PSEUDOSTATIC AND PROBABILISTIC STABILITY ANALYSES OF ASH CONTAINMENT SYSTEMS

by

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statistical analysis
Ash containment - Thermo power plant

Dedicated

to

My family

CERTIFICATE

This is to certify that the thesis entitled **PSEUDOSTATIC AND PROBABILISTIC STABILITY ANALYSES OF ASH CONTAINMENT SYSTEMS** submitted by **Mrs. R. Chitra** to Indian Institute of Technology, Delhi, for the award of the degree of the Doctor of Philosophy is a record of the bonafide research work carried out by her. **Mrs. R. Chitra** has worked under our supervision for the submission of this thesis, which to our knowledge has reached the requisite standard.

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

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(R.Chitra)

ABSTRACT

Construction of ash containment system using different methods such as dry disposal and wet disposal has their own pros and cons. The method of containing the ash materials at a thermal power plant is chosen as per the site conditions, availability of land and requirement. The stability of slopes of these ash containment systems is an area of major concern particularly under seismic condition. The stability of the ash containment systems by dry disposal method and wet disposal method have been examined in this thesis through an extensive stability analyses following an elaborative experimental testing programme.

The thesis presents an introduction to the status of the existing ash disposal system adopted in the thermal power stations in India and the need for steep sloped mounds and dykes. A brief review of various thermal power plants in India and the types of ash disposal system adopted in the plants along with the characterization of ashes from different thermal power plants located at different parts of India is also addressed. The ash samples collected from selected thermal power stations are thoroughly characterized. The thesis presents the stability analyses carried out on the ash mound of dry disposal containment system and the stability analyses carried out for the ash dykes of wet disposal containment systems constructed using downstream method of construction and the upstream method of construction. The probabilistic slope stability analyses carried out in respect of the ash mound and the ash dyke are also presented. The thesis ends with the summary of the work carried out and the salient conclusions arrived at based on the present study and the scope for the future research works.

The research programme included:

a) Characterization of ash samples collected from (i) Ash mound - Dry disposal containment system and (ii) Ash dykes - Wet disposal containment system.

b) Assessing the compaction behaviour of the ash samples collected from the containment systems.

c) Assessing the strength behaviour of the ash samples collected from the thermal power stations.

d) Assessing the chemical composition of the materials

e) Assessing the stability of ash mound of different slopes viz. 1:4, 1:3.5, 1:3, 1:2.5 to 1:2 with and without reinforcement and berms.

f) Assessing the stability of ash dykes - wet disposal containment system constructed using downstream method of construction up to three raisings with different slopes viz. 1:2, 1:2.25, 1:2.5 and 1:3 and with berms.

g) Assessing the stability of ash dykes - wet disposal containment system constructed using upstream method of construction with different upstream slopes viz. 1:2.5, 1:3 and 1:3.5 and with berm widths.

h) Assessing the probability of failure of the slopes of ash mounds

i) Assessing the probability of failure of the slopes of ash dykes with and without reinforcements.

The grain size distribution of the various ash materials collected from the dry and wet disposal containment systems indicate that the fly ash and bottom ash materials posses predominantly silt sizes and sand sizes respectively. All the tested materials exhibit non plasticity characteristics. The results of Standard Proctor Compaction tests conducted on the materials collected from the dry and wet disposal containment systems indicate that the maximum dry unit weight and optimum moisture content values from the Standard Proctor tests vary from 10.3 kN/m^3 to 13.4 kN/m^3 and 23.8 % to 42.1 % respectively. The maximum dry unit weight and optimum moisture content values from the Modified Proctor tests vary from 11.1 kN/m^3 to 14.2 kN/m^3 and 18.7 % to 30.2 % respectively. The unit weight values are much lower as compared to the unit weight of soils. The specific gravity values of the tested materials vary from 2.03 to 2.40 which are much lower than the specific gravity values of soils.

The relative density tests conducted on the ash materials indicate that the maximum dry unit weight values vary from 12.2 kN/m^3 to 15.4 kN/m^3 and the minimum dry unit weight values vary from 8.3 kN/m^3 to 11.4 kN/m^3. Drained triaxial shear tests conducted on the collected ash materials indicate that the ash at the compacted and saturated condition, exhibit only frictional part of the strength and the value of angle of shearing resistance are minimal. The values of effective angle of shearing resistance, ϕ' of the tested materials vary from 29.0° to 35.0°.

