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# Durability Properties of High-Strength Concrete Containing Fly Ash, Dolomite Powder and Slag Sand

**Gummadipudi Akanksha, B. Ajitha**

***Abstract:** Concrete is the most extensively utilized construction material worldwide. The production and demand for cement have seen significant growth, but this increased demand has raised concerns about its environmental impact within the construction industry. Concrete can be produced using alternative materials or substitutions for cement, fine aggregate and coarse aggregate, often utilizing waste materials. In this study, dolomite powder and fly ash used as a partial replacement for cement and slag sand is used as a 100% replacement to natural sand. Dolomite powder shares certain properties with cement, making it a cost-effective alternative that can enhance the strength of concrete. The disposal of fly ash is becoming a significant environmental concern due to its potential environmental hazards as a waste material. Using fly ash is not only cost-effective but also improves the workability, strength, and durability of concrete. Additionally, the use of slag sand not only contributes to environmental conservation but also enhances the structural strength and durability of concrete. The reason is the high tensile strength of slag. The durability tests on this project are water absorption, acid and alkali resistance tests. In these tests, an acid resistance test involves the use of 5% dilute sulfuric acid ($H_2SO_4$) by volume of water, while an alkali resistance test uses 5% sodium hydroxide (NaOH) by weight of water. These tests are conducted using M60 grade concrete mixtures, which incorporate partial replacements of cement with fly ash ranging from 0% to 10% by weight of cement, and dolomite ranging from 0% to 20% by weight of cement. Additionally, fine aggregate is replaced with slag sand in these mixtures.*

***Keywords:** Dolomite, Slag Sand, Fly ash, Sulphuric Acid, Sodium Hydroxide, Cement, Concrete.*

## I. INTRODUCTION

Cement, a cornerstone of contemporary construction, exerts a central influence in molding the built surroundings we inhabit. It serves as the primary adhesive in crafting concrete, the world's most prevalent construction material. Despite the transformative impact of cement and concrete on the construction sector, their manufacturing and utilization have sparked noteworthy ecological apprehensions.

The cement production process is intricate, commencing with the extraction of raw materials like limestone, clay, and other minerals, which are subsequently subjected to a high-temperature chemical transformation to form clinker. While this process has driven impressive advancements in architecture and infrastructure, it is accompanied by numerous environmental challenges. Chief among these concerns is the substantial carbon footprint of cement production. The chemical reactions responsible for converting raw materials into clinker release carbon dioxide ($CO_2$), a potent greenhouse gas, into the atmosphere. Moreover, the energy-intensive nature of this process, heavily reliant on fossil fuels, exacerbates carbon emissions. These emissions contribute to global climate change, posing a significant threat to ecosystems, weather patterns, and sea levels. In response to these challenges, the idea of substituting or enhancing cement with alternative materials has gained traction as a strategy for crafting eco-friendly and sustainable concrete. The utilization of dolomite as a partial cement replacement is an intriguing avenue within the domain of sustainable construction. Dolomite, composed of calcium magnesium carbonate, presents specific benefits that have the potential to lessen the environmental footprint of concrete while upholding its structural soundness.

Fly-ash, owing to its pozzolanic properties, offers significant benefits when employed as a mineral admixture to substitute a high percentage of cement in concrete. This choice is favored due to its numerous advantages; making it the most commonly used material for this purpose. In addition to cost-effectively producing concrete, fly-ash possesses a range of capabilities, as supported by studies (Langley et al. 1989; Bilodeau and Malhotra 2000; Mindless et al. 2003.

When concrete is allowed to cure adequately, with sufficient time dedicated to the curing process, concretes containing substantial amounts of slag or fly ash have the potential to develop robust strengths over time, often surpassing those of comparable concretes lacking slag or fly ash. However, this scenario only unfolds when the curing process receives the necessary duration. Nonetheless, because these minerals undergo hydration and reactions at a slower pace compared to others, concretes incorporating them typically exhibit lower early strengths compared to concretes devoid of slag or fly ash. This phenomenon stems from the slower hydration and reaction rates inherent to these minerals. Developing affordable construction materials suitable for impoverished regions necessitates the essential integration of supplementary cementitious materials.

