Experimental study of the mechanical behavior of dam sediment renforced by geotextiles and geogrids

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Abstract:

Introduction/purpose: Geosynthetic materials have been successfully used for soil reinforcement to improve bearing capacity. In this article, geotextiles are used as tension material for the reinforcement of a mixture based on dredged sediment from the Cheurfas dam (Mascara) and quarry sand.

Methods: Immediate bearing index tests were carried out in the laboratory to study the mixing behaviour, and the three-point bending flexural test was *carried out on prismatic specimens to study the traction capacity of the mixture. Mixture samples are selected and tested without reinforcement. Then, by placing one, two and three layers of geotextile at a certain depth of the sample, the effects of a number of layers and type of geotextile and geogrid on increasing the bearing capacity of the mixture are discussed.*

Results: The results of these tests show that the bearing capacity of the samples reinforced by geotextile and geogrid is increased compared to that of the unreinforced samples. Based on the results obtained from Proctor-IPI, their values do not permit the movement of construction machinery during the construction of pavement layers. The Immediate Bearing Index values are found sufficient for pavement layers. Geotextile introduction increases traction strength and improves stress distribution on soil samples, with the effect being significant for woven geotextile blends.

Conclusion: All things considered, the results point to the possibility of using reinforced local soils as an affordable and practical option for building pavements. To guarantee long-term performance and optimise building methods, more research is advised.

Key words: geotextile, sediment dredged, Cheurfas dam, soil reinforcement.

Introduction

The uses of geotextiles in many engineering applications have become more apparent proving to be an effective way to improve soil. In the first applications in roads and airport runway constructions, the emphasis was placed on the separation function of geotextiles. Resl & Werner (1986) carried out laboratory tests on the soil reinforced with a non-woven needled geotextile under axisymmetric loading. The results showed that the geotextile layer placed in the middle can significantly increase the bearing capacity of loose soils of the foundation. Fannin & Sigurdsson (1996) studied the performance of an unpaved road reinforced with different geosynthetics. Many papers have examined soil reinforcement by geotextiles (Bergado et al, 2001; Raymond & Ismail, 2003; Park & Tan, 2005; Yetimoglu & Salbas, 2003; Patra et al, 2005; Varuso et al, 2005). Current research mainly emphasizes the strength, mechanism and bearing capacity of reinforced soil (Haeri et al, 2000; Michalowski, 2004; Zhang et al, 2006; Madhavi Latha & Murthy, 2007; Duncan-Williams & Attoh-Okine, 2008). Dredging sediments from the Cheurfas Dam in Algeria were studied for their potential use in road embankments. The sediments were analyzed for their physico-chemical, mineralogical, and mechanical properties, and it was found that a treatment with sand, lime, and cement was necessary for their valorization (Bourabah et al, 2010). This article presents the immediate bearing index and the tensile strength by bending performed on a mixture of 35% sediment and 65% sand reinforced by a geotextile and a geogrid placed in one, two and three layers. It also compares the bearing capacity and the tensile strength of unreinforced soil reinforced with geotextiles.

Material properties

The soil used is composed of sediments dredging of the Cheurfas dam and quarry sand; the two materials are from the region of Mascara (Algeria). The properties of these materials are shown in Table 1. In this data base, sediments can be classified according to the Road Earthworks Guide (GTR) in class A2 and sand in class B2. Three types of geosythetics are used as reinforcement, a geogrid (Geo1) made of polyester, a non-woven geotextile (Geo2) and a woven geotextile (Geo3), both made of polypropylene.

Table 1 – Geotechnical characteristics of the Cheurfas dam sediments

Characteristics	Value
Unit weight of solids, γs (KN/m3)	25.17
Organic content, % MO (à 450°C)	5.15
Methylene blue value	25.17
Liquid Limit, WL (%)	3.66
Plastic Limit, WP (%)	57
Grains size < 2µm	27
2µm < Grains size < 80µm	46%
80µm < Grains size	49%

Table 2 – Geotechnical characteristics of quarry sand (Djbel Amanfous)

Characteristics	Value
Maximum grains size, D max (mm)	2
Grains size < 2mm (%)	100
Grains size < 80µm (%)	11.01
Unit weight of solids, γs (KN/m3)	25.5
Methylene blue value	0.26
Visual sand equivalent value, ESV	53
Piston sand equivalent value, ESP	52

