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Properties of Volcanic Tuff Sands as a New Material for Masonry Mortar

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Abstract

In constructions at urban areas, using materials with unknown chemical and mechanical characteristics in the manufacturing of load bearing walls and plastering results in damage occurrences, which are difficult and expensive to repair. The subject of this study is to research whether the material in question is suitable for use in mortar making. We tried to find a scientific identity for this material. The results were compared with the code of TS, ASTM and literature. The results show that the volcanic tuff sand (VTS) which was found in the material increased the mortars adhesion and bonding strength and durability. It is therefore, concluded that VTS can be used as a mortar material of the load bearing walls, plastering and other applications.

Key words: Volcanic tuff; lightweight sand; mortar, compressive strength, thermal conductivity

INTRODUCTION

The majority of masonry structures exhibit excellent long-term performance with comparatively low maintenance cost. Durability of a masonry structure is influenced by many factors including the durability of both the masonry units and mortar, as well as proper installation of a damp proof course; the durability of the mortar contributes significantly to the overall durability. Mortars are simply mixtures of bonding substance (cement, lime), sand and water, which is used for of the brick and stonewalls plastering and joints. According to the kind of bonding substance it contains, they are separated into five categories, which are, reinforced mortar (A), cement mortar (B, C, D) and lime mortar (E).

Suggested by TS 2848 [1] different proportions of the volcanic tuff sand VTS and its binding mixtures dry and wet density, consistency, water retention, fresh mortars water contents were also investigated with the thought that it would be of great benefit to the research. A sieve analysis in accordance with TS 2717 [2] was performed on the VTS where both the fine substance and the frost resistance degree were determined. A, B, C, D, and E class mortars were also researched in order to determine whether they had any effect on the strength of the VTS's mortar and on other mortar characteristics. The materials used in mortar preparation and its ratios and the mixture amounts are determined after viewing the structure in where the mortar mixture is to be used. If materials, which are used in mortar mixtures and their ratios, are not determined correctly, will cause to lower the strengh of the mortar and consequently mortar and shrinkage cracks will appear. Also, as the mortar is used for covering wall surfaces in structures it also acts like an isolation material [3]. For mortar materials used during constructions to be found locally and during cold winter conditions that possess specificatios such as low light conductors carry an important role due to the reasons that have been stated above and also due to the fact that Turkey is still a country in the process of developing.

The result of the literature research showed that although there were many studies done on concrete produced from lightweight aggregate there were very few studies on the production of lime and cement bonding mortar. In some studies, the compressive strength were researched of mortar produced from stream and quarry sand or an amount of normal sand replaced with light aggregate sand [4-7]. Green at al [8] reported that, the effects of lime and admixtures on the water-retaining properties of cement mortars. The subject of this research has not been limited to the VTS being used as a mortar for brick or stone structures, some physical and mechanical values of the material in question has also been researched. The effects of different volume contents of VTS on the strength and thermal conductivity were investigated as well.

MATERIALS AND METHOD

Volcanic Tuff Sand

The materials found as sedimanter were not broken or washed. It was used directly especially for building walls and plastering by adding a small amount of lime and cement. When the material, obtained from the quarry is inspected it can be seen with the naked eye that they are humid and clean and the tuffs, which are between 2–8 mm are visible immediately. When an amount of the material was put into water it was seen that the tuffs remained above water. These materials, which resemble a sponge, are each of 4/8 classes and the weight ratio is around 11%. Once it is crumbled by hand it gives a feel of lime hardness. Whilst humid it is the color of yellowy brown, however when dry it is a gray-white color.

The chemical composition and physical properties of the materials used in this study are summarized in Table 1. In order to give and idea of the chemical bonding quality of the researched material, Kaplan and Binici [9,10] inspected volcanic tuffs chemical analysis taken from various suburbs and with the intentions of making comparisons easier the results have been given in Table 2 along with the results of chemical analysis of the volcanic tuff used in the experiment.

