UTILIZATION OF THE SOLID WASTE FROM MARBLE TREATMENT IN THE PRODUCTION OF CEMENT MORTARS

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ABSTRACT

In Greece, many thousand tonnes of waste sludge originated from the processing of marble are generated annually. This sludge consists of limestone, which can be used in the form of powder in various applications such as for soil stabilization or as additive in cement and asphalt mixtures.
Present study examines the potential of using the solid waste from the marble treatment in cement mortars. For this purpose, a series of compositions have been conducted, where this solid waste has been used as a substitute for parts of aggregates (sand) in different amounts per weight of the sand while physical and mechanical characteristics of them have been examined.
Results showed an improvement in the characteristics of cement mortars modified with solid waste from marble treatment (S.W.M.T.). Thus its addition in such mortars and cement products in general can be beneficial to the environment since it may lead to the reduction of the great volumes of these solid wastes.

Keywords: environment, waste sludge, marble treatment, cement mortars

Aims

The main scope of this study was to investigate the potential of using the Solid Waste from Marble Treatment (S.W.M.T.) as aggregate for the production of cement mortars. Sand was substituted by S.W.M.T. in quantities ranged from 0-20%wt. Mechanical characteristics of cement mortars such as compressive and flexural strength and dynamic modulus of elasticity were measured at 28 days. Moreover, open porosity and capillarity by suction of cement mortars were investigated in the same time period.

Background

Greece produces huge amounts of marbles, which come up to 2000000 tones. Marbles of different colours (white, beige, black, green, pink etc) are produced. However, during marble treatment waste sludge- liquid waste, consisting mainly of limestone- is generated. The amount of the dry material of this marble sludge (**S**olid **W**aste from **M**arble **T**reatment) is estimated to be 20.000 tones per year for the area of Thessaloniki. This by-product can be used in a variety of applications, given that, its effect on the mixtures characteristics, to which it is added is known. Moreover the use of S.W.M.T. as aggregates might help meet the increasing demands and slow down any detrimental effects on the environment.

Studies so far showed that the addition of S.W.M.T. has a positive effect on the stabilization of soil mixtures and on the reinforcement of forest roads[1-3] while it has already been used as cement replacement in the production of slurry seals [4], as filler for road construction[5] and as additive in cement products[6,7] with satisfactory results. Eskioglou (1996) stabilized forest roads in the area of Drama, Evros and Xanthi by the use of S.W.M.T. Test results showed a decrease in plasticity index, which ranged between 15-30%, especially in soils with plasticity while the strength of the stabilized soils was improved by 25-50%. Maximum strength was measured for addition of 8% of S.W.M.T. after a stabilization period of 28 days. Moreover soil deformability was reduced by 11% while the CBR was increased by 50%.

Furthermore, Eskioglou, 2000 examined the potential of reinforcing forest roads by the stabilization method in 4 archeological sites by the use of S.W.M.T. originated from close quarries of Drama, Thasos and Kavala. The results of the research were encouraging since beside a 32% reduction in soils plasticity for addition of 8% S.W.M.T. especially in clay soils, a 20% increase in the optimum dampness and a 22% reduction in maximum dry density have been observed as well [2].

S.W.M.T. improves the plasticity and strength of red tropical soils, however the higher strength developed is not adequate for the improved soils to be used as a base material for the construction of heavily trafficked flexible pavements, So in this case S.W.M.T. may be used successfully as a base material for lightly trafficked roads or as a sub-base material for heavily trafficked roads [8].

Another possible use of this solid waste material is for the production of cement products. Especially for cement mortars, the highest strength was achieved at 8% S.W.M.T. [3]. Furthermore, addition of S.W.M.T in cement is effective since it provides to concrete improved mechanical characteristics, increased abrasion resistance and durability in terms of resistance to chloride ion penetration [6].

