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Research on the Technology of Anti-Erosion and Vegetation Promotion for Pisha Sandstone Region in the Middle Yellow River Basin

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Abstract. Pisha sandstone region is the most vulnerable and the most dramatic area of soil erosion, and it is also the concentrated source area of the coarse sediment of the Yellow River. It is of great significance to research the anti-erosion and vegetation promotion technology in the Pisha sandstone region. Based on the review of previous research results on soil erosion control technology in Pisha sandstone area, this paper mainly introduces the anti-erosion and vegetation promotion technology in recent years, including the anti-erosion and vegetation promotion material suitable for Pisha sandstone area in the middle Yellow River Basin, the modified dam-building material of Pisha sandstone, and the stereoscopic configuration mode of binary stereoscopic anti-erosion and vegetation promotion measures in Pisha sandstone area. Field monitoring experiments showed that the runoff and sediment yield of the experimental plot were reduced by more than 70% and 91% respectively, which can provide technical support for the harnessing and development of serious soil and water loss areas of Pisha sandstone and the harnessing and development of the Yellow River.

1. Introduction

The area of Pisha sandstone is about 16, 700 km^2, mainly distributed in the border area of Shanxi, Shaanxi and Inner Mongolia, centered on Zhungeer county, Ordos City, Inner Mongolia[1]. Several first-order tributaries of the Yellow River, such as Huangfuchuan, Kuye River and ten major watersheds, originated in the Pisha sandstone area, have become the main sources of the heavy sand and coarse sand in the Yellow River. Of the 200 million tons of sediment entering the Yellow River annually, 100 million tons are coarse sediment, and almost all of it is deposited in the lower Yellow River, accounting for 25% of the average annual sediment deposited in the lower Yellow River. A large amount of coarse sediment deposition makes the lower Yellow River a world-famous "overground suspended river", which significantly reduces the flood discharge capacity of the river, and poses a great threat to the flood control safety of both sides of the lower Yellow River and the relevant areas, and becomes the first hazard of the safety of the Yellow River. Because of poor site conditions and lack of water resources in Pisha sandstone area, it is difficult to implement biological measures in an all-round way[2]. In addition, Pisha sandstone has very low viscosity, high porosity and low strength, which makes it difficult to be used as materials for soil and water conservation projects such as silt dams, making it difficult to implement effective silt dam engineering measures[3]. Therefore, the management of Pisha sandstone area is extremely difficult, and the existing technical measures are difficult to effectively solve the serious soil erosion problem in Pisha sandstone area[4]. The effective control technology of soil erosion in Pisha sandstone area is still one of the key technologies to be broken through[5]. It is of great significance for the ecological security of the Yellow River Basin to carry out the integration and demonstration research of anti-erosion and vegetation promotion technology in the middle Yellow River Basin and to develop the key technologies for effectively controlling soil erosion in the Pisha sandstone area.

2. Anti-erosion and Vegetation Promotion Technology

2.1 W-OH Anti-erosion and Vegetation Promoting Materials

W-OH anti-erosion and vegetation promoting material is a kind of modified hydrophilic polyurethane composite material which is based on the original hydrophilic polyurethane material and combines nano-modification, structural change and functional material composite technology. The modified hydrophilic polyurethane composite material is obtained by the polymerization of isocyanate, polyether polyols and various functional modified materials under specific temperature, time and ratio conditions [6].

The Pisha sandstone with about 30% water content is put into the transparent acrylic tube with a diameter of 50 mm and a height of 5000 mm. The surface is sprayed with 3%, 4%, 5% W-OH and 0.5% water retaining agent, respectively, to form a consolidation layer with a thickness of about 1 mm. Then at 0, 6, 18, 42, 90, 162, 258, 618, 810, 1050, 1290h, the water content of Pisha sandstone samples is measured at 10-15 cm depth from the surface. The results are shown in Figure 1. It can be seen from Figure 1 that the water content of blank group of Pisha sandstone samples decreases rapidly, while the water content of samples sprayed with different concentrations of W-OH decreases slowly. Compared with blank samples, the longer the time, the more obvious the water retention effect. After 800 hours, the water content of blank samples without anti-erosion and vegetation promotion materials decreased from about 21% to about 12%, while the water content of samples with anti-erosion and vegetation promotion materials remained basically unchanged during the same period. At the same time, the water content of the samples sprayed with different concentrations of W-OH is not significantly different, indicating that the spraying concentration of 3% can achieve better water retention effect.

W-OH anti-erosion and vegetation promotion material has high water-holding capacity. The reason is that the original rock of Pisha sandstone is loose, the grain edges and corners are distinct, and the cohesion is poor. After spraying W-OH solution, a coating is formed on the surface of Pisha sandstone particles, which enlarges the size of Pisha sandstone particles, roughens the surface and improves the density, and relatively enhances the contact area between particles. W-OH forms a layer of gel on the surface of Pisha sandstone, which improves its cohesion and prevents water evaporation from Pisha sandstone.

