Missouri University of Science and Technology

Scholars' Mine

International Conference on Case Histories in Geotechnical Engineering

(2008) - Sixth International Conference on Case Histories in Geotechnical Engineering

14 Aug 2008, 4:30pm - 6:00pm

Evaluation of Dispersive Properties of Clays to be Used in Embankment of Arsuz - Gönençay Dam

Ayşe Aydin
Department of Geotechnical Services and Groundwater, Ankara, Turkey

Eray Özgüler
Department of Geotechnical Services and Groundwater, Ankara, Turkey

Follow this and additional works at: https://scholarsmine.mst.edu/icchge

Part of the Geotechnical Engineering Commons

Recommended Citation

Aydin, Ayşe and Özgüler, Eray, "Evaluation of Dispersive Properties of Clays to be Used in Embankment of Arsuz - Gönençay Dam" (2008). *International Conference on Case Histories in Geotechnical Engineering*. 20.
https://scholarsmine.mst.edu/icchge/6icchge/session02/20

This work is licensed under a Creative Commons Attribution-Noncommercial-No Derivative Works 4.0 License.

This Article - Conference proceedings is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in International Conference on Case Histories in Geotechnical Engineering by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

EVALUATION OF DISPERSIVE PROPERTIES OF CLAYS TO BE USED IN EMBANKMENT OF ARSUZ - GÖNENÇAY DAM

Ayşe AYDIN[1]
General Directorate of State Hydraulic Works,
Dept. of Geotechnical Services and Groundwater
Ankara,TURKEY
aysek@dsi.gov.tr

Eray ÖZGÜLER[2],
General Directorate of State Hydraulic Works,
Dept. of Geotechnical Services and Groundwater
Ankara,TURKEY
erayoz@dsi.gov.tr

ABSTRACT

Dispersive clays can easily be eroded when they contact with water having high percent dissolved sodium ion in pores. Colloidal clay minerals in these types of soil produce suspension even in stagnant water by dispersion and decomposition. Use of dispersive clays as an impervious material in embankments and dams can cause serious problems of internal erosion (piping) and failure induced by these problems. In this paper, impervious material areas of Arsuz Gönençay dam are discussed as an example of evaluation of usability of dispersive clays in dam fills. The dam type was selected as zoned earth fill at the stage of feasibility. 80 test pits having the depth of 2.1-7.5 m were performed. In order to determine the engineering characteristics and dispersive properties of impervious soils, samples taken from these pits were tested by using description and engineering tests, pore water analysis, double hydrometer, pin-hole and crumb tests. In case of a stability problem due to dispersibility, design of the embankment of Arsuz-Gönençay dam is revised by the design of clay core with an envelope zone at the downstream, upstream and foundation parts.

INTRODUCTION

The purposes of this study are discussion of the reasons of possible internal erosion for earth-fill dams, presentation of the recent investigation methods for this issue, evaluation of the possibility of internal erosion by using recent investigation methods and examination of the recent precautions which were presented in order to improve internal erosion possibility in our case study.

Recent studies show that some clays have unstable structure and can easily disperse and cause internal erosion. Dispersive clays can easily be eroded without any mechanical effect when they contact with water having low percent salt concentration and high percent dissolved sodium ion in pores. Using these clays as a fill material for dams and other embankments may cause serious piping (internal erosion) problems and failure may occur.

Erosion sources from dispersion phenomenon mainly depends on mineralogy and chemical structure of clay and quality and quantity of dissolved salts in pore water of fill material or in reservoir water. Dispersion behavior is generally seen in clay has 2:1 mineralogical structure (like montmorrilonite). Some Illite minerals are also dispersive. Kaolin minerals rarely show dispersive behavior (Şahin, 2004). Dispersive clays generally have high swelling potential, low resistance to erosion and low permeability. Unlike to normal clays colloidal clay minerals in such kind of soils can easily disperse and disintegrate even in stagnant water and electro-chemical boundary between clay minerals and other soil granules fails and become suspended in water. In case of contact of such material in dam embankment with high water mass is likely to disperse.

