Collapsible Behavior of Pond ash

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Abstract – *Vitality necessities for the creating nations like India specifically are met from coal based thermal power plants, where 75% of the aggregate force acquired is from coal-based thermal power plants. The coal used for power generation contains 30–40% of ash. The fly ash generation is more because of high ash coal. For this experimental study is taken up to known the collapsible potential of Pond ash. Attempts have been made to correlate the ash characteristics and the specific placement parameters such as dry unit weight, moisture content, and compaction energy and stress level at wetting with collapse. This was based largely on the single oedometer collapse test results. A sequences of tests, like, direct shear test, light compaction and in addition substantial compaction test are done to evaluate the quality attributes of compacted pond ash and also tests like specific gravity test, grain size distribution test by mechanical sieve analysis and hydrometer test etc. are performed to get some physical properties of the pond ash. Total 145 single oedometer collapse tests were conducted to get the collapse potential of pond ash. The results of oedometer test were very much helpful for evaluating the factors affecting the collapse potential of pond ash.*

***Key Words*: Pond ash1, collapse potential2, compaction test3, single oedometer test4, vertical stress5.**

1. INTRODUCTION-

Now-a-day large amount electrical power utilized by the growing population and developing industries for different applications and necessities. The large amount of power is generated from the thermal power plants which utilize pulverised coal as fuel. The coal used in India contains 40-50 % of ash. Which is higher than the coals utilized in the United States, Germany and Canada? Pond ash is the by-product of thermal power plants, which is as a waste material and its disposal is a major problem from an environmental point of view and requires large disposal area. Actually, there are three types of ash produced by thermal power plants viz. (i) fly ash (ii) bottom ash (iii) pond ash. The finer fraction of ashes which are collected in the electrostatic precipitators of thermal power plants is knows as fly ash. The heavier and coarser coal ash collected from furnace bottom is known as bottom ash and around 20-25% of the total coal ash production. Routinely, these two sorts of ashes are blended completely with water and sluiced to nearby storage ponds called ash ponds. The ash settled in the ash ponds is known as pond ash. The amount of pond ash produced by thermal power plants is very large as compared with other two ashes. The utilization of pond ash to the maximum possible extent is still a major task throughout the world. Indian coal based thermal power plants produce around 90×10^{6} ton of pond ash every year which can cover an area of 268 km2 as ash ponds. As the land requirement and the expense of land are increasing day to day, it is most important to recover or enhance these ash ponds so that the area could be utilized for the construction of light and medium civil infrastructures. Pond ash being utilized as a few geotechnical applications like construction of roads and highway embankments, backfilling, land improvement, ash dyke raising, filling low territories as development fills. Pond ash has potential applications in various ranges. In 1970s the variety of fly ash applications increased (Copp & Spencer 1970 Joshi et. al 1975), and applications including cement stabilized fly ash were introduced. Blended ash can be utilized in land reclamation (Turgon 1988) [1]. The soil that shows collapse have open type of structure with a high void ratio as expected in the case of ashes. As per Barden et al. (1969) [2] the collapse mechanism is minimised by three factors; (i) a potentially unstable structure, such flocculent type associated with soils compacted dry of optimum or with loess soils; (ii) a high applied pressure which further increase the instability; and (iii) a high suction which dissipates on wetting. According to an observational study by Meckechine (1989), the dry unit weight and water content are generally considered as critical parameters that control the collapse of metastable structure of soils, if the dry unit weight is under 16 kNm-3. Jennings and Knight (1975) [3] specified that collapse behaviour is also dependent on the clay fraction. An experimental work program was done to study the impact of pond ash characteristics, density, and moisture content and stress level on the collapse of ashes.

