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Evaluation of Tertiary Irrigation Canals' Lining Mutoubes District, Kafr El-Sheikh Governorate, Egypt

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ملخص عربى

تقدم هذه الورقة البحثية تقييم للمساقى المبطنة بالخرسانة العادية بمنطقة مطوبس بمحافظة كفر الشيخ حيث تمت زيارة الموقع وتجميع البيانات الحقلية اللازمة وأخذ عينات مياه من المساقى والمياه الجوفية وتم اجراء التحاليل الكميائية والفزيائية اللازمة لها بمعامل كلية الهندسة بجامعة الأسكندرية كما تم استخراج جسات وعينات من التربة وتم اجراء الاختبارات اللازمة وتبين من نتائجها المشاكل التى تعانى منها تباطين هذه المساقى وقدمت هذه الورقة البحثية التقييم والأسباب التى أدت الى تدهور حالة هذه التباطين نتيجة لوجود مشاكل بالتربة وكذلك ارتفاع منسوب المياه الجوفية المالحة مما يساعد متخذ القرار على اختيار البديل الأنسب للعلاج.

Abstract

This study presents the results of investigation activities conducted at the reclaimed lands Project site in Mutoubes District, Kafr El-Sheikh Governorate, Egypt,in order to figure out the main causes of deterioration/damage of the existing tertiary canals (Mesqas)concrete linings. Detailed field investigation was performed, whilst all available technical documents on this project were studied. The testing program consisted of laboratory as well as field tests. Several boreholes were dug along the lined canals' embankmentsto cover the study area.Soil samples were collected from different depths at 30 cm intervals. All samples were tested for theirchemical, physical, and mechanical properties. Irrigation water, drainage water, and groundwater samples were also collected and tested in the laboratory.On the other hand, the old lined mesqaswere visually assessed. According to field observations and results of laboratory tests, the main causes of damage to the new lined mesqaswere identified. The outcomes presented in this paper may employed to propose an appropriate maintenance solutionfor the damages of the new lined mesqas; and to recommend the most promising protecting alternative for the old lined mesqas.

Keywords: Irrigation canal lining -crack of concrete lining -lining evaluation -problematic soils - Kafr El-Sheikh - Egypt.

Introduction

Maysam Th.AL-Hadidi and Atheer G.Ibrahim 2018, studied reducing of erosion and solubility of irrigation canals soils which constructed on gypsum soil is important in civil and water resources engineering. Poly urethane is used to give the gypsum soil. Afera Halefom and Ermias Sisay 2017 studied the performance and diagnostic analysis of a minor irrigation canal, presented Osrabandi/Warabandi schedule, and evaluate the field application efficiency for soil and water quality analysis. Fariba Behrooz Sarand and Masoud Hajialilue Bonab 2016, was studied the phenomenon using field observations and numerical modeling to study the effect of unsaturated expansive soils on canal linings on the Tabriz Plain Canal, Iran. Paolo Clemente and etal., 2013, were study investigates the field methodologies to evaluate water losses from canals this methodology is based on Quest method. Askar Karimov and etal., 2009 was studied the initial costs of a canal lining project will vary depending on the type of material and whether a protective barrier was used. Jorage. V. Prado Hernandez and etal., presented experimental evaluation of control algorithms for irrigation canals to improve the operation of irrigation canals an upstream regulation scheme. The reclaimed lands are located along the Mediterranean coast and are constituted by sandy silt, which easily lose their low cohesion at saturation. These soils are therefore very erodible, subject to piping and their banks easily collapse in case of saturation or seepage. Moreover, since the lands are very close to the sea, their salinity is high as is that of their water table. These characteristics have important consequences for the durability and stability of the concrete lining of the irrigation canals and also for the drainage canals banks stability.

As a consequence, almost all tertiary irrigation canals (mesqas) concrete linings were damaged and need to be replaced.The paper was accordingly aimed to assess the durability of the mesqas lining works at Mutoubes District in Kafr El-Sheikh Governorate and identify the main causes of concrete failure As part of the evaluation process a comprehensive field investigation was carried out including several fields as well as laboratory tests. This study thus summarizes the results of thesite inspection visit and laboratory tests. The potential problems are also outlined throughout this study.

