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Impact of Date-Palm Fibers on Fine Soil's Compaction and Strength Properties

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ABSTRACT

This paper investigates the influence of date-palm fibers on the compaction and strength properties of fine soil. The laboratory tests, including specific gravity, compaction tests, and unconfined compression strength tests, were conducted, integrating different proportions (ranging from 0 to 2%) of date-palm fibers into the soil mixture. The palm fibers were divided into two distinct lengths (30 mm and 60 mm) to be mixed with the soil. Nine samples were prepared with varying proportions of date-palm fibers for the experimental investigation, aiming to specifically examine the influences exerted by both palm-fiber length and palm-fiber content on the soil's compaction and strength characteristics when mixed with date-palm fibers. The compaction test results demonstrate a decrease in the dry unit weight and an increase in the optimum moisture content by approximately 10%. Additionally, the length of the date-palm fibers impacts the optimum moisture content and the maximum dry unit weight of the soil mixture. In contrast, the unconfined compressive stress increased by about 30% with higher date-palm fiber contents. This increase in unconfined compressive stress due to increased date-palm fiber content is a significant finding, indicating improved soil strength. This finding holds the enhancing construction performance, sustainability, and cost-efficiency. In conclusion, this soil-fiber mixture shows suitable hydraulic applications. The utilization of natural materials in civil engineering demands the exploration of available natural fibers.

Keywords: Date-Palm fiber, Optimum moisture content, Dry unit weight, Unconfined compressive strength.

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تأثير ألياف نخيل التمر على رص التربة الناعمة ومقاومتها

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الخلاصة

يوضح هذا البحث تأثير ألياف نخيل التمر على خصائص رص ومقاومة التربة الناعمة. لمعالجة هذه المشكلة، تم إجراء الاختبارات المعملية، بما في ذلك الجاذبية النوعية، واختبارات الرص، واختبارات قوة الضغط غير المحصورة، ودمج نسب مختلفة (تتراوح من 0 إلى 2٪) من ألياف نخيل التمر في خليط التربة. ألياف النخيل هي مادة ذات أهمية خاصة، وقد تم تقسيمها إلى طولين متميزين (30 مم و60 مم) ليتم خلطها مع التربة. تم تحضير تسع عينات بنسب متفاوتة من ألياف نخيل التمر للتحقيق التجريبي، بهدف فحص التأثيرات التي يمارسها كل من طول ألياف النخيل ومحتوى ألياف النخيل على خصائص ضغط التربة وقوتها عند مزجها بألياف نخيل التمر. تظهر نتائج اختبار الرص انخفاضا في الكثافه الجافه وزيادة في محتوى الرطوبة الأمثل بنسبة 10٪ تقريبا. بالإضافة إلى ذلك فإن طول ألياف نخيل التمر له تأثير على محتوى الرطوبة الأمثل والحد الأقصى للكثافه الجافه لخليط التربة. في المقابل، زاد إجهاد الضغط غير المحصور بنحو 30٪ مع ارتفاع محتويات ألياف نخيل التمر. هذه الزيادة في إجهاد الانضغاط غير المحصور بسبب زيادة محتوى ألياف نخيل التمر هي نتيجة مهمة، مما يشير إلى تحسن قوة التربة. هذه النتيجة تبشر بتعزيز أداء البناء والاستدامة وفعالية التكلفة. في الختام، يظهر خليط ألياف التربة هذا ملاءمة واعدة للتطبيقات الهيدروليكية. يتطلب الاستخدام المتزايد للمواد الطبيعية في الهندسة المدنية استكشاف الألياف الطبيعية المناسبة المتوفرة بسهولة.

الكلمات المفتاحية: ألياف النخيل، محتوى الرطوبة الأمثل، الحد الأقصى الكثافة الجافة، مقاومة الانضغاط غير المحصورة.

1. INTRODUCTION

The progress in the economy experienced generally has caused a substantial rise in the generation of both solid and liquid wastes **(Ramachandra et al., 2018; Shah et al., 2023)**. Particularly, the waste has led to severe environmental problems, including groundwater contamination and soil degradation through indiscriminate land disposal. Despite efforts to reduce and recover wastes, the data obtained from the study on the chemical composition of Iraqi date cultivars can be used to assess their nutritional adequacy, aid in dietary planning, support the development of value-added products, and promote their utilization in the food industry **(Siddiqua et al., 2022; Al-Farsi and Lee, 2008)**. Landfilling remains the dominant method of waste disposal worldwide, albeit with its drawbacks, such as the production of contaminated liquid known as leachate once rainwater penetrates the waste. (**Arunbabu et al., 2017; Djoudi et al., 2021; Wijekoon et al., 2022)** studied the development of pollution from landfill leachate contributing to understanding the risks, pollution potential, treatment methods, and challenges associated with landfill leachate management. Also, there is an increase in utilizing non-industrial (i.e. natural) building resources. These materials are characterized by their simple, energy-efficient manufacturing processes, often employing raw materials available on-site or in the vicinity **(Daud et al., 2016; Nik Daud et al., 2017)**.

