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Geosynthetics in Traffic Infrastructure Construction in Contact with Groundwater and Surface Water – Environmental Aspects

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According to the European Construction Products Regulation, environmental protection represents a fundamental requirement with regard to structures. This also applies to assessing the suitability of geosynthetic products, which are used for transportation routes, e. g. federal waterways, that have contact with soil and water. This report deals with the regulatory situation and tests relating to leaching behaviour and abrasion. The focus is also on averting microplastics.

Geotechnics • Hydraulic engineering • Geosynthetics • Environmental protection • Testing • Standards

1 Introduction

The basic requirement 3 (hygiene, health and environmental protection) must also be reflected in the harmonised construction product standards throughout Europe in accordance with the European Construction Products Regulation (CPR) [1]. No dangerous substances are permitted to escape into the groundwater, maritime waters, surface waters or soil from the completed structure. In future, producers must also indicate in their declarations of performance, whether dangerous substances can possibly be released. In Germany the regulations valid in the appropriate federal state (Bundesland) apply for establishing test parameters or their limit values.

This article first deals with applying geosynthetics to produce transportation routes and the pertinent German regulations. It also examines the situation of standards at European level. Then it goes on to focus more intensely on the horizontal surface leaching test in keeping with CEN/TS 16637-2 [2] for assessing the release of dangerous substances from construction products and the applicability of tests for geosynthetics. In addition, further environmental aspects, especially the avoidance of microplastics in water bodies are dealt with.

2 Application of Geosynthetics in Traffic Infrastruture Construction

2.1 Navigable Waterway Constructions

Normally geosynthetics fulfil the role of "separating" or "filtering" for waterways. "Filtering" is understood to mean that water passes through the geotextile on a permanent basis while at the same time certain soil fractions are held back. Owing to the pore space between the armourstone there is also direct contact with water in this case. **Fig. 1** displays an example of how installation is executed for a "canal" as a navigable waterway. When a ship passes by, a restricted water exchange occurs.

In Germany, in 2015, ca. 380,000 m² of geotextiles were deployed for the 6,300 km of navigable waterways to secure embankments and beds. Generally speaking,

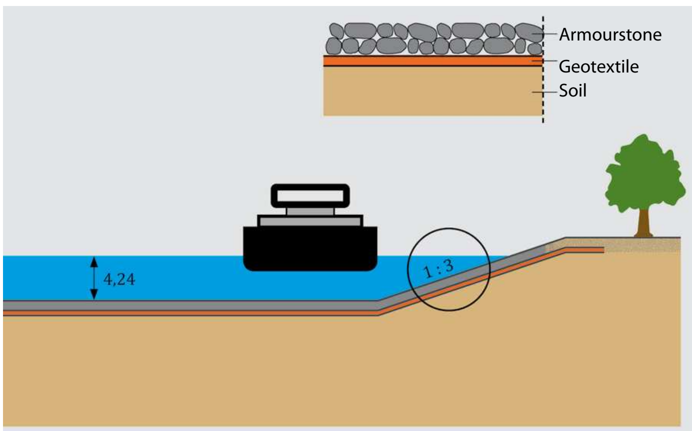

Fig. 1: Geotextile application according to DIN EN 13253 [3] – bank protection on a navigable waterway

Fig. 2: Installing a geotextile on a federal waterway

the geotextiles that were used were needle-punched nonwovens with masses per unit area in excess of 600 g/m². Installation can, as **Fig. 2** makes clear, be carried out by geotextile placement unit on the bed and embankment at the same time. The performance level is regulated by means of the technical delivery conditions for geotextiles and related products for waterways (TLG) [4]. Geotextiles and their connecting material must among other things be rot-resistant and environmentally compatible.

2.2 Road Construction

The entire spectrum of geosynthetics that is commercially available is deployed for road construction. Here too, contact with water in the form of precipitation, groundwater or stratum water exists in practically every application. As a consequence, the German Road and Transportation Research Association (FGSV) Inc. has recommended the examination of the influence of geosynthetics in conjunction with the test values of the Federal Soil Protection Act (BBodSchV) [5] for the soil-groundwater exposure pathway since 2005. As far as evaluating the test values is concerned, the transition area from the unsaturated to the saturated soil zone is accepted as the point of assessment. These boundary conditions are also taken into consideration in the latest edition of the bulletin [6]. With the method to evaluate environmental soundness described in [6], the mass ratio of geosynthetics to groundwater was adapted to the actual conditions at the point of application. Thus, the test values of the BBodSchV can be taken for assessment purposes without having to be modified.

