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A Field Survey of the Causes of Lining Cracks in Irrigation channels of Shadegan Network

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Abstract: In order to investigate the causes of deterioration of concrete channels of Shadegan irrigation network, first preliminary studies, data collection and field observations were conducted then the damaged points were identified and these points were individually characterized and sampled accordingly. Tests were carried out to determine characteristics such as grain size, density, etc, while chemical tests such as soluble salts, pH, etc *and* mechanical test like swelling test by consolidation device were conducted. By analyzing the field and laboratory data obtained and combining them one can conclude that the most affecting cause in damaging. The Shadegan irrigation network in short term are geotechnical conditions of the channel embankment such as swelling and existence of salts materials such as gypsum. Other causes such as soil divergence, inefficient project execution, low-quality construction materials and unsuitable operation maintenance strategies can devastate the concrete cover of the channels.

Key words: Irrigation channel . Crack . Lining . Geotechnical conditions

INTRODUCTION

Due to the ever-increasing growth of using concrete channels in irrigation projects in Iran, problems occur during the time of execution, operation and maintenance of such schemes including but not limited to developing cracks and their deterioration. This paper presents the results of the studies that have been conducted yet on the Shadegan irrigation network. This paper aims at the spotting of the damaged areas, analysis of the causes and providing effective preventive strategies. Extensive individual researches have been carried out on different causes deteriorating the concrete cover of the channels such as clay soil swelling, existence of various salts such as gypsum on the bed, clay soil divergence of the bed. The results of the researches on the soil divergence and swelling as the main problems of the Khuzestan region soils will be discussed in the following.

A review of literature on soil divergence and its damages: Middleton in (1930) for the first time introduced soil divergence as one of the affecting factors on eroding of the fine-grained soils. He also characterized the divergent soils with a high percentage of sodium salts. In his researches from 1935 to 1938, Volk considered the soil divergence as the main responsible for numerous damages occurring to small dams, weirs and embankments designed by the Soil conservation Society (SCS) of the US. During 1960 to 1970, most of the studies carried out in Australia on the causes of the deterioration of earthfill dams resulted in a better understanding of the erodible clays. In 1965, Wood and Aitchison studied internal erosion in the short dams considering the soil type, sodium adsorption ratio (SAR) and the quantity of soil water salts. Ingle and Aitchison (1969) presented the result of their research on the effects of water and soil chemistry on soil divergence along with the effects of the cracks and internal erosion. The researchers also reported on different devices that have been designed to determine the divergence of the clays including Arulandan in 1975 and Pinhole in 1976 by Sherard. The advent of Pinhole revolutionized the testing and researches relating to divergent soils. Sadr Karimi and A. Moradi (1993) showed in their study on modifying of the divergent soils that the electro-osmoses decreased considerably the sodium cations in Anode while it increased them in Cathode and finally resulted in a reduction in sodium adsorption ratio (SAR) in the Anode. In a study by Rahimi and Delfi (1992) on the divergent soils in Khuzestan province, introduced the Pinhole method as the best direct method in determining the divergence potentials of soil and presented a diagram to conduct the indirect (chemical) evaluation of the divergent soils with respect to pH, ECe *and* SAR.

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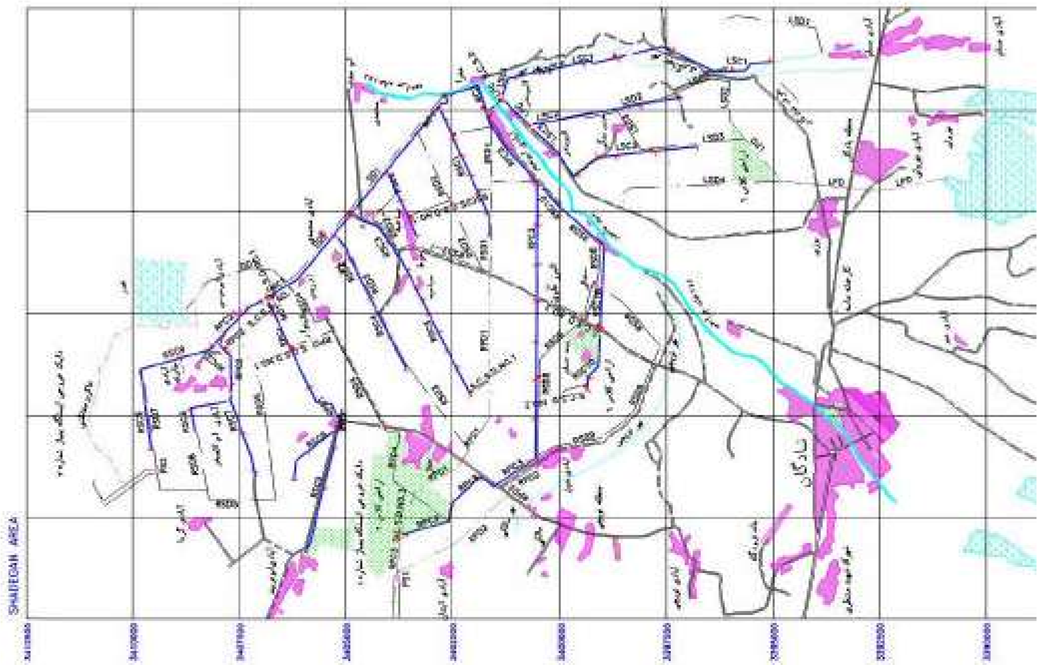

