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Utilization of Marble Dust, Fly Ash and Waste Sand (Silt-Quartz) in Road Subbase Filling Materials

S. Fırat*, G. Yılmaz, A. T. Cömert***, and M. Sümer******

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Abstract

Large volumes of earthen materials are used in construction each year in Turkey and elsewhere. The wastes generated from these materials can be utilised in various applications including road subbase filling materials. In this study, three different types of wastes namely fly ash, marble dust and waste sand are used. These wastes were mixed with natural soils as a potential alternative filling materials in the road subbase. Two types of natural soils were replaced with 0%, 5%, 10%, 15%, 20% of fly ash, marble dust and waste sand. Standard compaction, permeability and saturated California Bearing Ratio (CBR) tests, X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) analysis were performed on two types of natural soils, containing three industrial waste types in different ratios. The study indicates that the fly ash, marble dust and waste sand are fairly good additive materials in road subbase fill and reaction substantially improves their CBR, swelling ratio and water conductivity. It was found that a clear optimum replacement level of 15% for all of these by products for medium and low plasticity type of soils.

Keywords: *marble dust, fly ash, waste sand, permeability, california bearing ratio, XRD, SEM*

1. Introduction

The world has many industrial wastes generated as a result of extraction of the natural resources. Since extensive level of coal firing for power generation began in the 1920s, many millions of tons of ash and related by-products have been generated. The current annual production of coal ash worldwide is estimated around 600 million tones, with fly ash constituting about 500 million tones at 75-80% of the total ash produced. Thus, the amount of coal waste (fly ash), released by factories and thermal power plants has been increasing throughout the world, and the disposal of the large amount of fly ash is causing a serious environmental problem. The present utilization of ash on world-wide basis varied widely from a minimum of 3% to a maximum of 57% of the total ash produced with an average of 16%. This leaves a substantial amount of ash to be disposed of in landfills and/or lagoons at a significant cost to the utilizing companies, the consumers and the environment (Ahmurazzaman, 2010).

Coals are preferred widely in the world for the production of the electricity. One of these fuels is lignite which is used in the pulverized form as a source of energy in the thermal power plants. After burning, 43% of the coal is left as either fly ash or bottom ash. The fly ash can be used in the construction of many civil engineering structures (e.g., partial substitution of cement in concrete) but there is still a substantial amount of fly ash that is not utilised. There is potential to use the remaining fly ash as a sub-grade chemical additive material in road construction. The use of fly ash in road construction such as road subbase can increase the soil strength, bearing capacity while decreasing some geotechnical parameters such as compressibility, permeability, and swelling capacity. In addition the air quality is improved if less fly ash is deposed in landfill. The total amount of fly ash constitutes about 23% of the all lignite coal amount after burning (Misra *et al*., 2005). In Turkey, 55 million tons of lignite is burned and accordingly 13 million tons of fly ash is produced annually (Türker *et al*., 2004). If the free lime content is less than 10%, then the fly ash is classified as a class F fly ash; and its self-cementing period is longer when compared with class C fly ash (ASTM, 2005). Consequently, class F fly ash is named as late-self-cementing fly ash and causes more serious problems than class C fly ash in terms of environmental pollution. Lime is added in ratios of 5-20% to class F fly ash in order to obtain a higher strength value and to make hardening quicker (Misra *et al*., 2005; Cömert *et al*., 2006, Fırat and Cömert, 2011).

The glass production involves the use of natural sand and the quartz raw material contained in it. In Turkey, granulated limestone, up to 500 microns, is also used as the raw material of the glass. The waste sand is an inert material and generally does

*Professor, Civil Engineering Department, Technology Faculty, Gazi University, Ankara 06500, Turkey (Corresponding Author, E-mail: sfirat@gazi.edu.tr)
**Professor, Vocational School, Technical Programs, Anadolu University, Eskişehir 26140, Turkey (E-mail: gulgunyilmaz26@gmail.com)
***Lecturer, Vocational School, Technical Programs, Bilecik Şeyh Edabali University, Bilecik 11100, Turkey (E-mail: atcomert@gmail.com)
****Assistant Professor, Department of Civil Engineering, Sakarya University, Sakarya 54187, Turkey (E-mail: msumer@sakarya.edu.tr)

not cause pollution to the soil or water but can contaminate the air during the summer and spring seasons and therefore causes serious health hazards including specifically asthma and lung cancer (Turgut and Algin, 2007; Felekoglu, 2007).

Turkey and according to the recent data, contains 3.8 billion m^3 of marble reserves corresponding to 40% of the world potential reserve. The capacities of the marble treatment consistently increase with the help of modern production techniques; thus reducing the waste marbles. Natural marble stone production is approximately 4 million m^3 in Turkey per annum (Turkey Energy and Natural Resources, 2010). The amount of dust released in the treatment of one m^3 marble block (approximately 3 tons) is between the 30-40% of the block mass (Ersoy, 2003). For that reason, the mass of the block marble treated annually in Turkey is 17 million tons, and the amount of the marble dust released is approximately 5-7 million tons. The stabilization of soil by using industrial wastes is one of the oldest techniques known. The possibility for the utilization of marble slurry dust for soil stabilisation was investigated and found that 25-30% of the marble slurry dust can be mixed with various soils for the construction of roads and backfill material (Sabat *et al*., 2005).