FAILURE MECHANISM OF DISPERSIVE EARTHFILLS

Failures of earthfill dams related to inner erosion phenomenon occur generally after formation of seepage line on the body of dam. Influent water finds occasion to discharge from earthfill on downstream face of structure. Then it constitutes passage in the form of pipe or tunnel towards the downstream face by enlarging the erosion along the seepage line. Failure of dam structure occurs suddenly when the passage reaches downstream face. Piping mechanism occurring in dispersive clay fills is totally different from this. Failure of dispersive material used in dams occurs generally during the first getting wet of structure after water retention (Sherard et al., 1972, 1976; Mitchel, 1976; Logani, 1979).

To start mechanism of internal erosion resulting from dispersive clays, existence of a small crack or fissure is absolutely needed. Settlement cracks may form (constitute) due to being saturated at first wetting when material is placed drier than optimum water content and not compacted sufficiently. Besides this, desiccation cracks may form because of low water level in the reservoir. An earthquake motion affecting the structure may also cause forming of a crack. The risk of fissuring will be high around the constructed structures such as pipes, conduits or conduvi inside the dam body while compaction of soil around these structures may be insufficient. Because of mentioned mechanism of fissuring, one of the following two conditions may occur. If seepage rate is low, clay surrounding the seepage line may prevent the leakage by swelling in time. Otherwise if seepage rate is high enough, dispersed clay particles start to be carried in the solution, and flow channel widens depending on higher flow rate than rate of swelling (Tuncer, 1985).

Another failure mechanism may occur depending on decrease of ion concentration in reservoir water.

EVALUATION OF DISPERSIBILITY

Geological origins of dispersive clays are generally known as alluvial deposits settled as debris flow, lake floor and flood plain deposits. It is thought that residual soils constituted from decomposition of claystone and marine shale deposits are also prone to dispersibility. Geographic features such as surface erosion and trenches constituted vertically in the field, muddy (dim) water ponds in terraces may indicate dispersive clay material. Dispersive clays are generally special to arid, semi-arid climates. Areas with thin and chunky vegetation are indicators of highly saline soils and most of these soils are dispersive. These field observations can supply the idea of evaluation of dispersibility. But decision of dispersibility should be made according to results of laboratory test.

Laboratory tests

Several laboratory tests are used for evaluation of dispersibility of soils. These laboratory tests are grouped into two as physical tests and chemical tests. Physical tests are Pin-hole test, double hydrometer test and crumb test.

Details of Pin-hole test can be found in ASTM D 4647-93. A hole with 1 mm diameter is opened in the centre of a soil specimen with 22 mm length and 35 mm diameter. This test basically consist of opening a 1 mm diameter hole at the center of compacted soil specimen with 25 mm length and 35 mm diameter and passing of water with 50, 180, 380 ve 1020 mm drops from the hole. Assessment of dispersibility is made according to the observed flow rate and cloudiness of discharging water and extension of the hole.

Double hydrometer test is described in ASTM D 4221-99. Initially grain size distribution of the specimen is determined with standard hydrometer test which is done with mechanical mixer and chemical separator. Then hydrometer test is done without mixer and chemical separator on the second specimen prepared with same soil. Dispersion ratio is determined by comparing percentages of particles smaller than 0.005 mm from second hydrometer test to that of the first test. The soil is assessed as "non-dispersive" if dispersion ratio is smaller than 30%, "semi-dispersive" if dispersion ration is between 30% and 50%, and "dispersive" is dispersion ratio is higher than 50%.

A cubic soil specimen with 15 mm edge or a soil piece with same the volume is prepared for crumb test and placed into glass beaker filled with 250 ml distilled water carefully. Reaction of material with water and suspension production by disintegration of colloidal clay particles in water are observed during 5-10 minutes period. Soils are assessed as "non-dispersive" if cloudiness or turbidity and degree of reaction is too low, "semi-dispersive" if low, and "highly dispersive" if excessive".

Chemical test are composed of analyses of pore water. For these tests soil specimen is mixed with water up to liquid limit. Then a pore water sample is filtered with aid of vacuum. Quantity of cations such as (Ca^{++}), (Mg^{++}), (Na^{+}) ve (K^{+}) is determined with chemical methods (Acikgoz, 2000).

