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DURABILITY PROPERTIES OF CONCRETE CONTAINING METAKAOLIN, MARBLE DUST AND SLAG SAND FOR HIGH STRENGTH CONCRETE

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Abstract

Concrete is the material used most often in building. The worldwide generation of concrete has generously increased since 1990.Production of concrete mix entails a lot of natural contamination since it incorporates the outflow of CO2 gas. As the industry is shifting towards environmental friendly practices, different supplementary cementitious materials like silicon oxide exhaust, fly ash, slag, rice husk and metakaolin are being used. These materials help in developing High Strength Concrete (HSC) with advanced workability, durability, strength and diminished penetrability. Metakaolin (MK) is obtained from the clay mineral kaolinite in an anhydrous calcined form.

Designed the mix proportions of concrete for M60 Grade cement. Figure out things like cement's standard consistency, specific gravity, and fineness, as well as its beginning setting time and final setting time. Determine the characteristics of both fine and coarse aggregate, such as their bulk density, sand bulking, fineness modulus, specific gravity, and sieve analysis. Find out the concrete properties such as Slump test and Vee bee test and calculating the W/C ratio. Casting the cubes based on required W/C ratio and curing under water, Acid and base and tested after 28 days(water Cured Cubes), 30,90 & 120 Days (acid and base Cured Cubes). After the completion of the curing period, Use a compressive testing machine to determine the cubes' compressive strength. Sulfuric acid and sodium hydroxide are used for curing purposes in this instance. In terms of water weight, it accounts for about 5% of the consumption. Metakaolin can replace 5%-15% of the cement and 10%-20% of the marble dust.

Keywords: Metakaolin, Marble dust, Slag sand, High Strength, Durability.

I. INTRODUCTION

Strong and malleable, concrete is an excellent building material. It's a combination of water, cement, sand, and aggregate (like gravel or crushed rock). When mixed together, cement and water create a paste or gel that coats the aggregate and sand. Cement becomes firm and holds the mixture together once it has chemically interacted with water (hydrated). Within a few hours, you should notice the first signs of the hardening reaction. Optimal Metakaolin: The mineral kaolinite is calcined to produce metakaolin, which is an anhydrous version of the clay mineral. China clay, often known as kaolin, is a mineral utilised in the production of porcelain

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because of its high kaolinite content. Metakaolin particles are less than half as big as cement ones, but not quite as small as silica fume.

Metakaolin is a useful additive for concrete/cement applications due to its high reactivity, which is regarded as being double that of most other pozzolans. Positron emission from hydration of organophosphorus compounds (OPC), filler effect, and pozzolanic reaction are only a few of the technical features that improve when Portland cement is replaced by 8-20% (by weight) metakaolin in a concrete mix. The filler's effect is instantaneous, whereas the pozzolanic reaction's takes 3-14 days to take hold. Tests for compressive, split, and flexural strengths all rise by as much as 15% with an increase in metakaolin concentration. Metakaolin, as a pozzolanic substance for partial cement replacement in making high strength concrete, is recommended as a consequence.

Table 1: Chemical Composition of Metakaolin

Components	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	TiO_2	P_2O_5	L.O.I
Metakaolin	51.85	43.87	0.99	0.20	0.01	0.12	0.18	1.74	0.03	-
Cement	22.42	4.68	3.68	63.2	0.25	0.75	3.63	-	-	0.45
Silica Fume	93.16	1.13	0.72	-	-	-	1.6	-	-	1.58

Due to rising demands from both industry and consumers, natural resources have been rapidly depleting in recent years. The high rate of production has resulted in an equally high rate of waste, and this waste has had a negative effect on the natural world. As a result of the magnitude of these issues, it is wise to look into alternative raw material sources that use less energy and fewer natural resources (O'Farrell et al., 2006; Baroni and Binda, 1997). Waste reduction, recycling, and reuse are high on the list of environmental concerns for today's society, and a lot of work is currently being done to make that happen. Marble, slag sand, fly ash, and brick and ceramic waste are just a few examples of the types of industrial waste that play a crucial part in the long-term success of the building materials sector.

