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# Experimental Investigation On Properties Of Concrete Using Manufactured Sand Granite Powder And Bottom Ash As Partial Replacement Of Fine Aggregate

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**Abstract:** This experimental study investigates the influence of granite powder and bottom ash as partial replacements in manufactured sand (M-sand) on the properties of concrete. Fine aggregates play a crucial role in determining the strength and durability of concrete. However, natural sand resources are depleting, prompting the need for sustainable alternatives. Manufactured sand, a byproduct of crushed stone, offers a viable substitute. In this study, granite powder and bottom ash were used to partially replace M-sand in varying proportions (10%, 20%, 30%, 40%, and 50%) to analyze their effects on fresh and hardened properties of concrete. Standard M30 grade concrete was used to maintain consistency across all mixes. Tests such as workability, compressive strength, split tensile strength, and flexural strength were conducted at 7 and 28 days of curing. The results indicate that moderate replacement levels improved certain strength parameters, while higher replacements led to marginal reductions in strength. This study promotes the utilization of industrial and construction waste in concrete, enhancing sustainability and minimizing environmental impact.

**Key Words:** Granite Powder, Bottom Ash, M-Sand, Crushed Stone, Workability, Compressive Strength, Flexural Strength & Split-Tensile Strength.

## I) INTRODUCTION

Concrete is the most widely used construction material across the globe. With an ever-increasing demand for infrastructure development, there has been an exponential rise in the consumption of concrete, and consequently, its constituents such as cement, fine aggregates (sand), coarse aggregates, and water. Among these, fine aggregates play a significant role in determining the workability, strength, and durability of concrete. Traditionally, river sand has been the most commonly used fine aggregate. However, the excessive exploitation of river sand has led to ecological imbalance, degradation of riverbeds, and a significant depletion of this non-renewable resource.

To address these environmental concerns and to reduce the dependency on natural river sand, the construction industry has been exploring alternative fine aggregates. Manufactured sand (M-sand), a by-product obtained from crushing hard stones, has gained acceptance as a viable substitute. M-sand offers uniform grading and better strength parameters due to its angular texture, but concerns about its workability and higher water demand remain.

The innovative idea of combining M-sand with granite powder and bottom ash for partial replacement in concrete provides a two-fold advantage: it addresses environmental pollution caused by the disposal of industrial wastes and offers a sustainable alternative to river sand. This study focuses on replacing M-sand with a combination of granite powder and bottom ash in varying percentages (10%, 20%, 30%, 40%, and 50%) and evaluating their impact on the fresh and hardened properties of concrete.

## II. Literature reviews presented in a tabular format

| Sl. No. | Author(s) & Year | Focus / Material Used | Key Findings |
|---|---|---|---|
| 1 | Ilangovana et al. (2008) | M-sand | M-sand improves strength due to angular shape; reduces workability slightly; promotes sustainability. |
| 2 | Manasseh (2010) | Granite powder | 30% replacement improves strength; excessive use reduces workability; enhances density and cost-effectiveness. |
| 3 | Rajamane et al. (2013) | Granite powder in HPC | Improved packing density and compressive strength; best at 20–30% replacement; granite acts as a micro-filler. |
| 4 | Deepa et al. (2014) | Bottom ash | Strength increases up to 30%; further replacement lowers strength due to porous texture; suitable with proper mix design. |
| 5 | Mahendran & Nagarajan (2011) | Granite dust with M-sand | Best strength at 30% granite dust; high content reduces workability; results in denser concrete. |
| 6 | Naidu et al. (2013) | Bottom ash | Low replacements (10–20%) improve strength; high replacements weaken mix; recommended for non-structural concrete. |
| 7 | Gopalakrishnan et al. (2016) | Granite powder | Enhances sulfate resistance and durability; strength gain up to 30%; supports sustainable usage in mass concrete. |
| 8 | Parashar & Parashar (2011) | Granite powder & Bottom ash | Granite boosts early strength; bottom ash gives delayed but better long-term strength; hybrid use balances performance. |
| 9 | Khan & Siddique (2013) | Bottom ash | Improves acid/chloride resistance at 20–30%; blends with mineral admixtures enhance durability. |
| 10 | Prabha et al. (2014) | Granite dust in SCC | Enhances flowability and compressive strength up to 25%; excessive granite dust reduces workability. |