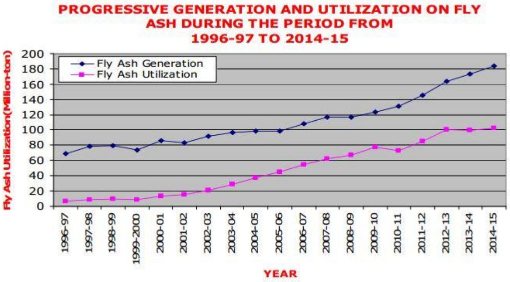

Fig-1: Fly ash generation and utilization over the years

It may be seen from Fig-1 above that:

- The fly ash generation as well as utilization has generally been increasing since 1996-97.
- Fly ash utilization has increased from 9.63% in 1996-97 to the highest level of 62.60% in 2009-10 with 55.69 % during 2014-15.
- The fly ash generation has increased from 68.88 million-ton in 1996-97 to 184.14 million ton in 2014-15 i.e. nearly 2.5 times.
- In any case fly ash use has increased from 6.64 million-ton in 1996-97 to a level of 102.54 million ton in 2014-15 i.e. almost more than 15 times over the same period.

In this way, in the present study an attempt has been made to examine the collapse behavior of pond ash at various water content, dry densities and stresses in detail. It was detected that the ash having a stamped morphological difference with the soils required a distinct criterion for the ordering of its collapsibility [4]. A new limit of collapse potential was assigned for the ashes based on the oedometer collapse test.

2. MATERIAL USED AND METHODS

2.1. Materials used

Thermal Power Plant Byproducts formed during com bustion of pulverized coal in thermal power plant stations are:

- Bottom ash -fused particles collected at the Bottom of furnace.
- Fly ash- Collected in electrostatic Precipitators
- Vapours- The distribution of bottom ash and fly ash is a function of burner type, type of coal, type of boiler bottom (Wet or dry).

2.1.1 Properties of fly ash

- Fly ash in the presence of moisture and at ordinary temperature chemically react with calcium hydroxide forms components possessing cementitious properties.
- Fly ash act both as cement and as fine aggregate.
- Fly ash lowers heat of hydration.
- Improves resistance to chloride inducing corrosion.

2.1.2 Methods of Disposal

In India most of thermal power stations adopt wet method of ash disposal and storage of ash in large ponds and dykes.
In wet method fly ash collected from ESP's and the bottom ash are with water and transported in a slurry form to this ponds. Fly ash and pond ash Pond ash differ from fly ash collected from ESP's in a dry form in that it contains significant amount of relatively coarse particles (greater than 45 μm and upto 50 μm).

2.1.3 Utilization

A. Pond ash and residue of integrated steel plant were mixed for manufacture of bricks and found.

- Superior in aesthetic and structural qualities.
- Saving in manufacturing cost.
- Better consumer response

B. High volume of pond ash up to 55% replacement of cement has been used for making dry lean concrete as base course in four /six lane highways.

2.2. Methods

- Specific gravity
- Determination of Grain Size Distribution
- Atterberg limit test
- Compaction characteristics
- Direct Shear Test
- Single oedometer collapse test

3. EXPERIMENTAL WORK

The thermal power plants produces very large amount of ashes. Which nearly occupied 70,000 acres of land by ash ponds? In the present study a test work was led to find out the collapse potential of pond ash [6]. The index as well as engineering properties have been calculated. Details of material used, processing test method accepted are described in this part of the paper.

The current samples are collected from ash ponds of NSPCL Rourkela. The specimens were oven dried at the temperature of 105-110 degrees. Then it was sieved by utilizing required sieves .The material passing through the sieve was utilized as a part of experimental work.

Specific gravity of ash samples was determined by density bottle following the standard method prescribed in IS 2720 (Part III/Section 1). Pond ash comprises both coarse and fine grained particles. For determination of grain size distribution, the pond ash was passed through an IS test sieve having an opening size 75μ. Sieve analysis was performed for coarser particles as per IS: 2720 part (4), 1975 and hydrometer analysis was performed for finer particles as per IS: 2720 part (4). Particle size distribution curve was plotted between percentages finer vs. particle size. Coefficient of uniformity and coefficient of curvature were calculated by using the following formula.

