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A Study on Strength Characteristics of Fibre Reinforced Concrete with Partial Replacement of Quarry Dust as Fine Aggregate with Acid Curing

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Abstract: The rapid growth of construction technology and the increasing rate of construction have raised concerns about the depletion of natural resources, particularly sand extracted from river beds. The excessive utilization of sand has led to environmental issues and a decline in its availability. Moreover, conventional concrete derived from sand exhibits low tensile strength and limited resistance to cracking. In response, researchers and scientists have been exploring alternative materials that are environmentally friendly, as well as admixtures that enhance concrete properties. Quarry dust has emerged as a promising substitute for sand, possessing similar characteristics to those obtained from stone beds. Additionally, nylon fiber has been identified as a suitable admixture to improve the tensile strength of concrete. This project aims to partially replace sand with quarry dust at varying percentages (10%, 20%, and 30% of sand content) and incorporate 6mm nylon fiber at a dosage of 0.1% by weight of cement. The study focuses on concrete grade M25, subjected to different concentrations (1%, 2%, and 3%) of hydrochloric acid (HCL) during the curing period of 7, 14, and 28 days. The fiber reinforced concrete (FRC) specimens cured in water are compared with those cured in varying concentrations of HCL. The evaluation of concrete properties includes compressive strength tests at 7, 14, and 28 days of curing, as well as a flexural strength test conducted after 28 days of curing.

Keywords: Quarry dust, Nylon 6 fiber, Hydrochloric acid (HCL), Fiber reinforced concrete, Compressive strength test, Flexural strength test.

I. INTRODUCTION

This project focuses on investigating the performance of quarry dust and nylon fiber reinforced concrete (FRC) in the presence of hydrochloric acid (HCL) in various concentrations. By partially replacing sand with quarry dust at different percentages and incorporating nylon fiber into the concrete mix, the study aims to assess the impact on the concrete's mechanical properties. Compressive strength tests will be conducted at different curing periods, and a flexural strength test will be performed after a designated curing duration.

The objective of this research is to explore the potential of using quarry dust as an alternative material and nylon fiber as an admixture to enhance the properties of concrete. The study also aims to evaluate the response of the fiber reinforced concrete when exposed to HCL, simulating an acidic environment. The findings will provide valuable insights into the suitability of these materials and their performance in acid-induced conditions, contributing to the development of sustainable and durable construction practices.

II. METHODOLOGY

- 1) **Materials Acquisition:** Obtain the necessary materials for the project, including cement, sand, quarry dust, nylon fiber, hydrochloric acid (HCL), and water.
- 2) **Concrete Mix Design:** Determine the appropriate mix proportions for the concrete grade M25, considering the partial replacement of sand with quarry dust. Prepare different concrete mixtures with varying percentages of quarry dust (10%, 20%, and 30% of sand content) while keeping the other ingredients constant.
- 3) **Nylon Fiber Addition:** Incorporate nylon fibers into the concrete mix at a dosage of 0.1% by weight of cement. Ensure proper dispersion and uniform distribution of fibers throughout the mixture.
- 4) **Casting of Specimens:** Prepare concrete specimens, such as cubes for compressive strength testing and beams for flexural strength testing. Follow the standard procedures for casting, compaction, and curing of the specimens.

- 5) *Curing*: Place the freshly cast specimens in a curing chamber and maintain a controlled curing environment. Cure the specimens for designated periods of 7, 14, and 28 days, ensuring they are adequately protected from moisture loss and external influences.
- 6) *Acid Exposure*: Prepare HCL solutions with concentrations of 1%, 2%, and 3% by volume. Submerge a set of cured specimens in each HCL concentration solution, while keeping another set immersed in plain water for comparison. Ensure all specimens are fully immersed and remain undisturbed during the exposure period.
- 7) *Compressive Strength Testing*: After the respective curing durations, remove the specimens from the curing environment and allow them to acclimate to room temperature. Conduct compressive strength tests on the cubes using a compression testing machine, following the relevant standards and procedures. Record the maximum load at failure and calculate the compressive strength of each specimen.
- 8) *Flexural Strength Testing*: After 28 days of curing, retrieve the beams from the curing environment and allow them to acclimate. Perform flexural strength tests on the beams using a three-point bending test setup. Apply a gradually increasing load until failure occurs and record the maximum load and deflection. Calculate the flexural strength of each specimen.
- 9) *Data Analysis*: Analyze the collected data, including compressive strength and flexural strength values, to evaluate the performance of the quarry dust and nylon fiber reinforced concrete. Compare the results between the different percentages of quarry dust and HCL concentrations to identify any significant variations.
- 10) *Results Interpretation*: Interpret the obtained data and draw conclusions regarding the effects of quarry dust and HCL exposure on the mechanical properties of the concrete. Assess the effectiveness of the nylon fiber admixture in improving the tensile strength of the concrete under different conditions.
- 11) *Discussion and Conclusion*: Discuss the findings in the context of the project objectives and research questions. Draw conclusions on the feasibility of using quarry dust as a sand alternative and nylon fiber as an admixture to enhance concrete performance. Highlight any limitations or areas for further research.

