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Asphalt for Use in Liquid Manure, Slurry and Silage Leachate Plants (JGS Plants) and Biogas Plants

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ABSTRACT
When constructing biogas plants and JGS plants, a wide range of legal regulations must be complied with from the point of view of environmental, health and consumer protection. The purpose of this article is to define a technical standard for planning, tendering and production specifically for both types of plants (both areas are summarised below under the term *drive-in silo*).

Keywords: asphalt, biogas, drive-in silo, fermentation substrate, liquid manure, silage leachate plant

USE OF JGS PLANTS (LIQUID MANURE, SLURRY AND SILAGE LEACHATE PLANTS)

JGS plants (liquid manure, slurry and silage leachate plants) (Figure 1) are used to store or fill:

- Farm manure (liquid manure, solid manure, slurry)
- Animal excrements of non-agricultural origin
- Liquids produced during the production or storage of fermented fodder and consisting mainly of water, cell sap, organic acids and micro-organisms, as well as rainwater (silage leachate) or
- Silage or ensiled material, as well as silage leachate (BBV 2024).

Figure 1. JGS plants (liquid manure, slurry and silage leachate plants) (BBV 2024)

Drive-in silos are understood to be the driven floor areas of the storage facilities for the above-mentioned fermentation substrates with exclusively agricultural origin. The dry matter content must be at least 250 g dry matter per *kg* fresh fermentation substrate. The drive-in silos must be covered in an airtight and watertight manner and there must be a drainage of the silage seepage juices (Behle & Louis 2019).

According to § 2 para. 8 of the AwSV, fermentation substrates of agricultural origin are defined as (Behle & Louis 2019):

1. Plant biomasses from basic agricultural production,
2. Plants or plant components produced in agricultural, forestry or horticultural operations or in the context of landscape management, provided they have not been used for other purposes in the meantime,
3. Plant residues from the production of beverages as well as residues from the treatment and processing of agricultural products, such as fruit, grain and potato skimmings, provided no substances hazardous to water are added during treatment and processing and the hazardousness is not increased during treatment and processing,
4. Silage leachate; and
5. Animal excreta such as slurry, liquid manure, solid manure and poultry droppings.

STORAGE AREAS FOR SUBSTRATES WITHIN BIOGAS PLANTS

In biogas plants, plant or animal material is broken down with the help of bacteria in the absence of oxygen (anaerobically), producing biogas. Depending on the material used, the bacteria produce biogas with a methane content of 50 to 75 %. This can be used to generate electricity and heat directly on site in a combined heat and power plant, or it can be upgraded to natural gas quality and fed into the natural gas grid. The fermentation residues produced during decomposition can usually be used as fertiliser in agriculture (Umweltbundesamt 2022):

Figure 2. Storage areas for substrates within biogas plants (Ohe 2011)

LEGAL BASIS

For the construction and operation of biogas plants and fermentation feed silos, the legal requirements of building and water law must always be observed. According to the so-called principle of concern of the Federal Water Act (§ 62, WHG (BMUV 2021)), facilities for storing, filling, producing and treating substances hazardous to water in the commercial sector and in the area of public facilities must be designed, maintained, operated and decommissioned in such a way that there is no reason to fear an adverse change in the properties of water bodies (Ohe & Behle 2012).

Laws, technical rules, standards and regulations for drive-in silos in Germany

1) WHG - Wasserhaushaltsgesetz - Gesetz zur Ordnung des Wasserhaushalts (en. Water Resources Act - Act on the Regulation of Water Resources), BMUV, Deutschland, 2021.

2) DWA-A 792; TRwS 792, Technische Regel wassergefährdender Stoffe (TRwS) - Jauche-, Gülle- und Silagesickersaftanlagen (JGS-Anlagen) (en. Technical Rules for Substances Hazardous to Water (TRwS) - Liquid manure, slurry and silage leachate plants (JGS plants), edition 2018-08.

