ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ СОФИЯ

Том 50 Volume 2017 Брой 1 Issue

ANNUAL OF THE UNIVERSITY OF ARCHITECTURE, CIVIL ENGINEERING AND GEODESY SOFIA

Получена: 07.11.2015 г.
Приета: 02.02.2017 г.

REHABILITATION AND LONG TIME BEHAVIOUR OF ASPHALT CONCRETE LINED RESERVOIRS AND DAMS

P. Tschernutter[1]

***Keywords**: rehabilitation, asphalt concrete linings, dams*

ABSTRACT

The technology of sealing reservoirs and dams with an upstream asphalt concrete facing is approximately 70 years old and very often used in Europe as well as on other continents. During the last decades the placing method of the impervious material as well as the design philosophy of the lining, the asphalt concrete mixture, etc. for the life time of the sealing important parameters have been adjusted due to the gained experience and the improved placing technology.

The report will focus on several long-term experiences of upstream asphalt concrete linings for reservoirs, channels and dams, the aging phenomena and aging influence, the average life time of asphalt concrete sealing, the amount of long term refurbishment and common technologies and repair methods of local damages or the general rehabilitation and renewing of the sealing blankets.

Important advantages of an upstream asphalt concrete sealing are the flexibility of the whole lining system up to a certain limit and therefore the adaptability to not very stiff foundation conditions, an easy access for checking and assessing the lining condition as well as for local and general rehabilitation work, if necessary.

1. Design Criteria and Elements of the Facing

The characteristics of this method are numerous but they are related to the properties of the structures applied to, namely:

[1] Peter Tschernutter, Prof. Dr. MSc., Department Hydraulic Engineering, Institute of Hydraulic Engineering and Water Resources, Vienna University of Technology, Karlsplatz 13/222 A-1040 Vienna, Austria, e-mail: peter.tschernutter@kw.tuwien.ac.at; phone: +43 1 58801 22230

- Sufficient flexibility in order to conform to deformations or irregularities in the embankments without cracking;
- Sufficient resistance to all loading forces and conditions;
- Good adherence of the facing to the embankment;
- Flow stability on inclined slopes, especially under higher temperatures;
- Resistance against aging due to sun, high and low temperatures, ultra-violet rays, etc.;
- Accessibility for inspection and repair work.

Asphalt concrete materials generally meet all these requirements rather well although some of them are contradictory.

The different types of structures to be faced, the variety of ambient conditions, the different evaluations of the requirements, the variety of bituminous materials available and varying construction techniques have resulted in considerable differences in the features and in the design of alternatives used for asphalt facings.

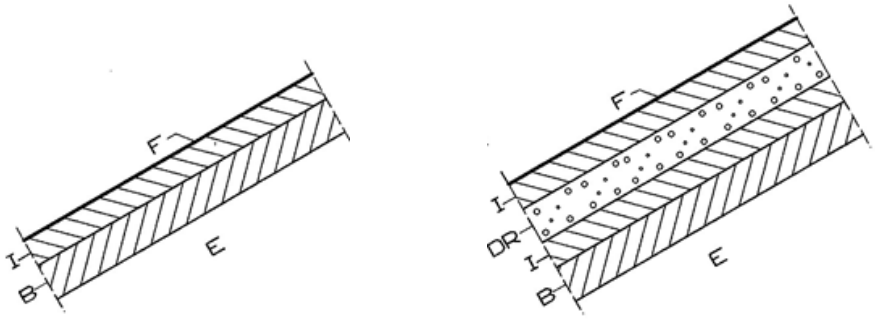
Type 1 – Single impervious lining system:

An asphalt concrete drainage layer and/or a binder course followed by an impervious layer are superimposed on a levelling layer.

Type 2 – Double impervious lining system or sandwich system:

An asphalt concrete drainage layer between two impervious layers is superimposed on an asphalt levelling and/or binder layer. The sandwich system has had a fair number of applications in dams but has seldom been used in reservoirs.

Each layer of the lining system has specific functions and requires different properties.



Type 1
I – Impervious layer
B – Binder layer
DR – Drainage layer

Type 2
F – Finishing layer
E – Embankment

Fig. 1. Basic Systems of Asphalt Concrete Linings

Each layer can be designed differently thick, with different mixtures and properties and the impervious layer can be laid in single or multiple courses.

About 40 years ago only multiple impervious layers with staggered joints of each course were placed. The thickness of a layer was generally among 4 and 5 cm. With the further development of the laying and compacting equipment (spreader with high vibrating screens) the design gradually changed to one single impervious layer with a thickness of at least 6 to 7 cm up to about 10 or 12 cm maximum instead of two thin overlapped layers.

