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Effect of Lime on the California Bearing Ratio Behaviour of Fly Ash - mine Overburden Mixes

B. Behera and M. K. Mishra

Abstract**—**Typically thermal power plants are located near to surface coal mines that produce huge amount of fly ash as a waste byproduct. Disposal of fly ash causes significant economic and environmental problems. Now-a-days, research is going on for bulk utilization of fly ash. In order to increase its percentage utilization, an investigation was carried out to evaluate its potential for haul road construction. This paper presents the laboratory California bearing ratio (CBR) tests and evaluates the effect of lime on CBR behavior of fly ash - mine overburden mixes. Tests were performed with different percentages of lime (2%, 3%, 6%, and 9%). The results show that the increase in bearing ratio of fly ash-overburden mixes was achieved by lime treatment. Scanning electron microscopy (SEM) analyses were conducted on 28 days cured specimens. The SEM study showed that the bearing ratio development is related to the microstructural development.

Keywords**—**California bearing ratio, Fly ash, Mine overburden, Lime.

I. Introduction

HUGE quantities of coal combustion byproducts are produced every year and only a small fraction of them are utilized. The current annual production of coal ash worldwide is estimated around 600 million tons, with fly ash constituting about 500 million tons at 75-80% of the total ash produced [1]. Disposal of ash in dry or slurry form in the proximity of the thermal power plants not only occupies a large area but also causes environmental pollution [2]. Utilization of coal ash in construction helps in saving of precious land area. Considering the practical significance of the problem, experimental investigations were carried out on fly ash to establish its suitability for geotechnical applications.

Thus, the amount of fly ash generated from thermal power plants has been increasing throughout the world, and consuming several thousand hectares of precious land for the disposal of the large amount of fly ash. It has become a serious environmental problem. The beneficial effects of lime treatment on the performance of a broad range of soils or soil-fly ash mixtures have been widely documented [3]–[10]. Mine overburdens (O/B) are very important raw materials which have been traditionally used in the most economical way throughout the world. The overburden is highly heterogeneous. Gradation results suggest that fines and coarse grains are approximately equally represented in the soil reported by Ulusay et al [11]. This paper investigates the effect of lime on California bearing ratio (CBR) of fly ash and overburden mixes. Microstructural features of the samples were analyzed by scanning electron microscopy.

II. Materials and Methods

A. Materials

The overburden used in this study was collected from Bharatpur opencast coal mine, Talcher, Orissa. The fly ash used in the present study was collected from electrostatic precipitators of a thermal power unit of Rourkela Steel Plant, Orissa, India. The fly ash used in the present study was collected from electrostatic precipitators of a thermal power unit of Rourkela Steel Plant, Orissa, India. The additive selected was commercially available superior grade quick lime. The fly ash and overburden mixes were stabilized with 2%, 3%, 6%, and 9% of lime. Weight fractions of fly ash of 15%, 20% 25% and 30% were used to mix with overburden.

B. Methods

The tests for specific gravity, consistency limits, free swell index, pH, and loss on ignition were carried out as per the prescribed Indian Standards. The compaction characteristics of the fly ash, overburden and all the mixes were determined by conducting heavy compaction tests on specimens according to IS: 2720 (Part 8) 1983 [12] with different amounts of lime. CBR tests on compacted specimens were conducted according to IS: 2720 (Part 16) 1987 [13]. All specimens for the CBR test were prepared at their optimum water content. SEM technique was used to study the morphological behaviour of fly ash, overburden and all the mixes. A JEOL JSM 6480 LV, (Japan) model was used for the SEM study.

III. Results and Discussion

The physico-chemical properties of fly ash and mine overburden were reported in Table I. The specific gravity of fly ash is found to be less than that of mine overburden, due to the presence of cenospheres. Free swell index of fly ash is found to be negative which is negligible due to flocculation. The morphological behavior of the overburden and fly ash are as shown in Figs. 1 and 2.

