Austrian Design Standards for Block Pavements

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ABSTRACT: The Austrian specification for pavement design which was modified the last time in 1998 consists of a catalogue type of standardized structures for bituminous and concrete pavements. Recently, an extension of this guideline by new pavement types was completed, covering block pavements and small slabs of concrete as well as of natural stones. The paper gives an overview on the structure of the specification, the underlying analytical design calculations, and on the new pavement types and their limits of application. The new version of the guideline was published recently.

KEY WORDS: Pavement design, block pavements, standardized pavement structures

1 INTRODUCTION

In 1986 a comprehensive Austrian pavement design catalogue was published for the first time, providing a complete range of different standardized pavement structures for bituminous and concrete pavements (Litzka and Herbst 1986). Following more than ten years of successful application, it became necessary to adapt the guideline to new requirements and increased traffic load situations. The underlying analytical design procedure, which forms the basis for the final structures included in the catalogue, was modified. Based on new research results, equivalency factors for the various commercial vehicles were developed, taking into account a realistic wheel load distribution and also the transverse wheel track variation. Furthermore, an additional load class for heavy duty road pavements was implemented, with respect to the increased amount of heavy traffic (Blab et al. 1997 and 1998). For the new version of the guideline, which was published in 1998, the principle of a catalogue type with standardized pavement structures was kept intentionally for practical reasons. Thus, for routine application, a suitable choice according to the design traffic can be made. On the other hand, for extreme load situations and/or other layer materials or combinations than standardized, a specific pavement design is recommended on the basis of the underlying analytical design procedure.

With respect to today's changes in the related material specifications and guidelines, and especially due to the increased use of block pavements and small slabs, it was decided to redraft the existing version of the design guideline and to include standards for these pavement types. This decision was supported by the elaboration of a new guideline for pavers and paving materials (RVS 8S.06.4, 2005), but primarily, because of frequent failures occurring in different types of block pavements, mainly due to an inadequate design of the full pavement structure. This paper presents the new extended guideline, which was published recently (RVS 3.63, 2005), covering block pavements and small slabs of concrete and natural stones.

2 STRUCTURE OF THE GUIDELINE

In using the guideline, the main influence parameters for pavement design are to be taken into account, i.e. design traffic, pavement type and materials of the various pavement layers, respectively, and the bearing capacity of the sub-grade or formation level. Consequently, one can find technically equivalent pavement solutions, from which the most appropriate one can be chosen.

2.1 Design traffic

Generally, the catalogue distinguishes between 7 classes of traffic load (S, and I to VI), but as far as block pavements are concerned, the lower load classes III to VI are applicable only (see Figure 5 and Figure 6). The allocation to a specific load class is based on the traffic load on the lane with maximum heavy traffic. This traffic load is expressed by the number of equivalent single axle loads of 100 kN (Design ESALs, DESAL), which is calculated from equation 1,

$$DESAL = ESAL_{day} \cdot R \cdot V \cdot S \cdot 365 \cdot n \cdot z \qquad \text{equation 1}$$

where $ESAL_{day}$ is the daily number of equivalent single axle loads, calculated from $AADT_{cv}$ (annual average daily traffic of commercial vehicles) using the equivalency factors from Table 1 or Table 2; R, V, and S are factors that take into account the different traffic directions (usually R = 0.5), the number of lanes per direction (V = 0.9 to 1.0), and the width of the lane (for calculation of S see Table 3); n is the design period, usually 20 years for bituminous and block pavements; and z is a factor for the consideration of traffic growth, depending on the annual growth rate and the design period.

Table 1: Mean equivalency factors for representative categories of heavy vehicles.

vehicle category	equivalency factor
truck	0.70
truck with trailer, semi-trailer	1.20
bus	0.60
low-floor bus, in urban public transport	0.80
articulated bus, in urban public transport	1.40

Table 2: Mean equivalency factors for the $AADT_{cv}$-collective for different road categories.

road category	equivalency factor
motorways	1.00
other roads	0.90

Table 3: Reduction factors for transverse wheel tracking in a cross section of a lane.

width of lane [m]	3.00	3.25	3.50	3.75	≥ 4.00
reduction factor S	0.90	0.85	0.80	0.75	0.70

Exceptionally, a general attribution to a load class can be made, depending on the function of the road and taking into account the frequency of truck traffic (pedestrian zones, parking areas, local access roads, etc.).

