Suitability of dolomite silica-sand in partial replacement with m-sand for cement mortar

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Abstract. One of the significant issues in the construction industry is that the cost of natural sand is expanding quickly and furthermore exhaustion of common assets happens at a quicker rate. To beat this issue we require a feasible material like the natural sand. Despite the fact that M-sand is utilized as a replacement for River sand, it has numerous burdens in view of its angular size and failure to fill the pore spaces. Dolomite-Silica sand is a material which contains silica content and can fill pores in the mortar productively. The principle motivation behind this investigation is to partially supplant M-Sand with Dolomite-Silica Sand to enhance the Masonry Characteristics. Dolomite-Silica sand is blended with M-Sand in fluctuating extents of 30%, 50%, and 70%. Fresh and Hardened mortar tests had been completed. Compressive and Flexural Brick-Bond Masonry tests have likewise been done. Results demonstrate that Dolomite-Silica Sand can be utilized as a partial replacement for M-sand up to 50%.

1. Introduction
Fine materials meddle with the development and introduction of large crystals at the paste-aggregate interface and large measures of little particles may adjust the rheology [1].Over the past years, the price of the river sand is increasing exponentially. Due to many reasons it shows no sign of decreasing any time soon, hence found the concept of M sand, which was much cheaper, compared to river sand. The M-sand which is formed by the crushing of aggregates loses its angularity. Either of these two different fine aggregates is the main component deciding the strength of the mortar. The aggregates have an impact on mechanical and also rheological properties of cement mortars. In the new state, Physical properties, shape, Particle-size distribution and surface notably impact different properties of mortar. In the solidified state, Elasticity modulus, Mineralogical structure, durability, and level of adjustment of Aggregates are by and large found to influence their properties. Utilizing diverse fine aggregates for delivering High Strength Concrete (HSC)[2].

Under these prospects requirement for a reasonable and sustainable material to regular natural sand without bargaining quality and strength aspects of mortar end up imperative to help the infrastructural development and to spare nature. Examinations affirmed that finely ground dolomite limestone, actually, can be utilized as cementitious material to deliver cement with dolomite limestone [11].on fractional replacement of sand by M-sand and eco sand and replacement of cement utilizing fly ash in concrete the properties were found to be noteworthy [15]. The necessity for Portland cement is increasing as a result of which emission of CO2 to the atmosphere increases which causes global warming. One tonne of carbon dioxide is emitted with every tonne of cement produced. Nowadays most preferred cement is PPC. Compatibility studies of PPC with different super plasticizers are already studied by many researchers [19].Exploratory outcomes demonstrated that the dolomite powder expansion to in part substitute for the pozzolanic materials had null effect on the setting properties of pastes with the mixed cover of slag and which fundamentally enhanced the pastes with fly ash and OPC [16].
A large portion of the exploration examines were done just for the replacement of cement with the dolomite powder. It is to be noticed that not very many examinations were performed for the replacement of fine aggregates in mortar with eco-sand. Moreover, the essential mortar tests were not performed on those investigations. This project deals with the partial replacement of M – Sand with Dolomite - Silica sand in cement mortar and tests that have been carried out for different proportions such as 70:30, 50:50, 30:70(m-sand: dolomite silica sand).

2. Materials and methodology

2.1. Cement:
Portland Pozzolana cement brought from ACC Cements, Coimbatore was used. It conforms to Indian Standards (IS-1489 (1991)).

Table 1 composition of Portland pozzolana cement

| Constituents       | Blended cement% |
|--------------------|-----------------|
| Loss on Ignition   | 1.05            |
| Insoluble Residue  | 20.0            |
| Total alkalis      | 0.71            |
| Chloride Content   | 0.01            |
| SiO2 Content       | 23.5            |
| Al2O3 Content      | 12.9            |
| CaO Content        | 47.0            |
| MgO Content        | 1.74            |
| Fe2O3 Content      | 2.04            |
| SO3 Content        | 2.21            |

2.2. Fine aggregates:
Fine aggregates used were tested as per Indian Standards Specifications. Different fine aggregates used are given below (IS-383(1970)).

