Abstract
Granite sludge powder generates in processing activities of granite stone, such as cutting, polishing and finishing process. This contributes of about 30% wastage in these processes. As granite sludge powder is non-biodegradable waste, it has to be effectively disposed without creating environmental hazards. In our present study the objectives are to prepare Granite Sludge blocks of size 230×110×70(mm) for varying mix proportions such as 20%, 30%, 40%, 50%, 60%, and 70% for granite sludge powder and sand, by keeping lime 8% and gypsum 2% as constant. To find Mechanical properties such as Compressive strength, Flexural strength and Water absorption, where maximum compressive strength value for 7 days of 5.54 MPa, maximum flexural strength of 2.17 MPa and maximum breaking load 4.33kN was obtained for A3 block type. Water absorption of granite sludge blocks increases with increase in addition of granite sludge powder in mix proportions, yet it is in limit as per IS code specifications. Utilizing granite sludge powder for manufacturing of granite sludge masonry blocks is one of efficient manner to minimize the disposal problems of granite sludge powder.
1. Introduction
Traditionally burnt bricks constitute the basic masonry unit for the construction of houses and it is well known that manufacturing requires significant quantities of energy to produce burnt bricks while utilizing the topsoil. Also, continuous removal of topsoil for production of conventional bricks creates environmental hazards. Hence, there is a strong need to adopt cost effective and sustainable technologies using local materials to produce alternatives for burnt clay bricks.

Recent development in the modern civilization has led to the increased industrial production to meet the needs of the people. The production of every product results in some waste end products, known as industrial waste. Leaving waste materials to the environment directly can cause environmental problems. Hence reuse of waste materials has been incorporated with recent techniques from past & present scholars to minimize the environmental hazards. Bulky waste, such as the wastes from the granite industry can be utilized by the construction industry, which is one of the most technologically active sectors. Both waste materials as resource and recycled products, utilized by the sector reduce the cost of the project. The use of wastes as an alternative to raw materials in the brick industry, which constitutes part of the construction activity, contributes to the diversification of basic raw materials in the manufacturing process of bricks and tiles and reduces the costs in a building.

Generation of large amount of wastes in the granite industrial sector is in the form of fine dust and sludge which are composed majorly of silicon dioxide, aluminum oxide, ferrous oxide and calcium oxide due to their sawing and polishing process, they can bring about genuine harm to nature, for example, soil and underground water defilement, if not proficiently treated before disposal. The reusing of granite wastes in the brick industry has pulled in mechanical consideration in the most recent years because of the likelihood of lessening the expense of creation, utilization of residue as a secondary raw material in the production.

2. Problem Context
Granite stones have vast application in the field of construction due to their nature of origin. Some of it applications are for size stone masonry, granite flooring slabs, as coarse aggregate in concrete etc. During the process of manufacturing granite flooring slabs which are used for flooring purpose in commercial and residential buildings, about 30% waste is generated in various processing activities. This granite sludge waste generated has negative impact to our environment. Hence reuse of this material need to be considered to minimize the disposal problems of granite sludge.

3. Problem Definition
In this experimental study, strength and other required parameters are evaluated by preparing Granit sludge masonry blocks using granite sludge powder 20% -70%, sand 70% -20%, lime 8% and gypsum 2% of varying mix proportions, by keeping in view fly ash bricks as principal reference. Granite sludge powder is collected from local granite stone processing unit and other materials are purchased from local market. The tests are conducted in order to study the strength characteristics such as compressive strength and flexural strength and water absorption. The results obtained will be cross checked with IS code specifications.

4. Experimental materials

4.1 Granite Sludge Powder
Granite sludge powder which results in processing activities of granite stone for flooring slabs such as cutting, polishing and finishing process. This contributes of about 30% wastage in these processes, which is non-biodegradable waste.

Figure 4.1: Granite Sludge Powder

4.2. Fine aggregate

Natural river sand which is locally available has been selected for the dissertation work. The sand was tested for their physical characteristic according to the relevant IS code provisions.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Physical properties of fine aggregates</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity</td>
<td>2.67</td>
</tr>
<tr>
<td>2</td>
<td>Fines modulus</td>
<td>2.507</td>
</tr>
<tr>
<td>3</td>
<td>Grading zone</td>
<td>3</td>
</tr>
</tbody>
</table>

4.3. Lime

Lime as binding material has been made use since ancient times in our country. But at present, the cement revolutionary has replaced usage of lime to great extent. And on other hand, scholars say that the manufacture of cement leads to Global warming, in this present study locally available lime of class-C (hydrated lime)

4.4. Gypsum

Gypsum is a naturally occurring mineral of sedimentary rock category which constitute of hydrated sulphate of calcium. Property of gypsum is such it has very poor solubility in water, which sets and hardens quickly. Gypsum of high purity is generally used as fertilizer in our country, such as ammonium sulphate fertilizer and low purity in manufacturing of ordinary Portland cement to act as a retarder, controlling setting time of cement. Here low purity gypsum is used as retarding agent in the mix proportions of granite sludge blocks.
5. Methodology

5.1. Mix Proportions

Keeping in view with fly ash bricks, granite sludge blocks are produced by varying percentage of granite sludge powder by 20%, 30%, 40%, 50%, 60% & 70%. Table 5.1 shows Mix proportions for various blocks to analyse in our study.

