Geotech Geol Eng (2013) 31:1137–1149
DOI 10.1007/s10706-013-9640-8

ORIGINAL PAPER

Effect of Construction Material on Dam Type Selection of the Büyük Karaçay Dam (Hatay, Turkey)

Sedat Türkmen · Hidayet Tağa · Eray Özgüler

Received: 20 December 2012 / Accepted: 12 March 2013 / Published online: 21 March 2013

Abstract This paper covers the investigation of construction materials and selection of the dam type for the Büyük Karaçay Dam, which was planned to be constructed on Büyük Karaçay River 20 km to the SW of Hatay (Southern Turkey). The purposes of the dam are irrigation, domestic water supply, and producing energy. Auxiliary structures locations have been determined during the study of detailed geological maps of the dam axis and reservoir area. Quality, quantity and hauling distance of natural construction materials were effective to select different dam types. For engineering geological studies exploration boreholes were drilled at the dam site; pressuremeter tests were performed in order to determine bearing capacity and elasticity properties of rocks; pressured water tests were also performed to determine permeability of the dam site. Moreover, physical and mechanical properties of rocks were determined by the laboratory test. In the feasibility stage, the dam type was chosen as the central core rock-fill dam, depending on state of natural construction materials. In design stage dam type was changed as faced symmetrical hardfill dam. Finally, the dam type was revised again during the design stage as concrete face rockfill dam.

Keywords Construction materials · Dam type selection · Engineering geology · Rock fill

S. Türkmen (✉)
Department of Geological Engineering,
Çukurova University, Adana, Turkey
e-mail: sturkmen@yahoo.com; sturkmen@cu.edu.tr

H. Tağa
Department of Geological Engineering,
Mersin University, Mersin, Turkey
e-mail: htaga@mersin.edu.tr

E. Özgüler
General Directorate of State Hydraulic Works,
Ankara, Turkey
e-mail: era_61@yahoo.com

1 Introduction

During the early stages of planning and design of the dam project, the site and type selection should be carefully considered. The selection of the best type of dam for a particular site calls for thorough consideration of the characteristics of each type, as related to geological conditions of the site and to the purposes the dam is supposed to serve, as well as safety, economy, environmental factors, engineering properties of the natural construction materials and other pertinent limitations (Emiroğlu 2008). In this study, the final decision of type of dam is made after consideration of these factors.

The aim of this study is to determine dam feasibility decide the location and type of dam and carry out the detailed engineering geological investigations of the Karaçay Dam. Boreholes were drilled in order to determine the geological and engineering properties of foundation rock at the dam site. Physical and mechanical in situ and laboratory tests were performed at different levels of these drillings. In this paper, studies related to dam-type selection, properties of natural construction materials and quarries, as wells as the environmental effects and costs were evaluated. Project characteristics are summarized in Table 1.

Karaçay dam is planned to be constructed around Samandağı area, (Hatay) which is located 20 km to the SW of Antakya (Antiochia). It has 110 m height and dam type is concrete face rockfill dam (CFRD) (Türkmen 1993). The purposes of the dam are irrigation, domestic water-supply and energy. Study area is located at south of Turkey near to Syria border and the dam is on the river Büyük Karaçay which runs to east at SW of Hatay Province (Figs. 1, 2).

The engineering features of natural construction materials are one of the most important factors in the selection of dam type. At two different areas six rock quarries and one aggregate area in the river bed were determined as possible dam filling materials. At the feasibility stage, the dam type according to availability of natural construction materials was selected as rockfill, central core dam. Then, the dam type was changed to faced symmetrical hardfill dam (FSHD, a variant of the type of RCC) due to the distance of the rock quarry area from the dam site and the unsuitable properties of rock materials (Öztürk and Yıldız 1998; Dunstan 1994). Finally, the dam type was changed again at the design stage to CFRD because of the legal and environmental problems relating to aggregate source area.

Table 1 Technical data for the dam

Purpose	Domestic water supply, irrigation and energy
Type	Concrete face rockfill dam (CFRD)
Crest elevation	365.00 m
Thalweg elevation	255.00 m
Height of dam from tailwater	110.00 m
Crest length	260.00 m
Reservoir surface area	110 ha
Reservoir volume	29 hm^3
Spillway location	Left abutment
Diversion tunnel location	Right abutment
Irrigation area	3,850 ha

The Geological map of the dam site and reservoir area was prepared after evaluation of drilling logs and materials, from which dam stability and permeability were also the determined. Also physical and mechanical properties of natural construction materials were investigated.

Outcrops of ultrabasic and basic magmatic rocks of Kızıldağ Ophiolites are located at the dam site and reservoir area (Selçuk 1985; Türkmen 1993). These ophiolites cover wide areas around Antakya and its vicinity. Many researchers have shown interest in this unit for many reasons and detailed geological studies were conducted on ophiolites. (Ericson 1940; DSİ 1957; Vuagnat and Çoğulu 1967; Aslaner 1973; Delaloye et al. 1980; Tinkler et al. 1981; Selçuk 1981, 1985; Bağcı 2004).

The proximity of the East Anatolian Fault is also important in neotectonics point of view. The dam site is located at 1st degree Earthquake zone according to Earthquake Zones Map of Turkey (ERD 1996).

At the site, engineering geological studies are few. The Yarseli, Karamanlı, Reyhanlı and Yayladağ dams are near. Engineering geology studies of such structures were carried out by different researchers and institutions (DSİ 1957; Karaoğullarından 1985; Bahadırlı 1992). Preliminary stage engineering geology and natural construction material studies of Karaçay Dam were conducted by in 1993 (Türkmen 1993).

2 Geological Setting

In the study area and its vicinity three main geological units can be distinguished. These are (1) Autochthonous units, (2) Allochtonous units (Kızıldağ ophiolite) and (3) Young Autochthonous units. Autochthonous units are represented by Upper Jurassic (Malm)-Upper Cretaceous (Santonian) shallow sea sediments. The data show that autochthonous units haven't been effected by important tectonic movements during this period (Selçuk 1985).

Alloctonous units are represented by the Kızıldağ ophiolite composed of ultrabasic rocks originated from upper mantle/oceanic crust and the uppermost part of ophiolites are characterized by volcano-sedimentary rocks. Kızıldağ ophiolite is comprised of tectonites, cumulates (ultramafic cumulates, cumulate gabro) isotropic gabbro, diabase dike complex and

Fig. 1 Location map of the study area

volcanic rocks, of which emplacement age was determined to be Upper Cretaceous (Selçuk 1985). Cenozoic units unconformably cover the Mesozoic units. These units are mainly made up of the alternation of reefal limestone and claystone-sandstone–siltstone, which probably deposited in a shallow marine environment (Fig. 3).