Replacement of some of the aggregate in mortar or concrete with these waste products is crucial due to the numerous benefits it provides, including the lessening of the need for natural resources and the lessening of environmental contamination. One of the most important tools for making good use of these elements in building is concrete. Producing cement and fine and coarse aggregates for use in concrete has a substantial ecological footprint. Concrete is an important material that is utilised in the construction of several structures, including homes, businesses, highways, bridges, and even dams. In terms of global cement production, India is the world's number two producer. Due to rapid industrialisation, significant natural resources for making concrete have been depleted during the past few decades. Additional materials are required to build concrete as a result of the increasing exploitation of natural resources. India will make great strides in the building and transportation industries in the years to come. So, it is expected that the cement sector would make significant progress as a result of these developments. The industry is expected to receive a significant boost from a few new significant acts, such as the creation of smart cities. According to Mohammed Raihan et al. [1], cement use has risen in recent years because of the infrastructural boom; nevertheless, for every thousand kilogrammes of cement produced, 900 kilogrammes of carbon dioxide are released into the atmosphere, which has a negative impact on the natural environment.

In order to create low-cost construction materials that may be used in poor nations, the usage of supplemental cementitious materials is essential. A number of concrete characteristics, including its workability, durability, strength, resistance to fractures, and permeability, can be enhanced by the incorporation of certain pozzolanic ingredients. Admixtures, which are added to many modern concrete mixes, are used to improve the microstructure and reduce the calcium hydroxide concentration via a pozzolanic reaction. Altering the microstructure of cement composites after they have been made enhances their mechanical qualities, longevity, and usefulness. Distributing fine pozzolana particles throughout the paste creates a considerable deal of nucleation sites for the precipitation of the hydration products. This process ensures uniformity throughout the paste. This effect is produced in cement hydration processes by the interaction of amorphous silica of the pozzolanic with calcium hydroxide. Fine grains, because to their physical qualities, allow dense packing within the cement and reduce the wall effect in the paste-to-aggregate transition zone. The increased bonding between these two phases reinforces the weaker zone, enhancing the microstructure and characteristics of the concrete. In most cases, smaller particles in the mixture have a greater physical or filling effect, which contributes to the overall pozzolanic effect. The addition of pozzolanas to OPC results in a higher mechanical strength.

II. LITERATURE REVIEW

[1] Chen, J.-F.; Ding, H.-M.; Wang, J.-X.; Shao, L. Hollow porous silica nanoparticles are prepared and characterised for use in medication delivery. Biomaterials By employing Porous hollow silica nanoparticles (PHSNP) with a diameter of 60-70 nm and a wall thickness of roughly 10 nm were fabricated using CaCO(3) nano-particles as an inorganic template. TEM and BET examination confirmed that PHSNP were uniform spherical particles with excellent dispersion and a specific surface area of 867 m(2)/g. The as-synthesized PHSNP were utilised as drug carriers to investigate the in vitro release behaviour of cefradine in a biofluid model. UV-spectrometry and TG studies were used to determine the total quantity of cefradine bound to the carrier. Analysis of the BJH pore size distribution of PHSNP was performed both before and after entrapping cefradine. PHSNP showed a delayed release effect and a three-stage pattern in its cefradine release profile.