Study Area

The study area is located within the reclaimed lands of Mutoubes District, Kafr El-Sheikh Governorate along the international coastal road and faraway from the Mediterranean coast by about 1.5 km. The new reclaimed lands are about 6000 feddans bounded from the North and the South by the Mediterranean coast and El Brullus Lake, respectively. The study area is adjacent to Mustarda Village at East and Mutoubes association for land reclamation at West, Figure 1.

The reclaimed lands are distributed among three villages:

1- Sedi Ibrahim El Desouki (1927 feddans),
2- Sedi Sayed El Badawy (1512 feddans),
3- Sedi Talha (2748 feddans).

The reclaimed lands are divided into small farms with an average farm sizeof 2.5 feddans per beneficiary. The study area has been reclaimed since 2004 and the surface water for the study area is released to Sedi Yusuf canal from the Rosetta branch. Within the three villages, a wide variety of crops is grown over cropping seasons.The major crops are beans, wheat, vegetables and fruits.

Figure 1: General layout of the study area

The study area is constituted by yellow sandy silt soil and exposed to airswirling permanently due to the coastal location.The elevation of lands is above the sea level by about 1-2.5 m. Moreover, being very close to the sea, the study area is characterized by high saline groundwater levels.

Irrigation Network in the Study Area

The main source of surface water in the study area is Sedi Yusuf canal.Sedi Yusuf canal takes its water from Rosetta branch through El Nour canal. It extends for a distance of about 18.500 km at the north side of the project area, feeding a total of seven branch canal offtakes.The reclaimed lands receive irrigation watervia mesqas off-taking directly from branch canals.

Drainage water from the project areas is discharged to the Moheet Zaghloul main drain through seven secondary drains, Table 1. Moheet Zaghloul drain discharges its water to El Brullus Lake via the Moheet Zaghloul pump station, Table 2.

Table 1: Drains in the study area

Drain name	Drain length (km)	Discharge to	Bed width (m)	Bed level (m+MSL)	Bed slope (cm/km)
West (Main)	5.500	MoheetZaghloul	2.5-3.5	-3.00 to -3.50	15
West branch (1)	1.425	West (Main)	1.25	-2.55	30
West branch (2)	2.350	West (Main)	1.50	-2.15	30
East (Main)	10.00	MoheetZaghloul	2.5-3.5	-2.45 to -3.50	15
Eastbranch (1)	2.200	East (Main)	1.50	-2.00	30
Eastbranch (2)	1.500	East (Main)	1.50	-1.60	30
Eastbranch (3)	1.400	East (Main)	1.25	-1.20	30

Table 2: MoheetZaghloul pump station

Purpose	**Drainage water**
Number of units	5
Discharge/unit	1.70 m^3/s
Area served	11000 feddans
Design water level at intake	-2.70 to -2.50 (m+MSL)
Design water level at outlet	+0.5 to +1.00 (m+MSL)
Design static head	3.30 m

On-Farm irrigation system

The on-Farm irrigation system in the study area depends on the existence of lined mesqas.One hundredlined mesqas were executedin order to irrigate the reclaimed lands in the study area.The age of these linings doesn’t exceed 17 years.Tables 3 through 5 illustrate the results of visual assessment of lined mesqas. The reclaimed area served by each mesqa ranges from50to 100 feddans. A branch canal feeds four or eight mesqas by a pipe concrete culvert of 50 cm diameter at the head of each mesqa. Drainage water is discharged from mesqas to branch drainsthrough a pipe tail escape provided by a sluice gate. Farmers lift irrigation waterto their fields by private diesel pumps.Farmers useirrigation water based on a four days rotation (Munawabah) system, where every farmer officially receives water at the same time each week. Figure 4 shows a cross-section of old linedmesqas, Abdelhaleem (2018) (17 years in service).The cross-section of the recently rehabilitated lined mesqa is also depicted in Figure 4. The new lined mesqa, with a trapezoidal shape, bottom width of 0.5 m, side slopes of 3:2, depth of 1.5 m and length of about 1 km, was designed to carry a discharge of 0.07 m3 s-1.The new unreinforced concrete lining has a thickness of 12 cm placed over a8cm subgrade of coarse aggregates (dolomite).