Placing of a single impervious layer has the advantage that normally blistering between multiple dense layers do not occur. In special cases, for example in seismic areas or under high water load, reservoirs and dams are still designed with multiple impervious layers or as type 2 (sandwich) system for reasons of difficult foundation conditions, a better leakage detection and a higher safety standard.

In the early years some dams with very steep slopes were lined with asphalt concrete material and additives (asbestos) but generally the slopes are inclined in a range of 1:1.5 to 1:2. Apart from the overall dam stability, placing and compacting technology, material properties of the asphalt mixture related to the required flexibility and stability limit, the inclination should be at least about 1:1.5.

For the protection of the upper impervious layer against weathering and aging the application or spraying of a finishing layer (sealing coat) is very common. This finishing layer does not have a sealing function and formerly cold applied bitumen emulsions were popular. Nowadays, hot applied bituminous mastics or other special cold applied materials are more common.

The sub-grade below the lining system normally consists of selected and/or processed coarse material with limited oversized grains and fines and stable against erosion (filter criteria for type 1). A firm compaction of the foundation and sub-grade is very important, and the surface should be relatively smooth. The top of the sub-grade was often sprayed with a cationic bitumen emulsion or with a penetration grade bitumen.

2. Refurbishment and Rehabilitation of Asphalt Concrete Facings (ACF)

The sealing and the foundation has to resist loading cycles during emptying and impounding the dam or the reservoir and is in addition also exposed to different weather conditions during hot and cold periods of the year, the influence of sun and ultraviolet radiation, aging, etc. This influence causes during the decades and the lifetime of an upstream asphalt concrete membrane a certain amount of rehabilitation work and refurbishment to guarantee the imperviousness of the lining and a safe operation of the reservoir.

Local Damages and Refurbishment Methods

Local damages in asphalt concrete liners can be easily repaired and are part of the regular maintenance work to improve the sealing and to prolong the lifetime.

- Along the sharp inner edges of concrete cut-off trenches and intake·structures, long-term differential settlements in the substructure, embrittlement of the asphalt concrete material and notch effects can cause cracks in the lining.

Where the damage was severe, a strip about 70 to 100 cm in width should be removed down to the concrete of the cut-off trench, edges of the existing lining must be heated and sprayed with bitumen, and new impervious material placed in layers. In order to improve the transfer of longitudinal forces within the facing, reinforcing mats (Structofors) can be placed.

- Blisters in a multiple layer system, which can locally led to a complete destruction of the upper layer and heavily attacked the lower layer. This phenomenon, believed to result from steam pressure effects between the impervious layers as well as from the freezing and thawing cycles, has in the long run called for repeated repair work, which usually, however, produces no lasting effects. As a local repair measure, the upper layer can be cutted out and

cleaned, edges heated and painted with bitumen/or emulsion, and a new impervious material must be applied. Repairing of blisters by heating and compacting did not yield satisfied results.

- Depressions in the asphalt concrete facing. Such failures coming either from problems in the substructure, i.e. embankment, filter with faulty compaction or grading, etc., or on the other hand defective or porous, or at least permeability in the asphalt sealing upper layer. The seepage can lead to erosions in the underlying levelling course and the filter. Immediate local repair measures by replacing the area of the depression and preparing a solid foundation of the lining becomes necessary.

- Horizontal or near horizontal tension cracks in the impervious layer caused in most cases by a defective bond between the binder course and the dense layer with forces acting on the facings and excessive stresses. Such damage can be repaired by removing the defective part of the facing, carefully cleaning the binder and spraying with bitumen and applying new impervious material. Edges and contacts to the existing layer must be sprayed, heated and welded.

- Sometimes shallow cracks up to 3 to 5 cm were caused by the rollers during placing and final compaction of the impervious layer. These cracks become larger in the course of time, with their edges crumbling away. If such cracks are not too deep and basically the liner is still impervious, no urgent rehabilitation can be decided. Otherwise local repair with different methods are common.

- Cracks extending some meter down from the dam crest. Cracking was accounted by ageing of areas never or rarely flooded as well as by the frequent and rapid temperature fluctuations in winter seasons combined with extremely low temperatures (–20 °C to –30 °C) at high altitudes and a material shrinkage phenomena. Often both the impervious layer and the binder course were entirely severed.

A number of attempts, using a variety of materials, in particular sealing compounds and other substances of comparable deformability, which were placed in grooves several centimetres in thickness milled in the facing, were not successful. In most cases, it was the bond with the asphalt concrete that failed. Another remedial technique consisted in applying two layers of Kemperol across the cracks, which mainly allowed free motion or elongation sections above the cracks. The width of these elongation sections was designed to resist possible temperatures of –35 °C, i.e. 6 to 10 cm.

