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# Role of Moulding Water Content on the Strength Properties of Red Earth treated with Mine tailings

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**Abstract**— The role of moulding water content from the dry of optimum to wet of optimum condition, in the strengt properties of Red earth (RE) in présence of mine tailings (MT) was investigated and presented in this paper. During compaction the structure of clay particles can change from flocculated to dispersed states when water content increased from dry of optimum to wet of optimum conditions. Water content plays an important role in soil-mine tailings mixtures and it increases from dry of optimum to wet of optimum conditions due to formation of pozzolanic compounds. In the present investigation an attempt has been made to improve the strength of red earth treated with mine tailings and to examine the possibility of using mine tailings as stabilizing agent for ground improvement at différent moulding water content for various curing periods. The test results clearly lndicate that the strength ratio of red earth treated with mine tailings is higher on wet of optimum condition than optimum and dry of optimum conditions at différent moulding water content for various curing period. The strength ratio increased by 2.5, 1.75and 3.56 folds respectively for dry of optimum, optimum and wet of optimum conditions respectively. However, the strength ratio is increased by 3.56 folds on wet of optimum condition which is advantages for constructions.

**Index Terms**— Agglomeration, Flocculation, Mine tailings, Moulding water content, stabilization, strength ratio, Unconfined compressive strength.



## 1 INTRODUCTION

RED earth is a non-expansive soil having kaolinite as primary clay mineral and it is abundantly available natural soil in vast areas of in Karnataka. Mine tailings is an industrial by-product which is produced in large quantity from mining industries after extraction of minerals from underground mined ores and poses serious disposal problems and creating environmental hazards. In recent years there is an increase in trend to utilize the mine tailings for geotechnical applications. Stabilization is found to be one of the effective methods to improve the engineering properties of soils. Mine tailings can be effectively utilized for civil engineering constructions which will minimize the disposal problems and reduce the environmental hazards (Pebble Project, 2005)[1]. Thian and Lee (2010)[2], studied the effect of plastic fine grained soil of kaolinite clay on over consolidated mining sand and to assess the main factors affecting the mechanical behaviour of the soils subjected to undrained triaxial compression tests resulted in normalized deviator stress decreases with increasing the over consolidated ratio. Soosan et al (2005)[3], investigated that the addition of quarry dust in to two different type of cohesive soils viz. kaolinite and Cochin marine clay resulted in the improvement of compaction properties and CBR values. A similar approach has been made to use industrial waste mine tailings for ground improvement technique to solve the environmental pollution problems. With these objectives, studies have been taken to assess the suitability of mine tailings for improving the engineering properties of red earth for different moulding water content for various curing period.


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## 2 MATERIALS AND METHODS

### 2.1 Materials

#### 2.1.1 Red earth

The red was collected at a depth of 1.5 meters below the natural ground level at Bangalore University, Jnanabharati campus, Bangalore, India. Red earth is a typically non-expansive clayey soil containing kaolinite as its chief mineral constituent. To ensure the uniformity of the soil sample it was oven dried, pulverized and sieved through 425 micron BIS sieve before used in the present investigation.

#### 2.1.2 Mine Tailings

Mine tailings was collected from an open dump from Kolar Gold Fields (KGF), Kolar, Karnataka, India. After removing the vegetations from the mine tailings, it was air dried, pulverized and passed through 425 micron BIS sieve before used in the present investigation.

The physical properties of Red Earth and Mine tailings are presented in Table 1 and the chemical analysis of red earth and mine tailings were carried out by adopting the standard procedures as per the text book of Soil Chemical Analysis by P.R.Hesse published by Chemical Pub. Co. (1972) [4]. University of Michigan, and are presented in Table 2 and 3 respectively.

Table1. Physical properties of Red earth and Mine tailings (Ramesh et al 2012)[5].

| Properties | Values | |
|---|---|---|
| | RE | MT |
| Colour | Brick red | Pale gray |
| Specific Gravity | 2.59 | 2.78 |
| Liquid limit (%) | 39.3 | 34 |
| Plastic limit (%) | 26.1 | Non plastic |
| Plasticity Index (%) | 13.2 | Non plastic |
| Shrinkage limit (%) | 15.4 | 24.6 |
| Fine sand fraction (%) | 11 | 17 |
| Silt fraction (%) | 42 | 70.4 |
| Clay fraction (%) | 47 | 12.6 |
| Maximum dry density ($kN/m^3$) | 16.3 | 15.7 |
| Optimum moisture content (%) | 20.26 | 21.54 |