Some studies were conducted on the stabilization of black cotton soil using crusher dust and found that the values of liquid limit and optimum moisture content decreased and the CBR values increased with the addition of stone dust (Sabat *et al*., 2005). On the other hand, the effects of marble waste on the plastic index and swelling characteristics of expansive soil have been investigated and found that the plasticity characteristics were decreasing with the increase in percentage of solid waste. Sabat *et al*. (2005) investigated the increase in the saturated CBR value for a soil mixed with up to 20% fly ash and 15% marble powder and found that for the mixes higher than these ratios the saturated CBR value decreased.

In many cases, waste materials can be replaced with reclaimed highway paving materials, secondary materials, and construction debris that are normally disposed in landfills, and can generate millions of dollars savings to taxpayers. Reuse in construction has several benefits, including reduction in solid waste disposal costs incurred by industry, reduction in landfill requirements, minimization of damage to natural resources caused by excavating earthen materials for construction, obtaining added value from waste materials, conservation of production energy, and ultimately providing sustainable construction and economic growth (Cetin *et al*., 2010).

In this study, the evaluation of the strength and stiffness of base layers stabilized with fly ash, marble dust, and waste sand was carried out. These materials were replaced in different ratios of 0, 5, 10, 15, and 20 %, into two types of natural soils for assessment of their possible use of in highway base construction. The samples were cured for 1, 7, 28, 56 and 112 days in order to study the effect of curing time on soil properties. California Bearing Ratio (CBR), permeability, swelling ratio were conducted at all curing times to investigate the engineering properties of soil-waste mixtures. In addition XRD and Scanning Electron Microscopy (SEM) analysis were determined after 7, 28 and 112 days of curing for samples with 15% waste additive.

2. Materials and Methods

2.1 Soils

The soil materials used in this study were obtained from the site during the construction of the Bozüyük-Mekece Road in Turkey. The characteristics values of soils which are termed as T and K in this study can be seen in Table 1.

2.2 Marble Dust

The sample of Marble Dust (MD) was obtained from a marble processing plant (Bilecik, Turkey) Care was taken that the plant constantly cuts the same type of marble and samples were collected before water was poured over them. Chemical analysis of MD is given in Table 1.

2.3 Fly Ash

The Fly Ash (FA) was supplied from Çayırhan thermal power plant (Turkey). The FA is of micron meter dimensions, sphere-shaped, and pozzolanic material that was separated from the thermal power plant exhaust gas with electrostatic methods. Chemical analysis of FA is given in Table 1. The SiO_2+Al_2O_3+Fe_2O_3 content of the fly ash is 65.50%, while its CaO content is 14.8%, and, according to ASTM C 618 (2005), it is classified as C type of fly ash.

2.4 Waste Sand

The waste sand WS sample was obtained from the disposal area of Bilecik Camis plant in Turkey. The chemical analysis of WS is given in Table 1 while their physical properties are presented in Table 2.

2.5 XRD Analysis and SEM

XRD patterns were conducted on specimens of natural soils, waste properties and soil-waste mixtures (Fig. 1) by using Bruker D8 Advance machine. The XRD pattern of the ethylene glycol-treated specimen clearly displays a reflection at 17.2 Å representing smectite. Among the swelling clays, the most common dioctahedral smectite is montmorillonite, which has two siloxane tetrahedral sheets sandwiching an aluminium octahedral sheet (Xi *et al*., 2005). Smectites are specified as 2:1

Table 1. Chemical Analysis of Materials Used for the Study

Materials	Chemical Analysis (%)									
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	SO_3	LOI
T	54.6	13.3	6.2	0.4	7.0	6.0	0.2	1.7	<0.1	10.6
K	38.9	9.8	4.8	0.5	21.9	1.6	<0.1	1.6	<0.1	20.9
Fly Ash	45.5	12.3	7.7	0.7	14.8	8.3	2.7	2.5	4.7	0.4
Marble Dust	0.6	0.4	0.1	0.01	55.0	2.5	<0.1	0.0	0.1	41.4
Waste Sand	86.7	7.9	0.6	0.1	0.7	0.1	<0.1	1.0	0.0	2.9

T, K: Soils, LOI: Loss on ignition

Table 2. Physical Properties of the Materials Used for the Study

Geotechnical Properties	Soils		Wastes		
	T	K	Fly Ash (FA)	Marble Dust (MD)	Waste Sand (WS)
Liquid Limit (%)	49.3	25.6	21.8	29.1	24.5
Plastic Limit (%)	26.3	17.8	17.5	20.8	17.0
Plasticity Index (%)	23.0	7.8	4.3	8.3	7.5
Specific Gravity	2.73	2.71	2.47	2.66	2.65
Soil Classification USCS (TS 1500)*	CI Middle Plasticity clay	CL Low plasticity clay	CL Sandy, Low plasticity clay	CL Low plasticity clay	CL Low plasticity clay
Clay/Silt/Sand (%)	21/40/39	22/51/27	7/47/46	25/72/3	14/61/25
Optimum Moisture Content (%)	22.9	14.4	-	-	-
Maximum Dry Density (kN/m^3)	15.45	18.31	-	-	-

*TS 1500 (2000). Classification of soil for civil engineering purposes, Turkish Standards Institution (TSI).

