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EFFECT OF LIME-FLY ASH ADMIXTURES ON THE BEHAVIOUR OF EXPANSIVE CLAYS

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ABSTRACT: The current article is coordinated to comprehend the enlarging conduct of expansive clays treated with lime and fly ash added substances. Various ongoing articles accessible regarding these matter/boundaries have been basically looked into, information has been separated from them, and generally amalgamation has been done. Utilizing programming bundle and the above information as info, appropriate bends and conditions have been created to show changes in free swell file, rate swell and enlarging pressure carried out by treating such clay with lime and fly ash added substances.

1. INTRODUCTION

The seasonal moisture variations in expansive soil deposits around and beneath the structures lead to their subsequent upward and downward movements resulting into damages of varying degrees. Civil engineering structures such as highways, canals, and embankments occupy vast areas of land as they often stretch over several kilometers.

Among various methods for the solutions to the problems posed by expansive soils, especially for large area coverage, the stabilization of such soils would be a natural choice. Stabilization of expansive soils using lime is widely adopted by practicing engineers the world over. The pozzolanic property of fly ash makes it a potentially useful material especially in the civil engineering industry. Thus, there is a growing awareness among civil engineers to explore the possibility of beneficial utilization of this industrial waste material, which is available almost free of cost in India.

In view of this, herein an attempt has been made to understand the effectiveness of fly ash and lime admixtures in reducing the deleterious behaviour of expansive clays when treated. The study pertains mainly to critical review, analysis and synthesis of relevant data extracted from recent literature.

2. LITERATURE REVIEW

Overview

The swelling phenomenon in clays is attributed predominantly to the presence of montmorillonite clay mineral in them. The montmorillonite is hydrated Aluminum silicates with 3 layered lattice structure in which intra particle space when occupied by layers of water molecules give rise to swelling and related phenomena. The reactions and structural changes taking place in expansive clays when treated with lime and/or fly ash additives are highlighted below.

Lime Stabilization

The addition of lime, quicklime (CaO) or hydrated lime [$Ca(OH)_2$] to expansive soil reduces swelling & swelling pressure and improves strength. Such behaviour of treated soil may be attributed to the following reactions.

(a) *Cation Exchange:* Replacement of the exchangeable cations (sodium, hydrogen, etc.) of the soil by the calcium cations from the lime.
(b) *Floculation:* An increase in grain size created by the suppression of the double water layer surrounding the clay particles due to an increased electrolyte concentration results in flocculation.
(c) *Carbonation:* Reaction of lime and carbon dioxide from the atmosphere to form relatively weak cementing agents, calcium and/or magnesium carbonate.
(d) *Pozzolanic Reactions:* Reaction between the silica and alumina present in the clay minerals and the calcium from the lime to form new cementatious minerals. (Generally, cation exchange takes place by initial addition of 1–2% of lime (by dry weight of soil), further addition of lime is responsible for pozzolanic activity.

Fly Ash Stabilization

Most of the Thermal Power Plants in India use crude coal and middlings, after burning which produce large quantity of fly ash. Fly ash is fine texture alkaline material, which can be classified as non-plastic fine silt. The presence of SiO_2 and Al_2O_3 in amorphous form in fly ash contribute towards its pozzolanic property. It is due to this property alone, such an industrial waste material is being researched in India and abroad for its beneficial utilization in civil engineering industry. Fly ash when mixed with expansive clays (under favorable moisture condition) the cation exchange (multivalent cations replacing monovalent cations), presence of free lime, and formation of calcium silicate or calcium aluminate as a gel (pozzolanic reaction) provide the required effect to control the swelling and improve the strength of expansive clays. The admixture of fly ash and small quantity of lime remarkably enhances this effect in addition to expediting the reactions.