2.2 Bearing capacity of the sub-grade

The bearing capacity of the sub-grade or the formation level is of high influence on the necessary thickness of the pavement. Within the guideline, a minimum value of E_{v1} = 35 MN/m² (deformation modulus from plate bearing test) is required for the application of the standardized pavement solution. If this requirement can not be fulfilled, additional measures have to be taken, in order to increase the bearing capacity of the sub-grade (soil stabilization, change of material, etc.).

2.3 Materials for the standardized pavements

Generally, the standardized pavements included into the catalogue consist of the following types of layers: (i) unbound sub-base and base layers, (ii) cement bound base layers, (iii) bituminous base and surface layers, and (iv) plain concrete layers.

In the special case of block pavements the following layers are used additionally, which are specified separately in the guideline RVS 8S.06.4 (2005): (v) block pavers in different laying patterns with different interlocking effects, (vi) small slabs of different sizes, (vii) bedding sand and joint filler (only unbound materials are taken into account), and (viii) porous concrete base layers. While there is significant positive long-term experience with pavement types from block pavers on unbound base layers, only a few sections were recently built with porous concrete base layers in the city of Vienna.

3 DESIGN CALCULATIONS

3.1 General procedure

The general procedure for the design calculations, applied for all constructions included in the catalogue of standard pavements, was already developed for the modification of the guideline in 1998, and is described in detail by Litzka et al. (1996).

For flexible and semi rigid pavements the elastic multilayer theory is applied. The sub-grade model takes into account four different periods of bearing capacity, according to the seasons of the year. The stiffness of the unbound sub-base and base layers is determined with respect to the stiffness of the underlying layer, the material type and the thickness. For cement treated layers a constant stiffness over the year is assumed. Contrary, for bituminous layers a stiffness-model is used, which comprises twelve different stiffness levels in total. Each level refers to a characteristic temperature distribution in the pavement, with respect to the related seasonal period, to a distinction of temperatures between day and night, and to the layer thickness (ref. Wistuba 2002).

The relevant stresses and strains are calculated using a multilayer theory computer program (e.g. BISAR©), and an improved strength hypothesis for asphalt materials (Litzka et al. 1996) is employed to predict pavement distress. The number of permissible load applications to fatigue damage is calculated for each individual period from the respective fatigue law. The summation over the whole year, based on Miner's law, results in the consumption of life-time during one year, and the reciprocal value leads to the life-time of the pavement expressed in years.

Following this design procedure, comprehensive additional calculations have been made at the Institute for Road Construction and Maintenance, Vienna University of Technology, covering the new pavement types with block pavers and small slabs (Janda 2003). The results of these design calculations are detailed hereafter.

3.2 Design calculations for block pavements

The representative stiffness of the block pavement layer, which consists of the paving blocks and the bedding sand, depends on various parameters, i.e. block shape and size, thickness, interlocking effect caused by block shape and laying pattern, etc. As far as the block shape is concerned, three different categories of pavers are distinguished. Category A comprises fully interlocking paving stones, category B pavers with partial interlocking effect, and category C pavers with plane lateral surfaces, and hence, limited interlocking effect caused by laying pattern only.

In accordance with the laying pattern, defined in the guideline RVS 8S.06.4 (2005) (see Figure 1), three different stiffness classes for block pavement layers are distinguished and used for the design calculations (see Table 4). The E-moduli included in Table 4 are average values, which take into account an increase in stiffness after the first loading phase, due to an activation of the interlocking effect. These average values are assumptions taken from literature (Shackel 1991), and from laboratory loading tests (Shackel et al. 2000a,b).

