

SHEAR STRENGTH OF SOFT CLAY REINFORCED
WITH POLYPROPYLENE COLUMN

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MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG



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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF SYMBOLS

| Symbol | Description |
|-----------------|--------------------------|
| PP | Polypropylene |
| R^2 | Cohesion value |
| $^{\circ}C$ | Degree Celsius |
| ρ_d | Dry density |
| k | Hydraulic conductivity |
| pH | Hydrogen Number |
| ϕ | Internal friction angle |
| kN | Kilo Newton |
| kPa | Kilo Pascal |
| w_L | Liquid limit |
| q_{max} | Maximum deviator stress |
| $\rho_{d(max)}$ | Maximum dry density |
| Mg | Mega Gram |
| MN | Mega Newton |
| m/s | Metre per Second |
| μm | Micrometre |
| mm | Milimetre |
| w | Moisture content |
| w_{opt} | Optimum moisture content |
| $\%$ | Percent |
| w_P | Plastic limit |
| I_P | Plasticity index |

| | |
|----------|--------------------------------------|
| G_s | Specific gravity |
| ϕ_u | Undrained angle of internal friction |
| c_u | Undrained shear strength |

LIST OF ABBREVIATIONS

| | |
|--------|--|
| c_v | Coefficient of Consolidation |
| ASSHTO | American Association of State Highway and Transportation Officials |
| ASTM | American Society for Testing and Materials |
| A | Area of specimen |
| BSCS | British Soil Classification System |
| BS | British Standard |
| CBR | California Bearing Ratio |
| C_c | Compression Index |
| K | Kaolin |
| LL | Liquid Limit |
| OL | Low Plasticity Organic Clay |
| PI | Plastic Index |
| PL | Plastic Limit |
| SEM | Scanning Electron Microscope |
| STP | Standard Penetration Test |
| SL | Shrinkage Limit |
| UCT | Unconfined Compression Test |
| UU | Unconsolidated Undrained Triaxial Test |
| USCS | Unified Soil Classification System |
| US | United States |
| USA | United States of America |

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ABSTRAK

Tiang berbutir adalah satu teknik yang mempunyai sifat-sifat penambahbaikan daya dukung, mempercepatkan pelepasan lebih tekanan air liang dan mengurangkan mendapan di dalam tanah lembut yang lemah. Penyelidikan ini bertujuan untuk mengenalpasti peranan tiang Polipropilena dalam penambahbaikan kekuatan ricih dan kebolehmampatan tanah liat lembut kaolin yang telah disusun semula dengan menentukan akibat-akibat daripada nisbah penggantian kawasan, nisbah tinggi penembusan dan nisbah penggantian isipadu bagi sesebatang tiang Polipropilena ke atas ciri-ciri kekuatan. Sampel-sampel kaolin yang telah diperkuatkan (bertelulang) adalah tertakluk kepada Mampatan Tak Terkurung (UCT) dan Tidak Disatukan Taktersalir (UU) ujian-ujian tiga paksi. Sampel-sampel kaolin berukuran 50mm diameter dan 100mm tinggi. Menggunakan tiang PP bertelulang, dengan nisbah penggantian kawasan sebanyak 0.3, 0.5 dan 0.8, sampel-sampel tanpa tiang PP adalah sample yang dikawal, yang mempunyai kekuatan ricih maksimum sebanyak 6.035-7.223 kPa. Manakala, bagi 10.24% nisbah penggantian kawasan dengan nisbah tinggi penembusan 0.3, kekuatan ricih maksimum adalah 8.422-11.231 kPa, yang membawa peningkatan maksimum purata kekuatan ricih, 55.65% berbanding dengan sampel-sampel yang dikawal. Adapun, tiang yang mempunyai nisbah tinggi penembusan 0.5 dan 0.8 dengan nisbah penggantian kawasan sebanyak 10.24%, masing-masing menunjukkan bacaan kekuatan ricih maksimum sebanyak 8.047-10.462 kPa dan 8.048-10.396 kPa, yang menjadikan peningkatan bagi purata kekuatan ricih untuk kedua-dua adalah 45.073% dan 46.494%. Sementara itu, bagi sample-sampel yang mempunyai 25% nisbah penggantian kawasan dan 0.3 nisbah tinggi penembusan, kekuatan ricih maksimum adalah 10.427-13.595 kPa, yang menandakan satu peningkatan sebanyak 88.095% bagi purata kekuatan ricih maksimum. Bagi nisbah tinggi penembusan 0.5 dan 0.8 untuk 25% nisbah penggantian kawasan, kekuatan ricih maksimum masing-masing adalah 8.432-9.627 dan 7.640-8.427 kPa. Ini membawa peningkatan kepada purata kekuatan ricih sebanyak 40.346% dan 23.247%. Ujian Tidak Disatukan Taktersalir (UU) menunjukkan peningkatan sudut geseran, ϕ kepada 17.2% daripada 1.5%, yang menunjukkan satu perubahan yang ketara dalam penambahbaikan. Ini dapat dijelaskan dengan ciri-ciri fizikal partikel PP dan keadaan permukaannya. Sementara itu, kejelekitan, c menunjukkan satu peningkatan yang memberangsangkan daripada 25.9% kepada 142.9% berikutan kelancaran dan ketiadaan lompong pada permukaan partikel PP. Tekanan deviasi berbanding dengan terikan paksi pada kegagalan bagi 70, 140 dan 280 kPa tekanan sel telah diuji, mempunyai julat peningkatan daripada 14.7 kPa kepada 67.9 kPa. Kesimpulannya, tiang Polipropilena banyak meningkatkan kekuatan ricih; oleh itu akan dilaksanakan dalam usaha mengurangkan kos bagi pembaikan tanah sebagai ganti kepada bahan-bahan yang tidak boleh diperbaharui.