2.3. River sand:
Natural coarse sand, having 2.36 mm maximum nominal size was used. They were tested as per Indian Standards.

2.4. M-sand:
Manufactured sand or Crushed sand conforming to Zone-II of IS-383 (1970), having 2.36 mm maximum nominal size was used. They were tested as per Indian standards. M-sand contains elements like Silica, Aluminium, Calcium, Magnesium, Sodium, Potassium, Iron, etc.

2.5. Dolomite-silica sand:
Dolomite-silica sand or Eco sand were brought from ACC Cements, Coimbatore and it conforms to Zone-IV of IS-383 (1970) Eco sand that holds elements like Silica, Aluminium, Magnesium and Calcium.

2.6. Bricks:
Fly ash bricks were brought from ACC Cement factory, Coimbatore (IS-12894 (2002)).
Table 2 Composition of fly ash bricks

| MATERIALS                                      | COMPOSITION % |
|------------------------------------------------|---------------|
| Fly ash                                        | 60            |
| Sand / stone dust                              | 30            |
| Ordinary Portland cement / (lime + gypsum)      | 10            |

3. Testing Of Materials

Before testing the mortars of different ratios,
- Cement was tested for specific gravity and setting time.
- Fine aggregate (river sand and M-sand) should be tested for sieve analysis and specific gravity.
- Bricks are to be tested for compression strength[3], flexural strength[20], water absorption and initial absorption

3.1 Tests on Mortar

3.1.1 Flow table test (IS 1155-1959)

The test technique includes placing the mortar in flow table of 60 mm height and inside diameters of 100 mm at the base and 70 mm at the top, filling it into 2 layers and each layer packed 25 times the temper. Excess mortar is expelled from the highest point of the shape. The flow table is jarred for 25 times and the spread diameter is estimated with scale.

3.1.2. Bulk density of Mortar (BS-EN 1015 PART VI)

The bulk density of mortar was found by measuring weight of the fresh mortar in a preconceived volume. Then the bulk density is found by

\[
\text{Bulk density} = \frac{(W_2 - W_1)}{V} \text{kg/m}^3
\]

where

- \(W_1\) – Weight of the empty container in kg
- \(W_2\) – Weight of the container + mortar in kg
- \(V\) – Volume of the container in m³

3.1.3. Compressive strength of mortar cubes (ASTM C-109)

Mortar cubes were cast with mixes of ratios 1:3 and 1:5 for River sand, M-sand and varying proportions of Dolomite-silica sand. Water content is determined by flow table test and cubes of size 50 mm * 50 mm * 50 mm is cast. The casted cubes are then determined for its compressive strength for 7 days and 28 days curing.

![Fig.1 Mortar cubes](image1)
![Fig.2 Testing of mortar cubes](image2)
![Fig.3 Failure of mortar cubes](image3)
3.1.4. Compressive bond strength of masonry prisms (ASTMC1072)
The compressive bond strength of masonry prisms is determined by five stack-bonded prisms after pre-wetting the bricks for 10 minutes. The prisms are then dried for 24 hours and then cured by steam curing and the strength is measured.

3.1.5. Flexural bond strength of masonry prisms
The flexural bond strength of masonry prisms [22] is determined by two stack bonded prisms with 4 courses. The masonry prisms are then dried for 24 hours and then the prisms are cured by stream curing and the strength is calculated.

3.1.6. Drying shrinkage of mortar (ASTM C01):
Mortar prisms of size 20 mm * 5 mm * 5mm were cast using River sand, M-sand and varying proportions of M-sand, and Dolomite-Silica sand and allowed to dry for 24 hrs. After 24 hrs, the specimens were demoulded from the mould and allowed to dry in air. Change in the length for each of the specimens was determined with the help of length comparator and strain was calculated for each specimens. The values of strain on 3rd, 7th, and 28th days were recorded.

4. Results and discussions

4.1. Cement
- The Specific gravity of cement was determined as per IS 2386 (part 3): 1963, which was found to be 3.07.
- The initial and final setting time of the cement was found to be 30 minutes and 9h 20 minutes.

