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DURABILITY CHARACTERISTICS OF REINFORCED CONCRETE SUBJECTED TO SYNTHETIC ACID RAIN

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Abstract: This research has included long-term exposure tests to synthetic acid rain to determine whether or not this kind of precipitation hastens the deterioration of reinforced concrete. The specimen of M20 grade concrete was evaluated after 28 days of curing. Tests were conducted using concrete specimens with dimensions of 150 mm x 150 mm x 150 mm, as well as a cylinder with a 100 mm diameter and a 200 mm depth, into which a 12 mm dia bar was inserted. After being immersed for the required time, individuals were put through a battery of chemical and physical analyses. At last, the samples were exposed to acid rain for 120, 100, and 80 hours respectively. The acid rain is made from purified water. The results of the PH paper tests show a significant linear relationship between the eroded depth of the specimen and the amount of time it was exposed to a simulated acid rain with a PH of 5. In addition, it was found that the length of time the specimens were immersed in synthetic acid affected their flexural strength (120, 100, or 80 hours, respectively). The level of carbonation may be determined using a phenolphthalein indicator and a synthetic acid rain dipping process.

Key words: deterioration, synthetic acid rain, exposure test, reinforced concrete, carbonation depth

INTRODUCTION

Over time, the performance of concrete infrastructure might degrade due to the effects of weather and other factors. Examples of degradation phenomena include salt damage to reinforced concrete (RC) constructions, freezing and thawing damage in cold climatic zones, carbonation due to carbon dioxide, chemical assault by acid solution, etc. Another factor that accelerates the deterioration of concrete buildings is acid rain, however its impact is regarded to be negligible. In the past, people would try to figure out what was going on and try to predict how bad things might become by using an acceleration technique specific to each occurrence. Concrete deteriorates over time due to salt damage, freezing and thawing, and carbonation. might be quantified Therefore, acid rain has to be studied on its own to fully comprehend the effects of the cumulative action of such occurrences in the context of natural environmental conditions. This research looked at the effects of acid rain on concrete structures by conducting long-term exposure experiments under simulated acid rain and reviewing the findings, which included physical testing of the specimens and chemical analysis of the hardened cement paste. .corrosion of steel bars and concrete damage, affects reinforced concrete structural beams, which are used in a variety of applications. Freeze-thaw cycles, concrete corrosion, reinforcement corrosion, and alkali aggregate reflection are some of the challenges with reinforced concrete composite beam constructions utilised in engineering. [2]. If the corrosion time is too lengthy, the reinforced concrete structure beams will be corroded for a long period by acid rain and other factors, reducing the dependability of the reinforced concrete structure's function and perhaps causing safety issues.

1.2 CARBONATION TEST

The moment concrete is exposed to acid rain simulating natural precipitation; it initiates a reaction with carbon dioxide. The composition of concrete itself is rather alkaline (high pH). This high alkalinity interacts with the bare steel on the reinforcing steel, which results in the formation of an oxide film surrounding the steel that is referred to as a passivation layer. This coating prevents the steel from rusting and corroding. The pH of the concrete is lowered when it reacts with