[2] Wu, L.; Lu, Z.; Zhuang, C.; Chen, Y.; Hu, R. Mechanical Characteristics of Thermally Treated Reinforced Concrete Containing Nano-SiO2 and Carbon Fiber. Materials In this study, we provide a comprehensive analysis of the effects that heating different Nano SiO2 carbon fiber-reinforced concrete (NSCFRC) mixtures has on their basic mechanical and residual characteristics. Seven different NSCFRC formulations were tested, ranging from 0% carbon fibre by volume to 0.35%, and from 0% Nano SiO2 by weight to 2%. When compared to PC (0% CFs, 0% NS), NSCFRC with 0.25% carbon fibre and 1% NS exhibited greater compressive strength, tensile strength, and flexural strength, by 6.8%, 20.3%, and 11.7%, respectively. Nano SiO2 enhanced compactness of the concrete matrix and decreased internal porosity, as seen by scanning electron microscopy (SEM). In addition, the experimental result shows that NSCFRC can enhance the mechanical properties of concrete after high-temperature, and equations were established to characterise the evolution of residual qualities at higher temperatures. According to the findings, carbon fibres have a smaller impact on the concrete's residual qualities after being exposed to high temperatures than steel fibre and polypropylene fibre. It was also suggested that using the right amount of Nano SiO2 in concrete is a good way to boost its performance even after being exposed to extreme heat.

[3] Tambichik, M.A.; Mohamad, N.; Samad, A.A.A.; Bosro, M.Z.M.; Iman, M.A. Recycling of Malaysian Construction and Agricultural Debris into Green Concrete: Concrete made with at least one recycled resource is called "green concrete" (GC). There are several environmental issues caused by regular concrete, which has led to a rise in the manufacture of GC as a solution. Annual increases in waste production in the agriculture and construction sectors were seen in Malaysia. Consequently, using it in concrete is one way to lessen the effects of regular concrete and the constraints on landfills caused by excessive trash. In order to create a novel Green Concrete, this article examines the potential substitution of some of the primary material with byproducts from construction (Recycle Concrete Aggregate) and agriculture (Palm Oil Fuel Ash, Rice Husk Ash, and Palm Oil Fibre). We also looked at the optimal replacement level for each waste category. In addition to lowering pollution levels and stopping the use of scarce natural resources, green concrete might be a game changer for the planet. This study concludes that the strength of concrete made from either agricultural or construction waste is improved and is good compared to that of regular concrete. CIDB's Construction Industry Transformation Plan (CITP) 2016-2020 puts an emphasis on using environmentally friendly building practises.

[4] Hossain, S.S.; Mathur, L.; Roy, P.K. Silica in ceramics may also be derived from rice husks and rice husk ash. The potential advantages of reusing waste or by-products from many industries including the agricultural sector have received increased attention from the scientific, technical, ecological, economic, and social communities in recent years. Milling rice produces two waste products: rice husk (RH) and rice husk ash (RHA). In order to create RHA, RH must be burnt in a special boiler. The world's top five rice-producing countries—China, India, Brazil, the USA, and Southeast Asia—also have relatively easy access to RH and RHA. So RH has been recycled by being burnt to produce energy. RHA, produced in this way, is constituted of (85-95%) of amorphous silica. Over the last two decades, RHA has been used in a broad variety of goods, including silicates, zeolites, catalysts, nanocomposite, cement, lightweight construction materials, insulators, and adsorbents. This report serves as an overview of the RH/RHA nano-silica processing sector. Simultaneously, it makes an effort to provide a critical study of RHA's application as a component in the production of several ceramic materials (such as refractories, glasses, whiteware, oxide and non-oxide ceramics, silica aerogel, and SiO2/C composites). RHA or RH amorphous silica may one day replace more prevalent silica sources (like quartz) in the manufacture of high-value ceramics.

[5] Le, V.H.; Thuc, C.N.H.; Thuc, H.H. The utilisation of a sol-gel process to generate silica nanoparticles from Vietnamese rice husk. Nanoscale Issues in Research Letters: Extracting nanoscale silica powder from Vietnamese rice husk through the sol-gel technique. Rice husk ash (RHA) is created using a thermal processing method, typically at 600 °C for 4 hours. RHA's silica was precipitated by adding H2SO4 to a cationic water/butanol solution at pH 4 to convert it to a sodium silicate solution. Examining the influences of surfactant surface covering, ageing temperature, and ageing time led to the finding of the optimal condition for generating the homogenous silica nanoparticles. The obtained silica product was amorphous, as confirmed by X-ray diffraction, scanning electron microscopy, and transmission electron microscopy; the nanosized sample was uniform, with an average size of 3 nm; and the BET result showed that the highest specific surface of the sample was approximately 340 m2/g. It has been proven that rice husk from agricultural wastes may be utilised in the manufacturing of silica nanoparticles utilising the aforementioned approach.