3) GülleAnlVV MV, Verwaltungsvorschrift gemäß § 4 Abs. 2 der Anlagenverordnung - VAwS; Wasserwirtschaftliche Anforderungen an Anlagen zum Lagern und Abfüllen von Jauche, Gülle, Festmist und Silagesickersäften (Verwaltungsvorschrift JGS-Anlagen - VVJGSA) (en. Administrative regulation pursuant to Article 4 (2) of the Installations Ordinance (VAwS); Water management requirements for installations for the storage and filling of liquid manure, slurry, solid manure and silage leachate (Administrative regulation on JGS installations), edition 1993-10-05.

4) DIN 11622-2, Gärfuttersilos, Güllebehälter, Behälter in Biogasanlagen, Fahrsilos - Teil 2: Gärfuttersilos, Güllebehälter und Behälter in Biogasanlagen aus Beton (en. Fermentation silos, slurry tanks, tanks in biogas plants, drive-in silos - Part 2: Concrete fermentation silos, slurry tanks and tanks in biogas plants), edition 2015-09.

5) DIN 11622-5, Gärfuttersilos, Güllebehälter, Behälter in Biogasanlagen, Fahrsilos - Teil 5: Fahrsilos (en. Fermentation feed silos, slurry tanks, tanks in biogas plants, drive-in silos - Part 5), edition 2015-09.

6) DIN SPEC 91425, Technische Regel, Anforderungen an Leckageerkennungssysteme für allgemein wassergefährdende Stoffe im Bereich der Landwirtschaft (en. Technical Rule, Requirements for Leakage Detection Systems for Substances Generally Hazardous to Water in the Field of Agriculture), edition 2019-12.

TECHNICAL BASICS

The chemical stress on the asphalt pavement depends primarily on the composition of the stored biomass. When preserving feedstuffs in fermentation feed silos such as grass and maize, a fermentation process takes place under exclusion of air. Depending on the dry matter content, considerable amounts of fermentation juice can be released, the composition and concentration of which varies greatly. The relatively low pH value of 3.9 to 4.9 is mainly due to lactic and acetic acid, which are present in concentrations of 10 to 20 g/kg fermentation juice. Table 1 shows possible compositions of fermentation juice (Ohe & Behle 2012).

Table 1. Exemplary composition of fermentation juices (Ohe & Behle 2012)

Substance	Unit	Proportion in fermentation juice
Ash	g/kg	12
Egg white	g/l	16
Sugar	g/kg	3
Calcium	g/kg	1,55
Acetic acid	g/kg	8,6
Propionic acid	g/kg	0,2
Butyric acid	g/kg	0,4
Lactic acid	g/kg	17,2
Ammonia	g/l	0,35
Ethanol	g/kg	3,8
pH value fermentation juice		**3,9**

Table 2 shows the range of pH values present depending on the type of fermented fodder (Ohe & Behle 2012).

Table 2. pH values of fermentation juices of different feeds (Ohe & Behle 2012)

Fermentation feed type	pH value
Meadow grass	4,7
Beet leaf with heads	4,4
Maize green	4,2
Maize milk ripe	3,9

In biogas plants, the starting material for fermentation (digestion and fermentation) is called substrate. This consists mainly of renewable organic raw materials such as maize or grain. Occasionally manure from livestock farming is added to the fermenter for process-related reasons (e.g. solid manure or pig or cattle slurry). In contrast to leachates from fermentation feed silos, no information is given in the literature on their chemical composition.

Based on tests in and extensive chemical resistance tests with bitumen conducted by Shell AG in 1990, the resistance of asphalt mixtures using low-carbonate fillers and aggregates (low calcium carbonate content) is considered to be technically proven (Table 3) (Ohe & Behle 2012).

Table 3. Extract from the list of chemical resistance of bitumen and asphalt (Ohe & Behle 2012)

Substance	Concentration up to %	Temperature until 30 °C	Temperature until 60 °C
Caustic soda	25	+	+
Formic acid	40	+	0
Ammonia water		+	+
Calcium chloride	100	+	+
Acetic acid	25	+	+
Ethylene glycol	100	+	+
Tannic acid	25 / 100	+ / +	+ / nu
Glycol	100	+	+
Liquid manure		+	+
Molasses		+	+
Methyl alcohol	100	+	0
Caustic soda		+	0
Nitric acid	< 10	+	0
Tartaric acid		+	+ to 25 %, > 25 % nu
Citric acid		+	+

Legend: + resistant, 0 not resistant in every case, “nu” not investigated

DESIGN OF THE SUPERSTRUCTURE

For the dimensioning of the overall construction and for determining the thickness of the frost-proof superstructure, the RStO (FGSV 2012) should be consulted. Drive-in silo systems are driven over by heavy vehicles with coarse tyres (e.g. wheel loader, tractor with front loader) both when the biomass is stored and when it is removed. Based on the empirical design method according to the RStO (FGSV 2012), a structure depending on the load seems to be reasonable.

