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Compaction and Sub-grade Characteristics of Clayey Soil Mixed with Foundry Sand and Fly Ash and Tile waste

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Abstract**:** *This paper brings out the results of experimental program carried out in the laboratory to evaluate the effectiveness of using foundry sand and fly ash with tile waste for soil stabilization by studying the compaction and strength characteristics for use as a sub-grade material. Foundry sand, fly ash and crushed tile waste are waste materials which are obtained from different industries. These wastes impose hazardous effect on environment and human health. These materials cannot be disposed of properly and their disposal is not economical. Utilization by exploiting their inherent properties is the one of the way to solve the above stated problem. The effect of mixing different proportions of foundry sand, fly ash and tile waste with clayey soil on compaction and California bearing ratio have been studied in this study.*

Keywords: *Compaction, California bearing ratio, foundry sand, fly ash, tile waste*.

I. INTRODUCTION

In countries like India which are at developing stage, waste management has become a serious problem as the pace of generation of waste materials is not meeting up to the pace of its recycling and disposing. Also reusing process is more economical than recycling process. Therefore a lot of R&D work is taking place is the direction of developing the methods for producing the ways of reusing these waste materials. Stabilising the problematic type of clayey soil with these waste materials is one of them. In this present study the waste materials like foundry sand, fly ash and tile waste has been used. About131.09 million tons of fly ash is yearly generated in our country, only about 55.79% of which is utilised. Similarly about 65% foundry sand and 55% of tile waste remains unutilised in our country. Many of the geotechnical researchers have used these waste materials in stabilization of soil. Some of the application areas of foundry sand include highway bases and retaining structures (Kirk, 1998; Goodhue et al., 2001), landfill liners (Abichou et al., 1998), flowable fill (Bhat and Lovell, 1996), and pavement bases (Kleven et al., 2000). Other studies have shown that the thermal or biological remediation of foundry sand provides an opportunity for their land applications (Leidel and Novakowski, 1994; Reddi et al., 1996). Bhuvaneshwari (2005) concluded that workability and maximum dry density was achieved at 25% of fly ash. Edil *et al.*, (2006) indicated the effectiveness of fly ash for stabilization of fine grained soils. Chauhan et al (2008) observed that optimum moisture content increases and maximum dry density decreases with increased percentage of fly ash mixed with silty sand. Bose (2012) reported that maximum dry density increases up to 20% fly ash mix, and then gradually decreases whereas the optimum moisture content decreased with increase in fly ash and also CBR values of clay-fly ash mixes tested under un-soaked conditions, shows peaks at 20% and 80% ash content. Some of the application areas of tile waste include stabilization of expansive soil (A. K. Sabat, 2012), Stabilization of dune sand (Ameta et al., 2013),used in brick (Rajgor et al., 2013). However, limited information exists about the combined use of foundry sand, fly ash and tile waste in soil stabilization. So in this paper, sub-grade characteristics of clayey soil blended with foundry sand, fly ash and tile waste in different proportions has been studied.

II. EXPERIMENTAL PROGRAM

2.1 Materials:

The soil used in the study was locally available clayey soil and waste foundry sand (FS) obtained from Nahan foundry. According to ASTM classification system (ASTM D2487-11), the soil was classified as clay with medium plasticity (CL) and the properties of clay are given in Table 1. The fly ash (fa) is obtained as residue left after electronic precipitation of the burnt gases. The chemical composition of fly ash is given in Table 2 (ASTM D5239-2004). Crushed tile waste is collected from the campus of NIT Hamirpur construction site.The laboratory tests were conducted in accordance with ASTM standards. The specific gravity tests, consistency limit tests and the standard proctor tests were conducted in accordance with ASTM D854-10, ASTM D4318-10 and ASTM D698-07e1 respectively. The physical properties of clay, foundry sand, fly ash and tile waste are presented in Table 1.

