An investigation of laterite as fine aggregate to develop eco-friendly mortar

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Abstract. Major objective of the study was to examine the suitability of laterite as fine aggregate in mortar. Conventional Cement mortar was prepared using river sand for different cement mortar ratios from 1:3, 1:2 and 1:6. Replacing the natural sand by laterite and manufactured sand by laterite for the replacement level of 20, 40 and 60\% were cured at room temperature and tested in accordance with IS:2250-1981. Water absorption and durability tests (sulphate attack, chloride attack and acid attack) are conducted after the initial curing of mortar cubes. Compressive strength of masonry was examined by testing masonry prisms. The test result shows that up to 40\% of replacement of laterite in river sand and manufactured sand is suitable for masonry work. The rebound losses, has a moderate impact on the workmanship of the masonry work.

1. Introduction

The need of locally available building materials in developing countries is very essential because of the expensive conventional building materials coupled with shortage of such building materials. The demand of mortar for plastering, masonry work is very high due to the rapid growth of infrastructure development in India. Fine aggregate is a major constituent of mortar. Hence the availability and cost of fine aggregate determines the viability and economy of mortar. Natural sand from the river bed is the traditional sources of fine aggregate. But due the huge demand, the river sand source gets depleted and excessive explorations create serious environmental problems. In the present scenario of sustainable infrastructural development demands the need of alternative cost-effective building material that should satisfy technical requisites of fine aggregate as well as it should be abundantly available in locally.

The fines of laterite (particle sizes < 10mm) known to have some similar physical characteristics as conventional sand which an alternative of fine aggregate can be. In Kerala -more than 60\% of the state is covered by laterite blanket over various crystalline rocks and used as building materials from thousands of years back. Although, its use as an extensive construction material, it is hardly accepted due to insufficient technical data, hence limiting its wider application in the form as ingredient in mortar.
There are large number of investigation was carried out throughout the world for replacing natural sand with alternative material such as manufactured sand. The study on replacement of natural sand with laterite is negligibly small. Olubisi A. Ige(2013) describes the compressive strength of laterized mortar with laterite-fine aggregate ratio variation decreases when subjected to alternate wetting and drying and increases when subjected to magnesium sulphate (Mg2SO4). It was also discovered that a laterized cement mortar with a laterite-fine aggregate ratio of 20% conditioned to a temperature range of 1000C attained optimum compressive strength.

2. Experimental investigation
Conventional Cement mortar was prepared using river sand for different cement mortar ratios from 1:3, 1:2 and 1:6. Replacing the natural sand by laterite for the replacement level of 20, 40 and 60 % were cured at room temperature and tested in accordance with IS:2250- 1981 for compressive strength after 3 days, 7 days, and 28 days of curing. Mortar cubes of size 50x50x50 mm were cast for the study. Water absorption and durability study was also carried out in this experimental investigation.

Compressive strength of masonry was examined by testing five brick high stack bonded masonry prisms. Prisms (size: 105 x 225 x 445 mm, having height to width ratio of 4.23) were prepared using burnt clay bricks using 1:2,1:3 and 1:6 cement mortar with replacement of laterite. The compression testing was performed according to Indian masonry code (IS: 1905–1987).

2.1. Compressive strength of mortar
The compressive strength tests were conducted on mortar cubes specimens of size 50 cm² face area. The cubes were tested after curing periods of 7 and 28 days. The results obtained for cube compressive strengths for 1:2, 1:3 and 1:6 ratio mortar for 7 day and 28 day are shown in Table 1 and Graphical representation depicted in Figure 1.