Fibers have assured the in-enhancing properties of soils, like tensile, compression, and shear strength. Incorporating fibers in the soil can prevent erosion in slopes and canals and reinforce embankments, especially in clay soils, thereby offering a prospective solution to environmental interests **(Syed et al., 2020).** Through an exploration of mechanical properties including strength, stiffness, and deformation characteristics of reinforced soil by glass-fiber, the research offers valuable perspectives regarding this reinforcement technique in improving the engineering properties of subgrade soils. **(Chegenizadeh and Nikraz, 2011; Mekkiyah, 2013; Ali and Yousuf, 2016; Sujatha et al., 2021; Alqaissi et al., 2022; Gul and Mir, 2022; Shakir et al., 2022; Aksu Alcan and Çelik, 2023)**.

Reinforced soil encompasses a range of theories and application approaches, forming a subdivision within geotechnical science that focuses on enhancing and stabilizing soil engineering characteristics like strength, durability, and deformability **(Santoni et al., 2001; Ghiassian et al., 2004)**. **(Santoni et al., 2001)** examined the impact of various factors on the performance of fiber-stabilized sand specimens. Five main findings were obtained through laboratory tests on sand samples reinforced with randomly oriented discrete fibers: 1) The inclusion of fibers significantly improved the sand's compressive strength. 2) An optimal fiber length of 51 mm was identified. 3) The best performance occurred with a fiber dosage rate between 0.5% and 1.0% of the dry weight. 4) Specimen performance was enhanced under wet and dry conditions, particularly near the optimum range. 5) Including up to 8% of silt did not significantly affect the fiber reinforcement's performance. (**Ghiassian et al., 2004)** focused on the behavior of fiber-reinforced soil, which acts as a composite material with high-tensile-strength fibers embedded in a plastic soil matrix. This was to understand how synthetic fibrous materials can improve the strength of fine sandy soil, with a particular interest in repurposing discarded fibrous carpet waste for soil reinforcement. Drained triaxial tests were conducted on cylindrical specimens. The results demonstrate that including fibrous materials from carpet waste enhances the shear strength of silty sands.

Reinforced soils can be created using two approaches: one involves including continuous strengthening presences (such as sheets, bars, or strips) in a specific arrangement within a soil mass, whereas the other method involves mixing detached fibers arbitrarily with a soil fill. The fibers are introduced and mixed into the soil **(Yetimoglu et al., 2005; Bawadi et al., 2020; Arfin et al., 2023)**. For example, (**Arifin and Normelani, 2019)** used natural fiber derived from oil palm empty fruit bunches (EFB), to reinforce soft soil and enhance its shear strength and load-bearing capacity. Their study investigates various fiber-to-soil compositions (5%, 6%, 7%, and 8%) through multiple tests, including compaction, unconfined compression, laboratory vane, and California Bearing Ratio tests. The results reveal that soft soil can be effectively compacted with a fiber content exceeding 5%, reaching a maximum density of 0.92 g/cm^3 at 7% fiber content. The soil-EFB mixtures significantly improve shear strength and load-bearing capacity, transitioning the soil's consistency from soft to medium. The optimal fiber content shows the highest unconfined compressive strength (q_u), undrained shear strength (S_u), and California Bearing ratio (CBR) values (0.8 kg/cm^2, 0.65 kg/cm^2, and 6%), respectively, which is found to be between 6% and 7%. This research demonstrates the potential of EFB-derived natural fiber to enhance the engineering properties of soft soil for construction applications.

On the other hand, laboratory tests were conducted by **(Yetimoglu et al., 2005)** using the California Bearing Ratio (CBR) method to examine the behavior of sand reinforced with randomly distributed fibers for soft clay. The study aimed to assess how varying fiber content affected bearing capacity, stiffness, and ductility in this system. The results indicated that adding fibers to the sand fill significantly increased the peak piston load, with greater