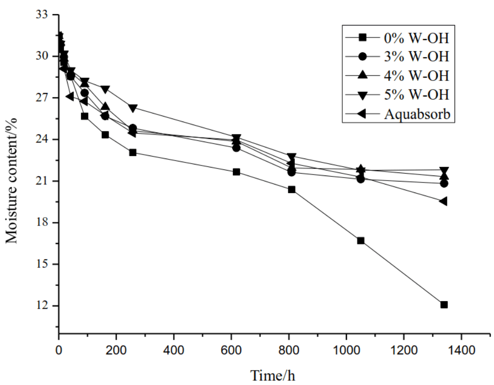

Figure 1. Water retention effect of W-OH anti-erosion and vegetation promotion materials with different concentrations

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2.2 Modified Pisha Sandstone Materials for Dam Construction

The main reason for the swelling and collapsing of Pisha sandstone in water is that there are a lot of hydrophilic montmorillonite which is easy to swell and collapsing in its rock composition. The expansibility of Pisha sandstone can be significantly reduced by adding modifiers and gelling inhibitors that inhibit minerals such as montmorillonite. At the same time, its mechanical strength can be significantly improved. According to this principle, the modified material of Pisha sandstone has been successfully developed through a large number of screening experiments. A demonstration project of silt dam with modified material of Pisha sandstone was built in 2015 (Figure 2).

The technology of building dam with modified material of Pisha sandstone is the technology of building dam with original rock modified material based on R&D design, experiment simulation and field verification feedback. This technology makes use of mechanical and chemical tests to simulate and analyze materials and dam-building process, further verifies dam design scheme and key procedures of dam-building with modified materials, and establishes corresponding feedback mechanism. Pisha sandstone modified material silt dam is built in Erlaogou watershed of Huangfuchuan basin. It consists of dam body and water discharge project. The dam height is 10.03 m, the area of the basin is 0.31 km^2, the total storage capacity is 32, 600 m^3, the silt storage capacity is 4, 400 m^3, and the silting life is 10 years. According to the requirements of the national standards for the stability, permeability and other engineering mechanical properties of silt dam body and the function of retaining sediment, the mechanical parameters of the layered roller compacted dam materials were tested during the construction of the dam. The main test parameters contained dry density, water content, seepage coefficient, shear strength, internal friction angle and so on. The results showed that the optimum water content of the material was about 11%. The seepage coefficients of different rolling layers were all below 1.8×10^{-7} m/s. The shear strength of the modified Pisha sandstone increased from 48 kPa to 74 kPa, and the internal friction angle is more than 35 degrees. The modified material meets the requirements of the code[7]. The construction of silt dam provides an example of using modified materials to build silt dam in Pisha sandstone area, and provides technical support for soil erosion control in Pisha sandstone area.

Figure 2. Silt Dam with Modified Materials of Pisha Sandstone

3. Integration and Demonstration Model of Stereo Configuration Governance Technology

There are many erosion types in Pisha sandstone area. Water erosion is the main erosion type. It generally occurs on the top and surface of the slope. Gravity erosion occurs on steep slopes and gully slopes with slope gradient greater than 40 degrees. Collapse mainly occurs on gully slopes with slope gradient over 60 degrees. Valley sediment yield in Pisha sandstone area accounts for 79.49%-84.1% of total sediment yield in small watershed, and intervalley sediment yield accounts for 15.86%-20.61%[8]. Runoff and sediment yield of Pisha sandstone are higher than that of loess and aeolian sandy soil[9]. Through field investigation and analysis, the stability angle of Pisha sandstone covered with sand concentrates around 35 degrees, the stability angle of Pisha sandstone covered with loess ranges from 35 degrees to 45 degrees, the slope of white Pisha sandstone bare slope concentrates between 35 degrees and 70 degrees, the slope of Red-white interlaced layer concentrates between 35 degrees and 45 degrees, and a small number of slope slopes are more than 70 degrees[10]. Based on the erosion environment and its regularity in the Pisha sandstone area, the vegetation types suitable for planting on the top of slope, slope, gully slope and gully bed, the three-dimensional allocation model of different types of vegetation and its regulation mechanism for environmental impact were studied. A y three-dimensional disposition model for the treatment of Pisha sandstone was proposed. That is, the integrated technology and mode of soil and water loss control, which is the combination of anti-erosion and vegetation promotion material measures, engineering measures and biological measures, and the slope-channel system geomorphological units, are shown in Figure 3.