Coefficient of uniformity, $C_u = D_{60} / D_{10}$

Coefficient of Curvature, $C_c = (D_{30})^2 / D_{60} \times D_{10}$

4. RESULTS

4.1 Specific gravity

Specific gravity of pond ash was found to be 2.09.

4.2 Determination of Grain Size Distribution

Grain size distribution curve was determined by sieving and hydrometer analysis [7]. Grain size distribution curve is characterized in Chart-1. The coefficient of uniformity and coefficient of curvature were found to be 3.67 and 1.63 respectively.

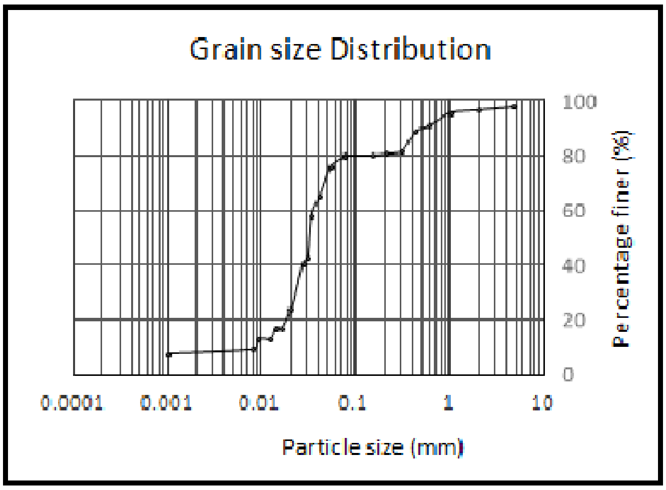

Chart- 1: Grain-size distribution curve of Pond ash

4.3 Compaction test

Light (standard proctor) compaction tests were carried out to determine the maximum dry density (MDD) and optimum moisture content (OMC) of given pond ash sample that is 1.05 gm/cm3 and 37 %. Also Compaction tests were carried out at different compaction energy (99734.32 kg-m/m3, 119681.18 kg-m/m3, 347127.17 kg-m/m3, 433908.96 kg-m/m3 and 520690.76 kg-m/m3) and equivalent MDD and OMC were found out. Maximum dry density of pond ash is increasing with increase in compaction energy whereas optimum moisture content is diminishing with increase in compaction energy [5]. The Chart-2 and Chart-3 demonstrates the diagram identified with compaction test.