III. MATERIALS USED

- 1) *Cement*: Cement is a binder used to hold the concrete mixture together. It provides strength and durability to the final concrete product.
- 2) *Fine Aggregate (Sand)*: Sand is a natural or manufactured material used as a fine aggregate in concrete. In this project, quarry dust is partially replacing sand to explore its suitability as an alternative material.
- 3) *Coarse Aggregate (Stone)*: Coarse aggregate consists of crushed stone or gravel and provides bulk and stability to the concrete mixture. It helps in enhancing the strength of the concrete.
- 4) *Water*: Water is an essential component in concrete as it hydrates the cement and allows the mixture to set and harden. It is used for mixing the ingredients and curing the concrete samples.
- 5) *Nylon Fiber*: Nylon fibers are synthetic fibers that are added to the concrete mix to improve its tensile strength and crack resistance. In this project, 6mm-sized nylon fibers are used as an admixture to enhance the properties of the fiber-reinforced concrete.
- 6) *Hydrochloric Acid (HCl)*: Hydrochloric acid is used to simulate acid attack in the project. Different concentrations of HCl (1%, 2%, and 3%) are employed to assess the acid resistance of the concrete samples.
- 7) *Chemical Admixtures*: Chemical admixtures may be used to modify the properties of the concrete. For example, SBR latex may be used as a chemical admixture to enhance the strength and durability of the concrete.
- 8) *Pozzolanic Materials*: Pozzolanic materials, such as fly ash or silica fume, may be included in the concrete mix to improve its durability and resistance to acid attack.

A. Effect of Acid on Concrete

Concrete is vulnerable to acid attack due to its alkaline nature. When in contact with acids, the compounds in the cement paste break down. One notable reaction is the dissolution of Calcium hydroxide, which can occur based on the concentration of the acid and the porosity of the cement paste. The solubility of acid calcium salts (CaX_2) in the paste affects the decomposition of the concrete. Some calcium salts may precipitate in the voids, slowing down the attack. Acids like H_2SO_4 , nitric acid, hydrochloric acid, and acetic acid are particularly aggressive as their calcium salts readily dissolve and are removed during the attack. Sulphuric acid poses a significant threat as it combines both acid and sulphate attacks, while hydrochloric acid has a milder effect, and sodium carbonate (Na_2CO_3) has a negligible impact.

B. Hydrochloric Acid (HCL) Attack

Although not commonly encountered in natural environments, hydrochloric acid can cause damage to concrete in industrial settings. The effects of HCL on concrete are diverse. Leaching processes lead to changes in mineralogy, resulting in strength loss. Corrosion caused by HCL poses a risk to the structural integrity of concrete, especially when subjected to tensile or bending loads. The loss of flexural strength in high-strength concrete is more significant compared to normal-strength concrete, indicating that sensitivity to HCL corrosion increases with higher concentrations.

Concrete damaged by HCL experiences dissolution, leading to the formation of soluble salts and subsequent leaching of the concrete. This process raises the pH of the acidic solution. Hydrolysis reactions take place, such as $2HX + Ca(OH)_2 \rightarrow CaX_2 + 2H_2O$ (where X represents the negative ion of the acid). As a result, Si, Al, and Fe gels are produced. The external surface of the concrete sample may appear yellow, while the inner surface may appear brown due to variations in the amount of $Fe(OH)_3$. Researchers have observed that the hydrochloric acid attack primarily occurs in the layers separating different areas of the concrete structure. These findings are supported by concrete demolition results.

