



Swedish Design Tables for Permeable Block Pavements



Nyckelord:

Permeable concrete block pavements, design table, heavy vehicle simulator (HVS) test, rut depth, *E*-modulus, equivalent standard axle load (ESAL).

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HVS-test at VTI

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Förord

Föreliggande rapport är en del av projektet Klimatsäkrade systemlösningar för urbana ytor, ett tvärvetenskapligt samarbetsprojekt mellan; CBI Betonginstitutet (Projektkoordinator, numer RISE/CBI), Statens Väg och Transportforskningsinstitut (VTI), Sveriges Tekniska Forskningsinstitut (SP) – Numer RISE, Sveriges lantbruksuniversitet (SLU), Benders, Cementa, NCC, Starka, Stenindustrins forskningsinstitut, Stenteknik, Stockholms stad, Helsingborgs Stad, Uppsala Stad, Göteborgs Stad, Lunds Kommun, Växjö Kommun, Trädgårdsanläggarnas förbund, Movium (SLU), VIÖS, CEC Design, StormTac, Ramböll och Sweco.

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Sammanfattning

Dränerande markstenbeläggningar har börjat bli populärare i Sverige på grund av klimathänsyn. Då fler konstruktioner uppförs samt behov av ökad trafikbelastning och kommande klimatförändringar är det nödvändigt att utveckla riktlinjer för byggandet av denna typ av vägkonstruktioner. Rapporten illustrerar framtagande av dimensioneringstabeller för dränerande markstenskonstruktioner av olika typer.

De föreslagna dimensioneringstabellerna har utvecklats genom att modifiera det befintliga tabeller för betongmarksten. Dimensioneringstabellen är baserade på studier av olika typer av dränerande markstenskonstruktioner jämfört med en standard betongmarkstenskonstruktion. Prestandan har utvärderats i accelererade tester med hjälp av en tunga fordonssimulatorn (HVS- Heavy Vehicle Simulator). Jämförande analyser har utförts med hjälp av PMS Objekt (dimensioneringsverktyg), som tagits fram av Trafikverket.

Grundprincipen bakom utvecklingen av dimensioneringstabellerna var att justera förstärkningslagrets tjocklek hos markstenskonstruktionerna så att de motsvarar prestandan av standard markstenskonstruktionen. De nödvändiga justeringar i förstärkningslagret tjocklek beräknades med PMS Objekt baserat på data av den uppkomna spårdjupsutvecklingen i konstruktionerna under test av HVS-utrustningen. Den erhållna justeringen för varje konstruktion applicerades på den befintliga dimensioneringstabellen och presenteras i denna rapport.

Redovisade dimensioneringstabeller baserar sig på preliminära resultat och kan komma att revideras vid kommande analyser. Dimensioneringstabellerna bör inte appliceras utan noggranna egna studier av aktuellt projekt. Denna rapport beskriver endast utvärdering av strukturella egenskaper. Flödesanalys och dimensionering av vattenmagasinerande egenskaper behandlas inte.

Summary

Permeable concrete block pavements (PCBPs) are getting attention in Sweden mostly due to environmental concerns. With the growing implementation of PCBPs with increased traffic loading and changing climatic conditions, it is necessary to develop guidelines for construction of such pavement structures. This report illustrates the development of design tables for PCBPs of a few different types.

The proposed design tables were developed by modifying the existing design table for standard concrete block pavements. The modifications were suggested based on comparative performance of the different types of PCBPs with respect to a standard concrete block pavement. The performance was evaluated in accelerated pavement tests employing the heavy vehicle simulator (HVS). The analyses were carried out using the pavement design software PMS Objekt, developed by Trafikverket.

The basic principle behind the development of the design tables was to adjust the subbase layer thickness of the PCBP in question to render equivalent performance of a standard concrete block pavement. The necessary adjustments in subbase layer thicknesses were calculated using PMS Objekt based on the rut development in the structures in HVS tests. The obtained adjustment for each structure was applied to the existing design table and presented in this report.

The presented design tables are based on preliminary results and may be revised in forthcoming analysis. The design tables should not be applied without careful structural analysis. Furthermore, the focus of the design tables is only on the structural or mechanical performance. The hydraulic and water storage designs are not included in this report.

1 Introduction

Increased urbanization is leading to increased impervious land surface which adversely affects the growth of trees and vegetation and local climate. Furthermore, the increased proportion of paved surface generates increased surface run off that often overloads the existing sewerage system resulting in floods. One approach to mitigate these issues is to build permeable pavement systems that can effectively drain out storm water, retain water and help growing of trees and vegetation while maintaining their demand on structural performance (Larson, 1990; Pratt, 1990; Hajek, et al., 1992; Li et al., 2014; Weiss et al., 2015; Weiss et al., 2017).

Permeable pavements can be of different types depending on their functions and local conditions. Permeable block pavements are getting increased attention in Sweden where they are mostly used in parking lots and other low trafficked areas. In many cases, the structures must handle large and repeated loads such as bus traffic, cleaning machines and truck traffic. These are required to improve climate on-site and manage climate change while being functional, sustainable and inexpensive in operation. This places great demands on materials, design and execution.

