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Details for timber bridges with asphalt wearing surfaces

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Abstract

Timber bridges for road traffic are built out with an asphalt wearing surface on the timber deck so vehicles can cross with high velocity (>50 km/h). The application of the asphalt layer on the majority of the surface is usually unproblematic, but is challenging along the edges. Engineers and practitioners often find themselves using their own creativity as constraints, geometry, and design of new timber bridges does not allow a direct copy of details of existing bridges. This paper presents base details along with recommendations listed by experienced timber bridge designers and experts from the field of detailing of concrete bridges. Furthermore, the advantages and disadvantages of existing details are discussed, and new details are presented. This forms a basis for new bridge designs, as the details from a basis for economic and robust construction of timber bridges and, hence, increases their longevity.

1 Introduction

The construction of road layup and especially that of the watertight layer can be produced in a high quality. It is generally unproblematic on majority of the bridge's wearing surface. However, experience won during inspection and repair of existing timber bridges shows that the expansion joints, side edges along curbs and details around drains are often weak and prone to damage. Leakages are often difficult to detect and can lead to uncontrolled water ingression. Until now, secure standard solutions have not been documented, yet. Although many bridges have been built already, engineers design new solutions, or variations to existing ones every time they design a new bridge. Secured standard details would substantially simplify the design process and improve the quality every time a new bridge is designed.

This objective was pursued in the research project VSS2016/326 [1]. During several meetings and workshops (Figure 1), experienced timber bridge designers gathered, discussed, and documented details that were based on their experience with design of different bridges. In the discussions, the specific requirements to details around expansion joints, curbs, and drains were agreed on. These are listed and detailed in this paper, along with the corresponding sketches and form a basis for future traffic bridge designs.

Figure 1: Workshop on detailing of timber bridges with engineers visiting the Obermatt bridge, Canton of Bern, Switzerland

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2 Designs found in literature

2.1 Detailing in timber bridge design

Details for timber bridges have been documented and published already. They show details and simultaneously show an overview of the state of the art. Traditionally, there are differences between countries. In Scandinavia and Switzerland, details are often published on a high level in which only principles of designs are shown, and leave room for own interpretation by the designing engineer. On the other hand, in Germany for instance, detailed designs and solutions are offered that leave little room for alternatives or variation.

Differences between countries are also found in the layup of bridge decks. In Switzerland and in Scandinavian countries, the asphalt wearing surface is applied directly on the load bearing bridge deck. This can be a stress laminated deck (SLT), cross laminated deck (CLT) or a laminated veneer lumber deck (LVL). This timber deck is relatively thick, order of magnitude of 160 mm to 600 mm, compared to the asphalt layer. Hence, the bridge deck provides a dual function: that of load bearing structure and support of the watertight wearing surface like asphalt. In Germany, the asphalt wearing surface is applied on a separate timber panel which is thin, in the order of a couple of cm. This LVL or laminated wood panel is separated from the load bearing timber deck by timber battens, thus creating a control and ventilation layer between road structure and timber structure [2][3]. In other words, two timber decks are built, a first one which supports the wearing surface and the second, which supports the first deck and has a load-bearing function.

In literature, the following details for timber bridges with asphalt wearing surfaces are found:

- Two details for side edges are found [4] from Scandinavia where the water proof polymer bitumen membrane (PBM) is used between the SLT deck and the asphalt wearing surface. This PBM is led upwards from the timber deck along the curb, thus, consisting a corner where water cannot be drained once the wearing surface leaks. Two other details are also shown where the PBM remains straight on the timber deck until the bridge deck's edge. In the latter, water on the wearing surface can flow off the sides of the bridge. In Scandinavia, SLT decks are commonly used in timber road bridges.
- Milbrandt and Shellenberg [5] (Germany) published several details for expansion joints and side edges. The side edge details without curbs consist of steel profiles. Details with curbs, in hardwoods, are suggested, too. In all the details, the PBM is consistently continued horizontally towards the edge of the bridge's timber deck. Along curbs or steel profiles used along the side edges, an extra layer of PBM is added and melted on the first, and subsequently led upwards over the edge of the curb. In all details a fugue grouting is drawn, too. On details of expansion joints, sufficient room to optimally stimulate air circulation is suggested.
- In the sketches published by Harrer engineers from Karlsruhe [2], the timber panel and load bearing bridge deck is separated by an air ventilation layer. Details for open connections and closed expansion joints are very detailed. In the steel profiles at all edges, drainage holes are drilled along the fugue grouting. This allows water to flow away, thus, preventing it from flowing onto the timber deck. Along the edges, drains along curbs are suggested, too.
- In the Holzbau Handbuch [3], details from the Protimb project [6] and Harrer engineers [2] are published. The handbook offers an overview of the state of the art for german bridge design practices. It even introduces one detail in which a drag plate is used to create a closed expansion joint.