Miocene units are characterized by shallow marine sediments in the study area. The general strikes of the bedding planes are around N30°E and dip of these beds range between 0 and 30° to the SE. Quaternary units such as conglomerates, alluviums and slope debris are present around the dam site (Fig. 3).

Ultrabasic and basic igneous rocks outcrop at the dam site and reservoir area (Figs. 3, 4). Karaçay valley is located in Kızıldağ (Hatay) ophiolite which is one of the best preserved ophiolitic massives of southern Turkey.

Ultramafic–mafic cumulates in the Kızıldağ (Hatay) ophiolite are perfectly observed in the Karaçay valley and have approximately 700 m thickness (Bağcı 2004). The basal parts of the ophiolites starts with tectonites. Tectonites mainly consist of harzburgite, dunite and small amount of lerzolite-verlite. Tectonites are highly fractured, where weathering surfaces are red-reddish beige, brown coloured; serpentinized fresh surfaces are dark green–green

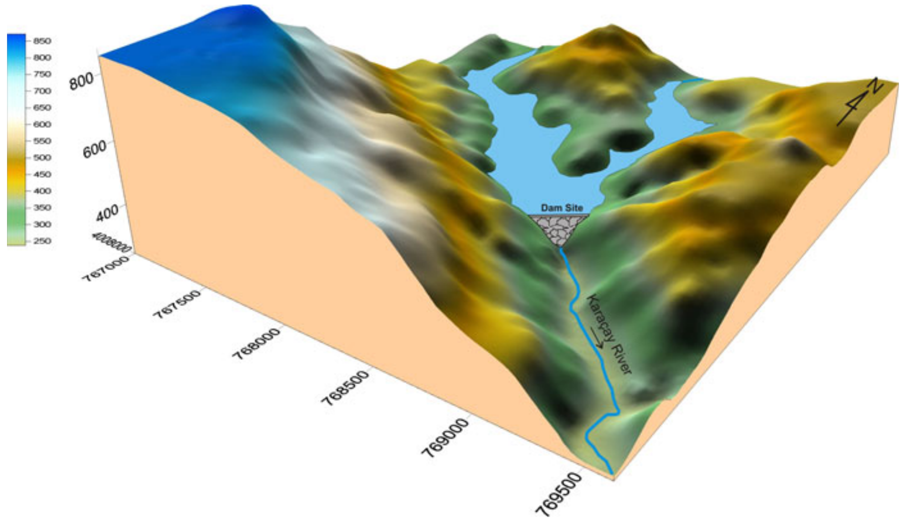


Fig. 2 Block diagram of the dam site

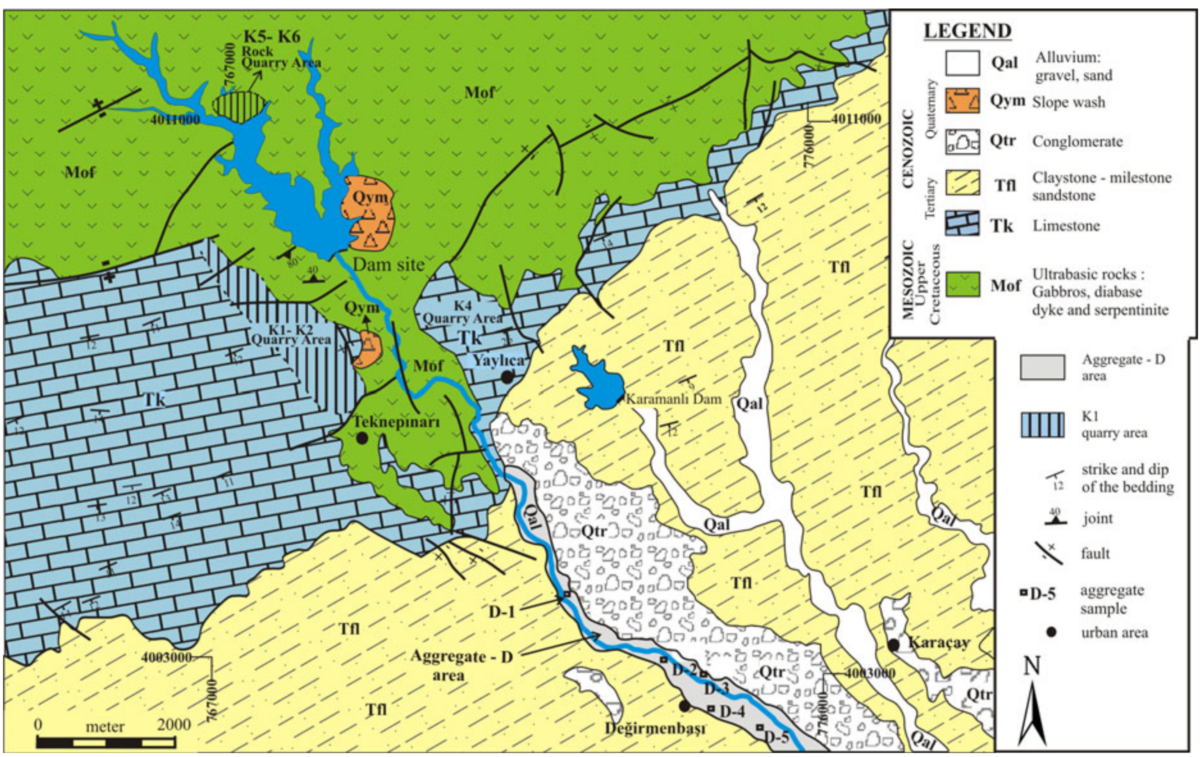


Fig. 3 Geological map of the dam site and surrounding area

coloured. Tectonites have foliation and lineation planes which show plastic deformation traces and serpentinized is common.

Mafic cumulates consist of gabbro, olivine gabbro and the upper parts pass into isotrope gabbros. The thickness of these bands range from 2 to 50 cm and from 2 to 3 m (Fig. 5).

