Paper No. 260
Year 1945

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The main advantages of lining a channel are saving in irrigation water, avoiding water-logging, stability of the section and reduction in maintenance cost. Improvement of command owing to flatter slopes is also possible. Two major lining schemes i.e. lining Gang Canal with concrete lining and lining Haveli Main Line with brick lining have been completed. There still, however, remains a controversy regarding the most effective and economical method of preventing absorption losses through the irrigation channels.

Financial analysis of lined channel scheme has been made in regard toe the benefits achieved from savings in water. This is based on the presumption that the area irrigated would increase proportionally with the increase in supply. It has been estimated that expenditure incurred to effect saving of 1 cusec of capacity for the three cases given hereafter would be Rs. 113,000, 65,000 and 30,000 respectively with 6% return. The categories are :

(i) Water saved utilised in Crown waste land on temporary cultivation.

(ii) Water saved utilised in Crown waste lands which are sold

(iii) Water saved utilised in areas already receiving irrigation.

These calculations do not take into account the indirect benefits derived from prevention of water-logging.

The design of lined channel is governed by the permeability, co-efficient of rugosity, durability, cost of construction and maintenance. The permeability of material determines absorption losses and the co-efficient of rugosity determines the carrying capacity of the channel. Weathering is caused by disruptive action of temperature variation, alternate freezing and thawing, and wetting and drying. The alkali soil causes corrosion of concrete and this can be prevented by the application of sulphate resistant cement. Cost of construction would vary with the locality and the availability of various materials. The lined section should be structurally stable. In reinforced concrete lining the reinforcement is designed to reduce the size of contraction cracks and to prevent damage due to settlement of subgrade, but it may delay the relief obtained through local failure in small patches. This was the main cause of failure of Haveli Main line resulting from back pressure of water. The side slope of the lined channel should be the same as the angle of repose of the retained soil. The thickness of lined section would depend upon the lining material, the side slope and the existence of hydro-static pressure. There should be proper drainage system to prevent failure due to back pressure.

Concrete lining is durable if laid properly and the absorption losses are reduced by 95%. The coefficient of rugosity is low and in view of high velocities possible, the section is reduced. The construction is carried out in panels and grooves are provided to prevent cracks due to shrinkage and alternate expansion and contraction. Oil paper, crude oil, 1 : 6 cement plaster or 1 : 4 cement sand slurry are used at the top of subgrade to avoid its becoming spongy and permeable. A greater control on the manufacture of concrete is possible through slump tests.

Cement mortar lining is not very durable unless suitably protected and as such can only be used in conjunction with some other protective material. Stone masonary has a limited application mainly on account of its cost and can thus only be used where stone is locally available. Road oil lining is not durable nor it is effective and the coefficient of rugosity is high. Sodium carbonate lining has been used in water courses and small channels, but its useful life is not more than two to three seasons.

Clay puddle lining reduces seepage losses by about 80%. The quality of puddle can be judged by its dry bulk density, which is a measure of its compaction. It has been shown that there is an optimum moisture content for each soil at which the dry bulk density obtained is maximum. This optimum moisture content is determined in the laboratory by compaction test, or approximately by formula devised by the author. The clay puddle is compacted in 6 inch layers at optimum moisture content by the use of toothed rollers.

Brick lining was used on a large scale for the first time in America in 1933. It was adopted with suitable modification for Haveli Canal in 1937. This lining failed due to inadequate compaction of the back-fill, lack of proper drainage of banks and insufficient free board. The absorption losses Q_A in an unlined channel are given by

$$Q_A = 0.0133\, LQ^{\frac{0.05625}{}}$$

Where Q is the discharge in cusecs and L is the length of the channel reach. The experience at Haveli Main line and Gang Canal show that the absorption losses in lined canal are of the order of 1.5 cusec per million square feet of wetted perimeter. Absorption losses in a brick lined channel can be estimated from Haigh's formula :

$$K = 1.25 \times Q^{\frac{0.056}{}}$$

Where K is the absorption loss per million square feet of wetted perimeter.

Haveli Canal was designed with Mannings N of 0.0146 whereas its observed value varies between 0.018 and 0.02 which is the result of sand blown in or brought in from the head and the presence of caddis worm in large number. In future a higher coefficient for brick lining say 0.018 should be adopted along with adequate free board. It is also proposed to use 10" x 4.87" x 2.75" bricks in place of tiles. The use of larger bricks means saving in mortar and low rate of expansion and contraction.

Certain precautions are required in brick lining. The salt content of earth used for brick manufacturing should be not more than 0.3%, fineness modules preferably not less than 1.2. It should be free from

organic impurities and excessive silt. The consistency of mortar should be regulated by slump tests. The plaster should be allowed to set properly and the subgrade should by properly moistened and oiled. Brick lining as compared to concrete lining does not require specialized labour, no elaborate or expensive equipment is needed, contraction cracks and buckling caused by expansion is reduced. The thickness of lining is controlled by the thickness of bricks and repairs, when necessary, can be carried out easily.

Mr. Haigh carried out certain experiments on various types of brick lining to decide on a suitable lining for distributaries. The following types were tried on Hassuwali distributary :

Type I : 25" thick tile masonary in 1 : 3 mortar laid on cured and dry 3/8" thick cement plaster with G.I wire No 10 as reinforcement.

Type II : 2.5" thick tile masonary in 1 : 3 mortar laid on cured and dry 3/8" thick cement plaster without reinforcement.

Type III : 2.5" thick tile masonary in 1 : 3 mortar laid on green cement plaster with Maxwell fabric reinforcement.

Type IV : 2.5" thick tile masonary over 3/8" thick cured and dry cement plaster with Maxwell fabric reinforcement

It was observed that based on measurement of absorption losses and the cost of construction, Type II is preferable as compared to other types.

Precast cement concrete blocks were tried to repair the damaged lining of Haveli Canal. The cost worked out to be Rs. 56/10/- against Rs. 25/5/- per 100 sq.ft. for tile masonary. These units have the advantage of facility in construction, structural strength and durability, low coefficient of rugosity and high degree of impermeability. The main drawback is its high cost. A slab and beam system was also tried in a short reach, but this was found impracticable. The permeability of bitumen impregnated cloth protected by Masonary was tested by the author and the losses remained under I cusec per million square feet.

However experiments indicated that under high hydraulic pressure this type of material deteriorated with time.

The back fill material should be compacted by toothed roller at optimum moisture content before lining the channel bed. Maximum dry bulk density would be obtained if the soil contains 70% sand and 10 to 20% clay. It is desirable to aim at compaction with a minimum of 110% of the dry bulk density of the natural soil in the locality. Suitable drain should be provided at the toe of the bank along with proper berm width and the dowel. The bank should slope outwards. In areas with high spring level, a continuous inverted filter, a system of drains or porous galleries or a system of vertical relief pipes may be provided depending upon cost and site conditions. The best form of lining section would be an arc having sloping sides, more or less at the same slope as the angle of repose of the soil. This may be possible for channels upto 2000 cusecs. For larger channels similar side slopes with flat bed are designed. In case of lining of existing canals, it is advisable to construct a new lined channel along the existing one.

Note :

Paper No. 260 appeared at pages 8 to 37 of the Proceedings of Punjab Engineering Congress 1943 Vol. XXXI. It has 7 Plates, Lengthy discussions on the paper at pages 37a to 37z and pages 37aa to 37ff.