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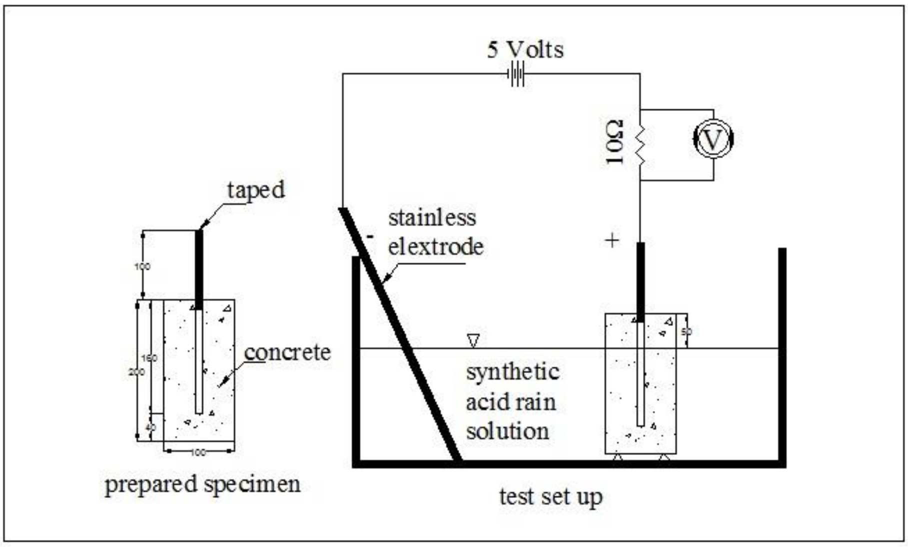
carbon dioxide because of the reaction. This procedure begins on the surface and continues deeper into the concrete. Cracking in the concrete surface might speed up the response if it is present.

1.3 VOLTAGE IMMERSED TEST

The material that is used the majority of the time in building is reinforced concrete. Steel that is embedded in concrete is often exposed to an alkaline atmosphere, which passivates the steel over time. Any circumstance that causes the environment immediately around the steel to become unstable may lead to the passive film being unstable and the corrosion process becoming activated. It takes years for the steel reinforcement to get corroded and to cause the degradation of reinforced concrete (RC) buildings, which is caused by the phenomena known as corrosion of reinforcing bar in concrete. Corrosion of steel caused by chloride exposure is one of the most significant global issues contributing to the degradation of steel-reinforced concrete buildings. Important structural components, such as the supporting columns, are susceptible to corrosion attack, particularly in areas of the world with cold climates where de-icing salts are often used. However, the accelerated corrosion test should be used when it is absolutely necessary to make a determination on the relative performance of various kinds of steel and binder in a relatively short amount of time.



LITERATURE REVIEW

Longxin Gao 1, Yong Lai 2, Mohammad Rashadul Islam Pramanic 1 and Wuman Zhang "Deterioration of Portland Cement Pervious Concrete in Sponge Cities Subjected to Acid Rain" The degradation of Portland cement pervious concrete (PCPC) exposed to wet-dry cycles in a simulated acid rain solution was explored; 4 percent silica fume (SF) and 8 percent fine aggregate (FAG) were employed to replace part of the cement and coarse aggregates (weight by weight). PCPC was evaluated for wear resistance, compressive strength, and flexural strength. The compressive and flexural strengths of control PCPC were reduced by 30.7 percent and 40.8 percent after 12 wet-dry cycles in acid rain solution, respectively. PCPC with 4% SF and PCPC with 8% FAG have final compressive strengths of 6.9% and 30.3 percent, respectively, and final flexural strengths of 25.4 percent and 72.3 percent. When 4 percent SF and 8 percent FAG are introduced to PCPC, respectively, wear loss is reduced by 58.8% and 81.9 percent. We also talk about the microstructures of PCPC after wet-dry cycles.

X. Chena, V. Achala,b "Effect of simulated acid rain on the stability of calcium carbonate immobilized by microbial carbonate precipitation "Under acid rain, the durability of carbonate compounds resulting from microbial induced carbonate precipitation (MICP) is questioned. The stability of CaCO3 precipitated by MICP in soil under simulated acid rain was studied in this work (SAR). For two months, soils were continually treated with four SAR pH levels: 3.5, 4.5, 5.5, and 7.0. To assure CaCO3 precipitation during SAR, bio stimulation with nutritional broth containing urea and calcium chloride was used. Soil samples from the top and bottom layers were analysed for bacterial diversity using Illumine Miscel sequencing, Fourier transform infrared (FTIR) spectroscopy for identification of chemical functional groups related to calcite precipitation, and X-ray diffraction (XRD) for identification of the main crystalline phases at the end of the treatments. Several ureolytic bacteria were discovered throughout the investigation, mostly from Bio stimulation increased Arthrobacter and Sporosarcina species in SAR-treated soils, and urease concentrations more than 300 mg NH4 per kg soil were found at all pH levels. Even when the pH was as low as 3.5, CaCO3 precipitation was noticeable, and its stability was maintained. The findings of this study will aid scientists in ensuring heavy metal immobilisation in soil during acid rain by microbial carbonate precipitation.

