BY-PRODUCTS AS MATERIAL FOR ROAD CONSTRUCTION

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ABSTRACT

By-products can be used as structural material for different types of road courses or as stabilisers . A laboratory study was undertaken to evaluate the effectiveness of shredded tire and marble dust as a soil stabilizer. The study revealed that plasticity was reduced by 12,5 to 24% ,the strength increased by 34 to 43 % by the addition of marble dust .As far as the shredded tire is concerned the results showed that the compacted dry density reduced solely due to the lighter weight of the tire and the unconfined compressive strength of the mixture was as low a 40% of the strength of the clay alone. These results are consistent with other published work on other soils .The stabilization of forest roads represents an environmentally friendly process.

ΠΑΡΑΠΡΟΪΟΝΤΑ ΩΣ ΥΛΙΚΑ ΣΤΡΩΣΕΩΝ ΔΑΣΙΚΩΝ ΔΡΟΜΩΝ

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ΠΕΡΙΛΗΨΗ

Διάφορα παραπροϊόντα έχουν χρησιμοποιηθεί μέχρι σήμερα είτε ως δομικά υλικά σε στρώσεις οδοστρωμάτων είτε ως σταθεροποιητές σε διάφορους εδαφικούς τύπους. Στην παρούσα εργασία η έρευνα μετατοπίστηκε στους δασικούς δρόμους και εδάφη και ερευνήθηκε η δυνατότητα χρησιμοποίησης μαρμαρόσκονης και τριμάτων ελαστικών ως σταθεροποιητών. Βρέθηκε ότι στο μίγμα εδάφους- μαρμαρόσκονη μειώνεται η πλαστικότητα του εδάφους 12,5 - 24% ,ενώ αυξάνεται η αντοχή του από 34 έως 43 %. Αντίθετα τα αποτελέσματα με τη μίξη εδάφους- ελαστικών δεν είναι ενθαρρυντικά , αφού και η μέγιστη ξηρά πυκνότητα μειώθηκε αισθητά και η θλιπτική αντοχή του μέχρι και 40%. Τα ανωτέρω συμπεράσματα έρχονται σε συμφωνία με αποτελέσματα άλλων ερευνητών σε διαφορετικά εδάφη. Γενικά μία τέτοια σταθεροποίηση εδαφών δασικών δρόμων, δεν παύει να είναι μία τεχνική επέμβαση με την οποία προστατεύεται το ευρύτερο περιβάλλον.

1. INTRODUCTION

As the world population grows, so do the amount and type of waste being generated. Many of the wastes produced today will remain in the environment for hundreds, perhaps thousands, of years. The creation of nondecaying waste materials, combined with a growing consumer population, has resulted in a waste disposal crisis. One solution to this crisis lies in recycling waste into useful products. Many types of waste are quite versatile and can be used to simultaneously solve different types of problems and also can be effectively used in soil construction applications instead of depositing them into landfills. Everywhere in the world road construction offers best possibilities for applications because of the need for high volumes of material; for example as base courses or for frost insulating, weight reduction, drainage or sealing purposes. Generally the recycling of waste in soil construction will promote the principles of sustainable development when saving non-renewable natural resources and reducing the volume of waste deposited in landfills [1].

The most significant waste types which were used in the highway construction are the following ones; ashes from power stations, slags, sands and sludge from steel industry, gypsum from chemical industry, sludge from pulp and paper industry, red mud , marble-dust and shredded tire. The mixture of the above recycling materials (RM) with the soil has succeeded to develop several viable solutions [2]

- The RM-structures are environmentally friendly. In comparison with conventional methods it is possible to cut down the consumption of non-renewable natural resources (gravel etc.) from 30% to 80% ; The RM-structures are very cost-effective. In comparison with conventional methods it is possible to save up to 50%; Technically and economically excellent results can be obtained by stabilizing old structures with help of binders based on different types of industrial waste or by-products; Another competitive group of solutions is based on the recycling of industrial by-products as new materials for base courses of road structures.

On the other hand , in the forest roads, because of the basic problems are frost heave and weak bearing capacity that usually cause really bad traffic conditions in the spring., there have been used fly ash, red mud and slag instead of traditional renovation methods which are expensive and require significant amounts of natural stone materials from non-renewable sources. We found that the stabilization of forest roads represents an environmentally friendly process since using materials of nature, which are abundant and provides the basis for improved road constructions, from the biological, technical and economical points of view. Therefore, the development of new, environmentally friendly and cost–effective renovation methods is necessary, even inevitable [3,4].

In this study, none of the above additives is used; rather, two waste products, marble dust, resulting from the quarrying and crashing of marble and shredded tire are utilized. Special the tires, that are from the litter that they manage very with difficulty, it is the first time where they are used in forest roads. The international research showed that their utilisation helps in the protection of environment, but also in applications of road construction [5].