Table 2. Chemical properties of Red Earth.

| Chemical composition | Percentage |
|---|---|
| Silicon dioxide | 60.4 |
| Alumina | 15.05 |
| Iron oxide | 6.6 |
| Titanium dioxide | 0.2 |
| Calcium oxide | 6.9 |
| Magnesium oxide | 1.7 |
| Potassium oxide | 0.4 |
| Loss on ignition | 8.4 |
| Sodium oxide | 0.3 |



Table 3. Chemical properties of Mine tailings.

| Chemical composition | Percentage |
|---|---|
| $P^H$ | 8.44 |
| $SiO_2$ | 40.5 |
| $Al_2O_4$ | 0.5 |
| $P_2O_5$ | 0.09 |
| $K_2O_4$ | 16.1 |
| Cu | 2.55ppm |
| Pb | 0.04 |
| As | <0.01 |
| $CN^-$ | Nil |
| $SO_3$ | 0.05 |
| $SO_4$ | 0.5 |
| CaO | 14.96 |
| MgO | 6.97 |

## 2.2 Methodology adopted

The compaction tests were conducted using mini compaction test apparatus as per the procedure of (Sridharan and Sivapullaiah 2005)[6]. Unconfined compressive strength tests were carried out as per BIS: 2720 (part X) (1973)[7], for various combinations of black cotton soil and mine tailings mixture treated with lime. All samples were prepared at their respective maximum dry density and optimum moisture content for dry of optimum, optimum and wet of optimum conditions. The prepared samples were kept in airtight plastic bags and placed in to desiccators and maintained 100% humidity for long term curing periods in such a way that there is no moisture movement.

## 3 Results and Discussions

### 3.1 Compaction

The compaction tests were carried out on red earth and mine tailings respectively. Further compaction tests were also conducted on red earth treated with mine tailings. The tests were carried out for dry of optimum, optimum and wet of optimum conditions. The wet of optimum and dry of optimum conditions the water content corresponding to 95% of maximum dry density were selected from the compaction curve on dry side and wet side of optimum values and are represented in Fig.1 and Table 4.

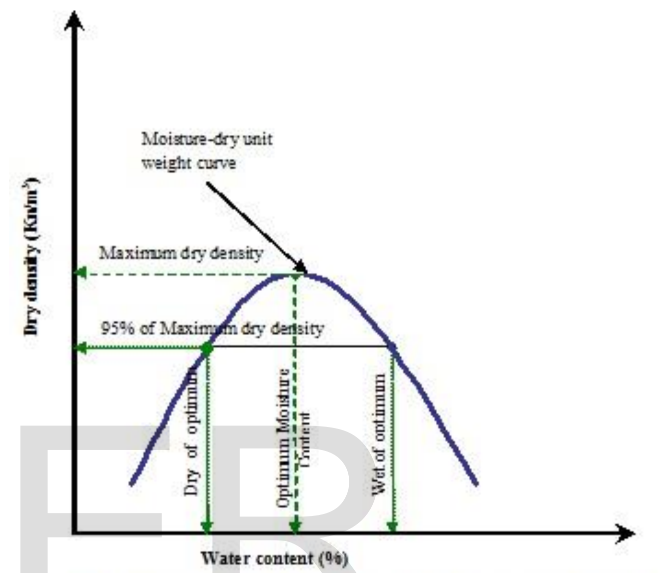


Fig. 1 Dry density versus moisture content at a particular compactive effort

### 3.2 Unconfined compressive strength

The unconfined compressive strength tests were carried out on red earth and mine tailings respectively. Addition of various percentages of mine tailings to red earth, unconfined compressive strength tests were conducted for immediate effect as well as with curing periods and 10% of mine tailings for red earth was found to be optimum percentage (Ramesh et al 2012)[8]. Unconfined compressive strength tests were carried out for red earth treated with mine tailings at dry of optimum, optimum and wet of optimum conditions respectively for 0, 7, 30, 90,180 and 365 days of curing periods and the results are presented.

