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Swelling Behavior of Black Cotton Soil Mixed With Lime and Fly Ash as Admixtures in Road Pavement

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Abstract

The This study uses lime(from local market) and fly ash (from State Rajasthan, Suratgarh Thermal Power Station), to study the swelling pressure behavior of expansive soil (black cotton soil). The main aim of this dissertation is to determine the optimum lime content (OLC), optimum fly ash content (OFAC) and optimum lime-fly ash content (OLFAC) to reduce the swelling of the expansive soil. For this we add different proportion of lime as (0, 1, 2, 3, 4, and 5%),fly ash as 0,5,10,15,20,25%),and lime -fly ash both as (1%lime+5% fly ash, 2% L+ 10% FA, 3%L+15%FA, 4% L+ 20% FA, 5%L+25%FA) in expansive soil and mix it at OMC, less than 2%OMC i.e. at dry of optimum and more than 2% OMC i.e. at wet of optimum and find out the swelling pressure of mixed soil at each percentage of lime ,fly ash, and both lime - fly ash and finally the optimum content of lime , fly ash,lime- fly ash determine on the basis of minimum swelling pressure of mixed soil at OMC.

Keywords: black soil, fly ash , lime specific gravity, pycnometer, plastic limit, liquid limit,

1. Introduction

Expansive soils also called swelling soils undergo harmful volume changes corresponding to alter in moisture content. The alternate swelling and shrinkage of expansive soils in alternate wet and dry seasons cause severe cracking in lightly loaded structures founded on them such as foundations, pavements, canal beds and linings. According to Jones and Holtz 1973, the damage caused due to these soils is more than any other natural hazards, including earthquakes and floods.There are so many additives such as fly ash, lime, cement rice husk, gypsum; geosynthetics etc. are available to improve the physicochemical properties of clay soils in order to permanently stabilize them. But fly ash and lime are easily available and more economical so it is used in large extent as additive to improve the strength of expansive soil. In general, the specific gravity of fly ash has low value as compared to the specific gravity of soils; hence ash fills tend to result in low dry densities. The reduction in unit weight is of advantage in the case of its use as a backfill material for retaining walls since the pressure exerted on the retaining structure as well as the foundation structure will be less. Attempts have been made to utilize fly ash in huge quantities in construction of embankments. Fly ash can be used economically for embankment construction in the vicinity of thermal power stations when lead distances are less than 10 to 15 km. In case of rigid pavements, usage of fly ash leads to considerable savings even if fly ash is to be transported more than 50 km or perhaps 100 km (SudipBasak et al 2004).

Soil stabilization by lime involves the admixture of this material in the form of calcium oxide (quicklime) or calcium hydroxide (hydrated lime) to the soil. Quick lime will slake in the presence of moisture to produce hydrated lime as a fine powder. According to (Petry and Armstrong, 1989)stabilization of expansive soil by lime consists of:

(a) Changing the physicochemical environment around and inside the clay particle,
(b) Changing the nature of the water that moves into and out of the voids, and
(c) Affecting behavioral changes in the soil mass as a whole.

2. Geo technical Behavior of Expansive Soil

2.1 Expansive Soil

The key element which imparts swelling characteristics to any ordinary non-swelling soil is a clay mineral. There are several types of clay minerals of which Montomorillonite has the maximum swelling potential. The origin of such soil is sub aqueous decomposition of blast rocks, or weathering in situ formation of important clay mineral takes place under alkaline environments. Due to weathering conditions if there is adequate supply of magnesium of ferric or ferrous oxides and alkaline environments.

2.2. Nature of expansive soil

There are two distinct types of swelling in clay such as:

- Elastic re-bounces in compressed soil mass consequent upon decrease in compressive force.
- Expansion in water sensitive clay due to ingress of free water.

2.3. Clay mineralogy

Generally clay-minerals can be divided into three general groups on the basis of their crystalline arrangements such as:

- Kaolinite group
- Montmorilonite group
- Illite group

Montmorilonite minerals:

This Crystals form weaker bondage between them. These soils containing higher percentage of Montmorilonite minerals exhibit high swelling and shrinkage characteristics; Structural arrangement of Montmorillonite mineral is composed of units made of two silica tetrahedral sheets with a central aluminum octahedral sheet.