Table 1. Chemical analysis results of the VTS

Chemical composition	%
Silica (SiO2)	67.21
Alumina (Al2O3)	15.80
Ferri oxide (Fe2O3)	1.130
Calcium oxide (CaO)	7.99
Magnesium oxide (MgO)	3.83
Mangan oxide (Mn2O3)	-
Sulphuric anhydride (SO3)	0.61
Loss on ignition	2.30
Total Sodium oxide and potassium oxide (Na2O +0.658 K2O)	1.13

Table 2. Chemical composition of the various volcanic tuffs in Turkey

Chemical composition of volcanic tuff in Turkey				
Chemical composit ion (%)	Region			
	Kayseri	Tatvan	Bitlis	Esendere/Erzurum*
SiO_2	64	64.72	67.80	67.21
Fe_2O_3	1.99	3.21	1.5	1.13
Al_2O_3	15.13	18.52	18.7	15.80
CaO	5.65	2.20	-	7.99
MgO	0.96	0.80	1.15	3.83
Other	9.41	6.58	7.15	4.04

* Materials currently being inspected

Cement and lime

ASTM Type II, Portland cement (PC), from Aşkale in Turkey was used in this study. Natural aggregate were obtained from the Aras River. Lime, which is mixed and dissolved in water and used when it has become like buttermilk is prepared and commercial available in 25 kg bags, which is in accordance with TS EN 459-1 [11].

METHOD

Standard mixes were used in the experimental work to include VTS: cement and VTS: cement: lime. Taking the TS 2848 [1] mixture ratios into consideration, the mortar strength and other characteristics were studied. The volume of the materials used for the mixture were weighted dry and in turn class A, B, C, D, E mortar was used and the VTS/cement/lime ratios were taken as follows, 3/1/0, 4/1/1, 5/1/1, 8/1/3 and 3/0/1 (type I). In addition another dry mortar mixture was prepared using class A, B, C and D mortars cement with ratio of 50% and 25%, meaning that the cement amount was decreased while the lime amount remained fixed (type II and type III). Furthermore, to experiment the ratio of VTS in A, B, C class mortar was increased 25%, 50% and 100% (type IV), by preparing dry mortar mix. İn this way, it will be found out if natural lime and tuff available in VTS influence mortar specifications. The texture designation of mortar mixes were measured according to TS 2848 [1]. It is stated that the mortar texture protection ratio and spread ratio should not be below 70 % and Y= 110 % ± 10 respectively. The VTS's sieve analysis was done and the fine substance ratio and the freeze resistance degree were appointed according to TS 2717 [2]. The amount of water added for the preparation of wet mortar is regulated in order to get a spread ratio of Y=110±5. Practically, there is no determined set water ratio and is dependent on where and for what reason the mortar is to be used for Ameritus [6]. Well graded, smooth aggregates enhance workability as do lime, air entrainment agents (plasticisers) and proper amounts of mixing water. Lime imparts plasticity and ability to retain water in the mix whilst plasticisers improve frost resistance [6].

The five type VTS mortar mixes were prepared in a laboratory counter-current mixer for a total of 5 min. Precuations were taken to ensure from homogeneity and full compaction. For each mix, three specimens 50×50×50 mm cubes were prepared and cured in lime saturated water (class A), at 20±3 °C at room temperature and 90% relative humidity (class B, C and D) and 21± 3 °C at room temperaturecured until 28 th day. A quick thermal conductivity meter (QTM 500) based on ASTM C 1113-90 hot wire method was used to measure of VTS mortar plasters.

RESULT AND DISCUSSION

The higher class of mortar provides better durability than the lower classes in the following order A, B, C, D and E. The higher cement content in the higher class resulted in lower scratch index. This confirms previous findings [12] of the relationship between penetration index and cement content. The A, mix, which contains no lime, is an exception, showing higher scratch index despite higher cement content and lower water-cement ratio. This was particularly the case with the dune sand and was partially caused by the absence of lime, which improves water retention and promotes continued hydration of cements.

Specific gravity, water absorbtion ratio and freeze bearing of VTS mortar

The water absorbtion ratio of VTS mortar mixes are also examined. A specific gravity (SG) and water absorbtion ratio results showed that Table 3. The VTS's water absorbtion degree, as a density was found to be fewer than 17.38% and due to this being lower than 80 % it can be expected to be anti-freezing. However, in TS 2717 [2], sand was taken from the same quarry and similar mortar mixtures were made and used.