B. Behera, is with the National Institute of Technology, Rourkela - 769008 India (corresponding author phone: 91-661-2464609; fax: 91-661-2462022; e-mail: banita@nitrkl.ac.in). She acknowledges the fund provided by Fly Ash Unit, DST, Govt. of India vide approval No: *FAU/DST/600(17)/2008-09* dated *12.09.2008*

M. K. Mishra is with the National Institute of Technology, Rourkela-769008 India (e-mail: mkmishra@nitrkl.ac.in).

TABLE I
PHYSICO-CHEMICAL PROPERTIES OF FLY ASH AND MINE OVERBURDEN

Property	Fly ash	Overburden
1. Specific gravity	2.16	2.6
2. Consistency limits		
Liquid limit (%)	30.75	25.70
Plastic limit (%)	Non-plastic	15.04
Shrinkage limit (%)	--	13.44
3. Plasticity Index (%)	--	10.66
4. Free swell index (%)	Negligible	20
5. pH value	7.2	4.85
6. Loss on ignition (%)	7.2	4.85

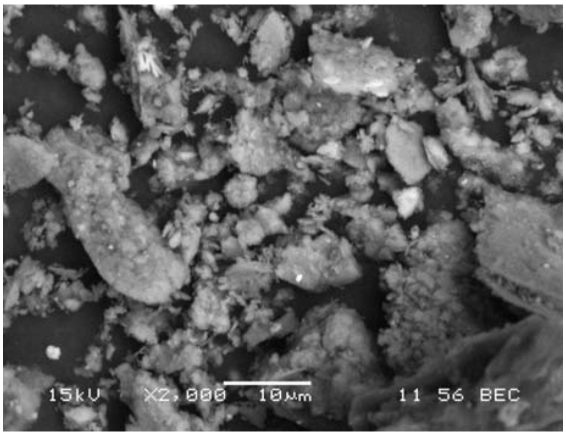

Fig. 1 Scanning electron micrograph of mine overburden

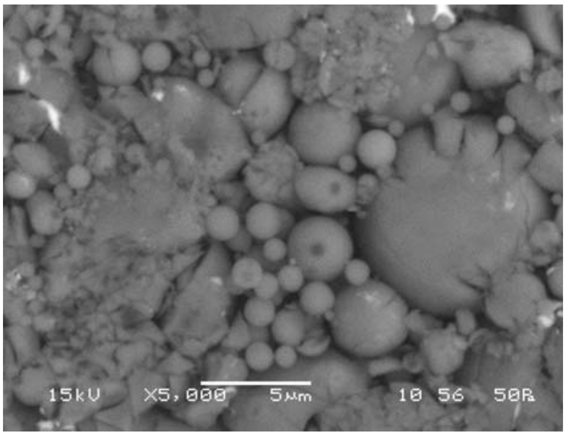

Fig. 2 Scanning electron micrograph of fly ash

A. Compaction behaviour

Moisture content against dry density relationship obtained from heavy compaction test for fly ash, mine overburden and the mixes are reported in Table II. The maximum dry density of flyash is lower than that obtained for mine overburden as flyash is non-cohesive in nature.

TABLE II
MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT ACHIEVED FROM THE COMPACTION TEST

Mix	MDD (kg/m^3)	OMC (%)
Fly ash	1396	20.06
Mine overburden	2040	8.15
15%FA+85%O/B	1965	8.77
20%FA+80%O/B	1914	10.4
25%FA+75%O/B	1872	10.8
(15%FA+85%O/B)+2%L	1867	11.63
(15%FA+85%O/B)+3%L	1841	13.2
(15%FA+85%O/B)+6%L	1833	12.81
(15%FA+85%O/B)+9%L	1826	13.4
(20%FA+80%O/B)+2%L	1842	11
(20%FA+80%O/B)+3%L	1806	11.15
(20%FA+80%O/B)+6%L	1804	12.6
(20%FA+80%O/B)+9%L	1807	11.3
(25%FA+75%O/B)+2%L	1788	13.2
(25%FA+75%O/B)+3%L	1775	12.2
(25%FA+75%O/B)+6%L	1766	12.2
(25%FA+75%O/B)+9%L	1726	14.4
(30%FA+70%O/B)+2%L	1759	12.6
(30%FA+70%O/B)+3%L	1768	12.44
(30%FA+70%O/B)+6%L	1747	12.66
(30%FA+70%O/B)+9%L	1729	13.6

Note: MDD = Maximum dry density, OMC = Optimum moisture content, FA = Fly ash, O/B = Overburden, L = Lime.