To determine dispersibility degree of soils, several parameters such as ESP (Exchangeable Sodium Percentage), SAR (Sodium Absorption Ratio), Na % (Sodium percentage), TDS (total dissolved salts), CEC (cation exchange capacity), are developed.

Total dissolved salts, $TDS=Ca+Mg+Na+K$ (meq/l) (1)

Sodium percentage, $Na\% = (Na/TDS)100$ (2)

Sodium Absorption Ratio, $SA=Na/[(Ca+Mg)/2]^{1/2}$ (3)

ExchangeableSodium Percentage, $ESP = (\overline{Na}/CEC)100$ (4)

A linear relation exists between SAR and ESP values (Kinney, 1979, Tuncer, 1985). Therefore, ESP is determined indirectly from SAR which is determined more practically. Soil assessed as "non-dispersive" if ESP < 7, "semi-dispersive" if 7<ESP<10, and "dispersive" if ESP>10. The graph given in Figure 1 is used to classify soils according to SAR, Na % and TDS values.

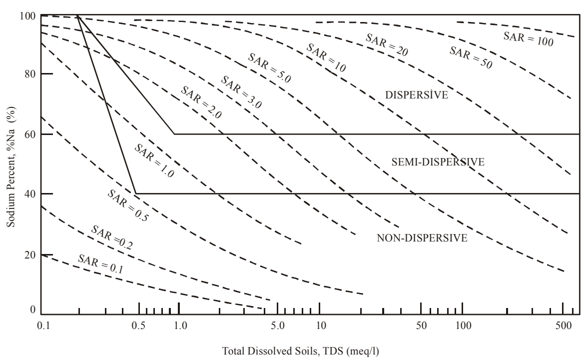

Figure 1. Degree of dispersibility according to SAR, %Na ve TDS values (Sherard vd., 1976).

IMPERVIOUS MATERIAL PROPERTIES OF ARSUZ GÖNENÇAY DAM

The feasibility studies of natural structure material of Arsuz Gönençay Dam were completed in 1995 by VI. Regional Directorate of DSI. Gönençay Dam is in the 25 km southwest of İskederun district of Hatay. Dam body is planned as zoned embankment with 96 m height. 1855000 m^3 impervious, 6515000 m^3 semi-pervious, 380000 m^3 filter and aggregate, 105000 m^3 rock material is needed for dam embankment. During the planning studies, 6 impervious borrow areas (A, B, D, E, F ve G) are also investigated and determined in economic haul distance in addition to pervious, semi-pervious, impervious and riprap material areas. The properties of these material areas are given in Table 1. 80 investigation pits with depth changing between 2.1-7.5 m were opened.

Description and engineering tests with physical and chemical dispersion tests were done on the soil specimens taken from investigation pits (Aykın vd., 2000).

Table 1. Properties of impervious material areas.

BA*	HD*[1] (m)	NTp*[2]	AS*[3] (m)	DE*[4] (m)	MQ*[5] (m^3)
A	1650	28	0.3	8.0	1620288
B	1050	20	0.3	7.0	1009148
D	3800	5	0.3	5.7	554204
E	3450	3	0.3	4.8	208139
F	2350	15	0.3	3.1	701907
G	3250	9	0.3	3.3	705542

* : Borrow area
*[1] :Haul distance
*[2] : Number of test pits
*[3] : Average stripping
*[4] : Depth of excavation
*[4] : Material quantity

Borrow area A contains landslide material and completely disintegrated clay exists at 3-4 m depth. Masses of sandstone layers with 50 cm or more thickness exists independently below 3.5 m. During the operation of material these sandstone layers should be debugged.

Laboratory Tests

Description and engineering tests are performed on 119 soil samples taken from test pits opened in the borrow areas. Minimum and maximum test results are given in Table 2. Soil classes determined according to Unified Soil Classification System are also given in Table 2.

To evaluate dispersibility according to chemical tests, SAR, Na % and TDS values of soil specimens taken from impervious borrow areas are determined and plotted on the graph proposed by Sherard vd. (1976) (Figure 2).

