Discussion on the Design of Fire Water Supply System in Mountainous Rural Areas

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Abstract: It is an important basic project to construct the firefighting water supply system in mountainous rural areas for their fire safety. Illustrated with a case of a mountainous area, this paper investigated the fire water supply system design methods by building the water storage facilities, water supply network and using natural water body, as well as integrating with the production and living water system. It would improve the level of rural fire infrastructure construction and have reference significance for vigorously implementing the strategy of "Rural Revitalization", building beautiful countryside.

1. Introduction

The party's 19th national congress put forward the strategy of "rural revitalization", which is of great significance for speeding up the construction of rural infrastructure and improving the quality of life of farmers. As an important basic work to ensure the safety of life and property of farmers, rural fire control work must be planned, designed and promoted together with rural infrastructure construction, so as to create a good fire control safety environment for local economic and social development and for farmers to live and work in peace and contentment. In response to major livelihood issues concerning the safety of drinking water for people and animals in rural areas, we increased funding year by year to build and renovate drinking water and water supply pipe networks in rural areas. It is of great practical significance to seize the historical opportunity of the transformation of drinking water supply pipe network in local rural areas and build and improve the fire control water supply system to improve the local rural fire prevention and control ability and fire safety level. Based on the engineering example, this paper discusses the simultaneous construction of fire water supply system in a certain place combined with the rural drinking water improvement project of human and animal.

2. Project Overview

Take Zhoujiawu Village, Qintang Township, Jiande City as an example, start the human and animal drinking water reconstruction project, use the abundant water resources such as the local stream, and build a water supply facility such as a dam, a collecting pond and a pump house to promote agricultural production and farmers' life. And the construction of fire water supply pipe network, and effectively improve and enhance local agricultural production conditions, domestic water security and fire prevention and control capabilities.

The village is far away from the central town, the infrastructure construction is backward, and the fire prevention and control and firefighting and rescue capabilities are relatively weak. The specific performance is as follows: The nearest voluntary fire brigade is far away from the village, and there is no fire pool or water supply pipe network; it cannot meet the requirements of fire truck driving, and it is difficult to reach the fire extinguishing force for 5 minutes.

3. Key points and difficulties in the design of rural fire water supply systems in mountainous areas

After on-site field investigation, the village was faced with the difficulty of mountainous terrain

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fluctuations, unstable stream flow, unreasonable layout of villagers' housing construction, and low fire protection rating of building forms.

1) The fluctuating terrain and the scattered housing distribution make it more difficult to arrange the water supply pipe network and the firefighting pool.

2) The natural water source has a large change during the wet season and the dry season, and it cannot provide reliable fire water supply.

3) There is no basis for the estimation of fire water consumption, and it is hard to guarantee the accuracy of the design of fire water supply system.

4) The layout and structure of the villagers! houses make them weak in withstanding the risk of fire.

4. Design principle of rural fire water supply system in mountainous areas

In view of the topographical features and the existing hydrological conditions of the village, the design adheres to the guiding ideology of “full utilization, rational layout, unified planning, and centralized construction![1], making maximum use of local river water resources. When building necessary water resources facilities, coordinating the needs of drinking, production water and fire water, the following basic principles are followed in the design:

1) Make full use of natural water. In order to reduce construction investment, make full use of local natural water, water storage facilities such as dams are built to ensure the village!s agricultural production, farmers! lives and the need of firefighting water.

2) Set up water storage facilities in partition. Due to the large difference in the distribution of villagers!, there are two high and low pools in the mountain and valley areas. There are two pools in the valley, one of which serves as a backup pool for emergency.

3) Set up water supply network in partition. In order to reduce the loss of the water supply pipe network, it is set up in accordance with the mountain and valley divisions, and the water supply pipe network takes into consideration the multi-purpose uses such as domestic water supply, fire water supply and the like.

4) Build a booster pump room according to the actual situation. In order to ensure the domestic water supply and fire water supply, according to the calculation of hydraulic power, a booster pump room is built to ensure the pressure of the water supply network.

5. Water supply facility design

5.1 Rolling dam design

The design of the rolling dam includes two parts: hydraulic calculation and structural calculation. Because the dam body of the project has low height, good geology and simple calculation of structure, the content of structural calculation is omitted in this paper, and the content of hydraulic calculation is emphasized.