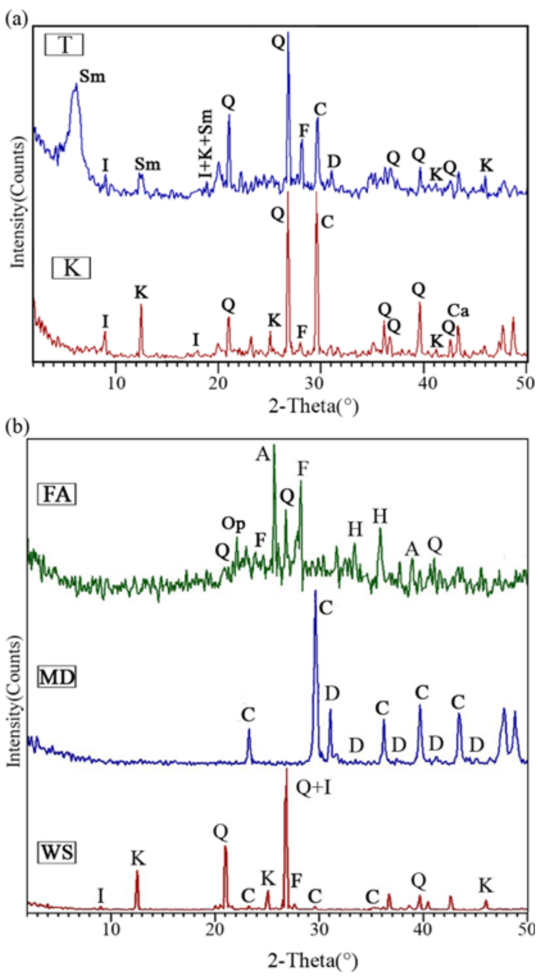

Fig. 1. XRD Patterns of Raw Materials: (a) Soils T and K, (b) Wastes FA: Fly Ash, MD: Marble Dust, WS: Waste Sand (Sm: smectite, I: illite, K: kaolin, Q:quartz, F: feldspar, C: calcite, D: dolomite, Op: opal-CT, A: anhydrite, H: hematite)

layered clays and swell in water.

The surface morphology of the raw materials and mixtures were examined by SEM of FEI Quanta 400 MK2. SEM figures show carbonate lumps (white arrow in Fig. 2a) and spherical senosfers (FA) formed as a consequence of sudden cooling (Fig. 2a, b). Some senosfer surfaces are coated by hematite (FA+H, black arrows) (Fig. 2b).

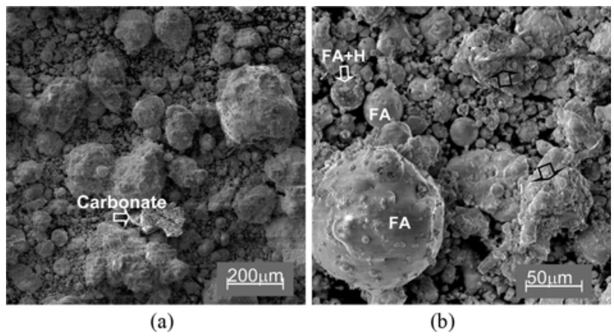

Fig. 2. SEM Micrographs of Fly Ash: (a) Fly Ash and Carbonate (White arrows) Masses, (b) Fly Ash Formed as Curve (FA), Fly Ash with Hematite Covered (FA+H) (White arrows), Carbonate-FA Formations (Black arrows)

As can be seen from Figs. 1(b) and 3(a), 3(b), marble dust contains calcium according to XRD and SEM results. Also, XRD analysis shows that the dolomites minerals are present which can be seen on the defragtograme. Figs. 3(a) and 3(c) are magnified to show the coating of sand grain by thin particles such as silt and clay (magnified Figures are given in Figs. 3b and 3d).

2.6 Sample Preparation

The natural soils was crushed with a rubber mallet and sieved by using No.4 (4.75 mm) sieve to make them ready for use in the mixtures. The soils and wastes to be used in the mixture were dried in an oven at 110±5°C for at least one day (until constant mass is achieved). The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) values of the mixture were calculated by performing compaction tests according to procedure defined in TS 1900-1 (2006). The contents of the wastes were calculated in mass by using the ratios of the additives.

Within the study the test samples were prepared at the optimum water content. All of the mixtures to be used in the tests were compacted with the standard proctor energy according to TS 1900-1 (2006). Permeabilities and saturated CBR values were determined for cured and uncured specimens.

By using the wastes and two types of soil, for the compaction test samples, total of 36 soil mixtures in different ratios (5 to 20%

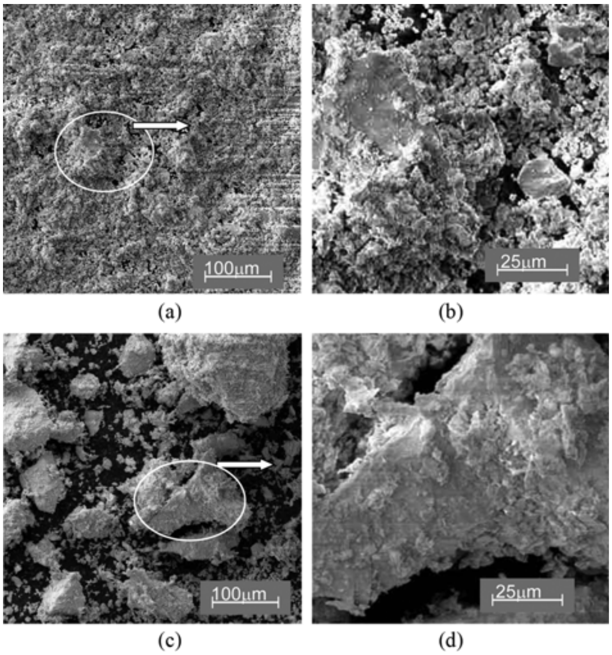

Fig. 3. SEM Micrographs of MD and WS Wastes: (a) MD Result, (b) Magnified MD Result, (c) WS Result, (d) Magnified WS Result