Study of mechanical behavior

Compaction and bearing parameters depending on the type of geotextiles

The experimental program includes three series of tests, depending on the type of geosythetics, to study the effect of three selected geosythetics (Photo 1) on the mechanical performance of lift. Each series includes three cases of reinforcement, namely the number of layers (one, two and three layers). During compaction, the geotextile material is placed in the form of a disc. A new sample of geosythetics was used for each test, to avoid any fatigue in the sample. Depending on the type of geosythetics and the number of layers, Proctor tests were carried out for five water contents between 8%; and 16%. The results of this program are presented in the following curves, which are the results of the Proctor test, as well as those of the IPI. The characteristics at the Proctor optimum are shown in Table 3.

Geo1 Geo2 Geo3

Photo 1 –Geosythetics (Geo1 is a geogrid, Geo2 is a non-woven geotextile and Geo3 is a woven geotextile

On the graphs of IPI, w, and γ_d (Figures 1-3), it can be noticed that the evolution of the compaction curve is substantially the same regardless of the type of reinforcement, which means that the compactness of the granulometrically corrected Cheurfas sediment reinforced by geosynthetics is not influenced.

In terms of immediate bearing, it is noted that the measured values decrease more rapidly with increasing water content after the optimum Proctor, which indicates a sensitivity of the bearing with the water content.

The penetration resistance values of 2.5 mm and 5 mm were obtained from the IPI curve corresponding to both unreinforced and reinforced samples. The greater of the values calculated at 2.5 mm and 5 mm penetration were taken.

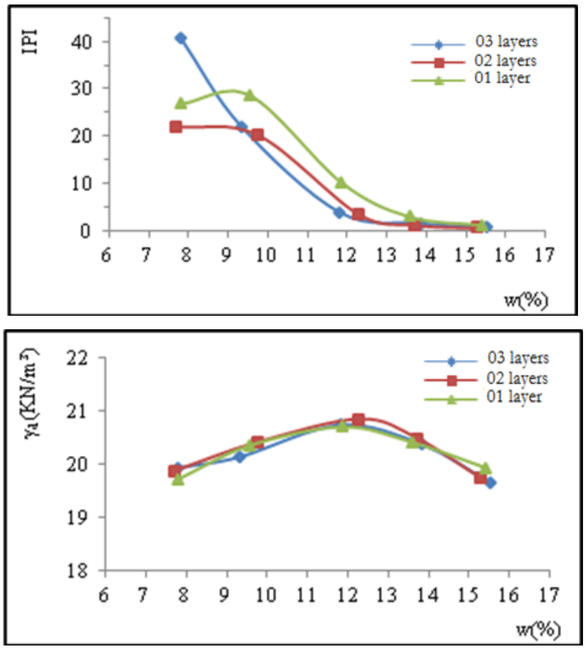

Figure 1 – Evolution of γ_d and the IPI as a function of w%, the soil reinforced by Geo1

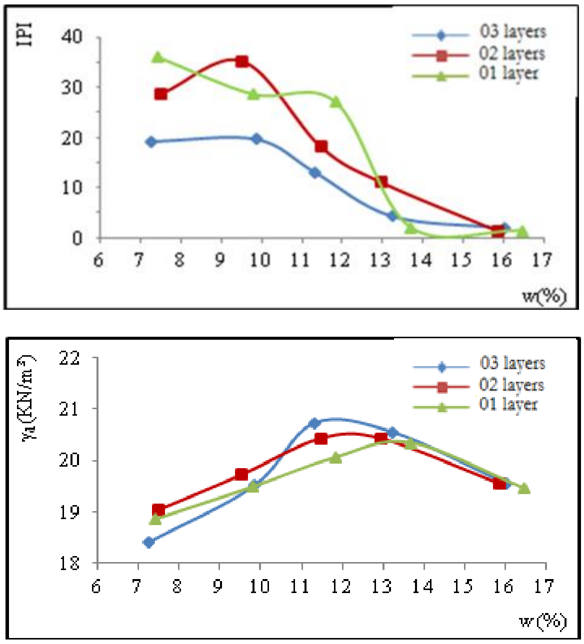

Figure 2 – Evolution of γ_d and IPI as a function of w%, the soil reinforced by Geo2