[6] Venkateswaran, S.; Yuvakkumar, R.; Rajendran, V. The Production of Nano Silicon from Nano Silica Using a Renewable Energy Source (Rha). Relative Elements of Phosphorus, Sulfur, and Silicon The alkaline extraction followed by acid precipitation technique was used to extract nano silica of high purity (99%) and average particle size (100 nm) from a natural resource, rice husk, at pH 3 at 650°C. Silicon (Si) nanoparticles have been manufactured using nano silica as a precursor and a high temperature magnesiothermic reduction technique. Numerous techniques, including instruments for X-ray diffraction, particle size analysis, Fourier transform infrared spectroscopy, transmission electron microscopy, X-ray fluorescence analysis, and ultraviolet-visible spectroscopy, were used to describe the generated sample. Studies of complete samples show that various sintering temperatures result in varying particle sizes, ranging from 70 nm to 100 nm, and that pure phase formation of Si occurs. The 850°C silicon nanoparticles show excellent absorption peaks, high purity, and pure phase formation. The efficiency of solar cells made from a mixture of silicon and ruthenium, as determined by IV characteristics, is 2.67 percent higher than that of ordinary solar cells. As a byproduct of this process, silicon nanoparticles might be used as an anode material in solar cells.

III. METHODOLOGY

Metakaolin (MK): creates Kaolin by a well managed heating process. Various studies have proposed varying combinations of heating time (1-6 hours) and temperature (600-850 °C) for kaolin to produce MK with a high pozzolanic index. Since MK has pozzolanic qualities, it may be used in lieu of cement in concrete, albeit the strength and durability of MK concrete is still up for debate. Due to the fact that MK is not a by-product, its engineering qualities may be managed. Therefore, by demonstrating the MK concrete's hardened qualities, it will offer potential benefits compared to existing cement replacement alternatives (Nazeer and Arun Kumar, 2014).

SLAG SAND: Slag sand, or LD slag, is a non-metallic substance composed mostly of silicates and aluminosilicates of lime glass. This byproduct results from the transformation of molten pig iron and steel scrap into high-quality steel in blast furnaces at high temperatures (14000C-15000C). On average, this method produces between 150 and 200 kg of slag per tonne of steel, making it the primary source of slags from steel plants. Slag granules are produced when molten ash from a furnace is quenched in water, air, or steam. Depending on its intended use, slag may be crushed, ground, and screened in one of many processing facilities.

JSW Steel is the first company in India to use a novel quenching method to granulate steel slag. This method uses a closed system to cleanly separate metal from slag while simultaneously removing any traces of free lime or magnesium oxide. When the molten slag is suddenly cooled, the metal and the slag contract at separate rates, facilitating a clean separation of the two. It granulates well, leading to a stable final product. This method, which may be thought of as a sped-up version of the natural ageing process, works to diminish the amount of free lime that isn't desired. The elimination of free lime and MgO also verifies its dimensional steadiness. The granulated slag resembles river sand in appearance. River sand and synthetic slag sand seem quite similar under the microscope. Screening the granulated slag into various size fractions depends on the end use. Aggregates used in construction must have such a size range. This is seen as a viable material to replace river sand in building due to its likeness to river sand.

This research made use of JSW Slag Sand from Zone II that was found to be in compliance with IS-383:2016. JSW Steel is the first company in India to use a novel quenching method to granulate steel slag. This method uses a closed system to cleanly separate metal from slag while simultaneously removing any traces of free lime or magnesium oxide. It granulates well, leading to a stable final product. This method, which may be thought of as a sped-up version of the natural ageing process, works to diminish the amount of free lime that isn't desired. The elimination of free lime and MgO also verifies its dimensional steadiness. The granulated slag resembles river sand in appearance. River sand and synthetic slag sand seem quite similar under the microscope. Screening the granulated slag into various size fractions depends on the end use. Aggregates used in construction must have such a size range. This is seen as a possible material to replace river sand in building due to its likeness to river sand. A sample of slag sand is shown in Fig. 2.