Critical Review

Free Swell Index and Swelling Potential

Kate (1998) reported reductions in free swell index (IS: 2720, part 40, 1997) by 60% and 63% for Anta expansive soils A and B respectively with 15% class C fly ash. The percentage reduction in swelling potential of expansive soil composed of 85% Na-bentonite and 15% kaolinite observed by Cokca (1999) was 52.6% and 58.3% by treating with 25% of soma fly ash and Tuncbilek fly ash (both class-C), respectively. Reduction of 65% in swelling potential by addition of 20% fly ash reported by Cokca (2001) was nearly same as that by 8% lime.

Nalbantoglu & Gucbilmez (2002) reported decrease in swell potential from 19.6% to 0% of calcareous expansive clay by addition of 15% soma fly ash (class-C). Kate (2005a) noticed that Free Swell Index (FSI) decreases curvilinearly with increasing proportion of fly ash and lime. The addition of 20% fly ash alone reduces the FSI to 260%, 214%, 105% and 116%, respectively, giving percentage reductions in FSI of the order of 31, 34, 54 and 38 for soils. A, B, C & D respectively. Adding 3% lime with 20% fly ash to soil A and 2% lime to soils B, C and D further reduces the FSI to 32%, 34%, 29% and 26% respectively.

Garcher & Trivedi (2005) observed reduction in free swell index from 65% (untreated) to around 20% of Ghed expansive soil treated with 30% class F fly ash. Addition of 20% lime sludge to BHAL expansive soil reduced free swell index from 68% to 39%, a change of about 74% as reported by Timani & Patel (2005).

Percentage Swell and Swelling Pressure

Kate (1998) reported decrease in swelling pressure (TC-6, 1993) from 120 kPa to 90 kPa of Anta expansive soil A and from 160 kPa to 105 kPa of expansive soil B by treating with 12% fly ash. Both these soils possessed high expansivity and were classified as CH. The percentage change (reduction) in swelling pressure was also reported by Cokca (1999) with increasing curing period.

Nalbantoglu (2004) reported decrease in swell pressure from around 490 kPa to 10 kPa by addition of 25% class C fly ash to Degirmanlik expansive soil. He noticed further reduction in swell pressure with increase in curing period.

The extensive experimental studies conducted by Kate (2005a) to understand percentage swell and swelling pressure behaviour of four expansive soils A, B, C and D (mixes of bentonite and Kaoline clay in proportion of 100:0, 80:20, 70:30 and 50:50 respectively) treated with different percentage of fly ash and lime reported the following observations.

(a) The values of maximum percent swell for soils A, B, C and D are 22, 17.5, 13.7 and 9, respectively. The addition of 20% fly ash alone reduces these values to 11, 8.7, 6.8 and 4.7, respectively, and further addition of lime (3% to soil A and 2% to soils B, C and D brings down these values to 4, 5.5, 4.9 and 2.8 respectively.
(b) The addition of 20% of fly ash alone decrease the swelling pressure from 425 kPa of soil A, from 345 kPa to 207 kPa of soil B, from 259 kPa to 185 kPa of soil C and from 167 kPa to 110 kPa of soil D. Further addition of lime (3% to soil A and 2% to remaining soils) lowers down these values to 50 kPa, 68 kPa, 62 kPa and 51 kPa for these soils, respectively.

Al-Rawas *et al.* (2005) reported reduction in swelling pressure from 250 kPa to 0 by addition of 6% lime to Oman expansive soil. They also observed reduction in percent swell from 9.5 to 0 with 6% lime.

3. METHODOLOGY

A number of recent articles on treatment of expansive clays using fly ash and lime have been critically reviewed. The data related with their swelling characteristics such as free swell index, swelling potential, percentage swell and swelling pressure with and without treatment have been extracted from these articles. Overall analysis and synthesis of this data has been carried out, using EXCEL software package and the above data as input, suitable curves and equations have been developed.

4. RESULTS AND DISCUSSION

Free Swell Index

The variation of free swell index with percentage of fly ash is illustrated in Figure 1.

