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Engineering Properties of Natural Structural Materials of Orhanlar (Kütahya- Turkey) Dam and Body Type Selection

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Abstract

Agricultural and rural projects become important depending upon the rapidly increasing world population. In spite of arable land existence in Turkey, agricultural activities are not economic due to the lack of irrigation. Contribution to agricultural economy of the small dams constructed for agricultural irrigation is considerably crucial. In some cases, Natural Structural Materials (NSM) utilized in small dams planned for irrigation purpose are taken from arable lands and usable agricultural areas are destroyed. For this reason, optimisation of NSM planned to use in these types small dams is very important with regard to the economic, agricultural and construction stage convenience. This study includes engineering parameters analysis of NSM necessary for Kütahya, Pazarlar, Orhanlar Small Dam and decision of bod type selection. In this study, engineering approach the optimisation processes of the dams which requires big amount of NSM is explained. Within the context of this study, desk, field and laboratory works have been performed. The representative samples handled from field are tested in the laboratory and usability of the NSM area is determined. Accordingly, dam body type is optimized regarding to distance, quantity and quality of NSM.

Keywords: Agricultural economy, natural structural materials, dam body type optimisation, Orhanlar Dam

1. Introduction

Dams make a significant contribution to the national economy, in terms of energy, potable water supply, agricultural irrigation, flood protection and many more. In some cases, the natural structural materials utilized in dams cause important destruction of arable soils especially for dams constructed for agricultural irrigation. For this reason optimisation of Natural Structural Materials (NSM) is crucial in context of economy, environment, agricultural benefits and reducing the construction stage potential transportation problems. Usability of available geological materials in a dam as a NSM is studied from different perspectives by many researchers [1, 2, 3, 4, 5, 6, and 7].

Study area is located in Aegean Region in which the climate has a semi-arid continental climate with hot, dry summers and cold, snowy winters. Water supply to 593 ha of agricultural area which cannot be irrigated is planned as the construction benefit of Orhanlar Dam. The dam and reservoir area is identified in 1/25000 scaled Kütahya K22-a1 topographic map prepared by National Mapping Agency of Turkey. Transport to the dam axis from Kütahya city is accessed by 131 km

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of asphalt and 3.5 km of dusty road (fig.1). Transport to the dam axis during rainy season is difficult and risky. For this reason, access road to the dam axis must be renewed for the construction stage.

