ESTIMATION OF WATER LEAKAGE FROM SEAMS AND CRACKS OF CONCRETE LINED CANALS

ESTIMATION DE LA FUITE D'EAU DES COUTURES ET DES FISSURES DES CANAUX REVETUS EN BETON

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ABSTRACT

In the usual concrete lined irrigation canals different types of cracks and pores develop in the concrete with time that tend to grow and get bigger creating water leakage problems. The leakage water is a loss to agriculture on the one hand and create salinity and waterlogging hazards on the other. Therefore if especial precaution procedures are not formulated and adopted initially, serious problems may occur later. With coordination established between authorities and available data and information about Doosti Dam irrigation canals, a decision was taken to pursue studies regarding the water loss due to its leakage from the cracks and pores of the concrete linings. The purpose of the study was to have a better knowledge about water resources management, especially in respect with irrigation canals, so that necessary guidelines could be developed.

Key words: *Water leakage, Irrigation canals, Cracks, Doosti Dam, Concrete lining*

RESUME

Dans les canaux d'irrigation en béton normal différents types de fissures et de pores se développent dans le béton qui tend à s'agrandir créant des problèmes de fuites d'eau. Les fuites d'eau est une perte de l'agriculture qui posent des risques de la salinité et de l'engorgement. Donc, il est nécessaire de formuler et d'adopter les procédures pour éviter les problèmes sérieux éventuels. Une décision a été prise de mener les études sur la perte d'eau due à la fuite des coutures et des pores du revêtement en béton, en collaboration avec les autorités et les données et informations disponibles sur les canaux d'irrigation du barrage Doosti. Le rapport

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vise à disséminer les meilleures connaissances sur les ressources en eau, en particulier en ce qui concerne les canaux d'irrigation, en vue de développer les lignes directrices nécessaires.

Mots clés : *Fuite d'eau, canaux d'irrigation, fissures, Barrage Doosti, revêtement en béton.*

1. INTRODUCTION

With growing population and increasing need for water, arid and semi-arid regions of the world, including Iran have been facing fresh water scarcity problem. This problem is further aggravated due to a lack of proper management of the limited available water. Inadequate management is most conspicuously perceived in the agriculture sector, particularly in irrigation, which happens to be the largest consumer of water in all irrigated regions in the world. In the dam-reservoir based and diversion based irrigation projects, the volumes of water handled and the irrigated areas are large. This requires long distances of water conveyance through canal systems from the water source to the farms. The loss of water during its conveyance assumes significant proportions in most of the cases if suitable leakage prevention measures were not considered at the time of designing the conveyance system. Lining of irrigation canals is a proven remedy to minimize water leakage losses during its transit from the source to the farm. In this context, several views have been advanced on the way of operating the system and the desirable quality of the concrete used for lining. In concrete lining, gradual appearance of some leaking joints and cracks are inevitable. Since these cracks and pores are the paths for exit of water from the main canal causing loss of water, adoption of special measures and contrivances are called for to minimize such losses. With arrangement made and access to information of irrigation canals of *Doosti* Dam (*Sarakhs* project), it was decided to do studies about the loss of water and actually leakage from positions of joints and cracks of lining coverage of canals, so be able to finally lead to better recognition of the problems and coming up with appropriate solution.

2. STUDY DETAILS

For different canal types namely, the main, 1st, 2nd and 3rd order canals, specifications such as geometry, discharges in each type canal, executional, thermal, shrinkage, expansion and contraction joints existing and their sizes were derived from executional drawings of Doosti dam irrigation canals project, and the calculations of seepage flow, and water loss for each type of canal were performed.

Specifications for each type canal are as shown in Table 1 and Table 2. Executional joint sizes considering the 30 meter spacing are calculated whose depths are the same as the concrete lining thickness. Also at spacing of 3 meters of main panels some incomplete joints exist. Positioning and locations of joints are in accordance with the figure for each kind canal.