| | | | |
|---|---|---|---|
| 11 | Kirthika & Brindha (2015) | Bottom ash with M-sand | SEM showed good bond at 20% replacement; suitable in HVFA concrete; microstructural performance was satisfactory. |
| 12 | Kumar & Dhinakaran (2012) | Granite powder | Strength increases with 20–30% replacement; enhances packing density; supports use in high-strength concrete. |
| 13 | Patil et al. (2014) | Granite powder & Bottom ash | Granite enhances early strength; bottom ash improves durability; combination is sustainable and cost-effective. |
| 14 | Shetty & Rao (2015) | Bottom ash | Improves workability due to spherical particles; best strength at 25%; suggested for pavements and slabs. |
| 15 | Balamurugan & Perumal (2013) | Granite powder | Reduces shrinkage and water absorption; increases durability; useful for water-retaining structures. |
| 16 | Hemalatha & Ramasamy (2017) | Bottom ash | Provides thermal resistance; suitable for lightweight and eco-friendly concrete; supports lifecycle cost savings. |
| 17 | Raghavendra et al. (2019) | M-sand + Granite powder | Strength improves up to 30% replacement; higher percentages cause cohesiveness loss; optimal blending needed. |
| 18 | Raju & Reddy (2016) | Bottom ash | Flexural strength increases at 20–30%; reduces autogenous shrinkage; improves elasticity. |
| 19 | Thirugnanasambantham et al. (2018) | M-sand + Granite + Bottom ash | Best results with 20% granite + 10% bottom ash; improved strength, workability, and thermal properties. |
| 20 | Anand et al. (2020) | Granite powder | Enhances high-strength concrete properties; reactive granite improves hydration; promotes sustainable cement replacement. |

## III. SCOPE AND OBJECTIVES

### 3.1 SCOPE OF THE PROJECT

1. The project is limited to M30 grade concrete.
2. M-sand is used as the base fine aggregate, partially replaced with a combination of granite powder and bottom ash.
3. Replacement levels studied are 10%, 20%, 30%, 40%, and 50% by weight of fine aggregate.
4. The study includes the evaluation of both fresh properties (workability) and hardened properties (compressive, tensile, and flexural strength).
5. The curing periods for strength tests are 7, 14, and 28 days.
6. The study focuses on laboratory conditions and may require further validation for field implementation.

### 3.2 OBJECTIVES

1. To investigate the effects of partial replacement of M-sand with granite powder and bottom ash on the properties of concrete.
2. To study the workability, compressive strength, split tensile strength, and flexural strength of concrete with varying replacement percentages.
3. To determine the optimal percentage of replacement (between 10% and 50%) that yields maximum performance.
4. To promote sustainable development by utilizing industrial by-products in concrete.
5. To provide recommendations for practical applications of the modified concrete mix in structural and non-structural elements.

## IV. METHODOLOGY

* Literature survey
* Collection of materials
* Study of materials properties
* Mix Design
* Casting and Testing
* Comparison of results to the conventional mix result
* Results and conclusion
* Conclusion
* References

## V. Mix Design for M30 Grade Concrete

| Material | Quantity (kg/m³) |
|---|---|
| Cement | 356 |
| Water | 149 |
| Fine Aggregate (M-sand + GP/BA) | 779 |
| Coarse Aggregate (20 mm) | 1191 |
| Superplasticizer | 3.2 |

**For 10% Replacement with Granite Powder**

M-sand: 701.1 kg (90%)

Granite Powder: 77.9 kg (10%)

Cement: 356 kg

Water: 149 kg

Coarse Aggregate: 1191 kg

Superplasticizer: 3.2 kg

## VI. TESTING

### 6.1 PREPARATION OF SPECIMENS

#### 6.1.1 Size of the specimens

Size of cube:150x150x150mm

#### 6.1.2 Casting of moulds

Casting of cement mixes typically involves the use of moulds to create objects or structures out of cement based mixtures. The process is similar to other casting processes in that a liquid material is poured into a mould and allowed to solidify, taking on the shape of the mould cavity.

