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Paving of concrete carriageway Case study Tauern motorway at the Wengen-Pongau junction

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A R T I C L E I N F O

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A B S T R A C T

Passenger and freight traffic on our roads continues to increase in number and severity. High axle loads, high tyre pressures and greater dynamic loads require load-bearing and stable road pavements. Concrete road pavements are highly suitable for meeting these demands over long periods of time. Therefore, they are well suited for the new construction and renewal of motorways, federal and country roads, local bypasses, bus traffic areas, intersections and roundabouts, and cycle paths. Concrete road pavements have a long service life even under heavy use. Nevertheless, the production costs are competitive and the maintenance costs are low. This makes concrete pavements particularly economical by comparison.

1. Introduction

Concrete pavements are a structural component of the road surface. The designation of the individual layers of a road construction with concrete pavement is shown in Fig.1. The road body with concrete pavement usually consists of the following:

- Subgrade
- ≥ 20 cm unbound lower base course
- 20 cm bound or unbound upper base course
- 5 cm bituminous base course (AC16 trag, 70/100, T3, G4)
- 25 cm non-reinforced concrete pavement (concrete C30/37/B7/XM2/GK22) [Zement + Beton, 2012].

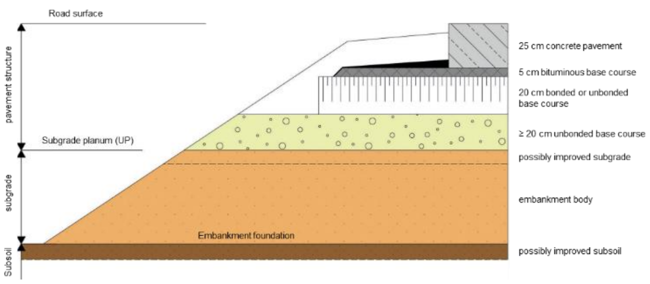

Figure 1. Road body with concrete pavement (schematic)
Source: Zement + Beton, 2012

The mix types for bituminous base courses under concrete pavements according to the Austrian guidelines and regulations for road construction RVS 08.97.05 [FSV, 2010] are shown in Table 1.

Table 1. The mix types for bituminous base courses under concrete pavements, *Source: Zement + Beton, 2012*

Load class according to RVS03.08.63	Mixed material type according to RVS08.97.05
S and I	AC 16 trag 70/100, T3, G4
≤II	AC 16 trag 70/100, T3, G5

2. Construction methods of concrete pavements in Austria

With the different rigid construction methods, the concrete pavements can also be produced in one or two layers. In the single-layer construction method, the entire thickness is produced in a uniform composition of the ceiling concrete. This means that it must meet all the higher requirements for the top concrete in terms of aggregate, composition, strength, polishing resistance, etc. The top concrete used can be single-layer or double-layer.

The top concrete used can be installed in one or two layers. In the case of two-layer paving, the upper layer must be placed and compacted before the concrete mix of the lower layer begins to dry or set.

The economic application of the single-layer construction method is therefore usually limited to (short) tunnel sections where space is limited or to traffic areas with lower demands on the top layer of concrete, such as rural roads, paths or car parks [Zement + Beton, 2012].

In the two-layer construction method, the bottom concrete and top concrete are placed and compacted separately, sometimes with different requirements. Particular importance is attached to the compaction of the top concrete on the fresh bottom concrete layer that has already been placed. Mixing of the top concrete and bottom concrete mixes and the formation of so-called vibrating alleys - an inadmissible accumulation of fines on the surface in the area of the vibrator of the concrete paver - must be prevented.

For this purpose, the composition and consistency of the concrete mix used must be coordinated with the paving method by means of a suitable type, arrangement, as well as frequency and amplitude of the compaction equipment and continuously monitored. The standard thickness of the top concrete is regulated in Austria depending on the nominal maximum grain size (GK in mm) of the top concrete (OB) according to Tab.2, whereby an unmixed top concrete thickness of at least 75 % of the target thickness must be maintained [Zement + Beton, 2012].

Table 2. Standard thickness of the top concrete for two-layer construction in accordance with RVS 08.17.02, *Source: FSV, 2010*

Concrete type	Minimum thickness of the top concrete [cm]
OB GK 16	5,0
OB GK 22	6,0
OB GK 8	4,0
OB GK 11	or thicker, if this is necessary because of the equipment is required (mixing under concrete/ Oberbeton, Rüttelgasen).