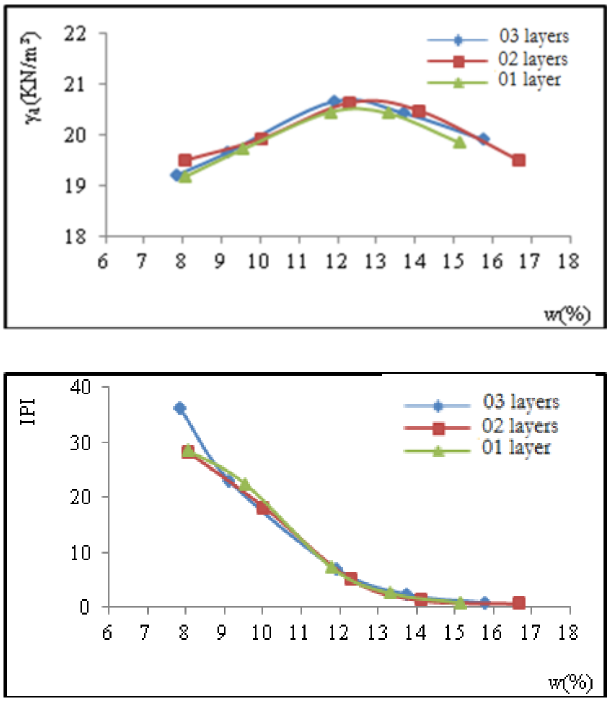

Figure 3 – Evolution of γ_d and IPI as a function of w%, the soil reinforced by Geo3

Table 3 summarizes the density of the dry material and the corresponding optimum water content, thus the desired values of IPI for unreinforced and reinforced with the three types of geosynthetics by one, two and three layers at optimum and at 98 % and 95% of the density of the dry material.

Note that the optimum of the state hydric values is practically the same. Thus the IPI values at the optimum and at 98% of $\gamma_{d\ opm}$ are below the values recommended by the GTR guide, which means difficulty in the movement of machinery on the site.

On the other hand, 95% $\gamma_{d\ opm}$ values of the immediate bearing index are much improved than those obtained at the optimum and also at 98% of $\gamma_{d\ opm}$; this increase is attributed to the decrease in water tuner.

This indicates that the integration of geosynthetics does not influence the bearing capacity of the mixture. Under these conditions, it is recommended, during the construction of pavement embankments, to take the water tuner corresponding to 95% $\gamma_{d\ opm}$ in order to guarantee the movement of machinery without difficulty.

Table 3 – Summary of the Proctor-IPI test

Type of geosythetics	Number of layers	w_{opm} (%)	γ_{dopm} (kN/m³)	IPI_{opm}	IPI 98% opm	IPI 95% opm
Without reinforcement	0	13.26	19.41	4	24	28
Geogrid (Geo1)	1	12.00	20.70	10	29	27
	2	12.28	20.84	4	20	22
	3	12.10	20.77	3	12	/
Non-woven geotextile (Geo2)	1	13.40	20.40	4	28	30
	2	12.20	20.55	14	25	34
	3	12.80	20.80	10	16	19
Woven geotextile (Geo3)	1	12.60	20.60	4	13	25
	2	12.80	20.70	3	12	/
	3	12.30	20.70	5	14	23

Influence of geotextile types and numbers on flexural tensile strength

An experimental procedure was carried out on prismatic specimens to study the influence of the geotextile type and the importance of the number of layers on the traction strength. In the presented experiment, the mixture is humidified with an optimum water tuner of Proctor and made in a wooden mold (4x100x16 cm3) to achieve a prismatic (4x4x16 cm3) form; at the same time, the geotextile is placed in one, two and three layers (Photo 2).

Photo 2 – Sample maker

The experiment consists of applying a vertical load (Photo 3a). At the end of the test, the layers of the specimen reinforced by the geotextile Geo3 are separated; on the other hand, the layers of the specimen reinforced by the geotextile Geo2 stayed stuck to each other (Photo 3b), which reflects the difference between the interfaces of a non-woven geotextile which is rough and a woven geotextile which is smooth. Consequently, it reflects the influence of the roughness of the geotextile face on cohesion with the soil.