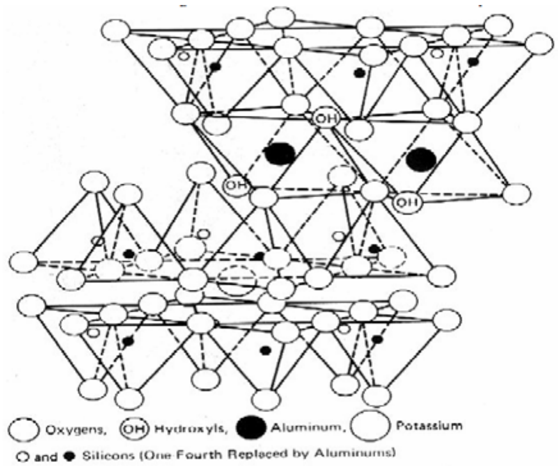

Fig. 1- Structure of Montmorilonite layer

2.4. Identification and classification of swelling soils

For identification of swelling soils, some laboratory tests are available. Clay minerals can be known by microscopic examination, ray diffraction and differential thermal analysis. From clay minerals by the presence of montomorillonite, the expansiveness of the soil can be judged. But the test is very technical.

3. Geo technical Behavior of additives

Fly ash

Fly ash is a by-product (waste material) of burning coal at electric power plants. It is a fine residue composed of unburned particles that solidifies while suspended in exhaust gases. Fly ash is carried off in stack gases from a boiler unit, and is collected by mechanical methods or electrostatic precipitators.

Engineering properties of fly ash

Following are the engineering properties of fly ash which are shown in the table 1

Parameter	**Range**
Specific gravity	1.90-2.55
Plasticity	Non plastic
Maximum Dry density(gm/cc)	0.9-1.6
Optimum Moisture Content in %	18.0-38.0
Cohesion in KN/m^2	negligible
Angle of internal friction	30^0-40^0
Coefficient of consolidation C_v (cm^2/sec)	$1.75x10^{-5}$-$2.01x10^{-3}$
Compression index C_c	0.05-0.4
Permeability cm/sec	$8x10^{-6}$-$7x10^{-4}$
Particle size distribution (%) Clay Sand Silt Gravel	 1-10 8-85 7-90 0-10
Coefficient of uniformity	3.1-10.7

Table 1- Engineering Properties of fly ash

3.2. Lime:
Lime is a generic term, but by strict definition it only embraces manufactured form of lime- quick lime (CaO) and hydrated lime ($Ca(OH)_2$). In the lime or dolime production processes, the blocks of limestone or dolomite obtained after blasting in the quarry are crushed and sorted by size in screening plants

5. Experimental Investigation

Tests carried out on these mixes:

Swelling pressure test to be carried on these mixes. For the preparation of sample first take soil and add water at OMC and different percentage of admixture (lime, fly ash) and mix them in trayproperly and compact in a swelling pressure mould as per IS:2720 Pt.61-2002. Now prepared sample assembly were kept on the swelling pressure machine and record the initial and final proving ring reading.

5.1 Experimental set up of swelling pressure

Fig.2 Equipment for swelling pressure test

Results:

The effect of lime, fly ash and lime-fly ash on the soil at different condition such as at OMC, at dry of optimum (less than 2% OMC) and at wet of optimum (more than 2% OMC) with different percentage of lime and fly ash are as follows-

At OMC, the swelling pressure of black cotton soil with 0%, 1%, 2%, 3%, 4%, and 5% lime are 48.3, 38.35, 25.3, 10.35, 6.9 and 19.55 KN/m^2 respectively, which are shown in the table 10. The swelling pressure of black cotton soil with 0%, 5%, 10%, 15%, 20%, and 25% fly ash are 48.3, 44.27, 38.35, 33.35, 27.6 and 52.9 KN/m^2 respectively, which are shown in the table 11. The swelling pressure of black cotton soil with 0-0%, 1-5%, 2-10%, 3-15%, 4-20% and 5-25% lime-flyash are 48.3, 60.95, 40.25, 16.1, 12.65, and 9.2 KN/m^2 respectively, which are shown in the table 12.

AT DRY OF OPTIMUM, the swelling pressure of soil at without additive, 4% lime, and 20% fly ash are 70.15, 11.5, and 40.25 KN/m^2respectively which are shown in table13.

AT WET OF OPTIMUM, the swelling pressure of soil at without additive, 4% lime, and 20% fly ash are 20.7, 5.75, 36.8 KN/m^2 respectively which are shown in table14.

