Tarig *et al.*, Sudan Academy of Sciences Journal, No. 10, 2015, 70-79
ISSN 1816-8272

Irrigation Canal Lining Using Precast Concrete Units: Experience of EL Rawakeeb Research Station

Tarig E. A. Ibrahim[1] and Nadia A. Hamza[2]

Abstract

Surface irrigation methods usually encounter very low water use efficiencies. Hence, improving such systems become imperative to contribute in alleviating water scarcity. About 20% of the diverted water for irrigation is being lost in tertiary canals. Meanwhile, good quality linings are able to practically eliminate seepage losses from such canals. Precasting which provides high quality control was advised for mass production of tertiary canals. The objective of the current study is to minimize huge seepage losses encountered in Rawakeeb Research Station (RRS) using canal lining. The J-section was selected and forms made of metal sheets, angle bars and removable pins were designed for casting concrete canal-lets. Locally available aggregates (sand and gravel) were used for casting by developing an appropriate concrete mix. After casting the blocks were left for one hour to allow for concrete setting then the form was released. The precast units were allowed to dry for 24 hours and cured for seven days using wet kenaf sacks. Volume of cut and fill was estimated for the whole channel and the sub-grade was prepared by hauling gravelly soil from the vicinity of RRS. The sub-grade was thoroughly compacted using hand compacter. The slope was set out at 1 cm every 10 meters using a staff rod and engineer’s level. The compacted sub-grade was elevated to the required level and a pair of precast canal-lets was placed to make the channel configuration while preserving alignment. The bottom and side gaps between each two adjacent pairs were filled with cement mortar made of locally available sand. The lined section proved to be efficient with smooth water flow while seepage was virtually eliminated. Moreover, conveyance time was reduced from about 2 hours to 10 - 15 minutes (depending on the location of the field to be irrigated). "Adoption of canal lining using precast units will make desert agriculture more lucrative since irrigation efficiencies will be improved", the paper concluded.

***Keywords**:* Irrigation, Seepage, Efficiency, Canal lining, Precasting

Introduction

It's anticipated that the problems associated with water scarcity will be aggravated in the very near future due to increased economic activities, improved standards of living and expansion in agriculture (Saeed and El Gamri, 2008).

Surface irrigation which is a gravity irrigation system is the eldest form of irrigation where the water is distributed over the surface of the soil. To achieve even distribution of irrigation water the land is to be with slight slope or leveled

[1] National Centre for Research.
[2] Ministry of Agriculture, North State- Sudan.

enough. The more leveled the land, the more efficient the flooding will be. The surface system efficiency may range between 45% and 75% depending on different factors like design, operation and management. However, Schwab *et al.*, (1992) pointed out that the efficiency of improved level basin systems may reach up to 80%.

Improving irrigation efficiency will conserve large amounts of water and contribute in alleviating the water shortages problems (Saeed and El Gamri, 2008). The authors attributed that to the general low efficiency of irrigated projects, particularly those under traditional surface methods. According to Haigh *et al.*, (1994) about 20% of the diverted water for irrigation is being lost in tertiary level canals. Meanwhile, it was revealed by Laycock, (1994) that good quality lining had the ability to reduce losses from such canals to only 1%. Similar results were obtained by El Gamri, (2000). Hence, it could be emphasized that lining tertiary level canals will conserve substantial amounts of water.

Beside its high capabilities to reduce seepage losses, irrigation canal lining also provides structural integrity, reduces maintenance costs, and provides weed control abilities (El Gamri *et al.*, 2013). Other benefits include reduction of erosion and right – of – way cost and control of water logging.

According to Kraatz, (1977) irrigation canal lining may be classified into:

1. Hard surface linings' (HSL).
2. Exposed and buried membrane linings'.
3. Earth linings'.
4. Soil sealant.

In USA a demonstration project of the Bureau of Reclamation and other partners showed that geo-membranes covered with shotcrete or grouted mattresses is the most promising lining combination (Swihart and Haynes, 1997).