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## II. LITERATURE SURVEY

[1][6][7][8] L. Ranjith Kumar et al. in 2017, it was observed that replacing cement with dolomite powder led to an enhancement in concrete strength. The highest permissible replacement percentage of cement with dolomite powder was determined to be 5%. At this replacement level, the maximum improvements in 28th-day compression and flexural strength were 5.84% and 2.73%, respectively. Regarding split tensile strength, the most effective replacement was also 5%, resulting in a 2.74% increase in split tensile strength.

[2][9] Athulya Sugathan's 2017 study found that the addition of dolomite powder increased compressive strength in cubes up to a 15% cement replacement, but further dolomite addition led to decreased strength. Likewise, split tensile strength in cylinders improved up to a 15% cement replacement with dolomite, beyond which it declined. This research offers a cost-effective construction solution using readily available dolomite powder while addressing environmental concerns—a primary goal for civil engineers.

[3] "S. Yeswanth Sai Krishna[1] and B. Ajitha[2] (2017) designed concrete mix proportions for M60 grade cement. Cubes were cast with the required water-cement ratio and cured in water, acid, and base solutions. Testing was conducted after 28 days for water-cured cubes and after 30, 90, and 120 days for acid and base-cured cubes, utilizing 5% by weight of water in the form of sulphuric acid and sodium hydroxide. Cement replacement with nano silica ranged from 0% to 20%.

[4] K. Sathish Kumar and K. Anitha investigated the impact of replacing cement with dolomite powder at percentages of 20%, 25%, and 30%, along with fine aggregate replacement by copper slag at 20% in M20 grade concrete. Dolomite powder and copper slag were blended with natural cement and fine aggregate in the M20 grade concrete. Test specimens were cured and assessed for compressive and split tensile strength at 7 days, 14 days, and 28 days. The results indicated that the use of dolomite powder and copper slag enhanced both the compressive and tensile strength of the concrete.

[5] Shaik Sony Sulthana1 and B. Ajitha2 designed concrete mix proportions for M60 Grade cement. They cast cubes based on the required water-cement ratio and cured them under different conditions. Testing was done after 28 days for water-cured cubes and after 30, 90, and 120 days for acid and base-cured cubes, using a combination of sulphuric acid and sodium hydroxide for curing at 5% by weight of water. The study also involved the partial replacement of cement with nano silica, ranging from 0% to 20%.

## III. METHODOLOGY

Characteristics of materials used in this research project including cement, slag, fly ash, dolomite, sand, coarse aggregate, superplasticizer, and water are described in this section.

### A. Cement

The cement utilized in this research is ordinary Portland cement (OPC-53 GRADE), readily accessible in the nearby market. It has been carefully stored in a dry and shaded environment, securely enclosed in a poly bag to safeguard it from any potential moisture exposure during the research work.

### B. Dolomite

By partially replacing cement with dolomite, the overall amount of cementitious material required in concrete can be reduced. As a result, carbon dioxide emissions associated with cement production are lowered, as cement production is a major contributor to CO2 emissions. Dolomite can enhance the workability and durability of concrete. It can improve the chemical resistance of concrete and reduce the risk of alkali-silica reactions, which can lead to cracking and deterioration. Utilizing dolomite as a cement replacement can reduce the demand for virgin raw materials used in cement production, such as limestone and clay. This helps conserve natural resources and reduces the environmental impact of mining and quarrying activities. Dolomite can be sourced from industrial by-products or waste streams, such as from mining or metallurgical processes. While dolomite shows promise as a cement replacement, there are technical aspects to consider, such as the appropriate dosage of dolomite, its reactivity, and its potential effects on concrete properties. Proper testing and evaluation are necessary to ensure that the desired performance standards are met. On-going research and experimentation are crucial to understanding the full potential of dolomite as a cement replacement. Researchers are investigating the optimal conditions for its use and its effects on various concrete properties, such as strength, durability and long-term performance.