Table 3: Assessment of linedmesqas atSedi Ibrahim El Desouki village

Item	Mesqa name (number of irrigated lands)	Length (m)	Visual Assessment	Remarks
1	6	1200	Poor	
2	7	1200	Poor	
3	8- 9	1200	Fair	
4	10- 11	550		Recently rehabilitated
5	12	1200	Fair	
6	13-14	1200	Fair	
7	15	1050	Fair	
8	16	1050	Fair	
9	17	1050	Fair	
10	18	1050	Fair	
11	19	1050	Fair	
12	20	1050	Fair	
13	21	600	Serious Problems	
14	22- 23	650	Fair	
15	24- 25	1100		Recently rehabilitated
16	26- 27	850	Serious Problems	
17	28- 29	850	Poor	
18	30	800	Fair	
19	32	595		Recently rehabilitated
20	33	1050	Fair	
21	34- 35	1100	Fair	
22	36- 37	1100	Fair	
23	38- 39	1100	Fair	
24	40	750	Poor	
25	41	1323		Recently rehabilitated
26	42- 43	1300	Fair	

Table 4: Assessment of lined mesqas at Sedi Sayed El Badawy village

Item	Mesqa name (number of irrigated lands)	Length (m)	Visual Assessment	Remarks
1	44- 45	1180	Serious Problems	
2	46	1170	Fair	
3	47	1090	Fair	
4	48	1000	Poor	
5	49- 50	810	Serious Problems	
6	51	990	Fair	
7	52- 53	1000	Serious Problems	
8	54	960	Serious Problems	
9	55	960	Poor	
10	56	960	Poor	
11	57	1050	Poor	
12	58	960	Fair	
13	59	960	Poor	
14	60	820	Fair	
15	60'	470	Fair	
16	61	1300		Recently rehabilitated
17	62	775		Recently rehabilitated
18	63- 64	760	Serious Problems	
19	65- 66	970	Poor	
20	67	800	Poor	
21	68	840	Serious Problems	
22	69- 70	825		Recently rehabilitated
23	71- 72	850	Serious Problems	
24	73	820	Fair	

Table 5: Assessment of linedmesqas at Sedi Talha village

Item	Feeding canal	Mesqa name	Length (m)	Visual Assessment	Remarks
1	1	1	1000	Poor	
2		2	1000	Serious Problems	
3		3	1000	Poor	
4		4	1000	Serious Problems	

Item	Feeding canal	Mesqa name	Length (m)	Visual Assessment	Remarks
5		5	1000	Poor	
6		6	1000	Poor	
7		7	1000	Serious Problems	
8	2	1	1100	Fair	
9		2	1000	Fair	
10		3	950	Poor	
11		4	1200	Serious Problems	
12		5	1200	Serious Problems	
13		6	1200	Serious Problems	
14	3	1	1000	Poor	
15		2	750	Poor	
16		3	650		Recently rehabilitated
17		4	650		Recently rehabilitated
18		5	650	Serious Problems	
19		6	650	Fair	
20	4	1	650		Recently rehabilitated
21		2	700		Recently rehabilitated
22		3	700		Recently rehabilitated
23		4	700	Serious Problems	
24		5	700	Serious Problems	
25		6	950	Serious Problems	
26	5	1	800	Poor	
27		2	650	Poor	
28		3	650	Fair	
29		4	650	Poor	
30		5	650	Fair	
31		6	650	Fair	
32		7	650	Poor	
33		8	400	Fair	
34	6	1	1000	Poor	
35		2	950	Poor	
36		3	950	Serious Problems	

Item	Feeding canal	Mesqa name	Length (m)	Visual Assessment	Remarks
37		4	950	Poor	
38		5	950	Poor	
39		6	650	Poor	
40	7	1	1000	Serious Problems	
41		2	950	Serious Problems	
42		3	950	Serious Problems	
43		4	1000		Recently rehabilitated
44		5	700	Poor	
45		6	350	Fair	
46	8	1	900	Poor	
47		2	1000	Serious Problems	
48		3	950	Serious Problems	
50		4	950	Poor	