1.1 Objectives

This report illustrates the development of design tables for permeable block pavements of a few different types for Swedish conditions. The design tables were developed based on accelerated pavement testing of different test structures with heavy vehicle simulator (HVS). The focus of the study was on the structural performance. Hydrological performance was beyond the scope of this work.

2 Methodology

The design tables were developed based on a comparative study of the rutting performance of a few permeable concrete block pavement (PCBP) structures and a standard concrete block pavement structure under HVS tests.

During the HVS tests, the rut depth for each structure was measured as a function of the number of wheel passes. The number of wheel passes was then converted to equivalent standard axle loads (ESALs) of 100 kN and plots of rut depths versus ESALs were generated for all the structures.

From the rut depth versus ESALs plots (shown later in Figure 6 and 8), the required number of ESALs to develop a certain rut depth (here 12 mm was chosen) for the different structures was determined. For some structures, linear extrapolation was necessary. For the standard structure (structure 3 as described later), the required number of ESALs to develop 12 mm

rutting was set as the reference and termed as ESAL1, whereas for the other structures it was termed as ESAL2. During the development of the design tables, the assumption was that by adjusting the thickness of the subbase layer of the permeable structures, their rutting performance could be equivalent to that of the standard structure, i.e., ESAL2 should equal ESAL1.

Next, the pavement design software PMS Objekt was utilized for comparison of pavement performance. For a certain permeable structure, the actual thickness of the different layers (except for the subbase layer since the thickness of this layer was calculated in PMS Objekt), and a range of assumed elastic modulus (E) values for all the layers were fed as input in the PMS Objekt calculations. With trial and error method, first the thickness t_1 of the subbase layer was estimated that results in a design ESAL equal to ESAL1. Then with further trial and error, the thickness of the subbase layer t_2 was estimated that results in a design ESAL equal to ESAL2. It was hypothesized that if the subbase layer thickness t_2 of the permeable pavement structure in question is modified to the thickness t_1 , its performance would become similar to that of the standard structure. Hence the percentage difference between t_2 and t_1 was applied to the subbase layer thickness of the existing design table for the standard structure. The whole process was repeated several times for a particular structure assuming a few different reasonable E modulus values and the most reasonable adjustment was adopted (based on engineering judgement and observation of the quality of measurements and construction of the HVS structures). Although FWD measurements were performed during the construction, backcalculation of layer moduli was not performed. The adopted methodology is schematically presented in Figure 1.

