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Laboratory method to simulate short-term aging of hot mix asphalt in hydraulic engineering

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HIGHLIGHTS

- Increased durability of an asphalt sealing element by minimizing the short-term aging.
- Optimization of the construction process due to appropriate lab simulations (HMAAT).
- Influences of long material hauling times on the bitumen characteristics.

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ABSTRACT

Asphalt sealing elements for dams have to be watertight and able to absorb strains without suffering from cracking and thus losing their sealing ability. As an effect of the aging process, bitumen becomes stiffer and more brittle accompanied by a deterioration of the asphalt flexibility. Construction sites in hydraulic engineering are in many cases in remoted areas. This leads to extended material hauling times and strong short-term aging effects. This paper presents a newly developed short-term lab-aging procedure (HMAAT – Hot Mix Asphalt Aging Test) to assess the changing of the material characteristics as a consequence of extended material hauling times and related high mix temperatures.

1. Introduction

The desired performance characteristics of asphalt mixtures used for hydraulic engineering (e.g. highly flexible etc.) deteriorate during its service-life by thermal and oxidative processes. The entire process is summarized by the term aging (A_{TOTAL}). The asphalt mix is composed of a mixture of bitumen, filler and aggregates, wherein the aging behavior of bitumen depends for a major part on the deterioration of the performance characteristics during the production process and in-service life. Aging is divided into short-term (A_{STA}) and into long-term (A_{LTA}) aging. The A_{STA} includes the manufacturing process of the mixed material, transportation and the placement. The A_{LTA} describes the aging process while in-service. A_{STA} is triggered by fast oxidation due to high temperatures and a high specific surface contacting oxidant agents during the mixing process, as well as the evaporation of the remaining volatile components from the bitumen [1]. A_{LTA} is driven by slow oxidation especially in the upper pavement layers by atmospheric oxygen and other highly oxidant gases (ROS – reactive oxidative species) available in the field [2–4]. All aging processes are irreversible and cumulative.

1.1. Asphalt sealing elements for dams

Rock fill dams with asphalt sealing elements are divided in two main types, asphalt faced rock fill dams (AFRD) and asphalt-core rock fill dams (ACRD). The material (asphalt concrete - AC) of both sealing types undergoes the same short-term aging influences during the construction but the long-term aging effects while in operation, which are mainly driven by the yield of ROS (e.g. NO_X, O_3, OH-radicals, UV-radiation etc.) depend on the type and related location (on or in the dam body) of the asphalt sealing element (see Fig. 1). Asphalt concrete facings (AF) of permanent impounded reservoirs have reduced long-term aging rates compared to AFs with highly fluctuating reservoir water levels due to the time dur-

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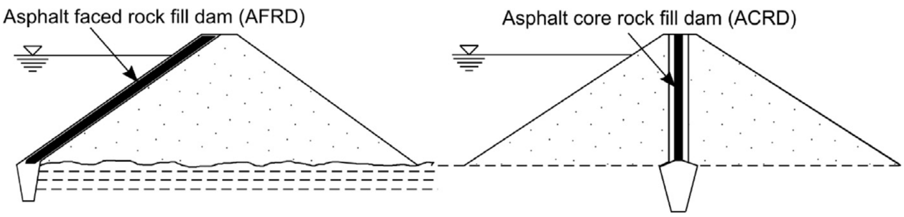

Fig. 1. Types of asphalt sealing elements, left: asphalt facing (AFRD), right: asphalt concrete core (ACRD).

ing water covers the sealing (e.g. amount of ROS in water is lower than in the air, protection against UV-radiation etc.). In addition, mechanical effects (e.g. scratches of drifting gravel-ice mixes etc.) which can have a negative impact on the long-term behavior must be considered in mountainous regions. Asphalt concrete cores (ACRD) have a decelerated long-term aging rate compared to AFs due to the protection of the asphalt concrete core against an oversupply of ROS and other harmful chemical and mechanical influences by the dam fill material.