4.2. Fine Aggregates

4.2.1. Sieve Analysis
Comparative study between percentage passing in respective sieve of river sand, m-sand and dolomite sand was shown in table 3, which clearly shows us that dolomite silica sand is much finer than the both river sand and m-sand.

| Sieve size (mm) | % passing | River sand | M – sand | Dolomite – silica sand |
|-----------------|-----------|------------|----------|------------------------|
| 4.75            | 96.7      | 98.675     | 100      |
| 2.36            | 91.9      | 79.675     | 100      |
| 1.18            | 73.7      | 48.025     | 99.65    |
| 0.6             | 40        | 27.4       | 95.55    |
| 0.3             | 9.6       | 2.175      | 69.125   |
| 0.15            | 1.8       | 0.6        | 18.725   |
| PAN             | 0         | 0          | 0        |

Table 4 shows the sieve analysis results of the both m-sand and dolomite silica sand mixed in three different ratios 30:70, 50:50, 70:30(m-sand : dolomite silica sand). Uniformity coefficient is much higher in 30:70 ratio and coefficient of curvature is higher in 70:30 ratio.
Table 4 Sieve analysis results for varying proportions of M-sand and Dolomite-Silica sand

| Sieve size (mm) | 30:70 | 50:50 | 70:30 |
|-----------------|-------|-------|-------|
| 4.75            | 99.75 | 99.65 | 99.55 |
| 2.36            | 97.05 | 93.4  | 92.55 |
| 1.18            | 89.75 | 79.05 | 73.05 |
| 0.6             | 79.3  | 64.4  | 53.25 |
| 0.3             | 46.7  | 35.2  | 23.05 |
| 0.15            | 17.2  | 14.3  | 10.65 |
| PAN             | 0     | 0     | 0     |

Table 5 Sieve analysis results

| Fine aggregates | Zonal classification | Effective size | Uniformity co-efficient | Co-efficient of curvature |
|-----------------|----------------------|----------------|-------------------------|--------------------------|
| River sand      | ZONE II              | 0.3            | 2.96                    | 0.9                      |
| M-sand          | ZONE I               | 0.38           | 4.34                    | 0.67                     |
| Dolomite-silica sand | ZONE IV | 0.09           | 2.88                    | 1.30                     |
| 30:70(MS:DS)    | ZONE III             | 0.08           | 6.625                   | 1.59                     |
| 50:50(MS:DS)    | ZONE II              | 0.1            | 7.2                     | 1.80                     |
| 70:30(MS:DS)    | ZONE III             | 0.07           | 5.57                    | 1.61                     |

Uniformity co-efficient is a parameter used to decide the gradation of aggregates. On the off chance that consistency co-efficient is between 4 to 6, at that point they are named poorly graded i.e. they have an indistinguishable size of particles and referred as poorly graded when consistency co-efficient is under 4. For this situation, River sand and Dolomite-silica sand are ineffectively graded though M-sand and 70:30 extent are well graded. 50:50 and 30:70 extents have high consistency co-efficient which implies they consist of an alternate range of particle sizes.

4.2.2. Specific gravity
- The specific gravity of river sand = 2.35
- The specific gravity of M-sand = 2.70
- The specific gravity of Dolomite-Silica sand = 2.63

4.3. Bricks
- Compressive strength of brick = 9.64 N/mm²
- Flexural strength of brick = 2.8 N/mm²
- Water absorption = 34.03 %
- Initial rate of absorption = 0.462 g/cm²/min

4.4. Mortar
4.4.1. Flow table test
Table 6 shows the water content for 100% flow of mortar. Water content for 1:3 cement mortar mix ratio is less than 1:5 cement mortar mix because the amount of fine aggregate and cement changes in the mix ratio which is one of the most important factors in determining the water content.