C. Fiber Reinforced Concrete (FRC)

Plain concrete is known for its low tensile strength, lack of ductility, and susceptibility to cracking. Internal micro cracks are naturally present in concrete, and its weak tensile strength leads to the propagation of these micro cracks, ultimately resulting in brittle fractures. Structural cracks can even develop in plain cement concrete prior to any applied load, particularly due to factors like drying shrinkage or volume changes.

To address these limitations, the concept of fiber reinforced concrete (FRC) has been introduced. FRC involves incorporating small, closely spaced, and uniformly dispersed fibers into the concrete mix. These fibers serve as crack arrestors, enhancing the static and dynamic properties of the concrete. By reinforcing the matrix, FRC improves tensile strength, ductility, and resistance to cracking.

IV. TESTS TO BE CONDUCTED

- 1) *Compressive Strength Test*: This test measures the maximum compressive load a concrete specimen can bear before failure. It is conducted at different curing periods (7, 14, and 28 days) to assess the strength development of the concrete samples.
- 2) *Flexural Strength Test*: The flexural strength test determines the ability of the concrete to resist bending or cracking. It is performed on concrete samples after 28 days of curing to evaluate their structural integrity.
- 3) *Acid Resistance Test*: The acid resistance test involves subjecting the concrete samples to different concentrations of hydrochloric acid (HCL) solution (1%, 2%, and 3%) to simulate acid attack. The weight loss and any changes in strength are measured to assess the concrete's resistance to acid corrosion.
- 4) *Weight Measurement*: The weight of concrete samples is measured before and after exposure to acid solutions to determine the extent of weight loss caused by acid attack.
- 5) *Microscopic Analysis*: Microscopic analysis can be conducted to examine the microstructure of the concrete samples before and after exposure to acid. This analysis helps identify any changes or deterioration caused by acid corrosion.
- 6) *Comparison Test*: A comparison test can be performed between conventional concrete and fiber-reinforced concrete (FRC) samples to evaluate the effectiveness of the fiber and quarry dust replacements. This test assesses the strength, durability, and weight changes in both types of concrete.

V. RESULTS

A. Observations And Calculations

1) Compressive Strength Test results

7days compressive strength test results for convention concrete cubes

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8200	22500	3375000	2.429	517	23.76	22.44
2	150 X 150 X 150	8210	22500	3375000	2.432	525.6	21.73	
3	150 X 150 X 150	7970	22500	3375000	2.343	532.8	21.23	

14days compressive strength test results for convention concrete cubes

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8250	22500	3375000	2.444	650	25.32	24.12
2	150 X 150 X 150	8460	22500	3375000	2.506	540	22.26	
3	150 X 150 X 150	8260	22500	3375000	2.447	850	24.88	

28days compressive strength test results for convention concrete cubes

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8160	22500	3375000	2.417	690	27.31	28.89
2	150 X 150 X 150	8110	22500	3375000	2.402	650	29.83	
3	150 X 150 X 150	8180	22500	3375000	2.423	780	29.53	

7days compressive strength test results for 10% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8070	22500	3375000	2.391	540	23.85	23.67
2	150 X 150 X 150	8098	22500	3375000	2.399	490	22.53	
3	150 X 150 X 150	8014	22500	3375000	2.374	480	24.63	

14days compressive strength test results for 10% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8143	22500	3375000	2.412	570	26.68	26.74
2	150 X 150 X 150	8156	22500	3375000	2.416	490	26.15	
3	150 X 150 X 150	8150	22500	3375000	2.414	500	27.39	

28days compressive strength test results for 10% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8190	22500	3375000	2.426	600	30.48	31.58
2	150 X 150 X 150	8178	22500	3375000	2.423	690	32.87	
3	150 X 150 X 150	8189	22500	3375000	2.426	640	31.39	

7days compressive strength test results for 20% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	7955	22500	3375000	2.357	560	24.68	24.32
2	150 X 150 X 150	8015	22500	3375000	2.378	580	25.93	
3	150 X 150 X 150	8125	22500	3375000	2.407	620	27.35	

14days compressive strength test results for 20% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8010	22500	3375000	2.373	650	28.85	28.17
2	150 X 150 X 150	8095	22500	3375000	2.398	670	29.51	
3	150 X 150 X 150	8105	22500	3375000	2.401	590	26.15	

28days compressive strength test results for 20% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8010	22500	3375000	2.373	700	30.96	32.33
2	150 X 150 X 150	8050	22500	3375000	2.385	750	33.89	
3	150 X 150 X 150	8160	22500	3375000	2.417	720	32.14	

