DESIGN AND EXECUTION OF IRRIGATION CHANNELS IN HALABJA GOVERNORATE

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2024

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ABSTRACT

All irrigation systems include “Water source, Conveyance system, and Distribution system” the source of water may be a reservoir, pond, well, karez, stream or river. A conveyance system allows water to be transferred from a water source to the fields. This can be achieved with canals, ditches and pipes or any combination of these. Ditches and canals are open to the air and are more susceptible to seepage (leaking) and evaporation than pipes. In this report we discussed about open canal and executed types of open canal in halabja governorates , and design steps of lined irrigation open canal and basic consideration in design and basic Consideration in Canal Construction .

CHAPTER 1:

1. HISTORICAL BACKGROUND OF OPEN CHANNELS

The following discussion relics on the excellent historical treatment of hydraulics by Rouse and Ince (I957), to which the reader is referred for further details. From the advent of civilization, the conveyance of water in open channels has been used to meet basic needs, such as irrigation for the Egyptians and Mesopotamians, water supply for the Romans, and waste disposal for Europeans in the Middle Ages, with the disastrous results of waterborne disease transmission. In some cases, artificial open channels were constructed, while in others natural river channels were utilized to convey water and wastes.

The Egyptians used a dam for water diversion and gravity flow through canals to distribute water from the Nile River, and the Mesopotamians developed canals to transfer water from the Euphrates to the Tigris Rivers, but there is no recorded evidence of any understanding of the theoretical flow principles involved. The Chinese arc known to have devised a system of dikes for protection from flooding several thousand years ago. Evidence of water supply pipes and brick conduits for drainage dated to 3000 years B.C. has been found in the Indus River valley. The success of these early, extensive hydraulic works was likely the result of experience only.

Roman aqueducts were used to transport water from springs to distribution reservoirs. The aqueducts were rectangular, masonry canals supported by masonry arches, and they conformed to the natural topography in longitudinal slope. The water discharge in the aqueducts was measured as the cross-sectional area of flow with no regard for the velocity or slope producing the velocity. Although the existence of a conservation principle was recognized. The conserved quantity of volume was misunderstood. Yet, these aqueducts served their engineering purpose albeit inefficiently and uneconomically in modern terms.

The philosophical approach of the Greeks toward physical phenomena w revived by the Scholasticism of the middle Ages, and it remained for Leonardo Vinci to introduce the experimental method in open channel flow during the Renaissance. Leonardo's prolific writings included observations of the velocity distribution in invers and a correct understanding of the continuity principle in streams with narrowing width. Some early experimental results on pipe and channel flow were reported by Du Buat in 1816, but the experimental work on canals begun by Darcy and completed by Bazin in the late 19th century. And Bazin's experiments on weirs were unsurpassed at the time and remain an enduring legacy to the experimental approach.

The problem of open channel flow resistance was recognized as important by many engineers in the 18th and 19th centuries. The work of Chczy on flow resistance began in 1768, originating from an engineering problem of sizing a canal to deliver water from the Yvette River to Paris. The resistance coefficient attributed to him, however, was introduced much later because his work dealt only with ratios of the independent variables of slope and hydraulic radius to the 1/2 power in a relationship for velocity ratios in different streams. His work was not published until the 19th century. The Manning equation for open channel flow resistance, about which much will be said in this book, has a complex historical development but was based on field observations. The Irish engineer Robert Manning actually discarded the formula because of its no homogeneity in favor of a more complex one in 1889, and Gauckler in 1868 preceded Manning in introducing a formula of the type that now bears the name of Manning.

The theoretical approach to open channel flow rests on the firm foundation built by Newton, Leibniz, Bernoulli. and Euler, as in other branches of fluid mechanics; but one of its early fruits was the analytical solution of the equation of gradually varied flow by Bresse in 1860 and the correct formulation of the momentum equation tor the hydraulic jump, which he attributed to the 1838 lecture notes of Belanger. In addition, Julius Weisbach extended the sharp-crested weir equation in 1841 to a form similar to that used today. By the end of the 19th century, many of the elements of the modern approach to open channel flow, which includes both theory and experiment, had been established.