**Table 6 Flow table test Results**

| Cement mortar mix ratio | Proportions | w/c for Flow percent (100%) |
|-------------------------|-------------|-----------------------------|
|                         | Conventional 0.7 |                   |
|                         | M-Sand 0.725 |                   |
|                         | 50:50 0.8    |                   |
|                         | 70:30 0.78   |                   |
|                         | 30:70 0.78   |                   |
| 1:3                     | Conventional 1.2 |                   |
|                         | M-Sand 1.29  |                   |
|                         | 50:50 1.32   |                   |
|                         | 70:30 1.31   |                   |
|                         | 30:70 1.315  |                   |

4.4.2. Bulk density test

**Table 7 Bulk Density Test results**

| Cement mortar mix ratio | Proportions | Bulk density(g/cm$^3$) |
|-------------------------|-------------|-----------------------|
|                         | CONVENTIONAL 0.5521 |                   |
|                         | M-SAND 0.5212   |                   |
|                         | 50:50 0.5290    |                   |
|                         | 70:30 0.5500    |                   |
|                         | 30:70 0.5183    |                   |
| 1:3                     | CONVENTIONAL 0.5449 |                   |
|                         | M-SAND 0.5279   |                   |
|                         | 50:50 0.5455    |                   |
|                         | 70:30 0.5381    |                   |
|                         | 30:70 0.5483    |                   |

Plant delivered mortar is made by bunching the constituent materials by mass. Be that as it may, wet prepared to-utilize mortar is every now and again sold by volume, in this manner the connection amongst mass and volume is critical. For this, conventional mortar is similar to 70:30 and 50:50 blend proportions for 1:3 and 1:5 cement mortar blends individually.

4.4.3. Compressive strength of mortar cubes

The part of mortar when strengthen in the entire structure is to exchange the tensile, compressive and shear stress between the units and it must be adequately tough to hold the stresses of the finished structure. The compressive strength of 70:30 extent is more than conventional mortar by 0.5%, in the event of 1:3 cement mortar blend and is more than conventional by 9.63%, in the event of 1:5 cement mortar blend proportion.
### Table 8 Compressive Strength results

| Cement mortar mix ratio | Proportions | Compressive strength for 7 days curing (n/mm²) | Compressive strength for 28 days curing (n/mm²) |
|-------------------------|-------------|-----------------------------------------------|-----------------------------------------------|
|                         | Conventional| 14.653                                        | 25.87                                         |
| 1:3                     | Conventional| 14.73                                         | 24                                            |
| 1:3                     | M-Sand      | 14.438                                        | 24                                            |
| 1:3                     | 50:50       | 14.816                                        | 26                                            |
| 1:3                     | 70:30       | 12.86                                         | 24.33                                         |
| 1:5                     | Conventional| 5.653                                         | 17.33                                         |
| 1:5                     | M-Sand      | 6.777                                         | 16.67                                         |
| 1:5                     | 50:50       | 6.354                                         | 16.67                                         |
| 1:5                     | 70:30       | 6.458                                         | 19                                            |
| 1:5                     | 30:70       | 5.845                                         | 14.67                                         |

4.4.4. Compressive bond strength of masonry prisms

Compressive strength is present in particulars because it is simple to compute. Sufficient mortar strength is fundamental however the ultimate strength of a mortar will not be more than that of the blocks or bricks utilized. The usage of a lot of cement would increase unbending mortar, which may bring about vertical splitting going through units and mortar joints as stresses are forced. Usage of the proper mortar will not bring splitting, but any that occurs will have a inclination to take after the joints, which will be considerably less urgent to repair.

### Table 9 Compressive bond strength of masonry prisms

| Cement Mortar Mix Ratio | Proportions | Compressive Bond Strength (N/MM²) |
|-------------------------|-------------|----------------------------------|
| 1:5                     | Conventional| 1.767                            |
| 1:5                     | M-Sand      | 1.460                            |
| 1:5                     | 50:50       | 1.487                            |
| 1:5                     | 70:30       | 1.867                            |
| 1:5                     | 30:70       | 1.432                            |

Bond strength of Masonry in 70:30 extent is more than conventional and M-sand by 5.65% and 27.87% respectively and was discovered smooth in plastering amid application in blocks.