Experimental

In the present study CEM IV/B 32.5 N cement, river sand (dried in oven and in 105^{o}C) and solid waste from marble treatment (S.W.M.T), consisting of $CaCO_3$ and $MgCO_3$ at 88.2 and 11.4%, respectively were used for the production of cement mortars. Cement was supplied by TITAN S.A., while S.W.M.T. was supplied by Zlakios S.A. [9]. The experimental part of the paper has been conducted into the Laboratory of Building Materials, of the Department of Civil Engineering of Aristotle University of Thessaloniki.

Gradation curve of the river sand (0-4mm) and of the S.W.M.T. used, are presented in Figure 1.

For control mixture (R) cement, river sand and water were used. For the others mixtures- 1M, 2M, 3M, 4M- cement content was kept constant, while water content and percentage of solid waste from marble treatment (S.W.M.T) changed. The control mixture was modified by 5, 10, 15 and 20% S.W.M.T. as substitute for fine sand aggregate. For all mortar mixtures, the workability in terms of flow test was kept constant at 11±1cm, while the ratio water to cement was between 0.5 and 0.56. Table 1 summarizes the characteristics and proportions of the materials used in the specimen's preparation.

Explanation of symbols

R: Conventional mixture without S.W.M.T.
1M: Mixture with 5% wt of sand S.W.M.T.
2M: Mixture with 10% wt of sand S.W.M.T.
3M: Mixture with 15% wt of sand S.W.M.T.
4M: Mixture with 20 % wt of sand S.W.M.T.

The mortars were prepared according to European Standards [10] by mechanical mixing and were compacted in moulds using a standard jolting apparatus. The specimens in the moulds have been stored in a moist atmosphere for 24 hours and then the demoulded specimens have been stored under water at 20±2^{0}C temperature for 28 days. Compressive and flexural strength, dynamic modulus of elasticity, porosity and capillarity by suction were studied on 4x4x16mm prismatic specimens. For each test, 3 specimens of every composition have been used and the test results are expressed as the arithmetic mean of a set of 3 specimens.

Results and discussion

Workability

The addition of S.W.M.T. in cement mortars resulted in a reduction in workability as percentage of S.W.M.T. increased. Fine solid waste from marble treatment absorbed more water compared to sand, so in order that workability of the mixtures in terms of flow test is kept constant at 11±1cm, it was necessary to increase the water amount. This increase did not have a negative effect on the mechanical characteristics of cement mortars with S.W.M.T.

Properties of hardened mortars

Table 2 shows laboratory results of mechanical characteristics of cement mortars with and without S.W.M.T. Test results are expressed as the arithmetic mean of a set of 3 specimens.

Mechanical strength and dynamic modulus of elasticity of cement mortars

Table 1 and figures 2, 3 and 4 show the mechanical characteristics (compressive strength, flexural strength, dynamic modulus of elasticity) of cement mortars modified with S.W.M.T. According to them, it is generally concluded that the addition of S.W.M.T. in cement mortars has a positive effect of their mechanical characteristics. Precisely:

- As far as compressive strength is concerned, an increase of 8.73-23.75% is measured.
- As far as flexural strength is concerned, this is found to increase with a smaller rate compared to compressive strength and it comes up to 10.96% for 4M composition, which contain 20% wt of sand S.W.M.T.
- Dynamic modulus of elasticity increases with a rate similar to the one of compressive strength. This increase does not exceed 22.16% in the mixtures examined.

Series composition 4M, with 20% S.W.M.T. showed the higher values in all characteristics measured. As noticed, results of this series do not differ from the ones of the series 3M, with 15% S.W.M.T. This means that addition of S.W.M.T. in higher percentages may not improve further the mechanical and physical characteristics of the modified mixtures. In addition to that, according to figures showing mechanical strengths, the optimum percentage of S.W.M.T added to the mixtures was found to be between 15-20%. However addition of S.W.M.T. in higher percentages (>20%) is possible only in terms of environmental protection regardless the improvement in mechanical characteristics.

