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# Evaluation of tensile strength characteristics of geosynthetic materials designed to ensure embankment stability

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**Abstract.** This article highlights the significance of geogrids and geosynthetic materials in addressing geotechnical engineering challenges and provides a foundation for further research and advancements in this field. The article explores the role of geogrids and geosynthetic materials in modern geotechnical engineering. Geogrids are three-dimensional structures made of polymer materials with apertures or cells filled with soil or other materials. They are extensively utilized for soil reinforcement, erosion control, surface stability, and ensuring the durability of various geotechnical structures. Geosynthetic materials, in turn, are artificial materials produced from polymers and are used for soil filtration, separation, protection, and reinforcement. They find wide application in various geotechnical systems and constructions, including drainage systems, hydrological barriers, road construction, and airports. The article also describes the Strain-control method for testing geosynthetic materials, allowing for result adjustments relative to specimen dimensions. The research underscores the significance of geogrids and geosynthetic materials in contemporary engineering practice and provides a foundation for further investigations and developments in the field of geotechnics.
**Keywords:** geogrids, geosynthetic materials, strength testing, tensile testing, embankment.

## 1. Introduction

Geogrids and geosynthetic materials are vital components in modern geotechnical engineering. They play a significant role in addressing various engineering challenges related to soil reinforcement, erosion protection, and land mass control.

Currently, the use of geosynthetic materials for soil improvement methods has gained significant popularity in geotechnical construction practices. These materials are employed for various methods of soil reinforcement, as local soil is one of the most cost-effective and readily available materials on construction sites.

Soil foundation reinforcement is widely applied in strengthening building foundations, transportation infrastructure, and the construction of various storage facilities.

This study provides experimental and theoretical research materials in the field of slope and embankment protection technology using geosynthetic materials. These materials enable more efficient design and construction of earth structures.

Reinforcing foundations with geosynthetic materials for deformable soil masses is one method of improving the strength and deformation properties of soils. However, the behavior of reinforced foundations under soil deformation is currently not well understood. Therefore, the research and development of stability methods for such foundations are of utmost importance [1].

Geogrids are three-dimensional structures made from polymer materials that feature openings or cells filled with soil or other materials. They are extensively used for soil reinforcement and stabilization, erosion prevention and control, the creation of stable surfaces, and ensuring the longevity of various geotechnical structures, such as roads, slopes, embankments, earth dams, and more.

Monograph [2] considers the reinforcement of the foundation, which leads to an increase in the ultimate load and a decrease in the die settlement. Reinforcement prevents the development of shear zones in depth - we can see the shear strain values dropping at the intersection of geogrids. Localization of shear strains in the form of strips is less evident. The character of deformation in general is similar to a natural base with a slightly wider and buried to the level of the lower layer of the geogrid stamp. The limit of linear proportionality of the pressure-settlement graph for the reinforced base also increases. This is due to the large distribution capacity of the reinforced base due to the lateral compression of the soil in the reinforcement zone

Geosynthetic materials, in turn, are artificial materials produced from polymers or polymer combinations that possess specific geotechnical properties. They serve various functions, including filtration, separation, protection, and soil reinforcement. Geosynthetics are employed in diverse geotechnical constructions and systems, such as drainage systems, soil and hydrological barriers, as well as in the construction of roads and airports [3].

Research objectives:

1) Testing five types of geogrids to determine the optimal choice:

– Conducting tensile strength tests on five types of geogrids.

– Performing tests on geogrids using standardized methods to evaluate their strength under various conditions.

2) Analyzing the results of geogrid testing and selecting the most effective and durable geogrid. Establishing optimal usage parameters for the selected geogrid based on the obtained data, such as element spacing, stress on the geogrid, and other factors.

3) Selecting an equivalent geogrid for model testing based on tasks 1 and 2:

– Defining the requirements for model testing, including soil parameters, loads, and operating conditions.

– Utilizing the test results from tasks 1 and 2 to select an equivalent geogrid that corresponds to the primary geogrid but can be utilized in more controlled model testing conditions.

– Conducting model tests using the chosen equivalent geogrid and comparing their results with the data from the main research.

– Analyzing the results of model tests and the draw conclusions to confirm the effectiveness of the selected equivalent geogrid.