To evaluate dispersibility according to physical tests, pin-hole and crumb tests are performed on some samples taken from A, B, D, F, G borrow areas. Double hydrometer tests are performed on some samples taken from A, D, F, G borrow areas. According to physical test results, distribution of dispersive, semi-dispersive and non-dispersive soils in the borrow area is shown on the relief map (Figure 3). As seen from Figure 3, dispersibility increases at places where ephemeral streams enter and leave the site. This observation isn't determined in flat regions. Therefore, areas with ephemeral streams are extracted from the borrow areas.

Table 2. Description and engineering parameters of impervious material.

	Borrow area					
	A	B	D	E	F	G
G_s, (g/cm^3)	2.61-2.75	2.61-2.80	2.68-2.80	2.65-2.78	2.62-2.69	2.61-2.68
γ_{kmax}	1.70-2.64	1.69-1.92	1.62-1.81	1.67-1.76	1.50-1.70	1.56-1.85
w_{opt}	12.80-18.10	12.10-19.80	14.80-20.30	15.20-18.20	14.30-25.80	14.00-24.00
LL	31.80-48.80	28.60-49.50	43.00-49.90	42.70-51.30	47.40-78.90	32.90-61.70
PL	17.70-25.40	16.50-24.90	20.60-25.50	19.00-22.60	20.10-30.40	17.20-25.80
PI	12.20-27.30	11.20-27.30	22.20-27.10	22.10-32.30	26.10-48.50	15.70-37.40
k (10^{-8} cm/s)	7.06-100	1.65-700	3.7-554	35-35	2.9-20	8.9-60
c (kgf/cm^2)	0.85-1.4	0.7-1.8	0.3-1.8	1.45-1.9	0.9-0.95	0.2-1.35
ϕ	12-27	8.5-27	12-27	14-22	12-15	3-29
Soil class	CL, CL-CH, GC-SC, SC-CL, SC	CL, CL-CH, SC-CL, GC-SC	CL, CL-CH	CL-CH, CL	CH, CL-CH	CL, CL-CH, GC-CL