The work of Bakhmeteff, a Russian emigre to the United States, had perhaps the most important influence on the development of open channel hydraulics in the early 20th century. Of course, the foundations of modern fluid mechanics (boundary layer theory, turbulent velocity and resistance laws) were being laid by Prandtl and his students, including Blasius and von Kármán, but Bakhmeteff's contributions dealt specifically with open channel low. In l1932, his book on the subject was published. Based on his earlier 1912 notes developed in Russia (Bakhmeteff 1932). His book concentrated on "varied flow" and introduced the notion of specific energy. Still an important tool for the analysis of open channel flow problems. In Germany at this time, the contributions of Rehbock to weir flow also were proceeding. Providing the basis for many further weir experiments and weir formulas.

By the mid-20th century, many of the gains in knowledge in open channel flow had been consolidated and extended in the books by Rouse (1950), Chow (1959), and Henderson (1966), in which extensive references can be found. These books set the stage for applications of modern numerical analysis techniques and experimental instrumentation to problems of open channel flow. [1]

CHAPTER 2:

2. Introduction and Classification:

2.1. Introduction

Open channels are natural or manmade conveyance structures that normally have an open top, and they include rivers, streams and estuaries. An important characteristic of open-channel flow is that it has a free surface at atmospheric pressure. Open-channel flow can occur also in conduits with a closed top, such as pipes and culverts, provided that the conduit is flowing partially full. For example, the flow in most sanitary and storm sewers has a free surface, and is therefore classified as open-channel flow. [2].

An open channel is a conduit in which a liquid flows with a free surface. The free surface is actually an interface between the moving liquid and an overlying fluid medium and will have constant pressure. In civil engineering applications, water is the most common liquid with air at atmospheric pressure as the overlying fluid. As such, our attention will be chiefly focused on the flow of water with a free surface. The prime motivating force for open channel flow is gravity. In engineering practice, activities for utilization of water resources involve open channels of varying magnitudes in one way or the other. Flows in natural rivers, streams and rivulets; artificial, i.e. man-made canals for transmitting water from a Source to a place of need, such as for irrigation, water supply and hydropower generation; sewers that carry domestic or industrial waste waters; navigation channels-are all examples of open channels in their diverse roles. It is evident that the size, shape and roughness of open channels vary over a sizeable range, covering a few orders of magnitude. Thus the flow in a road side gutter, flow of water in an irrigation canal and flows in the mighty rivers, such as the Ganga a7 the Brahmaputra, all have a free sur face and as such are open channels, governed by the same general laws of fluid mechanics. Basically, all open channels have a bottom slope and the mechanism of flow is akin to the movement of a mass down an inclined plane due to gravity. The component of the weight of the liquid along the slope acts as the driving force. The boundary resistance at the perimeter acts as the resisting force. Water flow in open channels is largely in the turbulent regime with negligible surface tension effects. In addition, the fact that water behaves as an incompressible fluid leads one of appreciate the importance of the force due to gravity as the major force and the Froude number as the prime non-dimensional number governing the flow phenomenon in open channels. [3].

2.2. Classification:

A canal is defined as an artificial channel constructed on the ground to carry water from a river or another canal or a reservoir to the fields. Usually, canals have a trapezoidal cross- section. Canals can be classified in many ways. Based on the nature of source of supply, a canal can be either a permanent or an inundation canal. Apermanent canal has a continuous source of water supply. Such canals are also called perennial canals. An inundation canal draws its supplies from a river only during the high stages of the river. Such canals do not have any headworks for diversion of river water to the canal, but are provided with a canal head regulator. Depending on their function, canals can also be classified as :) irrigation, (ii) navigation, (iii) power, and (iv) feeder canals. An irrigation canal carries water from its source to agricultural fields. Canals used for transport of goods are known as navigation canals. Power canals are used to carry water for generation of hydroelectricity. A feeder canal feeds two or more canals. A canal can serve more than one function. The slope of an irrigation canal is generally less than the ground slope in the head reaches of the canal and, hence, vertical falls have often to be constructed. Power houses may be constructed at these falls to generate power and, thus, irrigation canals can be used for power generation also. Similarly, irrigation canals can also be utilized for the transportation of goods and serve as navigation canals. Inland navigation forms a cheap means of transportation of goods and, hence, must be developed. [4].