### C. Fly-Ash

Cement production is a significant contributor to carbon dioxide emissions. By incorporating fly-ash as a cement replacement, the demand for cementitious materials is decreased, resulting in lower greenhouse gas emissions and a smaller carbon footprint. Fly ash can improve the workability and ease of concrete placement, allowing for better compaction and reducing the risk of segregation. The pozzolanic reactions of fly ash with calcium hydroxide during the hydration process contribute to the formation of additional binding compounds, resulting in improved compressive strength and durability of concrete. Fly ash can help mitigate the potential for alkali-silica reaction, a chemical process that can lead to concrete cracking and deterioration. The incorporation of fly ash can lead to reduced heat generation during concrete curing, which is beneficial in large mass placements and hot weather conditions. By utilizing fly ash, the demand for virgin raw materials is reduced, conserving natural resources and reducing the need for quarrying and mining activities.

### D. Fine Aggregate

*Slag sand*

Slag sand is a product of the metallurgical industry, generated during the smelting of metals such as iron and steel.

It is obtained by rapidly cooling molten slag, a high-temperature waste material, to create granulated particles with distinct physical and chemical properties. This process transforms what would otherwise be considered waste into a valuable resource for sustainable construction. Slag sand possesses excellent chemical and physical properties that contribute to improved durability in concrete. Its low porosity and resistance to chemical attacks make it particularly suitable for harsh environments, including marine and industrial settings. By using slag sand, construction practices can reduce the demand for natural sand, which is often extracted from riverbeds and beaches, causing ecological disruption. The angular shape and particle size distribution of slag sand can enhance the workability of concrete mixes.

### E. Coarse Aggregate

Aggregates influence the strength of concrete to great extent. For experimental 20mm size aggregate is used.

### F. Test Method Analysis

- ✓ Developed concrete mix proportions of M60 Grade cement specifications.
- ✓ Determined the cement properties, such as initial setting time, final setting time, standard consistency, specific gravity and fineness.
- ✓ Investigated Fine and Coarse Aggregate attributes, encompassing Bulk Density and Bulking of sand.
- ✓ Assessed fine aggregate properties, encompassing Fineness Modulus, specific gravity and sieve analysis.
- ✓ Examined concrete properties through Slump and Vee-bee tests, while calculating the Water/Cement (W/C) ratio.
- ✓ Casting the cubes based on required W/C ratio and curing under water, Acid and base.
- ✓ Tested after 28 days (water Cured Cubes), 30, 90 & 120 Days (acid and base Cured Cubes).
- ✓ After the curing period, find the compressive strength of cubes which are tested under a compressive testing machine.
- ✓ Here we use Sulphuric acid and Sodium Hydroxide for curing. It is used 5% by weight of water.
- ✓ Partial replacement of cement using fly-ash is 0, 2, 4, 6, 8 and 10%. And dolomite is 0, 5, 10, 15 and 20%.

## IV. WORKABILITY TEST ON CONCRETE

Workability refers to the effort needed for complete placement and compaction of concrete. In this project, workability is assessed through the Slump Cone Test and V-Bee Test.

### A. Slump Cone Test

The concrete slump test assesses the freshness of concrete before it sets, gauging its consistency. This test is conducted to evaluate the workability of newly mixed concrete, indicating how easily it flows.

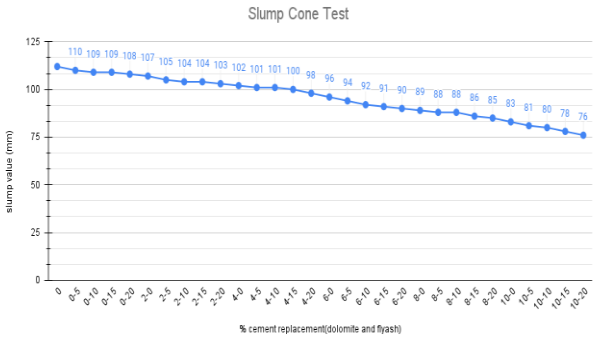

Fig. 1. Slump Cone Test

### B. Vee-Bee Test

The Vee-Bee test quantifies the relative force needed to transform a mass of concrete from one specific shape to another, such as from conical to cylindrical, using vibration.

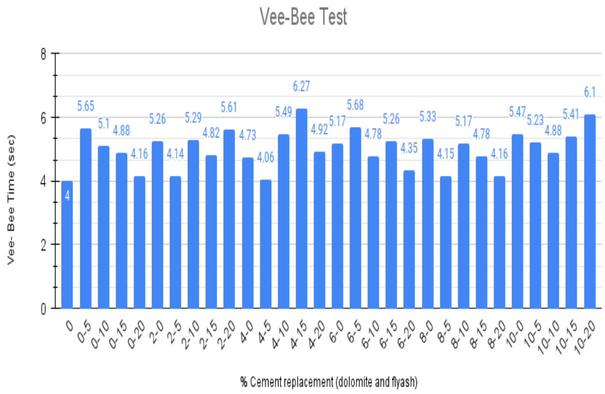

Fig. 2. Vee-Bee Test

## V. CURING TESTS OF CONCRETE

### A. Acid Curing

The acid curing process is a method used in the construction industry, primarily in the context of concrete or cement-based materials. It involves exposing freshly cast concrete or cement products to an acidic solution during the early curing stages. The main objectives of the acid curing process are to enhance the surface finish, change the color or accelerate the curing of the concrete.

### B. Curing Process

The curing process in concrete refers to the controlled maintenance of moisture, temperature, and time immediately after it's placed to ensure optimal strength and durability. It involves keeping the concrete damp and at the right temperature (typically above 50°F or 10°C) for a specified period, which can range from days to weeks, depending on the concrete mix. Proper curing is crucial because it allows the concrete to continue its chemical hydration process, strengthening over time.

**Table- I: Compressive Strength Under Acid Curing**

| % of Cement Replaced (Flyash-Dolomite) | Compressive Strength (N/mm$^2$) | | |
|---|---|---|---|
| | 30 days | 90 days | 120 days |
| 0 | 29.97 | 26.95 | 23.87 |
| 0-5 | 31.75 | 28.68 | 25.56 |
| 0-10 | 32.65 | 29.95 | 27.97 |
| 0-15 | 33.81 | 30.89 | 28.57 |
| 0-20 | 34.83 | 31.98 | 29.19 |
| 2-0 | 35.01 | 32.96 | 29.92 |
| 2-5 | 35.51 | 33.46 | 30.71 |
| 2-10 | 36.92 | 34.81 | 32.47 |
| 2-15 | 37.79 | 35.91 | 33.65 |
| 2-20 | 38.93 | 36.71 | 34.52 |
| 4-0 | 40 | 37.03 | 34.98 |
| 4-5 | 40.87 | 37.75 | 36.24 |
| 4-10 | 43.56 | 39.97 | 37.18 |
| 4-15 | 44.23 | 41.76 | 39.42 |
| 4-20 | 43.49 | 40.97 | 37.93 |
| 6-0 | 43.05 | 40.12 | 37.02 |
| 6-5 | 42.76 | 39.02 | 36.45 |
| 6-10 | 41.35 | 37.26 | 34.16 |
| 6-15 | 40.12 | 36.21 | 32.17 |
| 6-20 | 39.43 | 35.87 | 31.58 |
| 8-0 | 38.27 | 34.72 | 30.45 |
| 8-5 | 36.65 | 33.69 | 30.05 |
| 8-10 | 35.41 | 32.84 | 29.47 |
| 8-15 | 34.18 | 30.58 | 28.13 |
| 8-20 | 32.94 | 29.87 | 27.01 |
| 10-0 | 31.95 | 28.62 | 26.16 |
| 10-5 | 31.17 | 27.98 | 25.13 |
| 10-10 | 30.12 | 27.25 | 23.06 |
| 10-15 | 29.04 | 26.12 | 22.57 |
| 10-20 | 28.45 | 25.59 | 21.26 |