Mix Conception

Resistance to deformation

Driving on the dense wearing course with heavy vehicles with coarse tyres can cause slight impressions. The imprints do not represent a technical disadvantage and the impermeability of the surface course is not impaired (Figures 3, 4). However, the client must be informed of this in advance (Ohe & Behle 2012).

Figure 3. Light marks in the surface layer (Ohe & Behle 2012)

Figure 4. Driving onto a drive-in silo with a tractor (Ohe & Behle 2012)

Execution

Asphalt paving

In order to achieve the target void content of ≤ 4.0 % by volume in the finished asphalt surface course, it is necessary to plan the paving operation in such a way that a degree of compaction of approx. 99 % can be reliably achieved over the entire area. This value is above the usual degree of compaction of 97 % required by ZTV Asphalt-StB (FGSV 2013). For this reason, the asphalt surface course should not be laid if the mix temperature is too low. The asphalt surface course should only be laid when the air temperature is at least +3 °C, there is no precipitation and the base is clean and dry. In order to achieve sufficient load-bearing capacity of the layer package, the layer bond must be produced according to the specifications of the ZTV Asphalt-StB (FGSV 2013). For this purpose, the surface of the asphalt base layer is sprayed with approx. 300 g/m^2 bitumen emulsion C60BP1- S (Ohe & Behle 2012).

When constructing a fodder silo, first the walls are erected, then possibly the collection channel is laid and only then the asphalt or concrete sealing surface is installed (Figure 5).

Afterwards, the fixtures are grouted in the area and at the edges. For this purpose, the joints are often set aside and not cut, which can lead to adhesion problems with the jointing compounds used, especially when asphalt is used. In addition, it often happens that the surfaces executed in rolled asphalt cannot be sufficiently compacted in the edge areas, i.e. at the rising structures of the walls (Figure 6), and thus an excessive void content remains (Müller 2014).

Figure 5. The sealing surface is only inserted at the end (Müller 2014)

Figure 6. This must be done precisely up to the edge and compacted. (Müller 2014)

The layer structure and the requirements of a jointless silo system are shown in detail in Figure 7. According to this, there is the following structure (from bottom to top) (Müller 2014):

Subgrade with $E_{v2} \geq 45$ N/mm^2

Frost protection layer, 30 cm thick, $E_{v2} \geq 120$ N/mm^2

Gravel base course, 20 cm thick, $E_{v2} \geq 150$ N/mm^2

Bituminous base course, asphalt concrete AC 22 T, 10 cm thick, predominantly acid-resistant

Binder course AC 16 B, 4 cm thick, densely designed (acid-resistant)

Mastic asphalt MA 11, 4 cm thick, according to ABZ DEUGUSS© type 2, bitumen 20/300