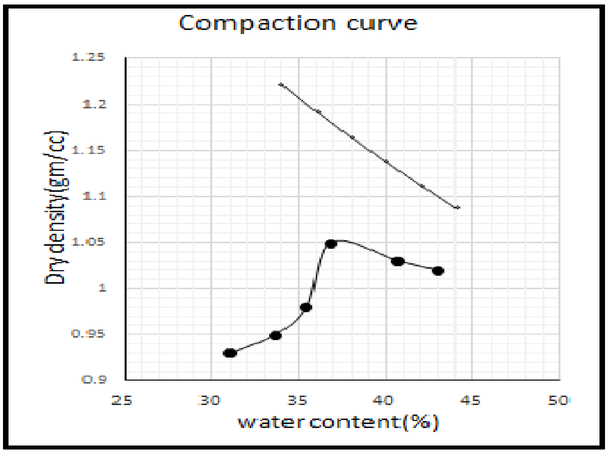

Chart-2: Compaction curve of Pond ash

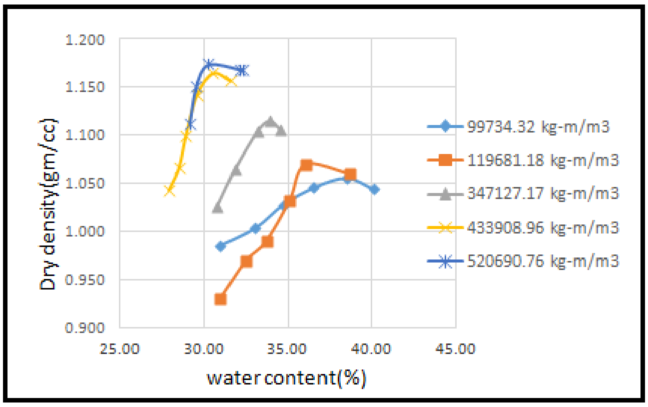

Chart-3: Variation of dry density with moisture content at compaction energy

4.4 Direct shear test

Direct shear test was directed for pond ash at OMC and MDD corresponding to light compaction test. Shear parameters was calculated from the graph between normal stresses vs. shear stress. Chart-4 shows the graph related to direct shear test. When the soil was compacted at light compaction density and moisture content, the unit cohesion and angle of friction are 5.8 kPa and 35.22^{0}.

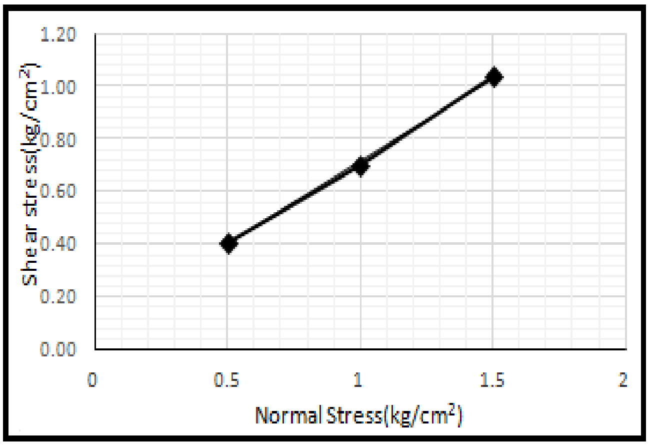

Chart-4: Direct shear test result

4.5 Single oedometer collapse test

The collapsibility of coal ash is one of the most important parameters for using ash as a fill material. The 145 experimental tests carried out on pond ash, compacted at different dry densities (1.05, 0.84 and 0.63 gm/cm³) and different water contents (37, 30, 22, 15 and 7%) with at a Stress level of 100kPa which gave the results reported in the graphs of Chart-5 to 15.