Table 2: Physical properties of Slag sand

SL.No	Physical properties	Slag sand
1	Specific Gravity	2.58
2	Fineness	2.82
3	Particle shape	Sub angular to sub rounded
4	Water absorption, %	3%
5	Loose bulk density, kg/m^3	1197.33

Concrete

Concrete is an engineered material made from coarse and fine aggregate that is held together with a fluid cement (cement paste) and then hardens (cures) over time. Concrete is the most frequently used construction material and the second most utilised substance in the world after water [1]. [2] It is used twice as much than steel, wood, plastics, and aluminium combined across the globe, as measured in tonnes. [3] The biggest section of the concrete market, ready-mix concrete, is expected to generate more than $600 billion worldwide by 2025. [4] Numerous adverse effects on the natural world are caused by such extensive use. Cement manufacturing accounts for a significant portion (net 8%) of worldwide greenhouse gas emissions. [5] [6] Illegal sand mining is a major issue that might have far-reaching consequences for the environment and society at large due to its scope, repercussions (such as increased surface runoff or the urban heat island effect), and the possible public health implications of hazardous substances. In order to establish a circular economy, significant effort is being put into researching and developing ways to decrease emissions or making concrete a source of carbon sequestration and increasing the recycled and secondary raw materials content in the mix. It is anticipated that concrete will play a crucial role in the construction of disaster-resistant buildings[7], and it may also provide a means to reduce the environmental impact of other sectors by recycling their byproducts, such as coal fly ash or bauxite tailings and residue.

IV. WORKABILITY TESTS ON CONCRETE

Workability is defined as the amount of work required to place and compact the concrete fully. In this project workability tests done here are Slump Cone Test and V-Bee Test.

Slump Cone Test

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.

Table 3: Slump Cone Test

S.No.	% Cement Replaced (MK - MD)	Water Cement Ratio (W/C Ratio)	Slump Value (mm)
1	0 %	0.36	112
2	0 - 10	0.38	110
3	0 - 20	0.38	107
4	5 - 10	0.38	104
5	5 - 20	0.37	100
6	10 - 10	0.38	98
7	10 - 20	0.40	97
8	15 - 10	0.39	95
9	15 - 20	0.37	91
10	20 - 10	0.36	89
11	20 - 20	0.36	85