of wastes) were prepared; 12 mixtures, with ratios of 10 and 20% prepared for the permeability test samples; and 24 mixtures, with ratios of 5, 10, 15, and 20% used for the CBR samples; the samples with ratios 15 and 20% used for XRD and SEM analysis, respectively. The samples were cured for 7, 28, 56, 90 and 112 days. XRD analyses were conducted on samples at 7, 28 and 112 days of curing after the unconfined compression test was conducted. for the additive ratio of %15 specimen.

3. Results and Discussion

The huge production of fly ash from thermal power plants and marble dust from marble cutting industry and waste sand from limestone triturating plants have been creating enormous problem of environmental pollution. These waste materials may be effectively used for the road subbase stabilization with natural soils which can be medium and low plasticity soil for the sake of safe disposal. Researchers have been investigating different types of waste materials as additive components in soil (Misra *et al*., 2005). Those materials have been used in many civil engineering constructions but the amount of utilization is not enough to decrease waste reserves. Waste materials can be used as a sub-grade chemical additive material in road constructions. This brings two benefits; (1) Waste materials increase the soil strength, bearing capacity, grain size distribution and also decrease some geotechnical parameters such as compressibility, permeability and swelling capacity and (2) chemical and physical pollution of soil, water and air due to waste materials are reduced in the environment. In this study, for evaluation of the strength and stiffness of base layers stabilized with by-products of fly ash, marble dust, and waste sand are carried out.

3.1 Permeability

The falling-head permeability test (TS 1900-2/T1, 2007; Head, 1982) was performed on the soil-waste series with 10% and 20% additive content. The samples were located on the falling-head permeability mechanism after compaction with the standard energy, inside the moulds with a, at the optimum water content. Porous stones were positioned at the top and bottom faces of the sample to prevent its disintegration and to allow de-aired water to permeate through the sample. Saturation process was continued by applying a low suction to the top of the sample by adjusting the vacuum line and air bleed valves. The suction was maintained and increased slightly until water was drawn up into the glass tee-piece. If air bubbles were present, the suction was maintained until the system was air free. This indicated that the sample was saturated. The saturation time took around 48 hours and the measurements were taken at different time intervals for 4 days. Using the data obtained, the coefficient of permeability was calculated with the Eq. (1):

$$k = 2.3\frac{aL}{A(t_1-t_2)}log_{10}\frac{h_1}{h_2} \tag{1}$$

Where k is the coefficient of permeability, a is the cross-sectional area of the standpipe, L the length of soil sample in the permeameter, A the cross-sectional area of the permeameter, t_1 the time when the water level in the standpipe is at h_1, t_2 the time when the water level in the standpipe is at h_2, and h_1-h_2 are the heads between which the permeability is determined.

The coefficients of permeability in the untreated T and K soils were, respectively, found as 4.3×10^{-7} and 4.5×10^{-7} cm/s. Fig. 4(a) shows the permeability of the T soil series using the different types of wastes. Using WS decreased the permeability

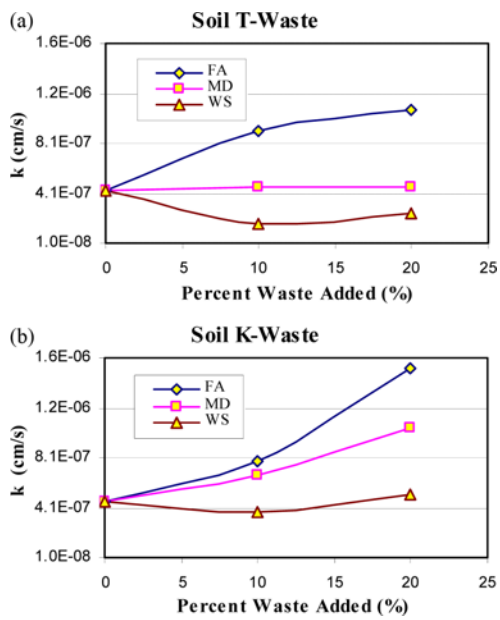

Fig. 4. Coefficients of Permeability (k) for Different Percentages of Waste in: (a) Soil T, (b) Soil K

while the inclusion of FA caused an increase in permeability. On the other hand the use of MD did cause any change in the permeability. The permeability of the K soil series is shown in Fig. 5(b). Except for the 10% WS, the use of the different types of waste (WS, MD, FA) has increased the permeability of the soil and the higher the waste content the higher the permeability. All of the coefficients were calculated to be smaller than 10^{-5}~10^{-6} cm/s; therefore, the soil mixtures fall into the class of soft clay. The permeability coefficient in the soft clays correlates with the void ratio (Casagrande and Fadum, 1940; Terzaghi *et al*., 1996). However, the permeability coefficients of the T and K soils series having the same compaction energy are different. As the waste content increases, there is in an increase in the void ratios. The highest void ratio was formed in the soil with FA content because FA contains some uniform silt size and a wide range of smaller particles. This mechanism results in flocculation of mixed samples and average pore size increases causing an increase in coefficients of permeability. It was concluded that the type of waste did also affect the permeability of the mixtures.