The chosen ash containment systems of dry disposal and wet disposal have been subjected to deterministic stability analysis. The properties evaluated from the experimental works and other investigations have been utilized for carrying out the stability analysis. Probabilistic stability analysis has also been carried out on these ash containment systems in order to evaluate the probability of failure.

The stability analyses carried out on the ash mounds – the dry disposal containment system indicate that the factor of safety of the mound remains unchanged irrespective of the increase in the height and for a given slope of 1:4 up to a height of 50 m. A slope of 1:4 and 1:3.5 are the safest slopes for any seismic conditions. For less seismic prone zones a steep slope of 1:3 shall also be considered.

The stability analyses carried out on the ash dykes – the wet disposal containment system constructed using the downstream method of construction indicate that the stability of the upstream slope under short term condition in static analysis and pseudostatic analysis remains unchanged irrespective of the height (raisings) of the dyke and with effective and clogged drains. The factor of safety of the downstream slope under long term condition increases when ash is used as construction material in place of soil for further raising of dyke condition in both static and pseudostatic analysis. The factor of safety of the downstream slope under long term condition decreases considerably when the drains are clogged. The dyke is safe under short term condition even if the drains are clogged in static slope stability analysis.

The stability analyses carried out on the ash dykes – the wet disposal containment system constructed using the upstream method of construction indicate that the factor of safety of the upstream slope under short term condition in static and pseudostatic analyses slightly increases with the height (raisings) of the dyke. The starter dyke and the raised dykes with a downstream slope of 1:2.5 and upstream slopes of 1:2.5, 1:3.0 and 1:3.5 are stable both under static and pseudostatic conditions irrespective of the construction materials. The reduced angle of internal friction of the ash fills decreases the stability of the dykes abruptly. The provision of effective internal drainage system under both static and pseudostatic conditions increases the stability of the dykes both using soil and ash as construction material. The factor of safety increases tremendously with the use of ash as construction material because of the improved strength characteristics of ash to that of soil. The factor of safety decreases with the increase in the height of the dykes. In order to have a safe steep dyke, the dykes are to be reinforced. A minimum length of 3.5 m geogrid with a long term design strength of 18 kN/m may be used. The reinforcements can be placed as basal reinforcement. They can also be placed at an interval of 1 m through out the slope. While choosing the upstream method of construction for the raising of ash dykes, one should keep in mind that the ash deposited in the lagoons is in loose condition. Therefore it is important to increase the density of the ash fill on which the dykes are to be constructed.

The probabilistic analyses carried out on the ash containment systems indicate that the ash mounds constructed with slopes of 1:4, 1:3.5 and 1:3 irrespective of the density and the angle of internal friction are safe. The steeper ash mounds with slopes of 1:2.5 and 1:2 need to be constructed with caution.

The ash dyke constructed using the downstream method of construction with the slope of 1:2 is unsafe irrespective of the raisings and irrespective of the materials used for construction. The ash dyke constructed using the downstream method of construction with the slopes of 1:2.25 are safe up to the second raising. The ash dyke constructed with the downstream slope of 1:2.5 is safe only when constructed using ash materials with very effective drains. The ash dyke with the downstream slope of 1:3 is the safest section irrespective of the raisings, conditions and materials used for construction. The probability of failure is more when the dykes are subjected to seismic conditions.

The probability of failure of the ash dyke constructed using upstream method of construction for the long term stability is found to be 0% at first raising, when ash is used as construction material with effective drain. At the third raising the probability of failure is about 100% except when the dyke is constructed with ash materials and with effective drain.

The ash dyke constructed with steep downstream slope of 1:1.5 (Average slope angle – 21.0° Slope - 1:2.61) can safely be raised upto a height of 24 m i.e six raisings @ 3 m height each without geosynthetic reinforcement. The ash dyke constructed with steep upstream slope of 1:1 can safely be raised only up to a height of 12 m without reinforcement. Provision of slope and basal reinforcement can allow the construction up to 15 m. The ash dyke constructed with steep downstream slope of 1:0.839 (Average slope angle – 25.3° Slope - 1:2.12), 1:0.75 (Average slope angle – 26.0° Slope - 1:2.05) and 1:0.7 (Average slope angle – 26.5° Slope - 1:2.01) can safely be raised only up to a height of 12 m with the provision of slope and basal reinforcements.

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