Gabbros are represented by gabbro-diorite and quartz-diorite and show hypidiomorphic texture and weathering surfaces that are brown, light brown–green coloured; fresh joint surfaces are dark green–green coloured. Ophiolitic rocks differ along Karaçay valley over short distances. Because of this high strength rocks and weak planes can be observed close to each

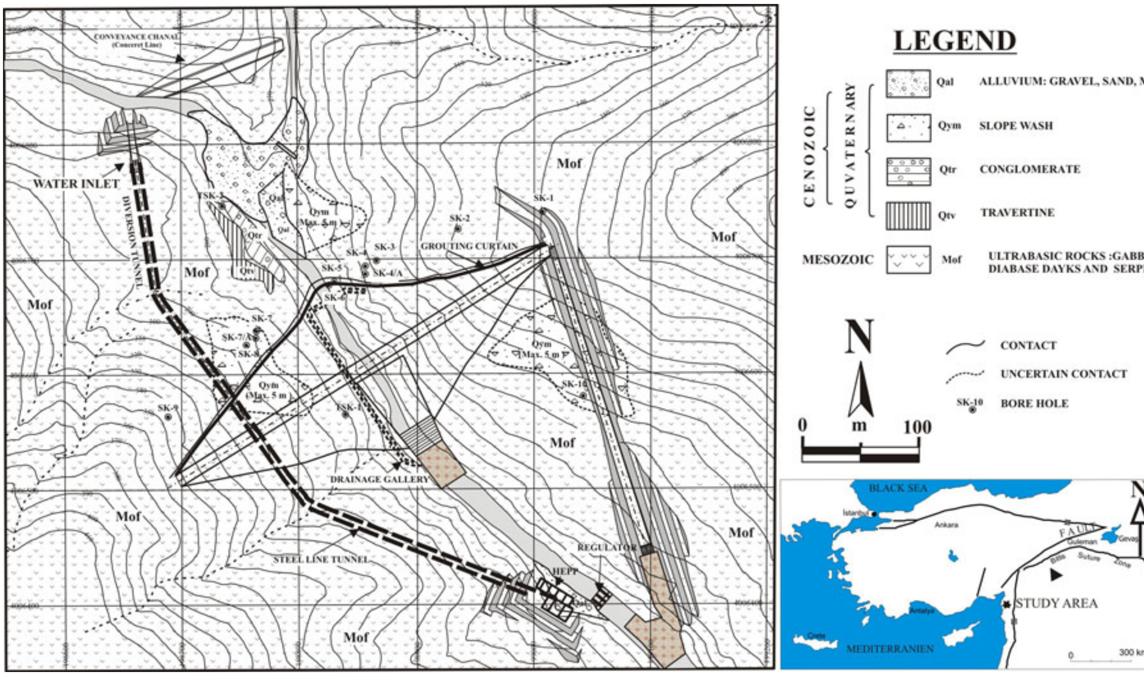


Fig. 4 Geological map of the dam site

other. These rocks are mapped as ophiolitic rocks (Figs. 4, 5).

More than one joint set can be observed in ultrabasic rocks which are outcropped at the dam site and in the reservoir area. Generally joint strike and dips are N30–50E/40–70NW. Folding is not clear but foliation and lineation can be seen at isoclinal foldings.

3 Foundation Investigations at the Dam Site

Engineering geological investigations and rock mechanics studies mainly include discontinuity surveying (ISRM 1981), core drilling (ASTM D2113 2008; ASTM D5079 2008), in situ and laboratory testing (ASTM C88 1999; ASTM C127 2001; ASTM C131 2003; ASTM D2113 2008; ASTM D5079 2008).

Borings were drilled at Karaçay Dam site to verify foundation conditions and to obtain rock samples for laboratory testing. A total of 14 boreholes, 870 m in length were drilled on the dam axis (Fig. 6), Additionally, 73 pressuremeter tests were performed at every 1.5 m of 3 pressuremeter holes which have 40 m depth. In studies of drilling cores, rock quality designation (RQD) and total drilling core recovery (TCR) average values were determined as 55.56 and 80.34 %, respectively (ASTM D6032 2008).

Quantitative description of discontinuities including orientation, spacing, persistence, aperture and filling were determined at the site by exposure logging in accordance to ISRM (1981). A total of 280 discontinuities on the dam site were measured. Four dominant discontinuity sets are determined on the dam site. Dominant discontinuity sets are J1: 300/48, J2: 20/65, J3: 130/70 and J4: 170/65 respectively. Table 2 shows quantitative descriptions and statistical distributions of discontinuities of foundation rock at the site according to ISRM (1981).

4 Physical and Mechanical Properties of Rocks at the Dam Site

Laboratory and in situ tests were performed in order to discover the physical and mechanical properties of core samples taken from boreholes. Laboratory test

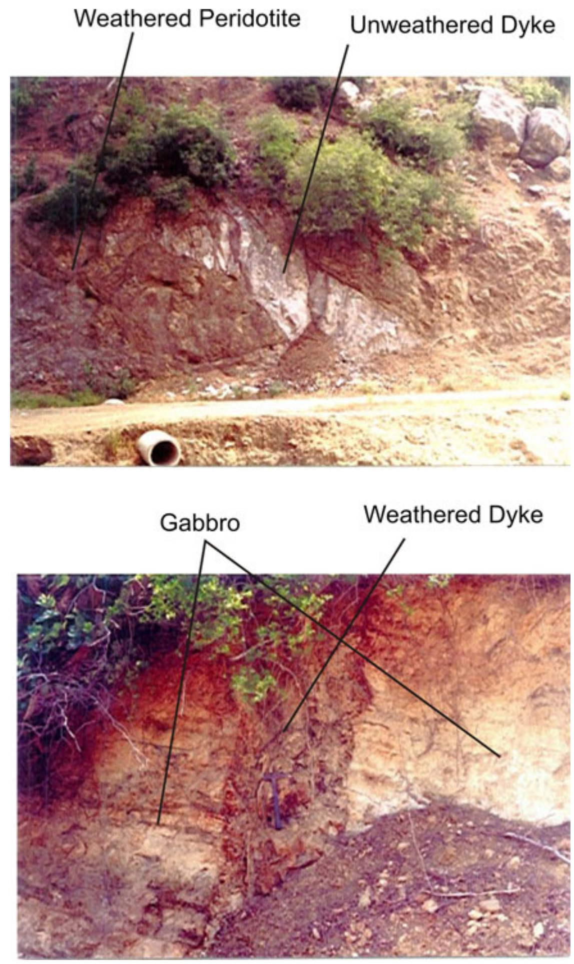


Fig. 5 View of dykes into the ophiolitic rock in the dam site

results are shown in Tables 3 and 4 (ASTM C97 2009; ASTM D2216 2005; ASTM D854 2010).