Table 2 Swelling pressure of soil at OMC (23%) with lime

Serial No.	Mix Designation	Swelling Pressure (KN/m^2)
M0L	Expansive Soil at OMC + 0 % lime of soil	48.3
M1L	Expansive Soil at OMC + 1 % lime of soil	38.35
M2L	Expansive Soil at OMC + 2 % lime of soil	25.3
M3L	Expansive Soil at OMC + 3 % lime of soil	10.35
M4L	Expansive Soil at OMC + 4 % lime of soil	6.9
M5L	Expansive Soil at OMC + 5 % lime of soil	19.55

Table 3 Swelling pres. of soil at OMC (23%) with fly ash

Serial No.	Mix Designation	Swelling Pressure kN/m^2
M0L	Expansive Soil at OMC + 0 % fly ash of soil	48.3
M5FA	Expansive Soil at OMC + 5 % fly ash of soil	44.27

M10FA	Expansive Soil at OMC + 10 % fly ash of soil	38.35
M15FA	Expansive Soil at OMC + 15 % fly ash of soil	33.35
M20FA	Expansive Soil at OMC + 20 % fly ash of soil	27.6
M25FA	Expansive Soil at OMC + 25 % fly ash of soil	52.9

Table 4 Swelling pressure of soil at OMC (23%) with lime and fly ash

Serial No.	Mix Designation	Swelling Pressure (KN/m^2)
M0L-0FA	Expansive soil at OMC + 0 % lime and 0 % fly ash of soil	48.3
M1L-5FA	Expansive soil at OMC + 1 % lime and 5 % fly ash of soil	60.95
M2L-10FA	Expansive soil at OMC + 2 % lime and 10 % fly ash of soil	40.25
M3L-15FA	Expansive soil at OMC + 3 % lime and 15 % fly ash of soil	16.1
M4L-20FA	Expansive soil at OMC + 4 % lime and20 % fly ash of soil	12.65
M5L-25FA	Expansive soil at OMC + 5 % lime and 25 % fly ash of soil	9.2

Table 5 Swelling Pressure of soil at dry condition with optimum lime and fly ash

Serial No.	Mix Designation	Swelling Pressure(KN/m^2)
D0L	Expansive Soil at less than 2% OMC + 0 % lime of soil	70.15
D4L	Expansive Soil at less than 2% OMC + 4 % lime of soil	11.5
D0FA	Expansive Soil at less than 2% OMC + 0 % fly-ash of soil	70.15
D20FA	Expansive Soil at less than 2% OMC +20 % fly-ash of soil	40.25

Table 6 Swelling Pressure of soil at wet condition with optimum lime and fly-ash

Serial No.	Mix Designation	Swelling Pressure (KN/m^2)
M0L	Expansive Soil at more than 2% OMC + 0 % lime of soil	20.7
M4L	Expansive Soil at more than 2% OMC + 4 % lime of soil	5.75
M0FA	Expansive Soil at more than 2% OMC + 0 % fly ash of soil	20.7
M20FA	Expansive Soil at more than 2% OMC + 20 % fly ash of soil	36.8

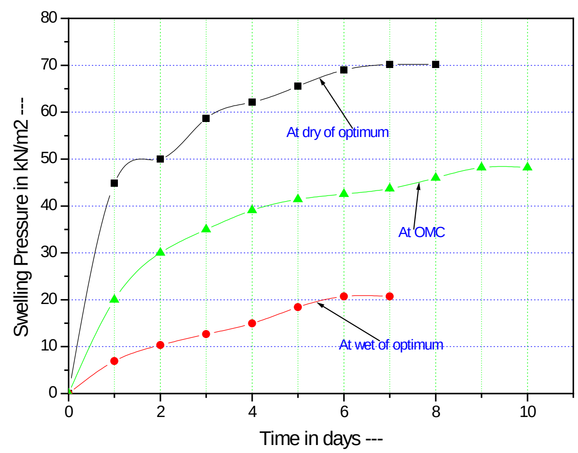

Fig 3 Comparison of Swelling Pressure of soil with time at dry of optimum, at OMC and at wet of optimum

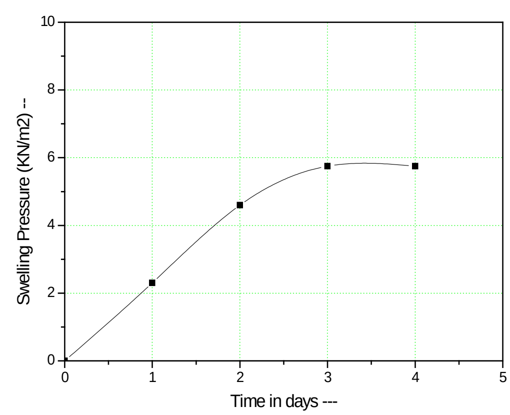

Fig 4 Variation of Swelling Pressure of soil at wet of optimum with 4% lime (OLC)