Table 1. Total length for each type of canal

L (m)			
main	first order	second order	third order
55,000	77,000	150,000	500,000

Table 2. Amount of discharge rate for each type of canal

Q (m^3/s)			
main	first order	second order	third order
30	15	4	0.14

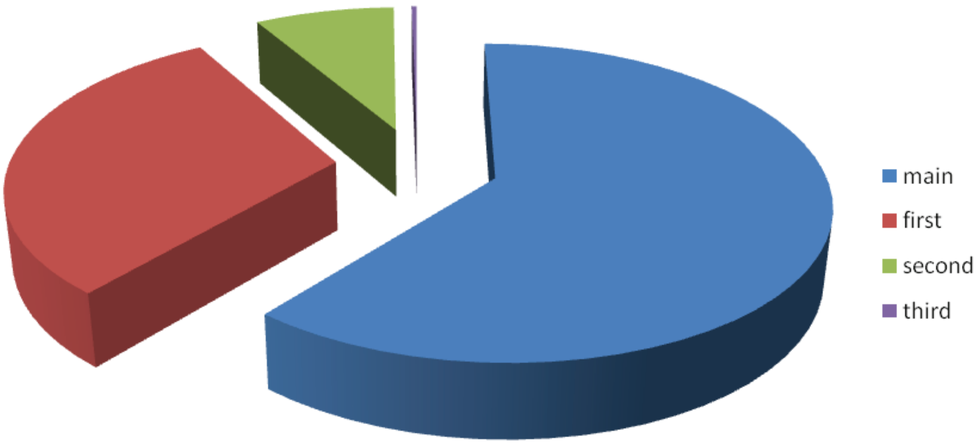

Figure 1. comparing the proportion of discharge for each type of canal

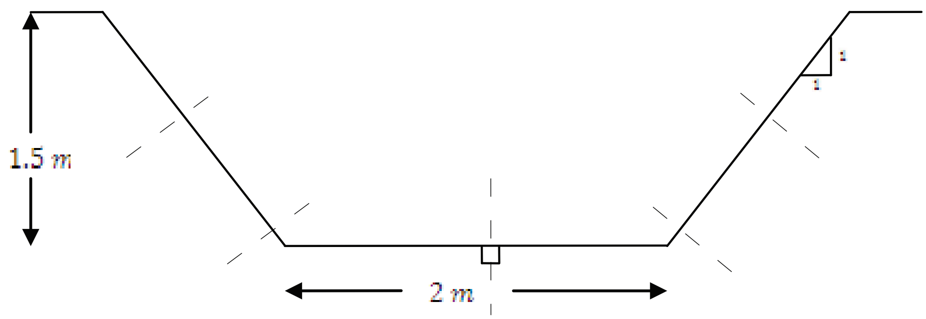

Figure 2. Positioning and locations of joints for main and 1st canals

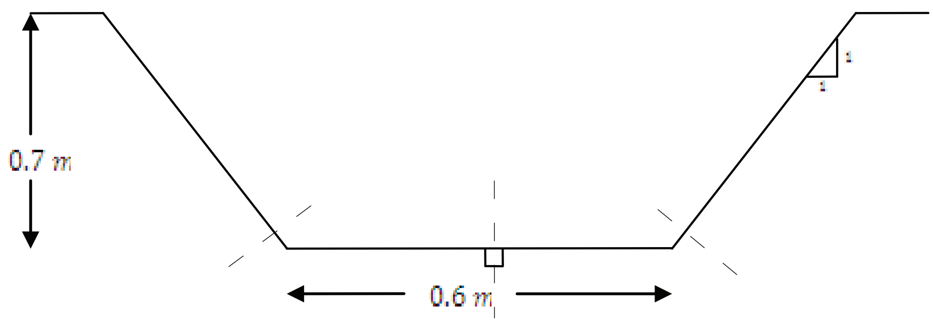

Figure 3. Positioning and locations of joints for 2nd and 3rd canals

When concrete is being placed its temperature due to lack of water inside canal, is the same as the ambient temperature (30-35 °C) and at the time of operating of canal when water is running inside, this temperature goes down to around 10 °C. This temperature reduction shall result in creation of contraction joints and heat diffusion due to concrete hydration shall also increase this contraction of concrete consequence from temperature reduction.

It should be mentioned that concrete contraction is calculated by using thermal module and can be transformed into surface contraction from which concrete shrinkage of two sides of the lining are determined. In fact, this is the same joint size that was taken as the basis of seepage flow calculations. This coefficient at 20 °C amounts to 3.6×10^{-6}.