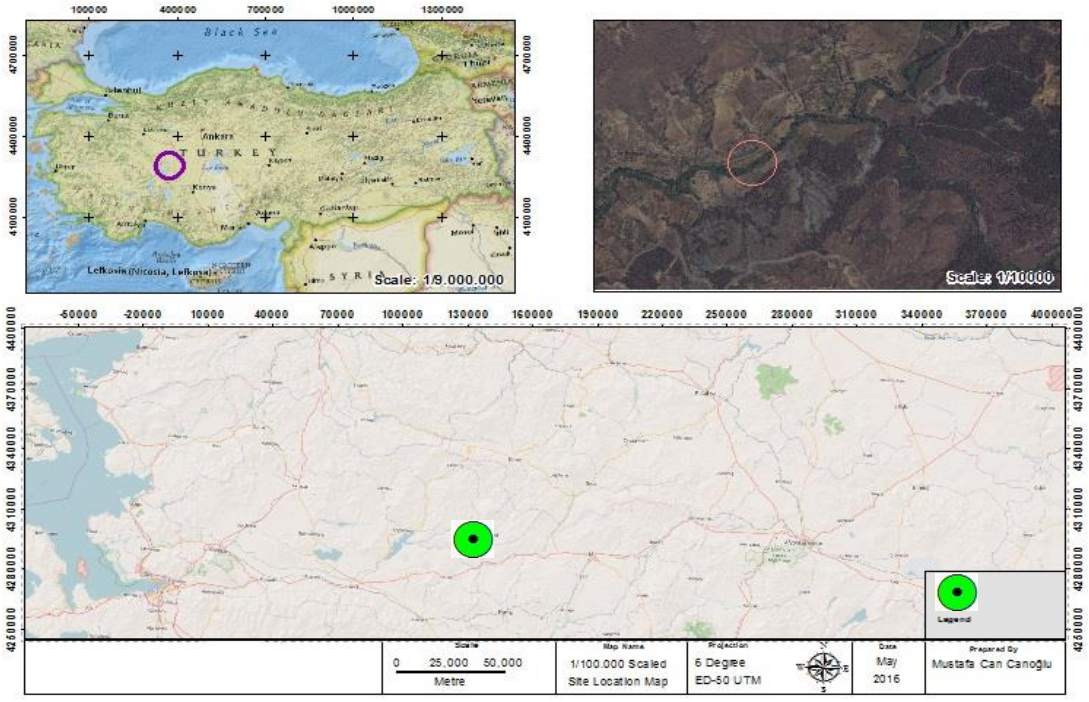

Figure 1. Location map of the study area

Within the context of this study, office works, field works and laboratory works have been performed. Office works includes, literature review and identification of potential NSM areas from the aerial photos. For literature review engineering reports are also analysed such as the reports of SuYapı [8].Within the field observations, the potential NSM areas are qualitatively and quantitatively evaluated. As the final stage, the samples handled from the NSM investigation pits were analysed in laboratory in order to determine the engineering characteristics and usability of NSM.

Laboratory tests performed on the soil samples taken from the impermeable material sites are, moisture content, specific gravity, Atterberg limits, sieve analysis and determination of the soil class based on the unified soil classification system, pin hole test, standard proctor test, unconfined compression test, triaxial compression test and swelling test. The tests realized on the samples from permeable material sites are, relative density, matric suction test, ratio of fine material, determination of clay pellets, Los Angeles abrasion tests, shear box test, sieve analysis and determination of the soil class based on the unified soil classification system, modified proctor test, alkali silica reactivity test and organic matter content test. According to [1, 2, 3, 4, 5, 6, 7] mineralogical structure of the permeable NSM can be changed by the alteration of hydro geochemical processes. In this case, acidity of NSM is changed and cannot be utilized as aggregate material. For this reason alkali silicate reactivity test is crucial for the use of the NSM in concrete aggregate. Finally, as the laboratory tests performed on the rock material are, specific gravity, porosity, uniaxial compressive strength, determination of strength loss after freezing etc. The results of these laboratory tests are interpreted according to the criteria and the risks in case of limit excess proposed by [2].

2. Geological Setting of the Study Area

Geological units in the study area and its near environ pertain to Mesozoic and Cenozoic Eras. The rocks observed are in the range of Cretaceous and Quaternary (Fig. 2). Nethermost Cretaceous aged Dağardı Melange (Kdm) is covered up with lower-middle Miocene aged volcanic units (Mv). Quaternary units such as Alluvium (Qal) and Slope Debris (Qym) draw nigh discordantly the older units. Geological map of the study area and its near environ is shown on figure 2.