#### 3.2.1 Effect of moulding water content on the red earth treated with mine tailings for various curing periods.

##### 3.2.1.1 Dry of optimum condition

The unconfined compressive strength of red earth and mine tailings for dry of optimum conditions are 230 kPa and 130 kPa respectively, strength of red earth treated with mine tailings is 261 kPa on immediate testing. The strength of red earth and mine tailings mixture has shown an increasing trend with increase in curing period and reached the value of 655kPa after 365 days of curing period. It indicate that the strength increased by 2.5 folds compare to red earth alone as shown in Fig.2 and Table 5. The increase in strength could

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be attributed to ion exchange at the surface of the clay particles. The calcium oxide present in mine tailings as additives reacted with silica present in red earth which has lower valence metallic ions in the clay which resulted in agglomeration and flocculation of clay particles. The gain in strength of specimens with age was due to primarily the long-term reaction as a result the strength increases

### 3.2.1.2 Optimum condition

The strength of red earth and mine tailings for optimum conditions are 145 kPa and 122 kPa respectively. Strength of red earth treated with mine tailings is 183 kPa on immediate testing. Further strength increases with increase in curing period of red earth treated with mine tailings is 320 kPa after 365 days of curing period. It was found that the strength increased by 1.75 folds compare to untreated red earth as shown in Fig.2and Table 6. The increase in strength is due to reaction between red earth and mine tailings having calcium concentration and $P^H$ of the pore fluid will increase.

### 3.2.1.3 Wet of optimum condition

The unconfined compressive strength of red earth and mine tailings on wet of optimum conditions are 91 kPa and 46 kPa respectively. Unconfined compressive strength of red earth and mine tailings mixture was found to be 54 kPa on immediate testing. The strength increases with increase in curing period of red earth and mine tailings mixture and was observed to be 192 kPa after 90 days of curing period. It indicates that the strength increased by 3.65 folds compare to red earth alone as shown in Fig.3 Table 7. The increase in unconfined strength red earth and mine tailings mixtures is due to cation exchange and flocculation of particles on the addition of mine tailings to red earth. This may be due to more water which is available at wet of optimum condition which enhances the pozzolanic reaction for long term curing at higher water content.



Table 4. Selected dry density & corresponding water contents on dry of optimum, optimum and wet of optimum from compaction tests

| Mixture | Dry of opt | | Optimum | | Wet of opt | |
|---|---|---|---|---|---|---|
| | Density | W/C | Density | W/C | Density | W/C |
| RE Alone | 14.1 | 18.1 | 16.3 | 20.2 | 14.1 | 26.8 |
| MT Alone | 14.9 | 17.6 | 15.7 | 21.54 | 14.9 | 28.7 |
| RE + 10% MT | 14.44 | 18.6 | 15.2 | 23.48 | 14.44 | 27.2 |

Table 5. Strength of red earth and mine tailings mixtures on dry of optimum condition for various curing period

| Mixture | Unconfined compressive strength for optimum condition | | | | | |
|---|---|---|---|---|---|---|
| | Curing period in days | | | | | |
| | 0 | 7 | 30 | 90 | 180 | 365 |
| RE | 230 | 230 | 230 | 230 | 230 | 230 |
| MT | 130 | 136 | 152 | 175 | 175 | 183 |
| RE+10%MT | 261 | 316 | 337 | 475 | 556 | 655 |

Table 6. Strength of red earth and mine tailings mixtures on wet optimum condition for various curing period

| Mixture | Unconfined compressive strength for optimum condition | | | | | |
|---|---|---|---|---|---|---|
| | Curing period in days | | | | | |
| | 0 | 7 | 30 | 90 | 180 | 365 |
| RE | 145 | 145 | 145 | 145 | 145 | 145 |
| MT | `122 | 130 | 137 | 138 | 138 | 145 |
| RE+10%MT | 183 | 193 | 201 | 221 | 245 | 320 |

Table 7 Strength of red earth and mine tailings mixtures on dry of optimum condition for various curing period

| Mixture | Unconfined compressive strength for optimum condition | | | | | |
|---|---|---|---|---|---|---|
| | Curing period in days | | | | | |
| | 0 | 7 | 30 | 90 | 180 | 365 |
| RE | 91 | 91 | 91 | 91 | 91 | 91 |
| MT | 46 | 46 | 53 | 53 | 53 | 69 |
| RE+10%MT | 54 | 83 | 106 | 122 | 151 | 192 |

