Analysis of Sediment-retaining Function of "7.26" Storm of Silt Dam in Xiaoli River Basin

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Abstract: The construction of silt dams on the loess plateau is one of the highlights of water conservancy construction. Because silt dams can effectively prevent soil erosion, silt dams have been built on a large scale in the loess plateau. But what is the function and effect of silt dam in the process of rainstorm? It is a scientific question to be answered urgently. Therefore, we selected six hundred and forty-six silt dams in Xiaoli river basin under "7.26" rainstorm to carry out field survey and measure the silt and sediment situation of silt dams, so as to explore the silt retaining capacity of silt dams in small watersheds and the main factors affecting silt and sediment of silt dams during rainstorm. The results show that the small and medium-sized dams in the Xiaoli river basin have a strong ability to retain sediment in rainstorm, but the large and medium-sized dams play a major role in retaining sediment. The average modulus of retaining sediment in the basin is 12587t/km².

1. Introduction

The loess plateau is one of the most serious soil erosion areas in the world. Flood and sediment disasters in the lower reaches of the yellow river mainly come from the loess plateau. The annual sediment input into the yellow river accounts for 80% of the total sediment transport in the loess plateau[1-3]. The sediment in the loess plateau mainly comes from gullies. Silt dam is a dam building built in all levels of ditches, which is mainly used to store runoff and sediment on slopes and prevent erosion of ditches. It is also one of the main engineering measures to control soil and water loss in the loess plateau, which has obvious function of sand retention and siltation. In 1945, the silt dam built in Jingyugou valley of Xi’an city is the first silt dam built by the Yellow River water conservancy commission in the loess plateau area. Since the pilot demonstration stage of silt dams, large-scale construction of silt dams has developed rapidly[4-5]. According to the bulletin on Soil and water conservation of the first national water conservancy census, as of 2011 year, fifty-eight thousand four hundred and forty-six silt dams have been built on the loess plateau, of which five thousand six hundred and fifty-five are the backbone of gully control projects[6]. Xiaoli river basin belongs to the loess hilly and gully region, and the soil is mostly loess and sandy soil, so the soil erosion is intense and serious. Warping dam is also one of the main engineering measures for soil erosion control in Xiaoli river basin. More than five hundred large and medium-sized silt dams have been constructed or strengthened since 2013. The silt dams play a certain role in preventing and reducing the sediment coming from the river basin. However, under this rainstorm, the ability of the built silt dam to retain sediment in small watershed is a scientific question to be answered urgently. To this end, this study
was conducted on July 26th, 2017 (abbreviated as “7.26”) under the heavy rain and flood of Wuding river, since 2013, five hundred silt dams of large and medium-sized silt dams have been built or strengthened in Xiaoli river basin. Investigation and analysis of silt deposition of silt dams have been carried out systematically. The analysis results can clarify the sediment retaining function of silt dam under the rainstorm and its contribution to the reduction of sediment transport, which can provide some scientific basis for the future construction of silt dam on the loess plateau.

2. The Study Area and Rainstorm analysis

2.1 The Study Area
Xiaoli river is a main tributary of Dali river in Wuding river system. It is located in 109°16’- 109°51’, 37°36’- 37°49’. It originated in Aihao Village, Hengshan County, Shanxi Province, and merged into Dali River in Lijiahe Village, Dianshi Town, Zizhou County, Shanxi Province. The river basin area is 807 km², the river length is 63.7 km, the average ratio of river courses is 5.5 and the density of river network is 0.116 km/km². There are six rainfall stations in the basin, namely, Lalumaoai, Gaozhen, Lijiagua, Shiyaogou, Lixiahe and Aihaimao, and one hydrological station in Lijiahe river.

2.2 Rainstorm analysis
On July 26th, 2017, the torrential rain and flood in Wuding River mainly occurred in Dali River, and the rainy area over two hundred mm basically ran along the Dali river to Xiaohegou river basin. The maximum discharge and sediment concentration of sude control station at dali river outlet are 3160 m³/s (ranking first in history) and 839 kg/m³, respectively. Among them, the maximum rainfall stations in Xiaoli river basin. Lijiahe Station, began to rain at 20 o’clock on the 25th, and the maximum rainfall of one hour, three hours and six hours were 66.6 mm, 125.8 mm and 232.8 mm, respectively. The Lijiahe Rainfall Station in Xiaoli river began to rain at 20 o’clock on the 25th. The maximum rainfall intensity occurred after 5 hours. The maximum rainfall in one hour was 72.4 mm. The maximum rainfall in three hours and six hours was 118.6 mm and 195.4 mm, respectively. It was a very heavy rain.