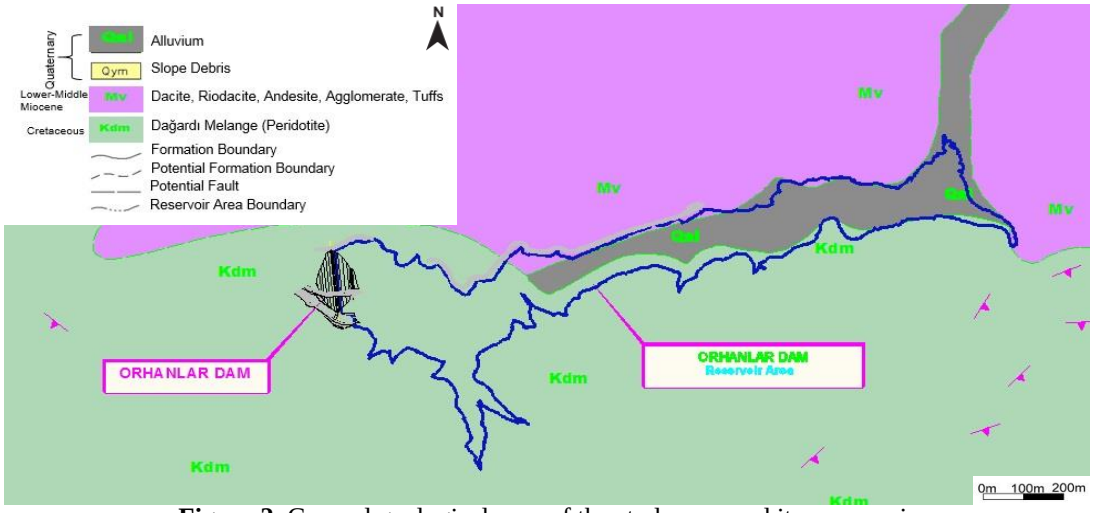

Figure 2. General geological map of the study area and its near environ

1.1 Mesozoic

Dağardı Melange (Kdm)

The geological unit defined as Dağardı melange exposed over large areas in Aegean Region. This unit is investigated by many researchers and aged as Cretaceous. In the study area peridotite type rocks which pertain to Dağardı Melange are observed. According to [9] Neogene units overly Dağardı Melange discordantly.

1.2 Cenozoic

Miocene Volcanics (Mv)

In the study area Miocene constitutes dacite, riodacite, andesite, agglomerates, tuffs and volcanoclastics. The unit is generally basaltic and locally rhyolitic. The tuffs are loose and contain ignimbrites. This unit is transitive with Miocene Flysch unit and discordant with Quaternary Units [10].

1.3 Quaternary

Alluvium (Qal)

Alluviums are observed along the main river (Koyulduk) of the project area. Clay, silt, sand and gravel sized sediments are observed in the river bed. Based upon the field observations the thickness of alluviums is up to 4.5 m and the width can be reached also 4.5m.

Slope Debris (Qym)

Slope debris is consist of gravel and clay sized material as a result of bedrock disintegration. Thickness can be reached up to 2.5m based on the field observations.

3. NSM Investigations

For the NSM investigations, distance to dam axis, material quality and quantity are considered. In this context, 2 impermeable (C and D impermeable NSM areas), 1 permeable (E permeable NSM areas) and 1 rock NSM areas are investigated (fig. 3). Within the scope of NSM investigations trial pits are opened in order to determine the net quantity of the NSM and laboratory tests have been performed on the samples gathered from these trial pits to specify the usability of NSM in terms of engineering properties.

5 trial pit in C impermeable NSM area, 10 trial pit in D impermeable NSM area, 8 trial pit in E permeable NSM area, total 23 trial pits are opened. From rock (Kaya-1 NSM area) NSM area intact rock samples are taken to perform the necessary laboratory tests.

In the current situation, considering the impermeable, permeable and rock NSM quantities and the transportation costs, the most economic and suitable dam body type is "clay cored rock filled dam". The optimization table showing the routing, NSM area (m^2), material quantity and the geological origin of NSM is presented below (table 1).

Table 1. NSM optimization table

NSM Area Name	Routing Conditions	Distance To Dam Body (m)	NSM Area (m^2)	NSM Quantity (Approximately) (m^3)			Geological Origin Of The Material
				Impermeable Material	Permeable Material	Rock Material	
C Impermeable Material Area	Dusty Road (3326 m) Asphalt Road (3549 m)	6 875	12 500	15 000			Disintegrated from Dağardı Melange
D Impermeable Material Area	Dusty Road (3334 m) Asphalt Road (1900 m)	5 234	75 500	219 000			
E Permeable Material Area	Dusty Road (2840 m) Asphalt Road (1950 m)	4 790	109 000		272 000		Alluviums of Koyulduk River
Kaya-1 Rock Material Area	Dusty Road (4365 m) Asphalt Road (1950 m)	6315	500 000			>1 000 000	Upper Miocene Aged Rhyolites
TOTAL				**234 000**	**272 000**	**>1 000 000**	

The NSM needed for the construction of Orhanlar Dam is 51776 m^3 impermeable material, 27000 m^3 permeable material and 223027m^3 rock material.