Kata kunci—Polipropilena, UCT, UU, Pembaikan Tanah, kaolin.

ABSTRACT

Granular columns is a technique that has the properties of improving bearing capacity, accelerating the dissipation of excess pore water pressure and reducing settlement in a weak soft soil. This research aims to investigate the role of Polypropylene (PP) column in improving the shear strength and compressibility of soft reconstituted kaolin clay by determining the effects of area replacement ratio, height penetrating ratio and volume replacement ratio of a singular Polypropylene column on the strength characteristics. Reinforced kaolin samples were subjected to Unconfined Compression (UCT) and Unconsolidated Undrained (UU) triaxial tests. The kaolin samples were 50 mm in diameter and 100 mm in height. Using the Polypropylene column reinforcement, with an area replacement ratio of 0.3, 0.5 and 0.8. Samples without the Polypropylene column are the controlled sample, which is having maximum shear strengths of 6.035-7.223 kPa. While for 10.24% area replacement ratio with height penetration ratio of 0.3, the maximum shear strengths are 8.422-11.231 kPa which brings the average maximum improvement of shear strengths of 55.65% compared to that of the controlled samples. As for the column with height penetration ratio of 0.5 and 0.8 with 10.24% area replacement ratio, The maximum shear strengths indicates the values of 8.047-10.462 kPa and 8.048-10.396 kPa respectively which makes the improvement of average maximum shear strengths for both set are 45.073% and 46.494%. Meanwhile, for the samples having 25% area replacement ratio and 0.3 height penetration ratio, the maximum shear strengths are 10.427-13.595 kPa, which indicates an improvement of 88.095% for the average maximum shear strengths. As for height penetrating ratio of 0.5 and 0.8 for 25% area replacement ratio, the maximum shear strengths are 8.432-9.627 and 7.640-8.427 kPa respectively. This brings the of average maximum improvements of shear strengths to 40.346% and 23.247%. UU testing showed that Friction angle ϕ improvement recorded to be from 1.5 to 17.2 % which shows a noticeable change in improvement. This can be explained by the physical properties of the PP particle and its surface. Cohesion c in the other hand shows a remarkable improvement of 25.9 to 142.9 % due to the smoothness and the unavailability of voids at the surface of PP particles. Deviator stress versus axial strain at failure for 70, 140 and 280 kPa cell pressure were tested to have the range of improvement from 14.7 kPa to 67.9 kPa. In conclusion, Polypropylene column greatly improved the shear strength; and could therefore be implemented in reducing the cost of soil improvement as a replacement for non-renewable materials.

Keywords—Polypropylene (PP), UCT, UU, Ground improvement, kaolin.

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