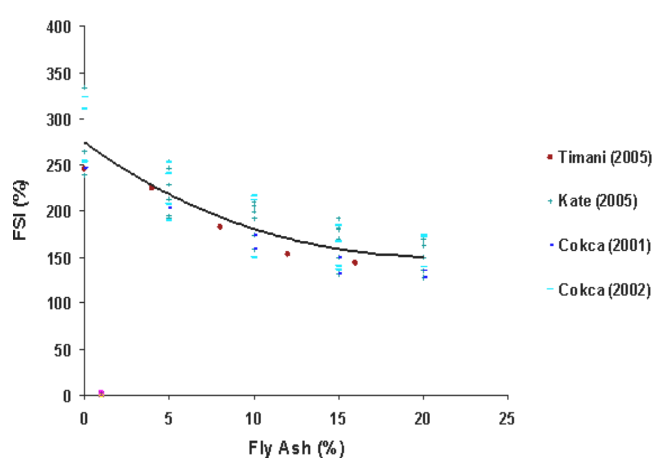

Fig. 1: Variation of Free Swell Index with Fly Ash

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It is seen that with increasing percentage of fly ash the FSI decreases non-linearly. By addition of small percentage of fly ash initially the decrease is substantial whereas the curve tends to be an asymptotic at a fly ash of around 20%. The FSI value of untreated soil is around 274%, which reduces to around 175% by addition of 20% fly ash indicating a reduction of 35%. The generalized equation for this variational curve is given below.

$$FSI = -0.004F^3 + 0.44F^2 - 13.33\,F + 274 \quad (1)$$

Wherein, FSI denotes percentage free swell index and F is percentage of fly ash.

Percentage Swell

The plot between percentage swell and fly ash (%) is illustrated in Figure 2, which shows non linear decrease in percentage swell of treated expansive soil with increase in fly ash.

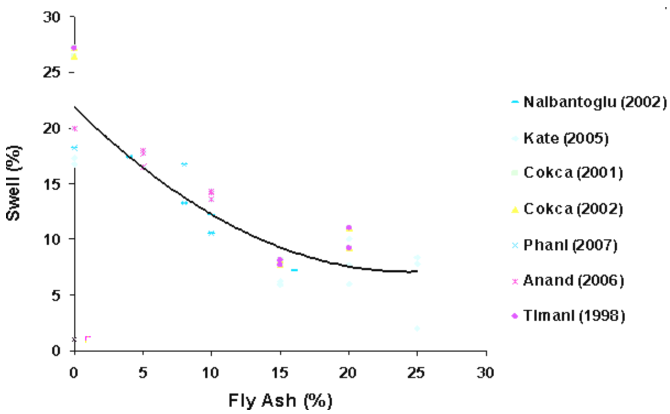

Fig. 2: Percentage Swell *versus* Fly Ash

The addition of 25% fly ash reduces the swell from 22% to 7% giving a reduction of the order of 68% of the untreated swell value. The correlation between them is expressed by Equation 2,

$$Swl = 0.025\,F^2 - 1.21\,F + 22 \quad (2)$$

Where, *Swl* is percentage swell.

The variation of percentage swell with lime shown in Figure 3 exhibit a relationship expressed by following equation,

$$Swl = 19.3\,e^{-0.29L} \quad (3)$$

Where, *L* is percentage of lime.

It is seen from Figure 3 that, the percentage swell reduces from around 19% to 3% by addition of 8% lime i.e. a reduction of around 84% of untreated swell value.

Swelling Pressure

The Figure 4 illustrates the variation of swelling pressure with fly ash showing decrease in swelling pressure with increasing percentage of fly ash.