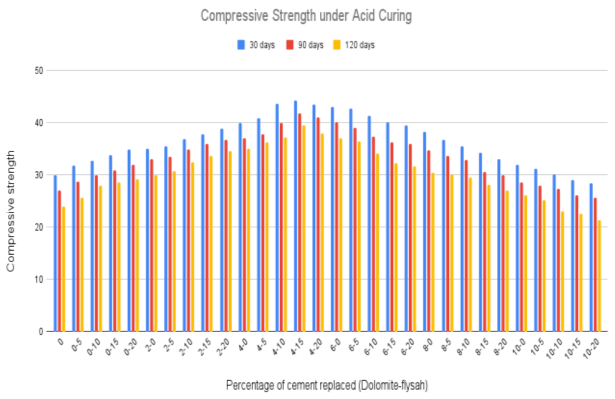

**Fig. 3. Compressive Strength Under Acid Curing for 30, 90 and 120-day**

## C. Base Curing

Base curing of concrete is a crucial process in construction. It involves maintaining the ideal moisture and temperature conditions for newly poured concrete to ensure its strength and durability. This curing method typically lasts for at least seven days, although longer durations are often recommended for optimal results. During base curing, the concrete is often kept continuously moist to prevent surface drying and cracking. Proper base curing enhances concrete's hydration and minimizes the risk of surface defects, resulting in a stronger and more resilient structure.

## D. Curing Process

During the curing process, neutral cure sealants emit a substance that is non-acidic in nature. This characteristic reduces the likelihood of causing harm to delicate substrates and surfaces. Neutral cure sealants, in particular, exhibit mild properties, making them safe choices that won't mar the appearance of natural stone or induce corrosion in metal surfaces. These attributes make neutral cure sealants a preferred option for various applications where the preservation of the integrity and aesthetics of materials is paramount. The absence of acidic elements in their curing process ensures compatibility with a wide range of construction materials, enhancing their versatility and reliability.

**Table- II. Compressive Strength Under Base Curing for 30, 90 and 120-days**

| Percentage of Cement Replaced (Flyash- Dolomite) | Compressive Strength (N/mm$^2$) | | |
|---|---|---|---|
| | 30 days | 90 days | 120 days |
| 0 | 29.97 | 26.95 | 23.87 |
| 0-5 | 31.81 | 27.96 | 25.56 |
| 0-10 | 32.73 | 29.72 | 27.98 |
| 0-15 | 33.76 | 30.93 | 28.61 |
| 0-20 | 34.71 | 31.98 | 29.26 |
| 2-0 | 35 | 32.07 | 30.1 |
| 2-5 | 35.63 | 32.67 | 30.69 |
| 2-10 | 36.87 | 34.81 | 32.4 |
| 2-15 | 37.83 | 35.74 | 33.65 |
| 2-20 | 39.85 | 36.81 | 34.56 |
| 4-0 | 40.05 | 37.46 | 34.99 |
| 4-5 | 40.97 | 38.09 | 35.31 |
| 4-10 | 43.51 | 39.93 | 37.16 |
| 4-15 | 44.27 | 41.83 | 39.26 |
| 4-20 | 43.48 | 40.97 | 37.84 |
| 6-0 | 42.59 | 39.94 | 36.68 |
| 6-5 | 41.61 | 39.02 | 36.09 |
| 6-10 | 40.39 | 38.01 | 34.42 |
| 6-15 | 39.16 | 37.76 | 33.29 |
| 6-20 | 38.52 | 36.97 | 32.61 |
| 8-0 | 37.72 | 35.86 | 31.78 |
| 8-5 | 36.59 | 34.69 | 29.52 |
| 8-10 | 35.43 | 33.84 | 28.27 |
| 8-15 | 34.20 | 32.58 | 27.64 |
| 8-20 | 32.91 | 31.87 | 27.04 |
| 10-0 | 32.06 | 30.65 | 26.59 |
| 10-5 | 31.67 | 28.71 | 25.32 |
| 10-10 | 30.19 | 27.97 | 23.19 |
| 10-15 | 29.09 | 26.12 | 22.41 |
| 10-20 | 28.56 | 25.03 | 21.35 |

