

A Design of Water Conservancy Project for the region of Shuiqin Road in the New District of Lanzhou

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Keywords: Water conservancy, Irrigation water, Fluid mechanics, Waterhead

Abstract. A scientific and feasible design of water conservancy project for the region of Shuiqin Road in the new district of Lanzhou is proposed in this paper. Combining with the requirement of local agriculture and the characteristic of fluid mechanics, we designed the construction of this project. The design includes the parts of reservoir, supply pump station and supply network. The irrigation area, method, amount are described in detail. The design of the supply network for the irrigation is elaborated accordingly, including direction of the network, material for the pipeline and the control parameters. The knowledges of fluid mechanics are used to ensure the design is reasonable and feasible. The work should be a demonstration for the construction of water conservancy in the new district of Lanzhou, with guiding significance for agriculture development.

Introduction

Gansu province is a strategic passage for Eurasia land bridge, which connects southwest and northwest of China as a traffic hinge and is an important ecological barrier of the northwest and even the whole country. According to the national project “the Silk Road Economic Belt and the 21st-Century Maritime Silk Road”, Gansu province is clearly specified as an important part of the Silk Road Economic Belt and the forefront of economic reform. Gansu will be built to be a significant part of the Silk Road Economic Belt and an important strategical foundation for economic opening, regional cooperation and the producing of special agriculture products. The new district of Lanzhou (NDLZ, hereafter) which locates at the center of Gansu Province, has the advantage of environmental condition, plays an important role in the economic activities. Since the 12th Five-year Plan, the NDLZ developed scientifically, focusing on green ecology, saving water, efficient agriculture ^[1].

However, there are still some shortages for the NDLZ because of the limitation of natural condition, including simplex agriculture structure, extensive manage, low agriculture output and is slowly increasing of farmers' income, which leads to the primary stage of the improvement of special agriculture. In addition, the development of economic and society is also suppressed because of the idle land sources ^[2]. As a demonstration project, the water conservancy project for the region of Shuiqin Road in the NDLZ has guiding significance for agriculture development. This paper proposed a scientific and feasible design for the construction of the water conservancy in the region of Shuiqin Road, according to the surrounding geographical conditions and soil vegetation characteristics.

Background

The water conservation in the region of Shuiqin Road

The irrigation project of bringing Datong River to Qinwangchuan Basin is the most important part of Irrigation project of Shuiqin Road. This project changed the water resource distribution and provided better living condition and environment.

The project was finished in 1990s, including East I, East II river and their 11 canals. This canala are totally 301.25 km long, with irrigaton area of 241.7 km² ^[3]. The serviceability rate is about 90%. East I project's designed flow is 14 m³/s, 15.3km long, including 9, 10, 11 branch canals, 145.31km, , the serviceability rate is about 80%, 94.7 km² control irrigation area(63.8km² in the end of 2010),

1~3.5 m³/s design flow, utilization factor of canal system is 0.616, utilization factor of irrigation is 0.555. East II project's designed flow is 18m³/s, 15.1 km long, including 10, 11, 12, 13, 14, 15, 16, 17, 125.54 km long, the serviceability rate is about 85%, 148.2 km² control irrigation area(134km² in the end of 2010), 0.75~3.3 m³/s designed flow, utilization factor of canal system is 0.616, utilization factor of irrigation is 0.555. This project mainly provide water for irrigation, eco-system, parts of towns and village living with about 0.2 billion m³ one year^[4]. The project provided water from March 16th to November 11st (191 days), including maintaining time from Aug. 12nd to Sep. 30th (50 days). When maintaining time is beginning, the water storage system will provide water.

Entire allocation for the project

The project is located in 500m south form the cross of Weishisan Road and Shuiqin Road, including the pump station driven by diesel. The main water pipe extends eastward along the Shuiqin Road, distributed three branches in Zhaojiapu, including southward, northward and eastward of Shuiqin Road, about 29km long. The southward pipe extends to Yangjiawan, which is the dedicated pipe for irrigation. The eastward pipe extends to Chenjiagou, which is used for the control region of west side of Shuiqin Road. The eastward pipe extends to planed Weiershiwu Road, which provide future irrigation water source. The pipe is designed in one side and through the road culvert for extending and irrigation. Given the thoughts for safety and stability for pipes, the pipe is made of welded steel tube, and some of pipe are made of glass reinforced plastic sand pipe. The steel pipe is above the ground and the glass pipe is buried under the ground. The steel pipe is lifted by concrete buttress. There are 18 high-level irrigation impounding reservoirs with 50m³ carbon steel structure each.