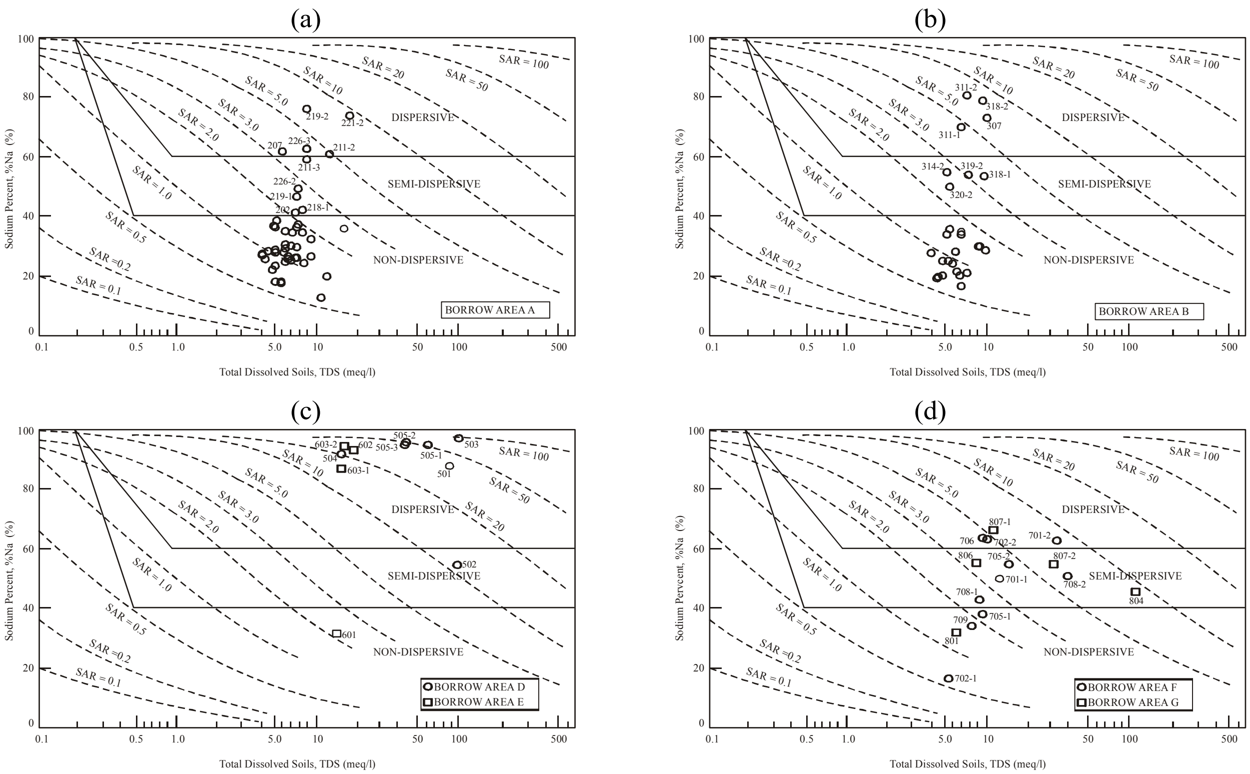

Figure 2. Evaluation of the dispersibility according to Sherard vd., 1976.

Dispersion percentages are evaluated according to physical and chemical test results (Figure 4). In borrow areas A and B all soils are assessed as non-dispersive according to physical test results, while dispersive and semi-dispersive soil percent are less than 20 % according to chemical test results. In the borrow area D double hydrometer and pin-hole test results show that all soils are dispersive, while 67 % of soil are semi-dispersive according to the crumb test and dispersive soil percent is 86 % according to chemical test results. In the borrow area E dispersive soil percent is 75 % according to chemical test results. The borrow area F has 30 % dispersive, 40 % semi-dispersive soil according to Sherard (1976), and 9 % semi-dispersive soil according to ESP. According to the pin-hole test all soils are semi-dispersive. According to crumb and double hydrometer tests percentages of dispersive soils are 40 % and 20 %, while percentage of semi-dispersive soils are 60 % and 80 % respectively. According to Sherard (1976) and ESP, in the borrow area G dispersive soil percentage is 20 %, semi-dispersive soil percent is 60 % and 20 % respectively. This area has 50 % dispersive soil according to the double hydrometer test. While all soils are assessed as semi-dispersive soil according to pin-hole and crumb test results.