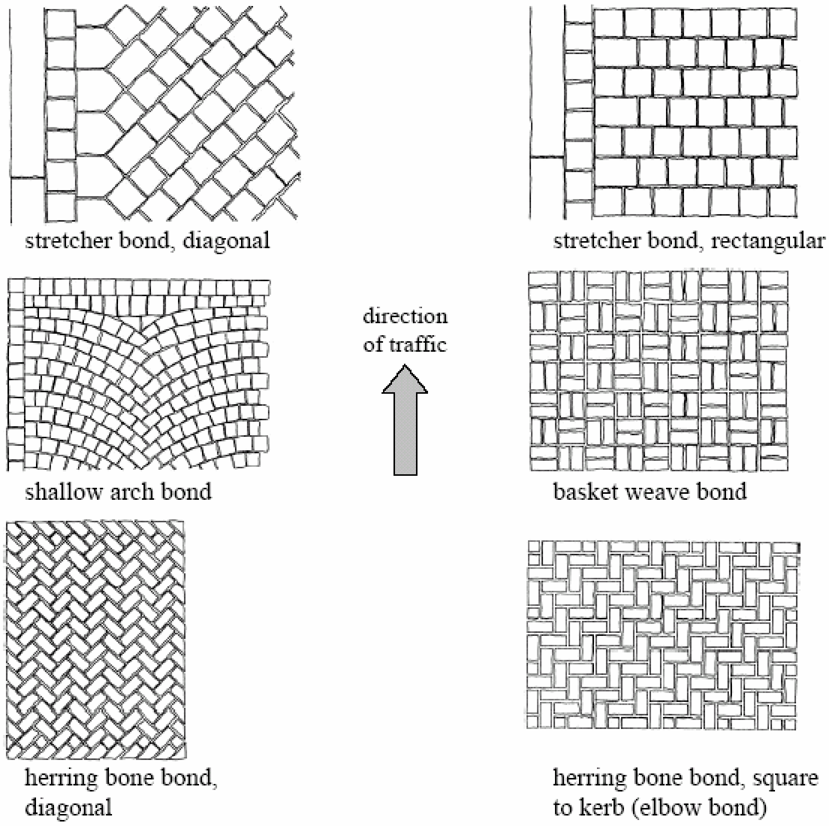

Figure 1: Laying patterns for block pavements according to RVS 8S.06.4 (2005), examples.

Table 4: Input values for design calculations for different stone categories and laying patterns.

stiffness-class	paver thick-ness [cm]	paver shape category	laying pattern	E-modulus [MN/m²]	Poisson's ratio [-]
I	6, 8, 10	A	herring bone, diagonal	3,200	0.3
II	6, 8, 10	A, B, C	all patterns acc. to Figure 1	750	0.3
III	≥ 17	C	all patterns acc. to Figure 1	1,500	0.3

Concerning a pavement type with unbound base courses, the vertical stress on the plane of the upper base layer is the critical one, which determines the lifetime. From a comparison of different fatigue laws the SHELL criterion for a confidence level of 95% (SHELL 1978) is regarded as the most reliable for fatigue calculation. As an example, Figure 2 represents the design curves resulting from various fatigue laws, for a pavement of stiffness class II, paver thickness 8 cm and a thickness of the unbound sub-base of 30 cm.