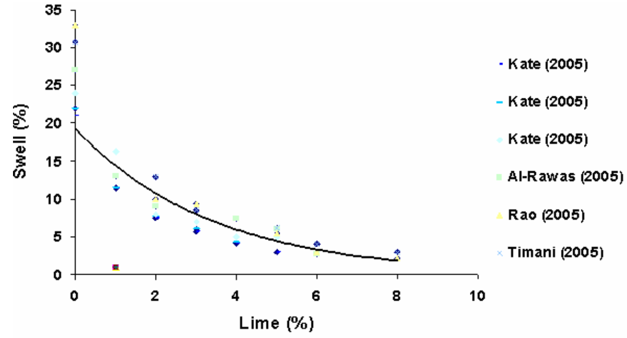

Fig. 3: Plot of Percentage Swell with Lime

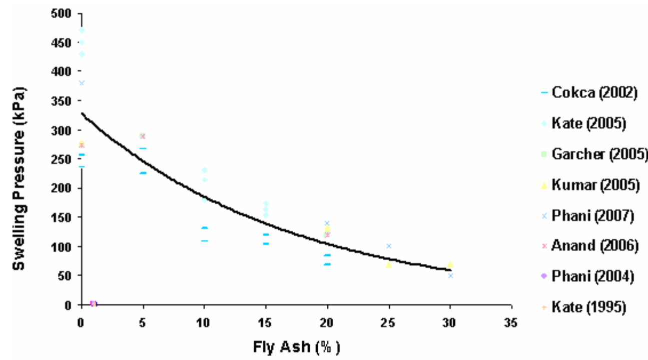

Fig. 4: Variation of Swelling Pressure with Fly Ash

It is seen that an addition 30% fly ash brings down swelling pressure from 328 kPa to 65 kPa thus indicating a reduction of 80% of untreated swelling pressure value. The following relationship have been obtained from curve in Figure 4.

$$Swp = 328\,e^{-0.057F} \quad (4)$$

Wherein *Swp* is swelling pressure in kPa. The variation of swelling pressure with lime presented in Figure 5 shows decrease of swelling pressure with increasing percentage of lime.

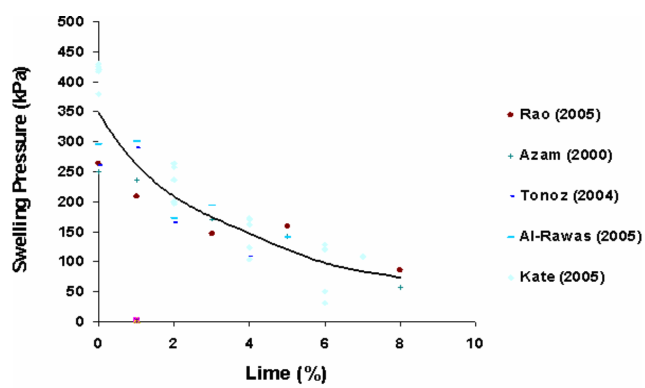

Fig. 5: Swelling Pressure *versus* Lime

The swelling pressure reduces from a value of 350 kPa to 85 kPa with the addition of 8% lime bringing a reduction of the order of 76% of its untreated value.

5. CONCLUSIONS AND RECOMMENDATION

The conclusions and recommendation arrived at are given below.

1. The percentage of good quality fly ash required to reduce swelling characteristics considerably is around 25%, whereas that of lime is maximum 8%.
2. In general, the reductions brought out in free swell index, percentage swell and swelling pressure by 25% fly ash are of the order of 35%, 68% and 80% respectively of the untreated values. Whereas, these reductions in percentage swell and swelling pressure are 84% and 76% respectively by 8% of lime.
3. These curves alongwith correlations between swelling characteristics and percentage of fly ash and/or lime, developed in the present study may prove to be useful to field/design engineers to predict the behavior of expansive clays. Further, they can be utilized for preliminary estimation of the quantity of lime and or fly ash required to achieve desired improvements in the behaviour of expansive clays.
4. On the basis of economic considerations, use of good quality fly ash alone is recommended for treatment of clays with low to medium expansivity. Whereas, for treating highly expansive clays, a combination of fly ash with small percentage of lime is recommended.

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