Table 3. Specification of VTS

Specification	
Dry surface Specific Gravity	2.17
Dry SG	2.04
Visible SG	2.34
Water absorbtion ratio by weight S_a (%)	6.20
Water absorbtion ratio by volume S_h (%)	7.91
Porosity (ρ)	0.455
Saturation degree (D)	17.38

Density of VTS mortar’s

The materials density experiment was done according to TS 3529 [13] and the results were compared to the values given in TS 1114 [14]. The VTS loose and dense density was found to be 1275 kg/m^3 and 1428 kg/m^3 respectively. For this reason, the density of mortar made from this material is evidently lightweight sand [15]. The lightweight aggregate loose density was determined as 1100-1200 kgf/m^3 in TS 1114 [14]. The mortars density of the used material and mixture ratios of which the specialities are determined and stated in TS 2848 [1] and TS 2717 [2] should be 1800-2000 kg/m^3 [16]. The completely hardened VTS that the mortar mixture it is made with is seen to have a density of 1370-1970 kg/m^3. Class E mortar was obtained by using low hardened density ratio sand 3:0:1 and a cement and lime mixture whereas, a mixture, with a ratio of 3:1:0 of sand cement and lime a class A mortar was created with the most heavy density of 1970 kg/m^3. Selection of the correct type is based on the anticipated exposure—interior or exterior—and structural requirements. Type E, for example, is not designed for exterior load-bearing applications, but may be used in non-load-bearing interior positions [17].

Texture designation (spread) and texture protection of VTS mortar

As described in TS 2848 [1] texture designation and texture protection experiments were done and the values taken from these experiments are given in Table 4, according to mortar classes. To determined water retention ratio of VTS, prior to testing, the dish, which had been fitted with a humidified and drained filter paper, is filled with mortar, levelled and weighed. Knowing the mass of the empty dish with the humidified filter paper, mass “M” of the mixed and placed product can therefore be calculated, along with mass “E” of the mixing water. Measurements are to be undertaken within 10 min following mixing. A vacuum is created for a 15 min period at a time of 15 min after mixing has begun. The apparatus is then exposed to a 50 mm Hg depression. Once the underface has been dried, the dish is reweighed. By taking differences, the water loss “e” is determined. The water-retention capacity is expressed by relationship (1) in terms of percentage of initial mixing water mass:

$$K = \frac{E - e}{E} \times 100 \qquad (1)$$

A workable mortar has a smooth, plastic consistency which is easily spread with a trowel and readily adheres to a vertical surface. Well graded, smooth aggregates enhance workability as do lime, proper amounts of mixing water. Lime imparts plasticity and ability to retain water in the mix whilst plasticisers improve frost resistance. Thin bed mortars with a 1:2 cement: sand mix together with water retaining and workability admixtures are increasingly used with accurately dimensioned units [5, 6].

Compressive strength of VTS mortar

According to the procedure given in TS 2848 [1], compressive strength test were done on three samples from each group and the results was given in Table 5 and Fig.1. The compressive strength has a big importance mostly in brick laying and plastering and due to this, the mortars required mechanic characteristics is a function of the mixture ratios and material quality [10, 18].

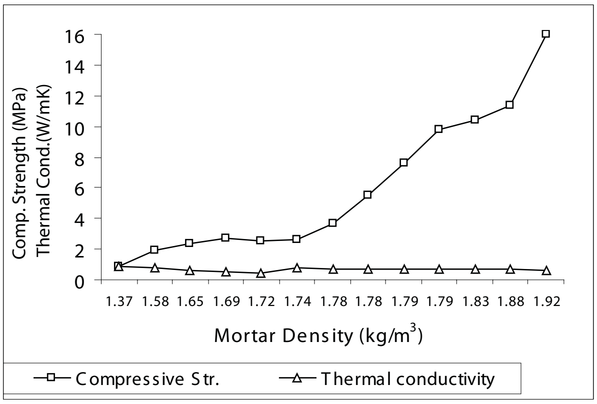

Figure 1. Effect of density, compressive strength and thermal conductivity of VTS mortar