The regulations contained in the bulletin [6] on environmental soundness are also cited in [7] and are in turn, to be observed for earthworks in road building. These regulations were introduced technically with the General Circular ARS-No. 17/2017 by the Department for Road Construction of the Federal Ministry of Transport and Digital Infrastructure for federal trunk roads. In accordance with EU Directive 2015/1535 [8], [7] was registered under EU Notification Number 2017/0132/D.

The specifications contained in ZTV-ING Part 5 § 5 and the related TL/TP KDB and TL/TP SD [9] apply for road tunnels. Accordingly, environmental soundness has to be verified in similar fashion to [6] according to BBodSchV. Furthermore, guidelines are provided governing resistance against leaching for polymeric geosynthetic barriers. In the EAG-EDT [10] it is also recommended not to use DEHP (diethylhexylphthalate), BBP (benzylbutylphthalate) and DBP (dibutylphthalate) as softeners in PVC-P-based geosynthetic barriers.

2.3 Railway Construction

The DB AG produces detailed guidelines for deploying geosynthetics for railway engineering applications. There are regulations for the structural design of earthworks as well as for quality assurance. Regulations for investigating the leaching behaviour of geosynthetics are to be found in the Technical Delivery Conditions [11] of the DB Netz AG. These represent the prerequisites for manufacturer-related product qualifications. Contentually [11] also refers to the recommendations contained in the latest edition of [6].

The specifications in Ril 853 [12] apply to rail tunnels. The Ril 853 refer to the ZTV-ING Part 5 § 5 and the related TL/TP KDB and TL/TP SD [9] for product demands on geosynthetics. This also applies to the specifications included therein on environmental soundness and resistance to leaching.

3 Situation of European Regulation

On account of European Commission (EC) mandate amendments, the Product Committee must integrate the basic requirement 3 (hygiene, health and environment) in the product standards for the European internal market as a further performance characteristic in future. In the case of the Technical Committee (TC) 189 responsible for geosynthetics, a draft for the amendment of the mandate was drawn up. With the publication of the CEN/TS 16637-2 [2] of the CEN/TC 351 "Construction Products – Assessment of release of dangerous substances", the horizontal test method – the "surface leaching test" – was made available to the CEN Technical Committees for the implementation of basic requirement 3. This relates to an index test method to evaluate surface-related release from monolithic, plate-like or sheet-like construction products. Test portions of the geotextile are placed in water and at fixed times samples of the eluate are taken for chemical analysis. The geosynthetic products dealt with by TC 189 are generally plate-like or sheet-like. A further test method available for this issue, the "percolation" test method after CEN/TR 16367-3 [13], is unable to be used practically for such products. Both test methods can essentially be deployed for both steps in the hierarchy (type testing and factory production control for the CE label in keeping with the European harmonised product standards). The CEN/TS 16637-1 [14] describes how the Technical Committees (TC) must determine the appropriate leaching test to ascertain the release of regulated dangerous substances from construction products in soil, surface water and groundwater. In future, the manufacturer can declare the performance characteristic "release of dangerous substances" in his performance declaration. In this way, the concepts of the CEN/TC 351 will also become binding for the product standards dealt with by CEN/TC 189 "Geosynthetics". Guidelines must be drawn up throughout Europe for geosynthetics to implement basic requirement 3. They contain for instance, regulations for taking samples, packaging and the transport of samples. These regulations must not necessarily be implemented by the manufacturer. A manufacturer could provide a declaration of performance with only one essential characteristic. However, there are market segments, in which complete performance declarations with all performance characteristics are required.

So far, only the Netherlands and Germany have presented methods to collate and assess dangerous substances that ensue through leaching from geosynthetics in national guidelines. In Germany, this relates mainly to the trough methods used up till now to produce the eluate according to DIN EN 1744-3 [15] or the batch test according to DIN EN 12457 [16]. They have been replaced by the tank test according to CEN/TS 16637-2 [2] based on the European guidelines that are now applicable. The technical method for releasing dangerous substances, which can be potentially contained in geosynthetics, has thus been specified. The evaluation of the measurement results is the responsibility of the member countries and can be geared to national requirements.