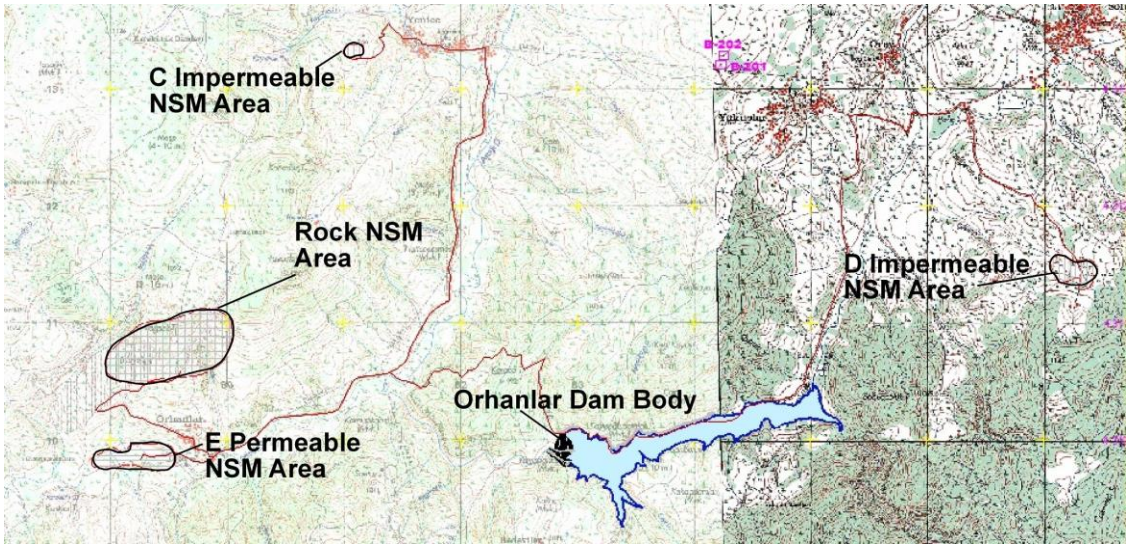

Figure 3. NSM areas locations map.

4. Investigations in NSM Areas

4.1 A Impermeable NSM Area

5 trial pits have been opened in C impermeable NSM area. Depth of these trial pits changes between 1.70 m - 3.50 m. Soil samples are taken from C-301, C-302, C-303, C-304, C-305 numbered trial pits. The samples taken from the C-301, C-302, C-303 and C305 numbered trial pits are CL and C-304 is SC based on the unified soil classification system (table 2).

Table 2. Laboratory test results of C impermeable NSM area

TRIAL PIT NO	DEPTH (m)	SAMPLE NO	WATER CONTENT (%)	SPECIFIC GRAVITY (Gs)	NATURAL UNIT WEIGHT (kN/m³)	ATTERBERG LIMITS			SIEVE ANALYSIS				USCS SOIL CLASS	Dispersivity	Permeability Test	PROCTOR		TRIAXIAL COMPRESSION TEST (UU)		CONSOLIDATION TEST	
						LL	PL	PI	4 (%)	10 (%)	40 (%)	200 (%)		Pin Hole Test	(k20) (cm/sn)	Max.Dry Unit Volume Weight (t/m3)	Wopt (%)	c (kg/cm²)	Φ (°)	Free Swelling %	Swell Press. (kgf/cm²)
C-301	0,30-2,10	TN-1	11.1	2.65	19.87	37.9	15.4	22.5	100	97.4	88.6	75.2	CL	ND3	2.20E-06	1.657	20.1	0.75	10	0.075	0.11
C-302	0,30-3,50	TN-1	17.1	2.67	20.34	41.7	17.1	24.6	99.4	96.9	86.1	67.8	CL			1.705	19.6			0.875	0.33
C-303	0,40-2,80	TN-1	15.0	2.69		49.5	18.6	30.9	98.6	96.4	88.4	77.1	CL			1.662	20.4			1.200	0.55
C-304	0,40-3,10	TN-1	10.0	2.66	21.15	39.6	21.1	18.5	77.0	66.4	43.0	23.9	SC	ND2	3.13E-06	1.840	14.2	0.90	11	0.625	0.245
C-305	0,30-1,70	TN-1	16.5	2.68		42.7	19.8	22.9	82.1	78.4	67.8	52.2	CL		2.23E-06	1.829	14.8			0.538	0.21

After stripping 30 cm of organic soil, 15 000 m3 impermeable NSM can be utilized in Orhanlar Dam with the 2.00 m of exploitation depth. Mean granulometric percentage of the material taken from A impermeable NSM is %13.8 gravel, %30.4 sand and %55.8 fine material (clay and silt). Grain size distribution chart is shown on figure 4.