2.2 Detailing in concrete bridges

Lehmann and Bernard [7] (Switzerland) published details for curbs in concrete bridges in 'Forschungspaket Brückenabdichtungen: EP6 Anschlüsse von Brückenabdichtungen'. In these details, a combination of use of PBM and liquid plastics like Polymethylmethacrylate (PMMA) is suggested. Contrary to what is often seen in details for timber bridges, PBM is led upwards from the bridge deck along the curb. The PBM layer on the side of the curb is fixed mechanically to the curb using steel strips. This detail, where transition from bridge deck to curb needs to be made, liquid plastics are also often used.

3 Creation of new details for timber bridges

3.1 General structure

Most of the details from German literature cannot be used directly, as these contain the principle that the road deck and the supporting timber load bearing deck structure are separated. As mentioned in the introduction already, these are traditionally combined in one single deck structure in Switzerland (and Sweden). The type of details are structured according to the following list.:

1. Expansion joint (abutment)
    a. Open
    b. Closed
2. Side-edges
    a. With curb
    b. Without curb, usually just a steel profile
    c. With guiding rail
3. Other drains
    a. In the asphalt surface
    b. At the edge

Although the focus lies on road bridges, the details can of course also be used for pedestrian and cyclist bridges, on which lighter traffic loads need to be born. This structure presented above is used in the following chapters to present the types of developed details.

3.2 Purpose and goals of the definition of details

In the following sketches are those of base details that can be used for new designs. When a dimension is not given, it means it can be adjusted to the requirements set by the bridge and its structure: traffic loads and frequency, specific constraints of the project, geometry, etc., and can be adjusted accordingly.

The timber bridge deck, the watertight membrane, and the asphalt wearing surface are sketched in a setup that can be used both for connected layup and the unconnected layup, such as given in the VSS 40 451 [8]. The listed details can be made under large constraints and set by time and costs found on the building site.

The details suggest robust solutions. It is, however, still necessary that bridge owners perform regular maintenance and inspect the structure regularly.

A drainage concept that prescribes the amount of needed drains, can be made, such as proposed by the ASTRA guideline 12004 [9]. In case of rainfall, sufficient drainage capacity over the bridge's surface has been planned.

3.3 Methodology

As mentioned in the introduction, the details were created in a combination of several meetings and workshops where engineers gathered, worked together, discussed and documented details, based on their experience with design of different bridges. During the discussions, the specific requirements, advantage, and disadvantages to details around abutments, curbs, and drains were agreed on.

4 Details for expansion joints

4.1 General

Experience shows that of all elements of the timber bridge, expansion joints require most maintenance and repair of the bridge. These need to be designed and built with utmost care to mitigate risk of water entry on the timber deck. The expansion joints are highly loaded by traffic which cause impact loads. These need to fulfill the following requirements according to the ASTRA guideline 12004 [9]:

- load bearing strength
- fatigue resistance
- functionality (deformation and elasticity)
- robustness for all traffic types, no matter what the weather conditions are
- traffic safety
- low noise emission
- good premises for inspection and repair.

The following recommendations are listed:

- The road and bridge-structure around the expansion joint should have a similar vertical stiffness. This prevents large relative deformations between the two systems every time a vehicle crosses.

