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# Effect of Partial Replacement of Natural Sand With Gold Mine Tailings on Some Properties of Masonry Mortars

S. Vignesh[1]
Post Graduate Student
Department of Civil Engineering
SRM University
Kattankulathur, Chennai, India

B. M. Ramalinga Reddy[2]
Professor and Head
Department of Civil Engineering
Bangalore Technological Institute
Bangalore, India

S. Sindhu Nachiar[3]
Assistant Professor
Department Of Civil Engineering
SRM University
Kattankulathur, Chennai, India

***Abstract*— Sand constitutes bulk of cement mortar. Meeting the demand for sand in the construction industry without exploiting the natural resources is becoming a challenging task. In search of an alternative material for natural sand, gold mine tailings are substituted partially for natural sand in the production of masonry mortars. Natural sand is reconstituted by replacing it with 10%, 20% and 30% gold mine tailings. The effect of replacement on the properties of masonry mortars such as water retentivity, drying shrinkage and compressive strength is investigated. Major findings of the study are (a) water retentivity increases with the increase in fineness of sand for all sand types (b) As the sand becomes finer, the drying shrinkage increases and compressive strength decreases**

***Keywords*— Gold mine tailings; natural sand; water retentivity: drying shrinkage; compressive strength***

## I. INTRODUCTION

Indian construction industry is one of the largest in terms of volume of raw materials/natural resources consumed. It is estimated that by the end of the year 2020, the consumption of cement will increase by 166% (1). This leads to large scale consumption of fine and coarse aggregates. Another estimate reveals that the annual consumption of fine aggregates in India is 350X109 m3 (2). It becomes a challenging task to meet the demand for fine aggregates without exploiting the natural resources. Hence, to sustain the demand for fine aggregates, it becomes essential to explore the possibility of utilizing alternative materials which are sustainable. Around 20 million tonnes of inorganic waste is generated annually (3), which includes red mud, lime sludge, zinc tailings, gold mine tailings etc. in this investigation an attempt is made to study the water retentivity, drying shrinkage and compressive strength properties of masonry mortars with gold mine tailings as partial substitute for natural sand.

## II. SCOPE OF THE WORK AND EXPERIMENTAL PROGRAMME

Gold mine tailings are very fine particles, which contain about 72% Silica as SiO2. The grain size distribution reveals that around 70% of the material is coarser than 75 microns. Thus, the main objective of this investigation is to characterize the properties of masonry mortar with gold mine tailings as partial substitute for natural sand. The properties determined are water retentivity, drying shrinkage and compressive strength. The details of mortar proportions and tests conducted are shown in Table I. Certain errors are bound to occur in volume batching. To minimize these errors, volumes of cement, natural sand and gold mine tailings are converted weight ratios based on their loose bulk densities. These converted ratios are used in the experiments. In order to study the effect of replacing natural sand by gold mine tailings, natural sand was replaced with gold mine tailings at three percentages (10%, 20% and 30%). The grain size distribution curves for the materials used are shown in Fig. 1. All the properties of mortar greatly depend on the water content of the mix. It is established that the flow values of masonry mortars in construction sites usually vary from 86% to 119% (4). In this investigation, water content corresponding to 100% flow is considered.

TABLE I. DETAILS OF TEST PROGRAMME FOR VARIOUS MORTARS

| Mortar proportion (By volume) | | | Mortar flow (%) | Properties investigated | | |
|---|---|---|---|---|---|---|
| *C* | *RS* | *GMT* | | *I* | *II* | *III* |
| 1 | 6 | - | 100 | √ | √ | √ |
| 1 | - | 6 | 100 | √ | √ | √ |
| 1 | (0.9)6 | (0.1)6 | 100 | √ | √ | √ |
| 1 | (0.8)6 | (0.2)6 | 100 | √ | √ | √ |
| 1 | (0.7)6 | (0.3)6 | 100 | √ | √ | √ |

C: Cement, RS: River sand, GMT: Gold mine tailings
I: Water retentivity, II: Drying shrinkage, III: Compressive strength