Fig. 1: Map of the study area

Fig. 2: The condition of shadegan irrigation network

A review of literature on swelling and its damages: Bara (2000) conducted a study on swelling bed clays of a channel in Saint Luis region of the US and concluded that in clay embankments there is a relation between the swelling and soil moisture on one hand and dry density and soil liquid limit on the other which can be obtained by using simple statistical methods. He demonstrated that in order to reduce the swelling potentials of the soil, for a soil with liquid limit of 40%, the soil moisture should be 23% while for a soil with liquid limit of 100%, the moisture should be increased 37%. He also stated that one of the best methods in decreasing the swelling potential of the soil is pre-moisturization of an embankment by submergence. In Iran and in recent years a few studies have been focused upon a channel concrete cover by clay embankment swelling. In 1994 and after the damages incurred to concrete cover of the newly-constructed channels of Kesht-va-Sana't Shoeibieh, Sano Consulting Engineering Co. initiated its studies and concluded that the swelling of the embankments along with other environmental conditions such as high temperature and high levels of the ground waters in the region were the main responsible for the damages incurred to the channels.

Table 1: Shadegan irrigation network channels and drainages

Area of irrigation	Degree one channels	Degree two channels	Total length of channels	Number of irrigation gates	Main and lateral drainage
Right bank	24.90	40.72	65.62	91	37.175
Left bank	1.35	15.23	16.58	12	22.705

Table 2: Hydraulic and physical properties of the shadegan irrigation network

Name of project	Shadegan irrigation and drainage network	Shadegan irrigation and drainage network
Name of channel	Mc1	Mc2
Bed width (m)	1.6-2.5	2
Cover Elevation (m)	1.9	1.65
Concrete cover thickness (m)	0.1	0.1
The surface of each panel (m^2)	2.5×2	2.5×2
Channel condition	Embankment	Embankment
Embankment condition	In good-condition	In good-condition
Concrete condition	Good-suitable	Good-suitable
Type of deterioration	Concrete cracks	Concrete cracks
The mean of crack distance from bed	0.5-0.9	0.5-0.9
Water proof Materials	Sand Asphalt	Sand Asphalt
Direction of channel	East to west	East to west
Age of channel	4	4
The periods of filling and emptying	Continual and irregular	Continual and irregular

The shadegan irrigation network components: The study area of the Shadegan irrigation network scheme is a part of the Khuzestan plain that have been formed by the alluvial of the Jarrahi River, 100 km southeast Ahwaz and 70 km northeast Abadan. This area is situated 48° 37′ to 48° 47′ E and 30° 40′to 30° 49′N. The net and gross areas of the Shadegan Plain croplands are 90.15 and 8195 ha. Respectively with a smooth surface. The highest point in this plain is 7 m and the lowest is 3 m ASL. The land slope is negligible almost 0.5/1000 on average. The slope is with a northeast-southwest direction and the city of Shadegan is only residential center in this plain.

The main Shadegan irrigation and drainage network is consisted of a short diversion dam, a pumping station and a series of channels and drainage systems.

METHODS AND MATERIALS

First, the data and information of the technical proposal of the project and technical reports and also point and field observations the critically damaging areas were identified in the channel and the main causes were determined. Then, according to the field observations and through soil mechanical tests (physical and chemical tests) and evaluation of the ground waters in terms of uplifting hydrostatic pressure by piezometric wells at critical points the ground water levels were determined in respect with the channel bed and the water seepage at different sections of the channel by measuring the seepage rate by Arian 2000 was conducted. Based on the field observations and the findings of the tests, the ultimate results of the causes of damages and cracks incurred to the channel were determined.

RESULTS AND DISCUSSION

Field investigations and the mechanism of data collection: In order to obtain a better understanding of the situation data and information of different damages of the irrigation channels were collected and categorized as presented in the Table 2.