Fig.6.1 Casting of moulds

**The casting of cement mixes typically involves the following steps**

1. Preparation of the mould: The mould is prepared by applying a release agent or coating to prevent the cement mixture from sticking to the mould

2. Mixing of the cement mixture: The cement mixture is prepared by mixing cement, sand, aggregates and water to form a workable mixture.

3. Pouring of the mixture: The cement mixture is poured into the mould and allowed to settle and consolidate

4. Curing: The cement mixture is allowed to cure, typically by being kept in a moist environment, to allow the cement to harden and develop the required strength.

5. Demoulding: Once the cement has hardened, the casting is removed from the mould and may be further processed, finished or cured

### 6.2 TESTING OF SPECIMENS

Three types of tests were conducted in this study, they are compressive strength test, splitting tensile strength test and flexural strength test. compressive strength test is performed for cube specimens, splitting tensile strength test is performed for cylindrical specimens and flexural strength test is performed for beam specimens. concrete cube specimens of dimensions Length=15cm,Breadth=15cm and Height =15cm were made by different fractions of polyvinyl alcohol fiber and basalt fiber with 15% of glass powder as a partial replacement of fine aggregate of 24 samples for 7 days and 24 samples for 28 days test as a total sample of 48 cube specimens were casted. Cylindrical specimen of dimensions 15cm diameter and 30cm height were made by different fractions of polyvinyl alcohol fiber and basalt fiber with 15% of glass powder as a partial replacement of fine aggregate of 24 samples for 7 days and 24 samples for 28 days test as a total sample of 48 cylindrical specimens were casted.


**Fig.6.2 Compression and tensile strength testing machine**

#### 6.2.1 Compressive strength

The capacity of a material or structure to support loads on its surface without cracking or deflecting is known as compressive strength. When a material is compressed, its size tends to decrease, and when it is stretched, its size elongates. Compressive strength formula for any material is the load applied at the point of failure to the cross-section area of the face on which load was applied.

Compressive Strength = Load / Cross-sectional Area

The compressive strength was calculated in Mpa

$F_C = P/A$

Where FC =compressive strength (N/mm2) P = ultimate load (N)

A = loaded cube specimen (150mm x 150mm)

Specifically, 150mmx150mmx150mm cubes are utilised for this test.

| Mix ID | Replacement Material | % Replacement | 7 Days (MPa) | 28 Days (MPa) |
|---|---|---|---|---|
| **CM** | — | 0 | 26.5 | 38.2 |
| **GP10** | Granite Powder | 10% | 27.4 | 39.8 |
| **GP20** | Granite Powder | 20% | 28.1 | 40.2 |
| **GP30** | Granite Powder | 30% | 27.8 | 39.6 |
| **GP40** | Granite Powder | 40% | 25.2 | 36.4 |
| **GP50** | Granite Powder | 50% | 23.9 | 34.7 |
| **BA10** | Bottom Ash | 10% | 26.9 | 38.7 |
| **BA20** | Bottom Ash | 20% | 27.2 | 39.5 |
| **BA30** | Bottom Ash | 30% | 26.5 | 38.3 |
| **BA40** | Bottom Ash | 40% | 25.1 | 36.1 |
| **BA50** | Bottom Ash | 50% | 23.8 | 34.0 |

