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Technical Note

Compressibility Characteristics of Pond Ash used as Geomaterial

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Introduction

The production of energy is essential for industrial growth in the country. Out of total installed generating capacity of around 82,000 MW at present in the country about 53,000 MW is generated from coal based thermal units. The coal used contains 40-50% ash which is higher in comparison to coal from other countries namely USA, UK, etc. Thermal plants naturally produce flyash as a byproduct and which is considered waste material. Its disposal is a major problem from environmental point of view (Sinha et. al., 1995, 1996, 1997; Sharma, 1996; Kumar, 1996).

Currently about 40 million tonnes of flyash is produced every year in India containing about 20% bottom ash and the rest 80% is flyash having variable physico-chemical properties resulting in variable density, strength, compressibility and permeability characteristics. Due to rapid industrialisation both in public and private sectors in India, the production of flyash is expected to be around 100 million tonnes by the end of 20th century. The flyash produced at various thermal plants is disposed either by wet or dry disposal systems. In case of wet disposal system, the flyash slurry normally contains 70-80% water for transportation. through pipe for storage in ponds or lagoons, Ash settled by sedimentation process is designated as pond ash.

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Similarly the dry disposal is carried out by depositing ash in the form of mounds using barren, cheap and low lying areas to control pollution hazard. (Sinha et al., 1997; Lister et al., 1996; Sinha et al.; 1996, Rajan, 1996).

Utilisation of bulk quantity of flyash as geomaterial is now catching up to a certain extent. Around 20% of flyash is being used for different beneficial applications on the globe and the rest is dumped as waste. The use of flyash in India is the lowest where 95-97% of flyash is still reported to be unutilised. However, use of 20-45% of fly ash is reported for use as sustainable geomaterial for construction of embankment, subgrade layer of road, dyke and ash pond embankment depending on the type of local soil and the quality of flyash. (Sinha et al., 1997; Misra et al., 1996; Singh, 1996; Kumar, 1996).

Based on the above salient points, authors undertook a research programme on compressibility characteristics of compacted pond ash. Ash samples were collected from the ash pond situated at the eastern part of Uttar Pradesh and the results of one-dimensional consolidation tests are presented.

Experimental Programme and Results

Physical Properties

The samples of pond ash were collected from two different locations for experimental works in the laboratory. The particle size distribution analysis tests were carried out for sample nos. 1 and 2 using a hydrometer for the material finer than 75 micron and are shown in Fig. 1. The results of grain

