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Investigation of interface between asphalt core and gravel transition zone in embankment dams

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HIGHLIGHTS

- Shear tests conducted to study the AC-GTZ interface in embankment dams.
- The interface is gradually deformed as it is interlocked during the construction.
- The core surface layer do not deteriorate due to the interface deformations.
- A sliding layer is suggested to be placed between the AC-GTZ interface.

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ABSTRACT

The asphalt core is located between the upstream and downstream transition zones that are simultaneously placed and compacted in the central part of the embankment dam to form a strong interlocking asphalt core–gravel transition zone (AC-GTZ) interface. The asphalt core usually settles a little more than the transition zones during dam construction, and AC-GTZ interface shear displacements develop. Shear tests were conducted in the laboratory to investigate the interface behavior. Test results show that the AC-GTZ interface was gradually deformed up to a shear displacement of 60 mm, but the properties of the asphalt surface layer did not deteriorate. The integrity of the asphalt core would be better maintained if a sliding layer is placed between the core and the transition zone.

1. Introduction

The asphalt core type embankment dam (ACED) has been applied worldwide since the 1960s due to the imperviousness and flexibility of the asphalt core. The flexible asphalt core allows the dam embankment design to use low quality rockfill and the dam to rest on foundations with deep compressive overburden. Some examples of ACEDs are the 85 m high Feistritzbach Dam [1], the 125 m high Storglomvatn Dam [2] and the 125 m high Yele Dam [3]. Near 200 ACEDs have been built, many are under construction and final design, and the dam height for several of them is more than 150 m. Recently Höeg and Wang [4] presented design guidelines for high ACEDs. The 174 m high Quxue Dam in China completed in February 2017 is the highest in the world [5]. The asphalt core for the 153 m high Zarema Dam in Ethiopia was completed in October 2017.

The asphalt core has two types of interfaces in embankment dams. One type is the asphalt core-concrete plinth connection along the core bottom, a category of soft asphalt-stiff concrete interface. The authors [6] conducted a large number of tension tests on asphalt-sandy asphalt mastic (SAM)-concrete connection and asphalt core-concrete plinth shear model tests. The authors determined the best material composition for the SAM that made the asphalt-SAM-concrete connection able to undergo large tensile strains without cracking. The SAM material composition was bitumen to filler to sand to be 20%:35%:45%, and 4% SBS was added to the bitumen. The model test results indicate that a plane plinth, curved-surface plinth and plinth with copper water-stop showed no significant difference in the shear behavior for the asphalt core-concrete plinth joint model.

The other type of core interface is the interface between the asphalt core wall and the upstream and downstream transition zones, i.e., the asphalt core–gravel transition zone (AC-GTZ) interface. Commonly, the transition zone uses natural gravel and sand or crushed rock gravel. This belongs to a category of aggregate-aggregate interface, with gravel with no cohesion on one side

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and the asphalt core with bitumen on the other. Zhang et al. [7] investigated the soil core-sand filter interface behavior using a laminar-ring simple shear apparatus and concluded that the shear strength of the interface was controlled by the weaker of the soil and sand. Kruntcheva et al. [8,9] investigated the asphalt layer interface behavior between pavement layers. It should be noted that the design guidelines and investigation purposes for asphalt pavements are to reinforce the bonding between pavement layers mainly to resist the horizontal loading by the traffic. Tajdini et al. [10] studied the interface behavior between the asphalt core and the gravel transition zone using direct shear tests. However, they used a small size 10 × 10 × 2.5 cm direct shear apparatus with a cut smooth face of the asphalt specimens for testing. The results and conclusions could have some limitations due to the small size of the test apparatus and the smooth face of asphalt specimens. The AC-GTZ interface in dams is rather rough and interlocked [11,12].