Irrigation canals are of two types; (i) lined and (ii) unlined, lining is indispensable when passing through porous or sandy tracks. How- ever in Pakistan majority of canals are unlined whether or not they pass through sandy soils. They were built during the last few decades and earlier in the century resulting in rise in groundwater table thus creating waterlogging and salinity problems. Recently irrigation canals are being built with lining. In designing of these two types of canals there are some concepts common to both and will be discussed first. Both the type of canals are designed for uniform steady flow. [5].

CHAPTER 3:

3.Types of lining open canals

3.1 Types of lining

Types of lining are generally classified according to the materials used for their construction. Concrete, rock masonry, brick masonry, bentonite-earth mixtures, natural clays of low permeability, and different mixtures of rubble, plastic, and asphaltic materials are the commonly used materials for canal lining. The suitability of the lining material is decided by: (i) economy, (ii) structural stability, (iii) durability, (iv) reparability, (v) impermeability, (vi) hydraulic efficiency, and (vii) resistance to erosion [7].

The principal types of lining according to G.L.ASAWA (2006) are as follows:

(i) Concrete lining,

(ii) Shotcrete lining,

(iii) Precast concrete lining,

(iv) Lime concrete lining,

(v) Stone masonry lining,

(vi) Brick lining,

(vii) Boulder lining,

(viii) Asphaltic lining, and

(ix) Earth lining.

3.1.1. Concrete lining:

Concrete lining is probably the best type of lining. It fulfils practically all the requirements of lining. It is durable, impervious, and requires least maintenance. The smooth surface of the concrete lining increases the conveyance of the channel. Properly constructed concrete lining can easily last about 40 years. Concrete linings are suitable for all sizes of channels and for both high and low velocities. The lining cost is, however, high and can be reduced by using mechanized methods.

The thickness of concrete depends on canal size, bank stability, amount of reinforcement, and climatic conditions. Small channels in warm climates require relatively thin linings.

Channel banks are kept at self-supporting slope (1.5H: 1V to 1.25H: 1V) so that the lining is not required to bear earth pressures and its thickness does not increase. Concrete linings are laid without formwork and, hence, the workability of concrete should be good. Also, experienced workers are required for laying concrete linings.

Reinforcement in concrete linings usually varies from 0.1 to 0.4% of the area in the longitudinal direction and 0.1 to 0.2% of the area in the transverse direction. The reinforcement in concrete linings prevents serious cracking of concrete to reduce leakage, and ties adjacent sections of the lining together to provide increased strength against settlement damage due to unstable subgrade soils or other factors. The reinforcement in concrete linings does not prevent the development of small shrinkage, which tend to close when canals are operated and linings are water soaked. The damage due to shrinkage and temperature changes is avoided or reduced by the use of special construction joints. Reinforced concrete linings may result in increased water tightness of the lining. However, well-constructed unreinforced concrete linings may be almost equally watertight.

The earlier practice of using reinforced concrete linings is now being replaced by the employment of well-constructed unreinforced concrete linings. However, reinforcement must be provided in: (a) large canals which are to be operated throughout the year, (b) sections where the unreinforced lining may not be safe, and (c) canals in which flow velocities are likely to be very high.

Proper preparation of subgrade is essential for the success of the concrete lining which may, otherwise, develop cracks due to settlement. Natural earth is generally satisfactory for this purpose and, hence, subgrade preparation is the least for channels in excavation. Thorough compaction of subgrade for channels in filling is essential for avoiding cracks in lining due to settlement.

Some cracks usually develop in concrete linings. These can be sealed with asphaltic compounds. The lining may be damaged when flow in the canal is suddenly stopped and the surrounding water table is higher than the canal bed. This damage occurs in excavated channels and can be prevented by providing weep holes in the lining or installing drains with outlets in the canal section.

Values of minimum thickness of concrete lining based on canal capacity have been specified as given in Table 1.

Table 1 Thickness of concrete lining [8]

Canal capacity (m^3/s)	Thickness of M-150 concrete (cm)		Thickness of M-100 concrete (cm)	
	Controlled	Ordinary	Controlled	Ordinary
0 to less than 5	5.0	6.5	7.5	7.5
5 to less than 15	6.5	6.5	7.5	7.5

15 to less than 50	8.0	9.0	10.0	10.0
50 to less than 100	9.0	10.0	12.5	12.5
100 and above	10.0	10.0	12.5	15.0

3.1.2. Shotcrete lining:

Shotcrete lining is constructed by applying cement mortar pneumatically to the canal surface. Cement mortar does not contain coarse aggregates and, therefore, the proportion of cement is higher in shotcrete mix than in concrete lining. The shotcrete mix is forced under pressure through a nozzle of small diameter and, hence, the size of sand particles in the mix should not exceed 0.5 cm. Equipment needed for laying shotcrete lining is light, portable, and of smaller size compared to the equipment for concrete lining. The thickness of the shotcrete lining may vary from 2.5 to 7.5 cm. The preferred thickness is from 4 to 5 cm.