## Methods

The tests were conducted using the Strain-Control method, which is based on maintaining a specified level of deformation in the specimen throughout the test. In the case of specimen elongation, the deformation is controlled and maintained at a constant level, while the tensile forces required to maintain this deformation are measured. In this method, we applied tensile forces that were adjusted relative to the actual length of the specimens [4].

For conducting Strain-Control tests, specimens of geosynthetic materials are subjected to elongation at a specified deformation rate, while the tensile forces are simultaneously measured. To adjust the tensile forces relative to the actual length of the specimens, relevant formulas or calculation methods are used, which take into account the specimen length and its geometric parameters.

Thus, when using the Strain-Control method to compare the strength of geosynthetic materials, the tensile forces can be adjusted considering the actual length of the specimens, enabling a more accurate comparison and analysis of their strength properties [5].

The tests were performed on specimens with a width close to the width of the clamping device (clamp jaws), which was 16 cm. Since the distance between the geogrid ribs and the aperture of each specimen is individual, the widths of the specimens varied. Therefore, when comparing the strength indicators of the specimens, it is necessary to adjust the tensile forces relative to the actual length of the specimens. The results of the actual tensile forces, obtained from the Strain-Control tests (at specified displacements), are presented in Figure 1 [6].

The tests were conducted for 5 different types of geogrids, as presented in Table 1.

Table 1 – Geosynthetic materials

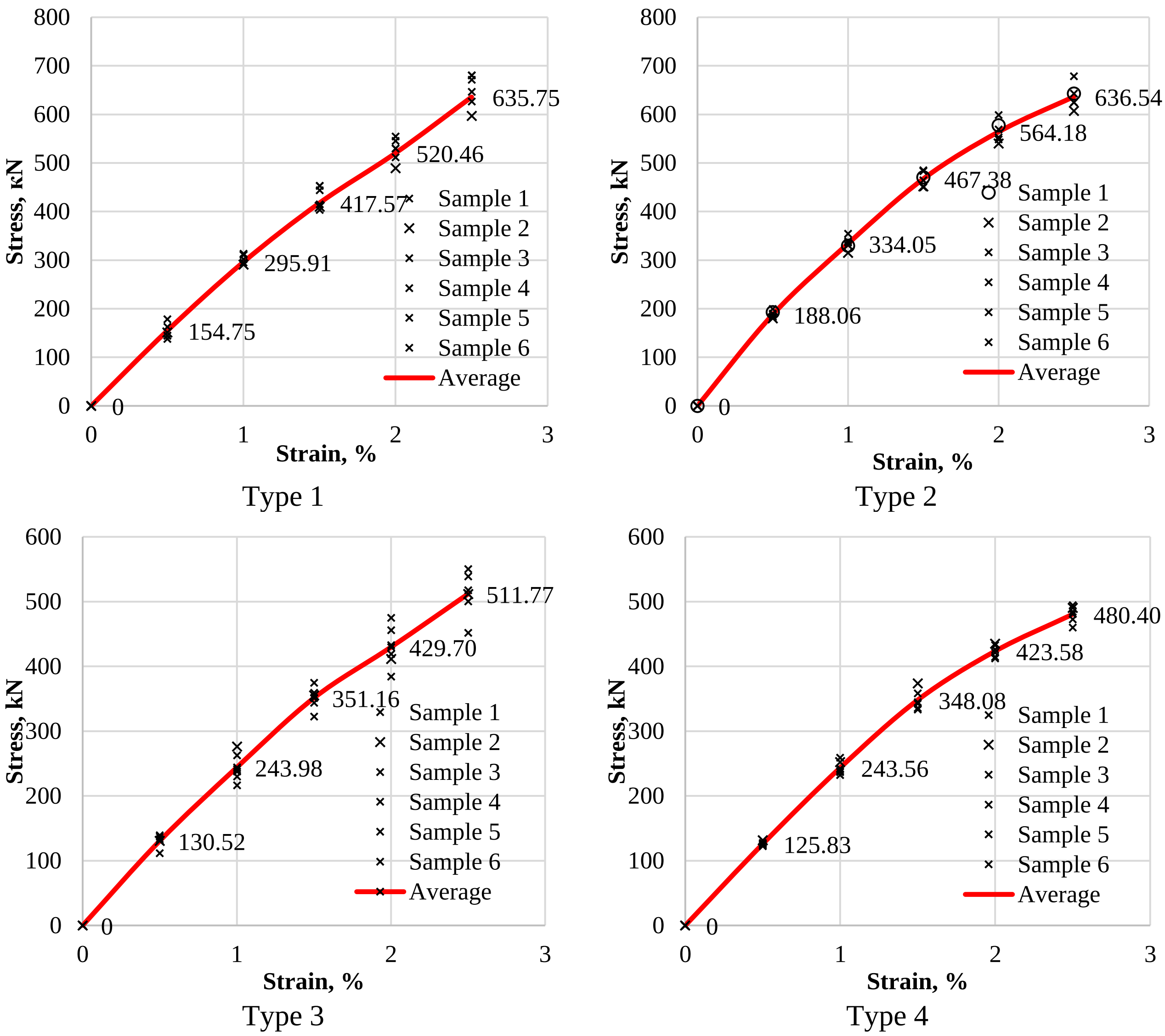
| No. of sample | Appearance | Characteristic |
|---|---|---|
| Type 1 |  | Polyester geogrids - reinforcing material used in the upper layers of pavements during construction, repair and reconstruction of roads and railways, airfields, bridges and overpasses, reinforcement of weak bases, as well as in other geotechnical constructions. |
| Type 2 |  | SD geogrid is a material made of polypropylene. In order to obtain high strength characteristics with low creep, the mesh is stretched in two directions during the production process Geogrid is specially designed to increase the ability of structures to bear high dynamic and static loads, including construction on weak soils. |
| Type 3 |  | The composite bonded in this way evenly distributes loads over large areas, thus dramatically increasing the bearing capacity of weak subgrade soils. This property lies in the ability of the material to absorb various tensile forces even with minimal deformation and settlement of the foundation. |
| Type 4 |  | Geogrid is specially designed for reinforcement of bearing pavement bases, as well as for construction on weak soils and for use in structures that support high dynamic and static loads. |