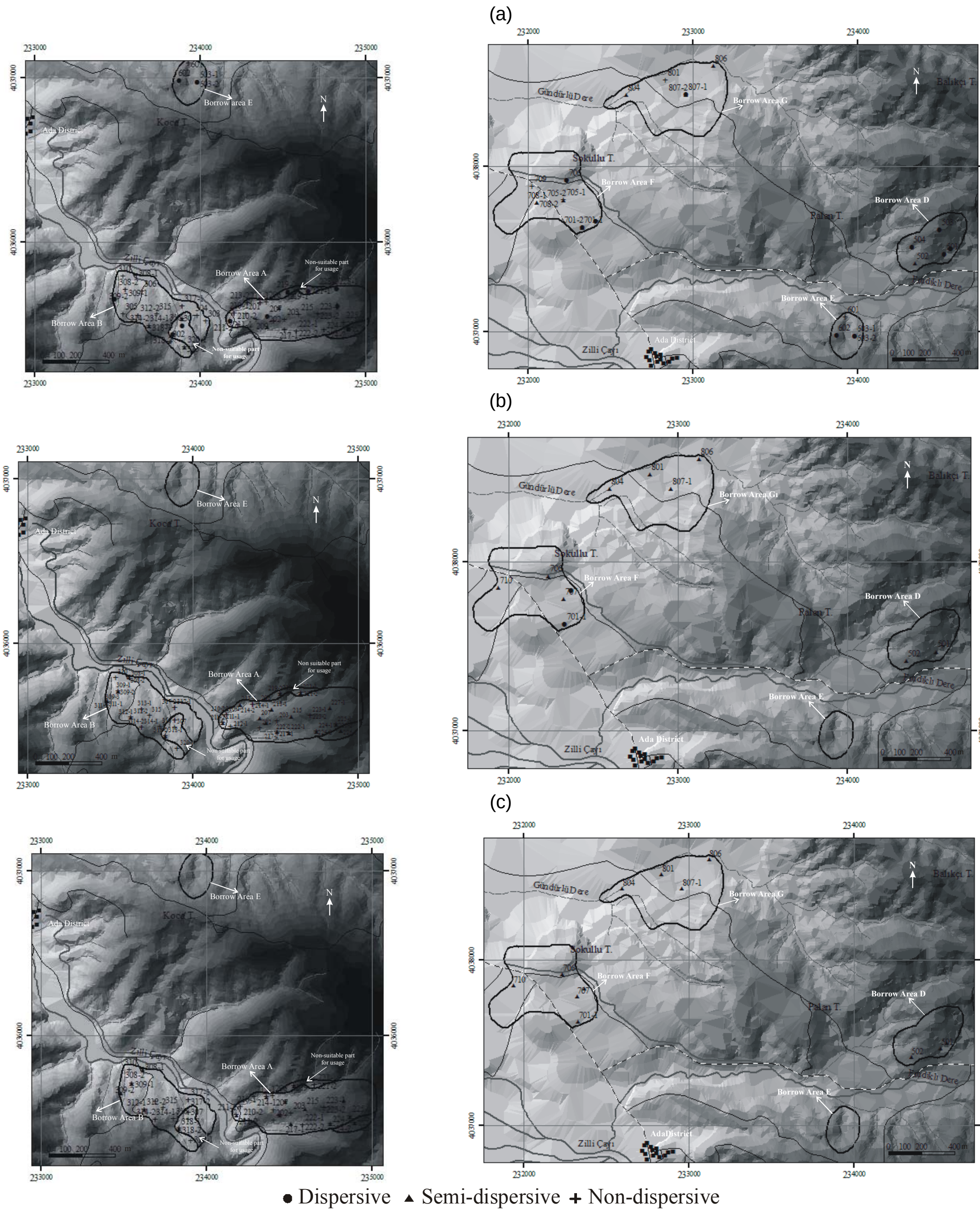

Figure 3. Distribution of dispersive, semi-dispersive and non-dispersive soils in the borrow area according to (a) Sherard et al., (b) crumb test, (c) pin-hole test results.

Although some of the samples taken from material areas A and B are semi-dispersive and dispersive, these areas weren't abandoned completely due to excessive impervious fill material requirement, economic hauling distances of these material areas, and having proper material properties such as material group, specific gravity, maximum dry unit weight, permeability, Atterberg limits and other engineering parameters. It is preferred to design the clay core with an envelope zone at downstream, upstream and base (Figure 5).

Material requirements of high quality clay material for envelope zone and normal quality clay for inner core zone are 715000 m^3 and 1140000 m^3 respectively. Purpose of this design is to use clay material which is dispersive but proper in point of other material properties in the inner core safely. Non-dispersive, high quality clay material will be used in the envelope zone surrounding the inner core. Besides this, filter zones of well graded sand and gravel will be used. Thus envelope zone will not be affected by any cracks or piping formed by one of the mechanisms discussed in Section 1.1.

In this case, it is proposed that non-dispersive parts of A and B material areas should be used firstly for the envelope zone. According to the physical and chemical test results, percentages of non-dispersive soils for A and B areas are 72% and 76 % respectively. Thus, it is possible to obtain approximately 1270000 m^3 non-dispersive material.