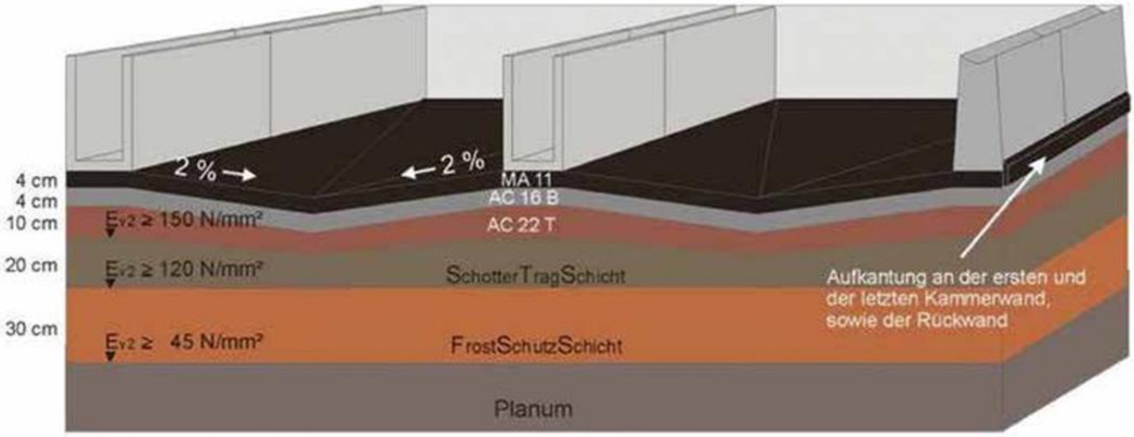

Figure 7. Layer structure and requirements of a jointless drive-in silo system (Müller 2014)

After the walls have been erected, an upstand of mastic asphalt is made on the outer and rear walls, creating a trough that is open on one side and ensures the bidirectional tightness of the drive-in silo system (Figure 7) (Müller 2014).

Table 4 shows examples of the construction of asphalt pavements for drive-in silo systems depending on the stresses (Behle & Louis 2019).

Table 4. Examples for the construction of asphalt pavements for drive-in silos depending on the loads (Behle & Louis 2019)

Layer sequence	Fermentation feed silo systems	Biogas plant storage areas
according to RStO	Table 1, line 1, construction class V	Table 1, line 1, construction class IV
Loading profile	• Driving with tractors • Vehicles with studded tires • Occasional driving	• Driving on with tractors and heavy trucks • Studded tires • Frequent driving
Asphalt surface course	4 cm (sealing layer)	4 cm (sealing layer)
Asphalt base course	10 cm	< 14 cm
unbound base	• EV_2 minimum 100 MN/m² To achieve these EV_2 values, it may be necessary to improve the upper area (15 to 20 cm) of the frost protection layer according to TL SoB-StB, e.g. by means of widely graded construction material mixtures (RC mixtures) or consolidation.	• EV_2 minimum 120 MN/m² To achieve these EV_2 values, it may be necessary to improve the upper area (15 to 20 cm) of the frost blanket in accordance with TL SoB- StB, e.g. by using widely graded construction material mixtures (RC mixtures) or consolidation.
	Frost protection layer (according to the thickness of the frost-proof superstructure) in accordance with ZTV SoB-StB	Frost protection layer (according to the thickness of the frost-proof superstructure) in accordance with ZTV SoB-StB
in-situ subsoil	EV_2 minimum 45 MN/m²	EV_2 minimum 45 MN/m²

The basis for the future requirements for asphalt sealing layers for the construction of driving silo facilities in agriculture is to be the DIBt (DIBt 2014) test programme for sealing systems. The DIBt test programme provides for the following verifications (Müller 2014):

1. Verification of the depth of damage in accordance with the DAfStB guideline "Concrete construction when handling substances hazardous to water" For this purpose, a test

medium consisting of 95 % water + 3 % lactic acid + 1.5 % acetic acid + 0.5 % propionic acid is used and the asphalt sample is exposed to it for 90 days.

2. Proof of trafficability after exposure to the medium. This is provided when a sample plate passes three test cycles with 3,600 passes in the rutting test after 1008 hours of media exposure.

3. Proof of the resistance of the joint sealants. For joint sealants for use in JGS systems, the DIBt has set up a separate test programme that must be passed in order to obtain the corresponding general building authority approval. However, it is prescribed to take into account the interaction of the joint sealant with the asphalt for the tightness in areas of movement joints and transitions to other sealing constructions (circulation) already during planning.

4. Proof of load-bearing capacity and serviceability. This includes the presentation of the interaction of the sealing layer and the associated sub-base (asphalt binder/asphalt base layer and the frost protection layer). The verifications may be carried out, for example, according to or based on RStO 12 (FGSV 2012). In addition, the evaluation of the interaction of the sealing layer and the base layer must be documented (Müller 2014).