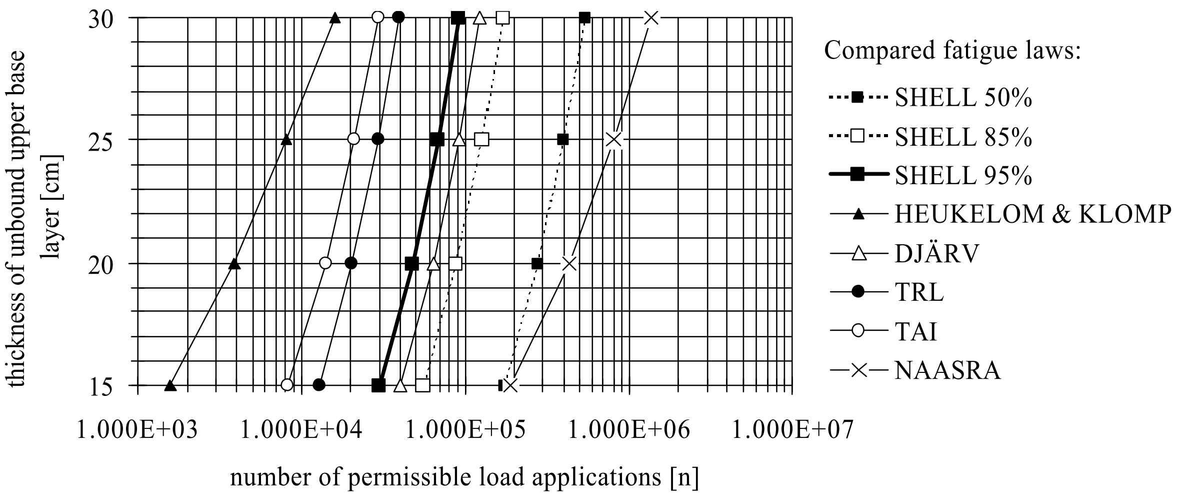

Figure 2: Design diagram for block pavement of stiffness class II, paver thickness 8 cm, with an unbound sub-base of 30 cm, and an unbound base of variable thickness (Janda 2003).

As regards the pavement type with a porous concrete base course, the horizontal bending stress at the bottom of the concrete layer is the critical one for thickness design. According to the requirements for the mix design and the strength of the concrete given in the guideline RVS 8S.06.4 an E-modulus of 27,500 MN/m² is assumed for the design calculation. As there are no laboratory tests available, a rather low value of 1.3 MN/m² is assessed for the bending strength, which is only twice the value taken for cement stabilized layers. Concerning the fatigue calculations, the criterion that is proposed by Leykauf (1982) for cement stabilizations is applied. However, the design assumptions are rather conservative, which can be justified by the lack of long-term experience with this type of material. Figure 3 compares the results of fatigue calculations for a pavement of stiffness class I, derived by means of the criterion of Leykauf, and of the Smith-diagram (Eisenmann 1999) for concrete slabs.

3.3 Pavements with small slabs

Usually, one single paving stone in a block pavement is loaded by compressive stresses only. In contrast, bending stresses appear in small loaded slabs. In many cases the bending provokes the slab to crack, and hence, early failure of this type of pavement occurs. Therefore, besides a full and homogeneous support from the bedding layer, the slab needs to be able to withstand the bending stresses, which are caused by the wheel load of the representative vehicle.

Within the framework of this study, various design calculations have been made for slabs from natural stones and plain concrete slabs, taking into account both, different bending strengths and different slab sizes. For the calculations different design approaches were applied, proposed by Eisenmann (1999), DNV (1984), and the Austrian standard ÖNORM B

3118 (2003) respectively. Detailed calculations are included in Janda (2003). The design method referring to Eisenmann is considered as the most promising one, also because of the possibility to take into account variations of most of the input parameters. Consequently, these results are used for the determination of the necessary design thickness. Figure 4 gives an example of the resulting design curves for a small slab.

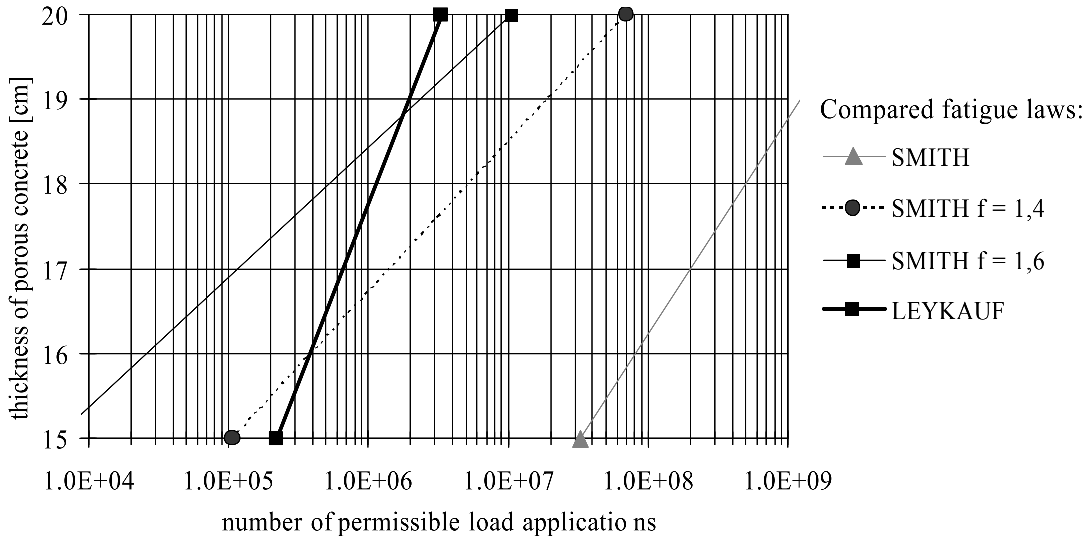

Figure 3: Design diagram for block pavement of stiffness class I, paver thickness 8 cm, and a porous concrete base layer (Janda 2003).