3. Placement of joints in concrete pavements in Austria

The concrete pavement in Austria is produced in fields with transverse and longitudinal joints without reinforcement. The field length L is the distance from transverse joint to transverse joint and the field width B is the distance from the slab edge to the longitudinal joint or between the longitudinal joints. The required slab thickness D is to be dimensioned taking into account technical and economic aspects. Longitudinal and transverse joints are usually designed as dummy joints [Zement + Beton, 2012].

In order to avoid wild cracks due to shortening of the concrete after production (mainly due to cooling, only after removal of the evaporation protection also due to drying), transverse joints are generally to be placed at a distance of 25 times the slab thickness, but at most at a distance of 5.0 m (load classes S and I according to RVS 08.17.02 [FSV, 2011]) or 5.5 m (other load classes). In order to limit the temperature stresses (arching stresses) that occur as a result of non-uniform heating of the ceiling in the state of use, the field length must generally not exceed 1.5 times the field width. As a general rule, square slab dimensions should be aimed for, as these guarantee the highest load-bearing capacity.

To prevent adjacent slabs from moving apart, anchors should be placed at all longitudinal joints. For higher traffic loads (load class S to III), all transverse joints should be doweled to improve the transmission of forces between the slabs. The structural design of an unreinforced concrete pavement with dummy joints is the standard construction method in Austria and is shown schematically in Fig.2 [Zement + Beton, 2012].

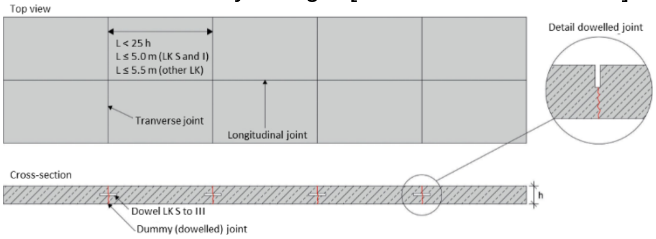

Figure 2. Joint division of a concrete pavement in Austria *Source: Zement + Beton, 2012*

Sustainability is an important issue in terms of environmental compatibility. Since concrete roads, with their extremely long service life of at least 30 to 40 years, also have to be renewed, considerations of recycling and reuse of the materials present in worn-out concrete pavements are unavoidable. The basis for the reuse of the recycled material is the two-layer construction of the new concrete pavement. The substructure consists of an asphalt base layer on a cement stabilization or unbound base layer.

On top of this is the concrete pavement in a two-layer design with sub-concrete made of recycled concrete and a relatively thin layer of the highest-quality top concrete with a low-noise exposed aggregate surface. Recycled fractions larger than 4 mm are used for the production of the bottom concrete. The requirements for the aggregate for the bottom concrete are regulated in Austria in the RVS 08.17.02 (Fig.3) [J. Steigenberger, H. Elsner, S. Marchtrenker, 2011].

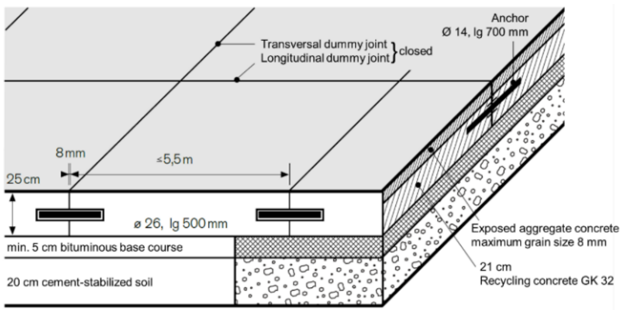

Figure 3. Two-layer structure of the concrete pavement with recycled concrete (Graphic: VÖZ), *Source: Steigenberger, H. Elsner, S. Marchtrenker, 2011*

In general, dowels (Fig.4, 5) are to be provided at transverse joints to transfer the load and to ensure that the concrete slabs are at the same height, and anchors (Fig.6, 7) are to be provided at longitudinal joints to prevent the concrete slabs from moving apart. According to ZTV Beton-StB 07 [FGSV, 2007], dowels and anchors are mandatory for concrete pavements of construction classes SV, I to III.

4. Dowels for transverse dummy joints

Dowels (Fig.4) are made of smooth round steel S 235 JR. They have a standard diameter of Ø 25 mm (limit dimensions +/- 0.5 mm) and a length of 500 mm (limit dimensions +/- 5 mm). They are sawn on both sides almost free of burrs, without any change in cross-section, and are PE plastic-coated (resistant to alkalis) over their entire length, including one end face. The coating thickness is at least 0.3 mm. One end face is painted with rust protection [Otto Brentzel, o.J.].

Figure 4. Smooth round steel dowel, *Source: K. Hrapović, 2021*

The dowels are inserted in the middle of the slab (Fig.5).

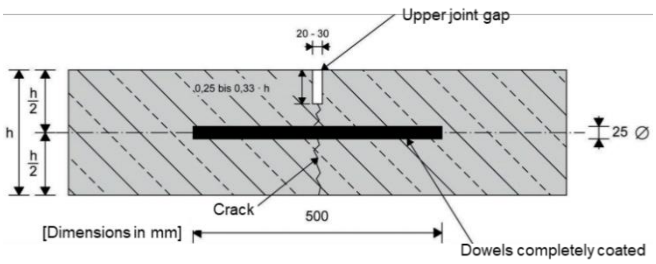

Figure 5. Unsealed, dowelled dummy joint (dimensions in mm), *Source: Zement + Beton, 2012*

5. Anchors for longitudinal dummy joints (standard anchors)

The anchor (Fig.6) is made of ribbed reinforcing steel B500B and has a standard diameter of Ø 20 mm and a length of 800 mm (limit dimensions +/- 15 mm). It is cut on both sides with reinforcing steel shears and is PE plastic-coated (resistant to alkalis) in the middle section over a length of approx. 200 mm. The thickness of the coating is also at least 0.3 mm [K. Hrapović, 2021].

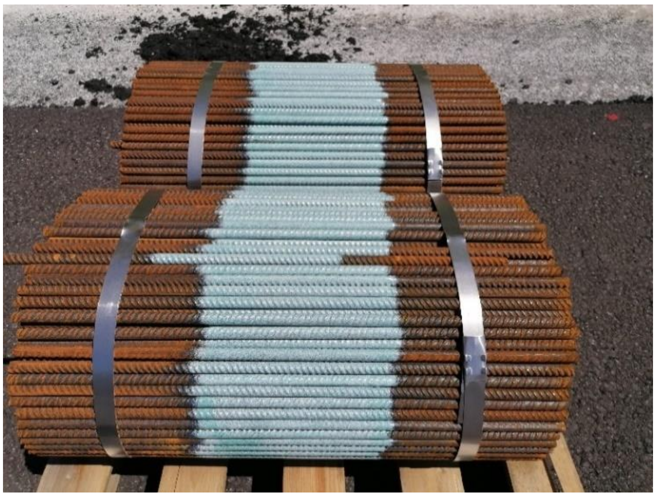

Figure 6. The anchor made of ribbed reinforcing steel B500B, *Source: K. Hrapović, 2021*

The placement of anchors at the press joints in the middle of the slab is shown in Fig.7.

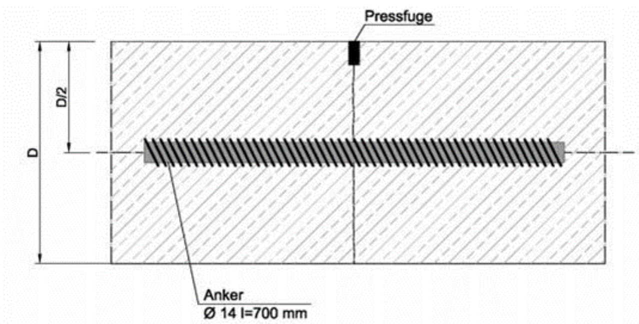

Figure 7. Anchor placement in slab middle, *Source: S. Wedl, 2007*

6. Verification procedure

The versatile stresses on the concrete pavement place very high demands on the concrete used. In addition to requirements for high load-bearing capacity and durability, these also relate to corresponding surface properties. A distinction must be made between the properties of the fresh concrete, which primarily concern the contractor, and those of the hardened concrete, which are of first priority for the builder.

The greatest possible bending tensile strength (splitting tensile strength) is an essential requirement in the service condition of the concrete pavement in order to prevent uncontrolled cracking due to traffic load stresses. Furthermore, concrete road pavements are exposed to large permanent stresses and high dynamic stresses. Basically, the following type of concrete is to be used according to the Austrian standard ÖNORM B 4710-1 [ASI – ÖNORM B 4710-1, 2018] [Holcim, o.J.]:

C 30/37 / B7 / XM2

For two-layer construction, concrete type C 30/37 / B7 may also be used for the bottom concrete. If specified in the bill of quantities, this type of concrete is also permissible for subordinate construction projects in single-layer construction. The consistency is to be adapted to the paving method (manually or mechanically by means of slipform pavers). Instead of the above-mentioned concrete types, the use of the relevant concrete types according to RVS 08.17.02 [FSV, 2011] is also permissible.

The verification procedure of concretes for traffic areas is carried out in three stages. As with other concrete structures, proof of suitability of the concrete and the aggregate to be used must be provided by means of an initial test. In the case of demanding construction projects, a trial production and trial installation can be agreed in order to check the tendered fresh and hardened concrete properties as well as the processing conditions including surface finishing.

In any case, fresh and hardened concrete properties (compressive strength, flexural tensile strength, frost de-icing salt resistance) are determined on samples and drill cores from the pavement during installation, and the surface properties (levelness, evenness, skid resistance) and finish (joint design, dowels) are tested. The tests for bending tensile strength and compressive strength are described under Mechanical Properties, those for frost de-icing salt resistance under Frost Resistance [Holcim, o.J.].

The requirements for concrete for traffic surfaces according to the Swiss standard SN 640 461b [VSS, 2014] are shown in Table 3.

Table 3. The requirements for concrete for traffic surfaces according to the Swiss standard SN 640 461b, *Source: Holcim, o.J.*

Requirements	Standard types 1-3: Roads and highways, roundabouts, bus stations, places	Standard type 4: Freight roads and forest roads, rural track paths, cycle and footpaths
Generel	Concrete according to SN EN 206-1	
Exposure classes concrete	XC4, XD3, XF4	XF3, XC4
Compressive strength class	C30/37	C25/30
Minimum value of bending tensile strength after 28 days (test according to SN EN 12390-5, prism 120 x 120 x 360 mm)	5.5 N/mm^2	4.5 N/mm^2
Air content	3.0 vol.% with maximum grain size 32 mm 3.5 vol.% with maximum grain size 16 mm	
Mineral aggregate according to SN EN 12620, SN 670115	D_{max} 32 mm, PSV ≥ 44	

7. Concrete composition

Table 4 shows examples of the mix design of a concrete for traffic surfaces in Switzerland.

Table 4. Examples of the mix design of a concrete for traffic surfaces in Switzerland, *Source: Holcim, o.J.*

			Road concrete for manual paving			Road concrete for paver laying		
		Density [kg/dm³]	Percentage [M.-%]	Quantity [kg/m³]	Volume [l/m³]	Percentage [M.-%]	Quantity [kg/m³]	Volume [l/m³]
zement	CEM I (Normo 4)	3.10		350	113			
	CEM II/B-M (S-T) (Robusto 4R-S)	3.05					350	115
mineral aggregate	sand 0/4	2.68	34	648	242	34	646	241
	gravel 4/8	2.68	6	114	43	6	114	43
	chipping 8/11	2.68	13	248	92	13	247	92
	gravel 8/16	2.68	13	248	92	13	247	92
	gravel 16/32	2.68	34	648	242	34	646	241
water		1.00		146	146		146	146
air					30			30
additive	superplasticizer, air entraining agent			as required				
raw density and volume of the fresh concrete				2402	1000		2397	1000
w/c value			0.42			0.42		
selected concrete properties flexural strength			f_{ct} ≥ 5.5 N/mm^2			f_{ct} ≥ 5.5 N/mm^2		
AAR						persistent		

8. *Pavement structure with concrete pavement on the Austrian A10 - Tauern motorway at the Wengen-Pongau junction*

For the road rehabilitation on the Austrian A10 - Tauern motorway at the Wengen-Pongau junction, the following pavement structure was constructed with the concrete pavement for the load class LK89, type BE2, namely with the exposed aggregate concrete surface (Fig.8):

- Concrete pavement two-layer GK 8 mm according to RVS 08.17.02 [FSV, 2011] 27.0 cm
- AC16 trag 70/100, T3, G4 5.0 cm
- Hydraulically stabilised base course according to RVS 08.17.01 [VSS, 2014] 20.0 cm
- Unbound base course, Existing min. 20.0 cm