WANG Yan1, NIU Ditao2*, SONG Zhanping2 "Effect of Acid Rain Erosion on Steel Fibre Reinforced Concrete" The performance of reinforced concrete structures can be harmed by acid rain. The properties of steel fibre reinforced concrete exposed to acid rain in China were researched in conjunction with the features of acid rain in China. The impact of steel fibre content and acid rain pH on mass loss, erosion depth, neutralisation depth, and splitting tensile strength of tested concrete was studied. The impact of steel fibre on the acid rain resistance of concrete matrix was investigated using the mercury intrusion pore (MIP) test. The findings reveal that the combined action of H+ and SO42- in acid rain causes corrosion of steel fibre reinforced concrete, and steel fibre can increase the acid rain resistance of the tested concrete. by boosting the concrete matrix's tie effect and improving the pore structure In comparison to the different mixing proportions in these experiments, the experiment also shows that the optimal percentage of steel fibre is 1.5 present. When the pH value of the simulation solution is 3 or 4, the tested concrete mass loss and splitting tensile strength decline, then increase as a function of corrosion time, but they decrease continuously in the simulation solution at pH 2. The spelling of concrete matrix is substantially improved, and the erosion depth and neutralisation depth are fewer than those of ordinary concrete, thanks to the tie effect of steel fibre.

Husnu Gerengia, Yılmaz Kocakb, Agata Jazdzewska c,⇑, Mine Kurtaya, Hatice Durguna "Electrochemical investigations on the corrosion behaviour of reinforcing steel in diatomite- and zeolite-containing concrete exposed to sulphuric acid" The research For most structural applications, corrosion is a key problem. Its negative impact affects the life of metallic components dramatically. The findings of an experimental research of corrosion in steel reinforcement of concrete samples with three distinct substituents: 20% diatomite, 20% zeolite, and a control without zeolite or diatomite are presented in this work. For 160 days, all concrete specimens were immersed in a 0.5 M H2SO4 solution, and electrochemical impedance spectroscopy (EIS) measurements were taken every 15 days. The findings revealed that porosity plays a critical role in concrete reinforcement. In comparison to the reference and diatomite samples, the steel reinforcement in the zeolite was less eroded by the H2SO4 solution.

Ding Yong "Effect of Acid Rain Pollution on Durability of Reinforced Concrete Structures" The corrosion process of concrete by acid rain and the corrosion process of steel bars by acid rain are analysed in order to solve the problem of insufficient accuracy and effectiveness of the current analysis model of reinforced concrete durability. The structure of reinforced concrete composite beams under acid rain erosion is based on the acid rain corrosion process. Carbonization depth of medium concrete; carbonization depth was used to compute corrosion depth of reinforced concrete composite beam construction; carbonization depth and corrosion depth were used to calculate durability index. It's ideal for determining the impact of acid rain pollution on the long-term durability of reinforced concrete composite beam constructions.