4.1 Pressuremeter Tests

Menard GA type device and 56 mm diameter prop were used (Ménard 1975). Test program was designed according to purpose of tests, foundation conditions and project characteristics. Limit Pressure (P_L) and Menard Elastic Modulus (Ep) were obtained in the results of the tests. Using these data bearing capacity (qu) according to foundation dimensions and settlement (S) under project loads were calculated (Bagualin et al. 1978), (Table 5).

Gabbros and peridotites were drilled along the boreholes. According to pressuremeter test results it was determined that peridotites have high and differential values. Gabbros have lower but regular values. At PRSK-A4 borehole Gabbros have P_L = 35.0–65.0 kg/cm^2, E_P = 586–1,290 kg/cm^2; E_P/P_L ratio differs 15.0–20.0. At PRSK-5A borehole Peridotites have P_L = 38.0–72.0 kg/cm^2, E_P = 1,138–2,151 kg/cm^2; E_P/P_L ratio is 30.0. At PRSK-7A borehole tests couldn't performed because of the talus and decomposed gneiss. Other levels are observed as peridotite and P_L = 38.0–58.0 kg/cm^2, E_P = 648–1,507 kg/cm^2; E_P/P_L ratio varies from 15.0 to 20.0. According to these results the dam site lithology can be determined as good rock.

5 Permeability of Dam Site

Lugeon values of rocks outcropped at dam site were obtained from pressured water tests at boreholes. Generally foundation rock is impervious or low permeable (Fig. 7). Although at some levels water losses are high due to the existing local faults and joints, generally a problem in terms of permeability is not expected.

A geological cross-section of the dam site was prepared using information from exploration holes. It has been determined that there are four different permeability zones at the foundation rock of the dam site according to lugeon test results. The permeability zones along the dam axis are shown in Fig. 7.

It was determined that a 30–45 m deep grout curtain is needed considering the permeability, degree of alteration, and lithological properties of the foundation rock. The contact grouting was planned at two rows along both sides of the grout curtain along the dam axis (Fig. 8).

6 Natural Construction Materials

During the studies the dam type was planned to be impervious cored rock-fill dam. So at that time four different areas four rock quarries were studied (Fig. 3). These rock quarries are named K1, K2, K3, and K4. K1 and K2 rock quarry areas which are 800 m from the dam site were investigated. The elevation of this quarry area is 400 m high from dam site, however a new road (total 7 km) would have to be constructed. The K3 rock quarry at the north of the dam site is

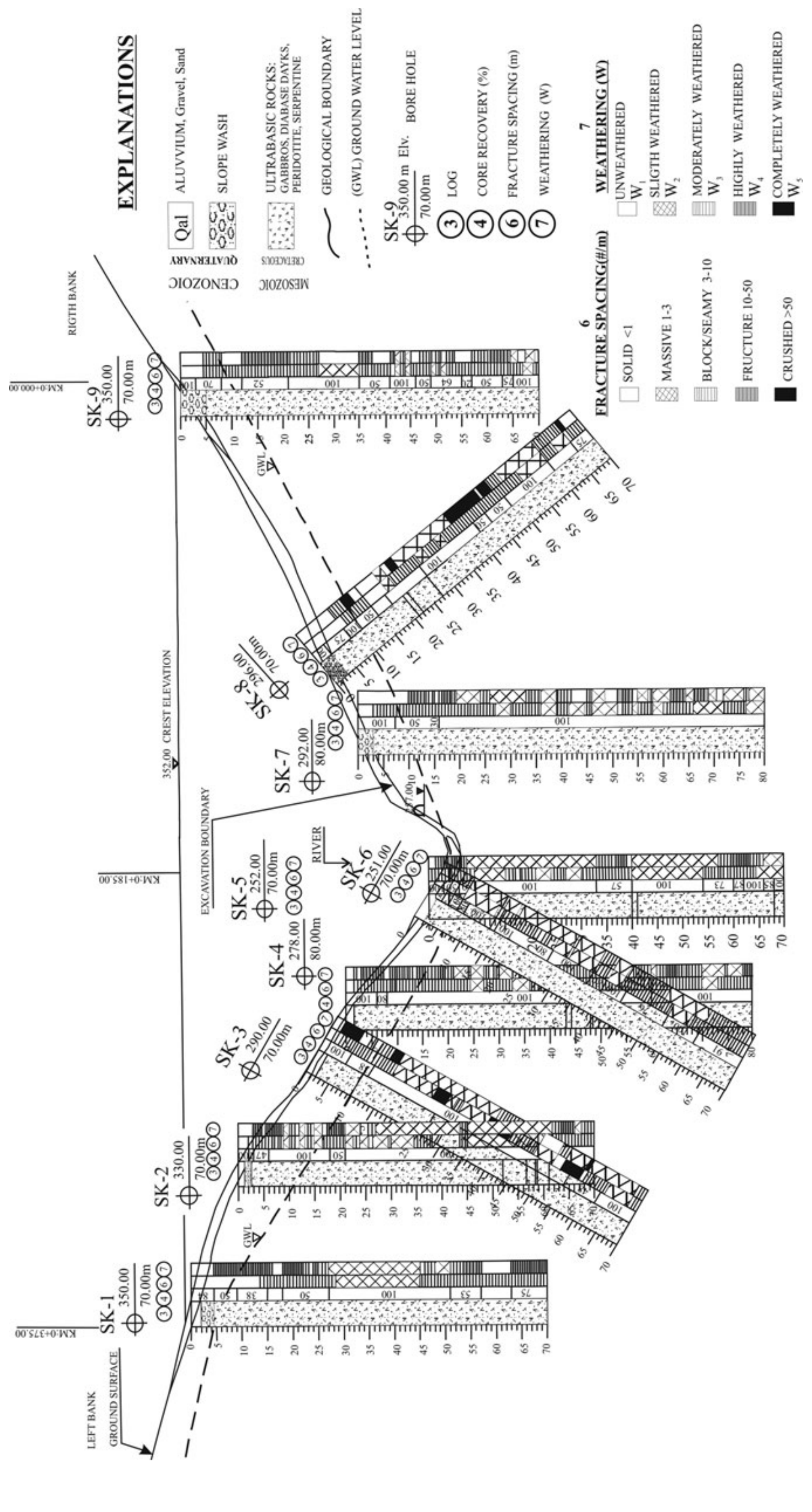


Fig. 6 Boreholes and cross section along the dam axis

Table 2 Quantitative descriptions and statistical distributions of discontinuities of foundation rocks