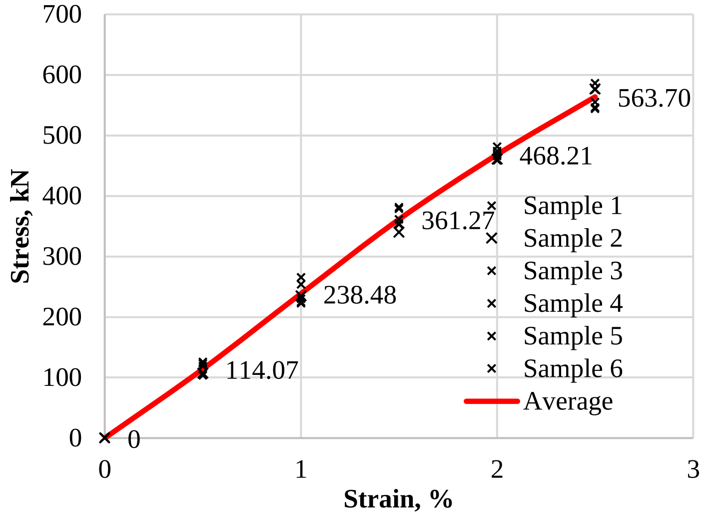
| | | |
|---|---|---|
| Type 5 |  | Polymer hexagonal geogrid "RGK" is a flat triaxially oriented polypropylene lattice with a triangular cell, used for reinforcement of large-fraction bearing layers of pavement, as well as for use in structures subject to increased static and dynamic loads and in the base of the earth bed on weak (subsidence) soils of the existing base [7]. |

The tests were performed on a tensile press. The results for all 5 samples are shown as follows.

### 3. Results and Discussion

Figure 1 depicts the results of the tensile forces tests conducted on specimens of the compared types of geogrids (Type 1 – Type 5). Each graph shows the results of all six individual tests for each type of geogrid. Figure 2 shows the mean value of the tests of all samples.