The two sides of Shuiqin Road are mostly loess hilly region, including breaking ground, hilly region, ravines and gullies criss-cross, less vegetation, and severe water and soil loss. The better forest in two sides of Shuiqin Road is good for economy, society progress, improving living condition, change ecosystem and invest environment. The development of new region, ecosystem protection and construction are foundation and important for economy development. The project is good for ecosystem construction, recovering vegetation, controlling water and soil loss.

Engineering design of impounding reservoir and water supply pump station

Feasibility analysis of water source supply

In 2015, there are 271270 thousand m³ water delivered to Lanzhou new district, including 60000 thousand m³ for ecosystem, about 22.12%; 79780 thousand m³ for modern agriculture, about 29.41%. The project provides 48.31% water source for Lanzhou new district, and 62700 thousand m³ extra water supply. The reclaimed water delivered to Lanzhou new district is about 90.37% of total reclaimed water source, and 5160 thousand m³ extra water supply^[5]. This project can provide abundant water source for needs of construction and engineering.

In 2020, there will be 393430 thousand m³ water delivered to Lanzhou new district, including 100000 thousand m³ for ecosystem, about 25.42%; 42450 thousand m³ for modern agriculture, about 10.79%. The project provides 63.08% water source for Lanzhou new district, and 1410 thousand m³ extra water supply. The reclaimed water delivered to Lanzhou new district is about 90.37% of total reclaimed water source, and 7860 thousand m³ extra water supply. This project can provide abundant water source for needs of construction and engineering.

In 2030, there will be 495170 thousand m³ water delivered to Lanzhou new district, including 100000 thousand m³ for ecosystem, about 20.20%; 38560 thousand m³ for modern agriculture, about 7.79%. The project provides 65.21% water source for Lanzhou new district, and no extra water supply. The reclaimed water delivered to Lanzhou new district is about 88.29% of total reclaimed water source, and 13320 thousand m³ extra water supply.

In conclusion, before 2020, the project can meet the need of the program. The water for the program can be provided by the project. With the water need of Lanzhou new district increasing till 2030, the project won't provide enough water, and then construction water can use reclaimed water.

Confirm of irrigation water amount

(1) Irrigation area

Based on the area of economy forest, the initial irrigation area of Shuiqin Road will be 4.1 km².

(2) Irrigation methods

The irrigation methods will influence the quality of irrigation and construction profit. In this design, based on mountains irrigation of Lanzhou, considering of water source condition, terrain, soil, rain, basic facility, custom and tree type, sprinkling irrigation is the main manner, including medium-pressure sprayer and low-pressure sprayer for some regions.

(3) Design dependability of irrigation design

Based on “Design Specifications of Irrigation and Drainage” (SDJ218-84) and “Design criterion of water-saving irrigation” by Ministry of Water Resources, and considering of the program and water source dependability. The project of “Introducing large into qin”’s design dependability of irrigation design is about 75%.

(4) Quota of irrigation water

Lanzhou Liangshan headquarter develop trickle irrigation technology since 2006, which has experience. Based on the experience and program’s climate and terrain condition, considering of “Design Specifications of irrigation and sewerage” (GB50288-99), confirm 15-day irrigation period, 15-hours each day (June 15th to July 25th). For the rest days, 13-hours each day, 8 times one year, 10m³/666.6m² quota each time, one time in winter and 20-days one period, 12m³/666.6m² quota each time, 1292m³/666.6m² quota each year. We will use impounding reservoir to store water, and use pipe to deliver water. The water conservancy coefficient of pipe is 0.95, and the water conservancy coefficient of the impounding reservoir water is 0.86.

(5) Irrigation Water Capacity each year

$$W=(S*M/\eta)/10000= 697.3\times 103 \text{ m}^3 \tag{1}$$

W---water need each year (ten thousand m³)

S---irrigation area(666.6m²)

M---irrigation quota(m³/666.6m²)

The percentage of Total water use to water provided by the project:

$$69.73/20000=0.35\%$$

The impounding reservoir design of adjusting water source

The reservoir can adjust the difference between the project water and irrigation water. The reservoir is 12h. The reservoir is located in the place southward 500m from the cross of Weishisan Road and Shuiqin Road.

Adjusting water capacity:

$$V=S*M/*\alpha=2600 \text{ m}^3 \tag{2}$$

V---adjusting volume (m³)

α ---proportion of adjusting (1/30)

3.4 Pump station design

Based on the irrigation and design, the pump station is built on one side of reservoir. Because of the short of power, we use pump station driven by diesel. There is no spare pump station because of batch-type work style with 75% assurance rate. Because of temp pump station, it won’t work in winter. The house for pump station is made of colored steel plate structure without water drain and heating equipment and no duty in winter.