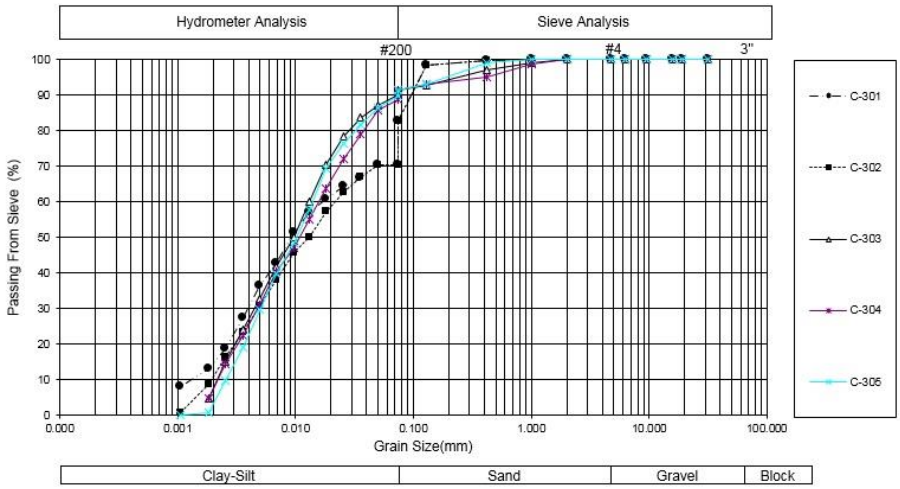

Figure 4. Grain size distribution of C impermeable NSM

4.2 D Impermeable NSM Area

10 trial pits have been opened in D impermeable NSM area. Depth of these trial pits changes between 1.20 m - 4.10 m. Soil samples are taken from D-401, D-402, D-403, D-404, D-405, D-406, D-407, D-408, and D-409 numbered trial pits. Due to the lack of suitable material and in exploitable depth, D-410 numbered trial pit and its near environ is ignored. Sample taken from D-401 is CH, D-402, D-405, D-406, D-408 are CL, D-403, D-407, and D-409 are SC based on the unified soil classification system (table 3).

Table 3. Laboratory test results of B impermeable NSM area

TRIAL PIT NO	DEPTH (m)	SAMPLE NO	WATER CONTENT (%)	SPECIFIC GRAVITY (Gs)	ATTERBERG LIMITS			SIEVE ANALYSIS				USCS SOIL CLASS	Dispersivity	Permeability Test	PROCTOR		TRIAXIAL COMPRESSION TEST (UU)		CONSOLIDATION TEST	
					LL	PL	PI	4 (%)	10 (%)	Max.Dry Unit Volume Weight (t/m3)	Max.Dry Unit Volume Weight (t/m3)		Pin Hole Test	(K20) (cm/sn)	Max.Dry Unit Volume Weight (t/m3)	Wopt (%)	c (kg/cm²)	Φ (°)	Free Swelling %	Swell Press. (kgf/cm²)
D-401	0,20-3,20	TN-1	22.1	2.73	79.2	21.8	57.4	95.8	91.8	83.3	72.9	CH			1.476	27.0			1.425	0.58
D-402	0,30-4,00	TN-1	24.5	2.66	37.3	18.1	19.2	93.6	91.2	77.9	65.3	CL	ND1		1.638	19.2				
D-403	0,20-2,00	TN-1	16.9	2.68	48.3	16.6	31.7	73.0	70.0	61.9	49.6	SC			1.693	16.3				
D-404	0,30-1,20	TN-1	8.2	2.69	48.7	18.6	30.1	94.9	92.2	89.0	82.5	CL	ND2		1.600	22.6				
D-405	1,20-3,20	TN-2	15.9	2.65	41.2	18.8	22.4	99.3	98.1	90.6	68.5	CL		1.08E-06	1.649	21.3	0.83	10	1.315	0.14
D-406	0,30-1,80	TN-1	16.5	2.68	42.7	19.8	22.9	22.9	82.1	78.4	67.8	CL		2.23E-06	1.829	14.8				
D-407	0,30-4,10	TN-1	14.1	2.65	38.4	21.9	16.5	16.5	76.5	67.4	49.2	SC		1.93E-06	1.762	18.1	1.51	11		
D-408	0,30-2,10	TN-1	12.4	2.68	47.5	20.4	27.1	27.1	94.3	90.8	83.6	CL	ND1		1.694	20.7				
D-409	2,10-3,70	TN-2	22.8	2.70	52.2	25.0	27.2	27.2	77.1	69.3	55.6	SC			1.510	26.1				