Open porosity- capillarity by suction

Open porosity of cement mortars has been measured according to standards (RILEM CPC3.11- waster absorption under vacuum[11]) at 28 days while its values for the mixtures examined are showed in table 1 and in figure 5 respectively. Addition of S.W.M.T. causes a reduction in the open porosity of all mixtures. This decrease is higher as percentage of S.W.M.T. increases.

As far as capillarity by suction is concerned, test results are given in figure 6. It can be observed that the rate of water absorption and the final value of it decrease by adding S.W.M.T. This means that capillarity by suction of cement mortars with S.W.M.T. is lower compared to the one of conventional mixtures, leading to less permeable mixtures.

Conclusions

In our country huge volumes of waste sludge from marble process are generated annually. This sludge consists of water and limestone while the solid waste after its drying (S.W.M.T) can be used in a variety of applications such as for soil stabilization and reinforcement, as alternative filler for the production of slurry seal complying with specifications for road maintenance and for the production of cement products as well. In such applications S.W.M.T. has a positive effect on geotechnical properties, when mixed with soils, or in physical and mechanical characteristics when being added to cement products or bituminous mixtures.

This paper examines the effect of S.W.M.T. in cement mortars. This solid waste substituted sand by 0-20% per weight. Higher amount has not been examined since strength and characteristics in general of the mixtures containing 15 and 20% S.W.M.T. have been found to be unchangeable. The produced mixtures were tested to compressive and flexural strength, dynamic modulus of elasticity, open porosity and capillarity by suction.

Test are encouraging since physical and mechanical characteristics of the modified with S.W.M.T. cement mortars have been improved.

In that way, high volumes of this sort of waste can be absorbed and utilized in such applications resulting in the elimination of the problem posed by theirs deposition and in the protection of the environment. At the same time, the modified with S.W.M.T. products (mixed with cement, asphalt or soil) show improved mechanical characteristics, are cost effective and have a reduced production cost.

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Captions

Table 1. Characteristics and proportions of materials used for the production of cement
mortars with and without S.W.M.T.

Table 2. Values of mechanical characteristics, open porosity and capillarity by suction with and without S.W.M.T.

Figure 1. Gradation curve of sand and S.W.M.T

Figure 2. Compressive strength of cement mortars with and without S.W.M.T.

Figure 3. Flexural strength of cement mortars with and without S.W.M.T.

Figure 4. Dynamic modulus of elasticity of cement mortars with and without S.W.M.T.

Figure 5. Open porosity of cement mortars with and without S.W.M.T.

Figure 6. Capillary by suction measurements at 28 days

Table 1.

Materials \ Compositions	R	1M	2M	3M	4M
Cement, CEM IV/B 32.5 N, g	450.0	450.0	450.0	450.0	450.0
River sand, g	1350.0	1282.5	1215.0	1147.5	1080.0
S.W.M.T. % wt		5.0	10.0	15.0	20.0
S.W.M.T., g	0.0	67.5	135	202.5	270
Water, g	225	230	240	250	255
Workability (flow test), cm	11	10.7	10.6	10.4	10.4

Table 2.

Characteristics \ Composition	R	1M	2M	3M	4M
Compressive strength, (MPa)	29.47	32.29	33.33	38.15	38.65
Flexural strength, (MPa)	6.5	6.6	6.8	7.2	7.3
$E_{d,}$(GPa)	26.79	30.16	31.22	32.07	33.16
Open porosity, (%)	9.55	9.18	8.86	8.44	8.37
Capillarity by suction at 24h, g/cm^2	0.44	0.39	0.36	0.34	0.33

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Table 2. Values of mechanical characteristics, open porosity and capillarity by suction with and without S.W.M.T.