(a) *(b)*

Photo 3 – (a) bending of a test specimen, (b)specimens after traction

The flexural tensile strength after 7 days is determined by the following formula:

$$R_{tf} = \frac{3F_r \cdot L}{a \cdot b \cdot h^2}$$

where:

F_r: the maximum load;
L: the free range;
b: the width; and
h: the thickness of the prism.

The experimental program consisted of two series, each series consisting of three cases of reinforcement depending on the number of layers.

The results of two series are shown in Figure 4 below:

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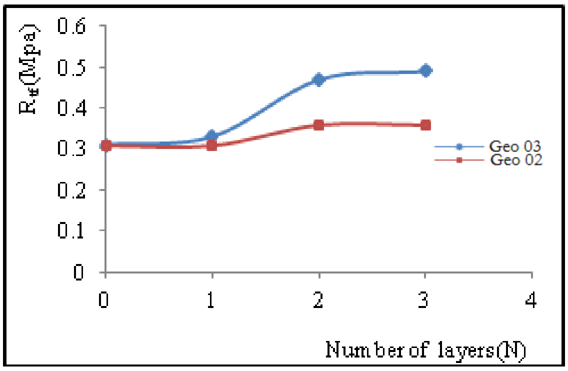

Figure 4 – Resistance t²o traction as a function of the number of layers (N)

Resistance to traction gradually increases with the number of geotextile layers, reflecting the effect of scale on the specimens. In each of the three cases of reinforcement, the tensile strength of the row reinforced woth Geo2 shows a significant increase compared to the row reinforced with Geo3. This shows the importance of the soil-geotextile interaction: the roughness of the Geo2 geotextile produces cohesion with the mixture, while no cohesion occurs due to the Geo3 geotextile. It is noted that the rigidities of the geotextile have an essential role in improving the tensile strength of the mixture.

Conclusion

The objective of this study is to contribute to the concept of safe, durable, and sustainable services and to build economic systems from reinforced indigenous soils for use in the road sector. The main findings of this study are summarized as follows:

Based on the results obtained from Proctor-IPI, their values do not permit the movement of construction machinery during the construction of pavement layers. From a geotechnical point of view, It has been shown that for 95% of the dry material density, the values of the Immediate Bearing Index are usually sufficient for all cases of reinforcement to be used in a pavement layer.

It appears from the traction test by bending, that the introduction of a geotextile in the mixture leads to an increase in traction strength and to improved stress distribution in the soil sample. This improvement is observed for both types of geotextiles. Also, the improvement in strength depends on the geotextile type. The effect is significant for the blend reinforced by the woven geotextile (Geo2).

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Estudio experimental del comportamiento mecánico de sedimentos de presa reforzados con geotextiles y geomallas

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CAMPO: materiales
TIPO DE ARTÍCULO: artículo de revisión

Resumen:

Introducción/objetivo: Los materiales geosintéticos se han utilizado con éxito para reforzar el suelo y mejorar la capacidad de carga. En este artículo se utilizan geotextiles como material tensor para el refuerzo de una mezcla a base de sedimentos dragados de la presa de Cheurfas (Mascara) y arena de cantera.

Métodos: Se realizaron ensayos de índice de carga inmediata en laboratorio para estudiar el comportamiento de la mezcla y el ensayo de flexión por flexión de tres puntos sobre probetas prismáticas para estudiar la capacidad de tracción de la mezcla. Las muestras de mezcla se seleccionan y prueban sin refuerzo. Luego, al colocar una, dos y tres capas de geotextil a una cierta profundidad de la muestra, se discuten los efectos de un número de capas y tipo de geotextil y geomalla en el aumento de la capacidad de carga de la mezcla.

Resultados: Los resultados de estas pruebas muestran que la capacidad de carga de las muestras reforzadas con geotextil y geomalla aumenta en comparación con la de las muestras no reforzadas. Según los resultados obtenidos de Proctor-IPI, sus valores no permiten el movimiento de maquinaria de construcción durante la construcción de las capas de *pavimento. Los valores del Índice de Rodamiento Inmediato se consideran suficientes para las capas de pavimento. La introducción de geotextiles aumenta la resistencia a la tracción y mejora la distribución de la tensión en las muestras de suelo, siendo el efecto significativo para las mezclas de geotextiles tejidos.*

Conclusión: Considerando todo esto, los resultados apuntan a la posibilidad de utilizar suelos locales reforzados como una opción asequible y práctica para la construcción de pavimentos. Para garantizar el rendimiento a largo plazo y optimizar los métodos de construcción, se recomienda realizar más investigaciones.