Type 5

Figure 1 – Graph of geogrid tensile strength

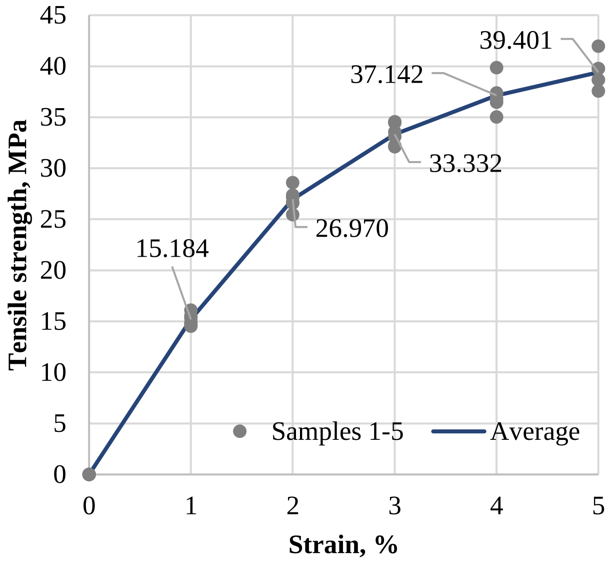



Figure 2 – Tensile test results without correction average of all specimens.

The correction factors for each sample type are presented in Table 2. The correction was made relative to the dimensions of Sample 1. The results, considering the corrections based on the specific length of the specimens, are presented in Figure 3. According to the test results, the highest tensile resistance values were observed for Sample 2. Therefore, for the selection of geometric dimensions for the equivalent geogrid, further tests to determine the tensile strength of a single rib will only be performed for Sample 2.

Table 2 – Correction indicators

| Indicators | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 |
|---|---|---|---|---|---|
| Sample width, cm | 12.8 | 12.4 | 10.8 | 13.6 | 13.5 |
| Correction, $\frac{\text{Sample width1}}{\text{Sample width } N}$ | 1.00 | 1.03 | 1.19 | 0.94 | 0.95 |