| Ratio | Mortar | Compressive strength |
|-------|--------|----------------------|
|       |        | 3 day (Mpa) | 7 day (Mpa) | 28 day (Mpa) |
|       | 1:2    | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 100% natural sand | 4 | 3 | 5 | 14 | 13 | 13 | 21 | 20 | 19 |
| 20% Laterite | 7 | 5 | 7 | 15 | 14 | 16 | 21 | 22 | 20 |
| 40% Laterite | 3 | 1 | 4 | 2 | 0 | 1 | 19 | 18 | 19 |
| 60% Laterite | 5 | 3 | 3 | 11 | 10 | 10 | 11 | 11 | 12 |
| 1:3    | 1:2    | 2 | 2 | 1 | 7 | 8 | 9 | 21 | 20 | 21 |
| 100% natural sand | 2 | 1 | 1 | 7 | 7 | 6 | 17 | 16 | 17 |
| 20% Laterite | 2 | 2 | 1 | 6 | 6 | 7 | 11 | 11 | 12 |
| 40% Laterite | 2 | 3 | 2 | 8 | 8 | 7 | 9 | 10 | 9 |
| 60% Laterite | 2 | 3 | 2 | 2 | 3 | 4 | 10 | 9 | 9 |
| 1:6    | 1:2    | 1 | 2 | 1 | 6 | 6 | 6 | 9 | 7 | 7 |
| 100% natural sand | 1 | 2 | 2 | 3 | 2 | 3 | 7 | 7 | 7 |
| 20% Laterite | 1 | 1 | 1 | 2 | 2 | 5 | 5 | 5 | 5 |
It is observed that gradual decrease in compressive strength for replacement of laterite with natural sand. The compressive strength is observed in 40 % replacement of laterite soil is above the minimum compressive strength and decreases with increasing the replacement content. The addition of laterite sand causes lower bonding strength between aggregates and cement as well as increase water requirement for workable cement mortar which in turn reduce the ability of mortar to sustain larger load.

Figure 1: Compressive strength of Mortar 1:2

Figure 2: Compressive strength of Mortar 1:3

Figure 3: Compressive strength Mortar 1:6
2.2. Compressive Strength of Masonry Prism

The test was conducted as per the specifications given in IS-1905 - 1987. Prism tested after 28 days normal wet curing. The prisms were held in proper position such that the load can applied gradually till the failure load is reached. The test specimen with flat face horizontal and mortar filled face facing upward between ply wood, and carefully cantered between ply wood were tested for compression by axially applied load at compression testing machine till the failure occurred.

Experimental value of Compressive strength of masonry prism was calculated as, maximum load taken by prism divided by the cross sectional area (200 mm x 95 mm). However a correction factor for different values of h/t ratio is to be applied; which is suggested by IS1905-1987 .For a present study the correction factor was 0.73 as the prism height was 400 mm and width is 200 mm. The values of compressive strength of masonry, obtained experimentally are provided in Table 2 .The Permissible Compressive Stress is obtained from Table 8 of IS – 1905 and Basic compressive strength is 0.25 $f_m$ where $f_m$ is the value of compressive strength of masonry as obtained from prism test.

| cement mortar | Replacement of sand | Compressive load (kN) | Compressive strength (N/mm$^2$) | Compressive strength (N/mm$^2$) after applying correction factor 0.73 |
|---------------|---------------------|------------------------|-------------------------------|-------------------------------------------------------------|
| 1:6 Natural Sand | 80 | 4.21 | 3.074 |
| 20 % Laterite | 90 | 4.73 | 3.458 |
| 40 % laterite | 95 | 5.0 | 3.65 |
| 60 % laterite | 90 | 4.73 | 3.45 |
| 1:3 Natural Sand | 130 | 6.842 | 4.999 |
| 20 % Laterite | 150 | 7.895 | 5.763 |
| 40 % laterite | 200 | 10.526 | 7.684 |
| 60 % laterite | 170 | 8.947 | 6.531 |
| 1:2 Natural Sand | 190 | 10 | 7.3 |
| 20 % Laterite | 200 | 10.526 | 7.684 |
| 40 % laterite | 240 | 12.632 | 9.221 |
| 60 % laterite | 240 | 12.632 | 9.221 |

The addition of laterite in cement mortar was found to increase the compressive strength of prisms averagely. For 1:2 ratio cement mortar, compressive strength increases 12.49 % than normal cement mortar, 5.26 % for 1:3 and 15.28 % for 1:6.
By referring all these results, it was found that 20-40 % replacement laterite shows the higher compressive strength.

2.2.1. Mode of failure
It has been observed each specimen that vertical cracks initiated the failure of masonry. Vertical splitting cracks were seen on all four sides of prism. Cracks were formed initially at the top of the prism where the load is applied then cracks spread in downward direction. The Crack pattern shows in Figure 5.