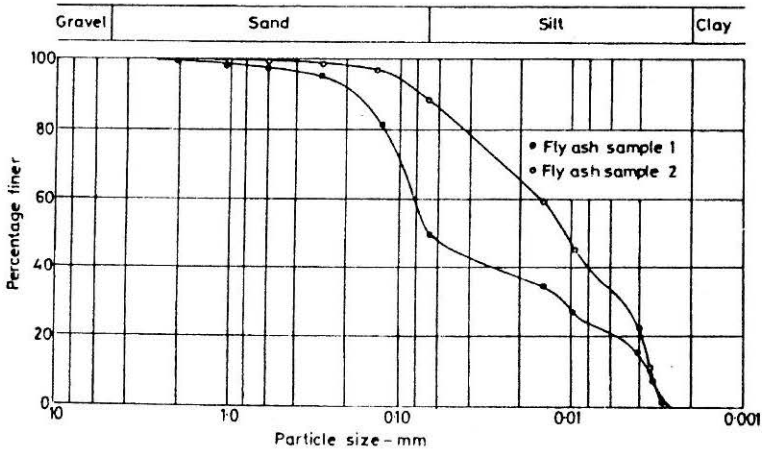

FIGURE 1 : Grain-size Analysis of Flyash Samples

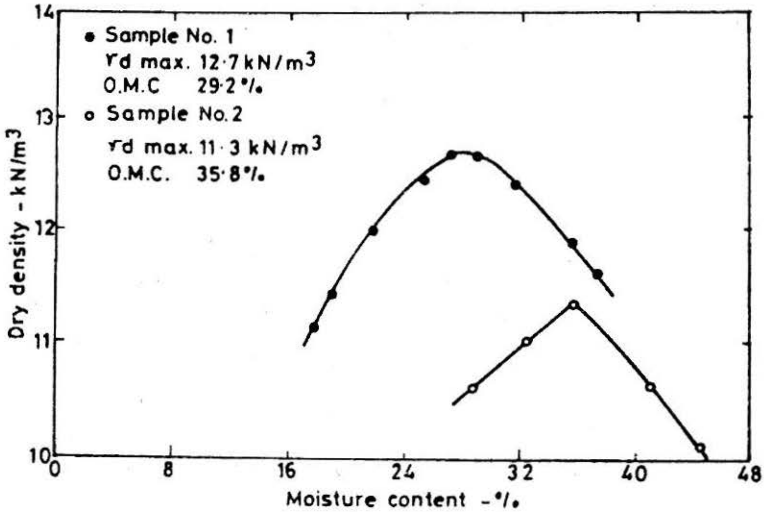

FIGURE 2 : Density – Moisture Relationship Plots

size distribution of sample no. 1 indicated 50% sand and 50% silt fractions. Similarly sample no. 2 indicated 12% sand and 88% silt fractions. 'Both samples did not contain any clay fraction i.e. finer than 2 micron. This could clearly indicate the spatial variation due to depositional system in ash pond. Both samples were nonplastic in nature. According to IS:1498-1970, sample nos. 1 and 2 were classified as silty sand and silt of nonplastic type of SM group considering them as geomaterial.

Compaction Characteristics

The compaction characteristics of pond ash samples were carried out according to IS:2720 part VII (1980) and plots of density–moisture relationship are shown in Fig. 2. The spatial variation in maximum dry density and OMC can be seen due to depositional system in ash pond showing variability in grain size which is not unusual. Because of lighter materials, the maximum dry density was found to be lower revealing higher OMC.

Compressibility Characteristics

To control environmental hazard, greater emphasis is given to utilise flyash in maximum quantity as geomaterial for the construction of flyash embankments or fills. For constructing structures over flyash embankments or on abandoned flyash deposits in ash pond for human settlements the estimation of settlement is important and it is essential to carry out one-dimensional consolidation test in laboratory. The consolidation tests of pond ash compacted at 85%, 90% and 95% of maximum dry density were carried out according to IS:2720(Part-15)-1986.

Based on experimental results various plots namely $e-\log_{10}\sigma'_v$, and m_v – effective vertical stress (σ'_v) are shown in Figs. 3 and 4. The test results for c_v and m_v were evaluated for the specific stress increment of 400 kN/m^2 compacted at various densities and the plots between dry unit weight and compression index (C_c), coefficient of consolidation (c_v), coefficient of volume change (m_v) were drawn to study the effect of unit weight on compressibility characteristics (Figs. 5 to 7).

The coefficient of permeability of flyash is equally important for geomaterial. Though it was not conducted using permeability apparatus but it was evaluated using the equation $k = c_v m_v \gamma_\omega$. The coefficients of consolidation (c_v) were evaluated using square root of time fitting method, m_v – coefficient of volume change, γ_w – density of water. The coefficient of consolidation (c_v), coefficient of volume change (m_v) were evaluated for each