from B impermeable NSM is %8.6 gravel, %27.6 sand and %63.8 fine material (clay and silt). Grain size distribution chart is shown on figure 5.

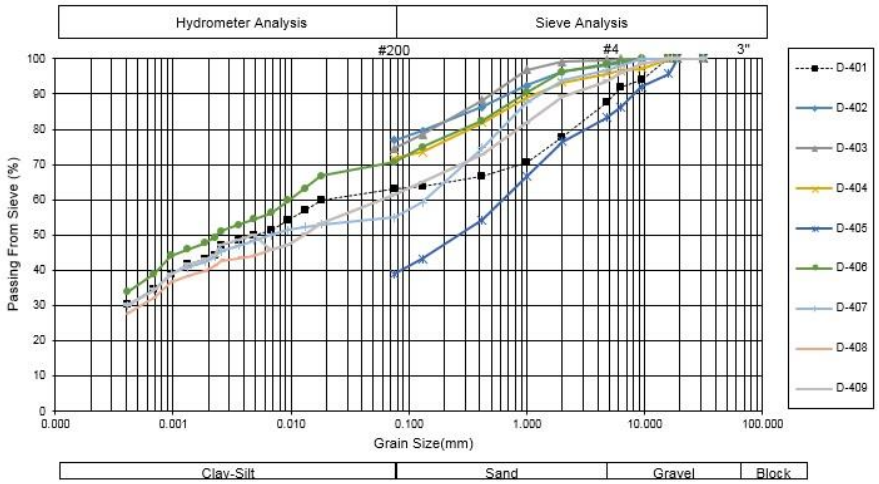

Figure 5. Grain size distribution of D impermeable NSM

4.3 E Permeable NSM Area

8 trial pits have been opened in E permeable NSM area. Depth of these trial pits changes between 2.00 m - 3.60 m. Soil samples are taken from E-501, E-502, E-503, E-504, E-505, E-506, E-507 and E-508 numbered trial pits. Sample taken from E-501 is GM, E-502 is SP-SM, E-503 and E-505 are GP, E-504 and E-508 are GW-GM, E-506 GP-GM and E-507 is GW based on the unified soil classification system (table 4).

Table 4. Laboratory test results of E permeable NSM area

TRIAL PIT NO	DEPTH (m)	NATURAL UNIT WEIGHT (g/cm3)	RELATIVE DENSITY (g/cm3)		WATER SUCTION (%)		WATER CONTENT (%)	RATIO OF FINE MATERIAL (%)		CLAY FLOCCULATION (%)		ABRASION	
			FINE	COARSE	FINE	COARSE		FINE	COARSE	FINE	COARSE	100 RPM	500 RPM
E-501	0,10-2,50	1.6	2.68	2.66	1.50	1.00	5.1	4.77	6.93	0.22	0.07	3.80	22.65
E-502	0,20-3,00	1.59	2.7	2.64	1.60	1.30	16.2	12.9	3.12	0.31	0.08	4.30	21.05
E-503	0,10-2,50	1.57	2.66	2.66	1.50	0.90	5.3	3.76	1.13	0.21	0.12	4.75	22.40
E-504	0,10-2,00	1.59	2.69	2.65	2.00	1.20	8.2	3.65	0.67	0.54	0.13	3.42	22.32
E-505	0,10-3,00	1.59	2.70	2.67	2.10	1.40	6.2	4.28	0.82	0.18	0.20	4.35	21.50
E-506	0,10-3,00	1.61	2.71	2.63	2.90	1.80	6.7	4.39	0.59	0.53	0.23	4.54	22.32
E-507	0,10-3,60	1.6	2.68	2.68	2.60	1.60	8.1	2.35	0.57	0.12	0.08	4390	21.80
E-508	0,10-3,10	1.58	2.70	2.66	2.50	1.90	6.8	2.31	0.49	0.23	0.12	2.84	22.15