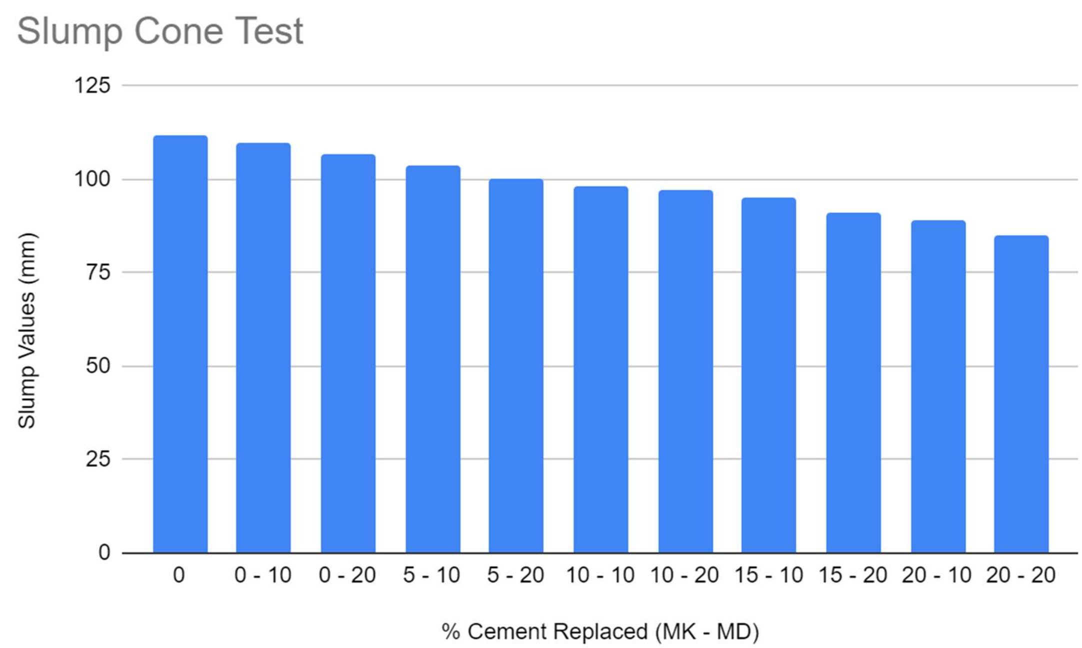

Figure 3: Bar Graph for Slump Cone Test

Vee - Bee Test

vee - Bee test that measures the relative effort required to change a mass of concrete from one definite shape to another (i.e., from conical to cylindrical) by means of vibration.

Table 4: Vee - Bee Test

S.No.	% Cement Replaced (MK - MD)	Water Cement Ratio (W/C Ratio)	Vee - Bee Time (Sec)
1	0 %	0.36	4
2	0 - 10	0.38	5.23
3	0 - 20	0.38	4.88
4	5 - 10	0.38	5.26
5	5 - 20	0.37	6.32
6	10 - 10	0.38	5.33

7	10 - 20	0.40	4.19
8	15 - 10	0.39	5.68
9	15 - 20	0.37	4.78
10	20 - 10	0.36	5
11	20 - 20	0.36	6.10

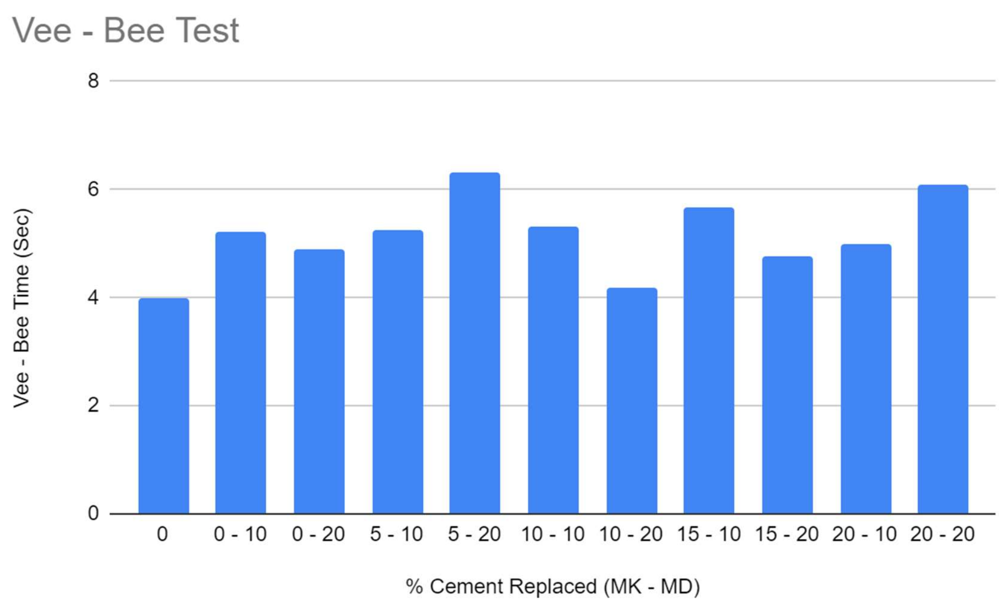

Figure 4: Bar Graph for Vee - Bee Test

Acid Curing

To create acid curing coatings (SH), sometimes called cold-curing coatings, a mixture of alkyd and amino resins is dissolved in organic solvents. Due to their great chemical resistance, quick drying periods, and extended pot lives (up to 5 days), these coatings find widespread application in the furniture sector. The widespread appeal of these coating techniques might be attributed to the introduction of formaldehyde-free variants.