## VII. RESULTS AND DISCUSSIONS

### 7.1 INTRODUCTION

**Table 7.1 compressive strength of 7 days test**

| Mix ID | Replacement Material | % Replacement | 7 Days (MPa) |
|---|---|---|---|
| **CM** | — | 0 | 26.5 |
| **GP10** | Granite Powder | 10% | 27.4 |
| **GP20** | Granite Powder | 20% | 28.1 |
| **GP30** | Granite Powder | 30% | 27.8 |
| **GP40** | Granite Powder | 40% | 25.2 |
| **GP50** | Granite Powder | 50% | 23.9 |
| **BA10** | Bottom Ash | 10% | 26.9 |
| **BA20** | Bottom Ash | 20% | 27.2 |
| **BA30** | Bottom Ash | 30% | 26.5 |
| **BA40** | Bottom Ash | 40% | 25.1 |

| | | | |
|---|---|---|---|
| **BA50** | Bottom Ash | 50% | 23.8 |

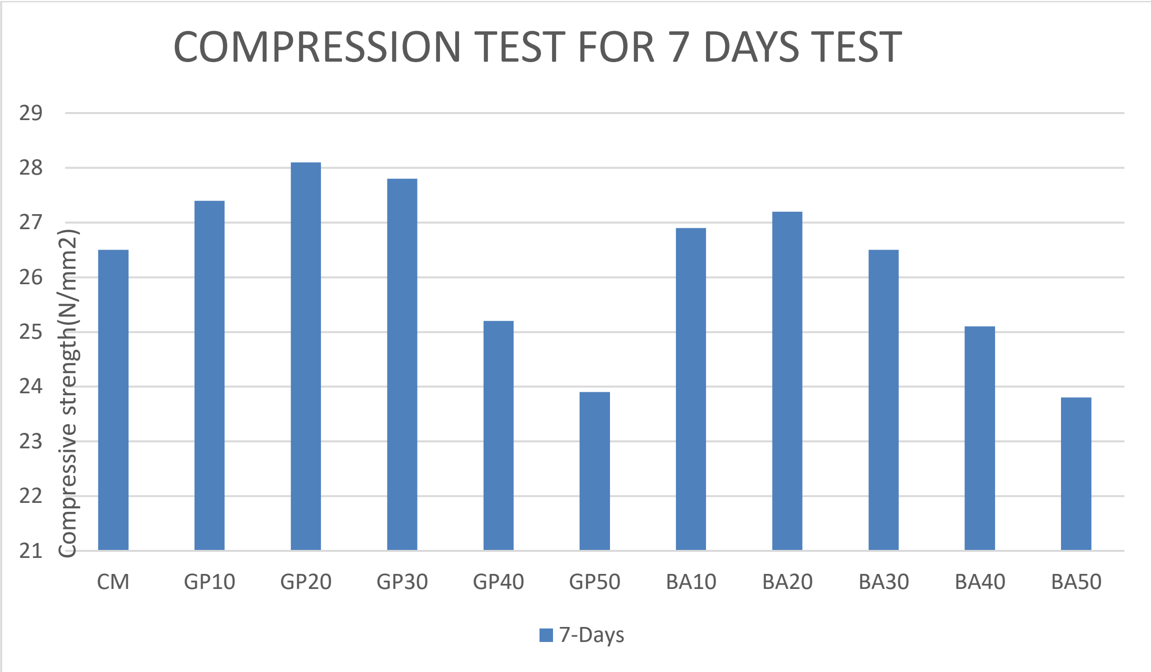


**Fig.7.1 Compression test for 7 days test**

**Table 7.2 compressive strength of 28 days test**

| Mix ID | Replacement Material | % Replacement | 28 Days (MPa) |
|---|---|---|---|
| **CM** | — | 0 | 38.2 |
| **GP10** | Granite Powder | 10% | 39.8 |
| **GP20** | Granite Powder | 20% | 40.2 |
| **GP30** | Granite Powder | 30% | 39.6 |
| **GP40** | Granite Powder | 40% | 36.4 |
| **GP50** | Granite Powder | 50% | 34.7 |
| **BA10** | Bottom Ash | 10% | 38.7 |
| **BA20** | Bottom Ash | 20% | 39.5 |
| **BA30** | Bottom Ash | 30% | 38.3 |
| **BA40** | Bottom Ash | 40% | 36.1 |
| **BA50** | Bottom Ash | 50% | 34.0 |