	Range	Description	Distribution (%)
Spacing (m)	<0.02	Extremely close	12
	0.02–0.060	Very close	28
	0.06–0.2	Close	32
	0.2–0.6	Moderate	26
	0.6–2	Wide spacing	2
Persistence (m)	1–3	Low	38
	3–10	Medium	44
	10–20	High	18
Aperturea* (mm)	0.1–0.25	Tight	44
	0.25–0.5	Partly open	32
	0.5–2.5	Open	20
	2.5–10	Widely open	4

* Aperture of discontinuities contain mostly chlorite, talc, silica, serpentine and clay infilling materials

located near residential area and it is not suitable as quarry. K1, K2, and K3 are composed of limestone quarries. The K4 rock quarry at the dam site is appropriate but the volume of material is insufficient. The results of laboratory studies carried out on samples are analyzed, the water absorption and frost Na_2SO_4 loss values higher limits (ASTM C88 1999), the limits on the uniaxial compressive strength is lower (ISRM 1981). During the feasibility stage three impervious material areas were determined also (1994). Now these areas have become urban areas. As a result of additional studies new impervious materials areas are not within in economical hauling distances. For that reason non impervious material dam types were considered. Therefore, it was decided to work on the FSHD type, a variant of the type of RCC (Dunstan 1994).

Aggregate need of hardfill dam is around 1,226,000 m^3. The material will be provided from "D" pervious material area. The area is 9 km from dam site. There is a asphalt road between dam site and material area. Material thickness is minimum of 2 m and according to this depth approximately 2,000,000 m^3 material can be obtained. This amount is nearly twice of material needed. Eight test pits were opened to investigate natural construction material. Group symbol of the material is GP-SP according to USCS (Fig. 9). Average granulometry of the material is as follows: gravel 65 %, sand 32 % and fines (clay-silt) 3 %. Cobble and boulder percentage becomes higher in deeper levels of test pits. For that reason 2 m of the area which is around 20 %, is recommended to be excavated. Due to economic conditions related to the aggregate area, the dam type was revised as CFRD.

Table 3 Physical properties of samples taken from boreholes

Sample location (bore hole and depth)	Rock type	Specific gravity	Unit weight gr/cm^3	Water suction %	Relative porosity %
TSK-1 19.60–20 m	Olivine gabbro	3.00	2.88	0.3	0.9
TSK-1 21.70–22 m	Olivine gabbro	2.96	2.86	0.5	1.4
TSK-1 34.10–34.45 m	Olivine gabbro	3.10	2.91	0.4	1.2
SK-7 47.00–47.30 m	Serpentinized peridotite	2.80	2.67	0.7	1.9
SK-7 29.40–47.30 m	Serpentinized peridotite	2.90	2.62	2.1	5.5
SK-7 21.15–21.65 m	Serpentinized peridotite	2.83	2.65	0.8	2.1
SK-5 17.00–17.30 m	Serpentinized peridotite with plagioclase	3.02	2.86	0.4	1.1
SK-9 23.00–32.20 m	Serpentinized peridotite with plagioclase	2.99	2.86	0.4	1.1
SK-9 24.00–24.18 m	Olivine gabbro	3.25	3.07	0.3	0.9
SK-8 24.50–24.75 m	Serpentinized peridotite	2.96	2.84	0.5	1.4
SK-1 44.35–44.60 m	Olivine gabbro	3.33	3.00	0.2	0.6
SK-1 51.25–51.45 m	Silisified gabbro	3.00	2.77	0.6	1.7
SK-3 15.15–15.30 m	Serpentinized peridotite with plagioclase	3.25	3.04	0.9	2.7
SK-3 23.50–23.80 m	Serpentinized peridotite with plagioclase	3.01	2.95	0.2	0.6
SK-3 37.50–37.70 m	Olivine gabbro	3.04	2.87	1.0	2.7
SK-5 21.50–21.70 m	Serpentinized peridotite	2.91	2.72	0.4	1.1

Table 4 Mechanical properties of samples taken from boreholes

Sample location and rock type	Dry unconfined compressive strength (MPa)		Saturated unconfined compressive strength (MPa)	Dry—elastic modulus (GPa)
	I	II		
TSK-1 19.60–20 m Olivine gabbro	62	77.5	13	77.8
TSK-1 21.70–22 m Olivine gabbro	21	35.5	–	56.8
TSK-1 34.10–34.45 m Olivine gabbro	50	55	50	73
SK-7 47.00–47.30 m Serpentinized peridotite	–	15	–	17.8
SK-7 29.40–47.30 m Serpentinized peridotite	6	7.5	–	27
SK-7 21.15–21.65 m Serpentinized peridotite	7.5	20	–	87
SK-5 17.00–17.30 m Serpentinized peridotite with plagioclase	55.0	77	36	76.5
SK-9 23.00–32.20 m Serpentinized peridotite with plagioclase	31	37	–	36.5
SK-9 24.00–24.18 m Olivine gabbro	34.5	61	–	97
SK-8 24.50–24.75 m Serpentinized peridotite	44	49	–	57.5
SK-1 44.35–44.60 m Olivine gabbro	57.5	74.5	72	85.3
SK-1 51.25–51.45 m Silisified gabbro	17.5	59	16	56.4
SK-3 15.15–15.30 m Serpentinized peridotite with plagioclase	15	27	–	72
SK-3 23.50–23.80 m Serpentinized peridotite with plagioclase	46	50	–	78.5
SK-3 37.50–37.70 m Olivine gabbro	7	17	–	28
SK-5 21.50–21.70 m Serpentinized peridotite	45	72	51	71.5

I-Tension at max. load; II-Tension at failure load

For this reason, at design stage alternative quarry areas were investigated determining two potential quarry areas. K5 and K6 rock quarry at the reservoir area is 2.5 km away from the dam site. K5 and K6 are composed ultrabasic rocks (e.g. gabbro, diabase). Rock samples taken from the rock quarries K5 and K6 have shown high values for the uniaxial compressive strength test. The other properties of rock materials are also very suitable to be used for filling. New reserves in the rock quarries are sufficient for CFRD. Mechanical and physical properties of the rock samples collected from the all quarries are given in Tables 6 and 7.

7 Environmental Issues

Faced symmetrical hardfill dam needs 1,226,000 m^3 of natural construction material for filling. It needs

Table 5 Bearing capacity and settlement of the dam foundation

Test location (borehole)	Test method	Foundation depth (m)	Bearing capacity (kgf/cm^2)	Safety number	Settlement (cm)
PRSK-4A	Pressiometter	3.00	52.8	3	0.85
PRSK-5A	Pressiometter	3.00	83.5	3	0.41
PRSK-7A	Pressiometter	7.00	57.9	3	0.73

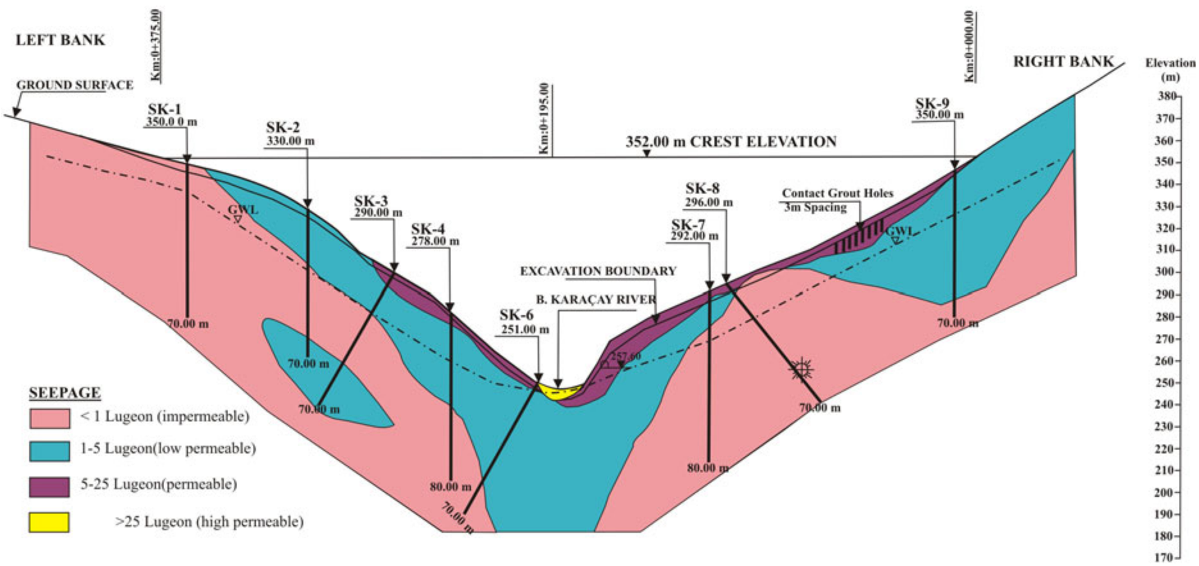


Fig. 7 Permability zones of along the dam axis

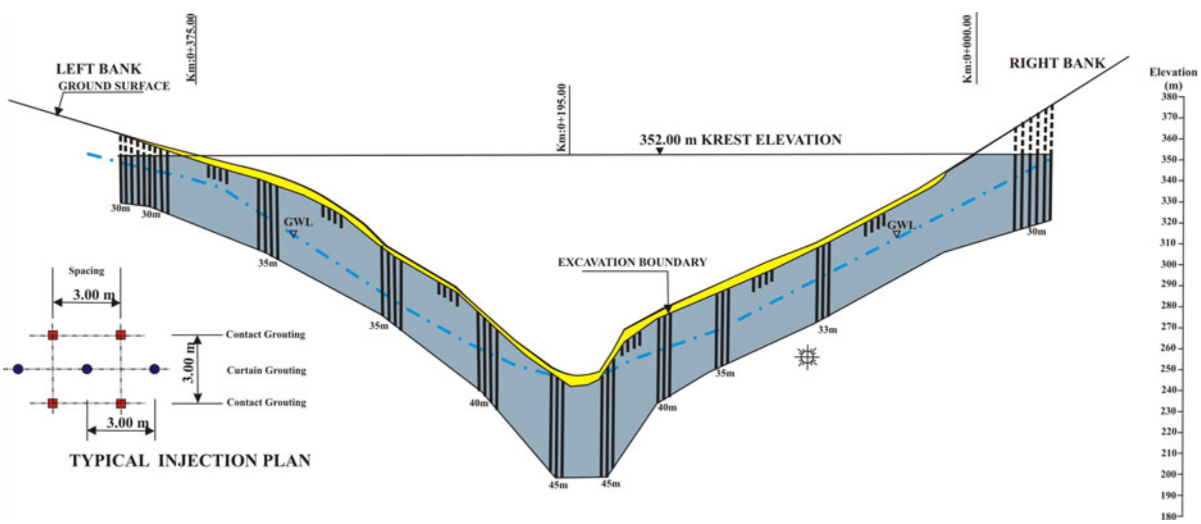


Fig. 8 Grout curtain of the Karaçay dam site

a large amount of excavation to obtain 1,226,000 m^3 of natural construction on the Karaçay River bed. “D” aggregate material areas are mostly used for agriculture.

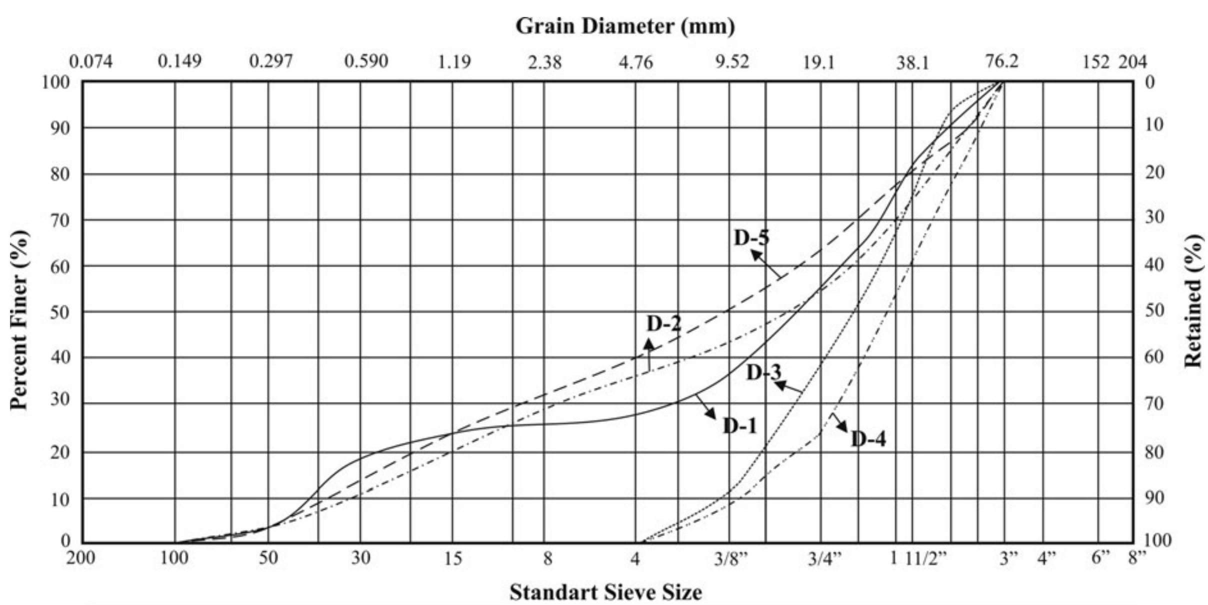
‘’D” aggregate material areas are completely covered with trees and vegetation will almost completely be destroyed. Source areas are composed completely of alluvial material. Groundwater is available in these areas and used for irrigation and drinking water. Excavations in this area may change the groundwater levels and flow directions. The purchase of private ownership of these areas will cost much and also some social problems may arise.

K1-K2-K3 rock quarries close to residential areas will create problems in terms of environmental impact because of quarry operation in this areas. Because these areas (K1, K2, K3) are forests or woods too many trees will have to be cut down. Besides, the limestone areas of excavations and land degradation will lead to accelerated erosion.

8 Conclusion

Mesozoic aged ultrabasic rocks and Cenozoic aged sedimentary rocks, Quaternary aged old and actual alluvium and talus are observed at the study area. Drillings were performed in gabbros and peridotites. Along the dam axis 14 boreholes, totalling 870 m in length were drilled. Also 73 pressuremeter tests were performed at every 1.5 m of three pressuremeter holes which have 40 m depth. Laboratory and in situ tests were performed to determine physical and mechanical properties of core samples taken from boreholes.

Drilling bore holes, the weathering of rock, core recovery, fracture spacing, groundwater level and lithologies are shown at the cross-section of the dam axis in the Fig. 6 in detail. The ultrabasic rocks making up the dam foundation is determined as high-strength and moderate jointed and impermeable according to the test results and field investigation. According to pressuremeter test results dam foundation can be determined as good rock.



Sand			Gravel		Block
Fine	Medium	Coarse	Fine	Coarse	

Sample No	Unit weight (g/cm^3)		Specific gravity		Water Suction (%)	Los Angeles Abrasion value (500 revolutions) (%)	Alkali reactivity		$Na_2 So_4$ Freeze resistance (%)		Group symbol
	Sand	Gravel	Sand	Gravel			Reduction in alkalinity (mmol/l)	Disolved silica (mmol/l)	Sand	Gravel	
D-1	1.42	1.68	2.70	2.72	1.16	16.10	210	17.00	8.59	17.90	GP-SP
D-2	1.63	1.70	2.63	2.68	1.10	15.80	290	16.00	13.70	10.25	GP-SP
D-3	1.84	1.90	2.77	2.80	0.90	11.62	140	19.10	13.00	11.80	GP-SP
D-4	1.83	1.89	2.72	2.73	1.50	13.62	180	16.40	16.10	13.30	GP-SP
D-5	1.87	1.94	2.74	2.77	1.20	11.82	190	14.20	14.40	12.50	GP-SP

Fig. 9 Grain size distribution and index properties of aggregate

Table 6 Laboratory test results of samples taken from rock quarries (feasibility phase)

Quarry no	Unit weight gr/cm^3	Specific gravity	Water suction (%)	Los Angeles abrasion loss %		Unconfined compressive strength MPa	Strength loss after frost ($NaSO_4$ loss), %	Alkali-aggregate reactivity		Relative porosity %	Effective porosity %
				100 Rev	500 Rev			Rc (1) Decrease in alkaline mmol/L	Sc (1) Soluble silica mmol/L		
K1	2.32	2.70	3.33	6.67	22.73	38.60	5.50	80	4.50	12.00	8.30
K2	2.43	2.67	7.10	7.10	26.00	54.50	5.30	–	–	8.70	7.70
K3	2.23	2.65	7.80	7.80	29.20	18.00	5.50	–	–	12.00	6.70
K4	2.93	2.95	2.50	2.50	9.30	63.50	4.50	–	–	0.70	0.50

Table 7 Laboratory test results of samples taken from rock quarries (design phase)

Quarry no	Unit weight Gr/cm^3	Specific gravity	Water suction (%)	Los Angeles abrasion loss %		Unconfined compressive strength MPa	Strength loss after frost ($NaSO_4$ loss), %	Alkali-aggregate reactivity		Relative porosity %	Effective porosity %
				100 Rev	500 Rev			Rc (1) Decrease in alkaline mmol/L	Sc (1) Soluble silica mmol/L		
K1	2.381	2.56	5.6	5.6	22.9	53	5.35	40	8.72	7.56	5.31
K5	2.674	2.84	0.83	1.8	8.2	146	7.25	70	14.17	−1.01	2.22
K6	2.705	2.91	0.76	1.8	7.7	261	5.00	90	13.10	−2.14	2.06

Primarily, quality, quantity, ownership status, hauling distance and road situation of natural construction material effect the type of dam. During the feasibility studies the dam type was planned to be impervious cored rock-fill dam. At this stage, four rock quarries were determined. However, due to some problems these four rock quarries turned out to be insufficient for their CFRD. K-1 rock quarry area which is 800 m far to dam site is investigated. But, this quarry area is 400 m high from dam site and 7 km new road should be constructed as well. The K3 rock quarry at the north of the dam site is located near residential area so K3 rock quarry is not suitable to operate quarry. K1, K2, and K3 are composed of limestone. The K4 rock quarry at the dam site is proper feature, but the volume of this area is limited. At that time three impervious material areas were determined (In 1994). But now these areas become urban areas. As a result of additional studies new impervious areas are not in economical hauling distances. For that reason other dam types which do not need impervious material come into focus. Firstly, FSHD type studied. For hardfill type dam pervious aggregate area "D" is 9 km to dam site and there is a wide asphalt road. Aggregates quarries in terms of economic distance is more suitable than the rock quarries. But some legal and environmental problems and also due to economic condition related to aggregate area the dam type was decided to change as CFRD.

Finally, the dam type was decided to change as CFRD at the design stage because two new rock quarries including qualified and sufficient materials were found at the reservoir area. K5 and K6 rock quarry at the reservoir area are 2.5 km to dam site. They are composed of magmatic rocks. These quarries were investigated during the design stage as alternative rockfill materials. The laboratory test results and field studies showed that rock material in the K5 and K6 quarry area is very suitable to be used for concrete face rock-fill dam in terms of quantity and quality (Table 7).

As a conclusion, economically and technically, 110 m high, concrete face rock-fill dam can be constructed. Permeability and stability problems won't be expected at the dam site and the reservoir area. Engineering geological characteristics of dam foundation as well as the filling material has been the most important criterion for dam type selection.

Acknowledgments The authors acknowledge the very helpful cooperation, in presenting the data, of the 6th Regional

Directorate of State Hydraulic Works. The authors would also like to thank engineering geologist Cabbar Yördem (State Hydraulic Works) for his help.

References

Aslaner M (1973) İskenderun—Kırıkhan bölgesindeki ofiyolitlerin Jeolojisi ve petrografisi (Geology and petrography of ophiolites at Iskenderun-Kırıkhan Region) MTA. Publication No: 150. Ankara

ASTM C88 (1999) Test method for soundness of aggregates by use of sodium sulfate or magnesium sulfate. ASTM International West Conshohocken, PA. doi:10.1520/C0088-99A. http://www.astm.org

ASTM C127 (2001) Test method for specific gravity and absorption of coarse aggregate. ASTM International West Conshohocken, PA. doi:10.1520/C0127-01. http://www.astm.org

ASTM C131 (2003) Test method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine. ASTM International West Conshohocken, PA. doi:10.1520/C0131-03. http://www.astm.org

ASTM D5079 (2008) Practices for preserving and transporting rock core samples. ASTM International West Conshohocken, PA. doi:10.1520/D5079-08. http://www.astm.org

ASTM D6032 (2008) Test method for determining rock quality designation (rqd) of rock core. ASTM International West Conshohocken, PA. doi:10.1520/D6032-08. http://www.astm.org

ASTM C97 (2009) Test methods for absorption and bulk specific gravity of dimension stone. ASTM International West Conshohocken, PA. doi:10.1520/C0097_C0097M-09. http://www.astm.org

ASTM D854 (2010) Test methods for specific gravity of soil solids by water pycnometer. ASTM International West Conshohocken, PA. doi:10.1520/D0854-10. http://www.astm.org

ASTM D2113 (2008) Practice for rock core drilling and sampling of rock for site investigation. ASTM International West Conshohocken, PA. doi:10.1520/D2213-08. http://www.astm.org

ASTM D2216 (2005) Test methods for laboratory determination of water (moisture) content of soil and rock by mass. ASTM International West Conshohocken, PA, 2005. doi:10.1520/D2216-05. http://www.astm.org

Bağcı U (2004) Geochemistry and petrology of Kızıldağ (Hatay) and Tekirova (Antalya) ophiolites. PhD Thesis, Çukurova University, Institute of Basic and Applied Sciences. Adana, Turkey

Bagualin F, Jezequel FJ, Shields H (1978) Pressuremeter and foundation engineering. Trans. Tech. Publication, Clausthal

Bahadırlı S (1992) ''Hatay-Yayladağı.Projesi Yayladağı Sulama Ana Kanalları Kesin Proje Aşaması Mühendislik Jeolojisi Raporu'' DSİ. 6. Bölge Müdürlüğü. Adana

Delaloye M, Selçuk H, Pişkin Ö, Vuagnat M, Vagner JJ (1980) Geological section through the Hatay ophiolite along the Mediterranean Coast, southern Turkey. Ofiyoliti 5(2/3): 205–216

DSİ (1957) Hydrogeological Report of Hatay Provence. General Directorate of State Hydraulic Works, Ankara, Turkey (in Turkish)

Dunstan MRH (1994) The state of the art of RCC dams. Int J Hydropower Dams, March, pp 44–54

Emiroğlu ME (2008) Influences on selection of the type of dam. Int J Sci Technol 3(2):173–189

ERD (1996) Earthquake map of Turkey. General Directorate Disaster Affairs Earthquake Research Department

Ericson DB (1940) Report on the geology of Hatay (Turkey) MTA., Rep. No 1118 (Unpublished) Ankara

ISRM (1981) Suggested methods for the quantitative description of discontinuities in rock masses. Rock characterization, testing and monitoring, London. Pergamon, Oxford, p 221

Karaoğullarından T (1985) Yayladağı Projesi Yayladağı Barajı ve Ana Sulama Kanalı, Planlama Aşaması Mühendislik Jeolojisi Raporu DSİ. 6. Bölge Müdürlüğü. Adana, Turkey

Ménard L (1975) Ménard pressuremeter interpretation and application of pressuremeter test result to foundation design. Sols Soil, 26, Paris

Öztürk A, Yıldız D (1998) RCC Silindirle sıkıştırılmış beton baraj (RCC) teknolojisi ve Türkiye'deki uygulamaları. DSI. Türkiye Mühendislik Haberleri, pp 39–46

Selçuk H (1981) Etude géologique de la partie méridionale du Hatay (Turquie). These Doctora, Universite de Genéve, suisse (unpublished)

Selçuk H (1985) Kızıldağ-Keldağ-Hatay Dolayının Jeolojisi ve Jeodinamik Evrimi Derleme Rapor. MTA, Ankara

Tinkler Ch, Wagner JJ, Delaloye M, Selçuk H (1981) Tectonic history of Hatay ophiolite (S. Turkey) and their relation with the Dead Sea rift. Tectonophysics 72:23–41

Türkmen S (1993) Preliminary report of engineering geological investigation of B. Karaçay Dam site. State Hydraulic Works, Adana–Turkey (in Turkish)

Vuagnat M, Çoğulu E (1967) Quelques reflexions sur le massif basique—ultrabasique du Kızıldag, Turquie. C R Soc Phys Hist Nat Geneve 2:210–216