Yan Zhoua,b,, Shansuo Zhengc,d,*, Liuzhuo Chena,b, Li Longc ,d, Bin Wange "Experimental investigation into the seismic behaviour of squat reinforced concrete walls subjected to acid rain erosion**" The physical and mechanical qualities of materials will continue to deteriorate as a result of acid rain erosion, eventually compromising the seismic performance of reinforced concrete (RC) structures. Despite this, no study has been done on the impact of acid deposition on squat RC walls, which are a major aspect of lateral force-resisting systems. Thus, an artificial climate simulation approach was employed in this research to speed up the acidic assault process on four squat RC wall specimens with an aspect ratio of 1.0. Then, under different acid rain spraying cycles, quasi-static stress experiments were performed to investigate their cyclic behaviour (ARSCs). The findings demonstrate that when ARSCs rise, the degree of concrete strength degradation and steel bar corrosion weight loss increase, and the bearing capacity decreases. The deformation capacity of the squat RC walls steadily deteriorates. Simultaneously, the ratio of shear displacement to total lateral displacement rises, showing that the inclusion of ARSCs causes a more evident shear failure characteristic. In addition, the failure mechanism changes from mixed flexure and diagonal compression to diagonal tension, resulting in a considerable reduction in ductility and energy dissipation capacity. It was also shown that the shear strength of squat walls degrades at a faster rate than the flexural strength under acid rain erosion, potentially leading to failure mode changeover.

ZHENG Yue1,2*, ZHENG Shansuo1,2, LIU Xiaohang1,2 "Constitutive model of confined concrete with stirrups by acid rain erosion" reinforced concrete prism specimens were subjected to acid rain erosion by artificial climate simulation technique followed by axial pressure tests in order to study the effect of stirrup corrosion level on peak stress, peak strain, ultimate strain, and shape of stress-strain curve of confined concrete. Based on Mander's model and previous study findings By using regression analysis of test data, the factor calculation formulae for peak stress, peak strain, ultimate strain, and shape factor of corroded specimens are constructed, and then the constitutive model of restricted concrete by acid rain erosion is established. When the simulation results are compared to the experimental data, it is discovered that the peak stress, peak strain, ultimate strain, and stress-strain curves all have the same form. The suggested approach produces specimens that are in good agreement with experimental results. As a result, the constitutive mode for confined concrete developed in this paper can accurately reflect the mechanical performance of

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RC prism specimens eroded by acid rain, indicating its adaptability for estimating residual bearing capacity and seismic performance of RC structures in acid rain environments.

Y.F. Fan*1, Z.Q. Hu2 and H.Y. Luan1 "Deterioration of tensile behaviour of concrete exposed to artificial acid rain environment" The purpose of this research is to determine the tensile qualities of concrete subjected to acid rain. In the lab, a combination of sulphate and nitric acid was used to replicate an acid rain environment. For faster conditioning, the dumbbell-shaped concrete specimens were immersed in pure water and an acid solution. The specimens were weighed, tensile tested, CT, SEM/EDS tested, and micro analysed. The tensile properties of the damaged concrete are quantitatively determined. The evolution of voids, microcracks, chemical compounds, elemental distribution, and contents in concrete are investigated. The mechanics of concrete disintegration when exposed to acid rain are well understood.

V. Marcos-Meson a,b,c,⇑ , G. Fischer a , C. Edvardsen b , T.L. Skovhus c , A. Michel a "Durability of Steel Fibre Reinforced Concrete (SFRC) exposed to acid attack – A literature review "Steel Fibre Reinforced Concrete (SFRC) is becoming more popular in civil infrastructure building. The behaviour of SFRC under chemical and biochemical exposure is of special importance since it can be used to create waste-water and agricultural infrastructure, among other things. However, inconsistencies among SFRC exposed to acidic environments limit its usefulness. International rules and regulations this research examines the existing literature on the long-term durability of SFRC. the victim of an acid assault According to research, untracked SFRC is damaged when exposed to acids. This is comparable to what happens in Plain Concrete (PC). Steel corrosion that isn't critical has been studied. Fibres entrenched in the neutralised concrete layer, with no corrosion-related cracking or spelling Steel fibres have been shown to prevent secondary damage by bridging cracks and slowing the chemical-erosion front's advance. However, there is a scarcity of information on the residual mechanical performance of cracked SFRC subjected to acids. According to published studies, there is an if the corrosion damage to the steel fibre is non-critical and there is a critical fracture width of less than 0.3 mm is the decrease of fracture toughness to a certain extent. It has been discovered, however, that exposing broken SFRC to when compared to other exposures, acids cause a greater loss of its residual mechanical performance.