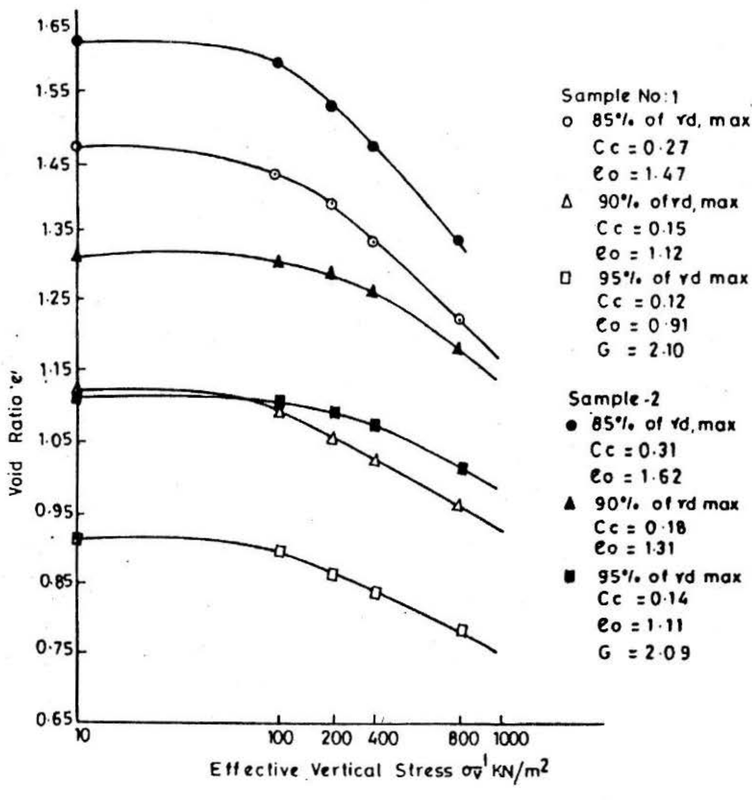

FIGURE 3 : $e-\log_{10}\sigma_v$ Relationship

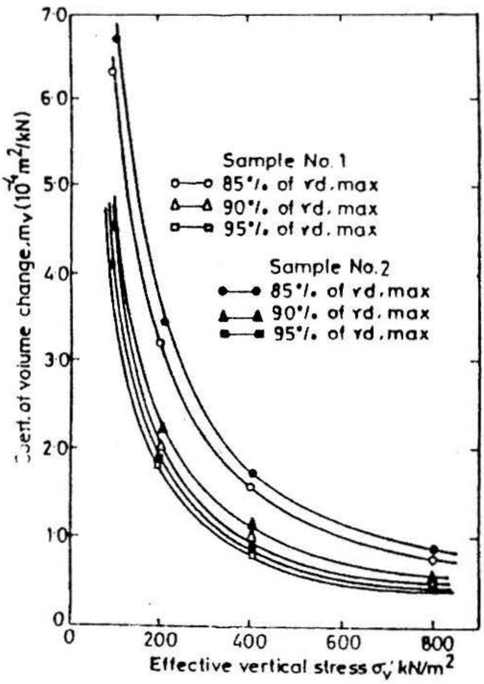

FIGURE 4 : Effective Vertical Stress – Coefficient of Volume Change (m_v) Plots

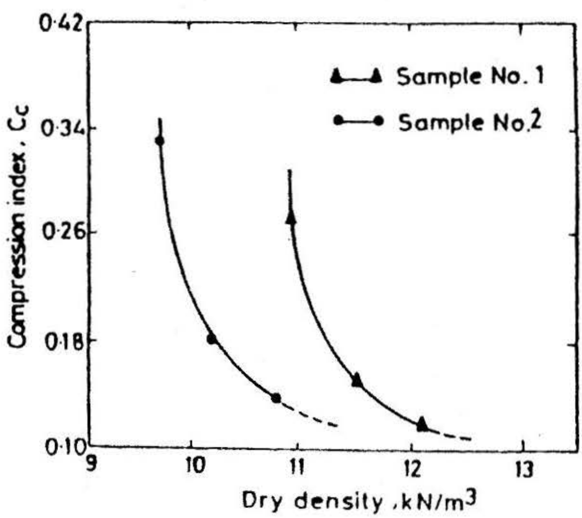

FIGURE 5 : Relationship between Dry Density and Compression Index (C_c)

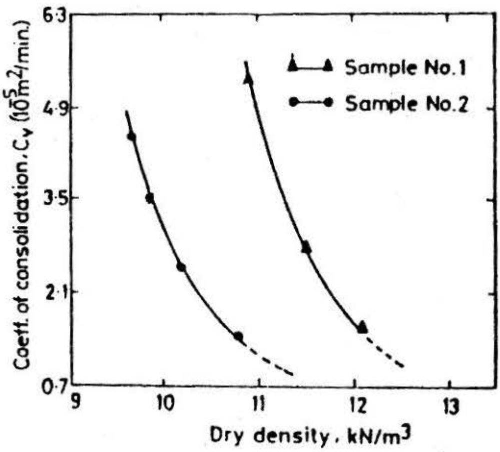

FIGURE 6 : Relationship between Dry Density and Coefficient of Consolidation (C_v)