Design of water supply network for irrigation

Direction of Irrigation Pipeline

According to the regional topographic conditions and the principle of pipeline layout of key projects, taking into account of the irrigated area is arranged as ribbon. Therefore, the water supply pipe extends from the trunk pipe to the irrigation area and extends to the irrigation area in the form of

branches. The overall structure of the irrigation pipe is like the stump network, which has the advantage of low cost, easy construction, fast, and the shortcomings is lacking of guaranteed rate about water supply security.

The irrigation and water supply system in Shuiqin Road, which has a main water supply pipeline along the south side of the Shuiqin Road, and eastward extension, in Zhaojiapu Interchange is divided into three branches, respectively, to the south, north, east extension of the Shuiqin Road. Among them, Shuiqin Road to the south of the extension to the Yang Jia Wan, for the irrigation pipeline of Shuiqin Road; The western pipeline of Shuiqin Road extends to Chenjiagou, which controls the west side of irrigation in Shuiqin Road (considering the long-term development of irrigation water); The eastern pipeline of Shuiqin Road extended to the planning of latitude 25 Road, reserved for long-term irrigation water valve wells. The water supply pipe is arranged on one side and extends to the opposite side through the road culvert, which is used for contralateral irrigation.

Determine of water supply pipe network

Irrigation pipes water pipes are generally small diameter, pipe material can be used commonly: steel pipe, FRP sand pipe, PE pipe and UPVC pipe.

The steel pipe has the advantages of strong toughness, pressure resistance, inappropriate damage, smooth surface, small water friction resistance and so on, but it is easy to rust during used, Internal and external walls must be taken for rust and corrosion, such as anti-corrosion properly, its service life is up to 30 years.

FRP sand pipe has long service life (40 years), smooth surface and low roughness ratio, which is suitable for large pipe diameter ($\Phi 500\text{mm}$). Its diameter is bigger than that of cast iron pipe under the same conditions, and it is so easy to install that not require corrosion. But its thin wall makes it easily damaged to external forces, and demand on the pipe bed (sand and gravel pipe bed will be replaced for base treatment), and the elasticity of material is low, once made cannot be bent. When connected with all kinds of valve body, the flange part in the process of long-term pressure reduces the physical properties, which is easy to leave.

PE pipe has high toughness, the performance of non-uniform settlement of the base is strong, seismic performance, smooth surface, small roughness, long service life (60 years), corrosion resistance, low temperature, small diameter pipe cost low, reliable quality, good construction performance and high toughness, for all types of body and pipe connections have a good fit. Pipe wall is smooth and flow resistance is small, the break elongation of pipe is more than 350%. The pipe is light in weight, and easy to install and transport. It is connected with hot melt, which is convenient to install and reliable to use as well as easy to maintain. The tensile strength and bursting strength of the connecting part are higher than the pipe itself. The shortcomings of pipeline is low resistance, vulnerable to external damage, and poor economic efficiency of large diameter pipe. At the same time, PE pipe is in the case of solar radiation, which aging easily, so do not try Ming Fu pipeline.

The surface of UPVC pipe is smooth, and roughness rate is small, light weight, low cost, the strength of UPVC pipe is higher than the PE pipe, long life (50 years) and so on. But it is brittle with poor ductility, when the ground subsidence or deformation due to vibration, which is easy to produce cracks, because it is easy to cause expansion of the damaged source, and when rapid cracking event occurred, the pipe bed is demand high.

Therefore, the water supply pipeline for this project can be welded steel pipe, FRP sand pipe, PE pipe and UPVC pipe, in which pipe diameter greater than 300mm can be chosen with welded steel pipe, FRP sand pipe, and pipe diameter less than 300mm can be chosen with welded steel pipe, PE pipe and UPVC pipe.

Compared the UPVC pipe, FRP sand pipe, PE pipe and UPVC pipe with a technical point of view, the four pipes are non-toxic, and they are all suitable for the water supply project, but there are some differences in the economic and technical aspects. From the point of economic view, PE pipe, UPVC pipe is better in economy, and FRP sand pipe in the large diameter has an economic advantage. From the point of construction, the strength of steel pipe can be strong and deposited, which can not only reduce the difficulty of construction but also the project investment.

In summary, the design in this project, taking into account of the safety and reliability of engineering water supply and the requirements of high pressure, the pipe is mainly used to welded steel pipe, part of the large diameter pipe uses FRP sand pipe, applying to buried construction technology, pipe diameter is less than DN100, which is used to buried construction technology.