Laycock, (1994) attributed the merits of precasting to the high quality control associated with the technique. Precasting was advised by Birch and Lockette, (1994) for mass production of tertiary canals. For larger canals precast slabs of various dimensions' may be produced to suit different canal sizes. The blocks may also be placed over polyethylene sheets'. The slabs are made with interconnects and the joints are grouted with cement mortar, asphalt or other sealant (Punmia and Lal, 1983; El Gamri *et al.*, 2013).

For small lined channels the tendency is towards U- shape, semicircular, and parabolic cross sections because they grant integrity in structure and offer superior hydraulic efficiency. Meanwhile, some developing countries viz. China and Pakistan developed mechanical techniques for both precasting and cast in-situ (El Gamri, 1998); El Gamri *et al.*, (2013).

In some parts of the country e.g. Rawakeeb Research Station (RRS) and Om Jawaseer Desert Farm Project seepage looses were found to be substantial (El Gamri, 2005). However, till recently irrigation canal lining was not adopted in Sudan since most of the large irrigated projects are situated in the central clay plains where seepage losses are negligible. El Gamri, (1998) concluded that based on technical virtues and economic viability concrete made of local small sized gravel, wire mesh reinforced cement-sand mortar (ferrocement) and khafgi are appropriate for canal lining under the Sudan's semi desert conditions. The author

ISSN 1816-8272

recommended cast *in situ* placement technique which suits the then general national economic conditions and technical capabilities. Ahmed *et al.*, (2009) adopted canal lining in the semi-desert climates of the Sudan and concluded that the technique improved the conveyance, application and storage efficiencies by 104%, 91.5% and 97% respectively. In addition to that "water depth increased by 100% and crop productivity by 290%", the author added.

Materials and Methods

Study location

In the year 1992 the National Centre for Research (NCR) was mandated by the Comprehensive National Strategy (1992 – 2002) to undertake basic and applied research in desertification. Consequently, RRS was established in the same year. The station is located in the semi-desert climate about 40 km west of Omdurman at the border of North Kordofan State. The soil was classified by El Haj *et al.*, (2006) as sandy clay loam. Hence, significant seepage is encountered; the situation is further aggravated by significant accumulation of wind transported sand. Irrigation water is of good quality however, costly since it is pumped from an aquifer of about 100 m deep (El Gamri, 2004).

The form

The J- Section was selected for ease of casting and steel form was made. The form dimensions of 40 cm breadth, 20 cm width, 40 cm elevation and 10 cm thickness were represented by those of the produced blocks' as shown in Fig. (1). To expedite production of the blocks 6 forms were made.

Materials used to fabricate the form include:

1. Metal sheets.
2. Angle bars of 1½ ″ side thickness (3.81 cm).
3. Removable pins.

Mix design

Aggregates

According to El Gamri, (1998) wadi transported sand at RRS is suitable for building works since it possesses an average silt content of 1.88% and gradation of medium sand which complies with the specifications of the British Standards BS 882: 1983. On the other hand, RRS gravel is classified as single- sized aggregate (1/2″) (14 mm) when tested in accordance with (BS 882:1983) (El Gamri, 1998). This type of gravel is of poor grading and of the elongated type and with a percentage of voids of 43%.

Workability of the concrete mix

Workability is defined as the ease with which a given set of materials can be mixed into concrete and subsequently handled, transported and placed with a minimum loss of homogeneity (USBR, 1988).

The concrete mix design of 1.25:2:4 (cement: sand: gravel) was found to be appropriate for RRS aggregates and Ordinary Portland cement was used. Water in RRS was pumped from deep boreholes for the last 40 year for human consumption and irrigation. This water was used adequately for mixing and curing. The concrete mix was tested for workability adopting the method described by El Gamri, (1998) for testing trail mixes.