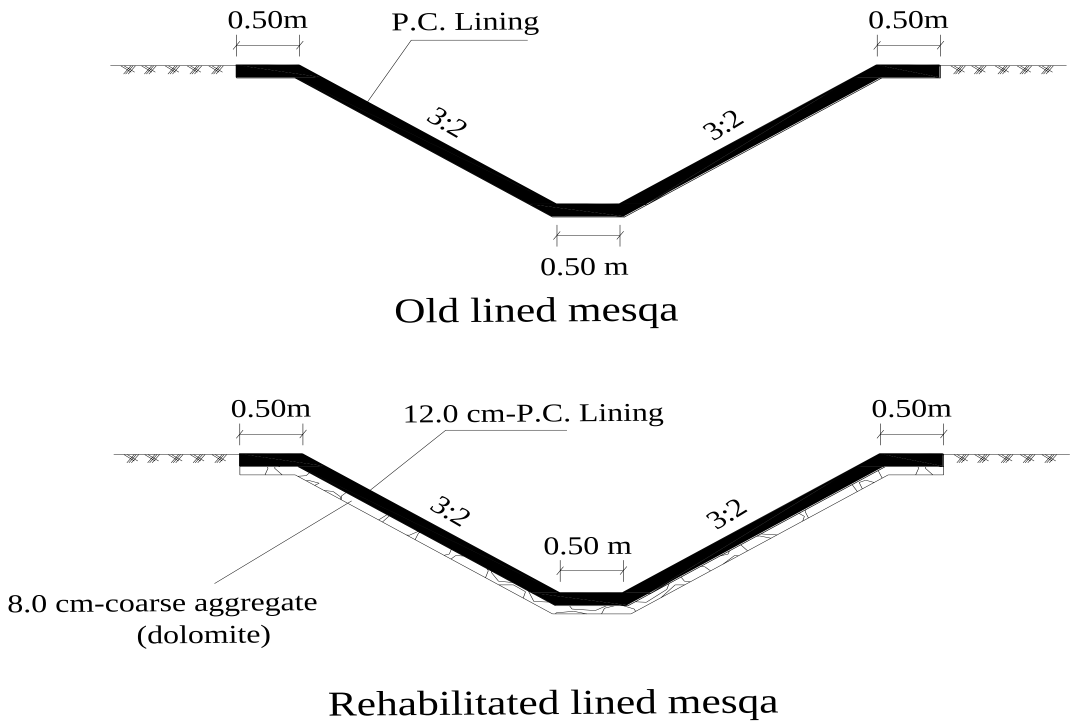

Figure4: Existing and rehabilitated lined cross-sections

Field Program

For evaluation of the nature of the damage and planning for the next phases of the study, the project site was visited on 9-12th April 2018. During the field visit, leveling instrument was employed to measure the difference in heights between water and land levels. Moreover, the Schmidt rebound hammer was used to determine the compressive strength of the new lined mesqas. Throughout the visits, the nature of the damage, geological aspects of land, and type of bed soil were examined.In addition, locations of the test pits for sampling as well as required field and laboratory tests were determined. Soil and groundwater samples were also collected from the three villages and were sent to laboratories of Faculty of Engineering, Alexandria University to define their physical, chemical and mechanical properties with the support of the project management.Several observations wells were employed to monitor the change in the groundwater tabledepth during the visit. Chemical analysis tests were also performedfor water samples from mesqasto compare them with the groundwater samples. The results of all lab tests are presented in the next section.

During the field program, it was observed that water levels were high in all drains. The water levels in drains were almost at the same elevations as those of water levels in mesqas. Most of the invert levels of tail escape pipes of mesqas were submerged in the drains' water (Clogged drainage), Figure 5. Grasses and shrubs were observed on the bottom and banks of all secondary drains. The bed levels of all drains were higher than the design ones. For the main drain (MoheetZaghloul drain), leveling instrument was employed during the visit to measure the difference in water elevation between the main drain and El Brullus Lake at the location of the pump station. Based on measurements, the water levelsin the main drain and in ElBrullus Lake were (- 1.30 m+MSL) and (+ 0.30 m+MSL), respectively. This indicated that the operatingstatic head of the pump station was 1.60 m, while the design one is 3.30 m, and hence the pump station operatedout of the design condition. The field investigations revealed that the water level in the main drain was higher than the design one by about one meter.This implies that the dredging works of drains were not functional as only the banks were just cleansed.

Figure 5: Submerged pipe tail escape at a secondary drain

Based on the observations, the concrete liningwas assessed for lining worksbeing in service for 17 years (old lined mesqas) and results areshown in tables 3 to 5. The damages noticed concerned either the poor condition of the concrete lining (eroded cement binder letting the gravels grains stripped), the fracturing of the lining, or both at the same time.It was found that the damage in the concrete linings was in the form of settlement and cracking in different directions and crushing of concrete and scouring of

the bed materials. Almost all the old lined mesqas were damaged and needed to be replaced.
The new lined mesqas were damaged due to insufficient weight of the lining to resist the hydrostatic pressures and sub-erosion by piping under the lining slabs. For the recently rehabilitated lined mesqas (being in service for 2 years), it was noticed that transverse and longitudinal cracks appeared in some mesqas, Figure6.The mastic filling of joints had completely disappeared or poorly repaired, resulting in open joints that allow the growth of wild grasses and piping erosion of the underlying soils across these joints, Figure 7.