Table 1: Physical properties of clay, foundry sand, fly ash & tile waste

Property	**Clay**	**Foundry Sand**	**Fly ash**	**Tile waste**
Specific gravity	2.62	2.609	1.966	2.388
Maximum dry density (MDD), g/cc	1.929	1.573	1.164	-
Optimum moisture content (OMC), (%)	12.0	6.0	32.0	-
Liquid limit (%)	43.0	-	40.0	-
Plastic limit (%)	22.6	-	-	-
Plasticity index (%)	20.4	-	-	-
Uniformity coefficient, Cu	-	1.84	-	1.125
Coefficient of curvature, Cc	-	0.97	-	8
Soaked CBR (%)	2.44	9.77	1.94	-

Table 2: Chemical composition of fly ash

Chemical Composition	**Proportion (%)**
Silica (Sio_2)	55.69
Alumina (Al_2o_3)	26.33
Calcium oxide (Cao)	3.43
Iron oxide (Fe_2O_3)	6.90
Potassium Oxide (K_2O)	0.98
Sulphur (SO_3)	0.45
Magnesium Oxide (Mgo)	0.62
Loss on ignition	5.60

The hydrometer analysis tests were conducted as per ASTM D422-63. The particle size distribution of clay, foundry sand, fly ash and tile waste tested as per ASTM D6913-04 (2009) are given in "Fig." 1.

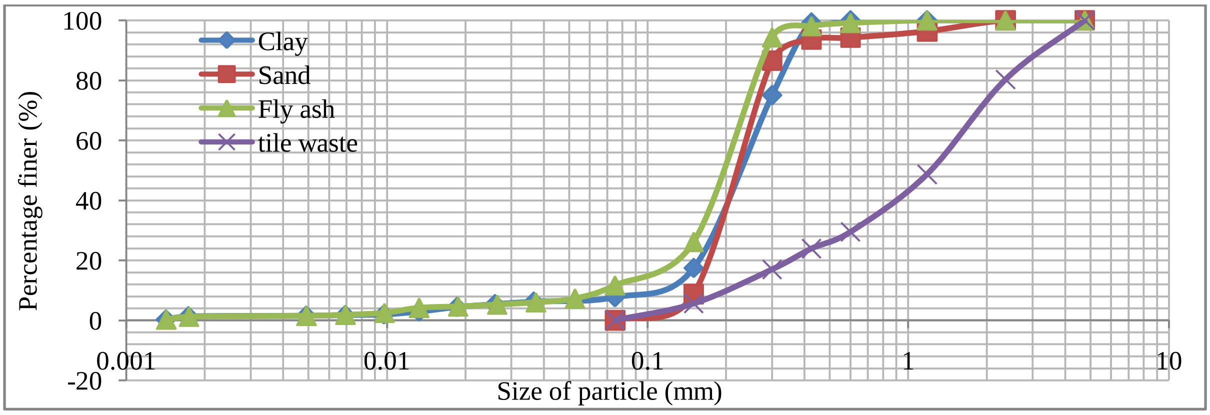

Figure1: Particle size distribution of clay, foundry sand, fly ash and tile waste

The sizes of the compaction mold used were of 101mm diameter and 125mm height. Compaction tests were conducted on clay with varying percentages of foundry sand from 10% to 50% and optimum mixes were obtained. After obtaining optimum mix proportion varying percentages of fly ash is added with clay-foundry sand mix from 10% to 40% in increments of 10%.Then appropriate mix of clay-foundry-sand-fly ash is chosen for compaction with tile waste of different percentage. The California bearing ratio tests were performed in laboratory in accordance with ASTM D1883-05. The sizes of samples were of 150mm diameter and 125mm height. Soaked CBR tests were conducted in standard mold for samples compacted statically at maximum dry MDD and OMC. Surcharge weight of 50N was used during the testing. A metal penetration plunger of diameter 50 mm and 100 mm long was used to penetrate the samples at the rate of 1.25 mm/minute using computerized CBR testing machine.

III. RESULTS AND DISCUSSIONS

3.1. Compaction Tests:

The water content-dry density curves of clayey soil mixed with foundry sand content varying from 10% to 50% are shown in "Fig. 2". It is observed that maximum dry density of clay-foundry sand composite increases with increase in sand content up to 40% after which it is reduced. The voids between the foundry sand particles are occupied by the clay particles when the sand content is less but larger sand content segregates the particles and the maximum dry density decreases.