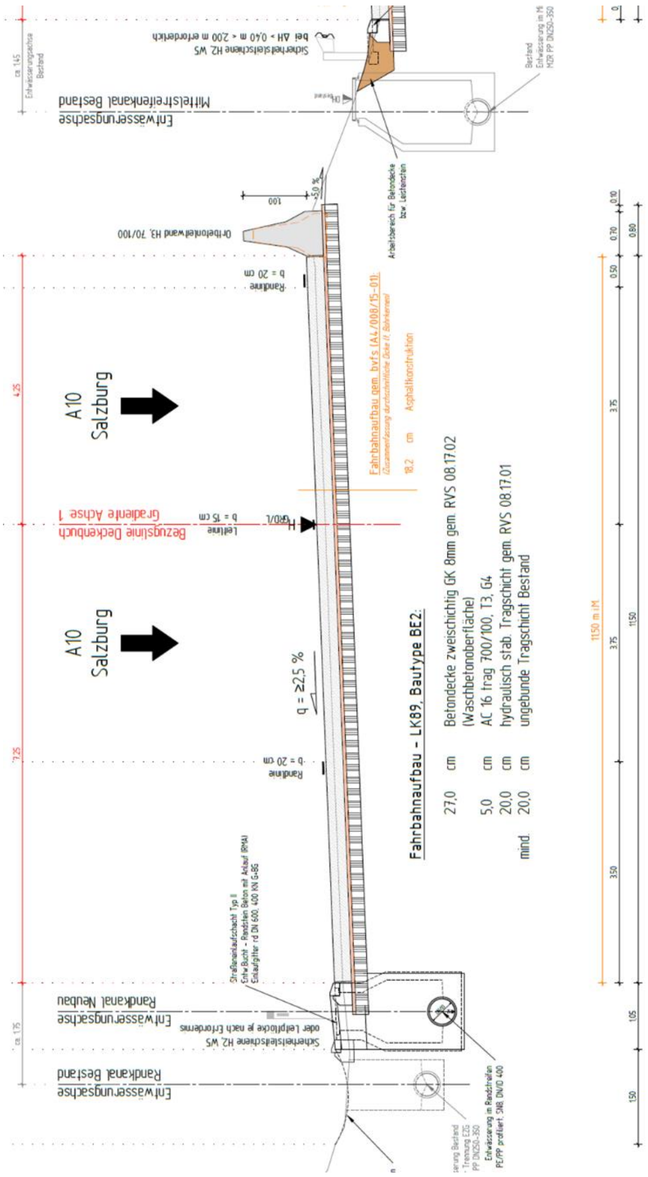

Figure 8. Pavement structure with concrete pavement on the A10 - Tauern motorway at the Wengen-Pongau junction, *Source: Asfinag, o.J.*

9. Concrete paver with for the two-layer paving of the concrete roadway

Schematic illustration of the concrete paver with four crawler tracks with additional equipment for two-layer paving is shown in Fig.9.

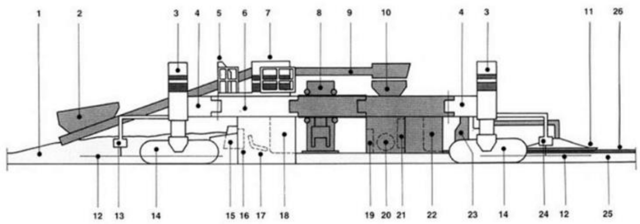

Figure 9. Schematic illustration of the concrete paver with four crawler tracks with additional equipment for two-layer paving (edited by author), *Source: H. König, 2014*

Fig.9-Key: 1- Delivered concrete, 2- Receiving hopper for top concrete, 3- Elevation adjustment, 4- Swivel arm, 5- Operator's platform, 6- Base frame, 7- Drive station, 8- Dowel setter, 9- Conveyor belt for top concrete, 10- Transfer hopper for top concrete, 11- Lengthwise smoother, 12- Tension wire, 13- Front levelling and steering buttons, 14- Chain drive, 15- Sword distributor, 16- Front wall shield, 17- Vibrators, 18- Formwork for bottom concrete, 19- Front wall, 20- Distribution auger, 21- Adjustable front wall, 22- Formwork for top concrete, 23- Oscillating cross screed, 24- Buttons for levelling and steering at the rear, 25- Built-in under concrete, 26- Built-in top concrete.

In the following pictures (Fig. 10, 11, 12, 13, 14, 15) we see the concrete paver with even twelve crawler units for the two-layer paving of the concrete carriageway on the Austrian Tauern motorway A10.

