be made with NDT methods to provide information for the performance of the concrete. C30 grade concrete cubes were cast with different water cement ratio of 0.35, 0.40, 0.45 and 0.50 by [6]. The cubes were tested after 28 days of curing for both NDT and DT. It was observed that the rebound hammer provides cheap, quick and simple method for determining the strength of concrete. The characteristic compressive strength of concrete after 28days of curing showed 32, 39, 28, 25N/mm2 for the water cement ratio of 0.35, 0.4, 0.45, 0.5 respectively and percentage variation of 11.50%, 15%, 15.70%, and 16.7%. After 7 days of curing, [7] subjected specimen to various level of durability test (acid and alkali attack, water absorption and chloride test) for 60days. From the result obtained, workability of the concrete decreases with silica fume increase, loss of weight in acidic media and increase in permeability of the concrete and reduction in compressive strength compared to normal cured concrete. [8] researched on the experimental replacement of cement by metakaolin at percentage ranging from 0% to 30% with 10 at interval on high performance concrete when subjected to acid attack for 30, 60 and 90 days. They concluded that the addition of metakaolin mineral admixture to the extent of 10% as replacement to cement enhances the resistance of HPC to acid attack. Also, the percentage weight loss due to acid attack increase with the increasing water binder ratio and 10%MK based HPC weight loss due to acid attack is minimum. [9] studied the physicochemical and mechanical properties of mortar cured for 28days and soaked in diluted HCl solution for 90days. The weight loss, longitudinal wave velocity and uniaxial compressive strength of the mortar was examined. The result

indicated increase in porosity, decrease of longitudinal wave, and increase in mass for certain period. The relationship between the compression and corrosion time of mortar was deduced by regression analysis. [10] found out that deterioration of cementitious material specimen under acid rain attacks was caused by H+ and SO42- which led to loss of cementitious materials, weight loss and higher porosity. [11] examined the rate of strength loss as well as durability of concrete when cured in acidic environment. It was concluded that acidic curing environment have negative effect on the compressive, flexural and tensile strength as well as density of concrete.

2. Materials and Method

2.1. Materials

Materials used in this investigation are sourced in Nigeria. Ordinary Portland Cement was used with conformation to the requirements stated by [12]. The water used was portable water which is clean and free from any visible impurities. It was obtained from borehole and it conforms to the requirements stated by [13]. The coarse aggregate used for this research is granite of size 20mm sourced from a quarry site and sharp sand used as the fine aggregate [14]. The chemicals used are sulphuric acid and nitric acid. PH meter was use for testing the acidity of the solution before and after dilution. The test carried on the fresh and solid concrete were the concrete workability test (slump), the test on density of the hardened concrete, the non- destructive test (UPV and RH) BS 1881-204 and the destructive test (compressive strength).

2.2. Preparation of specimen

The weight of the cement used for this research is 29.19kg, 58.212kg of fine aggregate, 116.424kg of coarse aggregate and water cement ratio of 0.5. 24 cubes of 150mm x 150mm x 150mm concrete grade 25 were cast. Using the mix ratio 1:2:4 according to the BS code 8110. Six cubes were cured in water, and eighteen cubes were cured in the chemical combination of sulphuric acid and nitric acid diluted into three different PH values of 1.5, 2.5 and 3.5. Six cubes were cured in the three different acidic concentration for 28 days.

2.3. Curing

After the preliminary and slump test were conducted on the mix, the concrete was cast in wooden formwork of 150mm by 150mm by 150mm. after the casting had been done and demolded after solidification (24 hours), a submerged method of curing was adopted where the cubes were immersed in a corrosionless curing tank containing clean water and a tank containing the varying diluted acid of 1.5PH, 2.5PH and 3.5PH solution.

3. Results and Discussion

3.1. Sieve Analysis

The manual method of sieve analysis was used as the sieve was arranged in sizes ranging from 25mm to 5mm and the result are shown in figure 1 and figure 2. It was observed that 62.73% of the coarse aggregates pass through the 20mm size and was retained on the 15mm size indicating that the average size of the granite used is within the range of 19mm to 15mm. the granite can be regarded as gap minded aggregates of medium sizes. The same approach was also used for fine aggregates of sieve ranging from 12.5mm to 75μm was observed that 96.96% was retained on 5mm sieve size and was used. Indicating that the size of fine aggregate used is within the range of 0 to 5mm.

3.2. Slump Test

Result of slump indicating workability for concrete grade 25 is shown in table 1. From the result obtained as seen in the table a true slump type was observed having a slump height of 35mm.

