INVESTIGATION ON THE APPLICABILITY OF BOTTOM ASH FOR RESTORATION OF CLAY MINES IN SRI LANKA

Sivaraman Suloshini

198034E

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Department of Civil Engineering

University of Moratuwa
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Thesis submitted in partial fulfilment of the requirements for the degree Master of Philosophy in Civil Engineering

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DECLARATION

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Signature of the supervisors: Date:

....

Dr.(Mrs). A.S. Ranathunga

....

Prof. S.A.S. Kulathilaka

....

Prof.(Ms). W.B. Gunawardana

ABSTRACT

Investigation on the Applicability of Bottom Ash for Restoration of Clay Mines in Sri Lanka

The higher cost associated with the restoration of clay mines and shortage of suitable filling materials have created many abandoned clay mines in Sri Lanka, leading to various environmental and health issues. Bottom ash (BA) generated during the coal combustion process as a by-product is one such potential fill material. Therefore, utilizing BA as a full or partial replacement of soil during clay mine restoration is the main objective of this study which was fulfilled under four sub-objectives: 1) potential as a backfill material, 2) ability to prevent soil erosion, 3) potential as a soil amendment material and 4) environmental impact.

BA was collected from the Lakvijaya power plant in Norochcholai, Sri Lanka. In addition, the suitability of BA as a full or partial replacement for soil was tested with six different fractions of BA (0%, 50%, 60%, 75%, 90% &100%) using a gravelly lateritic soil. The basic properties, shear strength parameters and compressibility characteristics of BA-soil mixtures were investigated. Annual soil loss due to rainfall was measured by conducting artificial rainfall tests for BA-soil mixtures. In addition, chemical composition, pH, electrical conductivity, water holding capacity and micro-structural morphology through Scanning Electron Microscope of BA-soil mixtures were determined to evaluate the potential of soil amendment capabilities. Furthermore, column leaching method was used to evaluate the trace metal concentrations of BA-soil mixtures.

According to results, BA behaves as a poorly graded sand, a free draining material with low compressibility and cohesion. BA has a lower maximum dry density (975 kg/m^3) and higher optimum moisture content (37%). The annual soil loss is "very low" when the fine fraction of the BA-soil mixture is lesser than 20%. BA has the potential to improve agronomic characteristics of soil due to the better water holding capacity and electrical conductivity. BA can adjust soil pH to a desirable plant growth range. Interestingly, the micropore structure of BA has a positive influence on compressibility characteristics, soil erodibility and plant growth while compaction characteristics are influenced negatively. According to column leaching test results, the leachability potential of trace metals in BA does not exceed the allowable limits.

Finally, an empirical relationship for the compaction characteristics was developed using multiple regression analysis with a prediction accuracy less than ±3%. Further, the specific gravity of BA was predicted using the chemical composition by soft computing techniques with an accuracy around 96%. The proposed models could be used for the preliminary assessment of the suitability of BA prior to a project.

By considering the results and economic benefits, it can be concluded that, utilizing BA as a partial replacement of a traditional fill material (up to 75%) is the most suitable combination for restoration of abandoned clay mines and similar applications according to the present study.

Key words: Bottom ash, Clay mines, Compaction and compressibility, Rehabilitation, Soil erosion

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Notations

Notations	Description
As	Arsenic
c	cohesion
Cc	Coefficient of curvature
C_c	Compression index
$C_c/(1+e_0)$	Compression ratio
Cd	Cadmium
Cr	Chromium
C_r	Recompression index
$C_r/(1+e_0)$	Recompression ratio
Cu	Copper
Cu	Uniformity coefficient
C_v	Coefficient of consolidation
E	Soil erosion per hour
G	Dry density of the sample
Gs	Specific gravity
H	Annual soil erosion
Hg	Mercury
I	Rainfall intensity
k	Coefficient of permeability
m_v	Coefficient of volume compressibility
Ni	Nickel
Pb	Lead
R	Annual rainfall
R	Correlation coefficient
R^2	Coefficient of determination
Se	Selenium
SP	Poorly graded sand
SW	Well graded sand
Zn	Zinc
Φ	Friction angle

Abbreviations

Abbreviations	**Description**
ASL	Annual soil loss
ASTM	American Standard for Testing and Material
BA	Bottom Ash
CE	Compaction Energy
EC	Electrical conductivity
FC	Fine content
GC	Gravel content
ICP-MS	Inductively coupled plasma – mass spectrometry
LL	Liquid Limit
MDD	Maximum Dry Density
MLR	Multi Linear Regression
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plastic Limit
PVC	Polyvinyl chloride
SC	Sand content
SEM	Scanning Electron Microscopy
SVM	Support Vector Machine
USEPA	United States Environmental Protection Agency
USLE	Universal Soil Loss Equation
WHC	Water holding capacity
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence