Water Science and Engineering, 2014, 7(1): 106-116
doi:10.3882/j.issn.1674-2370.2014.01.011

http://www.waterjournal.cn
e-mail: wse2008@vip.163.com

Abrasion test of flexible protective materials on hydraulic structures

Xin WANG*[1], Shao-ze LUO[1], Guang-sheng LIU[2], Lu-chen ZHANG[1], Yong WANG[1]

1. State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Nanjing Hydraulic Research Institute, Nanjing 210029, P. R. China

2. Beijing Oriental Yuhong Waterproof Technology Co., Ltd., Beijing 100123, P. R. China

Abstract: In this study, several kinds of flexible protective materials sprayed with polyurea elastomers (hereinafter referred to as polyurea elastomer protective material) were adopted to meet the abrasion resistance requirement of hydraulic structures, and their abrasion resistances against the water flow with suspended load or bed load were studied systematically through tests. Natural basalt stones were adopted as the abrasive for simulation of the abrasion effect of the water flow with bed load, and test results indicate that the basalt stone is suitable for use in the abrasion resistance test of the flexible protective material. The wear process of the polyurea elastomer protective material is stable, and the wear loss is linear with the time of abrasion. If the wear thickness is regarded as the abrasion resistance evaluation factor, the abrasion resistance of the 351 pure polyurea is about twice those of pure polyurea with a high level of hardness and aliphatic polyurea, and over five times that of high-performance abrasion-resistant concrete under the abrasion of the water flow with suspended load. It is also about 50 times that of high-performance abrasion-resistant concrete under the abrasion of the water flow with bed load. Overall, the abrasion resistance of pure polyurea presented a decreasing trend with increasing hardness. Pure polyurea with a Shore hardness of D30 has the best abrasion resistance, which is 60 to 70 times that of high-performance abrasion-resistant concrete under the abrasion of the water flow with bed load, and has been recommended, among the five kinds of pure polyurea materials with different hardness, in anti-abrasion protection of hydraulic structures.

Key words: *flexible protective material; polyurea elastomer material; abrasion resistance; hardness influence; hydraulic structure*

1 Introduction

Erosion and abrasion have been the most common problems in hydraulic structures. Overflow surfaces, flip buckets, spillway tunnels, flushing sluices, and stilling pool base slabs are all easily damaged by abrasion. The Fengman Hydropower Station overflow dam’s ogee section was damaged to a depth of 3 to 4 m because of flow erosion, and the maximum abrasion depth of the apron reached 4.5 m (Dai and Xu 2009). Behind the work gate of the

This work was supported by the National Natural Science Foundation of China (Grants No. 51109143 and 51209144), the Natural Science Foundation of Jiangsu Province (Grant No. BK2011109), and the Foundation of Nanjing Hydraulic Research Institute (Grant No. Y113004).

*Corresponding author (e-mail: *xwang@nhri.cn*)

Received Oct.16, 2012; accepted Sep. 16, 2013

Sanmenxia No. 2 bottom hole, a large area of abrasion-induced damage occurred, and the average abrasion depth was 14 cm. In the Yantan Hydropower Station, the bucket concrete surface was widely eroded, and the average thickness of exposed aggregate was 2 to 5 cm (Xia 1988). The stilling basin of the Indian Barkla Dam also had severe sediment erosion records (Vegas Merino et al. 2005). With increasing water conservancy project scale, the flow rate over discharge structures generally exceeds 35 m/s, and in some cases reaches 50 m/s, leading to more serious abrasion.

At present, in order to resist abrasion, high-performance concrete is mainly used. Lots of related research has been conducted, and some new kinds of abrasion-resistant concrete have been produced, with the abrasion resistance improved to some extent. With the progression of the research, polyurea, a new organic polymer abrasion-resistant material, has gradually drawn people’s attention (Henningsen 2002; Chen 2006). As an effective and environmentally friendly material, polyurea was used in construction of spillways and flip buckets at the Xin’anjiang and Fengman hydropower stations (Sun et al. 2006), the concrete volute at the Nierji Hydropower Station (Sun et al. 2009), the de-silting tunnel at the Xiaolangdi Hydropower Station, the plunge pool at the Xiaowan Hydropower Station, the stilling basin at the Guandi Hydropower Station, and the middle hole of the Three Gorges Dam in China. Outside of China, the discharge hole of the Tehri Dam in India is the most typical example of polyurea application in hydropower projects.

Spraying polyurea has been presented in the field of water resources and hydropower engineering for a few years. So far, though, the abrasion resistance of the polyurea material has not been studied systematically. Few indicators related to abrasion resistance can be referenced, and optimization of components of polyurea protective materials has never been conducted to meet the requirement of the abrasion resistance of hydraulic structures. Existing research on abrasion resistance is only based on a few simple tests and roughly qualitative evaluations. Through the high-speed erosion test, Wu (2005) showed that the abrasion resistance of polyurea materials was much higher than that of the C60 silica fume concrete. Zhong et al. (2007) evaluated the abrasion resistance of the polyurethane- or polyurea-coated layer in high-speed sediment jets using the wear-and-tear experimental machine and high-pressure water jet erosion tester. Guo et al. (2011) analyzed the main factors leading to the surface abrasion of the elastomeric coating. It was shown that the impingement of high-speed particles could lead to untimely dissemination of the stress wave in elastic bodies, which caused surface debacle. Chen et al. (2011) found that two-component polyurea material has a high ability to resist water erosion and abrasion. Some foreign research has focused on the mechanical properties of polyurea (Grujicica et al. 2010; Roland and Casalinj 2007; Sarva et al. 2007; Aly and Hussein 2010). However, study of the abrasion resistance has not been found reported aboard. This study aimed to determine the law of abrasion-induced damage and indicators related to the abrasion resistance of polyurea materials based on a series of tests.