The control parameters of pipe

(1) The control of fluid flow in pipe

In order to prevent pipe network from water hammer, or the occurrence of siltation, the pipe network is designed for the flow rate of faster than 0.5m / s, long-term development process controls flow rate of less than 2.5 m/s.

It is the main mission to determine the pipe network at all levels of pipe or pipe section diameter in the design of pipe network. The choice of pipe diameter is based on the designed flow rate and according to the following formula:

$$D = \sqrt{4Q/\pi v} = 1.13\sqrt{Q/v} \quad (3)$$

where:

D---Pipe internal diameter (mm)

Q---Designed flow rate (m³/s)

V---Pipe internal flow rate (m)

π---Circumference rate, taken as 3.14

(2) Calculation of Head loss

The pipeline is used to head loss along the pipeline system , the flow of its pipe flow is mostly smooth turbulence and rough turbulence. In order to design and calculate conveniently, refer to the "outdoor water supply and drainage design specifications" (GB50013-2006), head loss along the way h_f is expressed as the exponential function model of flow and diameter.

$$h_f = \lambda \frac{1}{d} \frac{v^2}{2g} = \frac{kq^n}{D^m} L \quad (4)$$

Taking into account of the status in the designed area and pipeline materials, using the Manning formula for the calculation of head loss along the way,

k,m,n---Are calculation parameters of head loss

D---Pipe diameter (m)

L---Pipe length (m)

q---Designed flow rate (m³/s)

Using Manning formula, n is 2.0, m is 5.333, k is used the following formula:

$$k=1029n_m^2$$

n_m is the pipe roughness coefficient, the designed steel pipe is taken as 0.012, FRP sand pipe is taken to 0.0089, PE pipe is taken to 0.009.

Local resistance loss refers to " outdoor water supply and drainage design specifications " (GB50013-2006), long-distance water pipeline, local head loss can be estimated in accordance with the proportion of resistance loss along the way, this project is designed as 10%.

Design of high water pool used for irrigation

Shuiqing Road with complex terrain, irrigation conditions are more difficult, it is more difficult to use the water supply pipe for irrigation directly. Set a certain number of high water tanks, which can not only save valuable water resources of New Area, but also improve the efficiency of irrigation and reduce the cost of irrigation.

According to the irrigation area and terrain conditions of the implementation area, there are set up 18 irrigation reservoirs. Irrigation service area of single-seat reservoir is about 40 acres, and irrigation time of single-seat reservoir is 1d, so the high water tank designs volume as:

$$V=S \cdot Q \cdot T \cdot 8.64=50 \text{ m}^3 \quad (5)$$

where:

Q---Irrigation rate (0.142 / s / Mu)

T---Designing irrigation time (d)

According to the current conditions of construction and installation, high-rise reservoir applies reinforced concrete structure or carbon steel structure. The use of reinforced concrete structure makes a larger amount of engineering quantity and construction restrictions, it is difficult to large-scale promotion of irrigation projects in the ShuiQin Road. But the use of carbon steel reservoir with the advantages of high construction speed, low project cost, easy to achieve and so on. Therefore, the design of high-water storage tank adopts carbon steel structure for irrigation in ShuiQin Road.

The radiation area of the high-level pool is the peripheral area around the high-level pool. With the surrounding elevation difference, the pressure of water supply from the pool is gradually reduced, thus forming different pressure areas and directly affect the irrigation methods. According to the characteristics of the pressure around the high-level pool, the high-level pool irrigation methods is divided into three types.

The first type of area is manpower irrigation type, mainly distributed in the height difference of 10m around the high-level pool. According to the terrain condition of the ShuiQin road, the manpower irrigation area is within 15m of the periphery of the high pool, the irrigation area is 1.5mu; The area of low pressure irrigation is mainly distributed in the area with height difference of less than 30m around the high-level pool. According to the terrain condition of the ShuiQin road, the irrigated area is 10mu in the area around the high-level pool of the manpower irrigation area. The third type is high-pressure irrigation type, in the high-level pool around the height difference of 30m outside the region, according to ShuiQin Road terrain conditions, irrigation area is 28.5 mu.

Summary

This paper mainly proposed the design for water conversation in the region of Shuiqin Road in the NDLZ. The main contents are as follows:

The related designed parameters of water conservancy project on both sides of the Shuiqin Road are as follows: 1) Sprinkler irrigation water uses New Area reclaimed water, the irrigation area is about 6192 mu, irrigation period is about 15 days, 15 hours a day, 8 times of irrigation every year, the required amount of water is about 697,300; 2) Irrigation pipe network is PE or UPVC pipe material with diameter of DN100, landfill way is applied with buried, and set 18 reservoirs, single-seat service area is about 40 acres / day.

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