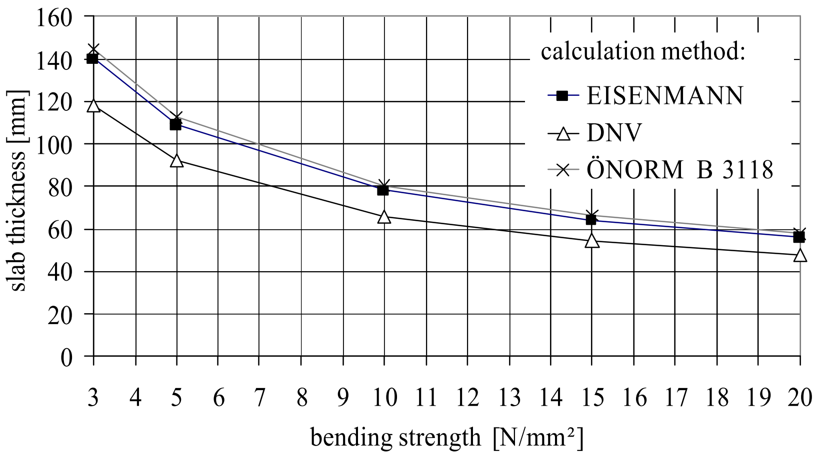

Figure 4: Design diagram for a concrete slab, sized 480 x 480 mm, according to different calculation procedures (Janda 2003).

4 DESIGN TABLES FOR ROUTINE APPLICATION

4.1 Block pavements

As a result from the design calculations described above, and taking into account the necessary rounding up and a grading of the thicknesses of the pavement layers for safety and practical reasons, two design tables are drawn. Figure 5 represents the table for block pavements with unbound base layers, while Figure 6 is applicable for pavements with base layers of porous concrete. The tables are entered by the load class, which follows from traffic assessment. Then, depending on the type of the paving stones and the laying pattern, the most suitable construction type out of the given three solutions is chosen. The only restriction of application concerns the types 7c and 8c, which must not be used in areas with high horizontal stresses, like braking sections, narrow bends, or roundabouts.