3.2 Saturated CBR

California Bearing Ratio (CBR) test is performed to determine the bearing capacity of the soil to be used in the road substructures. It is a universal standard used in road construction and simple to carry out for various conditions. In this study, saturated CBR test was performed in order to determine the bearing capacity of the soil under the critical conditions.

Two samples were prepared as two series for the CBR test; one of them was instantly put in the water receptacle while the other series was cured for 28 days. Their 4 day swelling values were then recorded and the CBR test was performed on the samples (TS 1900-2, 2006). Fig. 5 shows the saturated CBR values for the T and K soils containing varying amounts of wastes and cured for 0 and 28 days.

Generally, the CBR values for the K soils are larger than those of the T soils with and without wastes. Also it is noticeable that the CBR for K and T soils containing FA are larger than soils containing WS and MD. For the T soil and as the content of FA increases the CBR of the soil increases. The CBR for the K soils increases as the FA increases up to 15% but at 20% FA the CBR is similar to that obtained at 15%. For T soils with WS and MD there are an increase in CBR as the amount of waste increases and this increase is much less than those of T soils with FA. However, for the K soil, the trend in the CBR values with the increase in either WS or MD is not very clear and the CBR values did not show large changes with increasing the MD or WS content. For example, Fig. 5(c) with uncuring case, K soils containing up to 10% MD shows a slight increase in CBR compared with 0%. However, after 10% MD content, the CBR is decreased.

The saturated CBR values of the T and K soils (without waste) are 8% and 13%, respectively. According to the instantly performed CBR test values (Figs. 6a, c), the highest bearing ratio

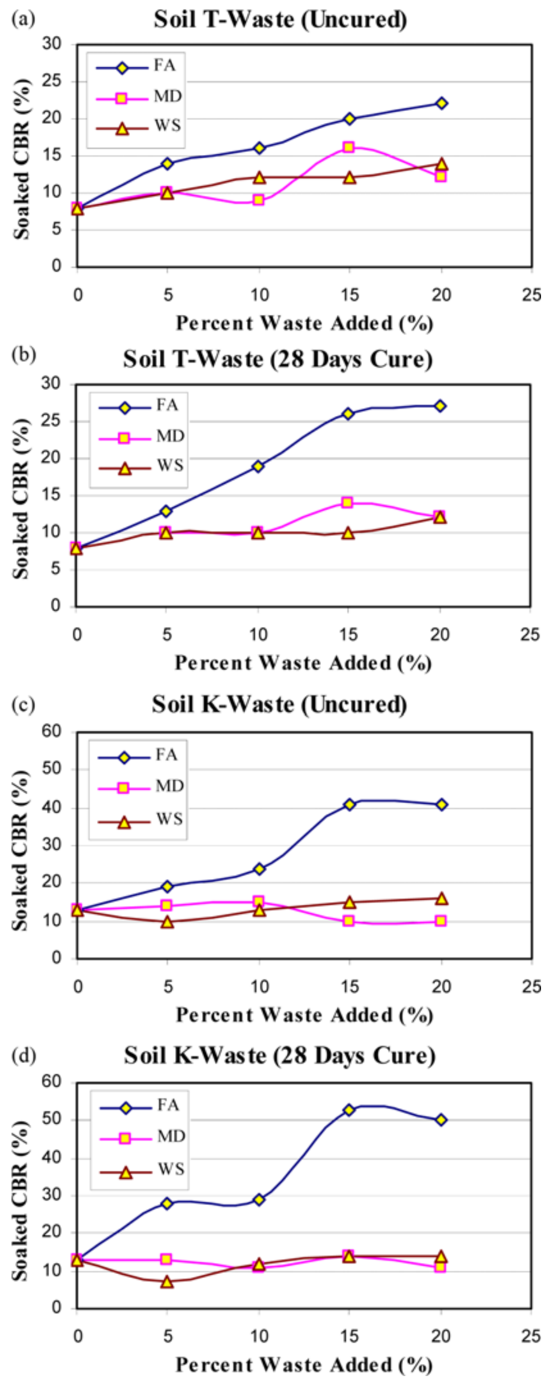

Fig. 5. Saturated CBR Measurements in Different Curing Regimes: (a, b) Soil T-Waste, (c,d) Soil K-Waste

values obtained in the soil-waste mixture series were T-20FA (22%) and K-15FA (41%), T-15MD (16%) and K-10MD (15%), and T-20WS (14%) and K-20WS (16%). According to the CBR test, values of the samples cured for 28 days (Fig. 5b, d), the highest bearing ratio values measured in the soil-waste mixture series were T-20FA (27%) and K-15FA (53%), T-15MD (14%) and K-15MD (14%), and T-20WS (12%) and K-20WS (14%). The values belonging to the samples cured for 28 days, as can be seen in Fig. 6, increased in ratios of 2-25% than the values of the