Table 5: Compressive Strength under Acid Curing 30, 90, 120-Days

Compressive Strength under Acid Curing			
	Compressive Strength (N/mm^2)		
% Cement replaced	30 Days	90 Days	120 Days
0	26.58	20.86	15.91
0-10	28.33	22.93	17.89
0-20	30.56	25.32	20.2
5-10	32.64	27.96	22.14
5-20	34.11	28.92	24.3
10-10	35.38	30.02	24.93
10-20	33.01	27.34	22.15
15-10	31.16	25.76	19.6
15-20	27.82	23.24	18.62
20-10	28.04	21.95	18.15
20-20	25.12	20.64	17.63

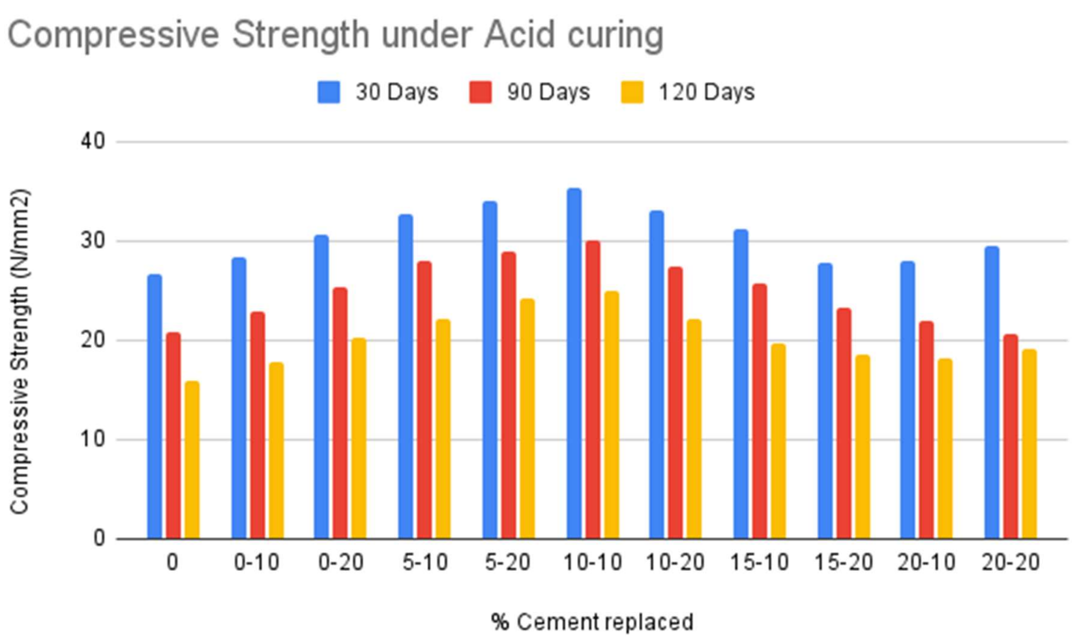

Figure 5: Bar Graph for Compressive Strength under Acid Curing 30, 90, 120-Days

Base Curing:

During base curing, the pace and amount of moisture loss from concrete as it hydrates are managed. As the name implies, this curing method involves keeping the exposed surface constantly wet to prevent it from drying out. Common techniques for achieving this goal include ponding water or spraying water over the top of the surface.