B. California bearing ratio behaviour

The CBR values of fly ash, mine overburden and the mixes are reported in Table III. The CBR value of overburden increased with the addition of fly ash. Pandian and Krishna (2002) reported an increase in CBR values of black cotton soil and fly ash with addition of cement and attributed this to change in the frictional angle. The CBR values under soaked condition are less than the unsoaked condition due to decrease in effective stresses and loss of surface tension forces upon soaking (Toth et al, 1988). The effect of lime content on CBR behavior of overburden-fly ash mixes are shown in Fig. 3. It is observed that the CBR values (77.08% and 60.73%) are more in 15%FA+85%O/B and 25%FA+75%O/B mixes with 3% lime content as compared to 2%, 6% and 9% of lime content. For 7 and 28 days cured samples, the CBR values of all the mixes are increased with increase in lime content (Figs. 4 and 5).

TABLE III
CBR VALUES OF FLY ASH, MINE OVERBURDEN AND MIXES

Sample	CBR (%)	
	Unsoaked condition	Soaked condition
1. Fly ash	22.42	0.72
2. Overburden	23.65	2.95
15%FA+85%O/B	32.07	2.34
20%FA+80%O/B	27.09	1.87
25%FA+75%O/B	26.16	1.4
30%FA+70%O/B	26.47	1.31

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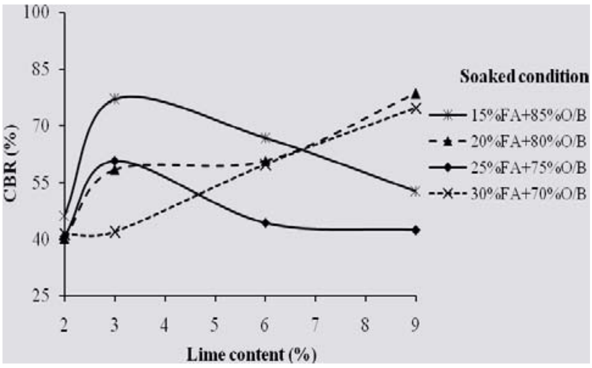

Fig. 3 Effect of lime on CBR behaviour of overburden-fly ash mixes

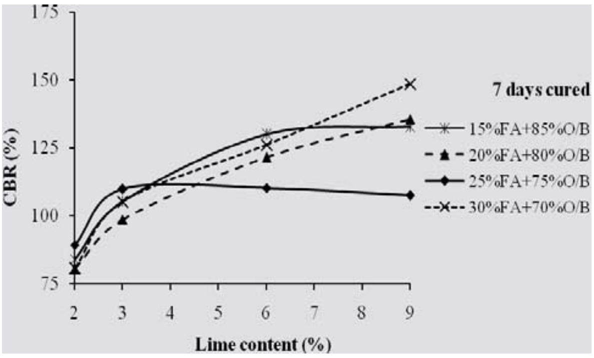

Fig. 4 Effect of lime on CBR behaviour of overburden-fly ash mixes at 7 days curing

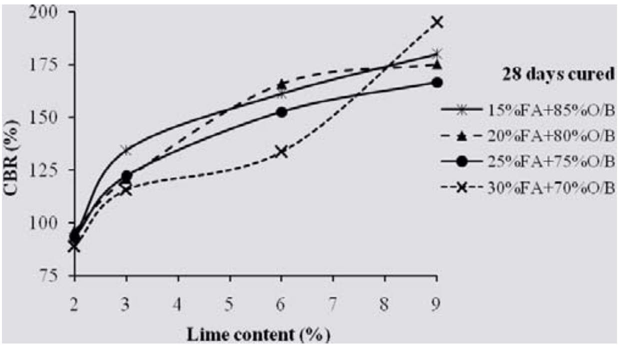

Fig. 5 Effect of lime on CBR behaviour of overburden-fly ash mixes at 28 days curing

C. Microscopy analysis

Scanning electron microscopy (SEM) analyses were conducted on 28 days cured specimens. The SEM photographs in Fig. 6 show the coating of fly ash and overburden particles as a result of lime addition, which indicates increase in compressive strength. It is clearly visible in the micrographs that new cementitious compounds such as calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A H) were formed around fly ash and overburden particles as a result of the pozzolanic reaction after 28 days curing. Cetin et al [14] reported that the CBR of lime kiln dust amended soil-fly ash mixtures increase with increasing curing time due to the formation of calcium silicate hydrate (CSH) and calcium aluminate silicate hydrate gels (CASH) around soil particles.