- Longitudinal cracks along the dam crest reaching widths of several centimetres in places after years and are mainly resulting of the design or difficulties during construction, settlements, low temperatures and local creep phenomena in the asphalt concrete along the line of slope of the embankment. The cracks can be repaired by carving strips some dm wide from the surfacing, placing new material in two layers, bonding it appropiately to the old asphalt concrete and finally cutting the new material at least 8 to 10 cm deep as a contraction joint. The joint must be sealed with a special compound at regular intervals.

- Destroyed bitumen – mastic and protective coatings. Mastic coatings of varying composition, applied for the prevention of early ageing from ultraviolet radiation in areas subject to major water level fluctuations can break up much like elephant's skin within a few years. Such damaged coatings render routine inspection of the facing and make remedial measures difficult.

Complete Rehabilitation of the Impervious Layer

The rehabilitation of an old lining includes basically milling-off the old sealing layer to a certain depth, cleaning the surface with compressed air, spraying of an emulsion and applying a new impervious layer – at least 7 or 8 cm thick.

The application of the new impervious layer requires absolute dryness of the base and a comprehensive site organisation with a mixing plant at or near the site, strict quality control by means of radioactive probes, drilled cores and laboratory testing as well as sampling from the mixing plant to ensure a uniform placing quality.

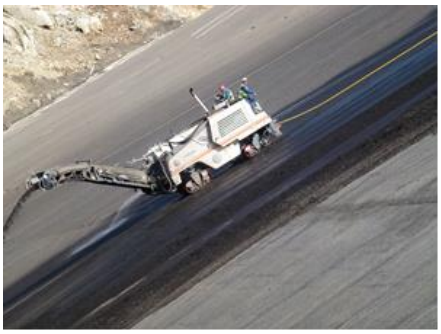


Fig. 2. Vertical milling of the existing ACF

Fig. 3. Horizontal milling of the existing ACF

Fig. 4. Spraying of emulsion on top of the milled surface

Fig. 5. Rehabilitation of an asphalt concrete faced dam, vertical placing

Fig. 6. Horizontal placing of the new asphalt concrete sealing

Fig. 7. Connection between ACF and plinth with copper water stop and bricks

РЕХАБИЛИТАЦИЯ И ДЪЛГОТРАЙНОСТ НА ЯЗОВИРНИ СТЕНИ С АСФАЛТОБЕТОНОВ ЕКРАН

P. Tschernutter[1]

***Ключови думи**: рехабилитация, асфалтобетонов екран, язовирни стени*

РЕЗЮМЕ

Технологията за изграждане на асфалтобетонови екрани е на около 70 години и е често използвана в Европа и на други континенти. През последните десетилетия полагането на водоплътния слой, конструктивното оформяне, рецептурите на асфалтобетоновите смеси и други фактори, имащи отношение към дълготрайността на екраните, бяха преоценени вследствие на натрупания опит и подобрението на технологиите на полагане.

Водоплътният елемент и основата трябва да са устойчиви на циклични товари, свързани със завиряване и източване на язовира, като в допълнение са изложени на различни климатични условия в студената и гореща част на годината, влиянието на ултра-

[1] Peter Tschernutter, Prof. Dr. MSc., Department Hydraulic Engineering, Institute of Hydraulic Engineering and Water Resources, Vienna University of Technology, Karlsplatz 13/222 A-1040 Vienna, Austria, e-mail: peter.tschernutter@kw.tuwien.ac.at; phone: +43 1 58801 22230

виолетовото лъчение, слънчевата радиация, стареенето. Тези въздействия са причина през годините да се извършват ремонтни дейности и обновяване на асфалтовите мембрани за гарантиране на водоплътността на облицовката и сигурната експлоатация на съоръженията.

Важни предимства на водоплътните противофилтрационни елементи по водният откос са гъвкавостта на цялата система и нейната адаптивност към деформируемата основа, лесният достъп за контрол и оценка на състоянието на облицовката, както и достъпът за частичен или пълен ремонт при необходимост.

Докладът се фокусира върху опита от експлоатацията на водоплътни асфалтови екрани за водохранилища, канали и стени, стареенето като явление и неговото значение, средния експлоатационен период на асфалтобетона, количеството рехбилитационни дейности през експлоатационния период, както и някои конвенционални технологии и методи за ремонт на локални повреди или цялостна рехабилитация на водоплътния елемент.