- The maximum vertical deformations recommended by ASTRA guideline 12004 are to be maintained. A low vertical deformation reduces wearing of the asphalt layer and increases the longevity of details.
- Timber decks that are not stiff enough can be reinforced with steel beams around the expansion joints. These need to be connected in such a way that they do not lead to fatigue failure of any elements either. This can subsequently cause to leakage of water onto the timber deck.
- Apart from large relative deformations in the expansion joint, weak transitions lead to rotations in timber deck, supporting steel beams, and fugue grouting. These can eventually lead to leakages.
- The asphalt types, layer thicknesses and layup used on the bridge and road should be similar, at least for one meter around the expansion joint. For instance, thickness of the mastic asphalt on both sides of the expansion joint should equal. It can even be increased locally, like done around expansion joints of concrete bridges, where the thickness is increased from 80 mm to for instance 120 mm in the first meter next to the expansion joint.
- The inclination of the road on abutment and bridge around the expansion joint should be equal. A vehicle crossing a bridge will thus not create additional (vertical) impact loads which can damage the bridge deck on the long run.
- The connection of PBM to the steel edge-profiles can additionally be sealed with PMMA.
- Water leaking into the fugue grouting close to the edges around the expansion joints, should be drained using tubes and Omega-type profiles (ETADRAIN). In case of leakage, water can be led to a drain through the timber deck.
- In the vicinity of the expansion joint, both on the abutment and bridge structure, ventilation must be encouraged. This improves the drying capacity of the timber elements. In addition, the end grains of the timber elements can be covered by any watertight material.

4.2 Closed expansion joints

- Closed expansion joints are generally to be carried out using a ‘trough filling', see Figure 2.
- Trough fillings are suited to obtain silent expansion joints in busy bridges or in bridges located in residential areas
- When using trough fillings, substantial braking or other horizontal loads are generated too an need to be led into the bridge or abutment.
- Although trough fillings can be used to overcome relative displacements between bridge and abutment (up to 1.5 mm vertically and 5 mm horizontally), it is still recommended to create a stiff structure around the expansion joint.
- Alternatively, closed expansion joints can also be made using solutions like the elastomeric sealing profiles, Figure 3, that allow movement up to 100 mm (manufacturer mageba "Tensa-Grip" or similar)
- Elastomeric sealing profiles like the "Tensa Grip" can be used to create the expansion joints, but must be connected/welded to steel beams that are fixed to the bridge structure.
- Expansion joints using drag plates are not recommended over traffic speeds of 50 km/h as they can produce too much noise pollution.