The asphalt core used as an impervious water barrier is protected by the adjacent transition zones in embankment dams. The transition zones commonly require using gravel with maximum grain particles of 60 mm and should be well graded. The asphalt core and transition zones are closely interlocked when constructed layer by layer with a compacted layer thickness of 20–25 cm. Fig. 1 shows that the asphalt core and transition zones are compacted by three vibratory rollers after being simultaneously placed by a paver in the field. Asphalt core width at the bottom is conventionally in the range of 0.5–1.5 m, depending on dam height, and the width of the adjacent transition zone on either side of the core is in the range of 1.5–2.0 m. When the dam is raised, the embankment is deforming due to the continuously-increasing load and creep. The asphalt core usually settles a little more than the transition zones as the core deformation modulus is much smaller than that of the transition zones. The magnitude of the AC-GTZ interface shear displacements depend on factors such as asphalt mix, temperature, widths of asphalt core and transition zone, gradation and stiffness of transition materials, shape of asphalt core (vertical or inclined), dam fill materials, foundation conditions and dam height. For a dam height of less than 100 m, there may be relatively small AC-GTZ interface shear displacements as the stiff transition zones hold up the asphalt core by the upward friction force of the transition zones acting on the core wall on either side (i.e. the core “hangs” on the transition zones). Field measurements showed no AC-ATZ interface shear displacements in the 58 m high Dhünn Dam [13], Germany, and 10–30 mm in the 100 m high Storvatn Dam [14], Norway, which has an inclined asphalt core (1V:0.2H). The measured maximum AC-ATZ interface shear displacements in the 104 m high Maopingxi Dam and in the 125 m high Yele Dam, China, were 50 mm and 60 mm, respectively, and the shear displacements took place during dam construction [3].

The AC-GTZ interface shear displacements have not been investigated much in the literature, and there is concern about possible detrimental effects on the asphalt core due to the interface shear displacements. Therefore, the behavior of the AC-GTZ interface shear displacements and its effects on the asphalt core are investigated and evaluated in this paper.

2. Shear test set-up

Fig. 2 shows the schematic for the shear test. The apparatus consists of two main boxes 120 mm wide and 400 mm long. The upper box with a height of 330 mm can move freely in the vertical direction. The lower box holds the asphalt specimen and can move horizontally. Eight stacked rectangular steel frames each with a thickness of 5 mm were placed between the upper box and the lower box to maintain a constant shearing area during shearing. Steel roller pins with a diameter of 1.6 mm were placed between the frames and arranged with a center-to-center distance of 80 mm to reduce the horizontal friction force. The total height of the stacked frames with the pins is 54.4 mm.

3. Shear test results for the transition zone gravel

Before investigating the behavior of the asphalt core–gravel transition zone (AC-GTZ) interface, a shear test was carried out to investigate the shear behavior of the transition zone gravel. Crushed limestone gravel was used for the tests. As the clear width of the model was limited to 120 mm, the maximum grain size of the gravel was selected to be 20 mm. The ratio of the sample size to the maximum grain size in the sample should be no less than 5 [15]. The composition of the transition zone in the model tests for the gravel sizes of 20–10 mm, 10–5 mm and less than 5 mm were 37%, 37% and 26%, respectively.

The gravel was placed and compacted in the boxes by a hammer layer by layer to reach a specified density. A normal (vertical in the test set-up) stress was exerted by a jack on top of the gravel. After keeping the normal stress for at least one hour, the lower box was

Fig. 1. Asphalt core and transition zone on either side of the core are compacted by three vibratory rollers after being simultaneously placed by a paver.

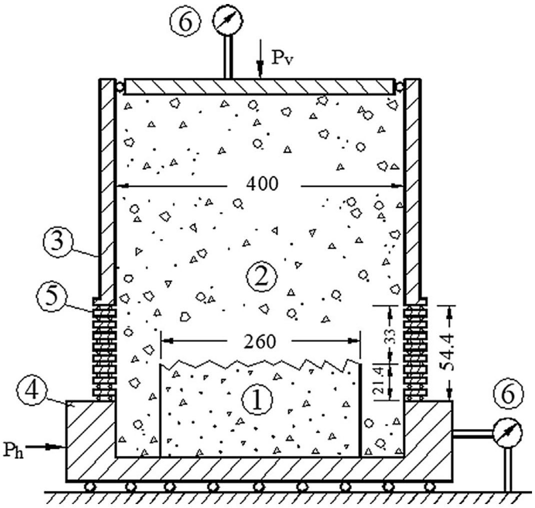

Fig. 2. Schematic (unit: mm) for asphalt core–gravel transition zone (AC-GTZ) interface shear test. 1. asphalt concrete; 2. crushed limestone (<20 mm); 3. upper box; 4. lower box; 5. stacked rectangular steel frames; 6. displacement meter.