Area covered by each section is actually area limited between the cracks and contraction occurs monolithically. This area is 3.9 m^2 for main, 2.1 m^2 for 1st order and 7.8 m^2 for 2nd and 3rd order canals.

In hot weather following commissioning especially when water is not running in canals temperature of lining increases when volumetric and then surface expansion of concrete takes place.

Running water brings in soil and other floating debris along with the flow, which may fill in the cracks and may temporarily prevent complete concrete expansion. Also later expansions won't be the same as the first one and thus, crack will remain for all the time and provide a path for water loss that gets bigger each day.

Another significant result of cracks is the upward movement of the underlying loose that tends to enlarge the cracks and cause higher water losses. Continuous washout may cause the soil under lining be emptied and differential settlements could result in the lining concrete which will consequently increase the existing cracks sizes and create new unwanted cracks.

Hydraulic structures along the flow route usually have executional joints of about 2 cm at the beginning and at the end of hydraulic structures. One should ensure that all these joints and unwanted cracks are filled in by suitable materials, which are water tight and flexible. But the common experience has been that due to the use of inappropriate material filling the gaps and also due to executional problems, these joints and cracks lose their sealing capacity as time passes.

Therefore some field surveys were performed on crack and watertight material used on them and estimations were made for their erosion and performances.

For performing various calculations, the location of hydraulic structures at different sections of the canal was determined and then the length of these cracks along the total length of each canal type were calculated. It may be noted that the cracks are mainly resulted by contraction and expansion of concrete linings. But the cracks due to differential settlement result in unwanted or undesirable and unforeseeable cracks and their positions are not predictable. However, these are the more vulnerable locations for a greater damage to the lining and greater water losses. In calculations based on observations made on Sarakhs irrigation canals these cracks were estimated 1 mm thick and averagely scattered on 10 percent of each type canal length. The fact to be considered regarding irrigation canals is that they have water running inside them for a specific duration of time, which is different for different type of canal. This duration will be longer for higher order canals, which supply water to the lower order canals in rotation.

Taking this as a general rule, in calculations of seepage discharge for water loss per annum, parameters and coefficients are used that are in direct relation with the order of canals. These coefficients by being multiplied to total seepage flow will result in calculation of daily, or annual water loss for each type canal.

Table 3 shows the annual coefficients for different types of canals.

Table 3. Annual operation coefficients for different irrigation canals

Canals type	Main	1st order	2nd order	3rd order
Coefficient	0.75	0.75	0.3	0.1

These coefficients are the resulted from existing information about intake model from different irrigation canals.

Table 4 displays crack calculations for different types of cracks

Table 4. Different lengths calculated for different types of cracks

Contraction joint (m)	Linear joints (m)	Structure joints (m)	Unexpected fractures (m)	Total (m)
19,250	206,250	1,155	4,125	230,780
18,865	288,750	1,617	5,775	315,007
7,785	90,000	882	4,500	103,257
2,870	0	0	5,000	7,870

Seepage calculations start at the end of each section of Sarakhs irrigation canals.

The seepage flow out of cracks and joints at the start is quite low but as time goes along, they become more. Therefore an estimate of the average flow has been performed. On the other hand seepage flow out of the joints depends on the effective head and the amount of entering flow. This information was for Sarakhs irrigation canals. The other effective parameter is the flow speed on which the water loss depends. In actual fact, seepage discharge calculations are based on the length of joints and their estimated average amount, and also the flow speed. Experiments and laboratory tests were helpful in finding the water loss discharge. In this laboratory tests relation between joint lengths with seepage discharge were studied. Joints or cracks were sharp without offsets and just the spacing between joint could be variable which were 1”, 1.2” and 1.8” as experimented on each type of Sarakhs irrigation canals and different flow speeds and ended up to an experimental formula for calculation of seepage discharge. As a result of field surveys and experiments the average flow speed was close enough to 1.2 m/s to be considered in the calculations as it is resulted from dividing each section flow by its cross section. These are shown in Table 5.

