PhD Thesis, titled

"**Physical Modelling of Encased Stone Columns with Tire-Derived Aggregates: Model and Field Experiments"**

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ABSTRACT

With the expansion of industrialization, the need for land with sufficient load-bearing capacity—especially soft soils—has grown to accommodate infrastructure such as heavy buildings, machinery, runways, port facilities, embankments, and oil storage tanks. However, the rising consumption of natural resources like stone aggregates, commonly used in stone columns for ground improvement, has led to the search for sustainable alternatives. This study focuses on shredded tire chips, known as Tire Derived Aggregate (TDA), as a potential replacement for stone aggregates in stone column applications. Discarded tires, which are difficult to dispose of due to their slow decomposition and landfill limitations, present a significant environmental issue. Recent developments in geotechnical engineering have highlighted the feasibility of using scrap tires as economical and eco-friendly materials. This research examines the performance of stone columns made with various combinations of stone aggregates and TDA, in accordance with ASTM D6270 guidelines for the use of scrap tires in civil engineering projects.

A comprehensive series of 170 element tests were conducted using large-scale triaxial tests to analyze the stress-strain response of stone columns with different TDA sizes and varying mix proportions with stone aggregates (SA). The results indicated that increasing the proportion of TDA reduces the failure deviatoric stress, decreases the angle of shearing resistance, and increases the apparent cohesion. Attempts were made to compensate the loss in shear strength of stone aggregates due to the inclusion of TDA by various reinforcing methods. Element tests were performed on SA+TDA mix proportions by horizontally reinforcement; encasement; horizontally reinforcement and encasement. The performance of the stone columns made up with SA+TDA mix proportions are compared to that of OSC made of 100% SA as a benchmark. The results indicated that with the help of encasement about 65% of SA can be replaced with TDA by volume.

To further evaluate the performance of TDA-based stone columns, 20 single-column and 4 group-column model tests were conducted on geogrid encased stone columns with a length of 660 mm and a diameter of 110 mm. Two types of geogrids with different tensile

strengths were used to assess the influence of tensile strength on the load-carrying capacity and bulging behaviour of the columns. Strain gauges were placed along the geogrid encasement to monitor the bulging behaviour of the columns. The model tests results are accessed with the help of efficiency of stone columns made of SA+TDA with that of OSC_100SA. The results from model tests indicated that with the help of encasement about 70% of SA can be replaced with TDA by volume.

To validate the findings from the model tests, six full-scale field studies were conducted in Madurai, Tamil Nadu, on encased stone columns with different proportions of stone aggregates and TDA. The field columns, measuring 300 mm in diameter and 4.5 m in depth, were installed in strata comprising 4 m of clay followed by 2 m of silt. Borehole investigations were carried out prior to field testing, and plate load tests were performed on the installed columns using a reaction arrangement. The results obtained from the field tests closely aligned with the outcomes of the model tests, confirming that encased stone columns with TDA aggregates perform comparably to conventional stone columns.

Following the successful completion of field tests, numerical analysis was performed using PLAXIS 3D software to simulate the behaviour of encased stone columns with varying proportions of TDA and stone aggregates. The simulations were conducted to analyse the load-settlement behaviour, stress distribution, and deformation characteristics of the columns. The results obtained from the PLAXIS 3D analysis further validated the experimental and field findings, providing deeper insights into the interaction between the encasement, stone aggregates, and TDA. Parametric study is also conducted on stone columns made of 70SA+30TDA mix proportions to quantify the improvement ratios by varying the stiffness of geogrid, diameter of column, undrained shear strength of clay.

The findings of this study demonstrate that TDA can serve as a viable and sustainable alternative to stone aggregates in stone columns. The use of TDA not only reduces dependency on natural resources but also provides an environmentally responsible solution for the disposal of non-biodegradable waste. Encased stone columns with TDA can effectively stabilize soft ground, reduce settlement, and maintain load-carrying capacity. The results from the comprehensive study done through triaxial tests, model tests, field tests and numerical analysis confirms that TDA-based stone columns perform similarly to conventional stone columns, making them a promising solution for sustainable ground improvement.