Figure 10. Concrete paver with even 12 crawler tracks for paving bottom and top concrete, *Source: K. Hrapović, 2021*

Figure 11. Concrete paver with even 12 crawler tracks for paving bottom and top concrete – front part, *Source: K. Hrapović, 2021*

Figure 12. Concrete paver with even 12 crawler tracks for paving bottom and top concrete – middle part, *Source: K. Hrapović, 2021*

Figure 13. Concrete paver with even 12 crawler tracks for paving bottom and top concrete – back part, *Source: K. Hrapović, 2021*

Figure 14. Loading the concrete from the truck by means of an excavator, *Source: K. Hrapović, 2021*

Figure 15. Transfer hopper for top concrete, *Source: K. Hrapović, 2021*

10. Drainage of the slab base - flat drainage (Germ. Flachdrain or Flachdrän)

Because even the joint seal cannot permanently prevent water penetration or contamination, the additional installation of a flat drain at the low points below the transverse joint is recommended. This should guarantee the drainage of the concrete slab base even if the joint seal is not watertight. To fix the position of the flat drain, a bed about 1 m long and 15 cm wide is cut into the bituminous underlay, into which the flat drain is inserted and fixed (Fig.16, 17, 18) [Zement + Beton, 2012].

Figure 16. Flat drain (Germ. Flachdrän), *Source: K. Hrapović, 2021*

In order to prevent soiling of the joint and the ingress of water under the concrete pavement, each joint in concrete pavements with load class II or higher is sealed at the top in accordance with RVS 03.08.63 [FSV, 2016]. Because even joint sealing cannot permanently prevent water ingress, drainage of the concrete pavement base is essential.

For this purpose, a flat drain is placed underneath the transverse joint on the base, which in Austria is usually a bituminous base course in the case of concrete pavements subject to high loads, whereby the drainage of the concrete pavement base can be ensured even if the joint seal is not tight. Flat drains are fleece-coated, 12 cm wide and maximum 8 cm thick plastic profiles, in which the water drainage can take place in the direction of the slope (Fig.17, 18, 19, 20).

Figure 17. For flat drainage, lightly milled bituminous base of asphalt AC16 trag 70/100, T3, G4 under concrete pavement, *Source: K. Hrapović, 2021*

Figure 18. Flat drain laid on milled bituminous base under concrete pavement, *Source: K. Hrapović, 2021*

The requirements according to RVS 08.17.02 for flat drains are listed in Table 5.

Table 5. The requirements according to RVS 08.17.02 for flat drains, *Source: Zement + Beton, 2012*

Hemija	Ne oštećuje beton, otporno na alkalije, rezistentno na sredstva za otopljavanje
Debljina	≤ 8 mm
Hidraulični poprečni presjek	≥ 600 mm²
Opšte osobine	Profilisana traka omotana filcom, pogodna za odvodjenje vode u podužnom pravcu kao i za ugradnju na asfaltnoj podlozi u sklopu ugradnje betonskog kolovoza.

The drainage drains are placed transversely under the joints and longitudinally at the edge of the concrete pavement, as shown in the example in Fig.19.

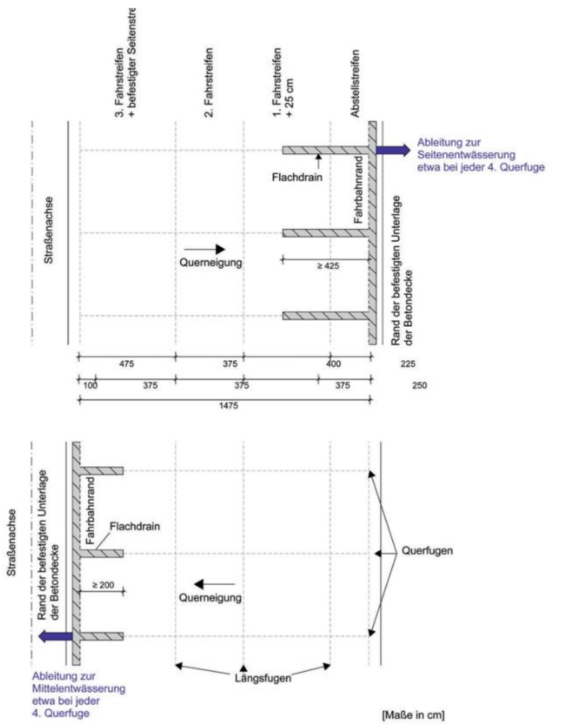

Figure 19. Design example for the placement of flat drains at the base of the concrete pavement, according to RVS 08.17.02, *Source: Zement + Beton, 2012*

Figure 20. Flat drain under concrete pavement, *Source: K. Hrapović, 2021*

11. *Concrete paving*

Concrete road surfaces require continuous placement of concrete with consistent properties. Any stoppage of the paver and any change in the composition and consistency of the concrete can lead to changes in the concrete surface, especially unevenness. These are often difficult to level out again. The fresh concrete should therefore come from only one mixing plant with sufficient mixing capacity and unchanged composition for each layer to be placed [N. Ehrlich, O. Hersel, 2010].