Chinnu Mariam Ninan ,K P Ramaswamy ,R Sajeeb "influence of Concrete Mixture Composition on Acid Resistance of Concrete: A Review"Cementations materials are very vulnerable to a wide range of acids that can induce microstructure damage and are abundant in ground water, sewage systems, industrial effluents, and acid rain. Material-related factors and test-related factors are two types of factors that can influence acid attack. Material-related factors can be linked to the acid solution or the composition of the concrete mixture. Concrete's acid resistance is heavily influenced by the composition of the concrete mixture. Type of cement, type and quantity of binders, water binder ratio, aggregate binder ratio, and mineralogical nature of aggregates are all factors that influence the composition of a concrete mixture. Despite the fact that the type of cement has an impact on acid attack, the difference is minor. Calcium hydroxide consumption and purification Because of the pore structure, the use of extra cementations materials is advantageous for acid resistance. Concrete's porosity is reduced when the water binder ratio is reduced and the aggregate binder ratio is increased, which enhances acid resistance. Calcareous aggregates are favored for concretes subjected to acids that produce fewer soluble salts, but not for acids that produce soluble salts. The impact of concrete mixture composition on acid resistance is highlighted in this research. The acid resistance of concrete should be improved with suitable formulation.

OBJECTIVES AND METHODOLOGY

3.1 OBJECTIVES

- To conduct a carbonation test on concrete using the ASTMB117 standard
- To investigate the qualities of concrete that may withstand being subjected to an artificial acid rain
- To investigate, with the use of the accelerated corrosion test and the voltage impressed test, the rate of degradation of reinforced concrete
- Analyses of chemicals performed on a sample of concrete

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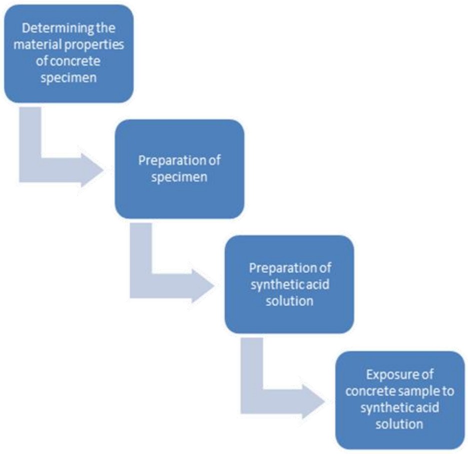

3.2 METHODOLOGY

MATERIAL PREPARATION

4.1 SYNTHETIC ACID RAIN PREPARATION

Synthetic acid rain was made by utilising the distilled water, and since distilled water is devoid of minerals and chemicals, we were able to produce acid rain that was pure and unclouded. The man-made acid rain manufactured by following the chemical formula as listed below in the preparation process.

Component	(mg/dm^3)
H_2SO_4 (96%)	31.85
$(NH_4)_2SO_4$	46.20
$Na_2 SO_4$	31.95
HNO_3 (70%)	15.75
$NaNO_3$	21.25
NaCl	84.85

4.2 INGREDIENTS IN CEMENT CONCRETE

1. Cement
2. Aggregate
a) coarse aggregate
b) fine aggregate
3. Water

BASIC TEST ON INGREDIENTS OF CONCRETE
T Normal Consistency of Cement

"The Standard Consistency of a cement paste described as the Consistency which will allows the vicat plunger to penetrate to a point 5 to 7mm from the bottom of the Vicat mould. APPARATU

:Normal Consistency of Cement.

% age of Water	**26%**	**28%**	**30%**
Quantity of water	104	112	120
Initial Reading [IR]mm	0	0	0
Final Reading [FR]mm	18	13	6
Depth of Un-penetration in mm	18	110	6

Time of Cement

It is necessary to have a longer initial setting time length in order to stall the hydration or hardening process. The final setting time is determined by the point at which the paste has entirely lost its flexibility. It is the amount of time that

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must pass before the cement paste or cement concrete may become sufficiently hard and take on the form of the mould in which it was cast.