4.5.1 Collapse Test Result at different Dry Density and at different Moisture Content at a Stress level of 100kPa

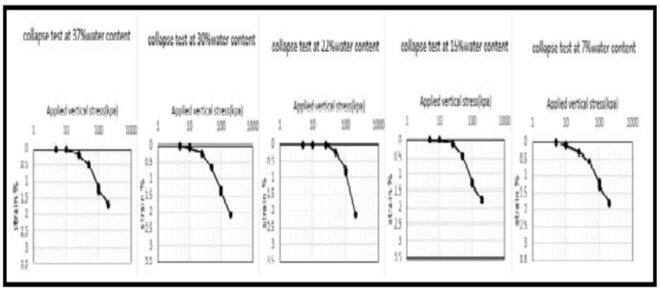

Chart-5: Collapse test Result at dry density of 1.05 gm/cm³

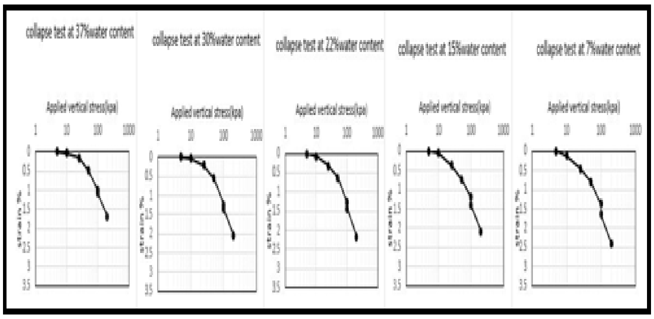

Chart-6: Collapse test Result at dry density of 0.84 gm/cm³

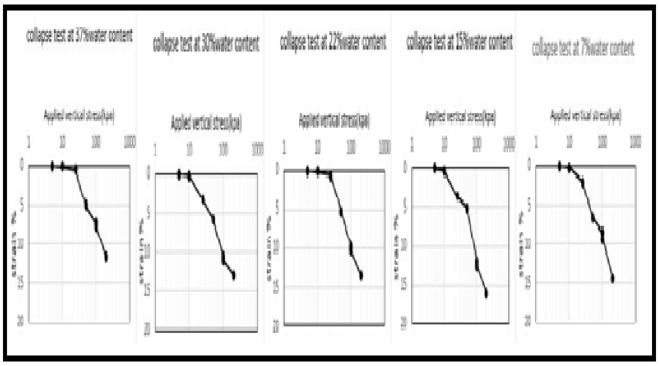

Chart-7: Collapse test Result at dry density of 0.63 gm/cm³

Chart 5 to Chart 7 shows the test result between applied vertical stress (kPa) vs strain (%). At dry density 1.05 gm/cc and water content 37 % the collapse potential is 0.08% which is less than 1%. It is found that at 100 kPa the collapse potentials are less than 1% at different water content and dry density.