Palabras claves: geotextil, dragado de sedimentos, presa de Cheurfas, refuerzo de suelos.

Экспериментальное исследование механического поведения донных отложений плотины, укрепленных геотекстилем и георешетками

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РУБРИКА ГРНТИ: 67.09.00 Строительные материалы и изделия
ВИД СТАТЬИ: обзорная статья

Резюме:

Введение/цель: Геосинтетические материалы успешно используются для укрепления грунта за счет повышения его несущей способности. В данном исследовании геотекстиль используется в качестве натяжного материала для укрепления смеси на основе донных отложений плотины Чеурфа (Маскара) и карьерного песка.

Методы: Прямые испытания индекса несущей способности проводились в лабораторных условиях в рамках испытаний поведения смеси. Испытание прочности на трехточечный изгиб проводилось в цилиндрических пробирках для проверки тяговой способности данной смеси. Образцы смеси были отобраны и испытаны без укрепления. Затем на определенной глубине в пробирку были добавлены один, два и три слоя геотекстиля с целью исследования влияния количества слоев и типа геотекстиля на несущую способность смеси.

Результаты: Результаты испытаний показали, что несущая способность образцов, укрепленных геотекстилем и георешеткой, увеличивается по сравнению с неукрепленными образцами. Результаты испытаний Proctor-IPI показали, что их значения не допускают движения строительной техники при укладке слоев дорожной одежды. Установлено, что значения показателя несущей способности достаточны для слоев дорожной одежды. Использование геотекстиля повышает прочность сцепления и улучшает распределение нагрузки на образцы грунта, причем эффект лучше выражен у тканых видов геотекстиля.

Выводы: Учитывая все обстоятельства, результаты указывают на возможность использования укрепленных местных видов грунта в качестве практичного и экономически выгодного решения для строительства дорожного полотна. Рекомендуется провести дальнейшие исследования с целью оптимизации методов строительства и гарантирования длительного срока эксплуатации.

Ключевые слова: геотекстиль, донные отложения, плотина Чеурфа, армирование грунта.

Експериментално испитивање механичког понашања седимента добијеног ископавањем бране и ојачаног геотекстилом и геомрежом

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ОБЛАСТ: материјали
КАТЕГОРИЈА (ТИП) ЧЛАНКА: прегледни рад

Сажетак:

Увод/циљ: Геосинтетички материјали се успешно користе за ојачавање тла јер побољшавају његов капацитет носивости. У овом раду геотекстили се користе као тензиони материјал за ојачавање мешавине седимента добијеног при ископавању бране Черфас (Маскара) и песка из каменолома.

Методе: Тестови непосредног индекса носивости изведени су у лабораторијским условима у оквиру испитивања понашања *мешавине. Тест на чврстоћу при савијању у три тачке изведен је на призматичним епруветама како би се испитао капацитет тракције дате мешавине. Епрувете мешавине су изабране и испитане без ојачања. Затим су на одређеној дубини епрувете додати један, два и три слоја геотекстила и испитани утицаји броја слојева и типа геотекстила на капацитет носивости мешавине.*

Резултати: Показано је да је капацитет носивости епрувета ојачаних геотекстилом и геомрежом повећан у поређењу са неојачаним епруветама. Резултати тестова Проктор-ИПИ показују да њихове вредности не дозвољавају кретање грађевинске машинерије током конструкције коловозних слојева. Утврђено је да су вредности непосредног индекса носивости довољне за коловозне слојеве. Увођење геотекстила повећава затезну чврстоћу и побољшава распоређивање напона на узорцима тла, при чему је код тканих врста геотекстила ефекат израженији.

Закључак: Резултати указују на могућност коришћења ојачаних локалних типова земљишта као на практично и исплативо решење за грађење коловоза. Препоручује се даље истраживање ради оптимизације метода грађења и гарантовања перформанси у дужем периоду.

Кључне речи: геотекстил, ископани седимент, брана Черфас, ојачање тла.

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