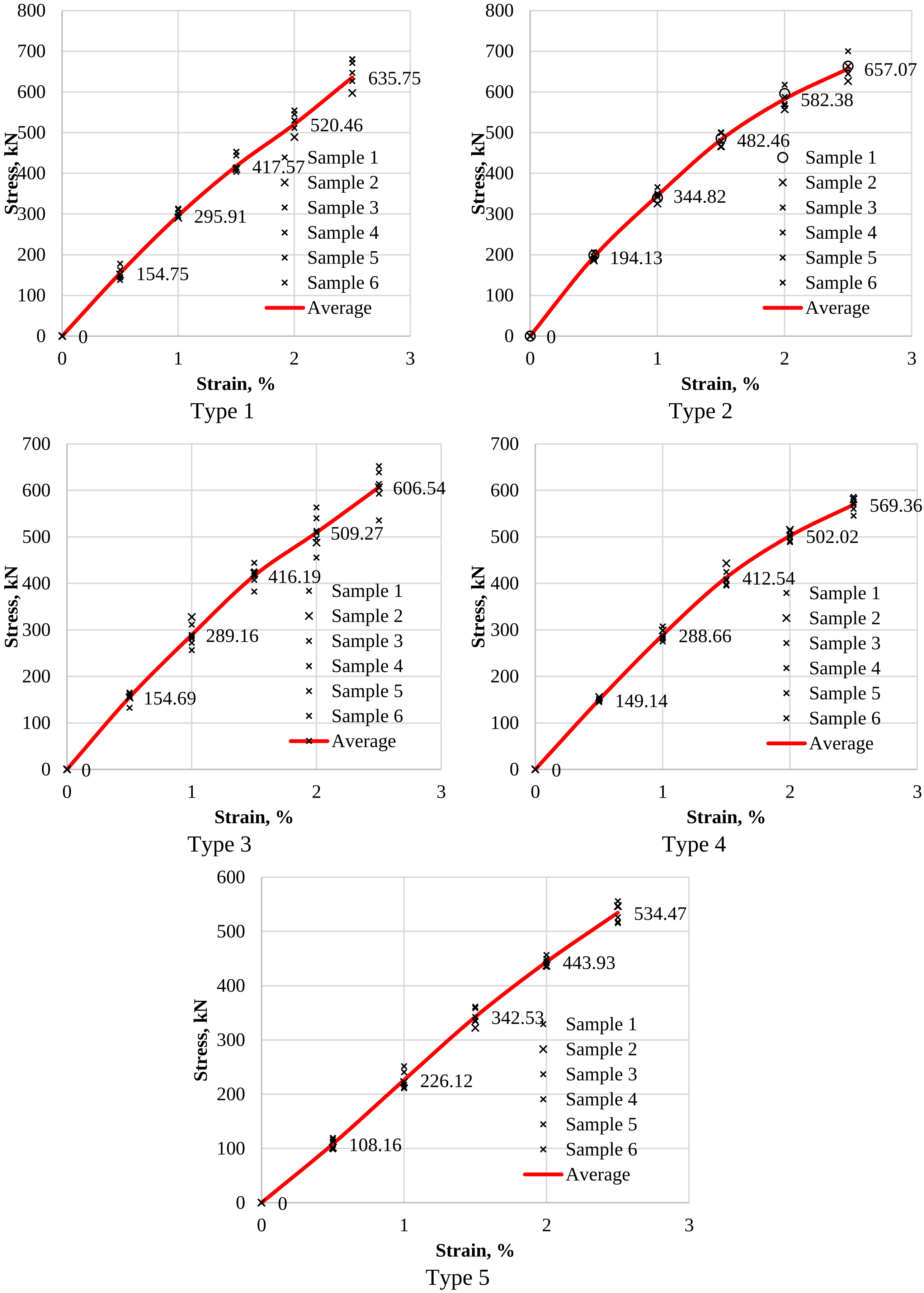



Figure 3 – Graph of geogrid tensile strength

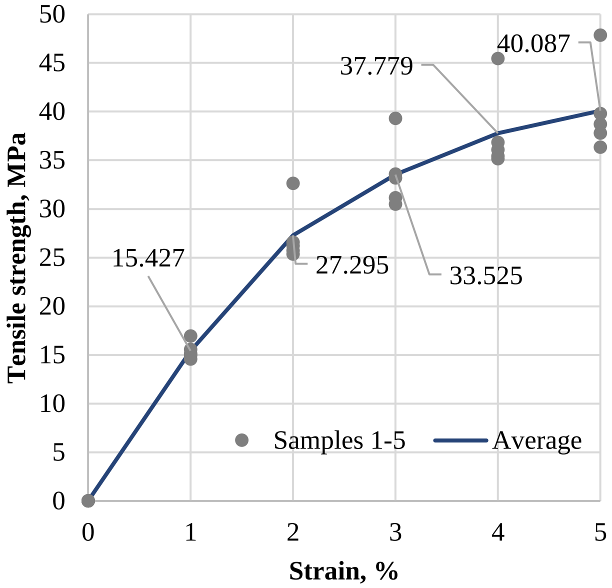



Figure 4 – Tensile test results with corrected average of all specimens.

Ultimately, Type 2 was selected as the most optimal choice due to its highest strength and performance relative to its geometric dimensions and specific cross-sectional area, as presented in Figure 4.

Research conducted by other authors in the past provides a context for our work and reinforces the overall significance of employing geogrids and geosynthetic materials in contemporary geotechnical engineering. This reaffirms the relevance and importance of our study, contributing to the broader comprehension of geotechnical and geotechnical engineering fields.

However, it should be noted that some discrepancies with prior research may arise due to differences in testing methodologies, experimental conditions, or characteristics of the utilized geosynthetic materials. These present opportunities for further research to refine and expand upon our findings [8].

In conclusion, the discussion of the results in comparison with analogous studies substantiates the significance and timeliness of our research and identifies prospects for further investigations in the realm of geotechnical engineering.

## 4. Conclusions

Based on the conducted research, the following conclusions can be drawn:

– By using the Strain-Control method to compare the strength of geosynthetic materials, the adjustment of tensile forces relative to the actual length of the specimens allowed for a more accurate comparison and analysis of their strength properties.

– The test results indicate a significant influence of geosynthetic materials on soil reinforcement, erosion prevention, and the durability of geotechnical structures. The effectiveness of geogrids and geosynthetic materials in solving engineering problems has been demonstrated.

– These findings can be utilized in further research and development in the field of geotechnical engineering to create more stable and reliable engineering structures.

– According to the test results, the highest tensile resistance was observed in Sample 2. Therefore, for further trough testing and Plaxis simulations, Sample 2 was chosen due to its higher resistance to tension.

– These findings provide valuable insights for the field of geotechnical engineering and can contribute to the development of more robust and reliable engineering constructions.

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