2.3. Water Absorption
The 70.7 mm x 70.7 mm x 70.7mm size mortar cube were prepared after that immersed in water for 28 days curing. Then these specimens were oven dried for 24 hours at the temperature85°C until the mass became constant and again weighed. After that the specimen was kept in water at 85°C for 24 hours. Then this weight was noted.
Table 3. Water absorption of the specimens

| Percentage replacement Cement mortar ratio | Cement mortar ratio | Dry weight(gm) | Wet weight(gm) | %water absorption |
|-------------------------------------------|---------------------|----------------|---------------|------------------|
| Natural Sand 1:2                          | 1:2                 | 790            | 801           | 1.39             |
| 20% Laterite 1:2                          | 1:2                 | 811            | 823           | 1.47             |
| 40% M sand 1:2                            | 1:2                 | 802            | 816           | 1.74             |
| 60% Laterite 1:2                          | 1:2                 | 754            | 779           | 3.31             |
| Natural Sand 1:3                          | 1:3                 | 757            | 770           | 1.71             |
| 20% Laterite 1:3                          | 1:3                 | 781            | 795           | 1.79             |
| 40% M sand 1:3                            | 1:3                 | 794            | 812           | 2.26             |
| 60% Laterite 1:3                          | 1:3                 | 792            | 825           | 4.16             |
| Natural Sand 1:6                          | 1:6                 | 698            | 717           | 2.72             |
| 20% Laterite 1:6                          | 1:6                 | 694            | 715           | 3.02             |
| 40% M sand 1:6                            | 1:6                 | 730            | 754           | 3.28             |
| 60% Laterite 1:6                          | 1:6                 | 762            | 796           | 4.41             |

Figure 6: Water absorption of Various Replacement level

2.4. Sulphate attack
Compressive strength and weight reduction for cubes immersed in magnesium sulphate solution for 28 and 90 days is found out. The concentration of MgSO$_4$ solution used is 20 g/lit. Weight loss and Compressive strengths of modified concrete mixes were compared with that of control mix.
Table 4. Effect of sulphate attack on weight and compressive strength

| Ratio | Specimen  | Weight of the specimen(gram) | Compressive strength(N/mm²) |
|-------|-----------|-------------------------------|----------------------------|
|       |           | Initial | 28 days | 90 days | 28 days | 90 days |
| 1:2   | Natural sand | 781   | 770     | 761     | 23      | 18      |
|       | 20% Laterite | 800   | 790     | 783     | 36      | 20      |
|       | 40% Laterite | 760   | 756     | 751     | 50      | 30      |
|       | 60% Laterite | 750   | 747     | 743     | 30      | 24      |
| 1:3   | Natural sand | 773   | 760     | 754     | 19      | 16      |
|       | 20% Laterite | 780   | 772     | 772     | 37      | 24      |
|       | 40% Laterite | 760   | 756     | 750     | 34      | 20      |
|       | 60% Laterite | 740   | 737     | 734     | 20      | 18      |
| 1:6   | Natural sand | 706   | 692     | 688     | 10      | 7       |
|       | 20% Laterite | 750   | 741     | 738     | 8       | 6       |
|       | 40% Laterite | 750   | 745     | 743     | 6       | 6       |
|       | 60% Laterite | 720   | 716     | 714     | 2       | 2       |

Figure 7. Specimens exposed to sulphate solution

The results at 28 and 90 days period showed the increase in weight loss percentage for laterite replaced mortar as the immersion time increased. As percentage replacement of laterite increases, percentage weight loss is reduced. The first 28 days of immersion indicated that the loss of weight of laterite at 20 % replacement was 1.25% for 1:2 ratio mortars. However after 90 days, the laterite experienced 2.1% weight loss. For control mix 28 and 90 days weight loss were recorded as 1.46 and 2.47% respectively. Similar increment was found for both 1:3 and 1:6 cement mortars.\
The compressive strength of all the cubes was found to initially increase from the day these cubes were immersed in the sulphate solutions and decreases the strength as percentage replacement of laterite increases. It is believed that the deteriorations caused by the sulphate solutions do not dominate during the initial immersion periods. However, beyond 28 day of immersion period, the compressive strength of mortars decreased most likely due to the deterioration caused by the sulphate solutions.

3. Conclusions

From the experimental investigations, the following conclusions are arrived:

- The compressive strength result of mortar shows the replacement of laterite from Malabar regions of Kerala up to 40% with natural sand for Cement mortar is suitable.
- The Brick prism tests show the 20-40% replacement of natural sand by laterite are possible without affecting the strength.
- The durability and water absorption test also show up to 40% replacement of natural sand by laterite is possible without affecting the strength.
- The results confirmed that Mortar of all the replacements show good resistance against acidic, chloride and sulphate environment.
- By replacement of 40% of laterite, 50% saving of cost in cement mortar can be achieved.

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