4.4.5. Flexural bond strength of masonry prisms:

Established masonry construction tends to be enormous comparative to modern construction, which means that the mass or bulk was normally resisting the numerous loads applied on it. The bond of the mortar and masonry unit is a major factor in the flexural strength. The flexural bond strength of masonry prisms in 70:30 mix proportion is more than conventional by 18% and M-sand by 6.06%.

### Table 10 Flexural bond strength of masonry prisms

| Cement mortar mix ratio | Proportions | Flexural bond strength (n/mm²) |
|-------------------------|-------------|-------------------------------|
| 1:5                     | Conventional| 0.089                         |
| 1:5                     | M-Sand      | 0.099                         |
| 1:5                     | 50:50       | 0.083                         |
| 1:5                     | 70:30       | 0.105                         |
| 1:5                     | 30:70       | 0.077                         |

4.4.6. Drying Shrinkage of mortar

Drying shrinkage is characterized as deflating of solidified mortar because of loss of capillary water. The shrinkage causes an expansion in tensile stress which may prompt breaking.
outside diversion and inside distorting. So it is essential to quantify the drying shrinkage. For this situation, strain is direct and little in all cases.

Table 11 Drying Shrinkage results for 3 days

| CEMENT MORTAR MIX RATIO | PROPORTIONS | STRAIN VALUES FOR 3 DAYS |
|-------------------------|-------------|--------------------------|
| 1:3                     | Conventional | 0.0288                  |
|                         | M-Sand      | 0.0286                  |
|                         | 50:50       | 0.0257                  |
|                         | 70:30       | 0.0256                  |
|                         | 30:70       | 0.0267                  |
| 1:5                     | Conventional | 0.0256                  |
|                         | M-Sand      | 0.03                     |
|                         | 50:50       | 0.0286                  |
|                         | 70:30       | 0.0267                  |
|                         | 30:70       | 0.0255                  |

Table 12 Drying Shrinkage results for 7 days

| CEMENT MORTAR MIX RATIO | PROPORTIONS | STRAIN VALUES FOR 7 DAYS |
|-------------------------|-------------|--------------------------|
| 1:3                     | Conventional | 0.0282                  |
|                         | M-Sand      | 0.02835                 |
|                         | 50:50       | 0.0262                  |
|                         | 70:30       | 0.0253                  |
|                         | 30:70       | 0.02525                 |
| 1:5                     | Conventional | 0.0259                  |
|                         | M-Sand      | 0.0295                  |
|                         | 50:50       | 0.0289                  |
|                         | 70:30       | 0.02615                 |
|                         | 30:70       | 0.02535                 |

Table 13 Drying Shrinkage results for 28 days

| CEMENT MORTAR MIX RATIO | PROPORTIONS | STRAIN VALUES FOR 28 DAYS |
|-------------------------|-------------|--------------------------|
| 1:3                     | Conventional | 0.0274                  |
|                         | M-Sand      | 0.02705                 |
|                         | 50:50       | 0.0257                  |
|                         | 70:30       | 0.02495                 |
|                         | 30:70       | 0.0251                  |
| 1:5                     | Conventional | 0.0244                  |
|                         | M-Sand      | 0.0292                  |
|                         | 50:50       | 0.0289                  |
|                         | 70:30       | 0.0259                  |
|                         | 30:70       | 0.0252                  |
5. Conclusion
The fractional replacement of M-sand with Dolomite-silica sand is found to enhance the strength and consistency of mortar in view of the investigation of the obtained results. 50:50 and 70:30 mix proportions has similar compression strength to the conventional mortar. The drying shrinkage values are straight and have less strain values in 50:50 and 70:30 blend extents. This meets the sustainability conditions and spares the common assets. The bond strength of 70:30 extent additionally demonstrates more strength than conventional and all blend extents. So it is construed to utilize 70% of M-sand and 30% of Dolomite-silica sand rather than conventional or M-sand mortar. It additionally demonstrates that utilization of 50% of M-sand and Dolomite-silica sand likewise indicates great strength conditions than conventional however it fails in durability and further increase in Dolomite-silica sand content diminishes the strength. Additionally work is required to locate the correct mix proportions of M-sand and Dolomite-silica sand to meet the conventional prerequisites.

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