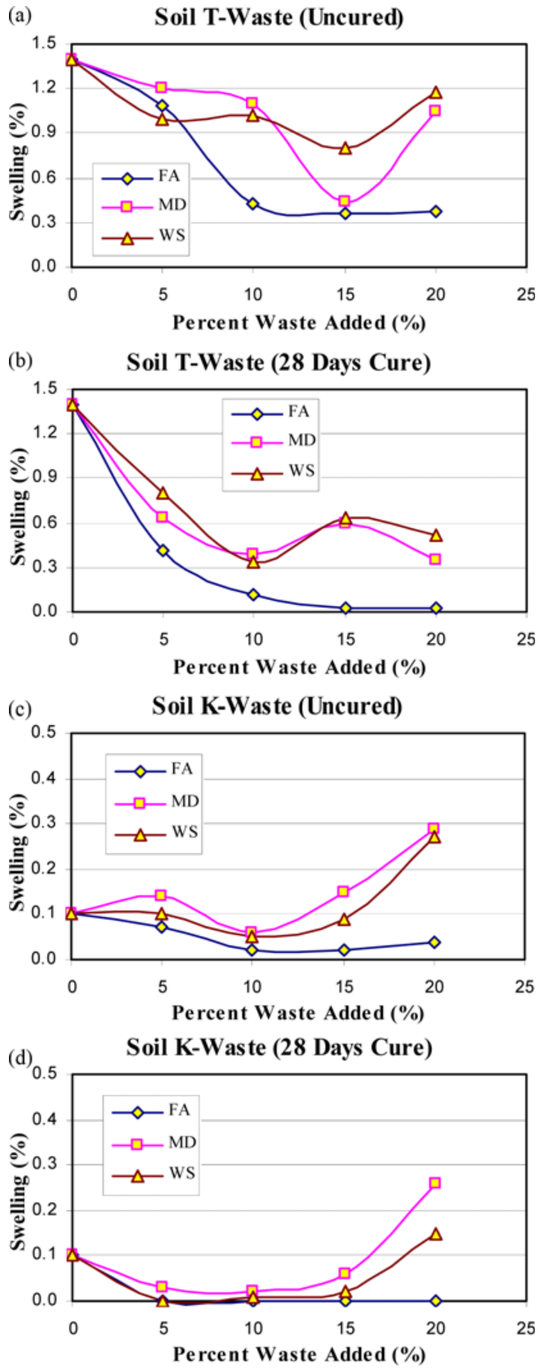

Fig. 6. Swelling (in CBR mould) Measurements in Different Curing Regimes: (a, b) Soil T-Waste, (c, d) Soil K-Waste

uncured samples in the soil-FA series, decreased in the ratio of 2% in T-MD and T-WS series 2%, increased in the ratio of 1% in K-MD series, and decreased in the ratio of 1% in the K-WS series 1%. When compared with the soils' own CBR values in all soil-additive series in the both curing regimes, the values belonging to the series with FA additives increased at least 250%, the series with additives MD and WS increased in ratios of 75% and 25%, respectively, in the type T soil. The value which belongs to type K soils increased with a ratio of 1%. In summary, in saturated conditions the soil bearing ratio were determined to be increasing at least 2.5 times when FA was added, and increasing with ratios of 50% and 1% in T and K type soils, respectively, when MD and WS were added, in the worst conditions.

MD is actually Calcium carbonate, $CaCO_3$. But Calcium carbonate is given as CaO in chemical analysis. On heating above 840°C calcium carbonate releases carbon dioxide to form calcium oxide CaO, which is then able to react due to its amorphous nature. The MD used in this work is not heated and therefore makes no contribution to cementing reaction.

Fly ash is a pozzolan, silica and alumina based material which in the presence of water will react with calcium hydroxide at ordinary temperatures to produce cementitious compounds. This is possibly the main reason why soils with FA gives higher CBR values compared to soils with WS or MD.

3.3 Swelling Properties

Swelling ratio was obtained by CBR mould. The swelling ratio measurements were recorded for the samples of uncured and 28 day cured test specimens as shown in Fig. 6. Among the soil-waste series, the swelling value was the lowest or considerably low in the mixtures with 15% content. At 15 % waist content, the highest swelling in T and K soils were 0.4%, and 0.9 % for soil containing FA, MD and WS respectively. These values are below the limiting values of the Turkish Highway Specification (2006) of 3%. Therefore soil containing 15% FA, MD and WS as replacement could be used as subbase filling materials in road construction.

3.4 XRD Analysis

Figure 7 shows XRD analysis for T and K soils containing 15% waist cured at 7, 28 and 112 days. Minerals structure of soil are also given in Fig. 8(a,b,c).

XRD diagrams shows that the main mineralogical constituents of all samples. These include smectite, illite, kaolin, quartz, feldspar, calcite, dolomite, opal-CT, anhydrite and hematite (Fig. 7). The possible hydraulic compounds that have appeared are products of the soil waist hydration. These include various types of calcium aluminium silicate hydrate as well as products resulted of the reaction mainly of the SiO_2 contained in soils. The formation of the hydration products during the curing stabilizing agent high calcium shows that a significant amount of tobermorite is formed leading to a denser and more stable structure of the samples. A comparison between XRD diagrams of mixed samples cured for 7 days and 28 and 112 days shows that there is a remarkable increase of the compounds corresponding to tobermorite as well as the decrease of SiO_2 which has reacted with $Ca(OH)_2$.