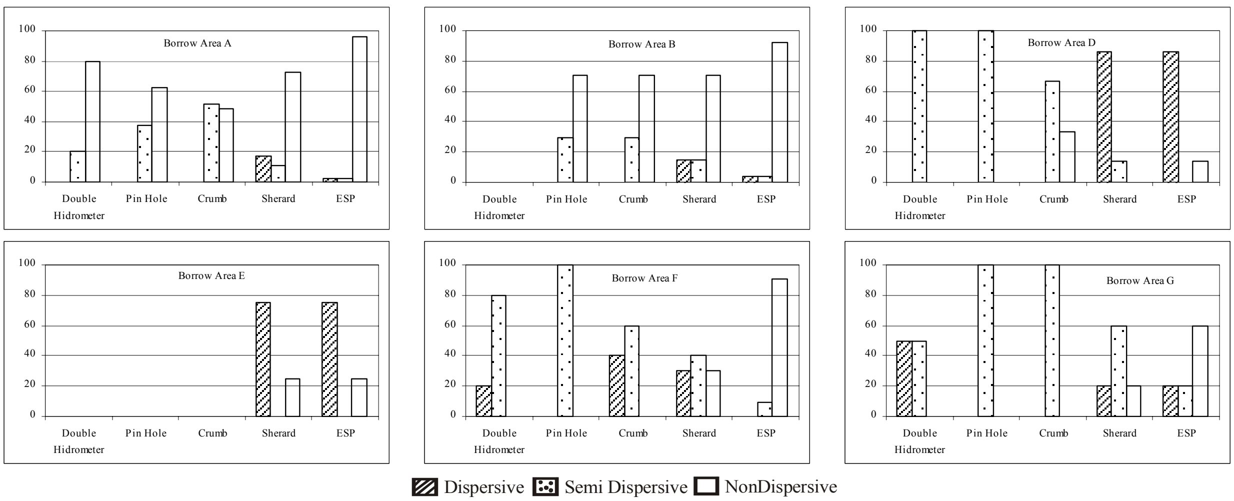

Figure 4. Dispersion percents according to physical and chemical test results.

It is assessed that using the dispersive material of A, B and other areas is not proper while, using semi-dispersive material by mixing with non-dispersive material for the inner core zone is more appropriate. Behavior of semi-dispersive clays couldn't be predicted. But mixture of semi-dispersive and non-dispersive materials will be utilized in the inner core. By the way, it is thought that semi-dispersive soils will be cured by mixing with non-dispersive soils the ratio of semi-dispersive and non-dispersive material is thought as % 50.

Besides the filter zones will be designed carefully in downstream and upstream parts of clay core. Properties of filter material and limitations for filter design are given in section 5.

FILTER MATERIAL PROPERTIES OF ARSUZ GÖNENÇAY DAM

According to the feasibility studies of natural structure material of Arsuz Gönençay Dam 380000 m^3 filter and aggregate material is needed for dam embankment. During the planning studies impervious borrow areas (C) is determined in economic haul distance. The properties of this material area are given in Table 3. 80 investigation pits with depth changing between 2.1-7.5 m were opened.

Table 1. Properties of filter material area.

BA*	HD*[1] (m)	NTp*[2]	AS*[3] (m)	DE*[4] (m)	MQ*[5] (m^3)
C	3000	7	-	2	1200000

* : Borrow area
*[1] :Haul distance
*[2] : Number of test pits
*[3] : Average stripping
*[4] : Depth of excavation
*[4] : Material quantity

Description and engineering tests are performed on 7 soil samples taken from test pits opened in the borrow areas. Minimum and maximum test results are given in Table 4.

Table 4. Description and engineering parameters of sand filter material.

Borrow area C		
G_s, (g/cm^3)		2.52-2.62
γ		1.68-1.79
Water absorption (%)		12.80-18.10
Passing 200# sieve (%)		2.12-4.64
Clay lumps(%)		1.99-4.27
Na_2SO_4 frost loss (%)		6.4-16.49
Los Angeles abrasion loss (%)	100 cycle	4.34-7.4
	500 cycle	22.02-29.40
D_{15} (mm)		0.38-0.59
D_{10} (mm)		0.3-0.42
D_{90} (mm)		3.57-4.16

Filter gradation limits are determined according to US Army Corps of Engineers (2004) as it is denoted that filter criteria are applicable for all soils including dispersive soils. All steps are applied and base soil is assessed as Category 2 with % 40-85 passed from number 200 sieve. Thus filter criteria D_{15} filter ≤ 0.7 mm is chosen for Category 2. While filter material has a value of minimum D_{15} value of 0.38, it satisfies the filter criteria.

To ensure efficient permeability, the minimum D_{15} is set to greater or equal to 3 to 5 x maximum D_{15} of the clay. As $0.5 < D_{15} = 0.38 < 0.5$, filter also ensures efficient permeability.

Sand filters with D90 less than about 20 mm generally don't need limitations on filter broadness to prevent segregation (Army Corps of Engineers, 2004). Thus filter material of borrow area C doesn't need limitations to prevent segregation.