Shotcrete lining is suitable for: (a) lining small sections, (b) placing linings on irregular surfaces without any need to prepare the subgrade, (c) placing linings around curves or structures, and (d) repairing badly cracked and leaky old concrete linings.

Shotcrete linings are subject to cracking and may be reinforced or unreinforced. Earlier, shotcrete linings were usually reinforced. A larger thickness of shotcrete lining was preferred for the convenient placement of reinforcement. The reinforcement was in the form of wire mesh. In order to reduce costs, shotcrete linings are not reinforced these days, particularly on relatively small jobs.

3.1.3. Precast Concrete lining:

Precast concrete slabs, laid properly on carefully prepared subgrades and with the joints effectively sealed, constitute a serviceable type of lining. The precast slabs are about 5 to 8 cm thick with suitable width and length to suit channel dimensions and to result in weights, which can be conveniently handled. Such slabs may or may not be reinforced. This type of lining is best suited for repair work as it can be placed rapidly without long interruptions in canal operation. The side slopes of the Tungabhadra project canals have been lined with precast concrete slabs.

3.1.4. Lime Concrete lining:

The use of this type of lining is limited to small and medium size irrigation channels with capacities of up to 200 m^3/s and in which the velocity of water does not exceed 2 m/s (16). The materials required for this type of lining are lime, sand, coarse aggregate, and water. The lime concrete mix should be such that it has a minimum compressive strength of about 5.00 kN/m^2 after 28 days of moist curing. Usually lime concrete is prepared with 1 : 1.5 : 3 of kankar lime: kankar grit or sand : kankar (or stone or brick ballast) aggregate. The thickness of the lining may vary from 10 to 15 cm for discharge ranges of up to 200 m^3/s.

3.1.5. Stone Masonry lining:

Stone masonry linings are laid on the canal surface with cement mortar or lime mortar. The thickness of the stone masonry is about 30 cm. The surface of the stone masonry may be smooth plastered to increase the hydraulic efficiency of the canal. Stone masonry linings are stable, durable, erosion-resistant, and very effective in reducing seepage losses. Such lining is very suitable where only unskilled labor is available and suitable quarried rock is available at low price.

3.1.6. Brick lining:

Bricks are laid in layers of two with about 1.25 cm of 1 : 3 cement mortar sandwiched in between. Good quality bricks should be used and these should be soaked well in water before being laid on the moistened canal surface.

Brick lining is suitable when concrete is expensive and skilled labor is not available. Brick lining is favored where conditions of low wages, absence of mechanizations, shortage of cement and inadequate means of transportation exist. Brick linings have been extensively used in north India. The Sarda power channel has been lined with bricks. The thickness of the brick lining remains fixed even if the subgrade is uneven. Brick lining can be easily laid in rounded sections without formwork. Rigid control in brick masonry is not necessary. Sometimes reinforced brick linings are also used.

3.1.7. Boulder lining:

Boulder lining of canals, if economically feasible, is useful for preventing erosion and where the ground water level is above the bed of the canal and there is a possibility of occurrence of damaging backpressures. The stones used for boulder linings should be sound, hard, durable, and capable of sustaining weathering and water action. Rounded or sub-angular river cobbles or blasted rock pieces with sufficient base area are recommended types of stones for boulder lining. Dimensions of stones and thickness of lining are as given in Table 2

Table 2 Dimensions of stones and thickness of lining

Canal capacity (m^3/s)	Thickness of lining (mm)	Average dimension along the longest axis (mm)	Minimum dimension at any section (mm)
0 to less than 50	150	150	75
50 to less than 100	225	225	110
100 and above	300	300	150

Wherever required, a 15-cm thick layer of filter material is to be provided. For the laying of boulders, the subgrade (both bed and side slope) of the canal is divided into compartments by stone masonry or concrete ribs. These compartments will not have dimensions more than 15 m along and across the centerline of the canal.