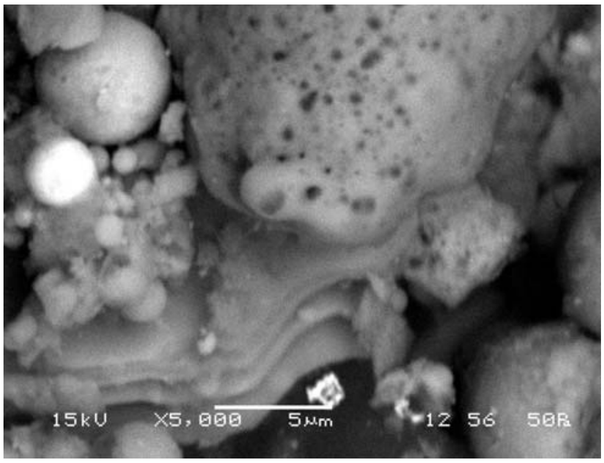

Fig. 6(a) Scanning electron micrograph of (15FA+85O/B)+2L

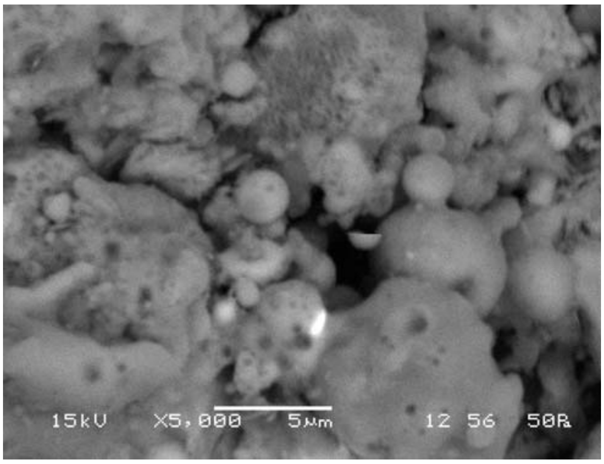

Fig. 6(b) Scanning electron micrograph of (15FA+85O/B)+3L

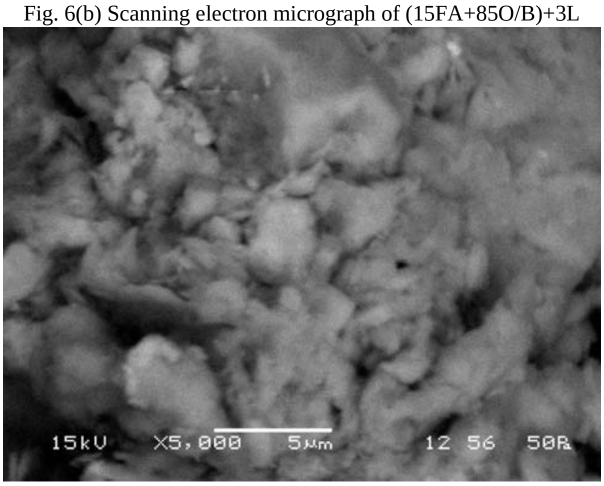

Fig. 6(c) Scanning electron micrograph of (15FA+85O/B)+6L

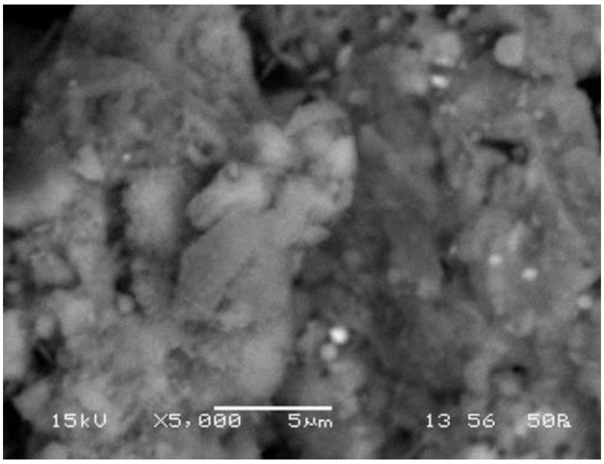

Fig. 6(d) Scanning electron micrograph of (15FA+85O/B)+9L

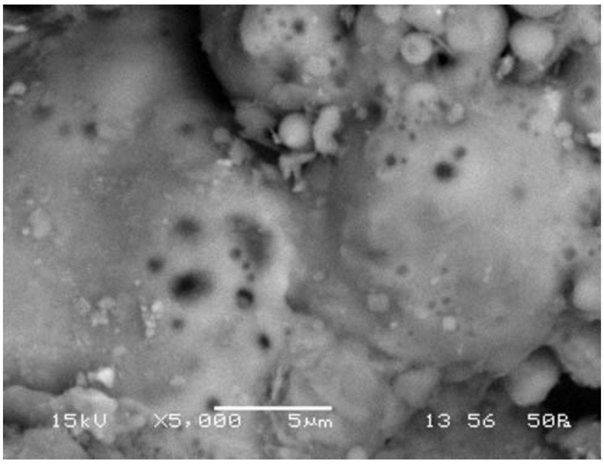

Fig. 6(e) Scanning electron micrograph of (20FA+80O/B)+2L

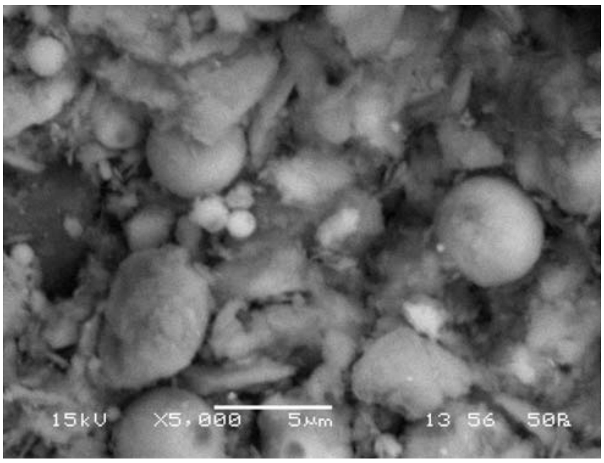

Fig. 6(f) Scanning electron micrograph of (20FA+80O/B)+3L

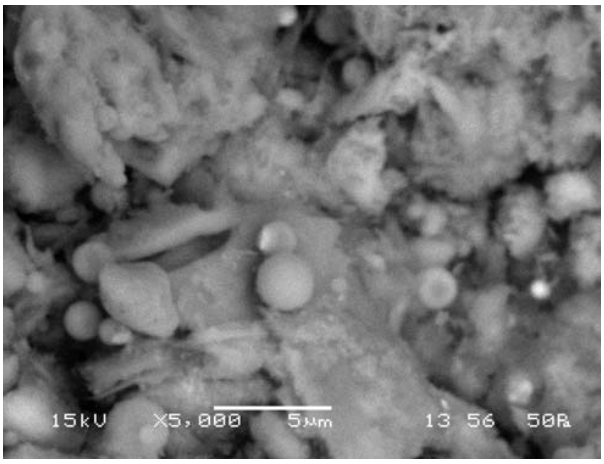

Fig. 6(g) Scanning electron micrograph of (20FA+80O/B)+6L

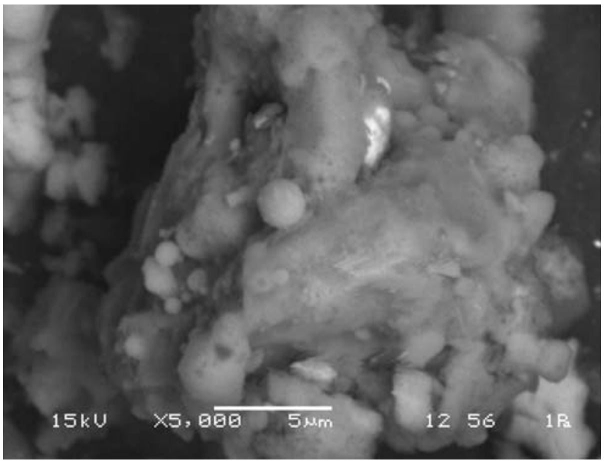

Fig. 6(h) Scanning electron micrograph of (20FA+80O/B)+9L

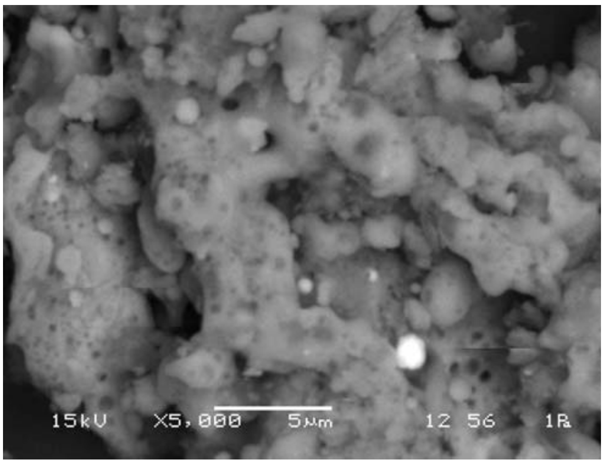

Fig. 6(i) Scanning electron micrograph of (25FA+75O/B)+2L

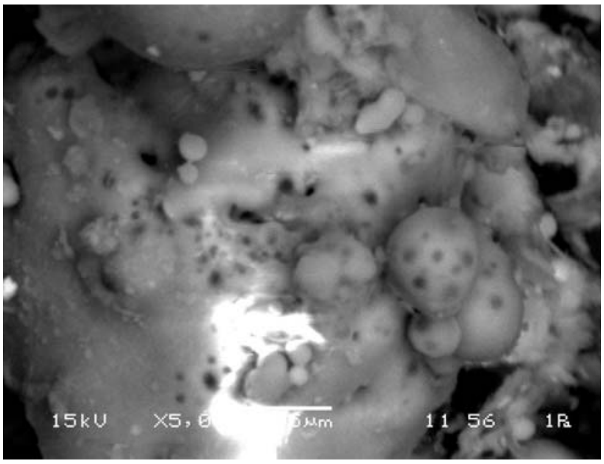

Fig. 6(j) Scanning electron micrograph of (25FA+75O/B)+3L

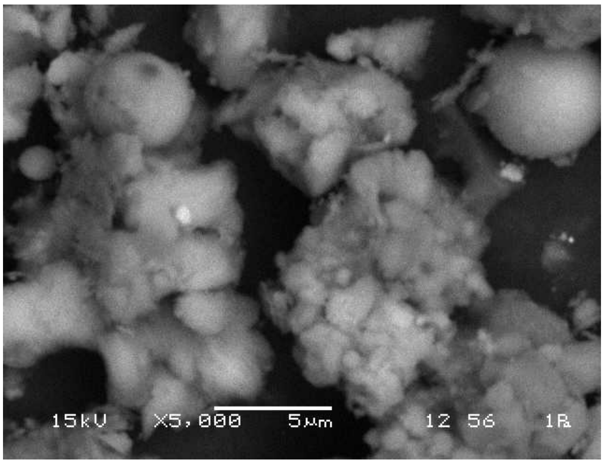

Fig. 6(k) Scanning electron micrograph of (25FA+75O/B)+6L

