GEOTECHNICAL CHARACTERISATION, STRENGTH AND EROSION ASPECTS OF FLY ASH-SOIL MIXTURES

by

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Dedicated to the global efforts on

ENVIRONMENTAL PROTECTION

which has become a biggest

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CERTIFICATE

This is to certify that the thesis entitled, 'GEOTECHNICAL CHARACTERISATION, STRENGTH AND EROSION ASPECTS OF FLY ASH-SOIL MIXTURES' being submitted by VASANT GURUSIDDAPPA HAVANAGI for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of the bonafide research work carried out by him. Mr. Havanagi has worked under my guidance, he has fulfilled the requirements for submission of this thesis, which to my knowledge, has reached the requisite standard.

This thesis or any part thereof, has not been submitted to any other university or institute for the award of any degree or diploma

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ABSTRACT

About 85 million tonnes of fly ash is being produced in India annually, of which only a very small fraction about 7% to 9%, is used in the manufacture of bricks, pozzolana cement and other products. Attempts are being made by the Department of Science and Technology, Government of India to increase the scale of utilization of fly ash. The present study is related to one of the thrust area 'Roads and Embankments'. Bulk utilisation of fly ash could be made when fly ash is used as an embankment fill material. Appropriate laboratory investigations are to be carried out to identify the feasibility of using fly ash for field applications. The problems related to this area of application were identified and the study was carried out in three phases.

In the first phase of the study is concerned with the geotechnical characteristics of fly ashes. The physical properties and chemical composition of two fly ashes, one from Rajghat thermal power station, New Delhi, India, and the other from a chemical manufacturing industry Baumineral near Bochum, Germany were studied. The two fly ashes were mixed with the soils available near their respective areas in different proportions and their geotechnical characteristics were investigated. The local soils used in the Rajghat fly ash-soil mixtures were silt and fine sand. In case of Baumineral fly ash-soil mixtures, the local soil used was a fine sand a deposit of the Rhine river. The laboratory test program included study of surface morphological characteristics of Rajghat fly ash, Delhi silt and Yamuna sand particles using scanning electron microscope, compaction tests, unconfined compression tests, direct shear tests, unconsolidated undrained triaxial shear tests, consolidation tests, permeability tests and *CBR* tests. Data about compaction characteristics of fly ash were collected from literature and correlations analyses were carried out. The results

of the experimental studies and the correlation analyses of light (standard Proctor) and heavy (modified Proctor) compaction data are presented.

The performance of fly ash-soil mixtures could be improved by addition of cement and fibres. Hence in the second phase of the study, the individual and combined effects of addition of ordinary Portland cement and fibres on the geotechnical characteristics of fly ash-soil mixtures were investigated. The individual effect of cement on compaction characteristics, unconfined compressive strength, and permeability was studied. Cement contents varying from 3% to 9% by dry weight were added to stabilise the Rajghat and Baumineral fly ash-soil samples. Unconfined compression tests were carried out on cylindrical samples at the maximum dry density and optimum moisture content state. The samples were cured in the laboratory, under controlled conditions and in the natural summer, winter and monsoon conditions, for different periods. For laboratory cured samples, correlations for unconfined compressive strength and secant modulus as functions of curing time, fly ash content, and cement content were established. The data were analysed with other correlations recommended in literature and comparisons between the correlations have been reported. The results of correlations for water content as functions of curing time, and cement content have also been presented. The unconfined compressive strength and other results of the samples cured under natural conditions (summer, winter and monsoon conditions) have been compared with the corresponding laboratory values of laboratory cured samples. Scanning electron microscope studies were also carried out on cement stabilised Rajghat fly ash-soil mixtures to understand the microstructural changes due to cement stabilisation.

The individual effect of fibres on the geotechnical characteristics was investigated by conducting experiments on the Rajghat fly ash-soil mixtures blended with 1% polyester fibres by weight. The tests conducted included light compaction (standard Proctor) tests, direct shear tests, unconfined compression tests, unconsolidated undrained triaxial shear tests, and consolidation tests. A few tests were conducted on the Rajghat fly ash with 0.5% fibre content. The combined effect of fibres and cement on the strength characteristics was investigated by conducting unconfined compression tests on laboratory cured Rajghat fly ash-soil samples containing 3% cement content and 1% fibre content.

It is important to pay attention to fly ash-soil mixtures when they are used as fill material. Fly ash is a silty material and the soils with high silt content are susceptible to erosion. During monsoons, the fly ash embankments are susceptible to erosion under the impact of raindrops and the subsequent runoff on the slopes. Hence, in the third phase of the study, experimens on the erosion characteristics of unstabilised and stabilised fly ashes were connducted. Experimental set-ups were fabricated in the laboratory to simulate surface flow and rainfall conditions. The surface flow erosion studies were carried out on both unstabilised and cement stabilised Rajghat fly ash-silt and Rajghat fly ash-sand samples. The cement contents used for stabilisation were 1% and 2%. The samples were prepared at standard Proctor maximum dry density-optimum moisture content state and cured for 7 days in the laboratory. The simulated rainfall erosion studies were carried out on Rajghat fly ash-soil samples stabilised with 3%, 4% and 5% cement contents. The results have been expressed in terms of C_s, the coefficient of surface erosion and C_r, the coefficient of rainfall erosion. The coefficients of erosion of fly ash-silt samples have been compared with the coefficients of erosion of corresponding fly ash-sand samples. The results of the effect of fly ash content and cement content on C_s and C_r have been discussed. The results of natural rainfall erosion studies on unstabilised and stabilised fly ash-soil mixtures are also presented.

The conclusions of the experimental studies are summarised at the end along with a brief presentation of the scope for further research.

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CHAPTER 3 GEOTECHNICAL CHARACTERISATION OF FLY ASH-SOIL MIXTURES