3.1.8. Asphaltic lining:

The material used for asphaltic lining is asphalt-based combination of cement and sand mixed in hot condition. The most commonly used asphaltic linings are: (a) asphaltic concrete, and (b) buried asphaltic membrane. Asphaltic linings are relatively cheaper, flexible, and can be rapidly laid in any time of year. Because of their flexibility, minor movements of the subgrade are not of serious concern. However, asphaltic linings have short life and are unable to permit high velocity of flow. They have low resistance to weed growth and, hence, it is advisable to sterilize the subgrade to prevent weed growth.

Asphaltic concrete is a mixture of asphalt cement, sand, and gravel mixed at a temperature of about 110°C and is placed either manually or with laying equipment. Experienced and trained workmen are required for the purpose. The lining is compacted with heavy iron plates while it is hot.

A properly constructed asphaltic concrete lining is the best of all asphaltic linings. Asphaltic concrete lining is smooth, flexible, and erosion-resistant. Since asphaltic concrete lining becomes distorted at higher temperatures, it is unsuitable for warmer climatic regions. An asphaltic concrete lining is preferred to a concrete lining in situations where the aggregate is likely to react with the alkali constituents of Portland cement.

Buried asphaltic membrane can be of two types:

(a) Hot-sprayed asphaltic membrane, and (b) Pre-fabricated asphaltic membrane.

A hot-sprayed asphaltic membrane is constructed by spraying hot asphalt on the subgrade to result in a layer about 6 mm thick. This layer, after cooling, is covered with a layer of earth material about 30 cm thick. The asphalt temperature is around 200°C and the spraying pressure about 3×10^5 N/m^2. For this type of lining, the channel has to be over-excavated. The lining is flexible and easily adopts to the subgrade surface. Skilled workmen are required for the construction of this type of lining.

Pre-fabricated asphaltic membrane is prepared by coating rolls of heavy paper with a 5 mm layer of asphalt or 3 mm of glass fiber-reinforced asphalt. These rolls of pre-fabricated asphaltic membrane are laid on the subgrade and then covered with earth material. These linings can be constructed by commonly available labor.

Materials used for covering the asphaltic membrane determine the permissible velocities which are generally lower than the velocities in unlined canals. Maintenance cost of such linings is high. Cleaning operations should be carried out carefully so as not to damage the membrane.

3.1.9. Earth lining:

Different types of earth linings have been used in irrigation canals. They are inexpensive but require high maintenance expenditure. The main types of earth linings are: (a) stabilized earth linings, (b) loose earth blankets, (c) compacted earth linings, (d) buried bentonite membranes, and (e) soil-cement linings.

Stabilized earth linings: Stabilized earth linings are constructed by stabilizing the subgrade. This can be done either physically or chemically. Physically stabilized linings are constructed by adding corrective materials (such as clay for granular subgrade) to the subgrade, mixing, and then compacting. If corrective materials are not required, the subgrade can be stabilized by scarifying, adding moisture, and then compacting. Chemically stabilized linings use chemicals which may tighten the soil. Such use of chemicals, however, has not developed much.

Loose earth blankets: This type of lining is constructed by dumping fine-grained soils, such as clay, on the subgrade and spreading it so as to form a layer 15 to 30 cm thick. Such linings reduce seepage only temporarily and are soon removed by erosion unless covered with gravel. Better results can be obtained by saturating the clay and then pugging it before dumping on the subgrade. The layer of pugged clay is protected by a cover of about 30 cm silt. This type of lining requires flatter side slopes.

Compacted earth linings: These linings are constructed by placing graded soils on the subgrade and then compacting it. The graded soil should contain about 15% of clay. The compacted earth linings may be either thin-compacted or thick-compacted. In thin-compacted linings, the layer thickness of about 15 to 30 cm along the entire perimeter is used. Thick compacted linings have a layer about 60 cm thick on the channel bed and 90 cm thick on the sides. If properly constructed, both types are reasonably satisfactory. However, the thick linings are generally preferred.

Compacted-earth linings are feasible when excavated materials are suitable, or when suitable materials are available nearby. Compaction operations along the side slopes are more difficult (particularly in thin-compacted linings) than along the channel bed. The lining material should be tested in the laboratory for density, permeability, and optimum moisture contents. The material must be compacted in the field so as to obtain the desired characteristics.