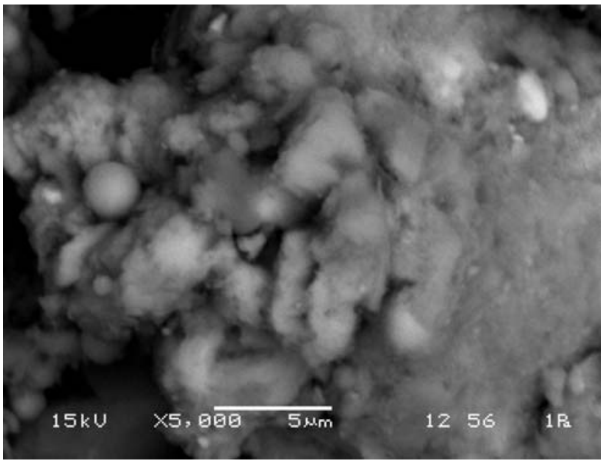

Fig. 6(l) Scanning electron micrograph of (25FA+75O/B)+9L

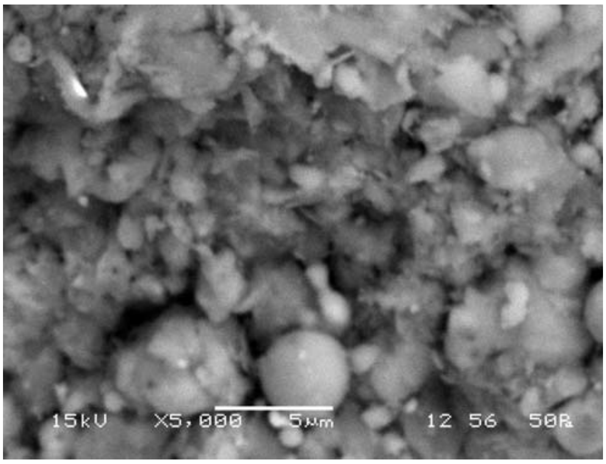

Fig. 6(m) Scanning electron micrograph of (30FA+70O/B)+2L

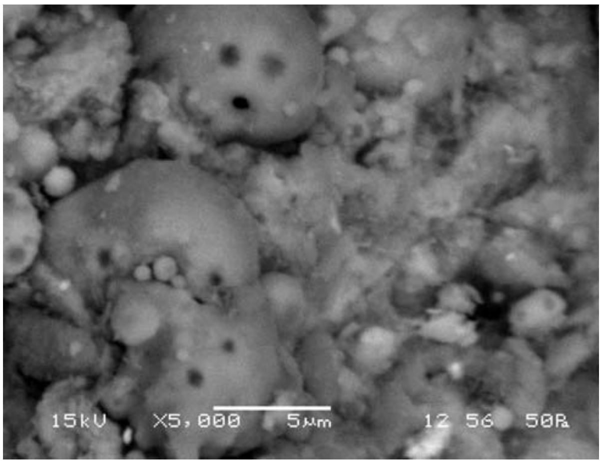

Fig. 6(n) Scanning electron micrograph of (30FA+70O/B)+3L

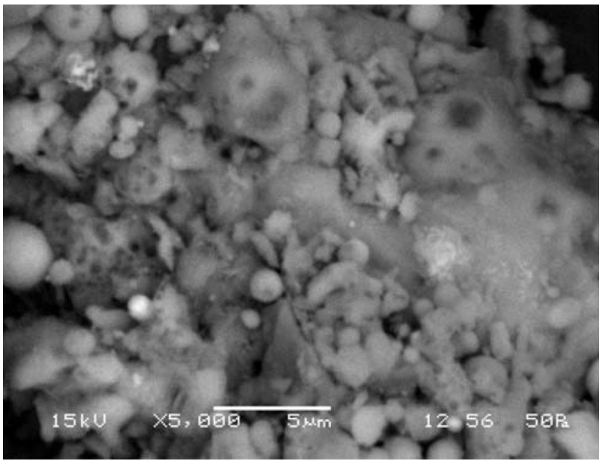

Fig. 6(o) Scanning electron micrograph of (30FA+70O/B)+6L

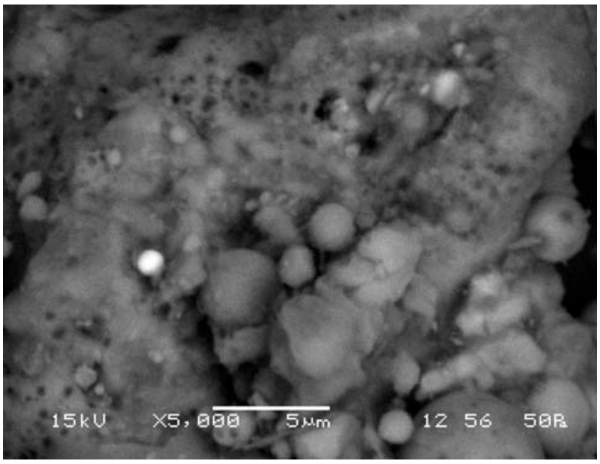

Fig. 6(p) Scanning electron micrograph of (30FA+70O/B)+9L

IV. CONCLUSION

Based on the test results obtained in this investigation, the following conclusions can be drawn: Lime content showed a significant effect on increase in CBR value and pozzolanic reaction rate of natural pozzolans. The results show that the addition of fly ash improved the CBR of mine overburden in unsoaked condition. With increase in fly ash content, the CBR increases up to a certain percentage then decreases due to class F type. The optimum fly ash content for higher CBR values was 20%. Almost all mixes have CBR values higher than 