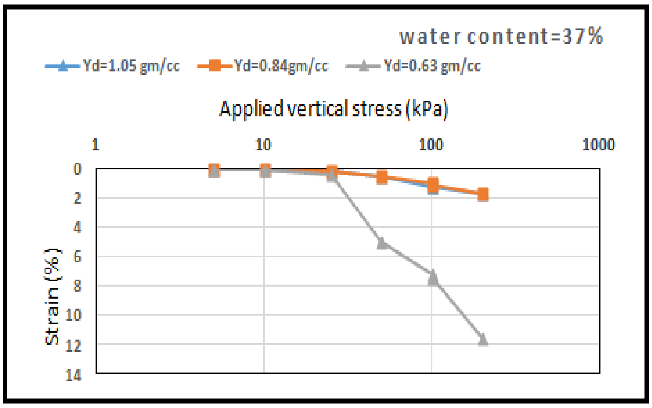

Chart-8: Collapse test Result at different dry density of water content 37%

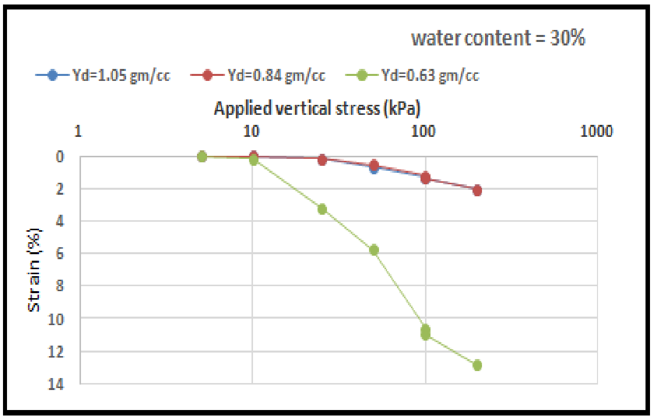

Chart-9: Collapse test Result at different dry density of water content 30%

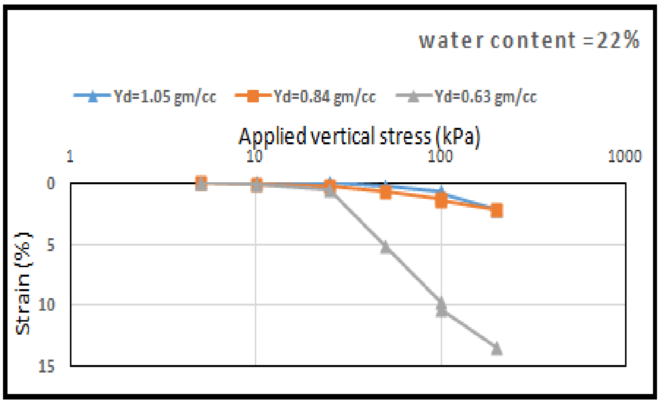

Chart-10: Collapse test Result at different dry density of water content 22%

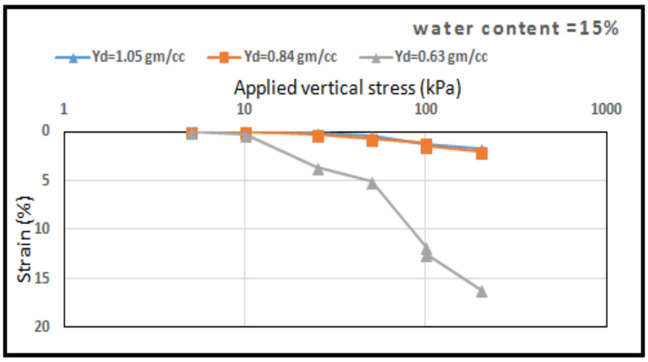

Chart-11: Collapse test Result at different dry density of water content 15%

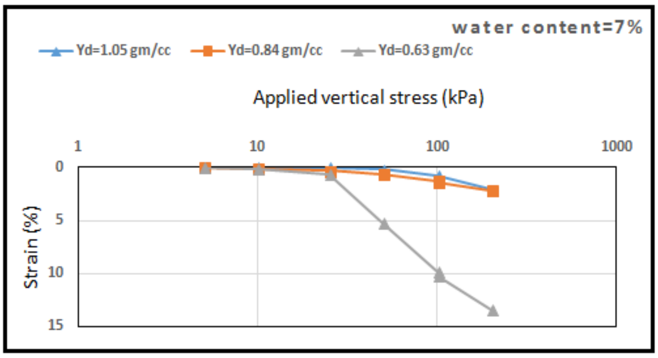

Chart-12: Collapse test Result at different dry density of water content 7%

The Chart-8 to 12 the initial water content is respectively 37 %, 30 %, 22%, 15% and 7%. In this case the potential collapse decreases while increasing applied dry density. The highest rate of collapse is obtained for a density of 0.63 gm/cc and a water content of 7%, the rate of collapse is 0.88%. This is phenomenon done by the mechanism that occurs after inundate at load of 100 kPa. In order to establish the influence of dry density and water content on collapse potential of the studied pond ash, shown in Table 1 and plotted the variation of collapse potential with both dry density (Chart-13) and the water content (Chart-14).

Analysing the Table 1, the results are:

- The lowest potential is obtained at the characteristics of standard Proctor optimum (w=37%,Υ_d=1.05 gm/cc)
- At lower density and water content, the potential of collapse is 0.88% for the studied Pond ash sample which is more than the collapse potential at 37 % and 1.05 gm/cc.

Table 1: Potential Collapse of Pond ash at 100 kPa

gm/cc	W=37%	W=30%	W=22%	W=15%	W=7%
Υ_d=1.05	0.08	0.08	0.08	0.08	0.12
Υ_d=0.84	0.08	0.12	0.16	0.20	0.28
Υ_d=0.63	0.28	0.30	0.48	0.64	0.88

Classification of Jennings and Knight (1975)

Legend:

No Problem (CP from 0 to 1%)	Moderate Trouble (CP from 1 to 5%)
Trouble (CP from 5 to 10%)	Severe Trouble (CP from 10 to 20%)
Very Severe Trouble (CP > to 20%)	