1) Basic situation of hydrogeology

The spillway flow is designed according to the 10-year flood, and the building is a Grade IV hydraulic structure. According to the rainfall ranking rules of the “Zhejiang Short-Term Rainstorm! period, the design rainstorm process is determined, and the design flow rate Q is calculated to be 32.2m3/s according to the instantaneous unit line method [3].

2) Determine the size of the rolling dam [4]

The rolling dam type adopts the fold line type utility raft. The designed dam bottom elevation is 24.50m, the designed dam crest elevation is 25.95m, the initial dome width is 1.4m, the slope is 1:1 (see Figure 1), and the flow coefficient is found. m = 0.36.

The design idea of dam height is as follows: according to the formula

$$q = mb\sqrt{2g}H_0^{1.5} \quad (1)$$

q-dam height (m);

m-turbulent flow coefficient, generally obtained empirically by empirical formula or data according to thin wall, practical section and wide top ;

b-the length of the dam crest (m);

g-gravitational acceleration (m/s2);

H0-the front head (m).

Assuming that the height of the dam q=1.45m, it can be seen from the design section of the river that the length of the top of the dam b=14.50m, substitute the formula to get the weir head H_0=1.25m. Take free height into account, when the flow reaches its peak, the water level H=(25.95+1.25)=27.20m ＜27.50m, It is lower than the shore elevation of 27.50m, which meets the requirements. Therefore, the size of the proposed rolling dam is reasonable.

3) Calculation of downstream water depth h_1[5]

According to the D-D cross-section diagram (figure 2) of Zhoujiawu village roller dam, the base width b=9m, the slope m=1.0, and the roughness coefficient n=0.030 of the channel, a trial algorithm was used to obtain the downstream water depth ht.

You can assume a series of ht values and plug them into the formula

$$Q=(b+mh)h\cdot\frac{1}{n}\left[\frac{(b+mh)h}{b+2h\sqrt{1+m^2}}\right]^{\frac{2}{3}}\cdot\sqrt{i} \quad (2)$$

Q-Maximum discharge under spillway (m^3/s)

b-Channel bottom width (m)

h-Channel depth (m)

m-Steep slope slot

n-Channel roughness factor

i-The bottom of the channel slope

After trial calculation, the downstream water depth h_1=1.45m

4) Size design of silt tank [6].

The total upstream energy based on the downstream riverbed:E_0=25.95-24.50+1.25=2.70m. The unit width discharge is known

$$q=\frac{32.2}{14.5}=2.22\, m^3/s \quad (3)$$

Then the critical depth is

$$h_k=\sqrt[3]{\frac{q^2}{g}}=\sqrt[3]{\frac{2.22^2}{9.8}}=0.80m \quad (4)$$

$$\frac{E_0}{h_k}=\frac{2.70}{0.80}=3.38 \quad (5)$$

The solution diagram of channel contraction depth and conjugate depth of trapezoidal section in table lookup is as follows:

$$\frac{h_{c1}}{h_k}=0.604 \quad (6)$$

Then h_{c1}=0.8×0.604=0.73m

$$\frac{h_{c1}}{h_k}=1.5 \quad (7)$$

Then h_{c2}=0.8×1.50=1.20m

Calculation of plunge pool length L_k:

Since hc2=1.20m < ht=1.45m, the hydraulic jump occurs at the contraction section of the rolling dam, which is the submerged hydraulic jump connection. So there is no need to dig a deep stilling pool.

According to the calculation formula of hydraulic jump length:

$$L_j=6.9(h_{c2}-h_{c1})=6.9\times(1.20-0.73)=3.24m \quad (8)$$

Therefore, the length of silt pool L_k shall not be less than 3.24m. Considering the imperfection of hydrological data in mountainous areas and the fact that local areas have been hit by typhoons in recent years, the length of silt pool L_k shall be 14.50m to minimize the erosion of rolling dam by mountain flood and avoid damage to water conservancy facilities.

5) Calculation of the storage capacity of the rolling dam.