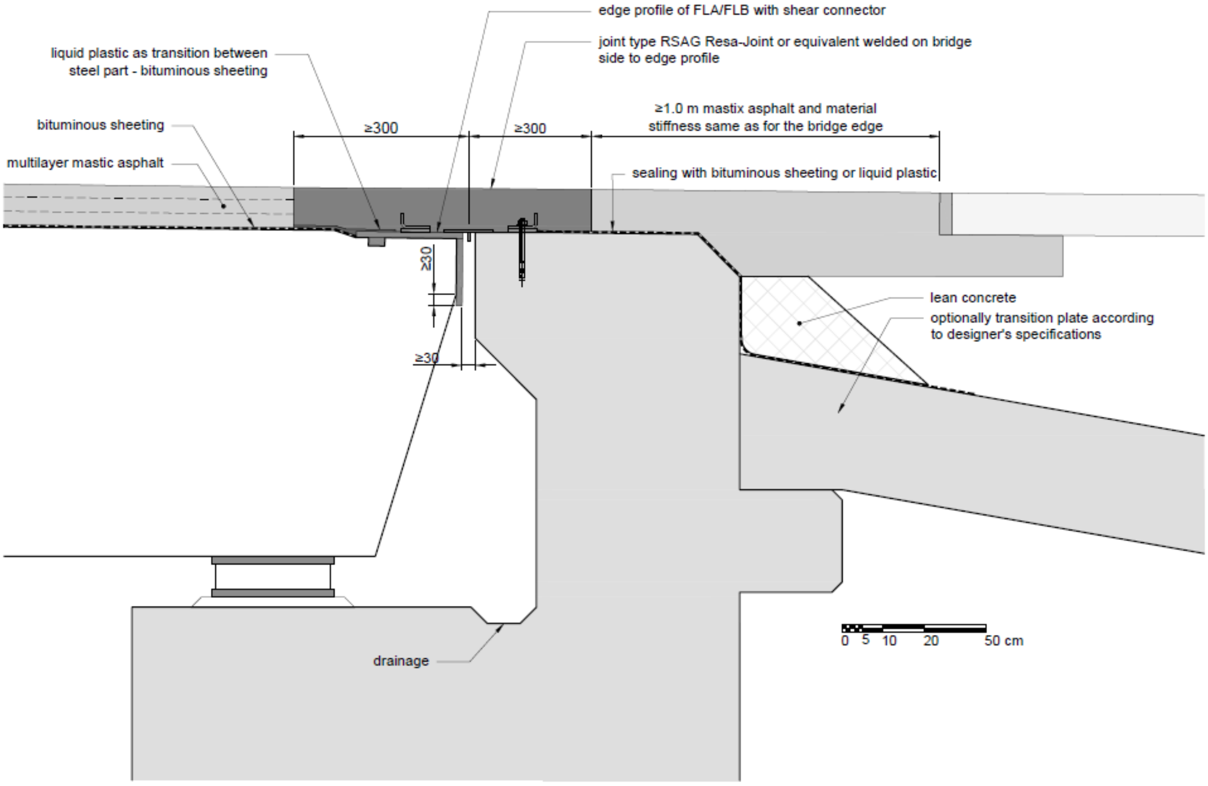

Figure 2: Closed expansion joint created with a trough filling

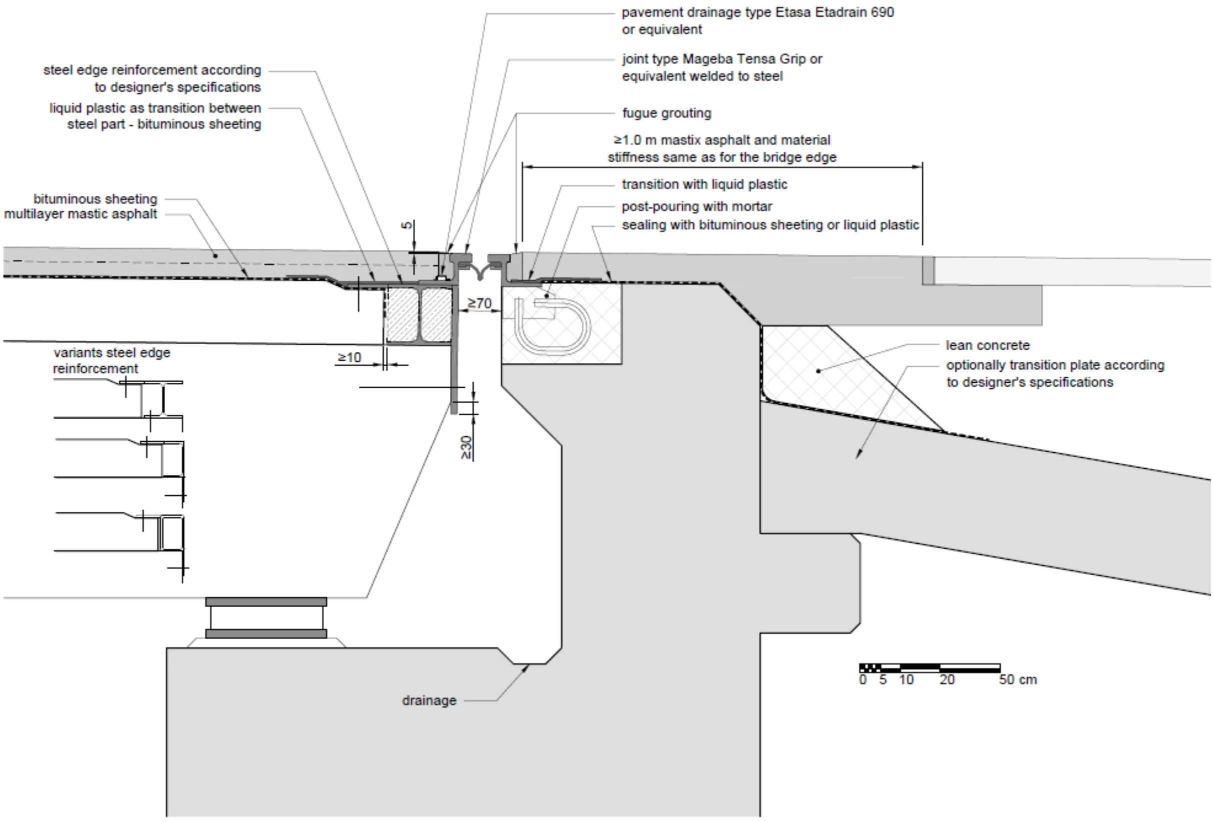

Figure 3: Closed expansion joint created with a elastomeric sealing profiles

4.3 Open expansion joints

- Open expansion joints, like seen in Figure 4, are to be used in exceptional cases. This is due to the low constructional protection of wood: water can, in principle get close to the timber structure. Any dirt, twigs, leaves, or gravel that gets stuck between bridge and abutment can prevent drainage of the joint.
- Open joints can however be used in pedestrian and cyclist bridges, or in bridges with a very low frequency of traffic.
- The open expansion joints lead to large noise pollution at traffic speeds above 50 km/h.
- Open expansion joints should offer sufficient possibility to drain water, clean, inspect, etc.
- Elements with dripping edges can be used to lead water away from the end grain of timber elements
- A sufficiently large space in the abutment encourages the air circulation, improves the drying capacity, and facilitates inspection. The condition of the expansion joint can be better monitored, too
- Optimal drainage of water below the expansion joint should be facilitated during a planning phase
- Open expansion joints are generally not wider than 20 mm
- Edges of steel beams or profiles should be to be located about 5 mm to 10 mm lower than the asphalt wearing surface to prevent damage caused by impact of snow ploughs.