11.1. Paving of the bottom concrete

In the case of two-layer construction, ensure the correct height of the bottom concrete so that the top concrete has the intended thickness of at least 5 cm. The concrete must be compacted evenly and completely over the entire cross-section. When paving in two layers, the bottom concrete must not be conveyed to the surface during compaction.

Slipform pavers are capable of compacting all existing thicknesses evenly and sufficiently. However, care must be taken to maintain the consistency and bulk density of the fresh concrete. The concrete must not segregate during compaction [N. Ehrlich, O. Hersel, 2010]. The following figures show the installation of bottom concrete on the A10 Tauern motorway (Fig.21, 22, 23).

Figure 21. Paving of the bottom concrete, *Source: K. Hrapović, 2021*

Figure 22. Vibrator for under-concrete; standing edge for concrete with high green strength, *Source: K. Hrapović, 2021*

11.2. Inserting the dowels and anchors

Dowels must be installed in the middle of the slab thickness. They must lie in the slope and longitudinal direction of the roadway so that the longitudinal movement of the slabs is not impeded and cracks are avoided. If the dowels are installed before the concrete is poured, they must be secured in their position in such a way that they do not move when the slab is produced. To secure their position, support cages made of reinforcing steel mesh anchored in the base course can be provided. The inclination of the anchors - in relation to the anchor length of 50 cm - must not exceed 20 mm.

If dowels are vibrated in, the concrete must be compacted before the dowels are vibrated in. If dowels and anchors are vibrated in (Fig.23), the slab must usually be constructed in two layers or two courses. Dowels and anchors must be vibrated before installing the upper layer. For this purpose, the bottom concrete must already be compacted. In the case of single-layer installation, dowels and anchors may only be placed if it can be proved that there is no structural disturbance of the concrete above the dowels and anchors. Anchors are to be installed in longitudinal dummy joints in the lower third of the slab thickness, in longitudinal compression joints in the middle of the slab thickness, so that they are not caught when the joint is cut. On the other hand, they should be at least 5 cm above the underside of the slab.

Figure 23. Automatic installation of anchors and dowels, *Source: K. Hrapović, 2021*

Generally, combined dowel and anchor setting devices with magazine-type storage are used today (Fig.23). If separately working dowel and anchor setting devices are used, the anchor setting must be carried out before the dowel setting to guarantee a perfect dowel position. Otherwise there is a risk that the anchor position will be influenced by the anchor vibration. Dowels and anchors must be vibrated in before installing the top layer. After vibrating in the dowels and anchors, smooth out any concrete deformations, if necessary.

Instead of the usual anchors, screw or composite anchors can be used for multi-strip installation or maintenance measures. The connection must be strong, durable and protected against corrosion.

11.3. Paving of the top concrete

In the case of two-layer or two-course construction, the top concrete must be placed no later than 30 minutes after the bottom concrete has been placed in warm, dry weather and no later than 60 minutes after the bottom concrete has been placed in cool, damp weather. If these guideline values are adhered to, the installation is carried out fresh in fresh and the bonding effect between the bottom and top concrete is thus ensured. The bottom concrete must also not be placed to such an extent that it is visibly dry before the top concrete is placed or begins to set before it is compacted [N. Ehrlich, O. Hersel, 2010].