3. Investigation methods and contents
According to the Google Earth image, 646 silt dams in Xiaoli river basin were captured. Dam-by-dam field survey is also carried out. The survey includes the intact degree of each silt dam body, dam height, dam length, whether there are drainage structures (spillway, shaft, horizontal pipe), siltation of dam and reservoir, etc. Special labeling is made for silt dams with water accumulation or sludge immeasurable and full storage. For silt dams destroyed by stormwater, the volume of water-destroyed section of dam body was measured, and field investigation forms and image files were established for dam body and drainage structure.

The amount of siltation in silt dams is obtained by measuring the depth and area of siltation in silt dams. According to the silting pattern of silted sediment in the dam, the silted area of silt dam is divided into several blocks, and then measured by range finder, GPS and total station. The depth of sediment deposition is measured by digging holes. In each silting block, 2-3 excavations are manually excavated horizontally to measure the siltation thickness of the excavations, the average siltation thickness of the exploratory pit is taken and the siltation area is multiplied to calculate the siltation amount of the silt dam.

4. Analysis of survey results

4.1 Basic Situation Analysis of Warping Dam
According to the survey results of six hundred and forty-six silt dams in Xiaoli river, three hundred and fifty-seven small dams accounted for 55.26%, two hundred and six medium dams accounted for 31.89%, Forty-seven large dams accounted for 7.28%, twenty-eight backbone dams accounted for
4.33%, eight storage dams accounted for 1.24%.
Under "7.26" rainstorm, two hundred and fifteen siltation dams occurred. The siltation dams concentrated in the middle and lower reaches of Xiaoli river basin, including 88 small dams, accounting for 40.93% of the total siltation, ninety-three medium dams, accounting for 43.26% of the total siltation, twenty-six large dams, accounting for 12.09% of the total siltation; and eight backbone dams, accounting for 3.27% of the total siltation.

It can be seen from this that the main types of Silt Dams in Xiaoli river basin are small and medium-sized dams. Under this "7.26" rainstorm, the small and medium-sized silt dams have a strong ability to retain sediment.

4.2 Analysis of silt retaining by silt dam
Among three hundred and fifty-seven small dams, eighty-eight have siltation, accounting for 24.65% of small dams; among two hundred and six medium dams, ninety-three have siltation, accounting for 45.15% of medium dams, among forty-seven medium dams, twenty-six dams have siltation, accounting for 55.32% of medium dams; among twenty-eight large dams, eight dams have siltation, accounting for 28.57% of medium dams.

Table 1 shows that: "7.26" rainstorm in the Xiaoli river basin, a total of 3 million 595 thousand and 600 tons of sediment were blocked by silt dams, and a total of 406.5 million tons of sediment were deposited by small dams, accounting for 11.31%, 141.97 million tons of sediment were deposited by medium dams, accounting for 39.48%, 118.05 million tons of sediment were deposited by large dams, accounting for 32.83%, 588.9 million tons of sediment were deposited by backbone dams, accounting for 16.38%.

It can be seen that, in the "7.26" rainstorm, although the small and medium-sized silt dams have a strong ability to retain sediment, the large and medium-sized dams play a major role in the "7.26" rainstorm, and the small-sized dams have a significantly lower role in retaining sediment than the large and medium-sized dams.

4.3 Analysis of Sand-retaining Modulus of Warping Dam
A total of 3.595 million tons of sediment were deposited by silt dams in the "7.26" rainstorm basin of Xiaoli River Basin. The average modulus of silt dams in the basin is 12587 t/km², of which the average modulus of small dams is 4714 t/km², the average modulus of middle dams is 17686 t/km², the average modulus of large dams is 11463 t/km², and the average modulus of backbone dams is 27389 t/km².