40, limit typically considered for subbase and base course construction. The morphology of all the mixes showed the formation of hydrated gel at 28 days curing. The voids between the particles were filled by growing hydrates with curing time. Microanalysis confirmed the formation of new cementitious compounds such as calcium silicate hydrate (C-S-H) gel and calcium aluminate hydrate (C-A-H) gel which leads to increase in bearing ratio of the material over time.

REFERENCES

[1] M. Ahmaruzzaman, “A review on the utilization of fly ash,” *Progress in Energy and Combustion Science J.*, vol. 36, no. 3, pp. 327-363, Jun. 2010.

[2] N. S. Pandian, A. Sridharan and S. Srinivas, “Angle of internal friction for pond ashes,” *Testing and evaluation J.*, vol. 28, no. 6, pp. 443-454, Nov. 2000.

[3] F. G. Bell, “Lime stabilization of clay minerals and soils,” *Engineering Geology J.*, vol. 42, no. 4, pp. 223-237, Jul. 1996.

[4] N. C. Consoli, P. D. M. Prietto, J. A. H. Carraro and K. S. Heineck, “Behavior of compacted soil-fly ash-carbide lime mixtures,” *ASCE J. Geotech. and Geoenviron. Engg.*, vol. 127, no. 7, pp. 774-782, Sept. 2001.