ISSN 1816-8272

Precasting and curing

The form was filled with concrete while being compacted with a steel rod, then left for an hour to allow for setting of concrete and then released as shown in Plate (1). The finished section was allowed to dry for 24 hours and then cured for 7 days by using wet kenaf sacks.

Defining of the Channel Hydraulic Slope

According to Michael, (1978) the channel hydraulic slope S is defined as the ratio of its vertical drop (h) for a length (l) of the channel.

$$S = h/l \quad \text{------------ (1)}$$

At RRS the slope was set out 1 cm every 10 meters; to insure the flow of water for a total length of about 300 m. This value of the hydraulic slope is within the range specified by Mashhadi, (1994) for lined channels. A staff rod and an engineer's level were used to define the gradient of the channel. As shown in Plate 2 at 10 m intervals a compacted sub-grade was raised to the required level and a pair of precast canal-lets was placed to set the channel configuration while preserving the channel alignment.

Estimation of volumes of cut and fill

Cut and fill entail removing earth from some parts of the channel line and place earth on other parts. There are a lot of methods to measure volumes of cut and fill however; the Cross- Section Method as suggested by Abdelhameed, (2012) was used. The method was applied for a length of 50 m and the average was taken for the total length of the channel of 280.40 m.

$$V_{total} = d/2\,[A1+An+2\sum Ai] \quad \text{------------- (2)}$$

Where:

V total= total volume of earth (m^3).
d: distance between points (m).
A: = cross- sectional area (m^2).
n: number of cross- sections.
i: 2,3,…… (n-1)
For the present study d= 10 m

Construction of the channel

The work was done manually, the channel was reshaped, and specific slope was set out. Gravelly soil was collected from the vicinity of RRS then laid on the sub-grade and thoroughly compacted using hand compacter. Two parallel rows of concrete J- section canal-lets were laid on the compacted sub-grade, the gaps between each two adjacent joints were filled with cement mortar made of local aggregates (sand) at a ratio of (1: 4).

To control the flow a steel gate was constructed on the down stream side of each field outlet pipe (FOP) as exhibited in Plate (3).

Results and Discussion

Estimation of the cut and fill

Table (1) shows the widths of the channel and the heights of points and distances between points.

ISSN 1816-8272

Table 1. Cut and fill parameters

Point	Distance (m)	Height (m)	Width (m)	Area (m^2)
1	0	0.817	1.50	1.23
2	10	1.095	1.70	1.87
3	20	1.165	1.50	1.75
4	30	1.305	1.40	1.83
5	40	1.400	1.40	1.96
6	50	1.500	1.50	2.25

V total = d/2 [A1+An+2 ∑Ai]

V total= 10/2[1.23+ 2.25+ 2(1.87+1.75+1.83+1.96)] = 91.50 m^3

V average= total volume/ length of channel= 85.35/50=1.83 m^3/ m.

This means that on average 1.83 m^3 is required to fill every meter of channel length.

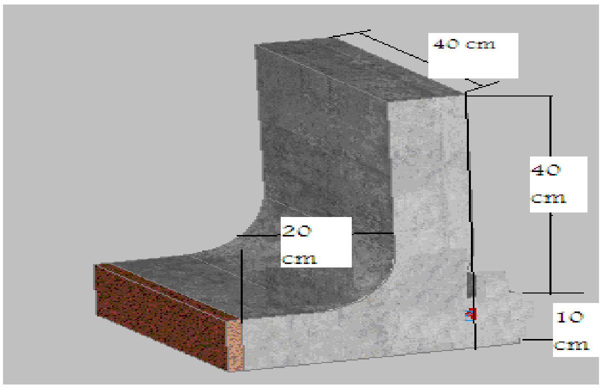

Fig. 1. Dimensions of a precast unit

Plate 1. Precasing and release of the form

Mix design

The void ratio of 43% of RRS gravel is consistent with Reynolds *et al.,* (1974) who confirmed that the void percentage may reach a maximum of 45%. To insure dense concrete the volume of sand should be about 5% in excess of that of voids

ISSN 1816-8272

of the coarse material (45% + 5% = 50%). Consequently, the universal ratio of 1:2 (fine: coarse) of the 1:2:4 mix (structural concrete) was obtained (Reynolds *et al.*, 1974).