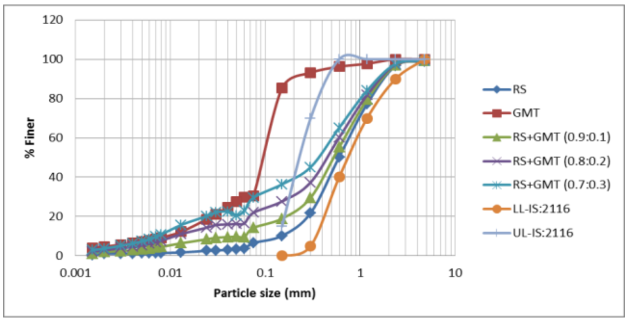


Fig. 1. Particle size distribution curves for river sand, gold mine tailings and reconstituted river sand

## III. MATERIALS USED IN THE INVESTIGATION

### A. Cement

Ordinary Portland cement conforming to IS: 8112 (5) is used in the preparation of mortars.

### B. River sand

Natural river sand was used in the investigations. The sand grading was altered by replacing certain percentages (10%, 20% and 30%) of river sand by gold mine tailings.

### C. Gold mine tailings

Tailings are one of the primary waste products of mining operations. They are made of fine grained particles of the parent rock from which the ore is extracted. The characteristics of tailings depend upon the composition of parent rock. The tailings used in this investigation were obtained from Hutti gold mines, Hutti village, Raichur district, Karnataka, India. Chemical composition of the tailings was evaluated and is shown in Table II.

TABLE II CHEMICAL COMPOSITION OF GOLD MINE TAILINGS

| Parameters | Result (%) | Parameters | Result (%) |
|---|---|---|---|
| Loss on ignition | 1.08 | Manganese as MnO | 0.077 |
| Calcium as CaO | 6.10 | Zinc as ZnO | 0.011 |
| Magnesium as MgO | 3.68 | Nickel as NiO | 0.006 |
| Iron as Fe2O3 | 6.70 | Chromium as Cr2O3 | 0.008 |
| Aluminium as Al2O3 | 3.85 | Lead as PbO | 0.007 |
| Sodium as Na2O | 0.078 | Silica as SiO2 | 71.6 |
| Potassium as K2O | 0.285 | Chloride as CL- | 0.070 |
| Copper as CuO | 0.010 | Manganese as MnO | 0.077 |

## IV. TESTING PROCEDURE

### A. Water retentivity

Water retentivity is defined as the ability of the fresh mortar to hold/retain water when placed in contact with absorbent masonry units. Some of the factors which affect water retentivity are, mix proportion, water cement ratio, type of cementitious binder etc. Different standard codes of practice such as IS: 2250 (7), ASTM C 91 (9) and BS: 4551 (6) give procedures to determine water retentivity of mortars. In this investigation, water retentivity is determined by adopting BS: 4551 (6) code guidelines.

### B. Drying shrinkage

The drying shrinkage of mortar is determined by following the procedure given in ASTM C 1148-92a (10). The drying shrinkage as found by this method is a measure of decrease in length of test specimen in unrestrained condition, under drying condition, after an initial period of curing. The average of five mortar specimens is reported as drying shrinkage value of mortar as specified in ASTM C 1148 92a (10).

### C. Compressive strength

The compressive strength of mortar was determined by testing 50 mm size cubes as specified in IS: 2250-1990 (7). Mortar is thoroughly mixed and filled into metal moulds in three layers, each layer being tamped twenty five times using a standard tamping rod. The mortar cubes prepared in this manner are removed from the moulds after twenty four hours of casting. The mortar cubes are tested for compressive strength in a compression testing machine after 7 and 28 days of curing. The mean of three cubes tested is reported as compressive strength of mortar.