Buried Bentonite Membranes: Pure bentonite is a hydrous silicate of alumina. Natural deposits of bentonite are special types of clay soil which swell considerably when wetted. The impurities of these soils affect the swelling and, hence, the suitability of these as canal lining material. Buried bentonite linings are constructed by spreading soil-bentonite mixtures over the subgrade and covering it with about 15 to 30 cm of gravel or compacted earth. Sandy soil mixed with about 5 to 25 per cent of fine-grained bentonite and compacted to a thickness of 5 to 7.5 cm results in a membrane which is reasonably tough and suitable for lining.

Soil-cement Linings: These linings are constructed using cement (15 to 20 per cent by volume) and sandy soil (not containing more than about 35 per cent of silt and clay particles). Cement and sandy soil can be mixed in place and compacted at the optimum moisture content. This method of construction is termed the dry-mixed soil-cement method. Alternatively, soil cement lining can be constructed by machine mixing the cement and soil with water and placing it on the subgrade in a suitable manner. This method is called the plastic soil-cement method and is preferable. In both these methods, the lining should be kept moist for about seven days to permit adequate curing.

The construction cost of soil-cement linings is relatively high. But these resist weed growth and erosion and also permit velocities slightly higher than those permitted by unlined earth channels. The use of soil-cement linings for irrigation canals is restricted to small irrigation canals with capacities of up to 10 m^3/s and in which the velocity of water does not exceed 1 m/s [4].

3.2. Type of Executed Lined Irrigation Canal in Halabja:

According to the nature of Halabja Governorates and its topography, availability and usable construction material and type of irrigation the following types of canals are constructed up to now

3.2.1. Concrete lining open canal:

Figure 1. Chalgai xwarw Canal in Sharazwr [6].

3. 2.2.Concrete pipe lining canal:

Figure 2. Gwnda Canal in Sirwan District [6].

3. 2.3.Polyathelen pipe (HDP) lining canal:

Figure 3. Bawakochak Canal in Halabja [6].

3.2.4. Riprap lining canal:

Figure 4. Awesar Canal in Byara District [6].

3.2.5. Stone Wall lining canal:

Figure 5. Canal in Xwrmal District [6].

CHAPTER 4:

4. Design of Lined Irrigation Canal

4.1. Basic considerations in design of canals

The design of canals must be done so as to provide an economic canal system with special attention to fulfill their functions for conveying and distributing water efficiently. It is as a comprehensive irrigation and drainage system in combination with other related facilities for water use, and to make possible safe and rational management of water use and facilities. In this respect, it is basically considered in design to keep 1) water conveyance capacity, 2) water distributing, confluence and regulating functions, 3) safety of the canal, 4) rational management of water use and facilities, 5) economic cost for construction and operation and maintenance, and 6) harmony with the surrounding environments.

4.1.2. Consideration of Rules Related to Canal Design

Canals are long-term structures that connect to rivers and lakes and are provided over a vast area. In design of canals related rules and regulations must be considered.

4.1.3. Basic Considerations in Canal Construction

The canal must be constructed according to the plan prepared for undertaking the work rationally, economically and safely, as well as to satisfy design details, in consideration of the field conditions. At the same time, the canal construction must comply with the relevant rules and regulations.

4.1.4 . Basic Consideration in Canal Construction

The construction must be executed economically and safely within the proposed period according to the design. Therefore, planning the construction must be prepared taking into account the intention of design and field conditions and the progress of the works must always be checked. If any field conditions different from design conditions are encountered, then the design must be restudied and modified.

4.1.5. Construction

Construction must be executed rationally, economically and safely in accordance with an appropriate construction planning and under construction management in consideration to field conditions. [10]

4.2. Introduction of irrigation canal equations:

Irrigation canals are of two types, (i) lined and (i) unlined, lining is indispensable when passing through porous or sandy tracks. How- ever in Pakistan majority of canals are unlined whether or not they pass through sandy soils. They were built during the last few decades and earlier in the century resulting in rise in groundwater table thus creating waterlogging and salinity problems. Recently irrigation canals are being built with lining. n designing of these two types of canals there are some concepts common to both and will be discussed first. Both the type of canals are designed for uniform steady flow. Manning's or Chezy's equation describe such a flow, i.e.

