

**CHARACTERISATION OF SHEAR STRENGTH BEHAVIOUR  
OF DELHI SILT  
AND APPLICATION TO BOUNDARY VALUE PROBLEMS**

*by*

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**Department of Civil Engineering**

*Submitted in fulfillment of the requirements of the degree of*

**DOCTOR OF PHILOSOPHY**

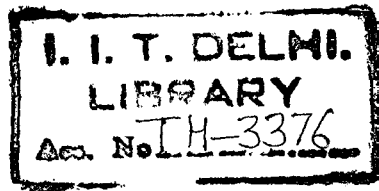
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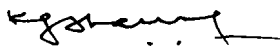
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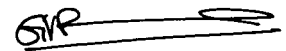
## **CERTIFICATE**

This is to certify that the thesis entitled “**CHARACTERISATION OF SHEAR STRENGTH BEHAVIOUR OF DELHI SILT AND APPLICATION TO BOUNDARY VALUE PROBLEMS**” being submitted by **Mr. Altaf Usmani** to the Indian Institute of Technology, Delhi is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion has reached the standard, fulfilling the requirements for **DOCTORATE OF PHILOSOPHY** degree. The research report and the results presented in this thesis have not been submitted, in part or full, to any other university or institute, for the award of any degree or diploma.



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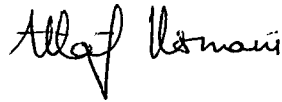
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## ABSTRACT

The Delhi state lies in the Indo-Gangetic alluvial trough. The main feature of these alluvial deposits is the presence of predominant silt content. This is always combined with varying amounts of sand and (or) clay. The average variation of silt in the Delhi region varies from 35% to 80%. The dominance of silt in the soils of Delhi region has finally acknowledged it to be known as “Delhi silt”. The Delhi silt comprises of silt and sand in varying proportion to make it either sandy silt or silty sand with insignificant clay fraction. The Delhi soil is lightly compacted/consolidated, rather than as an over-consolidated clayey type of soil. Delhi alluvium seems to have been consolidated essentially under its present effective overburden pressure with a maximum overconsolidation ratio of two.

In the present study a detailed analysis the soil profiles of Delhi region were carried out to assess the variation of silt in the Delhi region. After a careful analysis and evaluation of the silts in Delhi region, two soil compositions were considered in the study to be classified either as silty sand (S60M40) or sandy silt (S20M80). A detailed comprehensive triaxial testing was then followed for these representative soils. The triaxial testing program was carried out for four different stress paths under two types of drainage conditions varying over four different confining pressures for each of the soils. Slurry deposition technique was used to prepare saturated samples with a minimum level of disturbance to preserve the reported sensitive nature of silty soils to external disturbances. It took about 30 to 40 days to obtain a stable sample of sandy silt and silty sand using slurry deposition technique.

Subsequently 64 triaxial shear tests were conducted on these samples, covering four different stress paths with two each in compression and extension and four confining

pressures of 100, 150 200 and 300 kPa and two types of drainage conditions; i.e. consolidated drained and consolidated undrained.

In addition to triaxial tests on two different soil types of silty sand and sandy silt, some tests were also conducted for basic soil characterization and constitutive parameters determination.

Based on the detailed and elaborate testing, the engineering behaviour of silt containing two percentages of sand was studied and analysed in order to identify a suitable framework for characterization of silty soils.

The study illustrated that the transitional nature of silty soils cannot be captured either in terms of sand or a clayey type of framework. It was found that the engineering behaviour of silty soils is highly dependent on the composition and structure of soil matrix. The study also revealed strong stress induced anisotropic behaviour of silty soils with higher friction angle observed in extension than in compression. The results of the analysis also demonstrated that a unique failure line under different stress paths for both compression and extension does not exist which also highlighted their transitional nature.

The effect of fines in controlling the dilative behaviour of soil was also observed during the study, which showed that percentage of fines in sandy soils controls such behaviour.

It is recognized from the present study that against the backdrop of non-availability of studies on silty soils as compared to sands and clays, the attempt made in the present research work to understand the complex behaviour of silty soils could contribute to a better understanding of these type of soils and demonstrates the need for the development of an independent constitutive framework for silty soils.

The experimental results were further used to characterize the soil behaviour using one of the available constitutive models. In the present study Hardening-Soil (HS) model was selected and predictions were carried out using the general purpose finite element code PLAXIS. The predicted results were found to be in good agreement with the measured values under active compression i.e., conventional triaxial compression (CTC) and active extension i.e., reduced triaxial extension (RTE) stress paths. However the predictions for passive compression i.e., reduced triaxial compression (RTC) and passive extension i.e., conventional triaxial extension (CTE) stress paths were found to be comparatively less satisfying.

The predicted values using Hardening-Soil (HS) model also illustrated that the drained volumetric response was captured well in comparison to undrained pore pressure response for both the soils. The failure of the soil specimens under extension stress paths due to development of necking was also predicted satisfactorily well using the proposed model for both the sandy silt and silty sand soils. Keeping in view that this is the first of its type of attempt to model behaviour of sandy silty to silty sand soil; it is believed that this is a significant step in characterizing their behaviour within the available modelling constraints.

In the final stage of this study, two types of soil structure interaction studies, namely: (i) analysis of axisymmetric circular footing and (ii) a braced excavation were carried out.

The contact pressure distribution was found to be maximum at the centre of the footing for both the silty sand (S60M40) and sandy silt (S20M80) soils. The variation towards the edges was found to be different in the two soils, with parabolic nature observed in silty sand and a gradual decreasing slope observed in sandy silt soil. The predicted ultimate bearing capacities using the HS model were found to be in good

agreement with the computed values of other researchers for similar type of soils. It was observed from the critical analysis of bearing capacities values as given by various researchers that the bearing capacity factor  $N_\gamma$  has a major influence in estimation of bearing capacity of soils.

The soil-structure interaction of an underground braced excavation using the Hardening-Soil (HS) model indicated that the ground settlement and wall deflection were found to be less in silty sand (S60M40) due to its comparatively dense structure, as also substantiated in scanning electron micrographs. The maximum positive bending moments were found near the mid height of the wall and negative moments were recorded near the lower part of the wall in both the soils of S60M40 and S20M80. The net earth pressure was found to be passive at the toe of the wall under the applied loading in both the soil types. It is also acknowledged from the present analysis that the present model could be successfully employed in the analysis of different soil-structure interaction problems of various geotechnical structures.

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