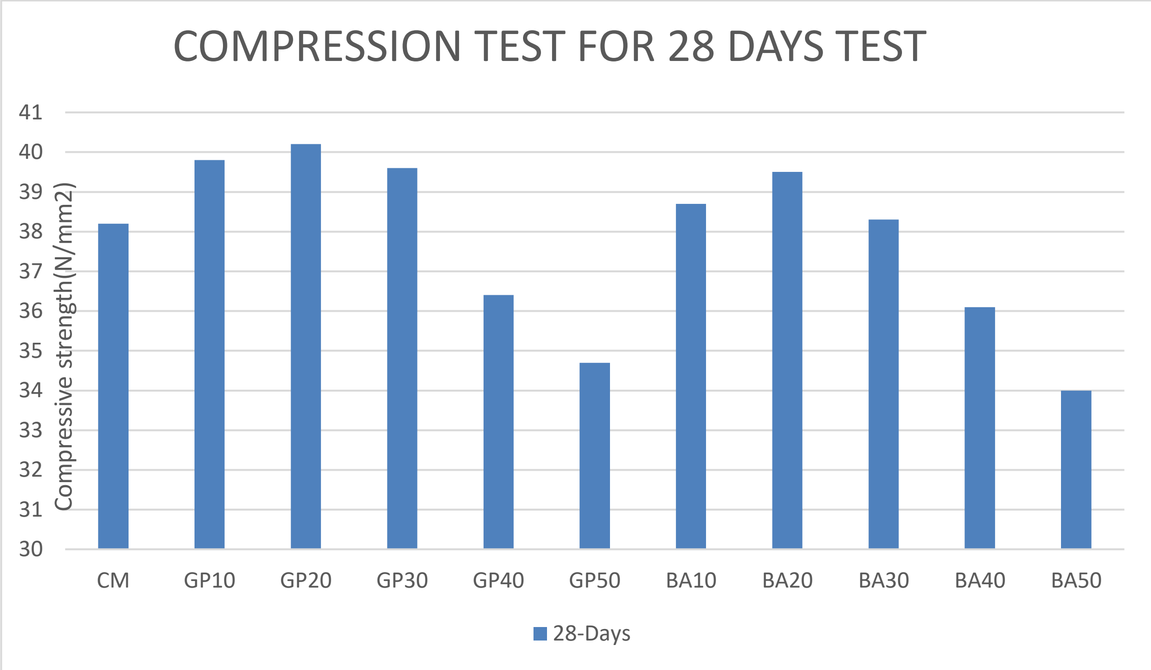


**Fig.7.2 Compression test for 28 days test**

**Table 7.3 compressive strength of 7 and 28 days test**

| Mix ID | Replacement Material | % Replacement | 7 Days (MPa) | 28 Days (MPa) |
|---|---|---|---|---|
| **CM** | — | 0 | 26.5 | 38.2 |
| **GP10** | Granite Powder | 10% | 27.4 | 39.8 |
| **GP20** | Granite Powder | 20% | 28.1 | 40.2 |
| **GP30** | Granite Powder | 30% | 27.8 | 39.6 |
| **GP40** | Granite Powder | 40% | 25.2 | 36.4 |
| **GP50** | Granite Powder | 50% | 23.9 | 34.7 |
| **BA10** | Bottom Ash | 10% | 26.9 | 38.7 |
| **BA20** | Bottom Ash | 20% | 27.2 | 39.5 |
| **BA30** | Bottom Ash | 30% | 26.5 | 38.3 |
| **BA40** | Bottom Ash | 40% | 25.1 | 36.1 |
| **BA50** | Bottom Ash | 50% | 23.8 | 34.0 |