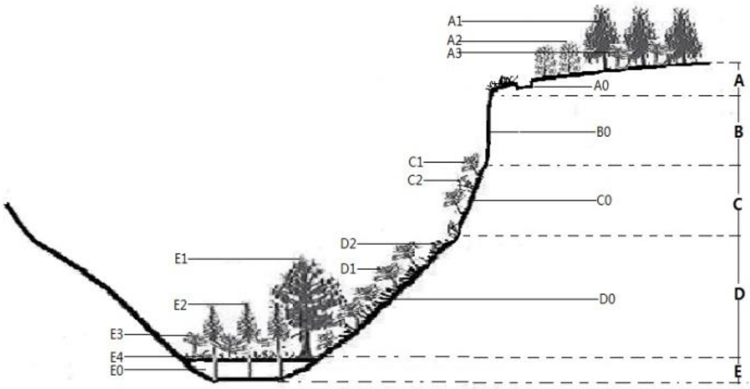

Figure 3. Schematic diagram of stereo configuration mode

As shown in Figure 3, the demonstration of stereo configuration can be divided into five zones. Area A is the top of the ridge, area B is the slope above 70 degrees, area C is the slope between 35 degrees and 70 degrees, area D is the gentle slope below 35 degrees, and area E is the channel. Different spatial structures are allocated with different governance measures. The top of the ridgr area is flat and suitable for large-scale plantation. The allocation mode of plantation construction is Pinus tabulaeformis (A1)×Hippophae rhamnoides (A3) mixed forest. The allocation mode of maintenance measures along ditches is to create two rows of Caragana microphylla (A2) cliff protection forest belt 2-3 m away from ditches and dig interception ditches (A0) 1.5-2 m away from ditches. Vegetation on slopes above 70 degrees is difficult to grow. The control measures are to solidify W-OH (B0) with a spraying concentration of more than 6%, to prevent soil erosion and wind erosion and stabilize the slopes. The treatment measures of 35-70 slopes adopt the combination of plant measures and engineering measures, digging deep fish scale pits to prepare land, planting seabuckthorn (C1)×wheatgrass (C2), digging shallow pits among forests to drill grass seeds, and spraying W-OH (C0) with concentration of 4%-6%.Under 35 degrees, the slope soil is soft and suitable for plant growth. The control measures are seabuckthorn (D1)×ice grass, Elymus alkali grass (D2), Salix sparse forest (D0) at the foot of the slope, and seabuckthorn is planted in horizontal ditches on the slope, spraying W-OH with concentration of 2%-4% to achieve the purpose of promoting growth, stagnating water and blocking sand. Suitable for the growth of herbaceous plants and Arbor-shrub vegetation with well-developed roots due to abundant water and loose soil in the gully, plant measures consisting of willow (E1)×salix (E2) and seabuckthorn (E3)×ice grass (E4) were adopted, and flexible dams of Salix (Hippophae rhamnoides) were arranged in the proper position of V-shaped gully to control the lateral erosion of the gully. A modified material silt dam (E0) of Pisha sandstone was constructed at the appropriate location of the main channel downstream of the demonstration area for sand interception and land reclamation.

4. Effect of Anti-erosion and Vegetation Promotion Test in Demonstration Zone

Large-scale demonstration experiments showed that the stereoscopic allocation model established in the Pisha sandstone area had achieved the goal of preventing soil erosion and rapidly restoring ecology. The construction effect of the Pisha sandstone anti-erosion and vegetation promotion demonstration area is shown in Figure 4. The vegetation planted in Pisha sandstone treatment experimental area grew over 100 cm in height and 75% in coverage after 4 months'growth period, which indicated that the anti-erosion and vegetation promotion material had good growth promoting function. The three-dimensional configuration model in the demonstration area has achieved remarkable results in vegetation promotion and anti-erosion.

Figure 4. The vegetation coverage in the demonstration area

According to the field observation of runoff plots in the demonstration area from July to September every year from 2014 to 2016, six runoff yields occurred. Based on the analysis of the measured data of runoff and sediment, compared with the bare control area without measures, the vegetation in the control area with anti-erosion and vegetation promotion measures has not only been well restored, but also the runoff and sediment yield has been significantly reduced. Runoff decreased by more than 70% and sediment yield decreased by more than 91%. The maximum rainfall on August 11, 2016 reduced runoff and sediment by 93.8% and 97.5%, respectively. The experimental results showed that the anti-erosion and vegetation promotion materials and the anti-erosion consolidation materials developed have preliminarily achieved the designed functions, and the proposed anti-erosion and vegetation promotion treatment model of Pisha sandstone is feasible.

5. Conclusions

The high content of montmorillonite, calcite and feldspar in soft sandstone and the development of pore microstructures in rock mass are the main reasons for the poor soil erosion resistance of Pisha sandstone. W-OH material has good permeability on the surface of soft sandstone. It can greatly improve the anti-aging performance of elastic solids by adding ultraviolet absorbers, and has anti-erosion and induced properties. The new materials developed to resist erosion have obvious effects on soil erosion. According to the filed monitoring experiment, the runoff was reduced by 70 % to 75 %, and the sediment yield was reduced by 90 % to 99 %.

Acknowledgments

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