The method to assess the environmental soundness in [6] is for example, also the basis for investigating geosynthetic sheet piles according to DIN 16456-1 [17]. When the bulletin was created in 2005 and its updating [6] as well as DIN 16456-1 [17], the trough method according to DIN EN 1744-3 [15] was regarded as state of the art for the products described there. The DIN 16456-1 [17], however, already contains a reference to CEN/TS 16637-2 [2] and the tank test described therein as a test method for releasing dangerous substances by means of dynamic surface leaching testing.

4 Surface Leaching Test according to CEN/TS 16637-2

4.1 General

The horizontal test method according to CEN/TS 16637-2 [2] is also known as the Dynamic Surface Leaching Test (DSLT) or tank test. The description of the method in the standard lacks any specifications relating to sampling, the number of test pieces or their conditioning.

Akin to the investigations of the durability of geosynthetics in the European harmonised product

Fig. 3: View via computed tomography of a needle-punched nonwoven geotextile

standards, e.g. EN 13253 [3] for the application of geotechnics and geotextile-related products in erosion protection systems (coastal protection, bank revetments), are products within the scope of an initial inspection test, followed by an evaluation test every five years. The test should always be carried out on a test piece representing the family of products.

As it can be presumed that primarily organic substances are released, leaching should be undertaken in a glass vessel. The created eluates should be analysed within the space of a week to establish their constituents. Production of the eight eluates of the surface leaching is carried out within a timeframe of altogether 64 days.

The liquor ratio between geosynthetics and water is no longer mass-related in the tank test according to CEN/TS 16637-2 [2] as was hitherto the case in [6], instead it is determined via the surface area of the geosynthetics. Furthermore, the concentration of released substances according to the tank test, initially determined in mg/l or µg/l, must be converted into mg/m² for evaluating the investigations to provide a surface-related specification of the release of hazardous substances. For this purpose, it is essential to relate the concentration of possible substances to the surface area of the investigated construction product, whose determination methods have so far not been specified.

4.2 Surface Area Determination

According to CEN/TS 16637-2 [2], the geometrical surface area can be calculated for construction products with regular side areas such as polymeric geosynthetic barriers. In order to ascertain the geometrical surface area of very irregular construction products as e.g. armourstone, an aluminium foil method is described. However, it is unsuitable for geosynthetics. As a result, various approaches were examined at the German Federal Waterways Engineering and Research Institute (BAW) and verified in conjunction with the German Federal Institute of Hydrology (BfG). The first studies on this range of topics were accomplished within the scope of a bachelor thesis [18].

Fig. 3 shows a commercial, needle-punched nonwoven geotextile made of staple fibres seen through computed tomography. The individual fibres only touch selectively and form the pore structure, which is relevant for filtering and makes contact with water. As each individual fibre surface area can influence the leaching behaviour, the inner (actual) surface area of the geotextile from the sum of all fibre surface areas is greater than the geometrical surface area comprising the dimensions length, width and thickness.

Owing to the different composition of the geosynthetics, three different approaches or variants come into question depending on the structure of the product:

- **Variant 1 – Products with regular side areas**
  In the case of geosynthetics, which possess simple forms such as polymeric or bitumenous geosyntheic

barriers according to EN 13491 [19], the surface area can be calculated on the basis of the dimensions of the test piece. The geometrical and inner surface areas do not differ.

- **Variant 2 – Products with partially irregular side areas**
  In the case of geosynthetics with a partially irregular open structure, such as geogrids and woven fabrics for instance, the inner surface area can be calculated from the dimensions of the individual components of the test piece.
- **Variant 3 – Products with irregular side areas**
  In the case of geosynthetics with an irregular structure, e.g. geotextiles in the form of mechanically bonded non-woven fabrics according to DIN EN 13253 [3], it is possible to calculate the surface area. The inner surface area can be determined accordingly from the fibre diameter, fibre length and number of fibres per m² for mechanically bonded staple fibre fabrics. For geotextile-related products made of monofilaments, this is also feasible by means of calculation providing the filament diameter and the density of the utilised material are known. In the case of thermally bonded fabrics, it is possible to ascertain the inner surface area non-destructively by means of computed tomography (CT). For other products the non-destructive method can be applied as an alternative to calculations within the scope of market surveillance.

Material studies with CT were for example, described by [20]. In the case of CT, a high number of x-ray images of the sample are created and converted into 3D voxel data (three-dimensional volume elements). In addition to the 3D surface area model, CT also offers an insight into the inner life of the geosyntetic substance (**Fig. 3**). The internal structure can be presented, and fibre diameter or surface area can be determined.