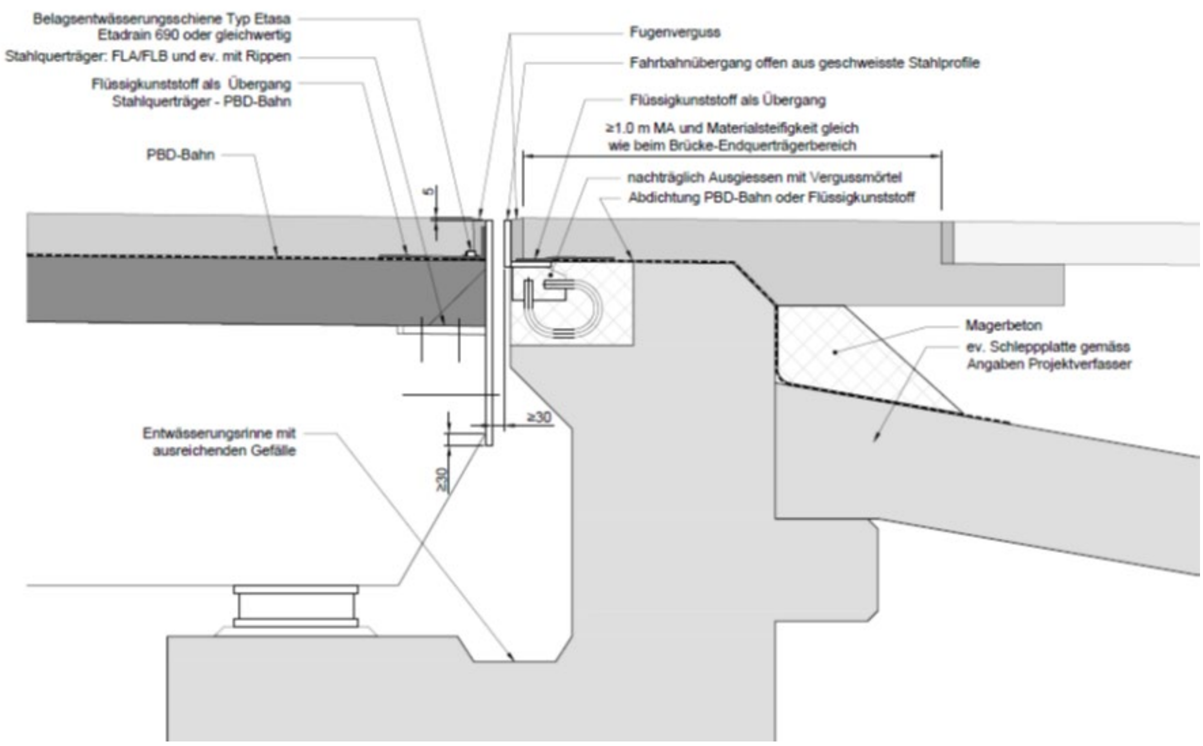

Figure 4: Open transition joint for pedestrian bridges or low frequent traffic

5 Details for side edges and curbs

5.1 General

The auxiliary drain in the fugue grouting along the edge profiles is best made using drainage pipes of Ø15 mm, located on the bridge deck, or like the so-called Omega profiles (e.g. ETADRAIN). both can be used to lead water away to drainage holes.

Bending or folding the PBM in corners is to be avoided it should not be led upward along the side edges. It can be melted on a steel profile, and an additional watertight sealing is best made using PMMA. Sharp edges and corners in the watertight membrane should be avoided as these tend to be weak in timber bridges, and subsequently, PBM or PMMA membrane can tear due to material fatigue.

5.2 Side-edges without curbs

- It is recommended to use a guide rails or timber lattice (sacrificial element) on the edges to prevent that snow ploughs, or any other vehicle or object, to damage edges or exposed watertight membranes.
- The edge between asphalt and edge profile can additionally be protected using a plastic profile ‘Kitt-teil’ that additionally protects the fugue grouting and increases longevity of the detail.
- When using steel edge profiles, a dilatation joint of about 8 mm should be made every six meters. This allows thermal strains to develop. These steel elements should be made using standard profiles. Welded profiles can bend/deform during a hot dipped galvanization process. Welding stresses are released.
- Along the edges of the timber deck, the watertight PBM membrane should be connected to the steel profile and additionally be sealed using PMMA. Application of PMMA on hot dipped galvanized steel profiles is unproblematic. On painted profiles however, application of PMMA has proven to be problematic.

5.3 Side edges with curbs

- It is recommended to make curbs using either pre-cast or cast in place concrete.
- Timber curbs can be made too, but it is recommended to leave an air gap to asphalt wearing surface. Water from the wearing surface can flow underneath the curb. Similar detailing as on edges with steel profiles should be made in those cases. Larger curbs may be required.
- The waterproofing membrane should be continued under the curbs too, so that standing water is avoided in case of leakage
- In case of impact, the shear displacement of the curb should best be prevented using heel-type connections to the timber deck. Horizontal shear loads are not easily transferred using screws or other mechanical fasteners. In addition, screws and mechanical fasteners would penetrate the watertight membrane and potential leakages cannot be detected as the details are inaccessible. They cannot be opened easily during an inspection.