The results of water stability level measurement and evaluation: Considering the water stability levels readings by the piezometers it was determined that the lowest water stability level at the time of system operation is 1.10 m below the channel bed that indicates the hydraulic slope of the channel to the sides. The result verifies that the up lifting forces do not intensify the damages and cracks on the channel.

A review of the materials and the concrete bearing capacity: Based on the investigations and the results of

Table 3: The physico-chemical characteristics of the soil samples

				m.e./Lit				
				Cations			Anions	
No	Description	PH	EC (d.s/m)	Na+	Ca++	Mg++	Cl-	Hco3-
1	Source material	7.4	99	1144	75	170	1187	0
2	Sample(2) from MC2 lining channel without crack	7.4	73	733	105	167	840	0
3	Sample(3) from MC2 lining channel with crack	7.5	108	1190	77	160	1235	0

				Soil Mechanical Analysis					
1 R	Description	SAR	ESP	%S	%Si	%C	*Texture*	CaSo4 (%)	Caco3 (%)
1	Source material	103	60.2	15	46	39	SiCL	3.5	39.9
2	Sample(2) from MC2 lining channel without crack	63	47.7	11	46	43	SiC	3.2	38.3
3	Sample(3) from MC2 lining channel with crack	109.2	61.5	11	62	27	SiCL	3.1	35.1

Table 4: The result of the mechanical tests

No	Description	The maximum dry density (g/cm^3)	Optimum moisture (%)	Liquid limit LL (%)	Plastic limit PL (%)	Plastic index Pi (%)	Classification by unified method
1	Source Material	1.79	15.9	34.4	22	12.4	CL
2	Sample(2) from MC2 lining channel without crack	1.84	14.2	28.7	19.5	9.2	CL
3	Sample(3) from MC2 lining channel with crack	1.77	17.2	30.8	20.2	10.6	CL

Table 5: The result of the infatuations tests

Potential expansion	EI expasion index	Sample
Very low	17.5	Sample (1): Source Material
Low	28.0	Sample (2) from MC2 lining channel without crack
Low	32.5	Sample (3) from MC2 lining channel with crack

the concrete bearing capacity testing, the materials used with the anti-sulfate cement Type 4 of 300 kg/m^3 included broken sands with a nominal size of 3.4 in according to the Iranian standards (ACI) and gravels as a mix of natural and broken gravels in a proportion of 40 to 60 respectively and Sand Equaling(SE) of 75% and with a sample specific weight of 2.35 in saturated dry surface and ratio of water to cement of 40% *and* 7-day bearing capacity of samples approximately 150-160 kg/m^3 and concrete slump of 3-4 cm with a specific weight of 2.2-2.3 gr/cm^3 and 28-day concrete bearing capacity of 246-257 kg/m^3 and the slump of 3.5-5 cm and specific weight of 2.32-2.35 gr/cm^3. The required concrete bearing capacity was met according to the Supervisor's reports of the project during all the stages and all the technical requirements including grain size and the mix of concrete were fulfilled. The curing stage of the concrete was carried out under the best technical condition and more than 95% of different tests on the concrete used produced results within the allowed range and were confirmed by the Supervisor accordingly. Thus, one can conclude that the concrete quality used for the lining of the irrigation channels is within the ranges defined for the concrete bearing capacity and slump.

The methodology of physical and chemical tests on the sampled soil: As described in the research methodology of this paper, samples were taken from the soil of the irrigation channel bed at the critical areas including damages and cracks and areas where no deterioration was found for the required tests. Then, the physical and chemical tests such as grain size, determining the limits of Ate burg, Standard Penetration Test (SPT), determining sulfate percent, gypsum percent and pH of the soil and also divergence test using proposed method by Rahimi and Delfi were carried out to determine the physicochemical characteristics of the soil. The results were compiled by those obtained by the field investigations and observations and analyzed accordingly.

CONCLUSIONS

Considering the results of the Table 3-5, the samples taken from material sources of cracked area and the uncracked area have an extraordinary high Ec>32(Ds/m), ESP>50 and SAR. Also calcium and magnesium quantities are less than the sodium portion which causes the dominance of sodium over the existing cations in the soil as one of the main causes of the soil divergence. Also, considering the heavy soil texture of the embankment, The deterioration of the channel is expected due to the swelling. In order to rectify the soils of the region, the use of lime, ammonium sulfate, filtration and electro-osmosis method are recommended. In the Shadegan irrigation network project, the sizes of the expansionary openings were reduced and consequently no cracks were observed on the concrete covers of the irrigation channels.

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