4.3 Calculation Example for mechanically bonded Staple Fibre Fabrics

For the calculation example, a nonwoven geotextile with the following parameters is assumed:

- Fibre diameter d: 25 µm
- Fibre fineness: 7 dtex (7g/10,000 m – fibre length)
- Mass per unit area: 700 g/m²
- Thickness at 2 kPa: 4 mm

The surface area O per 10,000 m fibre length works out at:

$$O = (0.5 \cdot d)^2 \cdot \pi \cdot 2 + d \cdot \pi \cdot l$$
$$= (0.5 \cdot 25 \cdot 10^{-6}\,m)^2 \cdot \pi \cdot 2 + 25 \cdot 10^{-6}\,m \cdot \pi \cdot 10{,}000\,m$$
$$= 0.785398\,m^2$$

A square metre of this geotextile with 700 g/m² mass per unit area has 700 g : 7 g = 100 fibres/m², of which each is 10 km long. This results in an inner surface area per m² of geotextile of:

$$O = 100 \cdot 0.785398\,m^2 = 78.5398\,m^2 = ca.\ 80\,m^2$$

The fabric with a base area of 1 m² with a thickness of 4 mm possesses a geometrical surface area of only 2.02 m². **Fig. 4** indicates the difference between the geometrical and inner surface areas in the calculation example.

As far as geosynthetics are concerned, these are plate-like and sheet-like products, in the case of which a factor in excess of 20 must be applied to ascertain the liquid to surface area ratio (L/A). For a test piece with a basic area of 5 x 5 cm², in the case of the needle-punched geotextile in this example with an inner (actual) surface area of approx. 0.2 m², a leachant volume of around 4 l is needed.

According to CEN/TS 16637-2 [2], a water of quality class 3 in accordance with EN 3696 [21] is to be applied. However, owing to the large inner surface area, only small masses of geosynthetic material eluted in comparatively large volumes of water – in the example, 1.75 g in 4 l. Nonetheless, in order to still be in a position to determine elutable components from the leaching agent without any appreciable blanks, it is advisable to pose increased demands on the water.

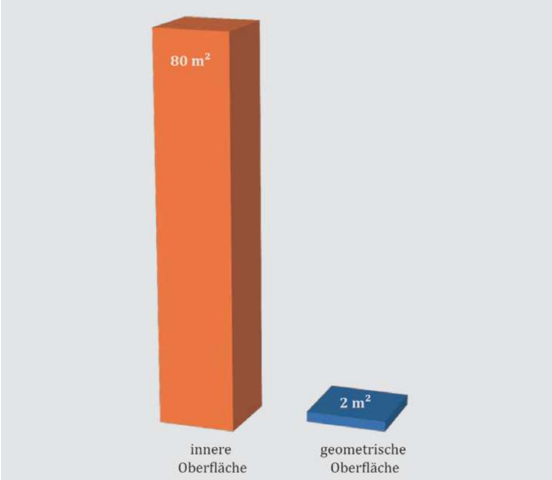

Fig. 4: Inner (otl) and geometrical (otr) surface area of the mechanically bonded staple fibre fabric with 700 g/m² mass per unit area

5 Avoiding Microplastics

Publicly, the topic of "microplastics in the environment" is gaining ever more recognition. Microplastics is generally understood to mean particles less than 5 mm in size. Primary microplastics were for example, produced especially for the cosmetics industry. Secondary microplastics are larger in terms of quantity and are created by the degradation of macroscopic particles, e.g. as a result of chemical reactive ageing processes such as oxidation. The production and the application of plastics

Fig. 5: Drum device for examining the abrasion resistance of geotextiles

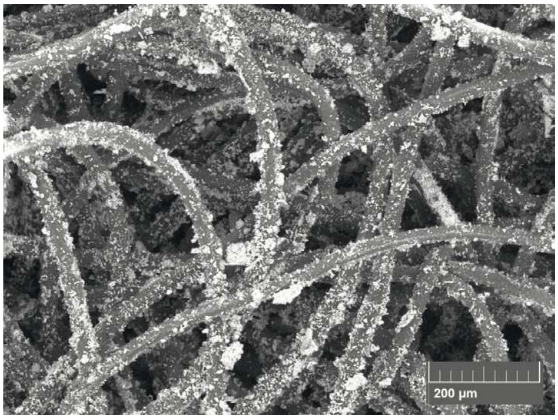

Fig. 6: Abrasion-resistant nonwoven needle-punched geotextile, no damage to the fibres after 80,000 revs in the abrasion drum [24]