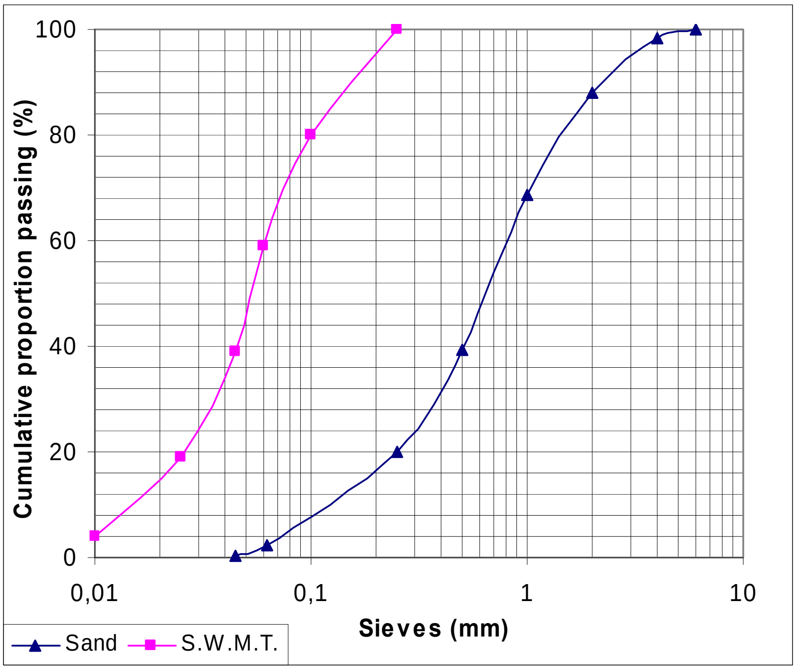


Figure 1.

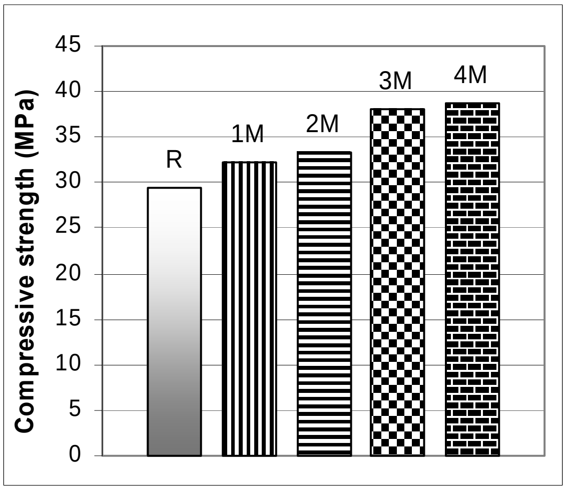


Figure 2.

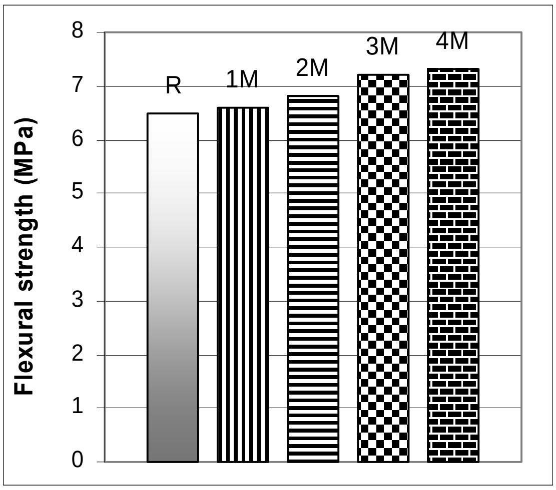
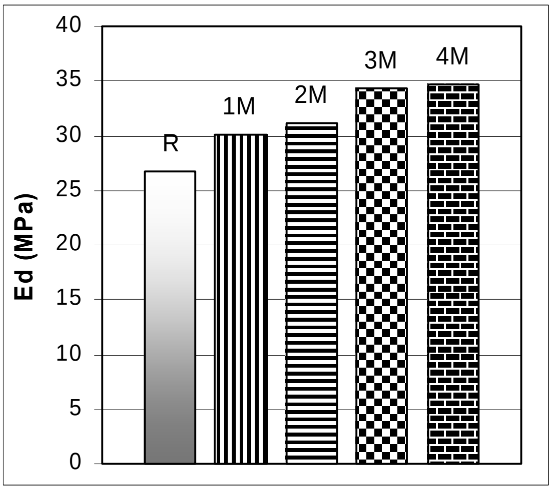


Figure 3.