Specific Gravity Test

. "The ratio between the mass of a particular volume of cement and the mass of an equivalent amount of kerosene is what is meant to represent the specific gravity of cement. Use of a liquid that does not react with cement, such as kerosene, may be one of the ways for evaluating the specific gravity of cement. Kerosene is often devoid of water.

Specific Gravity of cement

SI no	Observation	Trial1	Trial2	Trial3
1	Weight of empty bottle W1 in gram	52	52	52
2	Weight of bottle + water W2 in gram	154	154	154
3	Weight of bottle+ kerosene W3in gram	130	130	130
4	Weight of bottle+ kerosene+ cement W4in gram	176	175	176
5	Weight of cement W5 in gram	60	60	60
6	Specific gravity of cement	3.2	3	3.2

Test on Fine Aggregate

Specific gravity

Fine aggregate's specific gravity is defined as the ratio between the mass of a given volume of fine aggregate and the mass of an identical amount of water. This ratio is expressed as a percentage.

Table 5.1.2.1 :Specific Gravity of sand

SI.no	**Observation**	Trial1	Trial2	Trial3
1	Weight of empty pycnometerW1 in gram	632	632	632
2	Weight of Pycnometer +1/3 portion of sand W2 in gram	992	996	990
3	Weight of Pycnometer+ 1/3 portion of sand+ water W3 in gram	1760	1755	1757
4	Weight of Pycnometer + water W4 in gram	1530	1530	1530
5	Specific gravity of fine aggregate	2.76	2.61	2.73

Moisture Content of Fine Aggregate

The amount of water that is present in a substance, such dirt, is referred to as its water content or its moisture content (called soil moisture). A broad variety of scientific and technological fields make use of the water content ratio, which is stated as a number that may vary from 0 (totally dry) to the value of the materials' maximum allowable water content.

Moisture Content

Weight of empty pycnometer (W1) gm	608
Weight of pycnometer + Sand (W2) gm	1078
Weight of pycnometer + Sand + Water (W3) gm	1792
Weight of pycnometer + Water (W4) gm	1498

Tests on Course Aggregate

Specific Gravity

The ratio of the mass of a given volume of coarse aggregate to the mass of an equivalent amount of water is the definition of the specific gravity of coarse aggregate. This ratio is expressed as a percentage

Specific Gravity Of Course Aggregate

Weight of course aggregate in gm	2000
Weight of basket + aggregate in water A1 gm	3060
Weight of basket immersed in water A2 gm	1806
Weight of aggregate in water A=A1-A2 in gm	1254
Weight of aggregate after dry surface B gm	1986

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Loss of weight of aggregate in water B-A in gm	732
Weight of oven dry Course aggregate C	1966

Unit Weight (Bulk Density) & %age of Voids of Course aggregate

We will get %age voids by comparing loose state and compacted state.
Bulk density: It is the mass of the unit volume of bulk aggregate

Unit Weight & %age of Voids

Diameter of the cylinder 'd' in cm	15
Height of the cylinder 'h' in cm	17
Volume of the cylinder 'V' $\pi d^2/4$ x h cm3	3004.14
Weight of empty cylinder (W1) gm	4386
Weight of cylinder + Compacted QD (W2) gm	9314
Weight of cylinder + Loosely QD (W3) gm	8792

RESULTS

a. Compacted State:

- Unit weight of Compacted state is **1.64 gm/cm^3**
- The percentage of voids in compacted state is **36.92%**

b. Loosely Filled State:

- Unit weight of loosely filled state is **1.46 gm/cm^3**
- The percentage of voids in loosely filled state is **43.84%**

Fresh Concrete

Slump Test on Concrete

The concrete is used in the process of determining one of the characteristics of new concrete. This is an empirical test that examines how workable freshly mixed concrete is. The degree of stiffness that should be shown by the completed product should be matched to the criteria for the quality of the concrete mix