Fig. 7: Woven geotextile with damaged fibres after 80,000 revs in the abrasion drum [24]

constantly grew after World War II. When discussed by the general public, there is usually no distinction drawn between microplastics, found in bodies of water as a result of various transportation processes or as waste, and construction products such as geosynthetics, which are deliberately made durable and which show no signs of degradation. Furthermore, it is very frequently overseen that geosynthetics in their applications are generally not subject to direct UV rays and only experience very limited temperature fluctuations. Since the 1960s, there have been applications involving geosynthetics on federal waterways. Degradation due to ageing processes could easily be ascertained through reducing the filtering properties.

In the case of ISO TC 221 "Geosynthetics", a draft standard for a test method was prepared [22]. It is based on a BAW method devised in the 1970s and simulates the wear of geosynthetics in a rotating drum (**Fig. 5**). Here the samples are subject to an abrasive basalt-water mixture at a rotation speed of 16 rpm involving 40,000 revs anti-clockwise and 40,000 clockwise. The direction is changed every 5,000 revs. At the end of the test, the abraded material is to be found in the mixture together with the 4 kg of basalt gravel and 8 l of water. This method is also made use of outside of Germany, e.g. in India and Bangladesh to verify the abrasion resistance of sand bags [23].

Through this test method it is possible to simulate the development of microplastics for samples with low abrasion resistance. **Fig. 6** depicts an example of a commercial nonwoven needle-punched geotextile used for navigable waterway construction, a 6 mm thick, nonwoven needle-punched geotextile with a surface-related mass of 750 g/m², after being subject to abrasion. No damage to the filaments is discernible. **Fig. 7** shows a woven geotextile on the other hand, which normally is not used in hydraulic engineering. Damaged fibres are detected in this case, which are indicative of the formations of microplastics. In actual fact, following the test, plastic particles are also to be found in the abraded material present.

6 Logistics and Conserving Resources

If the filter layer required for waterways can be produced from a geotextile with a mass of less than 1 kg per m^2 filter area, there are firstly logistical advantages vis-à-vis a filter consisting of aggregates. For a two-stage filter made of aggregates with a thickness of 2 dm per layer and a bulk density of 1.45 kg/dm^3, the following volume V and mass m_1 of aggregates result for example, for a filter area of 1 m^2:

- $V = 2 \cdot 2\ dm \cdot 10\ dm \cdot 10\ dm = 400\ dm^3$
- $m_1 = 400\ dm^3 \cdot 1.45\ kg/dm^3 = 580\ kg$

The lesser effort for transportation and installation of a geotextile filter layer also signifies lower fuel costs and conserving resources.

7 Summary and Conclusion

The European Construction Products Regulation (CPR) [1] poses basic requirements for construction works. One of these demands relates to environmental protection. The release of dangerous substances in groundwater, maritime waters, surface waters or soil must be dealt with in the corresponding European harmonised product standard. At European level, a test method was devised, which describes the release scenario of substances stemming from construction products into the ambient medium water via the so-called leaching test according to CEN/TS 16637-2 [2]. The boundary conditions for the surface leaching method must be defined by the Technical Product Committee (TC). For this purpose, this article discusses the application of the test method for geosynthetics and describes various alternatives for establishing the surface area actually affected and in contact with water.

Geosynthetics represent a significant basis for solutions that are technically and economically advantageous for traffic route engineering. Geotextiles can also offer positive solutions under ecological aspects. Appropriate test methods can be used to assess and safeguard their relevant performance capability for instance, with regard to leaching behaviour or the formation of microplastics.

8 References

[1] Regulation (EU) No 305/2011, Construction Products Regulation (CPR): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R0305&from=EN.

[2] PD CEN/TS 16637-2: Construction products. Assessment of release of dangerous substances. Horizontal dynamic surface leaching test. London, BSI: 2014-08-311.

[3] BS EN 13253: Geotextiles and geotextile-related products. Characteristics required for use in erosion control works (coastal protection, bank revetments). London, BSI, 2016-10-31.