Figure 6: Damages to the concrete lining

Figure 7: Growth of grasses at the concrete lining

It was observed that most of reclaimed lands were at higher level by about 1.50 m than the irrigation mesqas, which led to sediment depositions in the mesqas due to the swirl winds (coastal nature). Damage was detected throughout mesqas length and at different locations. Most of these cracks occurred at places where mesqas constructed in cut embankment. The level of lands and flood irrigation contributed to the damage of lining due to the seepage line and nature of very loose soils, Figures 8-9.

Figure 8: Sediment depositions at lined mesqa

Figure 9: Seepage through the concrete lining

The dimension (top width and bed width), and side slopes of some lined mesqas (i.e. mesqa 24-25) are not complied with the design cross-section of the concrete lining.The field investigations indicated that the soil of the subgrade mostly consisted of unconsolidated sediments with fine/medium sand to sandy silt texture. The presence of fine particles of different sizes and quantity in the soil was an important feature of this region. The damagedemonstrated in Figure 12 was attributed to the poor condition of the concrete lining (poor preparation) and piping erosion of the underlying fine soil. Although the thickness of the concrete lining of the design section is 12.0 cm, field observations revealed that concrete thickness of the collapsed panelis less than that, which is not sufficient to resist the hydrostatic pressure resulting from the groundwater table depth. The subgrade layer of 8 cm coarse aggregate was not observedunder the collapsed panel. Meanwhile,farmers fractured the concrete lining in front of their farms without technical supervision to lift the water to their reclaimed lands, Figure 13.Farmers also cultivate very close to the top of the lined mesqas. These actions from farmer's side contributed tothe damage of concrete lining.

Figure 12: Sample of collapsed panels

Figure 13: Lifting water by farmers

Results of Laboratory Tests

The following section illustrates the results of laboratory tests that were conducted. The complete chemical analysis of irrigation water, ground water, and soil from the three villages were carried out during the field visit.The laboratory tests of the soil included grain size distributions, compaction, and direct shear test.The samples were analyzed at the laboratories of Faculty of Engineering, Alexandria University, Egypt. As the measured compressive strengths by the Schmidt hammer for collapsed and good slabs of the new lined mesqas were not significant, the laboratory tests included chemical analysis of a concrete sample from the collapsed slab of the new lined mesqas.

Results of Chemical tests of soil and water samples

Twenty observation wells were installed in the study area during the field visit to monitor the depth of groundwater and to determine itsElectrical Conductivity (EC). Table 6 presents the groundwater depth and its salinity, whilst Table 7summarizes the chemical analysis results of the collectedsoil samples.

Table 6: Observed depths and salinity of groundwater

Date	April, 9		April, 10		April, 11		April, 12	
Well No.	Water depth (cm)	EC (dS/m)	Water depth (cm)	EC (dS/m)	Water depth (cm)	EC (dS/m)	Water depth (cm)	EC (dS/m)
1	75	12	75	12	75	13	80	11.9
2	75	12.5	75	12.5	80	12.5	90	10.7
3	70	11	70	11	75	11	95	9.8
4	80	10	80	10	90	10	100	8.7
5	85	9	85	9	90	8	100	6.9
6	85	9.5	85	9.5	95	8	110	6.8
7	90	8.7	90	8.7	95	7.7	100	6.5
8	80	11	80	11	85	10	95	9.7
9	80	10	80	10	85	10	90	9.1
10	80	8.5	80	8.5	80	8.5	95	7.6
11	85	9.6	85	9.6	90	9.5	100	8.5
12	90	8	90	8	95	8	110	6.4
13	95	8	95	8	100	8	120	6.7
14	80	12	80	12	85	11	95	8.9
15	80	12	80	12	80	13	90	11.8
16	75	14	75	14	75	14	85	12.9
17	80	8	80	8	90	8.5	100	8.9
18	80	8	80	8	90	7.8	100	7.6
19	80	8	80	8	85	8	95	6.5
20	80	8	80	8	85	8	95	6.3