7days compressive strength test results for 30% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8010	22500	3375000	2.373	530	23.76	23.76
2	150 X 150 X 150	8095	22500	3375000	2.393	560	24.89	
3	150 X 150 X 150	8105	22500	3375000	2.401	510	22.64	

14days compressive strength test results for 30% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8065	22500	3375000	2.389	580	25.82	26.93
2	150 X 150 X 150	8164	22500	3375000	2.418	630	27.49	
3	150 X 150 X 150	8160	22500	3375000	2.417	610	27.48	

28days compressive strength test results for 30% FRC water curing

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8095	22500	3375000	2.389	670	29.61	29.36
2	150 X 150 X 150	8105	22500	3375000	2.401	700	31.24	
3	150 X 150 X 150	8110	22500	3375000	2.402	610	27.24	

7days compressive strength test results for 10% FRC & 1%HCl with water

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8005	22500	3375000	2.371	370	19.63	20.98
2	150 X 150 X 150	8095	22500	3375000	2.398	400	21.71	
3	150 X 150 X 150	8155	22500	3375000	2.416	450	21.6	

14days compressive strength test results for 10% FRC &1%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8100	22500	3375000	2.400	540	22.91	24.26
2	150 X 150 X 150	8165	22500	3375000	2.419	490	24.99	
3	150 X 150 X 150	8145	22500	3375000	2.428	480	24.88	

28days compressive strength test results for 10% FRC &1%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8095	22500	3375000	2.398	600	26.63	27.98
2	150 X 150 X 150	8105	22500	3375000	2.401	530	28.71	
3	150 X 150 X 150	8195	22500	3375000	2.428	630	28.6	

7days compressive strength test results for 20% FRC &1%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	7995	22500	3375000	2.368	570	22.7	21.21
2	150 X 150 X 150	8015	22500	3375000	2.374	440	19.37	
3	150 X 150 X 150	8045	22500	3375000	2.383	480	21.56	

14days compressive strength test results for 20% FRC &1%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8015	22500	3375000	2.374	630	27.78	26.88
2	150 X 150 X 150	8055	22500	3375000	2.386	590	26.33	
3	150 X 150 X 150	8105	22500	3375000	2.401	600	26.54	

28days compressive strength test results for 20% FRC &1%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8100	22500	3375000	2.400	720	31.78	30.86
2	150 X 150 X 150	8100	22500	3375000	2.400	640	28.68	
3	150 X 150 X 150	8105	22500	3375000	2.401	730	32.14	

7days compressive strength test results for 30% FRC &1%HC

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	7900	22500	3375000	2.346	490	21.48	20.73
2	150 X 150 X 150	7980	22500	3375000	2.364	430	19.41	
3	150 X 150 X 150	8200	22500	3375000	2.429	480	21.30	

14days compressive strength test results for 30% FRC &1%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	7990	22500	3375000	2.367	500	21.98	23.55
2	150 X 150 X 150	8199	22500	3375000	2.429	570	25.49	
3	150 X 150 X 150	7800	22500	3375000	2.311	520	23.18	

28days compressive strength test results for 30% FRC &1%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8020	22500	3375000	2.376	570	25.41	27.77
2	150 X 150 X 150	8040	22500	3375000	2.382	690	30.67	
3	150 X 150 X 150	8120	22500	3375000	2.405	610	27.24	

7days compressive strength test results for 10%FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8103	22500	3375000	2.400	320	14.11	15.73
2	150 X 150 X 150	8090	22500	3375000	2.397	380	16.61	
3	150 X 150 X 150	8117	22500	3375000	2.405	360	16.48	

14days compressive strength test results for 10% FRC &2%HCl

Trail no	Size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8048	22500	3375000	2.384	510	22.63	21.86
2	150 X 150 X 150	8123	22500	3375000	2.423	470	20.79	
3	150 X 150 X 150	8095	22500	3375000	2.425	500	22.16	

28days compressive strength test results for 10% FRC &2%HC

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8165	22500	3375000	2.419	590	25.95	25.17
2	150 X 150 X 150	8178	22500	3375000	2.423	500	22.16	
3	150 X 150 X 150	8185	22500	3375000	2.425	620	27.41	

28days compressive strength test results for 10% FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8165	22500	3375000	2.419	590	25.95	25.17
2	150 X 150 X 150	8178	22500	3375000	2.423	500	22.16	
3	150 X 150 X 150	8185	22500	3375000	2.425	620	27.41	