Product "DAsphalt® Silo"

The German Institute for Building Technology / "Das Deutsche Institut für Bautechnik" (DIBt 2014) has approved the product "DAsphalt® Silo" developed by TPA GmbH, the STRABAG competence centre for building materials technology: It is used for sealing layers of rolled asphalt in storage and filling facilities of liquid manure, slurry and silage leachate plants (JGS plants) as well as biogas plants (FGSV 2015). The sealing layer is impermeable to liquids and resistant to liquid manure, slurry and silage seepage juices as well as fermentation substrates and fermentation residues. DAsphalt® Silo can be used, among other things, in mobile silo systems or solid manure slabs as part of a load-bearing surface pavement (Figure 4) (FGSV 2015).

Figure 8. Installation of rolled asphalt in a drive-in silo plant (FGSV 2015)

The rolled asphalt sealing layer consists of a low void asphalt concrete for asphalt wearing courses optimised for this application. The basis for DAsphalt® Silo is the nationally uniform Ordinance on Installations for Handling Substances Hazardous to Water (AwSV) (Bundesgesetzblatt 2017) as well as the Technical Rule on Substances Hazardous to Water (TRwS) 792 (DWA 2018). The TRwS regulates the requirements for the production and maintenance of sealing surfaces in JGS and biogas plants. Products approved by the building authorities must be used for this purpose (Müller 2014).

Figure 5 shows another example of the installation of rolled asphalt in drive-in silo systems (GS 2024).

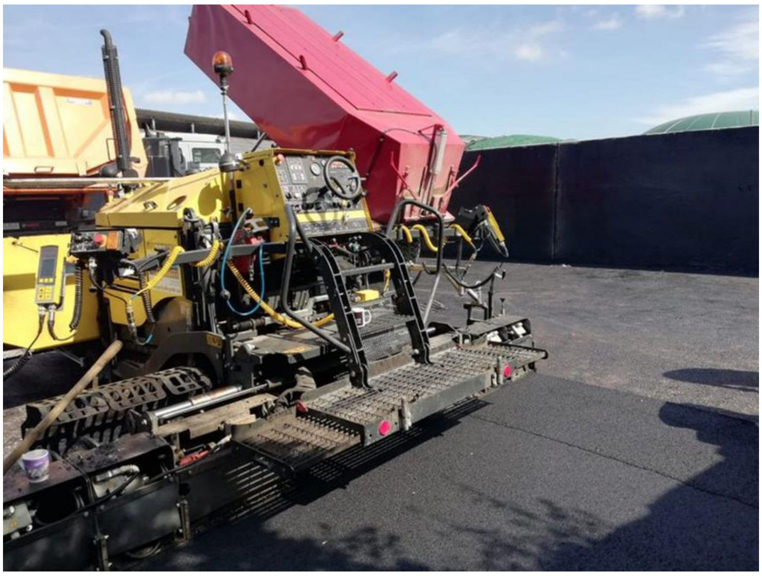

Figure 9. Paving of rolled asphalt in a drive-in silo plant (GS 2024)

Making Seams and Joints

Particular attention should be paid to the production of the seams between the pavement layers and in the area of day closures. In the opinion of the authors, this should be done in accordance with the withdrawn Code of Practice M SNAR (FGSV 1998), since experience has shown that the new asphalt pavement is placed against the previous pavement which has already cooled down (< +80 °C). The seam flanks are to be sprayed with a bituminous binder over the entire surface using suitable seam adhesives, e.g. polymer-modified bitumen. The seams of the asphalt wearing course should be offset by 30 to 50 cm relative to the seams of the asphalt base course (Figure 6).

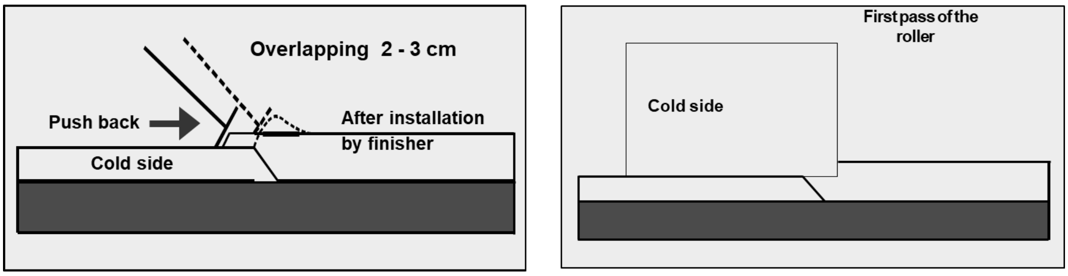

Figure 10. Making and compacting the asphalt seam (Ohe & Behle 2012)