1 Initial reading.

2. Final reading

Slump Test

w/c ratio	% of Fibre	Initial height (h_1) in mm	Final height (h_2) in mm	Slump ($h_1 - h_2$) in mm
0.5	0	300	228	72
0.5	1	300	250	50
0.5	2	300	281	19

Compacting Factor Test

Although it was mainly developed for use in a laboratory setting, the compacting factor test may also be carried out in the field. It is more accurate and sensitive than the slump test, and it is especially helpful for concrete mixes that have

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extremely poor workability. These mixes are often used whenever concrete is to be compacted by vibration. This kind of dry concrete is not affected by the slump test, which may be shown as a schematic of the equipment in figure.

Hardened Concrete

Different kinds of concrete's tensile strengths Because concrete is mainly intended to endure compressive loads, determining its compressive strength has garnered a significant amount of interest. This is due to the fact that concrete can be measured to determine its compressive strength. Compression test specimens may take the form of cubes, cylinders, or prisms, and all three of these shapes are employed to measure a material's compressive strength. The standard size for a cube is either 100 or 150 millimetres on a side, while the standard size for a cylinder is 150 millimetres in diameter and 300 millimetres in height. In France, the standard size for a prism is 100 millimetres on all three sides and 150 millimetres in height. The specimens are then tested according to the standards that have been specified for such testing after being cast and cured. Before the test can begin, any cylinders that will be used need to have the appropriate cap placed on them. This step is not necessary for the testing of other kinds of specimens

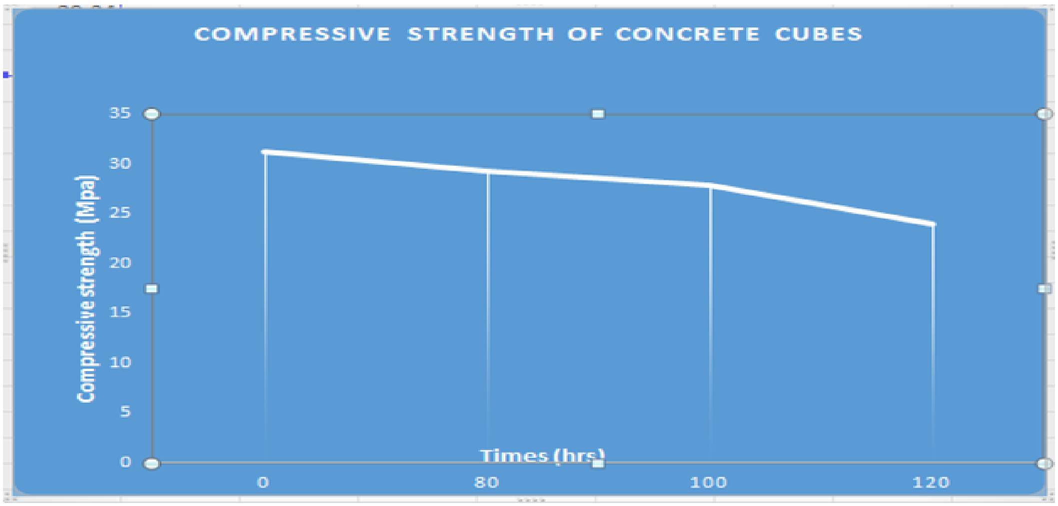
RESULT AND TABULATIONS

Compression Strength Test
Details of Specimen
'The Test specimen consisting of 150150150 mm cubes are created by M25 grade concrete curing for 28 days by employing water dipping. After curing for 28 days, the specimen is dipped in synthetic acid rain solution for 80,100, and 120 hours, respectively.
The Compression Testing Machine (often abbreviated as CTM) was used for all of the testing. There were a total of 12 samples examined, and the findings were reported in the table below..