7days compressive strength test results for 20% FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8055	22500	3375000	2.386	440	19.63	18.32
2	150 X 150 X 150	8090	22500	3375000	2.397	410	18.17	
3	150 X 150 X 150	8120	22500	3375000	2.405	380	17.17	

14days compressive strength test results for 20% FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8090	22500	3375000	2.397	550	24.57	24.63
2	150 X 150 X 150	8015	22500	3375000	2.378	600	26.49	
3	150 X 150 X 150	8110	22500	3375000	2.402	520	22.16	

28days compressive strength test results for 20% FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8106	22500	3375000	2.401	660	229.31	28.63
2	150 X 150 X 150	8050	22500	3375000	2.385	680	30.21	
3	150 X 150 X 150	8160	22500	3375000	2.417	600	26.38	

7days compressive strength test results for 30% FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	7095	22500	3375000	2.102	450	19.36	18.11
2	150 X 150 X 150	8025	22500	3375000	2.377	420	18.37	
3	150 X 150 X 150	8095	22500	3375000	2.398	360	16.11	

14days compressive strength test results for 30% FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8125	22500	3375000	2.407	490	21.74	23.17
2	150 X 150 X 150	8070	22500	3375000	2.391	580	25.56	
3	150 X 150 X 150	8005	22500	3375000	2.372	500	22.21	

28days compressive strength test results for 30% FRC &2%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8145	22500	3375000	2.413	610	27.23	26.37
2	150 X 150 X 150	8060	22500	3375000	2.388	570	25.33	
3	150 X 150 X 150	8010	22500	3375000	2.373	600	26.56	

7days compressive strength test results for 10% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8160	22500	3375000	2.417	300	13.39	15.11
2	150 X 150 X 150	8195	22500	3375000	2.428	370	16.38	
3	150 X 150 X 150	8190	22500	3375000	2.426	350	15.55	

14days compressive strength test results for 10% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8155	22500	3375000	2.416	490	21.63	21.32
2	150 X 150 X 150	8160	22500	3375000	2.417	460	20.48	
3	150 X 150 X 150	8150	22500	3375000	2.414	500	21.86	

28days compressive strength test results for 10% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8150	22500	3375000	2.414	520	23.21	23.16
2	150 X 150 X 150	8170	22500	3375000	2.420	480	21.49	
3	150 X 150 X 150	8190	22500	3375000	2.426	560	24.78	

7days compressive strength test results for 20% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8015	22500	3375000	2.374	420	18.48	17.62
2	150 X 150 X 150	8095	22500	3375000	2.398	370	16.21	
3	150 X 150 X 150	8160	22500	3375000	2.417	410	18.17	

14days compressive strength test results for 20% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8105	22500	3375000	2.401	510	22.54	23.66
2	150 X 150 X 150	8150	22500	3375000	2.414	580	25.73	
3	150 X 150 X 150	8175	22500	3375000	2.422	520	22.71	

28days compressive strength test results for 20% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8055	22500	3375000	2.386	530	23.57	24.21
2	150 X 150 X 150	8110	22500	3375000	2.402	600	26.64	
3	150 X 150 X 150	8155	22500	3375000	2.416	500	22.41	

7days compressive strength test results for 30% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	7955	22500	3375000	2.368	380	16.86	16.87
2	150 X 150 X 150	8105	22500	3375000	2.401	400	17.36	
3	150 X 150 X 150	8165	22500	3375000	2.419	370	16.4	

14days compressive strength test results for 30% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8010	22500	3375000	2.373	500	22.59	22.14
2	150 X 150 X 150	8090	22500	3375000	2.397	520	22.86	
3	150 X 150 X 150	8160	22500	3375000	2.417	470	20.97	

28days compressive strength test results for 30% FRC &3%HCl

Trail no	size of cube in mm	Weight of cube in gms	Area mm ²	Volume cm ³	Density g/cc	Load KN	Compressive strength N/mm ²	Avg. strength N/mm ²
1	150 X 150 X 150	8050	22500	3375000	2.385	460	20.49	23.55
2	150 X 150 X 150	8095	22500	3375000	2.398	580	25.98	
3	150 X 150 X 150	8110	22500	3375000	2.402	540	24.18	

2) Flexural Strength Test results

The following flexural strength test results of normal and fibre reinforced concrete with 10%,20% and 30% replacement of quarry with fine aggregate with water and acid curing of 1%,2% and 3% concentration in water of 28 days curing.