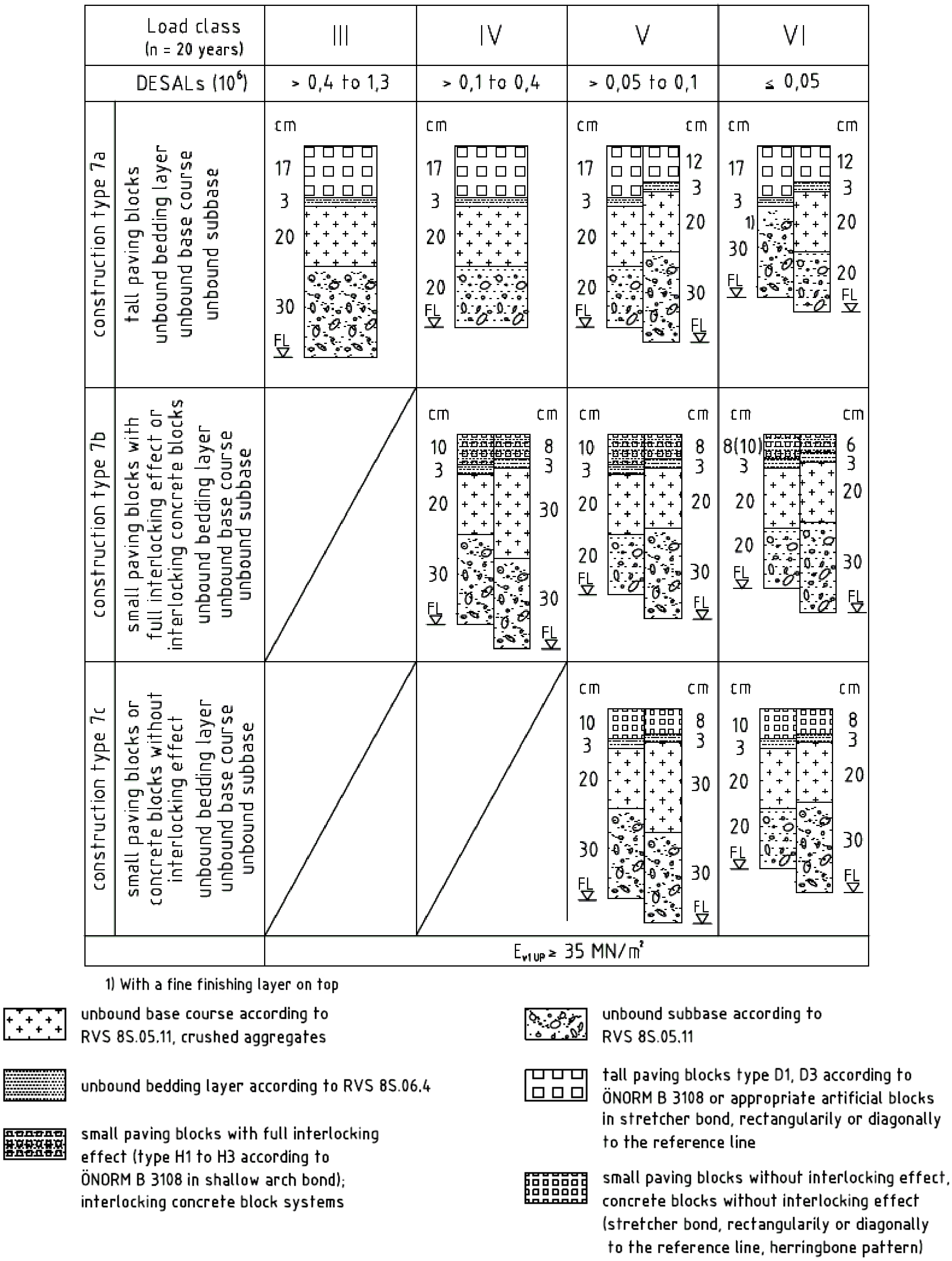

Figure 5: Design table for block pavements with unbound base layers (RVS 3.63, 2005).