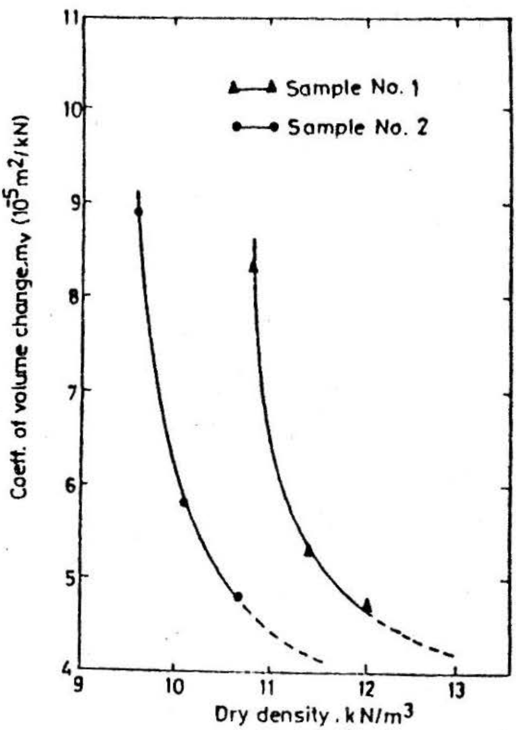

FIGURE 7 : Relationship between Dry Density and Coefficient of Volume Change (m_v)

increment of stress and the corresponding permeability were evaluated, the plots between permeability and effective vertical stress (σ'_v) and void ratio were drawn to study the effect of vertical stress, unit weight and void ratio and are shown in Figs. 8 and 9.

Discussion on Results

The particle size distribution and the Atterberg's limits are important physical properties to classify geomaterial. The pond ash being an hydraulically deposited material is supposed to have spatial variation (Sridharan et al., 1996 and Datta et al., 1996). Flyash collected from two different locations from the same ash pond revealed interesting results and indicated 50 to 80 % silt fractions showing nonplastic nature. The coefficients of uniformity (d_{60}/d_{10}) were found in order of 23.6 and 4.3 having mean diameter (d_{50} = 0.084 mm and 0.012 mm respectively) and indicated silty sand and silt of nonplastic type. As such foundation on silt deposit may be considered from geotechnical engineering point of view. Similarly compaction characteristics of pond ash were found different due to variation in grain size (Fig. 2).

The study on compressibility characteristics of two typical pond ash samples revealed interesting behaviour indicating the effect of density and found sensitive to it. (Figs. 5 to 7) The compressibility characteristics of pond ash compacted at 85% of maximum dry density revealed the characteristics of medium dense to loose state showing the condition of hydraulically placed material in ash pond, whereas the compressibility characteristics of pond ash compacted to more than 90% of maximum dry density revealed characteristics of very dense to medium dense type of flyash and found in agreement with other workers (Yudhbir and Honjo, 1991). The variation in compressibility characteristics due to variation in grain size was observed and supported the work of others.

Figures 4 and 7 show the effect of effective vertical stress (σ'_v), and unit weight on the coefficient of volume change (m_v). The plots indicate similar trend irrespective of density and grain size. However, the effect of density on coefficient of volume change (m_v) is seen clearly. The reduction in m_v with the increase of unit weight could be observed and this trend was found rapid upto effective stress around 500 kN/m^2 and thereafter the change in m_v was not found significant.

Figures 8 and 9 show the effect of effective vertical stress and void ratio on the permeability of pond ash compacted at various densities. Fig. 8 indicates the reduction in coefficient of permeability with increase of effective vertical stress, showing the effect of unit weight. Similarly the reduction in void ratio due to increase in vertical stress also revealed reduction in coefficient of permeability in a similar manner. The coefficient of permeability