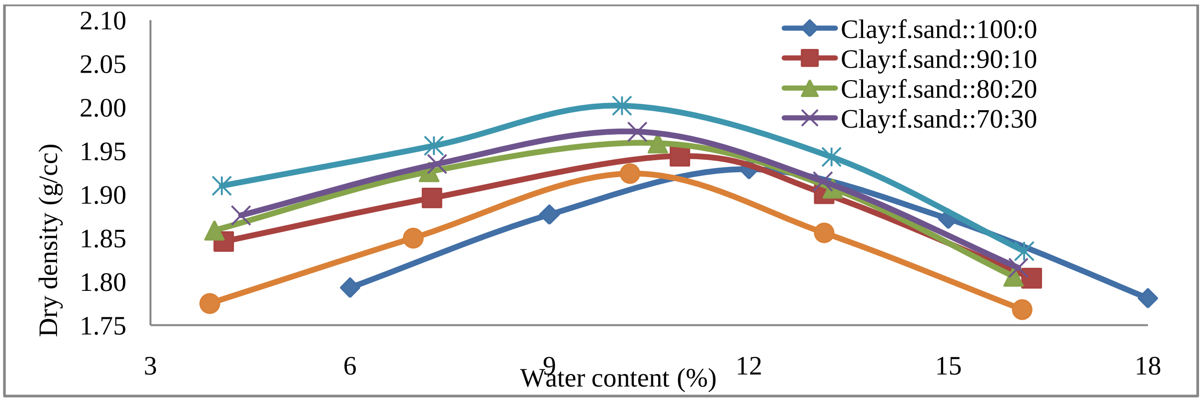

Figure 2: Compaction characteristics of clay-foundry sand (f.sand) mixes

The water content-dry density curves of the clay-foundry sand composite with fly ash content varying from 10% to 40% is shown "Fig.3". The maximum dry density achieved after the addition of fly ash is lesser compared with clay-foundry sand mix. This is due to the reason that the clay particles can fill most of the voids in the foundry sand when mixed in the ratio of 60:40. Further, it is observed that as the fly ash content increases, the maximum dry density decreases but the optimum moisture content increases. So suitable mix i.e. 54:36:10 ratio of clay: foundry sand: fly ash is used for further compaction with tile waste.