Table 1. Concrete grade 25 slump test

Height of cone	Collapse height	Height of	Slump type	Degree	Water	cement

(mm)	(mm)	Slump (mm)		workability	ratio
300	265	35	True	*medium*	0.5

3.3. Density Test

The test was carried out on 3 samples each from the categories of concrete cube specimen subjected to different acidic condition. The dimension of concrete cube is (150×150×150) mm. The mass of the specimen is obtained by using weighing balance after curing with different acidic condition. Density is obtained by dividing the mass of specimen by volume of concrete cube specimen. The result was tabulated.

Table 2. Showing density of cubes

Cured in water		**Cured in 1.5 PH**		**Cured in 2.5 PH**		**Cured in 3.5 PH**		**Volume of concrete cube**
Mass(kg)	Density	Mass(kg)	Density	Mass(kg)	Density	Mass(kg)	Density	
8.3	2459	6.9	2044	7.5	2222	8.0	2370	0.003375
8.2	2429	7.0	2074	7.3	2162	7.9	2340	0.003375
8.4	2488	6.8	2014	7.2	2133	7.8	2311	0.003375

It is observed from the result that the density of concrete cube reduces with increase in the potential hydrogen value of the solution of which the concrete was subjected to. While there is increase in the density of concrete specimen subjected to ordinary water as a result of absorption of moisture during curing. The average of the density is taken as follow ranging from the specimen ordinary water and 1.5, 2.5 and 3.5 PH value of acid (2458, 2044, 2172, 2340) Kg/m3. Indicating that the more the concentration of acid the more reduction in the density as a result of the formation of honeycomb and reduction in the mass.

3.4. Non-destructive test on the cubes

3.4.1. Ultrasonic pulse test

Each concrete cube specimen was evaluated. The pulse velocities of the specimen both subjected and not subjected (curing in water) to chemical condition were measured. The direct method was used for the test. The transducer and the receiver were properly placed and connected. Interpretation of the result showing the transit time for the concrete specimen subjected to water and acidic condition of the varying PH values are presented in the table 3.

Table 3. Showing transit time and pulse velocity of the sampled cured

Cured in water		Cured in 1.5 PH		Cured in 2.5 PH		Cured in 3.5 PH		Samples
Average Transit	Pulse velocity	Average Transit	Pulse velocity	Average Transit	Pulse velocity	Average Transit	Pulse velocity	
34.0	4.4	46.9	3.20	44.43	3.38	40.1	3.75	1
37.8	3.39	49.4	3.04	41.6	3.61	38	3.95	2
33.86	4.43	47.2	3.20	41.7	3.60	41.5	3.61	3
39.9	3.75	46.3	3.23	45.7	3.30	42.4	3.54	4
39.3	3.82	49.5	3.03	44.1	3.40	42.8	3.50	5
36.0	4.17	46.3	3.24	43.8	3.42	41.3	3.63	6

Different readings were taken and the average was obtained to note one reading on the ultrasonic pulse velocity which is reported in the table. As seen in table 3 the specimen all had satisfactory concrete quality grading but the specimen cured with water had excellent quality grading as per [15-19].

3.4.2. Rebound Hammer

The equipment is held at right angle after been calibrated to the clean and surface of the concrete specimen subjected to chemical condition and water curing. The interpretation the result showing the rebound index for concrete specimen are presented in table 4.

Table 4. Showing the rebound number of samples cured

Sample	Cured in water	Cured in 1.5 PH	Cured in 2.5 PH	Cured in 3.5 PH
	Rebound number	Rebound number	Rebound number	Rebound number
1	29	19	24	24
2	28	18	21	23
3	27	19	20	25
4	28	18	22	22
5	29	20	25	25
6	30	17	21	24

From the result in the above table 4, specimen sample cured in 1.5 PH acid yielded low value due to low strength and stiffness of the concrete there by absorbing more energy released from the spring mass. Concrete specimen with PH 1.5 ranged from 20 to 17 while specimen cure with water gave a good result with it rebound value index ranging from 30 to 27 which means the quality of the concrete is good giving a good layer.

3.5. Destructive Test

3.5.1. Compressive strength

The test was carried out after 28 days of curing both in water and chemical. The concrete specimen of standard cube specimen of 150x150x150mm in accordance to BS… The cubes were subjected to 1500kN capacity compression machine. The potential strength of the cubes specimen were shown as see in the figure 1.

