

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

by

VASANT G. HAVANAGI

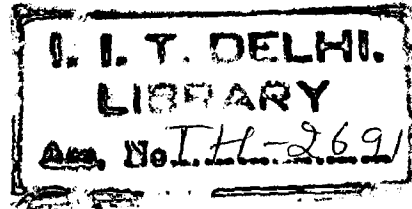
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DOCTOR OF PHILOSOPHY

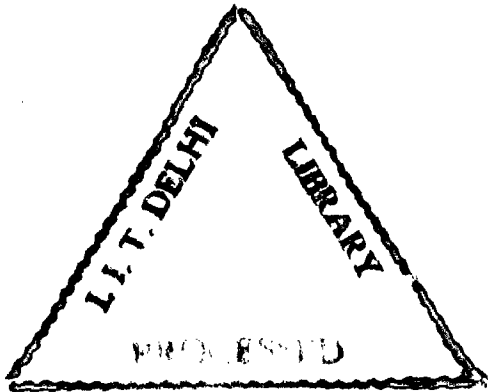
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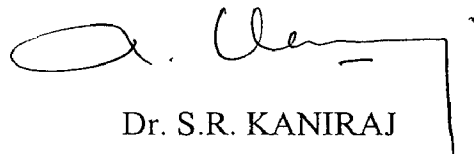


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CERTIFICATE

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, experiments on the erosion characteristics of unstabilised and stabilised fly ashes were conducted. 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.

CONTENTS

	Page No.
CERTIFICATE	I
ACKNOWLEDGEMENTS	II
ABSTRACT	V
CONTENTS	IX
LIST OF FIGURES	XVI
LIST OF TABLES	XXVIII
NOTATIONS	XXXII
CHAPTER 1 INTRODUCTION	
1.1 GENERAL	1
1.2 PRODUCTION AND UTILISATION OF FLY ASH	2
1.2.1 In India	2
1.2.2 In other countries	4
1.3 MANAGEMENT OF FLY ASH IN INDIA	6
1.4 SCOPE OF WORK	7
1.4.1 Geotechnical characterisation of fly ash-mixtures	7
1.4.2 Unconfined compressive strength of cement stabilised fly ash-soil mixtures	8
1.4.3 Behaviour of randomly oriented fibre reinforced fly ash-soil mixtures	9
1.4.4 Erosion of unstabilised and stabilised fly ash-soil mixtures	9
1.5 ORGANISATION OF THESIS	10

CHAPTER 2 GENERAL LITERATURE REVIEW

2.1 FLY ASH IN GENERAL	13
2.1.1 Field applications of fly ash as fill material	14
2.1.2 Physical and chemical properties of fly ash	18
2.1.3 Geotechnical characteristics of fly ash	29
2.1.4 Environmental considerations	49
2.2 CONCLUDING REMARKS	51

CHAPTER 3 GEOTECHNICAL CHARACTERISATION OF FLY ASH-SOIL MIXTURES

3.1 INTRODUCTION	53
3.2 MATERIALS	53
3.2.1 Fly ash	53
3.2.2 Soils	54
3.3 EXPERIMENTAL PROGRAM	54
3.3.1 Scanning electron microscope studies	54
3.3.2 Physical properties	54
3.3.3 Chemical composition of fly ashes	54
3.3.4 Geotechnical characteristics of fly ash-soil mixtures	54
3.3.4.1 Preparation of fly ash-soil mixtures	55
3.4 RESULTS AND DISCUSSIONS	58
3.4.1 Surface morphology of fly ash and soils	58
3.4.2 Physical properties of fly ashes	58
3.4.3 Chemical composition of fly ash	60
3.4.4 Geotechnical characteristics of fly ash-soil mixtures	62

3.4.4.1 Grain size analysis	62
3.4.4.2 Atterberg limits tests	62
3.4.4.3 Compaction characteristics	64
3.4.4.4 Direct shear tests	89
3.4.4.5 Unconfined compression tests	103
3.4.4.6 Unconsolidated undrained triaxial shear tests	108
3.4.4.7 Drained triaxial shear tests	116
3.4.4.8 Consolidation tests	117
3.4.4.9 Permeability tests	123
3.4.4.10 California bearing ratio tests	126
3.4.5 Solubilisation tests and heavy metal content	126
3.4.5.1 Soluble salt content	126
3.4.5.2 Determination of <i>pH</i>	128
3.4.5.3 Heavy metal content	128
3.5 CONCLUSIONS	129

CHAPTER 4 UNCONFINED COMPRESSIVE STRENGTH OF CEMENT STABILISED FLY ASH –SOIL MIXTURES

4.1 INTRODUCTION	132
4.2 LITERATURE REVIEW	134
4.2.1 Conclusions from literature review	138
4.3 MATERIALS	139
4.4 EXPERIMENTAL PROGRAM	140
4.4.1 Compaction characteristics of Baumineral fly ash-sand-cement mixtures	140
4.4.2 Unconfined compression tests	140