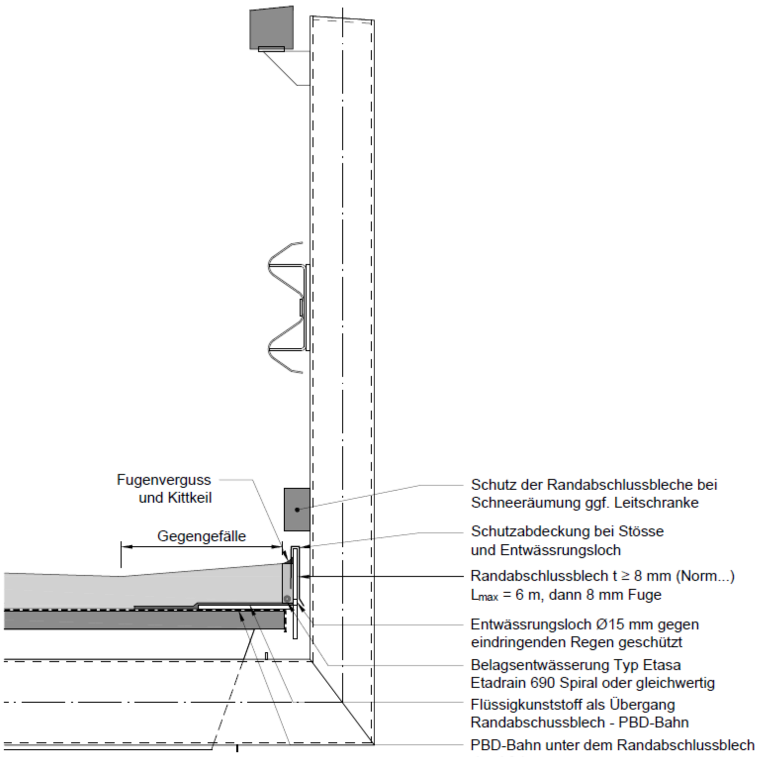

Figure 5: edge detail without curb, primarily with steel edge profile

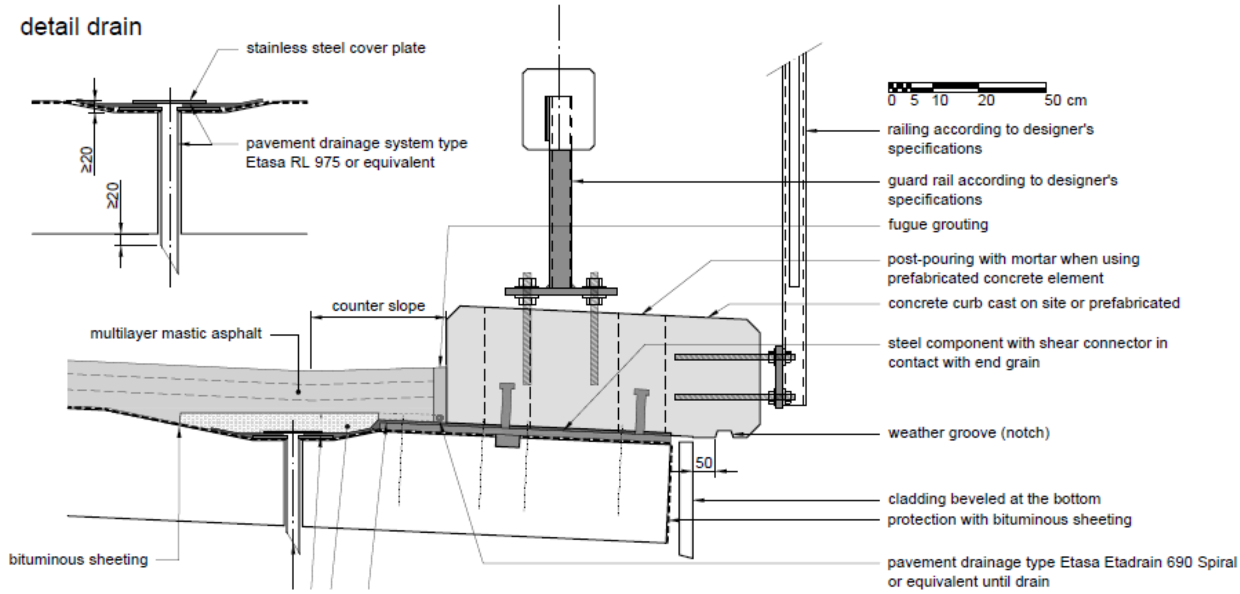

Figure 6: Edge detail with curb of concrete elements with guide rail

6 Drains in the asphalt wearing surface

In large bridges, water cannot always be led over the sides and drains in the middle of the deck are required. Standard details and products for drains can be obtained from details and solutions developed for concrete bridges. These have often proven to work well.

7 Discussion and conclusions

Experience gained during inspections and during repair of existing bridges show that apart from a robust layup of the wearing surface, the detailing along the edges of expansion joints, sides like curbs, and drains are essential for the longevity and durability of timber bridges. That means that they are important for correct and efficient maintenance of the bridges, too.

Leaks along these edges are often not detected timely and can lead to uncontrolled ingression of water onto timber decks in a short period of time.

The presented details are created using the expertise of experienced engineers and create a solid starting point for individual planning efforts for bridges with timber decks. This will significantly increase the economic aspects, efficient planning of construction process, and improve quality of future bridges. It still is, however, important that bridge owners realize that regular inspection and maintenance is carried out, too.

In all the listed details, polymer bitumen waterproofing membranes are used as a system structure on wooden roadway decks, both with and without bonding in the surface, and mastic asphalt is used for the protective layer and sealing. The creation of the asphalt road layups is usually unproblematic when robust components are used and can be made in high quality [10].

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