Normal concrete with 10%, 20% and 30% of quarry dust replaced with sand under water curing

S.No	% of quarry dust	Size of Beam In mm	Load KN	Flexural strength in N/mm ²
1	0%	100 x 100 x 500	5.2	2.6
2	10%	100 x100 x 500	4.7	2.35
3	20%	100 x100 x 500	4.4	2.2
4	30%	100 x100 x 500	3.2	1.6

Fibre Reinforced Concrete with 10%, 20% and 30% of quarry dust replaced with sand under water curing

S.No	% of quarry dust	Size of Beam In mm	Load KN	Flexural strength in N/mm ²
1	0%	100 x 100 x 500	8.8	4.4
2	10%	100 x100 x 500	7.8	3.9
3	20%	100 x100 x 500	6.3	3.15
4	30%	100 x100 x 500	4.8	2.4

Fibre Reinforced Concrete with 10%, 20% and 30% of quarry dust replaced with sand under acid curing of 1% concentration in water

S.No	% of quarry dust	Size of Beam In mm	Load KN	Flexural strength in N/mm ²
1	0%	100 x100 x 500	7.2	3.6
2	10%	100 x100 x 500	7.0	3.5
3	20%	100 x100 x 500	5.9	2.95
4	30%	100 x100 x 500	4.8	2.4

Fibre Reinforced Concrete with 10%, 20% and 30% of quarry dust replaced with sand under acid curing of 2% concentration in water

S.No	% of quarry dust	Size of Beam In mm	Load KN	Flexural strength in N/mm ²
1	0%	100 x100 x 500	5.9	2.95
2	10%	100 x100 x 500	6.2	3.1
3	20%	100 x100 x 500	4.7	2.35
4	30%	100 x100 x 500	4.3	2.15

Fibre Reinforced Concrete with 10%, 20% and 30% of quarry dust replaced with sand under acid curing of 3% concentration in water

S.No	% of quarry dust	Size of Beam In mm	Load KN	Flexural strength in N/mm ²
1	0%	100 x100 x 500	4.6	2.3
2	10%	100 x100 x 500	4.2	2.1
3	20%	100 x100 x 500	3.7	1.85
4	30%	100 x100 x 500	2.9	1.45

VI. CONCLUSION

- 1) The strength of Fiber Reinforced Concrete (FRC) decreases with increasing acid concentration. For example, at 1% acid concentration, the strength is 17.48 N/mm², while at 2% concentration, it is 15.73 N/mm². At high concentrations (3%), the loss of strength exceeds 30%.
- 2) Optimum results are obtained in both water curing and HCL exposure at different concentrations when 20% of stone dust is replaced with sand in normal and FRC concrete.
- 3) The weight of concrete decreases with increasing acid concentration.
- 4) Incorporating pozzolanic materials can help reduce concrete weight loss.
- 5) Pozzolanic mineral additives, such as fly ash, impact the durability of cement against acid attack.
- 6) Silica fume improves compressive strength, reduces porosity, and enhances concrete's resistance to severe HCL attack.
- 7) Partial replacement of fine aggregate with quarry dust increases the strength of concrete.
- 8) Quarry dust is a suitable and cost-effective replacement for sand, considering the scarcity and rising costs of natural fine aggregate.
- 9) FRC exhibits higher flexural strength compared to normal concrete, although flexural strength decreases with increasing quarry dust replacement and HCL concentration.
- 10) FRC cured with HCL up to 2% shows greater flexural strength compared to normal concrete cured with water.

- 11) FRC demonstrates resistance to flexural strength loss in acidic environments, making it suitable for concrete structures exposed to acids.
- 12) Adding 0.1% nylon fiber with quarry dust replacing fine aggregate improves strength compared to conventional concrete. The use of a chemical admixture, such as SBR latex, further enhances the strength.
- 13) Conventional concrete with full replacement of fine aggregate by quarry dust shows a 30% increase in strength at 28 days.
- 14) The tensile strength of M30 grade concrete increases by 8% when 0.1% nylon fiber is added with a chemical admixture at 28 days compared to conventional concrete.

In conclusion, the addition of 0.1% nylon fiber with quarry dust as a partial replacement for fine aggregate can be successfully used in construction applications, providing enhanced strength and durability.

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