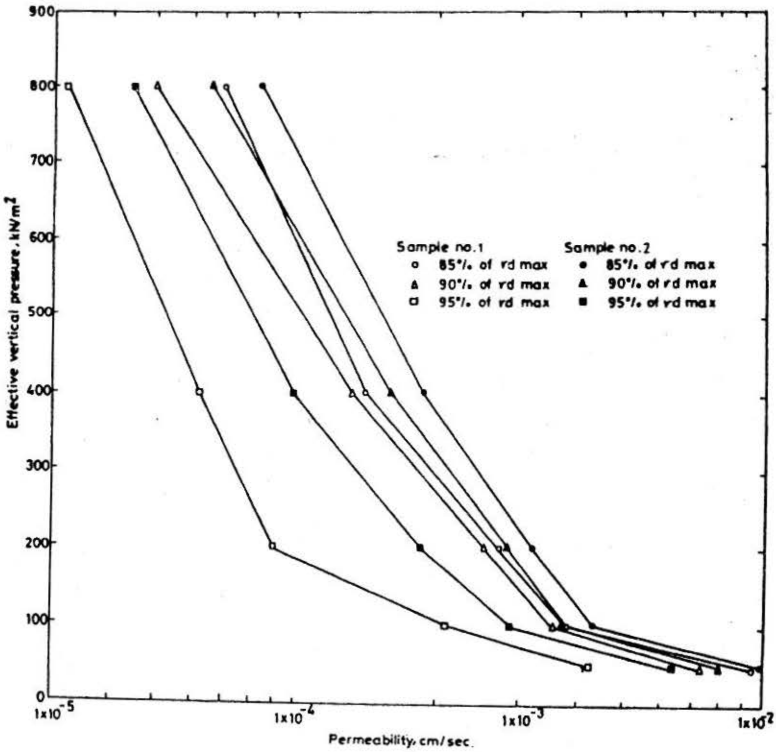

FIGURE 8 : Relationship between Permeability and Effective Vertical Stress (σ_v)

is found to change from medium to low permeability due to increase in vertical stress and reduction in void ratio showing the dependence on density and grain size of flyash.

Conclusion

Based on experimental results, the following conclusions are offered

- The compressibility characteristics of pond ash indicate effect of density on compressibility index (C_c) coefficient of consolidation (c_v) and coefficient of volume change (m_v)

- The compressibility characteristics of pond ash compacted at 85% of maximum dry density (MDD) indicated the characteristics of medium to loose density showing the condition of hydraulically placed flyash in ash pond.

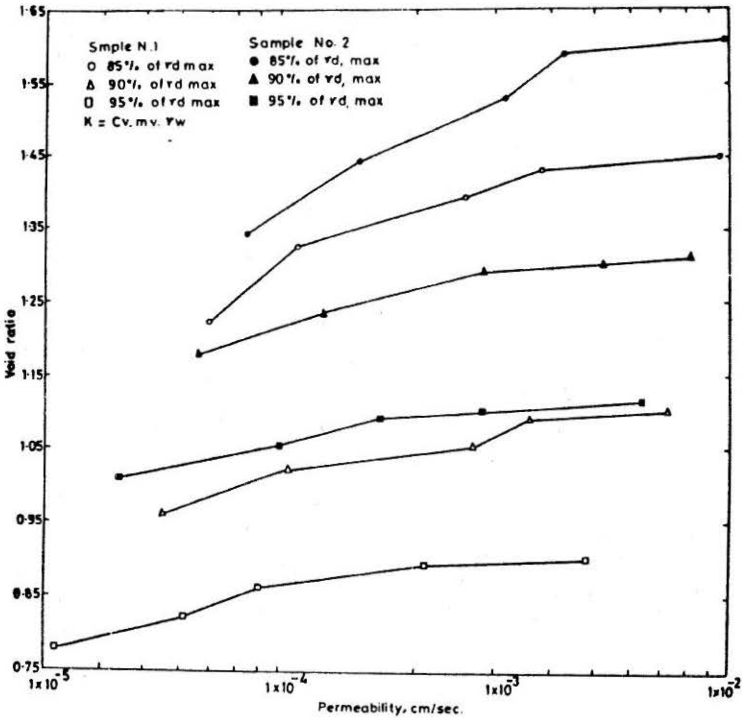

FIGURE 9 : Relationship between Permeability and Void Ratio

- The pond ash compacted at 90% and above of MDD revealed the compressibility characteristics of very dense to medium dense geomaterial
- The spatial variation in flyash of pond was found and the variation in compressibility characteristics due to variation in grain size was observed.
- The permeability characteristics were found dependent on void ratio, effective vertical stress and density.

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