RESULTS

During the planning studies, 6 impervious borrow areas (A, B, D, E, F ve G) have also been investigated and determined in economic hauling distance in addition to pervious, semi-pervious, impervious and riprap material areas.

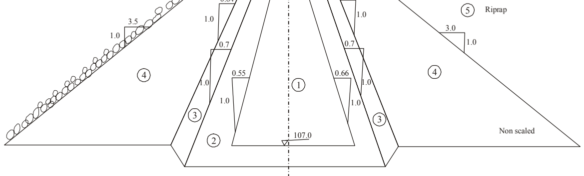

Figure 5. Proposed typical embankment section of Arsuz Gönençay Dam.

Samples taken from impervious material areas have appropriate material properties such as material group, specific gravity, maximum dry unit weight, permeability, Atterberg limits and other engineering parameters. According to chemical test results most of the samples taken from A and B material areas are generally non-dispersive while, most of the samples taken from D and E areas are dispersive, and most of the samples taken from F and G areas are semi-dispersive. According to physical tests (double hydrometer, pin-hole and crumb tests), most of the samples taken from A and B material areas are non-dispersive while, samples taken from D, F and G areas are semi-dispersive.

To prevent possible unstability problems due to the dispersive characteristics of impervious materials, designing the clay core with an envelope zone at downstream, upstream and base is preferred. It is assessed that using the dispersive material of A, B and other areas is not proper while, using semi-dispersive material by mixing with non-dispersive material for the inner core zone is more appropriate. Besides the filter zones will be designed carefully in downstream and upstream parts of clay core.

These recommendations have been evaluated by design engineers and it is judged that even after all these measures taken the behaviour of impervious zone is still unknown and based on some assumptions. As a result the dam type is changed to Concrete Faced Sand and Gravel (Pervious) Fill Dam.

REFERENCES

Acciardi, R. [1982]. "Quantification of pinhole test equipment hydraulic characteristics. Engineering and Research Center, Bureau of Reclamation". 82-15.

Açıkgöz, I. [2000]. "Laboratory tests for natural construction material investigations". DSI, Ankara, Turkey, 135-158.

ASTM D 4221-99. "Standartd test method for dispersive characteristics of clay soil by double hydrometer". Annual Book of ASTM Standarts, 04-08, 11-01.

ASTM D 4647-93. "Standartd test method for ıdentification and classification of dispersive clay soils by the pinhole test". Annual Book of ASTM Standarts, 04-08.

Aykın, M., Karaoğullarından, Y. and Sezen, H. [2000]. "Arsuz-Gönençay Project, Revised Report of the Natural Construction Materials of Gönençay Dam". DSİ, Ankara.

Kinney, J.T. [1979]. “Laboratory procedures for determining the dispersibility of clayey soils”. Engineering and Research Centre, Bureau of Reclamation, Denver Colarado,79-10.

Logani, K.L. [1979]. “Dispersive soils chosen for Ullum core”, World Water, 2, 8, 21-32.

Mitchell J.K. [1976]. “Fundamentals of Soil Behaviour”, John Wiley and Sons,Inc., NewYork,

Sherard J.L., Dunnigan L.P., Decker R.S. and Steele E.F. [1972]. “Pinhole test for ıdentfying dispersive soils”. Journal of The Geotechnical Engineering Division, ASCE, 69-85.

Sherard J.L., “Dunnigan L.P. and Decker R.S. [1976]. Identification and nature of dispersive soils”. Journal of The Geotechnical Engineering Division, ASCE, 287-300.

Sahin, M., [2004]. “An example of the design with dispersive clays - Koyunbaba Dam”. TMH, 430, 2, 48-54.

Tuncer E.R., [1985]. “Inner erosion of soil dams”. DSI, Ankara, Turkey, 27/1-15.

US Army Corps of Engineers., [2004]. “General Design and Construction Considerations for earth and rokfill dams. Appendix B filter design”.

USBR 5400-89. “Procedure for determining dispersibility of clayey soils by the crumb test method”. 414-418.

USBR 5404-89. “Procedure for determining dispersibility of clayey soils by the double hydrometer test method”. 419-424.

USBR 5410-89. “Procedure for determining dispersibility of clayey soils by the pinhole test method”. 425-429.