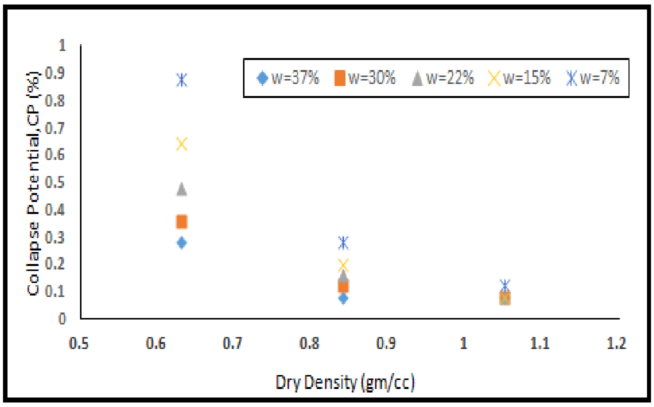

Chart-13: Effect of Collapse Potential at different Dry density

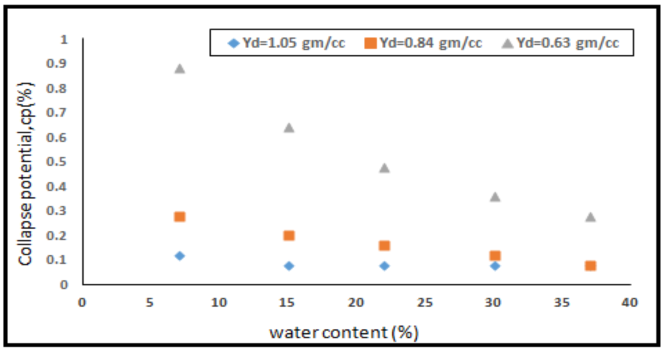

Chart-14: Effect of Collapse Potential at different Moisture content

The results in Table 1 are expressed as graphs (Chart 13 to 14). It clearly shows that there is an inverse relation between the collapse potential (CP) and dry density. The same thing is observed for the relation between CP and water content. At higher value of water content, a lowest potential of collapse is obtained. A summary of the potential collapse of the Pond ash in 3D presentation is given in Chart- 15.

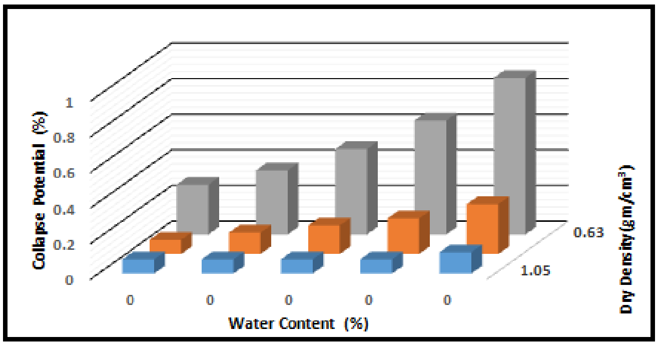

Chart-15: Summary of the potential collapse of Pond ash (3D representation).

5. CONCLUSIONS

The collapsibility of coal ash is one of the most important parameters for using ash as a fill material. The present work provides a framework for the assessment of collapsibility of the ashes. Several single oedometer collapse tests have been performed to test the collapsibility of coal ashes. Based upon the test results various outcomes of this study are summarized as:

- The collapse potential obtained by the oedometer test is a dependent parameter of several factors such as, stress level, degree of compaction, dry density, moisture content, etc.
- The collapse test carried out on Pond ash, it shows that the collapse potential at MDD and OMC is 0.08%.which indicates that it is non collapsible.
- It is observed that for constant water content, the potential of collapse increases when the dry density decreases. Also for constant dry density, the collapse potential increases with decrease in water content.
- It is observed that with the increase in compaction energy the collapse potential decreases.

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BIOGRAPHIES

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Deepika P. Palai was received her M. Tech. degree from NIT Rourkela in the year of 2015. Her interest areas of research are River Hydraulics and Hydrology. Now she currently works as a resource person at CAPGS, BPUT, Rourkela, India.