4.4.2.1	Sample preparations	142
4.4.2.2	Method of curing	143
4.4.2.3	Method of testing	145
4.4.3	Permeability tests	147
4.4.4	Scanning electron microscope studies on stabilised samples	147
4.5	RESULTS, ANALYSIS AND DISCUSSIONS	148
4.5.1	Compaction characteristics of stabilised fly ash-soil mixtures	148
4.5.2	Unconfined compression tests on laboratory cured samples	150
4.5.2.1	Failure strain	166
4.5.2.2	Secant modulus	166
4.5.2.3	Change in water content	177
4.5.3	Unconfined compression tests on samples cured under summer conditions	180
4.5.4	Unconfined compression tests on samples cured under winter conditions	189
4.5.5	Unconfined compression tests on samples cured under monsoon conditions	195
4.5.6	Permeability tests	195
4.5.7	Scanning electron microscope studies on stabilised samples	198
4.6	CONCLUSIONS	202

CHAPTER 5 BEHAVIOUR OF RANDOMLY ORIENTED FIBRE REINFORCED FLY ASH-SOIL MIXTURES

5.1	INTRODUCTION	206
5.2	LITERATURE REVIEW	208
5.2.1	Conclusions from literature review	215
5.3	MATERIALS	216
5.4	EXPERIMENTAL PROGRAM	216

5.4.1 Geotechnical characteristics of fibre-soil-fibre mixtures	
(with & without cement stabilisation)	216
5.4.1.1 Preparation of fibre reinforced fly ash-soil and fly ash-soil-cement mixtures	218
5.4.1.2 Scanning electron microscope studies	219
5.5 RESULTS, ANALYSIS AND DISCUSSIONS	219
5.5.1 Fly ash-soil-fibre mixtures (without cement stabilisation)	219
5.5.1.1 Light compaction tests (standard Proctor)	219
5.5.1.2 Direct shear tests	224
5.5.1.3 Unconfined compression tests	228
5.5.1.4 Unconsolidated undrained triaxial shear tests	233
5.5.1.5 Consolidation tests	250
5.5.2 Cement stabilised fly ash-soil-fibre mixtures	254
5.5.2.1 Unconfined compression tests	254
5.5.2.2 Individual and combined effects of cement and fibres on <i>UCS</i>	259
5.5.3 Scanning electron microscope studies	264
5.6 CONCLUSIONS	264
CHAPTER 6 EROSION OF UNSTABILISED AND STABILISED FLY ASH-SOIL MIXTURES	
6.1 INTRODUCTION	269
6.2 LITERATURE REVIEW OF EROSION STUDIES ON SOILS	270
6.2.1 Erosion due to surface run-off	270
6.2.2 Erosion due to simulated rainfall	274

6.2.3	Conclusions from literature review	280
6.3	MATERIALS	280
6.4	EXPERIMENTAL PROGRAMME	281
6.4.1	Erosion studies under surface flow	281
6.4.1.1	Experimental set-up	281
6.4.1.2	Calibration of velocity of water through channel	282
6.4.1.3	Preparation of fly ash-soil samples	282
6.4.1.4	Surface erosion tests	288
6.4.2	Erosion tests in laboratory under simulated rainfall conditions	291
6.4.2.1	Experimental set-up	292
6.4.2.2	Laboratory rainfall simulation	297
6.4.2.3	Calibration of exit velocity from nozzles	301
6.4.2.4	Preparation of fly ash-soil samples	302
6.4.2.5	Erosion tests under simulated rainfall conditions	302
6.4.3	Erosion tests under natural rainfall	304
6.5	RESULTS ANALYSIS AND DISCUSSIONS	306
6.5.1	Surface flow erosion tests	306
6.5.1.1	Velocity of flow in the channel	306
6.5.1.2	Experiments on unstabilised fly ash-soil samples	307
6.5.1.3	Experiments on stabilised fly ash-soil samples	311
6.5.2	Erosion tests under laboratory simulated rainfall conditions	311
6.5.2.1	Results of calibration of exit velocity of water from the nozzles	311
6.5.2.2	Results of the erosion tests	315
6.5.2.3	Variation of C_r with fly ash content	320
6.5.2.4	Effect of cement content on C_r	320

6.5.2.5	Effect of fibre content on C_r	325
6.5.2.6	Comparison of C_r of fly ash-silt and fly ash-sand samples	325
6.5.3	Erosion of fly ash-soil samples under natural rainfall	325
6.6	CONCLUSIONS	328
6.6.1	Surface flow erosion tests	328
6.6.2	Simulated rainfall erosion tests	329
6.6.3	Natural rainfall erosion tests	330
CHAPTER 7	SUMMARY OF CONCLUSIONS	
7.1	Geotechnical characterisation of fly ash-soil mixtures	332
7.2	Unconfined compressive strength of cement stabilised fly ash-soil mixtures	334
7.3	Behaviour of randomly oriented fibre reinforced fly ash-soil mixtures	336
7.4	Erosion of unstabilised and stabilised fly ash-soil mixtures	338
7.4.1	Surface flow erosion tests	338
7.4.2	Simulated rainfall erosion tests	339
7.4.3	Natural rainfall erosion tests	340
7.5	SCOPE FOR FURTHER RESEARCH	340
REFERENCES		339
BIO-DATA OF AUTHOR		