For the construction of fixtures, joints must be made in accordance with ZTV Fug-StB (FGSV 2015) (Figure 7). After the asphalt surface course has been paved, a joint gap of the total thickness of the asphalt surface course and a maximum width of 15 mm must be cut in. The joint edges are prepared for the application of the hot-melt joint sealant by using a primer adapted to the joint sealant. For this purpose, the joint flank must be absolutely dry and dust-free. The suitability of the primer for different component flanks must be taken into account. Before applying the joint compound, an underfiller must be placed in the lower area of the joint gap to prevent three-sided adhesion. When applying the joint compound, the ZTV Fug-StB (FGSV 2015) must be observed. Analogous to the requirements for the construction materials of the asphalt layers, the joint compound to be used must also be selected to be acid-resistant (Figure 7) (Behle & Louis 2019).

In the case of vertical retaining walls, roller compaction of the asphalt layers cannot be carried out directly up to the rising retaining wall. The experience of the past years has shown that problems with leaks due to compaction deficits existed in the edge areas of individual construction projects. In order to provide the basic structural conditions for compaction in line with the requirements also in the edge area, it is recommended to construct the silo wall by means of an angle profile (monolithic or prefabricated). In this case, both asphalt layers are connected to the horizontal component base. A joint is formed between the rolled asphalt surface course and the concrete component (see Figure 7). The base of the component and the subsequent asphalt surface course must be designed with sufficient transverse slope (Ohe & Behle 2012).

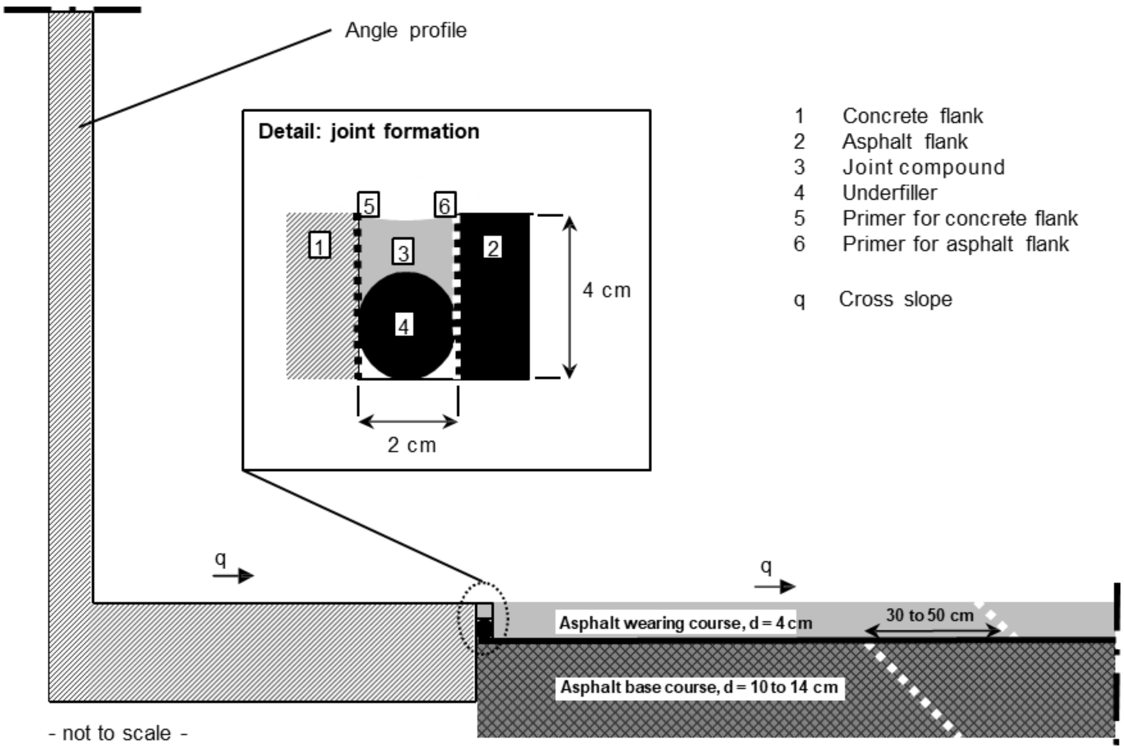

Figure 11. Joint formation for vertical partition walls (Ohe & Behle 2012) (edited by author)