Table 5. Different discharges for different canals

Canal type	Q*(ft^2/s) = 0.0002V
Main	0.000787
1st	0.000787
2nd	0.000787
3rd	0.000787

Having established the sizes of cracks created on each canal type, a suitable formula was selected for discharge calculations. These calculated discharges according to laboratory tests was done on unit crack length and for calculation of seepage flow of a section this amount is multiplied by the total sum of the lengths of all cracks in the section. At the end of the calculations of seepage discharges of each canal section, it is observed that the main part of the water loss occurs through leaking out of the joints or cracks. This water loss caused by seepage when calculated for one whole year, shows a considerable amount that is a significant problem to be prevented and the costs of precaution works to minimize the water loss is justified as it saves valuable amounts of water. This is performed by improving the performance and execution works to get better quality of watertight and more suitable material with higher flexibilities.

Damages on account of water losses due to poor performance are obviated in this way. It should be mentioned that water resources are being more and more important in comparison with executional costs of irrigation networks. Results of water loss of each canal type in relation to its length for annual seepage, and also ratio of leakage discharge to total flow in the relevant canal annual amounts are displayed in Table 6.

Table 6. Calculations and comparison of water loss discharges for different canals

Canal tip	Q” (m^3/s)	Q” (m^3/day)	Q” ($m^3/year$)	Q”/Q0	Q”/L ($m^3/year. L$)
main	0.16882	14586.03486	5323903	0.007503	96.8
first	0.230433	19909.45092	7266950	0.020483	94.4
second	0.075534	6526.172987	2382053	0.062945	15.9
third	0.005757	497.4091965	181554.4	0.411218	0.37
Σ			15154460		207.42

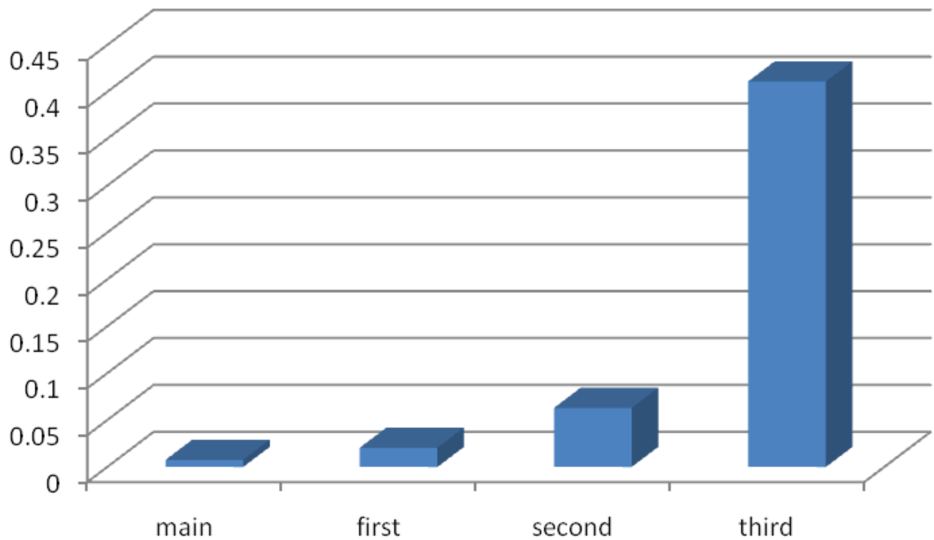

Figure 4. Unit length annual water loss comparison of different canals

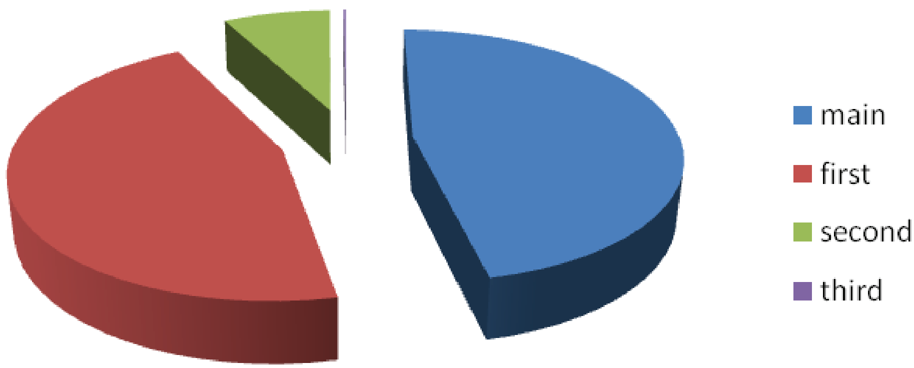

Figure 5. ratio of leakage discharge to total flow in each canal type Chart

3. CONCLUSIONS AND RECOMMENDATIONS

As is observed, maximum seepage discharge to canal length ratio occurs in the main canals. The reason behind this is that 2nd and 3rd canals are mainly of high lengths and due to low flows of water running in them, lower amount of water per unit length is lost in these canals. Also, as it is observed in figure 5 or the above chart, the ratio of water loss discharge divided by total flow, is higher for the 3rd order canals than the others in Sarakhs irrigation network. Therefore it is necessary to consider improving the quality of these type canals.