Note: dS/m = 640 ppm, water depth measured relative to the ground land level as a datum

Monitoring of observation wells showed that the study area was floated on ground water. The ground water depth appeared at 70 cm up to 120 cm from the ground surface. Electrical Conductivity (EC) results of the pore water ranged between 6.3 dS/m and 14 dS/m. The salinity results revealed that ground water was formed due to seepage from the Mediterranean Sea and drains. The results of chemical tests proved that irrigation water samples had a good quality and its salinity varied from 1.8dS/m and 2.2 dS/m. Although the irrigation water had a low percent of a drainage water (water reuse),notoxic elements were observed in the samples. Drainage water samples werealso collected from secondary drains and the results of their chemical testsshowed a variation in the salinity that ranges from 2.6 dS/m to 13.6 dS/m.

Table 7: Chemical properties of soil samples

Profile No.	Sample location	Sample depth (cm)	pH	TDS (ppm)	Cl (ppm)	Sulphate (ppm)	$CaCo_3$ (%)
1	Sedi Ibrahim El Desouki village	0-60	7.42	1452	362.10	279	6.80
		60-115	7.54	2240	610.00	460	7.20
		115-190	7.66	3264	951.00	582	8.90
2		0-70	7.62	1369	390.00	259.2	8.40
		70-120	7.51	2060	468.00	312	6.00
		120-190	7.43	5318	1501.00	941	8.50

Profile No.	Sample location	Sample depth (cm)	pH	TDS (ppm)	Cl (ppm)	Sulphate (ppm)	$CaCo_3$ (%)
3		0-50	7.42	1203	315.00	230	7.40
		50-110	7.62	1401	404.70	320	7.90
		110-180	7.54	2368	596.40	532	6.80
4		0-60	7.42	1152	322.00	266	7.90
		60-130	7.54	1388	347.00	247	9.80
		130-200	7.66	2432	646.20	362	8.90
5	Sedi Sayed El Badawy village	0-60	7.58	1305	401.00	249	6.80
		60-100	7.42	2432	958.00	571	9.80
		100-210	7.69	3347	1324.00	865	9.00
6		0-40	7.62	1664	397.60	187	7.80
		40-80	7.58	3072	816.00	672	8.20
		80-160	7.89	4057	1306.00	859	9.00
7		0-100	7.54	1913	525.40	426.3	7.90
		100-140	7.84	1216	347.90	283	6.80
		140-180	7.55	3123	951.00	566.3	9.60
8		0-60	7.43	2291	624.80	542	6.70
		60-120	7.58	2496	862.60	566.4	8.70
		120-190	7.65	3072	1128.90	806	8.90
9	Sedi Talha village	0-60	7.62	1203	365.65	331	7.40
		60-120	7.51	1491	578.30	441	5.90
		120-180	7.54	4096	1160.00	795	9.00
10		0-60	7.51	2624	827.00	639	8.90
		60-130	7.69	2496	745.00	563	7.60
		130-190	7.54	3072	968.00	524	8.00
11		0-70	7.51	1286	397.60	184.6	6.30
		70-130	7.54	1990	497.00	335	8.90
		130-190	7.62	3411	854.00	515	9.30
12		0-50	7.84	1452	468.50	289.9	8.50
		50-140	7.54	1843	543.60	359.6	6.50
		140-210	7.44	2476	646.30	473.2	7.80

The total dissolved solids (TDS), Chloride, pH and Calcium carbonate of the soil in distilled water was determined to define the appropriate type and content of cement for the proposed concrete lining. The results of the chemical testsindicated that a low salinity of the soil at surface layers. However, a high degree of salinity was measured at deep depths (70 to 200 cm). The TDS of the soil samples ranged between 1152 ppm and 5318 ppm. Generally, the soil in the study area had a high percentage of TDS and this may affectits stability.A pH is a measure of acidity or alkalinity on a scale of 0 to 14, with 7 being neutral. pH for all tested samples are above 7, this means that the soil in the region is alkaline.

Physical properties of soils

Twelve boreholes with a depth up to2 m were excavated.The test pits were positioned to cover the three villages.In every village, one boreholewas dug beside the damaged point of a lined mesqa. Samples weretaken from the bottom of the test pits at 30 cm intervals and were sent to the Soil Mechanics and Foundation laboratory at Faculty of Engineering, Alexandria University for physical and mechanical tests after proper sealing. Boreholes and tests were conducted according to the Egyptian Code for Soil Mechanics- Design and Construction of Foundations, ECP (202-2001). Grainsizeanalysis, direct shear test, minimum and maximum unit weight, residual and peak angle of internal friction of six different soil samples collected from different locations of the study area wereinvestigated.