TRIAL PIT NO	FREEZING RESISTANCE (Na2SO4)		SHEAR BOX (UU)		*SIEVE ANALYSIS*			*USCS SOIL CLASS*	*ALCALI SILICATE REACTION*		Permeability Test	Organic Material (%)	MODIFIED PROCTOR	
	FINE	COARSE	c (kg/cm²)	ϕ (°)	Clay Silt (%)	Sand (%)	Gravel (%)		(Sc) (mmol/l)	(Rc) (mmol/l)	(k20) (cm/sn)		Max. Dry Unit Weight (t/m3)	Wopt (%)
E-501	3.15	2.67	0.237	22	13.20	24.30	62.5	GM	111.30	153.0	1.18E-03	1.12	2.005	9.9
E-502	2.95	3.15			7.20	48.30	44.5	SP-SM					2.105	11.0
E-503	2.85	2.65			1.50	26.60	72.0	GP					2.100	9.6
E-504	3.20	3.15			5.30	28.10	66.7	GW-GM					1.872	12.2
E-505	3.61	3.34	0.221	26	4.40	32.80	62.8	GP	98.10	144.5	1.21E-03	1.53	2.029	10.4
E-506	3.75	3.58	0.253	25	5.80	32.90	61.3	GP-GM	102.30	144.0	1.17E-03	1.72	2.017	10.3
E-507	3.34	3.22	0.174	24	4.10	31.80	64.0	GW	88.10	153.0	1.12E-03	1.64	2.016	11.2
E-508	3.49	3.29	0.223	21	5.40	32.30	62.3	GW-GM				1.34	2.085	10.7

After stripping 10 cm of organic soil, 272000 m3 permeable NSM can be utilized in Orhanlar Dam with the 2.70 m of exploitation depth. Mean granulometric percentage of the material taken from C permeable NSM is %52.0 gravel, %42.1 sand and %5.9 fine material (clay and silt). Grain size distribution chart is shown on figure 6.

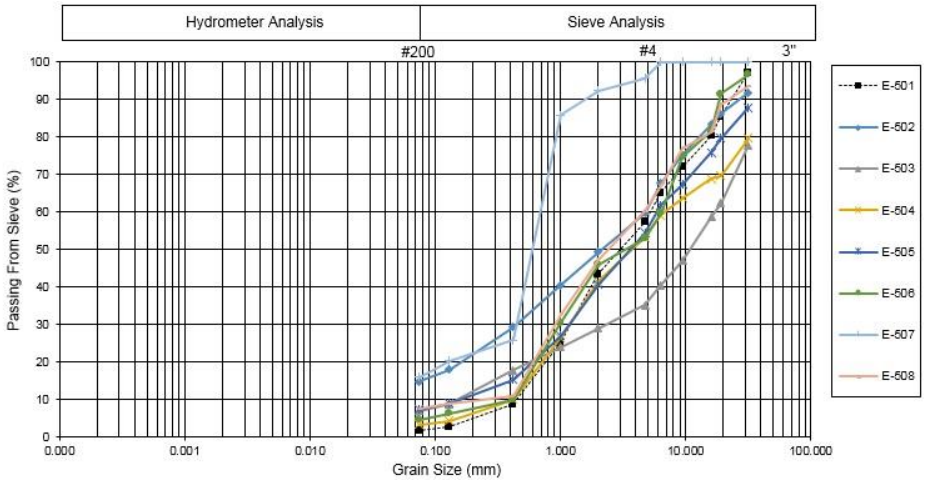

Figure 6. Grain size distribution of C permeable NSM

4.4 Rock NSM Area

Intact rock sample is taken from Rock NSM area, in order to analyse the usability as a rock fill material in Orhanlar Dam. Laboratory test results performed on the intact rock sample are within tolerable limits (table 6). With regard to the quantity also Rock NSM area provides sufficient rock material. More than 1 000 000 m^3 rock NSM can be utilized in Orhanlar Dam with the 20 m of exploitation depth. Transportation from Rock NSM area to Orhanlar Dam axis is planned to realize with 6.3 km of existing road.