COMPRESSIVE STRENGTH TEST OF CONCRETE CUBES

Compressive Strength Test of Cubes

Sl. no.	Immersed in acid rain In hours	Weight of the cube (kg)	Compressive Strength(N/mm^2)	Average strength (N/mm^2)
1.	0	8.263	31.64	31.31
		8.540	31.11	
		8.016	31.20	
2.	80	8.400	28.90	29.34
		8.600	30.10	
		8.330	29.02	
3.	100	8.344	27.55	27.98
		8.522	27.52	
		8.526	28.88	
4.	120	8.590	26.57	23.96
		8.624	24.00	
		8.468	21.33	

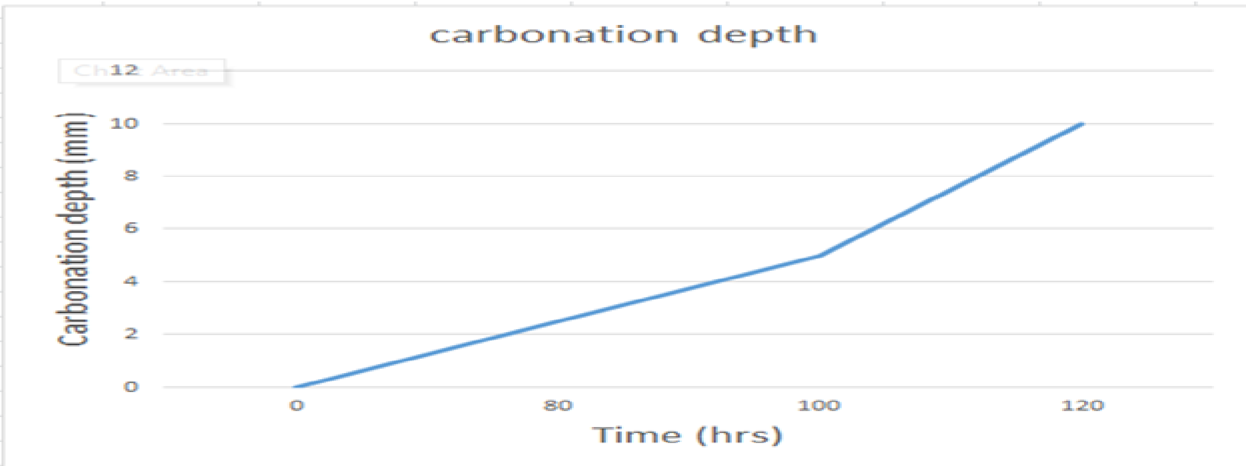


CARBONATION TEST

The specimen for testing is a cube with dimensions of 150 by 150 by 150 millimeters, and the specimen is examined using phenolphthalein as an indicator.

Table7.3: Carbonation depth Cubes

SI no	Immersed in acid rain In hours	No of cube immersed	Carbonation depth in mm	Avg carbonation depth In mm
1	0	3	0	0
			0	
			0	
2	80	3	2.5	2.4
			2	
			2.7	
3	100	3	4.5	4.6
			4.5	
			5	
4	120	3	9	9.5
			9.5	
			10	



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Carbonation Depth

Surface Carbonation Check

Normal concrete and acid rain dipping concrete

Voltage immersed test

The test specimen, which consisted of a cylinder measuring 200 millimeters in diameter and 100 millimeters in height and which had a rebar insert measuring 12 millimeters in diameter and 150 millimeters in depth, was cured by submerging it in water for a total of 28 days.

After 28 days of curing, the specimen was allowed to rest for 20 days at a temperature that is considered typical for the room. The remainder of the specimen was dipped in a synthetic acid rain solution for 80, 100, and 120 hours.

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Tested specimen

CONCLUSION AND FUTURE SCOPES

The following conclusion is drawn based on tests conducted on reinforced concrete that was exposed to artificial acid rain.
According to the findings that were gathered, the strength of concrete that was exposed to acid rain for varying durations of time (80 hours, 100 hours, and 120 hours), decreased in proportion to the length of time that the concrete was dipped in acid.
It has a direct impact on rebar and causes it to start rusting and lose its strength. The carbonation depth is 10 millimeters after being submerged for 120 hours.

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