Table 5.1: Mix Proportions for various block types

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Type</th>
<th>G.S.P</th>
<th>Sand</th>
<th>Lime</th>
<th>Gypsum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₁</td>
<td>20%</td>
<td>70%</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>2</td>
<td>A₂</td>
<td>30%</td>
<td>60%</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>3</td>
<td>A₃</td>
<td>40%</td>
<td>50%</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>4</td>
<td>A₄</td>
<td>50%</td>
<td>40%</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>5</td>
<td>A₅</td>
<td>60%</td>
<td>30%</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>6</td>
<td>A₆</td>
<td>70%</td>
<td>20%</td>
<td>8%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Quantity of ingredients required for one Granite sludge block

Size of granite sludge blocks = 230 × 110 × 70 (mm)
Volume of block moulds = 0.23 × 0.11 × 0.07 (m)
Mass = Density × Volume
Mass of one Granite sludge block = 1800 kg/m³ × 1.771X10⁻³ m³
= 3.18 kg + 10% wastage
= 3.5 kg

For A₁ block type

Quantity of Granite sludge powder = Mass of solids × % of granite sludge powder requirement
= 3.5 × 0.2 = 0.7 kg
Quantity of sand = Mass of solids × % of sand requirement
= 3.5 × 0.7 = 2.45 kg
Quantity of Lime = Mass of solids × % of Lime requirement
= 3.5 × 0.08 = 0.28 kg
Quantity of Gypsum = Mass of solids × % of Gypsum requirement
= 3.5 × 0.02 = 0.07 kg

Above mix proportion method is followed for various mix proportions of Granite Sludge

5.3 Mixing

The granite sludge powder is ensured its dry and by visual examination any gravels or debris are removed if any, the granite sludge powder, sand and gypsum are mixed dry till it attains uniformity. Then the hydrated fat lime which is sand drained over night to remove excess water from lime is also mixed along with water for about 3- 4 minutes till the mix becomes cohesive.
5.4 Casting
The mixture is filled in 230 x 110 x 70 (mm) wooden mould in three layers and compacted by tamping 25 times each layer by using tamping rod. And the top layer is smooth finished by using a trowel. After which the specimen is allowed to dry for 24hrs in the mould itself.

5.5 Curing
The granite sludge blocks are de-moulded after 24hrs from the wooden moulds after casting and are water cured for 7 days by covering wet gunny bags.

5.6 Testing
After 7 days of water curing granite sludge blocks are tested to know its compressive strength, flexural strength, percentage of water absorption.

6. Results and Discussions

6.1 Compressive Strength Test
7 days compressive strength test for Granite sludge masonry blocks of mix proportions of 20%, 30%, 40%, 50%, 60%, and 70% were carried out as per IS code 3495:1992.

Table 6.1: Compressive strength test values

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Type</th>
<th>7 days Compressive load in (kN)</th>
<th>Avg Compressive strength in (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₁</td>
<td>70</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td>A₂</td>
<td>92</td>
<td>83</td>
</tr>
<tr>
<td>3</td>
<td>A₃</td>
<td>138</td>
<td>144</td>
</tr>
<tr>
<td>4</td>
<td>A₄</td>
<td>114</td>
<td>119</td>
</tr>
<tr>
<td>5</td>
<td>A₅</td>
<td>94</td>
<td>88</td>
</tr>
<tr>
<td>6</td>
<td>A₆</td>
<td>66</td>
<td>62</td>
</tr>
</tbody>
</table>

Length of Granite sludge block, l=230(mm)
Breadth of Granite sludge block, b= 110 (mm)
Area of the Granite sludge block, A=l x b=25300(mm)²

6.1.1 Observation and Discussion on Compressive Strength Test

![Figure 6.1: Bar chart representation of compressive strength (MPa) v/s Block Types](image)
The compressive test result shows that, A₃ block type has obtained maximum compressive strength value of 5.54 N/mm² after which the compressive strength drops down due to the increase in powder content and particle size distribution of granite sludge powder in the mix proportions. Since maximum compressive strength obtained is 5.54 N/mm², it belongs to class 5 designation as per IS code 1077:1992.

6.2 Flexural Strength

The flexural test on granite sludge blocks was conducted as per IS 15658: 2006 code specifications, which specifies breaking load and flexural strength for pre-cast concrete blocks for paving. Table 6.2 shows flexural strength values for different granite sludge block types.