1.2. Impact of the construction on the aging process

As an effect of the aging process, the bitumen becomes stiffer and more brittle accompanied by a deterioration of the asphalt flexibility. The main aim during the construction process of asphalt concrete facings and asphalt concrete cores is to obtain a highly flexible and water tight sealing element. To achieve the water tightness, the air void content after compaction must be lower than 3% by volume [5]. The temperature-dependent viscosity of the bitumen is a major influencing factor in the compaction process of the hot asphalt. Table 1 depicts minimum temperatures for placing and compaction in hydraulic engineering.

In order to guarantee the required minimum specific compaction temperature, the mixing temperature must be selected according to the cooling of the HMA (Hot Mix Asphalt) during the transportation and placing considering also the maximum allowable temperature of the bitumen brand. The remote construction sites in hydraulic engineering can lead to material manipulation times between 60 and 210 min and can be associated with high mixing temperatures (180–195 °C). Asphalt concrete facings and cores for dams and canals must be able to absorb strains without developing cracks. The aging effects of bitumen are the major factors influencing and changing the asphalt flexibility. With the deterioration of the flexibility behavior, the risk of cracking and leakage under stress increases. Investigations on bitumen samples in various production steps (mixing, transportation and placing) and after longer operation periods have shown that a crucial part of the deterioration of the good performance characteristics of asphalt occurs during the production process [6,7].

1.3. Simulation of short-term aging in the lab

In order to take the mentioned circumstances in Section 1.2 at the time of the suitability tests into account (mix design), it is important to be able to assess the bitumen aging in the lab as precisely as possible. The RTFOT [8] and the pressure aging vessel test [9] are standardized and widely accepted as methods to transfer virgin bitumen into the state of A_{STA} (RTFOT) and A_{LTA} (RTFOT & PAV) [10–13]. Both tests are designed to simulate the aging process of bitumen (asphalt) for road construction under the typical influences. As previously mentioned, construction sites in hydraulic engineering have different asphalt requirements related to A_{STA} due to exposure and the associated material manipulation times. As a consequence of deviating requirements (hot material manipulation time) no satisfactory short-term aging forecasts in hydraulic engineering could be done for extended material manipulation times (>75 min) with the RTFOT for HMA. These circumstances resulted in the development of a necessary and appropriate A_{STA} laboratory test which also considers long material manipulation times and related high mixing temperatures. With the new A_{STA} – HMAAT (Hot Mix Asphalt Aging Test) the change of the bitumen characteristics during the manufacturing process can be simulated depending on the site exposure and associated material manipulation times as well as related temperatures. By applying HMAAT according to the most suitable bitumen types, appropriate site equipment (e.g. type of truck – conventional or thermo isolated etc.) and the maximum transportation time can be determined for each site condition. The HMAA-Test leads to an increased durability and a better long-term behavior of the asphalt sealing elements.

Table 1
Material temperature ranges for placing and compaction in hydraulic engineering [5].

	50/70	70/100	PmB
T_{paver}	150–180 °C	150–180 °C	150–180 °C
$T_{compaction}$	≥120 °C	≥120 °C	*

* Special requirements after suitability tests.

2. Materials and test methods

2.1. Materials

For the presented study, a standard asphalt concrete mix design commonly used in hydraulic engineering with a maximum nominal aggregated size of 11 mm (AC 11) was applied for tests. The coarse aggregates used for the mix consisted of limestone and the filler was powdered limestone (Fig. 2 displays the design grading curve for the investigations). The design grading curve was approximated to the Fuller curve (n = 0.45) in order to achieve a low air void content and to ensure a good compactibility.

The content of the used modified bitumen (PmB) 45/80 – 65 was set to 6.7% by mass. The polymer-modified bitumen consists of bitumen 70/100 with a modification of 4.3 M.% SBS.

2.2. Specimen preparation

The mix (15 kg HMA for each test) was prepared in a laboratory reverse-rotation compulsory mixer, according to EN 12697-35 [14]. The mixing temperature for each test was selected depending on the experimental stage (see Table 3). The hot asphalt mix was transferred directly from the mixer into the test rig (Fig. 3). For bitumen analysis after aging in the HMAAT, bitumen was extracted according to EN 12697-3:2013 [15] with tetrachloroethylene (C_2Cl_4) as a solvent. The solvent-bitumen solution was distilled according to EN 12697-3:2013 [15] to recover the bitumen.