According to the measured data, there are twenty silting dams without drainage structures, 16 of which have been screened and calculated the modulus of single dam (see Table 2), the average modulus of sixteen sullen gourd dams is 20862 t/km², and the maximum modulus of sullen gourd dams is 4517 t/km² and the minimum is 11265 t/km², which are not affected by upstream dams.

Table 1. Table of sedimentation of different types of silt dams in 7.26 Rainstorm in Xiaoli river basin

| Dam type     | Sedimentation volume (ten thousand T) | Percentage of total siltation % | Average deposition thickness (m) | Maximum. thickness (m) |
|--------------|--------------------------------------|--------------------------------|---------------------------------|------------------------|
| Small dam    | 40.65                                | 11.31                          | 0.33                            | 2.20                   |
| Medium dam   | 141.97                               | 39.48                          | 0.50                            | 1.90                   |
| Big dam      | 118.05                               | 32.83                          | 0.46                            | 1.42                   |
| Key Dam      | 58.89                                | 16.38                          | 0.61                            | 2.00                   |
| Impoundment dam |                                    |                                 |                                 |                        |
| Total        | 359.56                               |                                |                                 |                        |
Table 2. Sedimentation of 16 stuffy gourd silt dams during 7.26 rainstorm in Xiaoli river basin

| Name of dam       | Maximum depth of Siltation (m) | Sediment intercept (t) | Dam control area (km²) | Sediment intercept modulus (t/km²) |
|-------------------|--------------------------------|------------------------|------------------------|----------------------------------|
| Qiaogou 2#        | 1.32                           | 15476.01               | 0.856                  | 18079                           |
| Dongmao 2#        | 2.2                            | 6392.32                | 0.193                  | 33120                           |
| Malianta          | 1.1                            | 15354.67               | 0.322                  | 47685                           |
| Qiangou           | 0.6                            | 6835.19                | 0.574                  | 11908                           |
| Shiyaogou         | 0.14                           | 2862.88                | 0.592                  | 4835                            |
| Yangjiagou 2#     | 1.1                            | 2703.70                | 0.246                  | 10991                           |
| Yanglumao         | 0.84                           | 13355.73               | 0.592                  | 22560                           |
| Miaoayan          | 0.1                            | 3594.62                | 0.503                  | 7146                            |
| Jinggou           | 1.1                            | 16045.43               | 0.385                  | 41676                           |
| Kucaimao          | 0.9                            | 14381.29               | 0.849                  | 16086                           |
| Xizuimao          | 0.75                           | 10472.90               | 0.529                  | 19797                           |
| Jingzigou         | 0.5                            | 14929.08               | 0.702                  | 21266                           |
| Yangjiagou 1#     | 1.6                            | 1677.29                | 0.104                  | 16127                           |
| Daicungou 2#      | 1.2                            | 26640.39               | 0.111                  | 217903                          |
| Caohougou 1#      | 0.75                           | 14023.91               | 0.339                  | 41369                           |
| Yuzimantan        | 1.6                            | 5485.43                | 0.217                  | 25278                           |

5. conclusion
First, Xiaoli river basin is mainly small and medium-sized dams. In the “7.26” rainstorm, the small and medium-sized silt dams have strong ability to retain sediment, but the large and medium-sized dams play a major role in retaining sediment, and the small-sized dams have a significantly lower role in retaining sediment than the large and medium-sized dams.

Second, the average sediment interception modulus of silt dams in Xiaoli river basin is 12587t/km². The average sediment interception modulus of small dams is obviously higher than that of large and medium dams, and slightly higher than that of backbone dams. Among them, the average sediment interception modulus of 16 silt dams without drainage structures is 20862 t/km², the maximum sediment interception modulus is 47685 t/km² and the minimum is 4835 t/km².

Three, the southeastern part of the Xiaoli river basin, the sediment interception modulus is between 30000—40000 t/km². Along with the decrease of the storm rainfall, the sediment interception modulus is gradually reduced from 30000 t/km² to less than 1000 t/km² in the northern margin. In the western region, there are fewer silt dams, and the loess material is relatively loose. The modulus of sediment interception is more than 18000 t/km².

Acknowledgments
This paper is based on work supported by the Central Nonprofit Research Institutions Basic Scientific Research Special Fund(HKY-JBYW-2018-08).

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