Manning’s Equations

$$V = \frac{1.49}{n} R^{2/3} S^{1/2} \quad \text{(fps units)}$$

$$V = \frac{1.0}{n} R^{2/3} S^{1/2} \quad \text{(S. I. units)}$$

The term non-silting non-scouring velocity refers to a velocity which will be high enough to prevent silting and low enough to prevent scouring in case of unlined channels.

A minimum free board (i.e. a vertical distance between maximum water level and top of canal bank) for unlined channels varies between 1ft(0.3m) for small distributaries to 4 ft (1.2m) for main canals carrying 3000 cfs (85m'/sec) discharge. For irrigation canals with a dischrage of 10,000 cfs (283m^3/sec) or more it is 5.5 ft (1.65m). While the increase in dischrage is on log Scale, the increase in free board is on an arithmetic scale. The equation

$$F = \sqrt{Cy}$$

where F = free board in ft

y = design depth of flow, ft

C = coefficient which varies from 1.5 at Q=20cfs (0.57m^3/sec) to 2.5 for Q = 3000 cfs or more.

Also provides an estimate for free board in unlined irrigation canals. The curvature is important in lined canals as the rise in water levels on outer side of the curve affects the free board.

$$h = \frac{v^2 b}{gR}$$

h = change in water surface elevation across channel.

b = width of channel.

R = distance from the center of the curve to center line of channel.

v = subcritical average velocity.

This effect of curve is negligible when the ratio of the radius of curvature to the distance to the center of the canal is greater than 3 times the bed width of the channel. However, in case of unlined channel, curvature assumes a greater significance due to silting on the inner side and scouring on the outer side of the curve. In Pakistan where most of the irrigation canals are unlined, the practice recommends a minimum radius of 300 ft (91 m) for canals carrying less than 10 cfs (0.3 m^3/s), to 5000 ft (1500 m), for canals carrying more than 3000 cfs (85 m^3/sec).

4.2.1 Design of lined irrigation canals

The design of lined section is very simple, since there is no severe and Chezy's equation is

$$V = C\sqrt{RS}$$

where V = velocity

R = hydraulic mean redius A/P

A = area of cross-section

P = wetted perimeter

S = longitudinal energy line slope; in case of uniform flow it is equal to bed slope

n = Mannings Coefficient

C = Chezy's coefficient

The equation describes that the discharge Q= (AV) in uniform flow is a function of

i) Section factor AR in case of Mannings Equation and $AR^{1/2}$ case of Chezy's Equation and ii) Longitudinal slope (S)

The best hydraulic cross-section is defined as the one having minimum perimeter for a given area i.e this will give maximum discharge for the given area since $Q=A.(A/P)^{2/3}$. Among all cross-sections, the best hydraulic cross-section is a semicircle

The proportions of the best hydraulic cross-section in case of rectangular, trapezoidal, and triangular channels are given below:

Table 3 Best hydraulic section

Cross section	Area A	Wetted perimeter P	H.M.R. R	Top width T	depth D
Rectangular	$2.0y^2$	4y	0.40y	2y	y
Trapezoidal	$1.73y^2$	3.46y	0.50y	2.31y	0.75y
Triangular	y^2	2.83y	2.354y	2y	0.50y

y = depth of uniform flow

The term minimum permissible velocity means a lowest velocity which will prevent silting and vegetative growth. Normaly an average velocity of 2 to 3ft/sec (0.61 to 0.91m/s) will prevent silting restrictions on higher or lower values in selecting the velocity. As long as Manning'sn or Chezy's C is estimated correctly for the given limning material, the canal would work as per design. Following design procedure may be adopted.

1. Estimate n or C for the given lining material.

2. Compute as per Mannings Equation, section factor

$$AR^{2/3} = \frac{nQ}{\theta\sqrt{S}}$$

Θ and 1.49 in fps unit and 1 in metric units. Here n, Q, Θ and S are known quantities.

3. Assume the shape of the lined section as trapezoidal, with suitable side slopes 1:2 (vertical: horizontal) and bed width b. Using dimension-less between $AR^{2/3}/b^{8/3}$ and y/b, the value of y can be determined.

4. For the best hydraulic cross-section, channel parameters can be used as given in table 3 Otherwise use normal relations for A etc. to compute the channel parameters using y from curves between steps 3.