2. MATERIALS AND METHODS

Two different soils from the forest roads of the Forest Offices of Aridea and Fourna were used for the study. Various geotechnical parameters (Atterberg limits, standard compaction characteristics, strength, of the soils in their natural state and when mixed with varying proportions of marble dust and tire were determined. In a frame of laboratory testing of waste materials and by-products to be used in the road construction field, marble-dust and shredded tire were tested as filler admixture in mixtures with two types of soil at differences proportion. For the purpose of this research work we have taken soil samples from the forest districts as follows: Applying random sampling (AASHTO-T 86), we have fixed the plot points from which we have taken the soil samples. The soil weight taken from each plot was 10 Kg and this has been separated into 10 subsamples for the experimental testing. As testing methods have been applied: The particle size distribution (according to method AASHTO-T 27). The maximum dry density (γ_d) and the optimum moisture content (w) on the basis of the method AASHTO-T 190 and the Atterberg limits. All mixtures were cylindric specimens and prepared at optimum moisture content and maximum dry density. Also were tested with regards to resistance in compression of 7 and 28days. Unconfined compression tests were conducted on samples molded with a Harvard miniature devices. This miniature procedure was calibrated (ASTM Standard D 4609) [6].

Marble dust was obtained from marble residuals in the under research area and it was the resulting from the quarrying and crushing of marble. The fraction used for the test was that passing the B.S. sieve size 63μm. The amount of dust required to stabilize the soil depends upon the quantity of fines contained as well as the final compacted density. Typical values range between 6 and 8 percent by weight of the final compacted material.

The same two types of soil was mixed with shredded tire, 4mm and 8 mm angular size particles, in weight percentages between 10% and 20% and examined for use as a constituent in a land-fill liner in terms of compaction and unconfined compressive strength. Figure 1 shows the machine that is useful for the chopping of tres. The tire was mixed with the dry soil and water was added to the dry mixture to give the required moisture content.

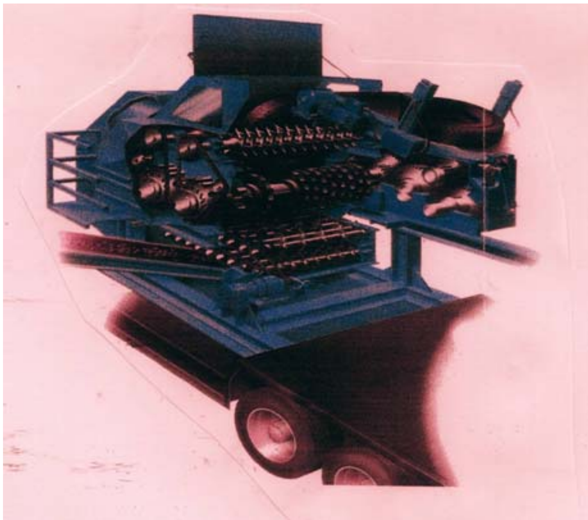

Figure 1. The machine which chops the tires

3. RESULTS AND DISCUSSION

3.1 Marble-dust

Table 1 shows for the soils (CL and GC-CL), the results of particle size distribution, Atterberg limits, γ_d and w_{opt}. The values of the plasticity index of natural soils, as well as the marble dust-treated soils are presented in Table 2.We can see that the soil with the highest clay content showed the best improvement (highest reductin of PI). This is attributed partly to the initial compaction characteristics of the soil and, to the reaction between the clay minerals and the marble dust.

TABLE 1:Results of particle size distribution, Atterberg limits, γd and w_{opt}.

Properties	Fourna	Aridea
Type of soil	CL	GC- CL
%< 0.075mm	86	47
%< 0.002mm	63	12
LL	42	30
PI	21	12
γ_d (Mg / m^3)	1.65	1.8
w_{opt}. %	23	14

TABLE 2: Plasticity index of the natural and marble dust- treated soils

Marble dust %	PI soil CL	PI soil GC-CL
0	21	12
2	19	12
4	18	11
6	17	10.5
8	16	10.5

Unconfined compressive strength (UCS) is showed against the percentage of (MD) and curing time in Table 3. Each data represents the average UCS curing time from three tests.

TABLE 3: UCS results of soil treated with 2, 4 , 6 , 8% MD ,after 7 and (28) days

Marble dust %	UCS of soil CL kPa	UCS of soil GC-CL kPa
2	205 (220)	320 (400)
4	240 (250)	360 (440)
6	265 (280)	390 (490)
8	275 (300)	450 (570)

Some important observations follow:Unconfined compressive strength (UCS) of untreated soils were in all cases lower than treated soils.For untreated soils the UCS did not increase with increasing time after molding (curing time).Significant increases in UCS occured with increases in (MD) content in treated soils. The highest strength was achieved at 8% marble dust. The increase in UCS due to the addition of similar amounts of MD is higher for the low PI soil relative to the higher PI soils . However , the change in UCS of treated soils as a function of percent of MD is roughly similar for each soil. For MD- treated soils, the most significant strength gains occurred after 28 days. These results are consistent with other published work on other soils [7]

3.2.Shredded tires

The compaction behavior of the soils alone and with 10% and 20% of 4 and 8 mm size tire respectively was investigated in terms of dry density versus moisture content as shown in Table 4. The Table shows that the maximum dry density decreased and optimum moisture content remained roughly the same as the amount of tire increased. A decrease in the dry density was expected due to the lighter weight of tire compared to the soil .The decrease in the dry density was found by calculations to be mainly due to that effect which shows that the presence of the tire did not have a detrimental effect on the compaction of the soil.