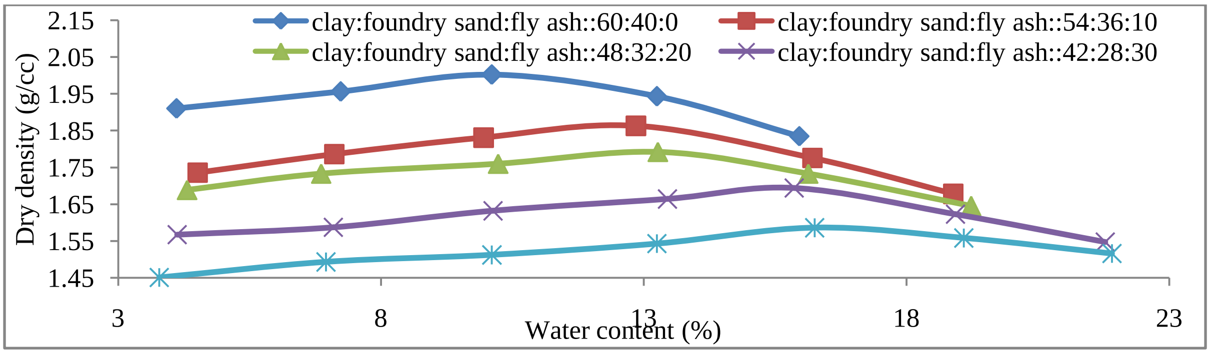

Figure 3: Compaction characteristics of clay-foundry sand-fly ash mix

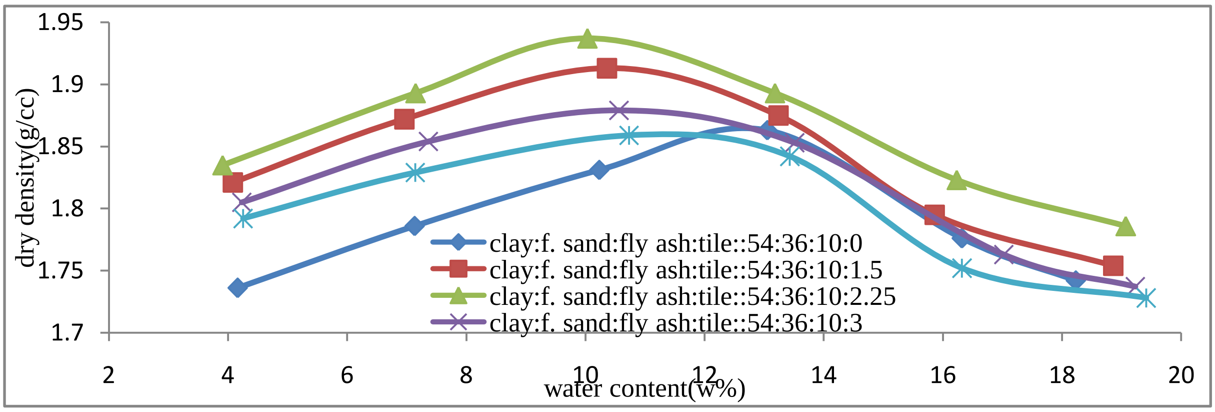

Figure 4: Compaction characteristics of clay-foundry sand-fly ash-tile waste mix

The water content-dry density curves of the clay-foundry sand –fly ash composite with tile waste content varying from 1.5% to 6% is shown in "Fig.4". The maximum dry density achieved after the addition of tile waste is more compared with clay-foundry sand-fly ash mix. This is due to the reason that the clay particles can fill the voids in the foundry sand and crushed tile waste when mixed in the ratio of 54:36:10:2.25. It is observed that maximum dry density of clay- foundry sand-fly ash-tile waste composite increases with increase in tile waste content up to 2.25% after which it is reduced. The voids between the foundry sand and tile waste particles are occupied by the clay particles when the tile waste content is less but larger tile waste content segregates the particles and the maximum dry density decreases.

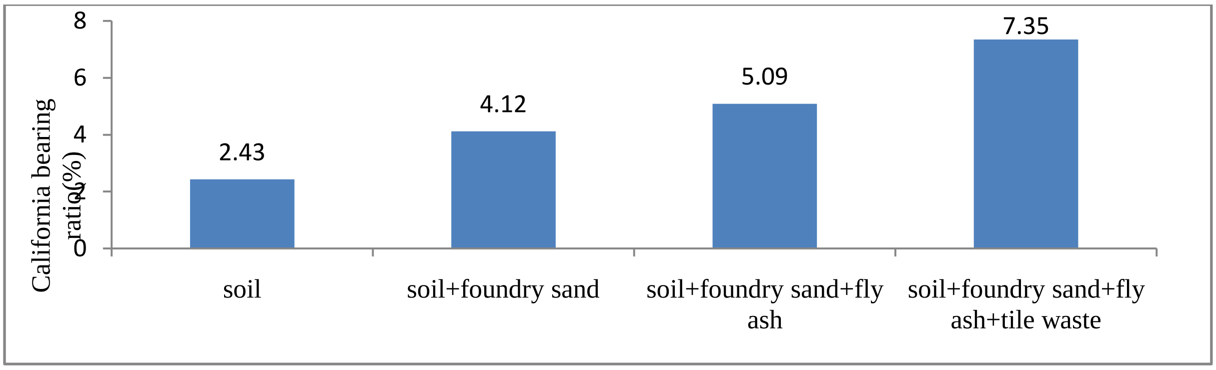

Figure 5: Variation of soaked CBR value with optimum mix

The improvement in CBR value may be attributed to better compaction and packing of the mix particles with addition of foundry sand, fly ash and tile waste. The California bearing ratio provides a basis of designing the sub-grades of flexible pavements. Usually, a value of CBR more than 5.0 is considered to be satisfactory for the design of flexible pavements with traffic intensity of 1 to 10 million standard axles (msa). Thus, the clayey soil blended with foundry sand, fly ash and tile waste can be effectively used in the construction of sub-grades of roads with low traffic volume.

IV. CONCLUSIONS

The following conclusions can be drawn from the study conducted on clayey soil-foundry sand-fly ash-tile waste mix:

The highest value of maximum dry density is achieved for clay-foundry sand mix of 60:40 followed by other proportions "Fig." 2. This occurs due to the reason that the voids between the foundry sand particles are occupied by the clay particles when the sand content is less but larger sand content segregates the particles and the maximum dry density decreases.

The maximum dry density of clay-foundry sand (60:40) mix decreased with addition of fly ash which is a light weight material as compared to clay and foundry sand "Fig". 3. This is mainly attributed to flocculated structure formed by addition of fly ash having lesser specific gravity. However, the clay: foundry sand: fly ash (54:36:10) mix was considered for conducting California bearing ratio tests.

The highest value of maximum dry density is achieved for clay-foundry sand-fly ash-tile waste mix of 54:36:10:2.25 followed by other proportions "Fig." 4. This occurs due to the reason that the voids of the mix are occupied by the tile particles but after a certain percentage it creates segregation in the mix and thus maximum dry density decreases after this percentage.

The California bearing ratio value of clayey soil improved significantly i.e. from 2.43% to 7.35% with addition of foundry sand , fly ash and tile waste in appropriate proportion.(Figure 5).

Thus, clayey soil stabilized with foundry sand, fly ash and tile waste can be used as a sub-grade material for construction of flexible pavements in rural roads with low traffic volume.

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