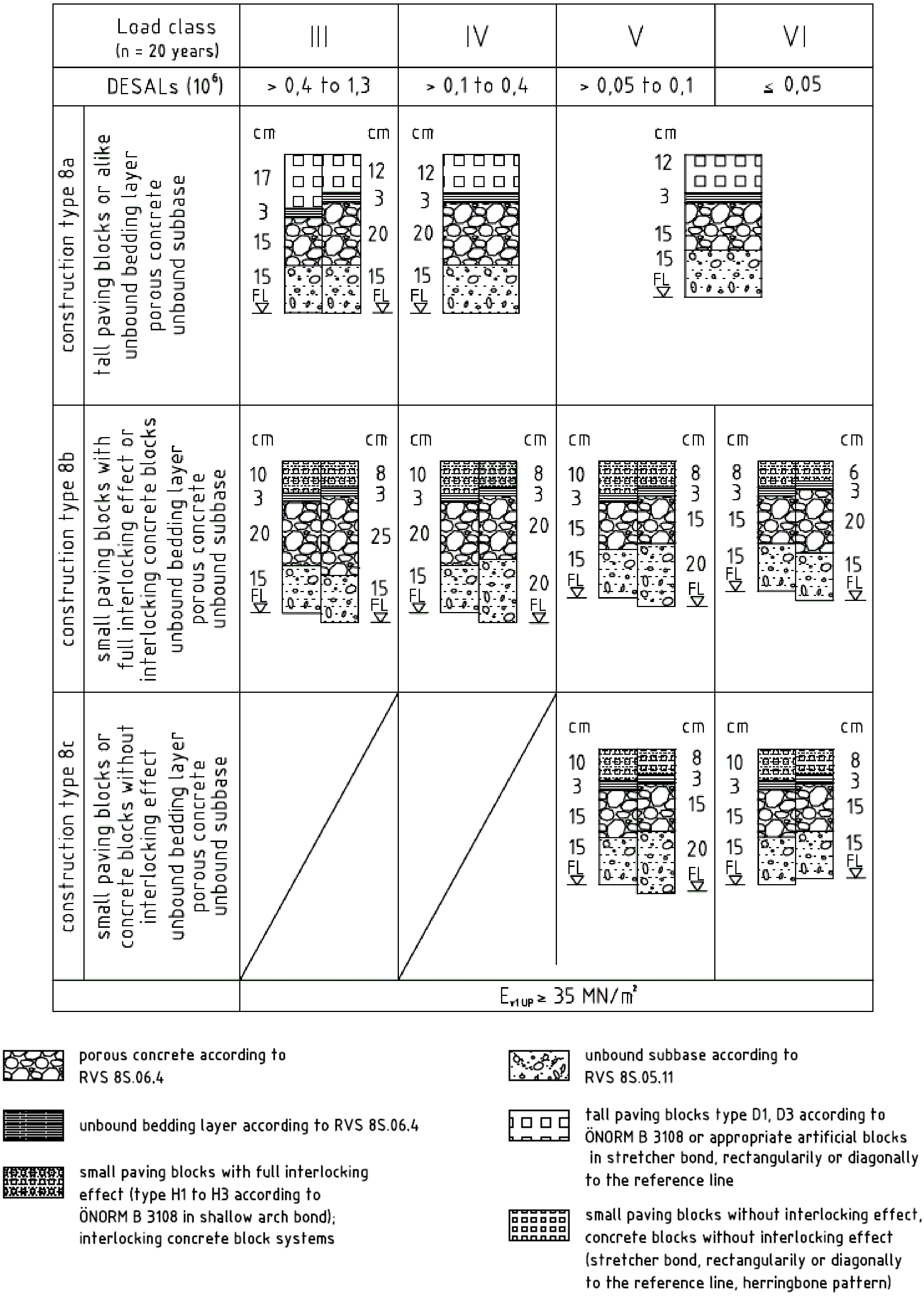

Figure 6: Design table for block pavements with porous concrete base layer (RVS 3.63, 2005).

4.2 Pavements with small slabs

Two tables for the minimum thickness requirements of small slabs have been derived from the design calculations (see Table 5 for natural stone slabs and Table 6 for concrete slabs), and again, some rounding up and necessary simplification have been applied for the practical use. The application of these tables is restricted to a minimum bending stress of 10 N/mm² for natural stone slabs and of 4 N/mm² for concrete slabs respectively. If slabs of different sizes are combined in a pattern, the higher minimum thickness has to be respected for the complete pavement (no variation of thickness is allowed).

For pavements with small slabs the thicknesses of the base layers have to be taken from Figure 5 or Figure 6, from construction type 7c or 8c only, according to the given load class and taking into account the required minimum thickness of the slab. Generally, these types of pavements should be used for load classes V and VI only.

Table 5: Required minimum thickness for natural stone slabs

slab size, up to length/width [cm]	minimum slab thickness [cm]
24/24	8
32/32	10
36/24	12
48/32	12
48/48	12
72/48	14

Table 6: Required minimum thickness for concrete slabs

slab size, up to length/width [cm]	minimum slab thickness [cm]
30/30	10
40/40	12
50/50	14
60/40	16
75/50	18
100/100	18

5 CONCLUSION

The increased use of block pavements and pavements with small slabs especially in urban areas during the last decade on the one hand, and a lot of poor experience with early failure of these pavements on the other, are the background for the implementation of respective standard construction types in the existing Austrian design guideline. The first step was the development of a guideline for the requirements of the layers and paving materials used in this type of pavement to have a clear basis for quality control and contracting (RVS 8S.06.4, 2005).

The second step was to extend the existing guideline for pavement design by adding block pavements and pavements with small slabs, while taking into account the given traffic load and the necessary supporting base layers to ensure the full bearing capacity of the pavement (RVS 3.63, 2005). The structure of this new guideline, which was published recently, the principles of its practical application for design calculation, and the new design catalogues of standardized block pavements and pavements of small slabs are presented in this paper.

One of the interesting experiences during the drafting of the guideline was the fruitful and good cooperation between design engineers and experts from the handcraft side with great experience in constructing these types of pavements.

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