[4] BMVI: Technische Lieferbedingungen für Geotextilien und geotextilverwandte Produkte an Wasserstraßen (TLG), Ausgabe 2018, Bundesministerium für Verkehr und digitale Infrastruktur Abteilung Wasserstraßen, Schifffahrt. EU-Notifizierung Nr. 2018/206/D vom 15.05.2018. Berlin, 2018.

[6] FGSV e.V. (Hrsg.): Merkblatt über die Anwendung von Geokunststoffen im Erdbau des Straßenbaus – M Geok E. Köln: FGSV, 2016.

[5] Bundesministerium der Justiz und für Verbraucherschutz: Bundes-Bodenschutz- und Altlastenverordnung (BBodSchV). Ausfertigungsdatum 12.07.1999, zuletzt geändert 27.9.2017.

[7] FGSV e.V. (Hrsg.): Zusätzliche Technische Vertragsbedingungen und Richtlinien für Erdarbeiten im Straßenbau - ZTV E-StB 17. Köln: FGSV, 2017

[8] Directive (EU) 2015/1535 of the European Parliament and of the Council of 9 September 2015 laying down a procedure for the provision of information in the field of technical regulations and of rules on Information Society services (codification)5.

[9] BASt (2017): Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauten ZTV-ING, Teil 5 Tunnelbau, Abschnitt 5 Abdichtung von Straßentunneln mit Kunststoffdichtungsbahnen und zugehörige TL/TP KDB und TL/TP SD. Online: www.bast.de

[10] DGGT (Hrsg.): Empfehlungen zu Dichtungssystemen im Tunnelbau EAG-EDT. 2. Auflage, 2018, Verlag Ernst & Sohn.

[11] DB Netze AG: Geokunststoffe für den Eisenbahnbau. Technische Lieferbedingungen, DBS 918 039. Frankfurt/Main: DB AG, 2015.

[12] DB Netz AG: Module 853.4201 und 853.4202, Ril 853 Eisenbahntunnel planen, bauen und instand halten, 2018.

[13] PD CEN/TS 16637-3: Construction products. Assessment of release of dangerous substances. Horizontal upflow percolation test. London, BSI: 2016-06-30.

[14] PD CEN/TS 16637-1: Construction products. Assessment of release of dangerous substances. Guidance for the determination of leaching tests and additional testing steps. London, BSI: 2018-10-17.

[15] DIN EN 1744-3: Tests for chemical properties of aggregates - Part 3: Preparation of eluates by leaching of aggregates; German version EN 1744-3:2002. Berlin: Beuth, 2002-11.

[16] DIN EN 12457-1: Characterization of waste - Leaching; Compliance test for leaching of granular and sludges - Part 1: One stage batch test at a liquid to solid ration of 2 l/kg with particle size below 4 mm (without or with size reduction); German version EN 12457-1:2002. Berlin, 2003-012.

[17] DIN 16456-1: Plastic sheet piling - Extruded sheet piling of plasticizerfree polyvinylchloride (PVC-U) - Part 1: Product. Berlin: Beuth, 2017-10.

[18] Pineda, A.: Oberflächenbestimmung von im Verkehrswasserbau verwendeten Geokunststoffen für die Beurteilung der Freisetzung von gefährlichen Stoffen in Gewässer, HS Karlsruhe. Karlsruhe, 2018.

[19] BS EN 13491: Geosynthetic barriers. Characteristics required for use in the construction of tunnels and associated underground structures. London, BSI: 2018-03-277

[20] Weiß, R.; Kühn, S.; Schultz, F.: Zerstörungsfreier Blick ins Bauteilinnere – die Computertomographie. In: Dichtungstechnik Jahrbuch 2011, pp. 30-37.

[21] BS EN ISO 3696: Water for analytical laboratory use. Specification and test methods. London, BSI: 1987-12-31.

[22] ISO/DIS 22182:2019-04 - Draft: Geotextiles and geotextile-related products - Determination of abrasion resistance characteristics under wet conditions for hydraulic applications.

[23] Oberhagemann, K.; Stevens, M. A.; Haque, S. M. S.; Faisal, M. A. (2006): Geobags for Riverbank Protection. In: Verheij, H. J.; Hoffmans, G. J. (Hrsg.). Proceedings 3rd International Conference on Scour and Erosion (ISCE-3). 1.-3. November 2006. Amsterdam: CURNET, S. 494-501.

[24] Karlsruher Institute of Technology (KIT): Mikroskopische Aufnahmen von Geokunststoffen. Karlsruhe: 2018.

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