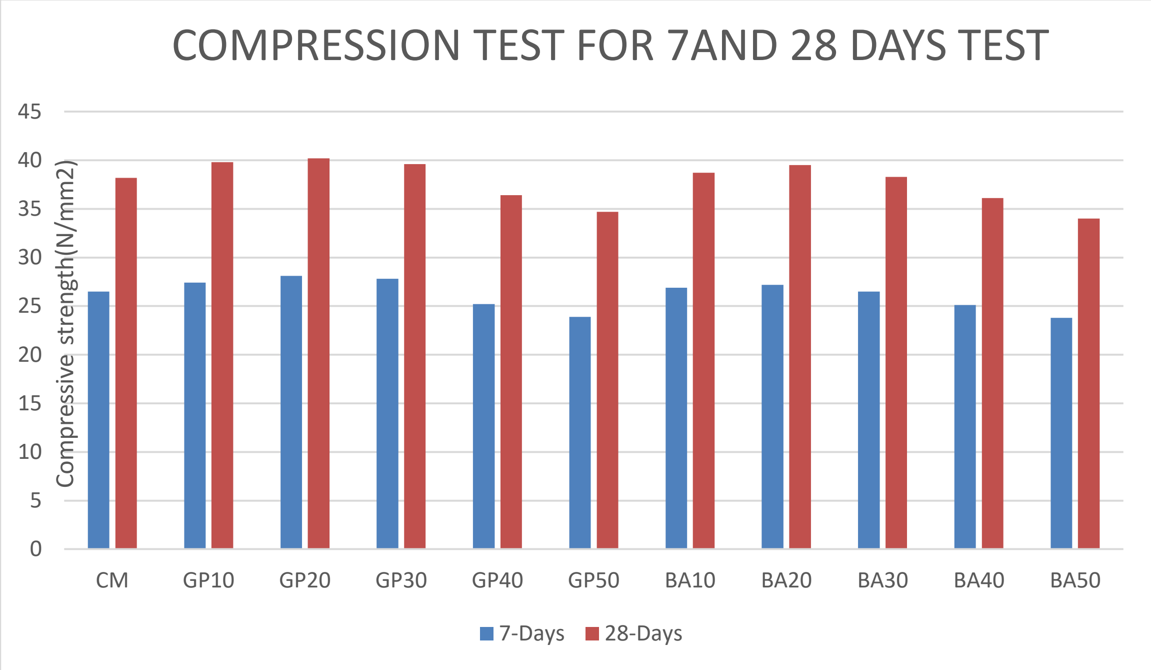


**Fig.7.3 Compression test for 7 and 28 days test**

## 7.2 DISCUSSIONS

### 7.2.1 Control Mix (CM)

At 28 days, the control mix reached 38.2 MPa, which confirms the target strength for M30 grade concrete.

### 7.2.2 Granite Powder Mixes

**GP10 and GP20**: Showed an improvement in strength compared to the control mix.

This is due to the **micro-filling effect** of fine granite powder, which improves the **packing density** and reduces voids.

**GP30**: Maintained strength close to the optimum.

**GP40 and GP50**: Showed a **decrease in strength**.

At higher levels, granite powder behaves more like a filler than a fine aggregate, reducing the effective binding and load distribution.

### 7.2.3 Bottom Ash Mixes

**BA10 and BA20**: Improved or maintained compressive strength.

Bottom ash's **porous structure and pozzolanic nature** may contribute to secondary cementitious reactions.

**BA30**: Slight reduction, yet within acceptable limits.

**BA40 and BA50**: Further reduction in strength.

Possibly due to reduced density, increased porosity, and poor interlocking between particles and the cement matrix.

## VIII. CONCLUSIONS

**1.Optimum Replacement Level:**

- 20% replacement of M-sand with Granite Powder (GP20) and Bottom Ash (BA20) provided the best compressive strength, exceeding the control mix.

**2.Granite Powder Effectiveness:**

- Enhanced compressive strength at 10–20% due to better packing and reduced porosity.
- Beyond 30%, it leads to strength loss due to insufficient aggregate interlock.

**3.Bottom Ash Performance:**

- Acts as a pozzolanic filler at lower levels, improving hydration and strength.
- At higher levels, it weakens the mix due to lower particle strength and high porosity.

**4.Sustainability Aspect:**

- Both materials offer a viable and eco-friendly alternative to natural fine aggregates when used in limited percentages.

**5.Structural Recommendation:**

- For structural applications requiring high strength and durability, do not exceed 20–30% replacement.
- Further studies on long-term durability (chloride attack, sulphate resistance) are recommended for large-scale applications.

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