## V. RESULTS AND DISCUSSION

### A. Compressive strength and water retentivity

The specimens for compressive strength, water retentivity and drying shrinkage were casted with water cement ratio corresponding to 100% flow. Results of compressive strength and water retentivity for various mortar proportions are given in Table III. The variation in compressive strength with age is shown in Fig. 2. The variation of water retentivity for different sand types is shown in Fig. 3.The following points emerge from the results given in Table III, Fig. 2 and 3.

a) Water cement ratio increases as the fineness of sand increases in order to maintain 100% flow for all the sand types.

b) The increase in water cement ratio and fineness of sand leads to reduction in compressive strength.

c) The compressive strength of cement mortar with river sand at 28 days is 9.47 MPa. This value reduces by around 31%, when river sand is reconstituted with 10% gold mine tailings. And for 20% and 30% reconstitution, the reduction in strength is 35% and 57% respectively.

d) To explore the possibility of increase in compressive strength beyond 28 days, the cubes were tested after 56 days of curing. The compressive strength increases for all the sand types. For reconstituted sand with 10% gold mine tailings the increase in compressive strength is around 69%. And for 20% and 30% reconstitution the increase is 65% and 100% respectively. This increase in compressive strength may be attributed to the presence of CaO in gold mine tailings which contributes to the hydration of cement.

e) The water retentivity of cement mortar with gold mine tailings and river sand is 88.3% and 77% respectively. The water retentivity increases as the fineness of sand increases. When river sand is reconstituted with 10%, 20% and 30% gold mine tailings, the water retentivity increases by 4%, 6% and 8% respectively.

TABLE III COMPRESSIVE STRENGTH AND WATER RETENTIVITY FOR DIFFERENT SAND TYPES

| Mortar type | Flow of mortar (%) | Water cement ratio | Compressive strength (MPa) | | | Water retentivity (%) |
|---|---|---|---|---|---|---|
| | | | σ 7 | σ 28 | σ 56 | |
| RS | 100 | 1.30 | 2.93 | 9.47 | 13.6 | 77 |
| GMT | 100 | 2.48 | 0.67 | 3.47 | 3.73 | 88.3 |
| RS+GMT(0.9:0.1) | 100 | 1.29 | 2.42 | 6.53 | 11.04 | 79.8 |
| RS+GMT(0.8:0.2) | 100 | 1.30 | 2.05 | 6.16 | 10.16 | 81.5 |
| RS+GMT(0.7:0.3) | 100 | 1.43 | 1.53 | 4.07 | 8.23 | 83.4 |

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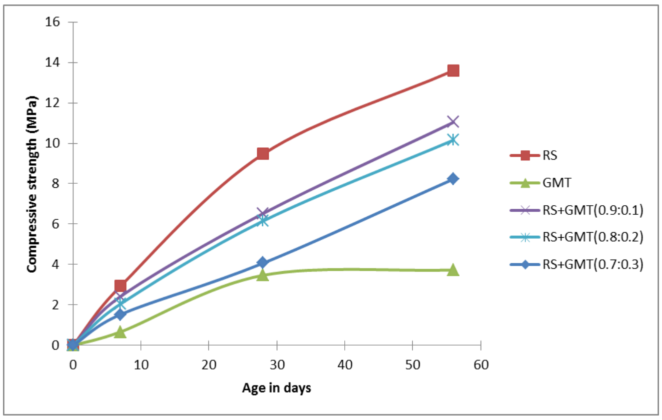