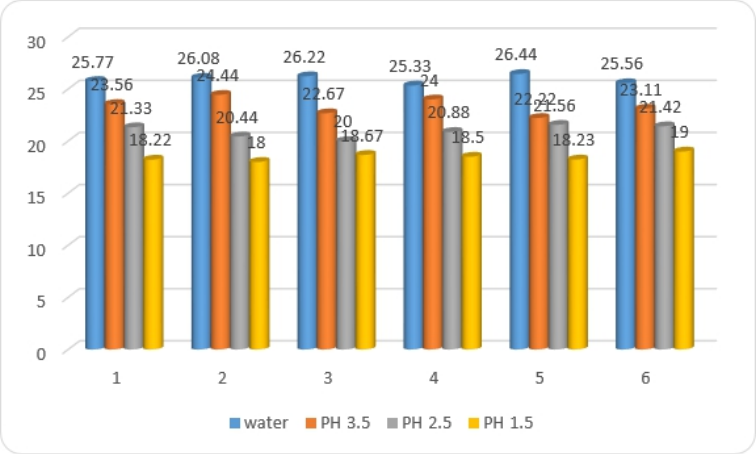

Figure 1. Showing the compressive strength of sample cured in both acid and water

From the result obtained from the destructive test (compressive strength) on the concrete specimen subjected to chemical and water. It was observed that the mix cured in water gave the highest compressive strength of 25.77, 26.08, 26.22, 25.33, 26.44 and 25.56 N/mm2. While the concrete specimen subjected to 1.5PH as seen the figure 1 had a poor compressive strength at 28 days. It had a low compressive strength ranging from 18 to 19 N/mm2.

3.5.2. Comparison between Results

From each test carried out (non-destructive and destructive) on the specimen cubes subjected to both water and chemical curing, the result are explored and compared. The specimen cured in water did not show any sign of deterioration instead had the highest strength compared to the rest. The average values for the six specimen of each curing (water and acid) of ultrasonic test was obtained and compared, giving 3.99, 3.66, 3.45 and 3.15km/s which 3.99km/s being the average of the sample cured with water and 3.66km/s the average of the sample cure by acid of 3.5 PH value. The rebound value being 29, 28, 27, 28, 29, 30 and the average giving 28.5. Also, the compressive strength giving an average of 25.90N/mm2 for sample cured in water. Gradual reduction is observed from the sample cured in acid; the strength of the specimen deteriorates as the concentration of the acid increases. From the result gotten from the specimen cured in various acidic PH values, the sample cured in acid solution of 3.5 PH had better strength compared to the rest. It is observed that as the acidic solution increases the concrete cube deteriorate making the specimen more porous because cement does not resist acidic compounds well. The strength deterioration factor for the sample subjected to acidic solution for 1.5PH, 2.5PH and 3.5PH for ultra-pulse are 26.9%, 19.10% and 9.92% respectively. While the strength deterioration factor for compressive strength are 32.06%, 19.44% and 7.29% respectively.

Test	Cured in water	Cured in 1.5 PH	Cured in 2.5 PH	Cured in 3.5 PH
Ultrasonic pulse (km/s)	3.99	3.15	3.45	3.66
Rebound Hammer	28.5	18.5	22	24.3
Compressive strength	25.90	18.93	20.93	23.33

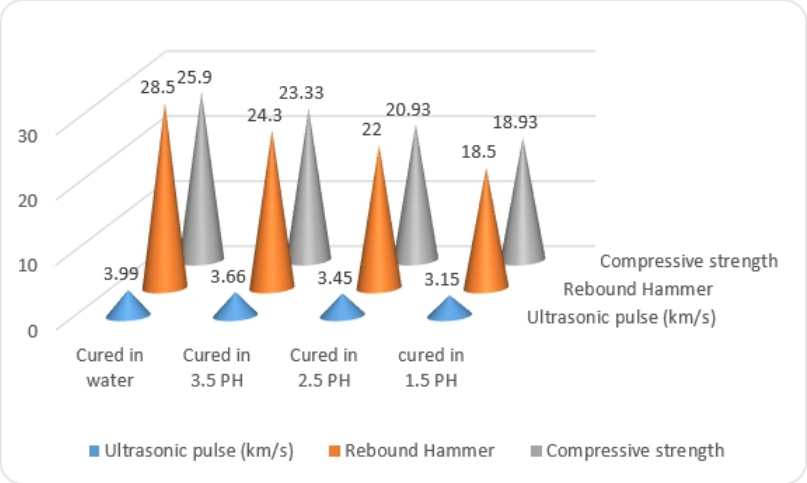

Figure 2. Showing various test against method of curing

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4. Conclusion

The concrete had good slump (true slump). The concrete cured with water had better compressive strength than the concrete cured in acid. Test on the specimen both non-destructive and compressive strength showed that acid curing environment have a negative effect on concrete (pulse velocity, rebound hammer and compressive strength). The decrease in strength of concrete increase with the concentration of the acid. The cube specimen reduced in not only strength but density as the concentration of acid increases 3.5PH to 1.5PH. At 28 days of curing in acid solution the concrete deteriorated instead of gaining strength. Concrete cured in 3.5, 2.5 and 1.5 PH had deterioration rate of 7.29%, 19.44% and 32.06% respectively. Special attention should be giving to concrete in an acidic environment or concrete prone to the acid attack because as seen the effect is rapid.

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