Table 6. Laboratory test results of Kaya-1 rock NSM area

	UNIT VOLUME MASS AND VOID RATIO							DENSITY AND POROSITY				NATURAL UNIT WEIGHT (g/cm^3)	UNIAXIAL COMPRESSIVE STRENGTH (qu) (kg/cm^2)	STRENGTH LOST AFTER FREEZING (%)	RESISTANCE TO FREEZING (% aggregate loose)	LOS ANGELES ABRASION (%)	
	UNIT MASS (g/cm3)			VOID RATIO (e)	NATURAL WATER CONTENT (%)	WATER SUCTION (%)		SPECIFIC GRAVITY (GS)	DENSITY-SATURITY RATIO (%)	POROSITY (%)						100 RPM	500 RPM
	NATURAL	DRY	SATURATED			BY MASS	BY VOLUME			EFFECTIVE POROSITY (%)	REAL POROSITY (%)						
T-1	2.60	2.60	2.61	0.013	0.22	0.49	1.37	2.70	98.20	1.37	6.07	2.60	544.0	2.15	3.12	4.90	21.20

5. Results and Conclusions

Agricultural and rural projects become important depending upon the rapidly increasing world population. In spite of arable land existence in Turkey, agricultural activities are not economic due to the lack of irrigation. Contribution to agricultural economy of the small dams constructed for agricultural irrigation is crucial.

The most important factor for the decision of dam body type during planning stage is NSM possibility and usability. For this reason, NSM potentialities are analysed in the near environ of Orhanlar Dam axis and suitable dam body optimization have been performed. In this context, Orhanlar Dam is planned to construct as "clay cored rock filled dam" with the height of 33.20 m.

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7. References

[1] Aral İ F. Karatepe bazaltlarının (Çorlu Tekirdağ) yapı malzemesi olarak kullanılabilirliği. İstanbul Üniversitesi Mühendislik Fakültesi Yer Bilimleri Dergisi 2004; 17: 69-76.
[2] Akçalı E ve Arman H. Baraj dolgularında kullanılan doğal malzemenin seçim kriterleri ve limit aşımının doğuracağı tehlikeler. *DSİ Teknik Bülteni* 2008; 103: 1-9.
[3] Çelik M Y ve Kavas T. Elvanpaşa (Afyon) trakiandezitlerinin jeolojisi ve yapıtaşı olarak kullanılabilirliğinin araştırılması. Osmangazi Üviversitesi Müh. Mim. Fak. Dergisi 2001; 14: 24-36.
[4] Binal A. The determination of gel swelling pressure of reactive aggregates by ASPGM device and a new rective-innocuous aggregate decision chart. Construction And Building 2008; 22:1218-1228.
[5] Binal A and Kasapoğlu K E. Design and application of the mortar cylinder test for determination of effect of the alkali silica reaction concrete aggregates. International Symposium on Industrial Minerals and Building Stones (IMBS 2003), İstanbul, 625-632, 2003.
[6] Ulusay R, Tuncay E, Hasançebi N. Preliminary assessment on geo-engineering properties of peaty soils and consolidation settlement at an organized industrial district (Turkey). Bulletin of Engineering Geology and the Environment 2010; 69: 397-410.
[7] Avşar Ö, Güleç N, Parlaktuna, M,. Hydrogeochemical characterization and conceptual modeling of the Edremit geothermal field (NW Turkey). *Journal of Volcanology and Geothermal Research* 2013; 262: 68-79.
[8] Suyapı. Orhanlar Göleti Mühendislik Jeolojisi Raporu. 2015.

[9] Bacak G ve Uz B. Dağardı güneyi (Kütahya) ofiyolitinin jeolojisi ve jeokimyasal özellikleri. *Itüdergisi/d mühendislik* 2003; c2-4: 86-98
[10] Kalafatçıoğlu A. Balıkesir – Kütahya Arasındaki Bölgenin Jeolojisi. *MTA dergisi* 1964; 46-62.