According to the cross section of D-D of the rolling dam of Zhoujiawu Village, the length of the section from the actual rolling dam to the stream estuary is 600m, and according to the design flow Q is set to 32.2m3/s, the formula for calculating uniform flow of open channel

$$Q=(b+mh)h\cdot\frac{1}{n}\left[\frac{(b+mh)h}{b+2h\sqrt{1+m^2}}\right]^{\frac{2}{3}}\cdot\sqrt{i} \quad (9)$$

Try to calculate the water level H1=1.3m, and so

Section area:

$$A=(b+mh)h=(9+1\times1.3)\times1.3=13.39m^2 \quad (10)$$

Rolling dam storage capacity:

$$V=SL=13.39\times600=8034m^3 \quad (11)$$

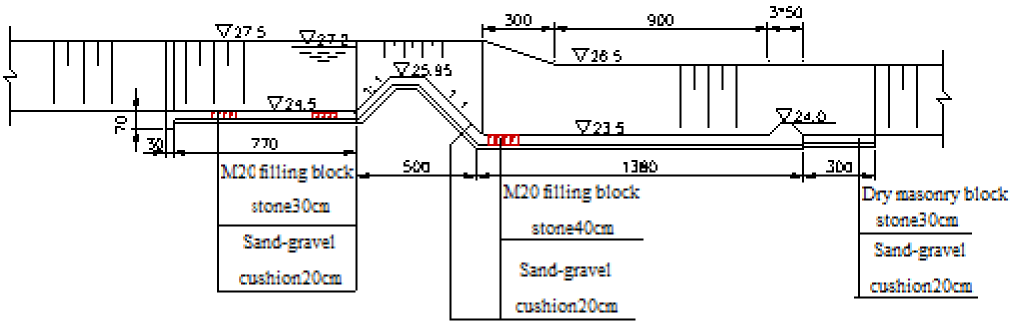

Figure. 1 Longitudinal section of the rolling dam

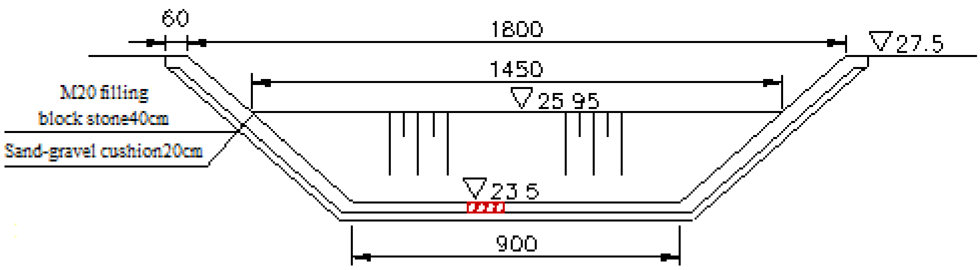

Figure. 2 D-D cross-sectional view

5.2 Pool design

1) The pool capacity is determined. It should be determined according to the fire duration and the amount of fire water. The self-built houses of the villagers are mainly brick-wood structure, the fire resistance level is low, the fire duration is calculated according to 3h, and the fire water consumption meets one mobile fire pump according to the initial fire. Two water guns 10L/s (5L/s for each water gun) are calculated: Q=10L/s·60s·180m=98m3, and the capacity of the fire pool should not be less than 98m3. Taking into account the usual domestic water and considering a certain amount of allowance, the capacity of the three outlets is 200m3.

2) Set up production and living and fire outlets. In order to prevent fire water from being occupied by production and domestic water, the outlet pipes for production and domestic water shall be placed above the fire water outlet pipes to ensure that fire water is not used.

3) Positional arrangement. Each pool is arranged at a relatively high position in the respective areas in order to utilize the height difference to form a constant high pressure water supply. The water intake of each pool is not less than 2, and the height of the water intake is not more than 6m.

5.3 Water supply network and outdoor fire hydrant design

In view of the dual functions of providing water, fire water and fire water for the water supply pipeline, in order to ensure sufficient water pressure and water volume during the fire extinguishing, the main pipe diameter of the water supply pipe is not less than 150mm, and the annular main network is designed according to the valley and mountain areas. According to the distribution of villagers' houses and roads, the pipe diameter is not less than 100mm. In view of the low fire resistance of villagers' houses, the distance between outdoor fire hydrants is not more than 60m.

5.4 Design of booster pump room

In order to ensure the water supply in dry season and that in the upper region, the water intake pumping room and the water booster pump room for the mountain pool are respectively arranged.

6. Conclusion

1) Making full use of natural water resources and scientifically and rationally designing rolling dams can not only effectively save rural water supply system construction funds, but also improve local flood control and drought relief capacity.

2) The water supply system used for living and firefighting effectively reduces the cost of pipe network construction.

3) The selection of water source for firefighting should first consider the reliability of its water supply, which can guarantee the quantity, quality and pressure of firefighting water supply.

4) Separate water supply system is adopted according to topography, which can effectively reduce the loss of water head of pipe network and ensure the stability and reliability of water supply.

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