If the use of angle sections is not possible for soil mechanical reasons, a circumferential mastic asphalt strip about 20 cm wide must be placed in front of the silo wall. Joints must be formed between the rising concrete part and the mastic asphalt strip as well as between the mastic asphalt strip and the rolled asphalt surface layer (Ohe & Behle 2012).

In the case of inclined partition walls (e.g. "Traunsteiner" construction method (Alfons Greten Betonwerk GmbH & Co. KG 2007)), it is possible to install the asphalt pavement right up to the rising structural element and to arrange the joint in front of the inclined wall. Due to the inclined walls and the resulting working space, the compaction of the rolled asphalt surface course can be carried out with the rollers directly in front of the concrete elements (Figure 8) (Ohe & Behle 2012).

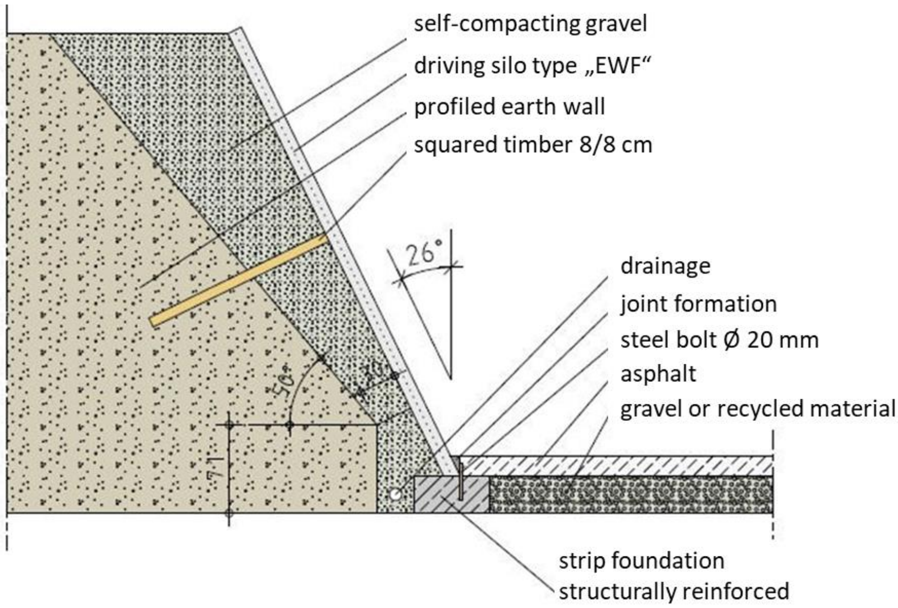

Figure 12. Joint formation with "Traunsteiner" construction method (Ohe & Behle 2012) (edited by author)

Figure 13. A drive-in silo in Upper Austria (Hrapović 2022)

CONCLUSION

Environmental protection plays an important role in an increasing number of construction projects and must therefore be strictly observed. In Germany, the Water Resources Act (WHG) (BMUV 2021) has been in force since 1957, and in Austria the Water Rights Act (WRG) (BMUV 2021) since 1959. Both laws stipulate that no substances hazardous to water may enter drinking water. Section 62 of the WHG (BMUV 2021) requires, among other things: "For installations for the transfer of substances hazardous to water as well as for the storage and filling of liquid manure, slurry and silage leachate as well as of comparable substances arising in agriculture, sentence 1 (of Section 62) applies accordingly, with the proviso that the best possible protection of water bodies against adverse changes in their properties is achieved". Anyone who violates these legal requirements is personally liable (Section 89 WHG) and can be prosecuted under private law.

In practice, the requirements of the WHG (BMUV 2021) mean that all areas where media hazardous to water are produced, stored or processed must be permanently sealed with suitable building materials and products. In agriculture, this particularly affects biogas plants and facilities where liquid manure, slurry and silage leachate (JGS plants) may be produced.

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