The CBR is considerably enhanced. CBR values in all soil-additive series in the both curing regimes, the values belonging to the series with FA additives increased at least 250%, the series with additives MD and WS increased in ratios of 75% and 25%, respectively, in the type T soil.

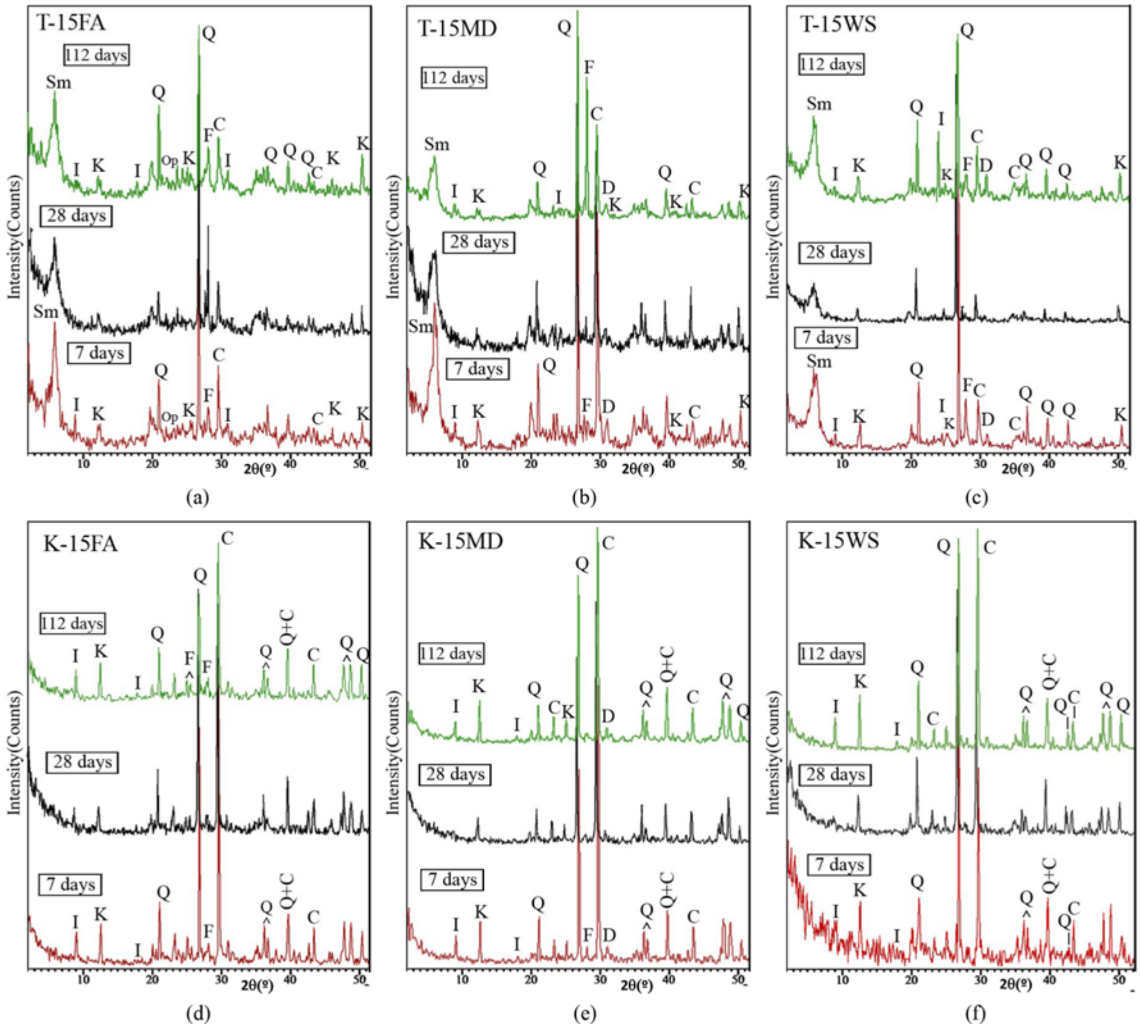

Fig. 7. XRD Pattern of Mixtures in Three Different Curing Times: (a, b, c) Soil T-Waste, (d, e, f) Soil K-Waste (FA: Fly Ash, MD: Marble Dust, WS: Waste Sand, Sm: Smectite, I: Illite, K: Kaolin, Q: Quartz, F: Feldspar, C: Calcite, D: Dolomite, Op: Opal-CT)

3.5 SEM Micrograph

Figure 8 shows SEM micrograph of T and K soils containing 15% FA, MD and WS. After the drying samples in oven at 110±5ºC, they were gold-plated, SEM micrographs were then taken. The micrographs were used for the characteristic surface structure of the samples. Some typical SEM micrographs were presented in Fig. 8. Smectite (Sm) was observed as curled (non-flat) leafs in T soil containing 15% FA (Fig. 8a). This is associated with less swelling compared with 100% T soil (Figs. 6a, b). In K soil containing 15% FA the kaolin seems to be joining together with fly ash (FA). This grain positioning has also caused that dry unit weight of K-FA mixtures are lower than the expectations. However it was observed that dry unit weight of T-FA mixture has approximately equal value to 100%T soil. These mixtures have also the highest CBR (Fig. 5), the lowest swelling percentage (Fig. 6) and the highest permeability (Fig. 4) in all T-FA and K-FA mixtures which are examined at the end of the 28 days cured procedure.