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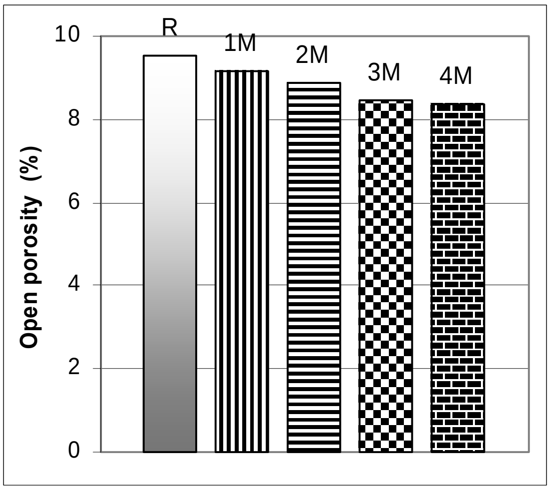

Figure 5.

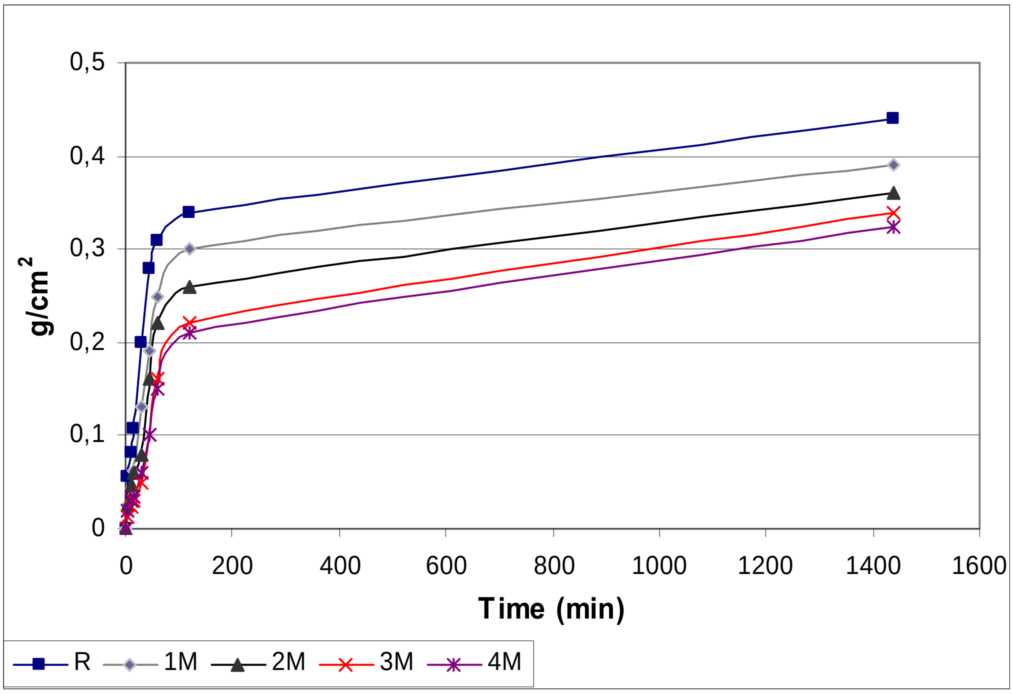

Figure 6.

Figure 1. Gradation curve of sand and S.W.M.T

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