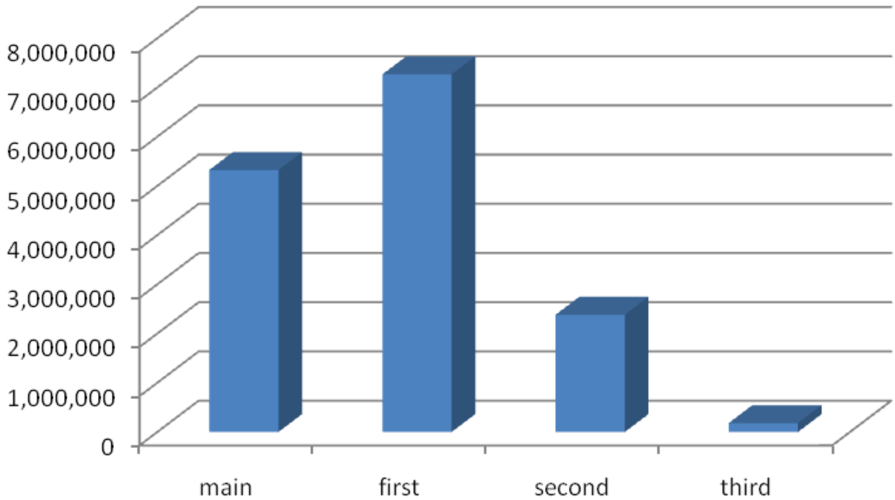

Figure 6. Annual water loss of different canals (m³/yr)

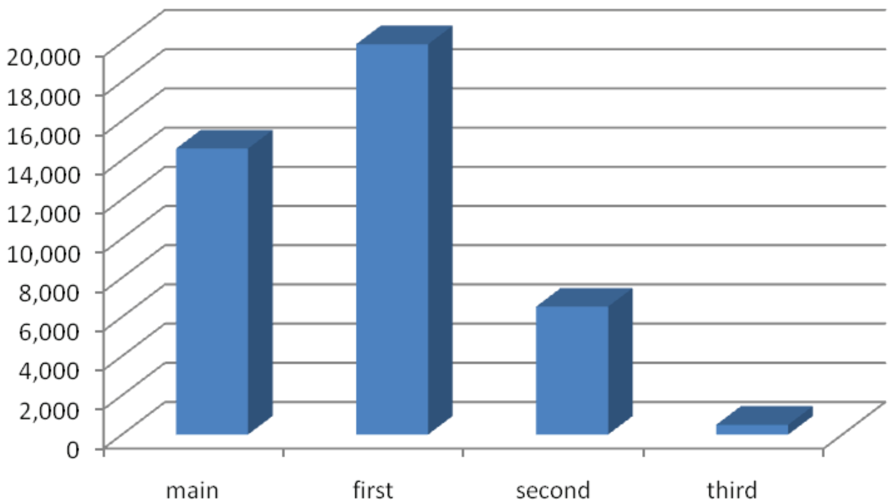

Figure 7. Daily water loss of different canals (m³/yr)

As it is observed, main and 1st order canals have the highest share of daily and annual water losses in Sarakhs irrigation network canals between which 1st order canals have higher loss values due to their longer total lengths as compare with the main canals. The least ratio belongs to 3rd order canals, and considering that these types of canals have the highest total length in the network, we conclude that seepage flow is considerably reduced.

At the end ratio of losses to current flows for different types of canals are calculated and compared. As we observe, the most amount of water loss flows allocate to 3rd order canals that means these canals are of low performance efficiencies compared to the main discharge inflow.

Main and 1st order canals are of higher priorities and accordingly have better performance efficiencies as well.

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