The T-MD mixtures is given in Fig. 8(c). Shaped in thin thread smectite (Sm) and calcite (C) grains which have T soil characteristic was observed in the mixtures. Dolomite (D), kaoline (K) and mound of carbonates (shown with black arrows Fig. 8d) in K-MD mixture are remarkable. In soil-MD mixtures, C and D grains which are mixtured with clay flakes were not spaced closely to each other. Therefore voids were observed among the grains. This grain structure was also observed in soil-WS mixtures. This grain geometry which has void, affects CBR and swelling percentage in negative and the spaced arrangement has caused increase or decrease in permeability coefficient of water, related to sort of additive and soil. In WS added mixtures, large spaced and interferenced structures were not observed.

In soil-waste mixtures, some similarities were observed in swelling and CBR characteristics of WS and MD mixtures. When permeability coefficient of Figs. 8(e) and 8(f) are compared, it is explained that if grains of K soil mixture are positioned more perpendicularly, permeability increases (Fig. 8f). Fig. 8(d) and Fig. 8(c) have shown that K-MD has better CBR than T-MD does and K-MD has less swelling value (characteristic) than T-MD does. As a result geotechnical characteristics of soil rise if microstructure has less space in their structure and if position of

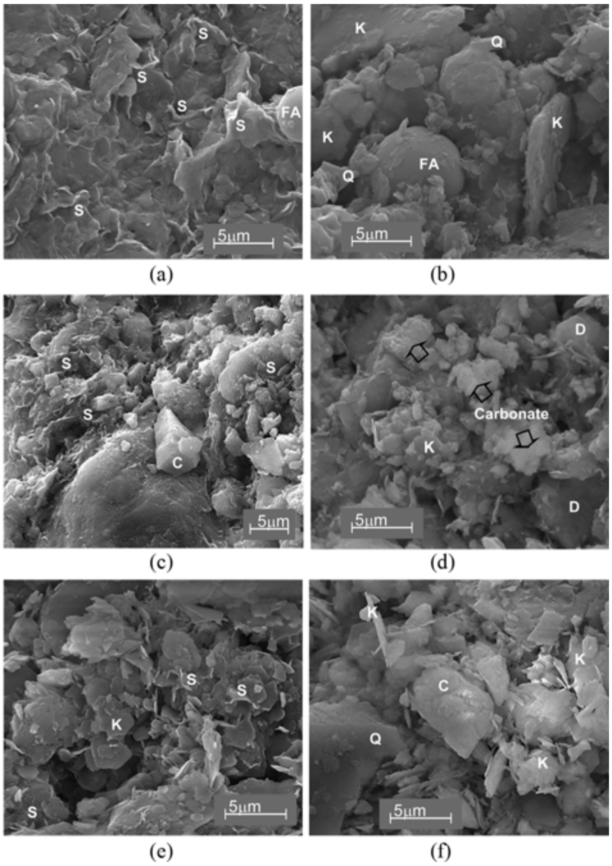

Fig. 8. SEM Micrographs of Mixture: (a) T-FA, (b) K-FA, (c) T-MD, (d) K-MD, (e) T-WS, (f) K-WS (Sm: Smectite, FA: Fly Ash, K: Kaolin, Q: Quartz, C: Calcite, D: Dolomite)

clay flakes is more parallel to other.

The SEM images of all samples indicate that large quantities of hydrated products are propagated in the curing time. Especially, SEM photograph of fly-ash show that some needle like crystals have been formed, they can enhance the conjunctures of the different solid particles in the road subbase filling material.

4. Conclusions

Reuse of suitable waste materials in highways and railroads that are the largest construction fields can reduces environmental problems significantly while meeting the objectives of the standards and regulations. Laboratory studies were carried out to investigate feasibility of reusing waste materials namely the fly ash, waste sand and marble dust in road subbase filling material. The following main conclusions were derived from the results of the experimental studies:

1. The huge production of fly ash from the thermal power plants, marble dust from the marble cutting industry, and waste sand from the limestone triturating plants create an environmental pollution problem, and their safe disposal can be effectively used for the road subbase stabilization in medium and low plasticity soil.
2. As the additive ratios of the mixes do increase, the permeability coefficients also increased and, accordingly, their void ratios increased. The highest void ratio was encountered in the series containing FA additives whereas the highest CBR values were found in the soil-FA additive series.
3. When test findings for the saturated CBR are considered, their CBR values were increased with a ratio of 250% for the two different soils in the soil-FA series; in the MD and WS soil-waste series, on the other hand, the CBR values increased in ratios of 75% and 25%, respectively for the medium plasticity soil type (T) whereas this increase was 1% for the low plasticity soil type (K).
4. The values for the un-saturated CBR, however, increase for the soil mixtures with a maximum waste content of 15% while the values are observed to decreasing after that limit.
5. According to the swelling percentages and the results of the saturated CBR tests, it was determined that FA, MD, and WS mixtures, with a ratio of 15%, could be used inside the road subbase filling materials. The optimum proportioning of soil-waste is 85-15.
6. As a consequence of this experiential studies, it was determined that Fly Ash, Marble Dust, and Waste Sand can be used for the stabilization and inside the road subbase filling material and thus, reuse of the waste materials is considerably significant in relation with keeping the nature clean as well as increasing the bearing ratio of the soils.

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