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Type</th>
<th>Breaking load (kN)</th>
<th>Avg Breaking load (kN)</th>
<th>Flexural strength $f_b = \frac{3Pl}{2bd^2}$ (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₁</td>
<td>3  2  3</td>
<td>2.67</td>
<td>1.33</td>
</tr>
<tr>
<td>2</td>
<td>A₂</td>
<td>4  3  3</td>
<td>3.33</td>
<td>1.67</td>
</tr>
<tr>
<td>3</td>
<td>A₃</td>
<td>4  5  4</td>
<td>4.33</td>
<td>2.17</td>
</tr>
<tr>
<td>4</td>
<td>A₄</td>
<td>5  4  2</td>
<td>3.67</td>
<td>1.83</td>
</tr>
<tr>
<td>5</td>
<td>A₅</td>
<td>2  2  2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>A₆</td>
<td>1  2  1</td>
<td>1.33</td>
<td>0.67</td>
</tr>
</tbody>
</table>

$f_b$ = flexural strength, in N/mm².
P = Breaking load, in N.
l = distance between central lines of supporting rollers. ie, overall length of the specimen minus 50mm (230 – 50 = 180mm)
b = width of the block, 110mm.
d = thickness of the block, 70mm

6.2.1 Observation and Discussion on Flexural Strength

![Figure 6.2 Flexural strength (MPa) v/s Block Types](image-url)
IS code 15658: 2006 specifies following minimum breaking load values to be considered for using in pavers for different aspects of application such as:

- For residential and public pedestrian pathways, minimum breaking load of 2kN
- Residential driveways, minimum breaking load of 3kN
- Commercial vehicle pathway, minimum breaking load of 5kN
- For trafficked roads, minimum breaking load of 6kN
- Heavy duty industrial roads, minimum breaking load of 7kN

By considering specifications, the average maximum breaking load of 4.3kN was achieved in our present study. Hence granite sludge block concept can be adopted in manufacturing of precast paver blocks of required size/shape and used as paver block for residential driveways.

As with flexural strength of granite sludge blocks, the maximum strength value of 2.17 N/mm² was observed for A3 block type, after which the flexural strength reduces significantly. Where it is also noted that flexural strength as low as 0.67 N/mm² for A6 block type which might be due to the high granite sludge powder content and insufficient binding agent in the mix proportion.

6.3 Water Absorption Test

Water absorption test for different mix proportions of Granite sludge blocks were carried out as per IS code 3495:1992 and are tabulated in table 6.3.

**Table 6.3 Water absorption test values**

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Type</th>
<th>M1 in kg</th>
<th>M2 in kg</th>
<th>Average (M2–M1 × 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1</td>
<td>3.89</td>
<td>3.77</td>
<td>3.94</td>
</tr>
<tr>
<td>2</td>
<td>A2</td>
<td>3.8</td>
<td>3.77</td>
<td>3.72</td>
</tr>
<tr>
<td>3</td>
<td>A3</td>
<td>3.67</td>
<td>3.56</td>
<td>3.83</td>
</tr>
<tr>
<td>4</td>
<td>A4</td>
<td>3.79</td>
<td>3.92</td>
<td>3.69</td>
</tr>
<tr>
<td>5</td>
<td>A5</td>
<td>3.73</td>
<td>3.98</td>
<td>3.79</td>
</tr>
<tr>
<td>6</td>
<td>A6</td>
<td>3.82</td>
<td>3.68</td>
<td>3.73</td>
</tr>
</tbody>
</table>

6.3.1 Observation and Discussion on Water Absorption

From fig 6.3 it can be clearly seen that percentage of water absorption increases with increase in addition of granite sludge powder for various block types. The maximum water absorption rate is for A6 block type which
constitutes 70% of granite sludge powder in mix. But none of the granite sludge blocks from A₁ – A₆ as water absorption rate beyond IS code 1077:1992 specification, which specifies water absorption rate not to be more than 20% by weight for blocks up to 12.5 class designation. Where as in our study, the maximum water absorption rate is 11.74% for class 5 masonry block, which is well within the limiting value of 20%.

7. Conclusion
The following conclusions can be drawn from the results of the present study;
1. By using granite sludge powder as prime material granite sludge masonry blocks of size 230×110×70 (mm) is casted for varying mix proportions of 20%,30%,40%,50%,60% and 70% for granite sludge powder and sand, by keeping lime 8% and 2% gypsum as constant.
2. Maximum Compression strength value for 7 days of 5.54 MPa was obtained for A₃ block type, which conforms to class 5 masonry blocks according to IS 3495:1992, which specifies minimum compressive strength of 3.5MPa for masonry blocks.
3. Maximum Flexural strength of 2.17MPa for A₃ block type is observed. The maximum breaking load 4.33kN was noted for A₃ block type, while conducting flexural strength test.
4. Water absorption in granite sludge blocks increases with increase in addition of granite sludge powder in mix proportions. But the water absorption values of all the granite sludge blocks A₁-A₆ are within the limit as specified by IS code 1077:1992, which specifies maximum percentage of water content should not exceed 20% by weight of the specimen.
5. Utilizing granite sludge powder for manufacturing of granite sludge masonry blocks is one of efficient manner to minimize the disposal problems of granite sludge powder.

References
Sabarinath N, Prof. Virendra Kumara K N, Dr. S B Anadinni : Experimental Study on Granite Sludge Blocks


**IS Codes**

[20] IS 3495 (Parts 1 to 4) : 1992 Methods of Tests of Burnt Clay Building Bricks