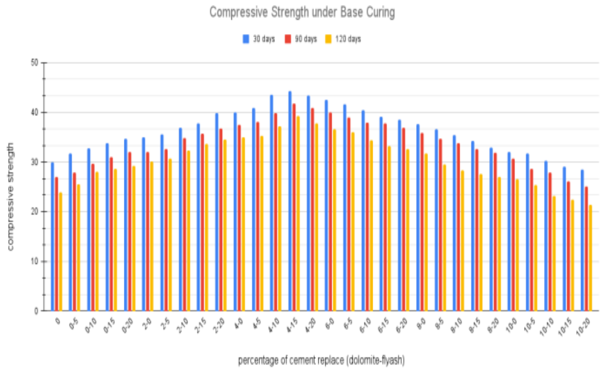

**Fig. 4. Compressive Strength Under Base Curing for 30, 90 and 120-days**

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## VI. CONCLUSION

- The primary objective of this investigation is to ascertain whether the inclusion of dolomite and fly-ash in concrete, in conjunction with curing using either an acidic or alkaline agent, yields an enhancement in the resultant material's strength.
- This study set out to test the idea that cement might be substituted in part with dolomite and fly-ash in a predefined ratio, and that the material could subsequently be cured using diluted $H_2SO_4$ and NaOH.
- The results of this study strongly suggest that, once the hypothesis is confirmed, dolomite shows significant promise as a viable partial substitute for cement. The consistent findings indicate that dolomite could potentially take on specific cement-related roles, subject to the hypothesis being validated.
- Embracing supplementary cementitious materials like fly ash and naturally occurring minerals like dolomite aligns with sustainability goals. It reduces the reliance on energy-intensive conventional cement production, curbing carbon emissions in the process.
- Concrete subjected to acid and base curing, combined with these alternative materials, exhibits heightened resilience against environmental factors, including chemical attacks and corrosion. This makes it an attractive option for specialized applications in challenging conditions.
- Depending on local availability and pricing, dolomite and fly ash can emerge as cost-effective substitutes for cement. This could potentially confer economic benefits to concrete producers and construction projects alike.

## DECLARATION STATEMENT

| | |
|---|---|
| Funding/ Grants/ Financial Support | No financial support or any kind of funds, grants, or financial support received. |
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| Ethical Approval and Consent to Participate | The article does not require ethical approval and consent to participate. |
| Availability of Data and Material | Not relevant. |
| Authors Contributions | All authors have equal participation in this article |

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**Gummadipudi Akanksha,** has completed civil engineering from Sri Venkateshwara College of Engineering karkambadi, tirupati, Andhra Pradesh during 2015-2019 with 1st class. B.Tech project was on "Planning, Analysis, Design and Estimation of Multi-Storey Residential Buildings". Participated in some workshops like Interior Desinging 3 days work shop. Presently pursing masters in Structural Engineering at Jawaharlal Nehru Technological University Anantapur college of engineering (JNTUA), Participated in some workshops like how to make Smart villages, Earthquakes analysis, "Modern Day Bridges and Metro structures" organized by Indian Intitution of B ridge Engineers and also having knowledge on software like Etabs, Staadpro, 3Ds Max and Revit. Committed to delivering innovative solutions for complex construction projects. And done some projects under Panchayat raj & Rural development Department and Rural Drinking Water & sanitation department Andhra Pradesh.

**B. Ajitha**, Associate Professor, Departemnt of Civil Engineering, JNTUA College of Engineering, Anantapuramu, India. Completed her M.Tech in 2012 and B.tech in 1998, Civil and Structural Engineering from JNTUH. Always rated as a very good teacher by the students. The various subjects taught at U.G. & P.G level. She served as the Officer In-charge of the Academic Section, overseeing examination-related tasks, including confidential responsibilities such as paper evaluation and result publication, at the Academic Section for a period of two years, from March 2010 to March 2013. Additionally, she serves as the Coordinator for the SC/ST Students Book Bank at J.N.T.U.A. College of Engineering Anantapur since March 2008 to the present day. From March 2013 to April 2019, she fulfilled the role of Coordinator for the Central Library at J.N.T.U.A. College of Engineering Anantapur. Currently, she continues to serve as the Coordinator for the Women Empowerment Cell at J.N.T.U.A. College of Engineering Anantapur since April 2019."

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