Table 6: Compressive Strength under Base Curing 30, 90, 120-Days

Compressive Strength under Base Curing			
	Compressive Strength (N/mm2)		
% Cement replaced	30 Days	90 Days	120 Days
0	26.58	18.58	15.91
0-10	28.33	21.98	18.11
0-20	30.56	24.06	19.87
5-10	32.64	25.98	21.22
5-20	34.11	28.66	23.14
10-10	35.38	30.85	25.02
10-20	33.01	28.35	21.94
15-10	31.16	25.99	20.12
15-20	27.82	23.21	17.56
20-10	26.22	20.18	14.49
20-20	25.82	18.65	10.98

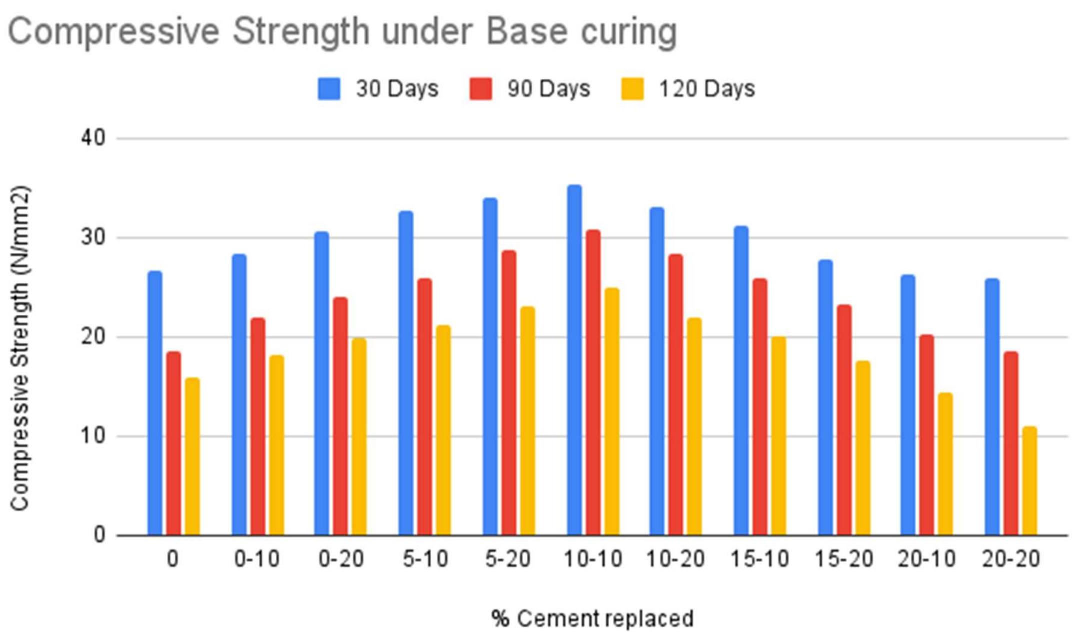

Figure 6: Bar Graph for Compressive Strength under Base Curing 30, 90, 120-Days

V. CONCLUSION

- The primary objective of this investigation is to determine whether or not the addition of Metakaolin and Marble Dust to concrete, followed by curing with either an acid or a base, results in an increase in the strength of the concrete.
- This will be accomplished by determining whether or not the addition of Metakaolin and Marble Dust results in an increase in the strength of the concrete.
- It will be determined whether or not the addition of Metakaolin and Marble Dust results in an increase in the strength of the concrete.
- This will be done so that it can be accomplished. It will be examined to see whether or not the incorporation of metakaolin and marble dust into the concrete leads to an increase in the material's tensile strength.
- This will be carried out in order to ensure that the goal can be realised. The tensile strength of the material will be evaluated to determine whether or not the addition of marble dust and metakaolin to the concrete results in an increase in the material's overall strength.
- In order to make certain that the objective can be accomplished, this step will be carried out. According to the findings of this research, it was hypothesised that a portion of the cement could be substituted with Marble Dust and Metakaolin in a predetermined ratio, and that the mixture that would result could then be cured by applying diluted H2SO4 and NaOH. This hypothesis was supported by the findings of this research.
- The findings of this research lend credence to the validity of this hypothesis. The results of this research lend support to the idea that the validity of this hypothesis has been established. The findings of this study lend credence to the idea that the correctness of this hypothesis has been demonstrated through their empirical evidence.
- The results of this research lend credence to the idea that the accuracy of this hypothesis has been demonstrated through their empirical evidence, and those findings lend credence to the idea that this hypothesis has been demonstrated correctly.

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