Although RRS gravel possesses volume of voids within the specified range of 45%, the amount of sand should be increased for the following reasons:

1. Elongated gravel reduce workability and hence mix designs of high sand are required (Neville, 1963 and USBR, 1988).
2. The amount of gravel that may be incorporated in a certain mix increases as the maximum size of the aggregate increases (Neville, 1963 and USBR, 1988).
3. Canal lining in particular necessitates the use of dense concrete so that imperviousness is secured.

Hence, instead of 50% of fine aggregated, 60% was used (3:5 fine coarse aggregate ratio) which agrees with Reynolds *et al*., (1974) who described ratios of (1:1.25) and (1:3) for liquid containers. The conventional cement aggregate ratio for structural concrete is 1:6 however; lower ratios (more surface area) are tolerable for irrigation canal lining when adopting the cast *in situ* technique. The ratios of (1:9), (1:10), (1:12) (1:7) were described by Punmia and Lal., (1983), Ahmed, (1994), Laycock, (1998) and El Gamri, (1998) respectively. The amount of cement was slightly increased since precasting demands higher strength than that of cast-in-situ hence, the mix of 1.25:2:4 was adopted i.e. with a cement aggregate ratio of 1:6.4 which is slightly lower than that of structural concrete.

The selected mix was found to give dense concrete and with 1.5 volume of water a paste with workability suitable for canal lining as recommended by (Kraatz and Mahajan, 1975; El Gamri, 1998) i.e. the mix was plastic enough to consolidate thoroughly and stiff enough to stay in place on the side slopes.

As shown in Plates 1 and 3 the steel form produced the desired units with no cracks and honey combing. This is in agreement with Kraatz (1977) who recommended the use of sheet metal forms rather than wooden forms. In addition to that Ahmed, (2007) and Ahmed *et al.*, (2011) revealed the fact that a wooden form failed to produce satisfactory products of precast canal-lets. According to the authors the canal-lets witnessed cracks and honey combing. However, according to Skutsch, (1994) and Haigh *et al*., (1994) crack free lining is of prime importance because only 0.1% faulty area will cause the lining to leak at the same rates as earth channels. Beside that, cracks and honey combing will reduce durability and increase maintenance cost.

As shown in Plate (3) the precast lined channel in RRS maintained smooth water flow. Meanwhile, time needed for the irrigation water to reach the field (conveyance time) was reduced from about 2 hours to only 10-15 minutes depending on the location of the field to be irrigated.

ISSN 1816-8272

Plate 2. Set out of the hydraulic slope and channel alignment

Plate 3. A lined section and field out-let pipe made of local aggregates

Conclusions and Recommendations

1. Canal lining is important to conserve water especially where the water is scarce and/or the soil is light**.**
2. Use of steel forms is advisable for precasting concrete canal-lets.
3. Lining tertiary canals proved to be very essential since it will save substantial water losses.
4. Adoption of canal lining will create job opportunities for local people and upgrade their technical know – how.
5. Research studies on canal lining particularly, when local materials are used are highly advocated.

References

Abdelhameed, N. (2012). Development of Precast (J-Section) Concrete Lining. M.Sc. Thesis, Sudan Academy of Sciences (SAS).

Ahmed, T.M., El Gamri, T. and Abdelmagid, I.M. (2009). Use of precast concrete slabs and bricks for lining irrigation canals. *J. of Sci. and Tech.,* 10(2): 201-214.

Ahmed, T.M., El Gamri, T. and Abdelmagid, I.M. (2009). Impacts of canal lining on irrigation efficiencies and crop productivity. *Al Buhuth*, 12(1):70-82.

