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Short communication

Investigation of asphalt core-plinth connection in embankment dams

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ABSTRACT

The asphalt core itself is a no-joint water barrier in embankment dams and is connected to the concrete plinth on the bottom of the core. A reliable asphalt core-plinth connection is crucial and must remain watertight when the core deforms due to deformations in the embankment and foundation and due to reservoir water pressure. A large number of tension tests were conducted to determine the best ratios, joint thickness and suitable additives for the sandy asphalt mastic (SAM) mix used for the connection. With the ratios of bitumen to filler to sand of 20%:35%:45% and by adding 4% SBS in the bitumen, one got a very suitable composition for the asphalt core-plinth connection in tensile conditions. Model tests were conducted to study the connection behavior when subjected to large shear displacements and high water pressure. The joint model test results indicate that the plane-surface plinth, curved-surface plinth, and plinth with or without copper water-stop showed no significant difference for the connection in the joint shear behavior. However, plinth with copper water-stop is suggested to enhance its tensile and shear behavior.

1. Introduction and background

The asphalt core type embankment dam (ACED) with its many advantages has been applied worldwide since 1960s. Among the completed asphalt core dams, the Storglomvatn Dam in Norway and the Yele Dam in China were the highest until 2017, both with a dam height of 125 m [1,2]. In recent years, many investigations and applications for asphalt cores in embankment dams have been done. Wang and Höeg [3] proposed a simplified material model for analyzing asphalt cores in embankment dams based on extensive long-term creep triaxial test results. Wang and Höeg [4] as well as Akhtarpour and Khodaii [5] studied the cyclic behavior of asphalt concrete used as impervious cores in embankment dams for dam sites located in seismic regions. Zhang et al. [6] investigated the conditions that hydraulic fracturing would take place for asphalt cores in very high embankment dams and concluded that hydraulic fracturing would be of no concern. Asphalt concrete used as water barrier in dams provide watertightness, cracking resistance, and self-healing properties [7]. With the experience gained from research and field experience, the dam height of ACEDs has reached a level of more than 150 m. The 174 m high Quxue Dam was completed in February 2017 in China and other high ACEDs are under construction or under final design [8,9]. The 153 m high Zarema Dam is about to be completed in Ethiopia and the Moglicë Dam in Albania is in the early stages of construction and will be about 170 m high [9].

Asphalt core is placed and compacted layer by layer with transition zone on either side of the core with a compacted thickness of 20–25 cm to form a no-joint impervious wall protected by the transition zones in the embankment dam. The interface between asphalt core and transition zones play an important role to transfer stresses and deformations during the dam construction and

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reservoir impounding. The behavior of the interface of asphalt core-transition zone has not been investigated very much in the published literature. Tajdini et al. [10,11] studied the interface behavior between asphalt concrete and granular materials using direct shear tests. However, they used a small size 10 × 10 × 2.5 cm direct shear box with a cut smooth face of asphalt specimens for testing. The results and conclusions could have some limitations due the small sizes of the test box and the smooth face of asphalt specimens while the interface of the asphalt core-transition zone in a dam is rather rough and interlocked [12,13]. The authors have studied the interface behavior of asphalt core-transition zone in embankment dams using a large shear box with overlapping rectangular steel plates for an interlocking interface, and the results will be published in another paper [14].

In most of the ACEDs constructed so far, the asphalt core rests on a concrete plinth (sill), and the plinth is anchored to the rock foundation to serve as a cap for contact and curtain grouting. In cases where there is deep soil overburden, the plinth may rest on a concrete cut-off wall or jet-grouted wall.

The asphalt core width is conventionally in the range of 0.5–1.2 m, and the core width is doubled toward the contact with the plinth on the foundation and against the abutments. The asphalt core-plinth connection (joint) is crucial and must remain watertight when the core and plinth undergo deformations (displacements) during construction and dam operation. For situations with gentle abutment slopes the connection is subjected to compressive and moderate shear strains that are unlikely to cause any leakage [2,12,13]. Kruntcheva et al. [15,16] studied the layer interface behavior for asphalt pavements. However, the design requirements and purposes of the investigations for asphalt core-plinth connection in an embankment dam are quite different as the connection on steep abutments has to be designed to tolerate large shear and tensile deformations without cracking when the dam embankment and foundation settle during dam construction and operation [2,9]. Previous asphalt core-plinth connection model tests to simulate the conditions at the 125 m high Yele Dam, showed that no leakage was detected even if the shear displacement of the connection reached about 20 mm [2]. However, when the dam height is increased to more than 150 m, and the dam is located in a gorge with very steep abutments, special design considerations are required. An example is the 174-m high Quxue Dam with an abutment slope f 1V: 0.33H (72°) [8]. For that dam the connection on the steep abutment towards the top of the dam may be subjected to tensile strains and significant shear displacements. The asphalt core-plinth connection (joint) for the Quxue Dam was therefore subjected to special experimental investigations and evaluations. Fig. 1 shows the Quxue Dam under construction and the connection of the asphalt core on the steep plinth.

The asphalt core-plinth connection has a stiff concrete plinth on one side, sandy asphalt mastic (SAM) in-between, and asphalt concrete on the other side. The SAM normally consists of sand of either crushed aggregates or natural sand, filler (limestone powder) and different grades of bitumen. In some cases, the SAM contains additives to improve the SAM behavior. The surface of the concrete plinth should be dry and clean and is normally sprayed with a special coating in a quantity of 0.2 kg/m^2. The coating is a mixture of bitumen mixed with a small amount of gasoline to facilitate spraying and absorption by the surface of the plinth. After the plinth surface has dried and the gasoline in the coating has been fully volatilized, the SAM is sprayed and then asphalt concrete is placed and compacted. The SAM is the essential connection material to bond the stiff plinth and the flexible asphalt core. This paper presents the results of experimental studies of: (1) the effects of various ratios of bitumen to filler content, various ratios of filler to sand content and various types of additives in the SAM on the tensile behavior of the connection; (2) the effects of different thicknesses of SAM on the tensile behavior of the connection; and (3) different plinth surface shapes by model testing under large shear displacements and

(a) (b)

Fig. 1. (a) The 174-m high Quxue Dam under construction; (b) asphalt core-plinth connection on the dam left abutment with a slope of 1 V: 0.33H (72°).