5. Check for a) Minimum permissible velocity if water carries sediment b) Froude number to be less than 1.

6. Estimate free board, and the height of lining to be 50% of the free board, above the maximum water level.

7. Make a sketch providing all the dimensions. [9]

CHAPTER 5:

5. Role of engineer in country

Dr. Tetsu Nakamura left his home in Japan in the 1980s to treat leprosy patients in Afghanistan and Pakistan. He later found, however, that severe drought was killing more people than his clinics could save.

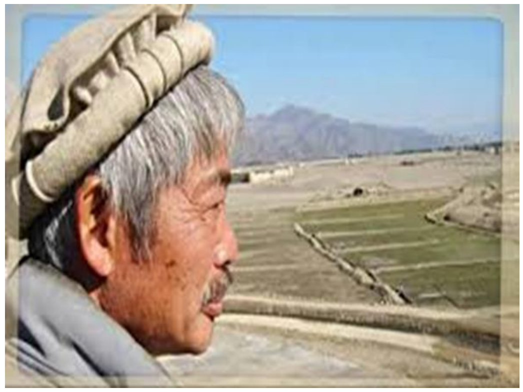

Figure 6. Dr. Tetsu Nakamura .

So he discovered a new calling: irrigation. In the 2000s, adapting old Japanese techniques that required little technology, he helped villagers displaced by drought build a network of canals that has transformed an area of nearly a million residents.

He was born in Japan's Fukuoka Prefecture in 1946, and his first exposure to eastern Afghanistan was in his early 30s. According to a biography published by the Ramon Magsaysay Award, a prize for "greatness of spirit and transformative leadership in Asia" that he received in 2003, he was initially drawn to the mountainous borderland between Afghanistan and Pakistan by a fascination with insects. He quickly found himself besieged with requests for medical help.

After finishing medical school, Dr. Nakamura returned to the Pakistani border city of Peshawar, establishing clinics to treat the locals and Afghan refugees fleeing the Soviet war. He then opened clinics in the eastern Afghan province of Nangarhar, just as a severe drought was affecting the region. His patients were not only suffering from malnourishment but also diarrhea, as sources of clean water were scarce.

Dr. Nakamura, who also learned to speak the local language, Pashto, initially tried to improve the situation by digging hundreds of wells for clean water, but soon realized that wasn't the answer.

"Starvation, drought — medicine can't solve these problems," Dr. Nakamura told the Japanese channel NHK in what was likely one of his last interviews. "We realized we needed to go beyond the narrow field of medicine and work to ensure that people had enough food and water."

So he turned to building canals from existing water sources to irrigate arid regions. After facing difficulties in procuring equipment to dig the first canals, he drew inspiration from those built more than 200 years ago in his hometown in Japan.

Back then, Dr. Nakamura said, "You didn't have dump-trucks and things like that. The villagers had to all work together to construct it by hand. So there was no reason why people living today couldn't do the same thing. The thought inspired me. If we tried, we could do it."

Over six years, with a work force drawn from drought-stricken villages, Dr. Nakamura helped build a main canal about 15 miles long. He continued the work even after militants abducted and killed one of his colleagues, Kazuya Ito. The smaller canals his team built spread across four districts. All in all, the Afghan authorities in Nangarhar said, by the time of his murder his canals had improved the livelihood of nearly a million people, and irrigated nearly 60,000 acres of previously arid land.

Due to his serve for Afghanstan , peoples construct a park named it nakamuras park in the country . Figure 7. [11]

Conclusions

Open canal is one of the most important parts of any kind of construction. Open canal has a great influence on reduce of seepage and water loss due to high level of infiltration in natural soil. In this report, the historical of irrigation open canal, and classification of canals and executed types of open canals in halabja governorates and design, construction consideration and design steps were reviewed. In this report , and it is understood that any canals before lining we must be very carefully collect data for design and execution of types and material that be used for construction due to position properties. In this report, we were reviewed role of engineer in country , Dr. Tetsu Nakamura was as an engineering role in afhganstan that he construct the irrigation canal for arid region in afghanstan ,where he turned to building canals from existing water sources to irrigate arid regions. After facing difficulties in procuring equipment to dig the first canals, he drew inspiration from those built more than 200 years ago in his hometown in Japan.

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