Cement is used in the mixture of plaster and wall mortars in order to add strength to the mortar. The amount of cement used is never as much as of the concrete, and it also cannot be compressive strength with dosage instead of this the phrase “part” can be used. In the compressive strength tests done using VTS, it was determined that class E mortars made up of three volume sand and one volume lime had the lowest bearing being 0.9 MPa. According to TS 2848 [1], the reference value this class mortar (E) was 0.5 MPa. The highest resistance is found in mortar made up of three volume sand and one volume cement, 16 MPa. In the same reference the resistance value this class mortar was given as 15 MPa. The influence of the different

Table 4. Experiment results of mortar spread (Y) and water retention ratios (K)

Mortar class	Mix proportions (by volume) VTS+ C +L	Mortar spread ratio (Y) %			Water retention ratio (K) %		
		Mortar spread ratios (Y)	Reference value TS 2848[1] (%)	Result	Water retention % (K)	Reference value TS 2848[1] (%)	Result
A	3/1/0	110	110 ±10	sensible	71%	70%	acceptable
B	4/1/1	115	“	“	68%	“	good
C	5/1/1	115	“	“	75%	“	good
D	8/1/3	105	“	“	61%	“	good
E	3/0/1	110	“	“	77%	“	acceptable

VTS=Volcanic tuff sand, C= cement, L=lime cement and lime ratios on the density, compressive strength and thermal conductivity of mortar is shown in Table 5.

Table 5. Density, compressive strength and thermal conductivity of VTS mortars.

	Type of mortar	Dry Mix proportion VTS+C+L	Hardened mortar dry density (γk). (kg/m3)	Compressive strength (MPa)	Thermal conductivity (λ) (W/mK)
TYPE I	A.1*	3:1:0	1.92	16.0	0.85
	B.1*	4:1:1	1.88	11.4	0.80
	C.1#	5:1:1	1.65	6.5	0.60
	D.1#	8:1:3	1.58	3.7	0.55
	E+	3:0:1	1.37	0.9	0.42
TYPE II	A.1/2*	3:1/2:0	1.83	8.3	0.75
	B.1/2*	4:1/2:1	1.79	7.6	0.72
	C.1/2#	5:1/2:1	1.78	3.7	0.71
	D.1/2#	8:1/2:3	1.74	2.6	0.67
TYPE III	A.1/4*	3:1/4:0	1.79	3.5	0.72
	B.1/4*	4:1/4:1	1.72	2.5	0.66
	C.1/4#	5:1/4:1	1.78	1.7	0.71
	D.1/4#	8:1/4:3	1.69	1.2	0.63

*28 day cured at 23 ± 2oC water.

28 day 21 ± 3oC cured at room temperature and 90% relative humidity

+28 day 21± 3oC cured at room temperature.

The higher class of mortar provides better durability than the lower classes in the following order A (3:1:0), B (4:1:1) and C (5:1:1). The higher cement content in the higher class resulted in lower scratch index. This confirms previous findings of the relationship between penetration index and cement content. The A (3:1:0) mix, which contains no lime, is an exception, showing higher scratch index despite higher cement content and lower water-cement ratio. This was particularly the case with the VTS sand and was partially caused by the absence of lime, which improves water retention and promotes continued hydration of cements. Another reason is that the other sands, even in a 5:0:1 mix, contain sufficient fines to produce a denser surface with a lower scratch index. As a result, it has been seen that VTS, are very good and give possitive results when using to lay bricks. Natural lime in the VTS improved plasticity and consequently workability of mortars. This material like all materials, which have lime in their structure, has sensitivity to water and for this reason mortar made up of normal sand should have the same amount of cement in the building of walls of the structure parts beneath the ground. And, it was decided that the trass and volcanic tuff in the material studied has increased the ability of mortar's adhesion and bonding, and that it's a suitable material in building interior walls and plastering. However, it would not be possible to utilize as structural concrete.

The study has also confirmed that the durability of masonry mortar improves with increased cement content. Increased lime dosage from the recommended dosage by five to ten times did not appear to detrimentally affect the durability, possibly due to the reduction in water demand of mortars. However, overdosing of lime can result in reduced bond strength and must therefore be avoided.

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