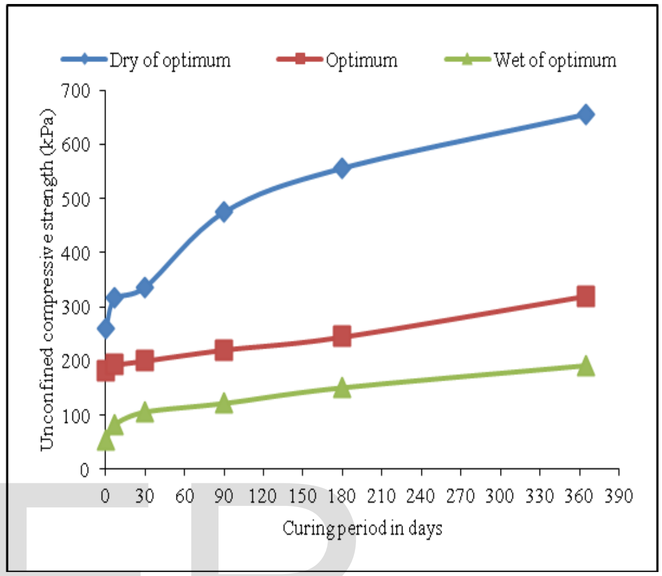


Fig.2 Effect of moulding water content on the strength of red earth and mine tailings mixture at various curing period

### 3.2.2 Effect of moulding water content on the strength ratio of red earth and mine tailings treated with mixture.

Strength ratio is defined as the ratio of strength of soil matrix at any stage of curing with strength of the soil matrix at immediate testing of the same combinations (Viswanath, 2007)[8].

Strength Ratio = [Qs / Qo]

Where Qs = Unconfined compressive strength of treated speci men at any curing period

Qo = Unconfined compressive strength of specimen at corresponding combinations without curing Period

The strength ratio of red earth treated with mine tailings are 2.5, 1.75 and 3.56 folds for 365days of curing at dry of optimum, optimum and wet of optimum conditions respectively. The strength ratio increases considerably as the water content is increased from dry of optimum to optimum condition. However, with further increase in water content beyond optimum level the strength ratio increases further. This could be probably due to development of pozzolanic reaction compound which will contribute for increase in strength. The strength ratio increases continuously with increase in water content and it exhibit higher value on wet of optimum than dry of optimum and optimum conditions. The variation of strength ratios of red earth treated with mine tailings for different moulding water content for various curing period are as shown in Fig3. This is due to the effect of pozzolanic reaction which is favored by the higher water content (Viswanath, 2007)[8].

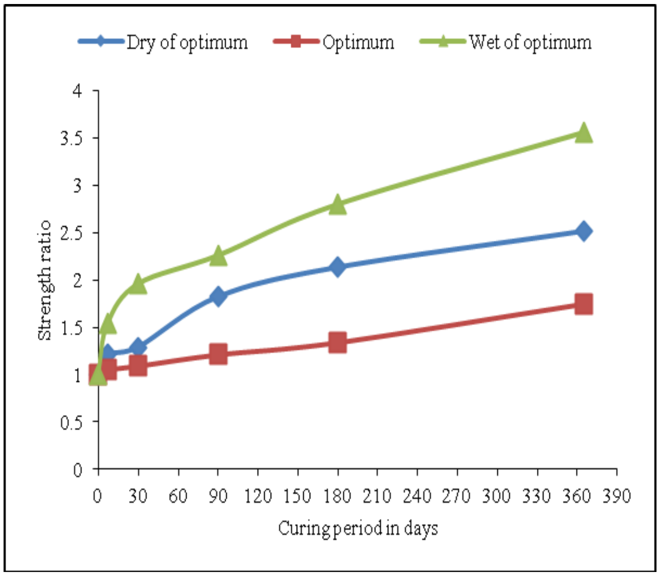


Fig.3 Effect of moulding water content on the strength ratio of red earth and mine tailings mixture at various curing period

## 4 CONCLUSIONS

The detailed analysis of the results of the Red earth and Mine tailings mixture the moulding water contents have varied the strength and the following conclusions have been drawn:

1. The strength of red earth and mine tailings mixtures increases with increase in curing period for all the moulding water contents. However, higher strength was observed in dry of optimum condition compare to optimum and wet of optimum conditions.
2. Strength of red earth and mine tailings mixture increases with increase in curing period for all the moulding water contents. Addition of optimum mine tailings to red earth, strength increased by 2.5 folds, 1.75 folds and 3.56 folds respectively for dry of optimum, optimum and wet of optimum conditions respectively compare to red earth alone after 365 days of curing.
3. The strength ratio increases continuously with increase in water content and it exhibit higher value on wet of optimum than dry of optimum and optimum conditions. From the present study, it has been concluded that mine tailings can be effectively used for stabilization of soils.

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