ISSN 1816-8272

Ahmed, T.M., El Gamri, T. and Abdelmagid, I.M. (2011). Design considerations of concrete lined channels: Experience of Rawakeeb Research Station. *SASJ* 4 (1): 105-120.

Ahmed, T.M., El Gamri, T. and Abdelmagid, I.M. (2012). Economic evaluation of precast concrete lining in deserted areas. Chapter (19): Environment People and Development: Experiences from Desert Ecosystems. New India Publishing Agency, India.PP.

Ahmed, N. (1994). An overview of canal lining experience in Pakistan. Proceedings of the International Workshop on Canal Lining and Seepage. Lahore, Pakistan.

Birch, D. R., Lockette, N. J. (1994). Alternative Materials and Construction Techniques for Lining Tertiary Level Irrigation Canals. Proceeding of the International Workshop on Canal Lining and Seepage. Lahore, Pakistan.

BS 812: Part 103: 1983 (1994). Testing Aggregates. British Standards Institution.

BS 882:1983, (1994). Specification for Aggregate from Natural Resources for Concrete. British Standards Institution.

Chow, V. T. (1988). “Open Channel Hydraulics,” McGraw-Hill Classic Text Book Reissue, McGraw-Hill Publishing Company.PP.

El Gamri, T. (1998). Development and evaluation of low cost muilding materials for canal lining. M.Sc. Thesis Dept. of Agric. Eng., Fac. of Agric., U. of K.

El Gamri, T. (2004). Prospects and constraints of desert agriculture: Experience from *West Omdurman. Environmental Monitoring and Assessment* J. 99:57-73. (Special Issue: Alternative Ways to Combat Desertification) Kluwer Academic Publishers, The Netherlands.

El Gamri, T. (2005). Lining irrigation canals on expansive soils: Experience of Um Jawaseer Desert Farm Project, Sudan. *Al Buhuth*. 8(2): 61-75.

El Gamri, T. and Saeed, A.B. (2000). Use of Khafgi for lining irrigation canals. U. of K. J. of Agric. Sci., 8 (2): 69-80.

El Gamri, T., Saeed, A.B. (2013). Canal lining: A research experience from Sudan. Presented at New Nile Perspective Conference, Grand Holiday Hotel, Khartoum, Sudan.

El Hag, M.M., El Hiraika, A. A., ElHadi, S.A., Saad, S.A. (2006). Characterization of El Rawakeeb Soil. *Al Buhuth*. 10(2): 45-56.

Haigh M., Jones C. and Davey, C. (1994). “Unlined Canals: The Grateful Earth”. Proceedings of the International Workshop on Canal Lining and Seepage. Lahore, Pakistan.

Kraatz, D.B. (1977). Irrigation Canal Lining. FAO Land and Water Development Series, No.1. FAO, Rome.

Kraatz, D.B. and Mahajan, I.K. (1975). Small Hydraulic Structures. FAO Irrigation and Drainage Paper 26/2. FAO, Rome.

Laycock, A. (1994). Precast Parabolic Canals: Revelation and Revolution in Pakistan. Proceedings of the International Workshop on Canal Lining and Seepage, Lahore, Pakistan.

ISSN 1816-8272

Mashhadi, S.N.H. (1994). Role of Design and Construction Technology in Canal Lining, Proceedings of the International Workshop on Canal Lining and Seepage, Lahore, Pakistan.

Michael, T.E. (1978). Irrigation Theory and Practice. 1st Ed. Vikas Publishing House PVT Ltd. New Delhi, India.pp

Neville, A.M. (1963). Properties of Concrete. 1st Ed., Sir Isaac Pitman and Sons Ltd.pp.

Punmia, B.C. and Lal, P.B.B. (1983). Irrigation and Water Power Engineering. 7th Ed., Standard Publishers Distributors, Nai Sarak Delhi, India.pp.

Reynolds, C.E. and Steedman, J.C. (1974). Reinforced Concrete Designers Handbook. 8th Ed., Viewpoint Publications.pp.