Textures of most samples are yellow brown fine/medium sand, with a few samples being dark brown fine/medium sand with some silt.Trace of crushed shellsonly found for two samples at Sedi Ibrahim El Desouki village. No particles coarser than sand were observed, the percentage of the particles of coarse sand (bigger than 0.6 mm) is mostly less than 5%. This shows that most of the samples have fine/mediumsandy texture with up to 70–80%.The percentage of silt in samples ranged between 3.3% and 10.7%. The effective diameter ranged between 0.07 and 0.08 mm with a uniformity coefficient of 3.06 to 3.74. For all samples, the angle of internal friction varied from 36.1 ^{o} to 25.4^{o}. The unit weight of the soil material ranged between 1.71 t/m^{3}and 1.08 t/m^{3}. The above mentioned characteristics was also taken into accountin the analysis of the lining damage.

Results of chemical test of concrete samples

A sample from the collapsed concrete slabs of the new lined mesqas was collected and chemically investigated by the Chemical Analysis Laboratory at Faculty of Engineering, Alexandria University. Inadequate construction method of canal lining was noticed. The results of the chemical tests indicated that concrete mixture contents were: the percentage of (Cement = 10%, Sand = 50.42%, and Coarse aggregate= 39.58%). It was noticed that the percentage of sand was very high with low percentage of coarse aggregate. Each cubic meter of plain concrete mixture had 210 kg/m^{3}.This quantity of cement does not comply with the mix design of the technical specification. The results of the chemical tests indicated that the percentages of Chloride and Sulphate salts to the weight of cement in the mixture were1.8% and 5.7%, respectively. These values arehigher than the allowable values (0.3% and 4%,respectively).

According to the results of the chemical the concrete mixture contents were: the percentage of (Cement = 10.60%, Sand = 42.80%, and Coarse aggregate = 39.20%).The results mentioned that, each cubic meter of plain concrete mixture had 260 kg/m^{3}. Also stated that percentages of Chloride and Sulphate salts to the weight of cement in the mixturewere 0.198% and 1.057%, respectively. These values are within the allowable values (0.3% and 4%,respectively, ECP 203- 2003).

Results of Core Tests of concrete samples

Eleven core test samples were collected from the new lined mesqas at the study area on May 17,2018 and laboratory tests was performed. Defined the thickness of each sample and the comprehensive strength of the concrete after 28days, F_{cu}. They mentioned that the average thickness of the lining at the three villages of the study area ranged between 13.30 and 15 cm. They believed that the average estimated actual strength of the concrete lining were 170, 139, and 182 kg/cm^{2} for Sedi Ibrahim El Desouki, Sedi Sayed El Badawy, and Sedi Talha village, respectively and they also stated that the design strength for each collected sample was determined according to ECP (203-2003).Moreover, the laboratory mentioned that the quantity of cement at the mixture of samples were accepted and they also recommended for the constructions of a new lining.

Results

Based on the results obtained in site, field investigation, and laboratory tests the main causes of the concrete lining damage are as follows:

- Unavailability of tertiary drains(farm level) around the mesqas except some subsurface drains made by farmers.
- High water levelsin secondary and main drains (higher than the design values).
- Very erodible and cohesionless soil texture.
- High salinity values of water and soils.
- High saline groundwater levels.
- Mostof reclaimed lands are at higher levels than the irrigation mesqas.
- Insufficient weight of the concrete lining to resist the under hydrostatic pressures of the groundwater.
- Application of inadequate design and construction methodsto the lined mesqas.

Conclusions

The lining of old mesqas should be replaced by a new protecting approach with an appropriate design and construction method. As illustrated before, the new lined mesqas has been damaged due to the abovementioned problems. Therefore, solutions should mainly focus on how to tackle the issues of soil texture in the subgrade layers, the high saline groundwater depth,and the drainage problem. Since repair works are usuallycostly, selecting the proper method should be based on the extent and the type of damage on one hand andon economic and technical aspects, on the other. For the project under investigation, it is recommended to redo a detailed design for the whole drainage system. Secondary and main drains should be dredged and cleaned every two or three months. The pump station at the main drain should operate within the design limits.

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