Fig. 2. Compressive strength versus age for different sand types

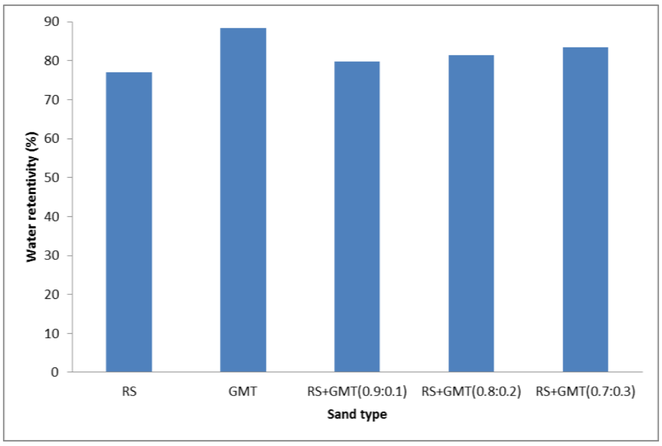



Fig. 3. Variation of water retentivity for different sand types

### *B. Drying shrinkage*

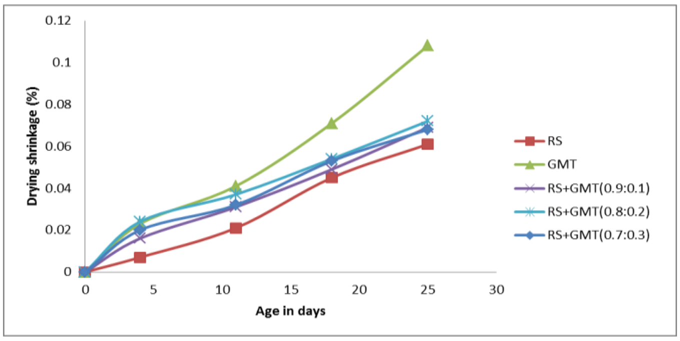
Shrinkage that takes place during hardening of the mortar is called drying shrinkage and most of it occurs during the first few months. Various factors such as water cement ratio, water content, sand grading etc, effect the drying shrinkage of mortar. In masonry construction, drying shrinkage causes shrinkage cracks observed at the masonry unit-mortar interface (11, 12). The drying shrinkage of mortar was tested in the laboratory through a mortar prism 250X25X25mm in unrestrained condition. This differs from the actual drying shrinkage experienced in masonry construction. Thus drying shrinkage value of the mortar examined in the laboratory is more useful for comparative purposes. The variation in drying shrinkage with duration of drying for cement mortar made with different sand types is shown in Table IV and Fig. 4. The following points emerge from the results on drying shrinkage

a) The drying shrinkage of mortars increase with the duration of drying
b) The fineness of sand greatly affects the drying shrinkage values. The drying shrinkage value increases as the sand becomes finer.
c) The ultimate drying shrinkage of cement mortar with gold mine tailings increases by 77% when compared with that of cement mortar containing river sand.
d) The ultimate drying shrinkage of reconstituted sands, increase in the range of 13% to 18% in comparison with cement mortar containing river sand.

TABLE IV DRYING SHRINKAGE VALUES FOR MORTARS

| Mortar type | 1st day | 4th day | 11th day | 18th day | 25th day |
|---|---|---|---|---|---|
| RS | 0 | 0.007 | 0.021 | 0.045 | 0.061 |
| GMT | 0 | 0.023 | 0.041 | 0.071 | 0.108 |
| RS+GMT(0.9:0.1) | 0 | 0.016 | 0.031 | 0.049 | 0.069 |
| RS+GMT(0.8:0.2) | 0 | 0.024 | 0.037 | 0.054 | 0.072 |
| RS+GMT(0.7:0.3) | 0 | 0.02 | 0.032 | 0.053 | 0.068 |

Fig. 4. Variation in drying shrinkage with drying duration




## VI. SUMMARY AND CONCLUSIONS

The influence of gold mine tailings as a partial substitute for river sand in cement mortar on the properties such as water retentivity, compressive strength and drying shrinkage was investigated. The following conclusions are drawn from the investigation.

a) The compressive strength of cement mortar containing gold mine tailings is more sensitive to the fineness of sand when compared to cement mortar with river sand. The compressive strength of reconstituted river sand with 10%, 20% and 30% gold mine tailings at 28 days decreases by 31%, 35% and 57% respectively.

b) Water retentivity increases with the increase in fineness of sand for all sand types.

c) Fineness of sand greatly affects the drying shrinkage values. The ultimate drying shrinkage value of reconstituted sand is greater than ultimate drying shrinkage of cement mortar with river sand by 13% to 18%.

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