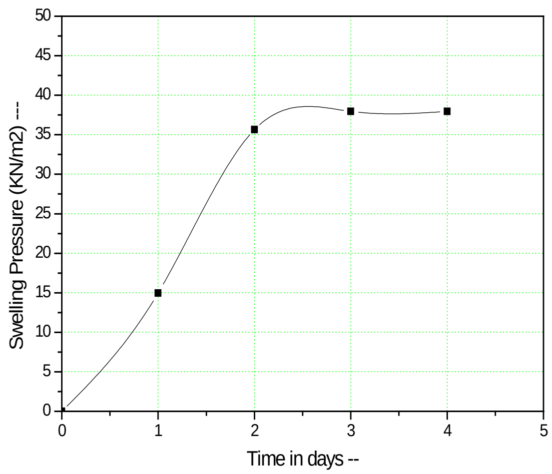

Fig 5 Variation of Swelling Pressure of soil at wet of optimum with 20% fly ash (OFAC)

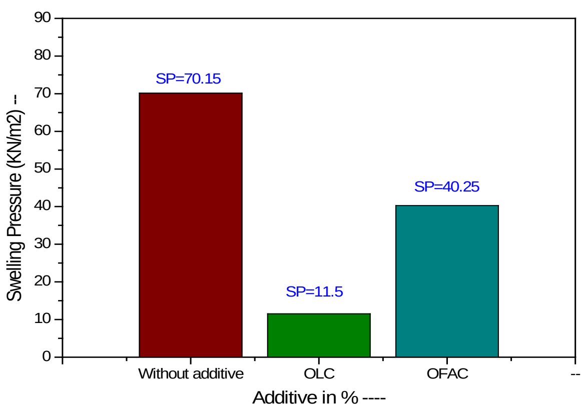

Fig 6 Swelling Pressure of soil at dry of optimum with additive

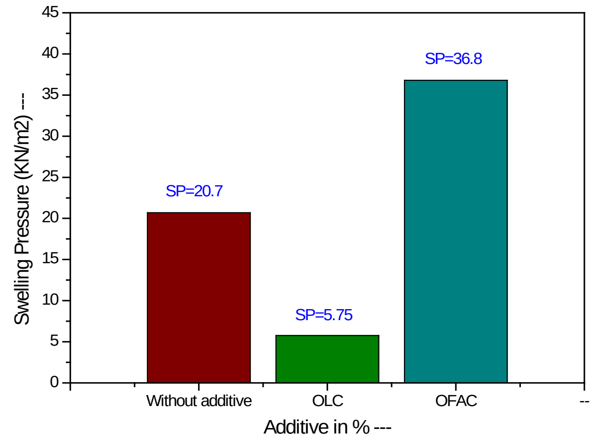

Fig 6 Swelling Pressure of soil at wet of optimum with additive

Discussion: From the above result it is clear that the swelling pressure of soil at OMC, decreases with increasing the lime content and it occurred up to 4% lime content and after then it increases slowly. So the optimum lime content to arrest the swelling i.e. 4% lime content is more effective. Similarly in the case of fly ash the swelling pressure of soil at OMC, decreases up to 20% fly ash content and after then it increases rapidly. So the optimum fly ash content to arrest the swelling pressure i.e. 20% fly ash content is more effective. And the swelling pressure also decreases with the lime and fly ash both but 1% lime and 5% fly ash is not more effective because the swelling pressure of soil with admixture is more than without admixture. This may be happen due to the formation of new compound between the soil and lime–fly ash. Also the swelling pressure of soil at dry of optimum is more than the wet of optimum.

4. Conclusions

- On increasing the lime content the swelling pressure of soil at OMC decreases steadily to a lowest value at 4% lime and then it increases slightly. Therefore the Optimum Lime Content (OLC) is equal to 4%.
- On increasing the fly ash content the swelling pressure of soil at OMC decreases steadily to a lowest value at 20% fly ash and then it increases rapidly. Therefore the Optimum fly ash Content (OFAC) is equal to 20%.
- On increasing the lime-fly ash content the swelling pressure of soil at OMC, first increases

at 1% lime-5% fly ash after then it decreases steadily.

- The swelling pressure of the soil in case of dry of optimum is more than the wet of optimum i.e. the swelling pressure of soil is decreases with increase in the moisture content.
- At Optimum Lime Content, Lime retards the swelling pressure of soil in case of dry of optimum as well as in wet of optimum.
- At Optimum Fly ash Content, Fly ash has less role to retards the swelling pressure of soil in dry of optimum and wet of optimum condition.

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