Figure 24. Installation of top concrete, *Source: K. Hrapović, 2021*

Figure 25. Installation of top concrete after automatic installation of dowels in the bottom concrete, *Source: K. Hrapović, 2021*

Figure 26. Vibrator for top concrete, *Source: K. Hrapović, 2021*

Figure 27. Lengthwise smoother for top concrete, *Source: K. Hrapović, 2021*

Figure 28. Application of the chemical surface protection over the finished concrete, *Source: K. Hrapović, 2021*

Figure 29. Finished, two-layer concrete pavement on the Austrian A10 Tauern motorway, *Source: K. Hrapović, 2021*

12. *Exposed aggregate concrete by brushing*

Based on many years of positive experience in Germany and Austria with the two-layer construction method with a brushed-out exposed aggregate concrete surface, the decision was made in Uri (Switzerland) to install a new roundabout using this method. High expectations were placed on the construction with the exposed aggregate concrete method: Among other things, the requirements for a permanently high skid resistance as well as low noise development were to be fulfilled. Various examples from practice have shown that traffic surfaces with exposed aggregate concrete surfaces achieve both goals, provided that they are executed professionally [G. Müller, 2015].

The exposed aggregate concrete construction method was introduced in Austria as early as 1990 with its good noise-reducing properties and high skid resistance level. Today it is the standard construction method and has proven itself in motorway construction and in the construction of urban roads. Recent investigations confirm its good long-term behaviour. The exposed aggregate concrete surface with a maximum grain size of 8 mm hardly loses any of its skid resistance properties even after well over 10 years under traffic.

As a rule, exposed aggregate concrete is laid in two layers "fresh in fresh". The damp concrete surface is treated with a combination agent (retarder and curing agent) and brushed out in the earth-moist state (Fig.30). The texture depth is reached after 3 to 24 hours, depending on the time of brushing. This depends on the ambient temperature. This can be tested by means of preliminary trials. The desired texture depth is approximately 0.8 to 1.1 mm [G. Müller, 2015].

Figure 30. Brushing out the surface, *Source: G. Müller, 2015*

With this construction method, a bottom concrete layer with a maximum grain size of 32 mm is placed and compacted in a first step. In a second step, a top concrete layer of high-quality 0 to 8 mm chipped concrete is applied to the still fresh bottom concrete. Mixing of the two layers must be avoided. Brushing the surface mortar with exposed aggregate also improves the surface's resistance to frost and de-icing salt [G. Müller, 2015].

Fig.31 a) shows the pavement concept and Fig.31 b) an exposed aggregate concrete surface GK 0-8 mm.

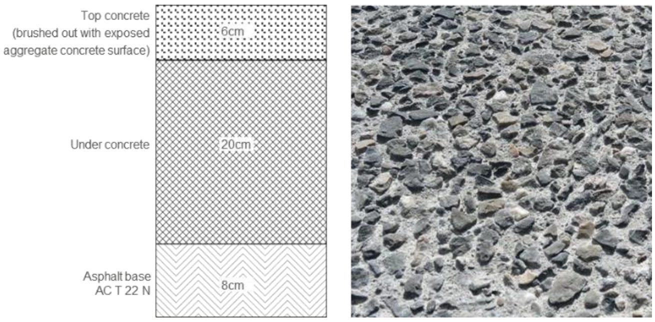

Figure 31. a) Surfacing concept, b) Example of an exposed aggregate concrete surface GK 0-8 mm, *Source: G. Müller, 2015*

The treatment of the concrete surface with retardant and removal by rotary brush is shown in Fig.32a and the treatment with retardant and removal by high pressure water is shown in Fig.32b.

Figure 32. Exposed aggregate concrete surface: a) directly after brushing out; b) after cleaning, *Source: G. Müller, 2015*

13. Conclusion

The concrete road is not an invention of our days. Already more than 2000 years ago, the Romans often paved their city and country roads with a concrete-like layer, the "opus caementitium". Remains of these roads can still be seen today, for example in Trier and the surrounding area (Germany). The Romans used gravel and/or crushed rock for their road concrete, which they mixed with mortar or lime and laid in layers up to 50 cm thick. Concrete road surfaces are resistant to deformation at any practical temperature. Ruts, deformations and waves therefore do not occur with them.

The trafficability of the concrete pavement and the rapid drainage of surface water are maintained [R. Oesterheld, M. Peck, S. Villaret].

Until now, the selection of a construction method for the construction or renewal of a motorway section was almost exclusively based on constructional and economic aspects. In the production phase, for example, a large savings potential in concrete construction methods lies in the replacement of Portland cement by cements with several main constituents.

In this work, it was shown, among other things, that the basis for the recycling of the recycled material is the two-layer construction of the new concrete pavement. Here, the substructure consists of an asphalt base layer on a cement stabilisation or unbound base layer. On top of this is the concrete pavement in a two-layer design with a bottom layer of recycled concrete and a relatively thin layer of the highest-quality top concrete with a low-noise exposed aggregate surface.

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