TABLE 4: Compaction behavior of soil [CL,GC-CL] and soil-tire mixture

Moisture content %	DRY DENSITY (Mg/m^3)					
	SOIL CL			SOIL GC-CL		
	Tire content			Tire content		
	0%	10%	20%	0%	10%	20%
18	1,54	1,47	1,36	1,43	1,40	1,36
20	1,58	1,48	1,40	1,46	1,42	1,38
22	1,64	1,55	1,45	1,54	1,48	1,40
24	1,66	1,53	1,47	1,58	1,55	1,42
26	1,58	1,50	1,42	1,52	1,50	1,40
28	1,55	1,46	1,40	1,45	1,44	1,39

The Table 5 shows that the introduction of the tire caused a considerable decrease in the unconfined compressive strength (UCS) with the optimum mixtures still producing the highest strengths. The change in moisture content away from optimum had a lesser effect on the reduction in UCS than the tire content. A reduction in UCS due to the introduction of angular shaped tire particles is consistent with the results of others [8], but the degree of reduction is found to be dependent on the type of soil tested such that as the clay content increased a smaller reduction was observed. The effect of tire on the UCS of soil-tire mixtures is also found to be dependent on the shape of the tire particles.

TABLE 5 : Unconfined compressive strength (UCS) of soil-tire mixture with moisture content

Moisture content %	Unconfined compres sive Strength kPa					
	SOIL CL			SOIL GC-CL		
	Tire content			Tire content		
	0%	10%	20%	0%	10%	20%
18	470	280	200	500	310	260
20	480	300	220	515	370	280
22	500	320	240	540	390	300
24	500	310	230	530	380	305
26	490	300	210	510	360	300
28	420	290	205	505	350	290

4.CONCLUSIONS

Worldwide, the industrial expansion and the development of the construction sector are constantly dependent on the possibilities of supply of raw materials. On the other hand, industrial by-products and waste materials constitute serious ecological problems for developed and developing countries. Reuse and recycling techniques, such as utilization of waste materials and by products in the construction field (stabilization) offer satisfactory solutions to these problems. Application of these techniques presents noticeable advantages: Reduction of quantities of useless materials, reduction of energy consumption, reduction of environmental pollution and improvement of the soil so that it can be used for subbases, bases and in some rare instances, surface courses

Trying to obtain an environment-friendly construction of forest roads, we investigated, in our laboratory, the possibility of using shredded tire and marble dust as substitutes of the inactive materials aiming at saving up energy and raw materials with a concurrent protection of the environment from avoiding dumping them into it. The motive for our research came from research efforts of using the above materials in rural low-volume roads.

From the above discussion of research results on soil stabilisation with the marble dust and tire,we come to the following conclusions:

- Results showed that the geotecnical parameters of forest soils are improved substantially by the addition of marble dust.
- Plastic soils can be successfully improved after stabilization with marble dust. The soil with the highest clay content showed the best improvement. This is attributed partly to the initial compaction characteristics of the soils (maximum dry density) and, perhaps more importantly, to the reaction between the clay minerals and the marble dust. Significant PI reductions occurred with MD treatment, particulary for high PI soils.
- Compaction results showed that maximum dry density is reduced with increased marble dust content.
- Plasticity was reduced by 12,5 to 24% and strength increased by 34 to 43 %. The highest strength were achieved at 8 % marble dust .For MD- treated soils, the most significant strength gains occurred after 28 days.
- Althought marble dust improves both the plasticity and strength of soils, the higher strength developed is not enough for the improved soil to be used as a base material in the construction of heavily trafficked flexible pavements. The improved material may, however, be successfully used as base material for lightly trafficked roads and as a sub-base material for heavily trafficked roads.
- The addition of 10-20% by weight of shredded tire in two different sizes of 1-4 and 4-8mm angular particles , at a moisture content range of 10% around the optimum value produced clay- tire mixtures with improve geotechnical properties
- The results also showed that the compacted dry density reduced solely due to the lighter weight of the tire and the unconfined compressive strength of the mixture was as low a 40% of the strength of the clay alone.
- Compacted dry densities between 1,4 and 1,6 Mg/m^3 which is around 90% of that of the clay alone. The reduction was purely due to the lighter weight of the tire indicating minimal detrimental effect.
- Unconfined compressive strengths of between 200 and 380kpa which are as low as 35 - 45% of the strength of the clay alone.

- The range of results produced shows the high dependency of the behavior of the clay –tire mixtures on the moisture content and the tire content. Hence, each situation will need to be considered separately to arrive at a clay- tire mixture suitable for the site and problem conditions.
- Generally however the stabilization of forest roads with marble dust represents an environmentally friendly process, as using materials of nature, which are abundant and they provide the basis for improved road constructions, from the biological, technical and economical points of view.

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