Saeed, A.B., El Gamri, T. (2008). Efficient use and appropriate management of irrigation water in Sudan. Assessed Proc. the Nile Basin Development Forumpp 236 – 252. The Nile Basin Initiative, 17-19 Nov., Friendship Hall, Khartoum, Sudan.

Schwab, G.O., Fangmeir, D.D., Elliot, W.J. and Fervent, T, R. K. (1992). Soil and Water Conservation Engineering. 4th Ed., John Wiley and Sons, Inc.pp

Skutch, J.C. (1994). The Role of Maintenance in Extending lining Service Life. Proceedings of the International Workshop on Canal Lining and Seepage. Lahore, Pakistan.

Swihart J. and Haynes, J. (1997). Deschutes- Canal Lining Demonstration Project: Year 5 Durability Report. R-97-01 US Dept. of the Interior, Bureau of Reclamation, USA.

USBR, (1988). Concrete Manual. 8th Ed., US Dept. of the Interior, Bureau of Reclamation. USA.pp

Zaidi, M.A. (1994). Lining of Irrigation Channels: The Punjab Experience. Proceedings of the International Workshop on canal Lining and Seepage. Lahore, Pakistan

ISSN 1816-8272

إستخدام قنوات ري مسبقة الصب مصنوعة من مواد محلية: تجربة محطة أبحاث الرواكيب

طارق الجمري[1] ونادية عبد الحميد[2]

مستخلص البحث

تعاني معظم نظم الري السطحي من تدني كفاءة إستخدام المياه. مما يجعل تحسين هذه النظم ضرورياً للمساهمة في تخفيف شح المياه. حوالي 20% من مياه الري تضيع في قنوات المستوى الثالث. فيما وجد إنا التبطين الجيد لقنوات الري القدرة على التخلص عملياً من فواقد الرشح من مثل هذه القنوات. يفضل إستخدام تقنية الصب المسبق والتي تعطي فرصة كبيرة لإدارة الجودة في إنتاج الكميات الكبيرة من قنوات المستوى الثالث. تهدف الدراسة لتقليل الفواقد المقدرة لرشح القنوات بمحطة أبحاث الرواكيب بإستخدام تبطين القنوات. تم تطوير خلطة خرسانية تناسب خصائص المواد المتوفرة بمحطة أبحاث الرواكيب. بعد الصب يترك القالب لمدة ساعة قبل تحريره لتتصلب الخرسانة. ثم تترك الوحدات المصبوبة لتجف لمدة 24 ساعة ثم تعالج بإستخدام جوالات الكناف المبللة لمدة 7 أيام. تم تحديد كميات القطع والردم كما أستخدمت الخرسانة الترابية المتوفرة جوار المحطة بعد دمكها كارضية للقنوات. تم عمل إنحدار القناة بواقع 1 سم لكل 10 متر بإستخدام نظارة التسطيح والقامة (المسطرة). رفعت القناة مع دمكها للإرتفاع المطلوب ثم وضع زوج من الوحدات في شكل القناة مع مراعاة إستقامة القناة. تم حشو الفراغات على الأرضية والجوانب لكل وحدتين متجاورتين بمونة الأسمنت المصنوعة من الرمل المتوفر قرب المحطة. وجد أن القطاع المبطن ذو كفاءة عالية وجريان سلس فيما تم التخلص من الرشح بصورة شبه كاملة. وكذلك تم تقليل زمن نقل المياه من حوالي الساعتين الى 10 – 15 دقيقة (حسب الجزء المراد ريه من المزرعة)، خلصت الورقة الى أن تبطين قنوات. الري بإستخدام القنوات المسبقة الصب يعظم الفائدة من الزراعة الصحراوية لقدرته على تحسين كفاءة نظم الري.

---

[1] المركز القومي للبحوث.

[2] وزارة الزراعة – الولاية الشمالية.

ISSN 1816-8272