[5] H. A. Acosta, T. B. Edil and C. H. Benson, “Soil stabilization and drying using fly ash,” *Geo Engineering Report No. 03-03*, *Geo Engineering Program*, University of Wisconsin, Madison, USA, Jan. 2003.

[6] S. O. Faluyi and O. O. Amu, “Effects of Lime Stabilization on the pH Values of Lateritic Soils in Ado-Ekiti, Nigeria,” *Applied Sciences J.*, vol. 5, no. 1, pp. 192-194, 2005.

[7] G. Rajasekaran, “Sulphate attack and ettringite formation in the lime and cement stabilized marine clays,” *Ocean Engineering J.*, vol. 32, no. 8-9, pp. 1133–1159, Jun. 2005.

[8] R. K. Goswami and C. Mahanta, “Leaching characteristics of residual lateritic soils stabilised with fly ash and lime for geotechnical applications”, *Waste Management J.*, vol. 27, no. 4, pp 466-481, 2007.

[9] A. Ghosh and U. Dey, “Bearing ratio of reinforced fly ash overlying soft soil and deformation modulus of fly ash,” *Geotextiles and Geomembranes J.*, vol. 27, no. 4, pp. 313-320, Aug. 2009.

[10] R. Mackos, T. Butalia, W. Wolfe and H. W. Walker, “Use of lime-activated class F fly ash in the full depth reclamation of asphalt pavements: environmental aspects,” *Proceedings of World of Coal Ash Conference ’09*, Lexington, Kentucky, USA, paper no 121, May 2009.

[11] R. Ulusay, F. Arlkan, M. F. Yoleri and D. Caglan, “Engineering geological characterization of coal mine waste material and an evaluation in the context of back-analysis of spoil pile instabilities in a strip mine, SW Turkey,” *Engineering Geology J.*, vol. 40, no. 1-2, pp. 77-101, Nov. 1995.

[12] IS: 2720 Part 8, “Laboratory determination of water content – dry density relation using heavy compaction”, *Indian Standard methods of test for soils*, Bureau of Indian Standards, New Delhi, pp. 1-9, 1983.

[13] IS: 2720 Part 16, “Laboratory determination of CBR”, *Indian Standard methods of test for soils*, Bureau of Indian Standards, New Delhi, pp. 1-15, 1987.

[14] B. Cetina, A. H. Aydilekb and Y. Guneyc, “Stabilization of recycled base materials with high carbon fly ash,” *Resources, Conservation and Recycling J.*, vol. 54, no. 11, pp. 878–892, Sept. 2010.