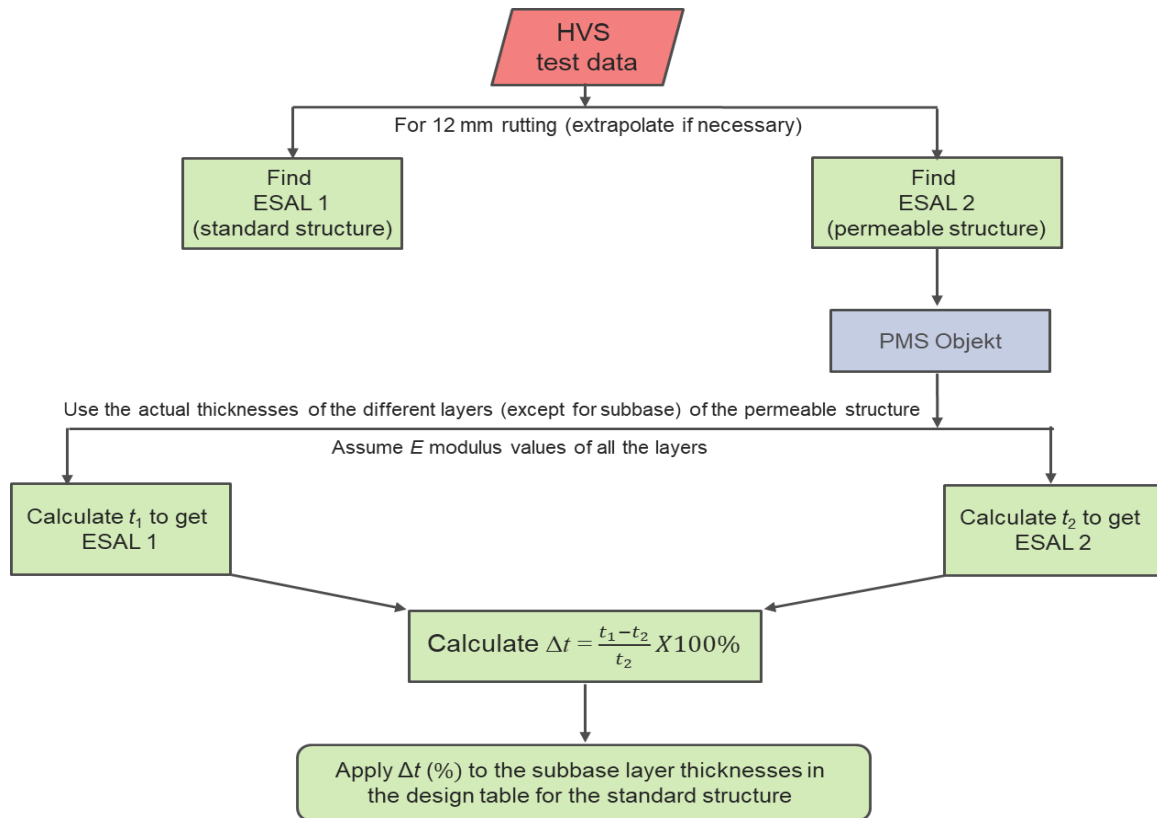


Figure 1. Schematic of the adopted methodology for developing the design tables

3 HVS testing

3.1 The HVS equipment and test conditions

The HVS equipment, shown in Figure 2, simulates degradation of pavements from heavy traffic. The tests can be performed relatively quickly where many years of traffic can be simulated in a few weeks. The HVS equipment is a movable unit which remains stationary over a test structure when performing the test. It has a running wheel (single or dual configuration) in the middle part of the equipment that applies the traffic loading on the structure. The wheel can run at a speed of up to 12 km/hour. The wheel load is adjustable from 30 kN up to a maximum of 110 kN. The position of the wheel can also be shifted laterally to simulate the effect of lateral wander of traffic.

For this study, all the test structures were built inside VTI's HVS test facility. The test pit is a concrete structure of 15 m in length, 5 m wide and 1.2 m deep. During each run of the HVS equipment, two structures were built and tested simultaneously in the test pit, as shown in Figure 3. During these tests, the lateral movement of the wheel was restricted. The load was gradually increased from 30 to 60 kN due to uncertainties about how well the construction would withstand heavy traffic. In most part of the test the load was 60 kN, which corresponds to the axle load of 12 tons from a heavy truck. The resulting rut depth was measured along five profiles on each surface and a mean rut depth was calculated. During the tests, the ground water table was raised from the bottom in two steps. The details of the test conditions are presented in Table 1. More information about the test procedure is in the report about the HVS-test. (Hellman, 2017).

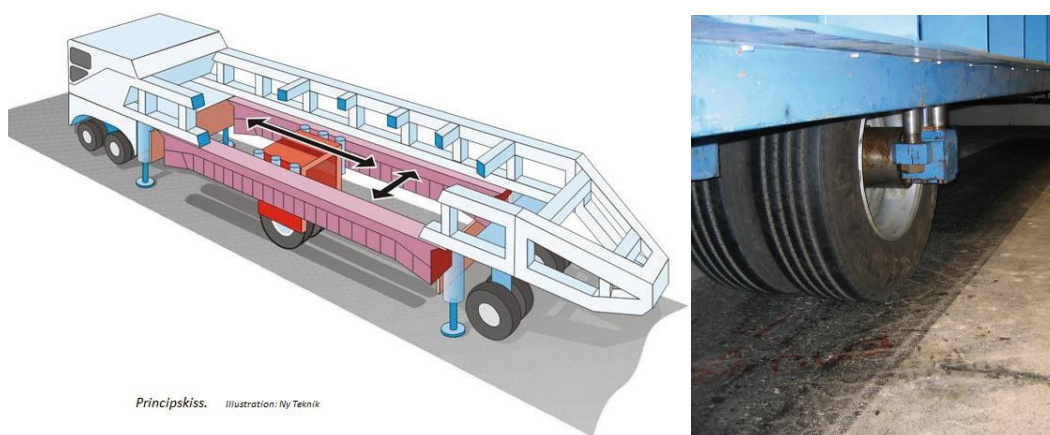


Figure 2. The HVS equipment



Figure 3. Plan view of the HVS test structure

Table 1. HVS test conditions

Number of wheel passes	Wheel load (dual wheel)	Moisture condition	Wheel speed	Tire inflation pressure
0-500	30 kN	Natural moisture	12 km/h	800 kPa
500–59 000	40 kN			
59 000–145 000	60 kN			
145 000–350 000	60 kN	Groundwater table 30 cm below the surface of the subgrade		
350 000–420 000	60 kN	Groundwater table up to half of the subbase layer		

3.2 The test structures

Ten different structures of interest were tested in this study. The structures were constructed partly for other purposes rather than developing a design table. However, it was possible to use the output data in this work. Due to the fact that some data is missing some extrapolations has been carried out. The structures are numbered and shown schematically in Figure 4. In this case, structure 3 is a standard non-permeable type concrete block pavement structure which is considered as the reference structure. The performance of all the other structures were compared to this structure. The design tables were developed in such a way that the performance of all the structures become equivalent to structure 3. The structures 7, 8, 9 and 10 were instrumented internally, as shown in Figure 4 (only for structure 7 and 8 are shown), to measure the various responses in the different layers (for more information about instrumentation see Hellman 2017). During each run of the HVS, two structures were tested simultaneously (for example structure 1 and 2, 3 and 4 and so on).

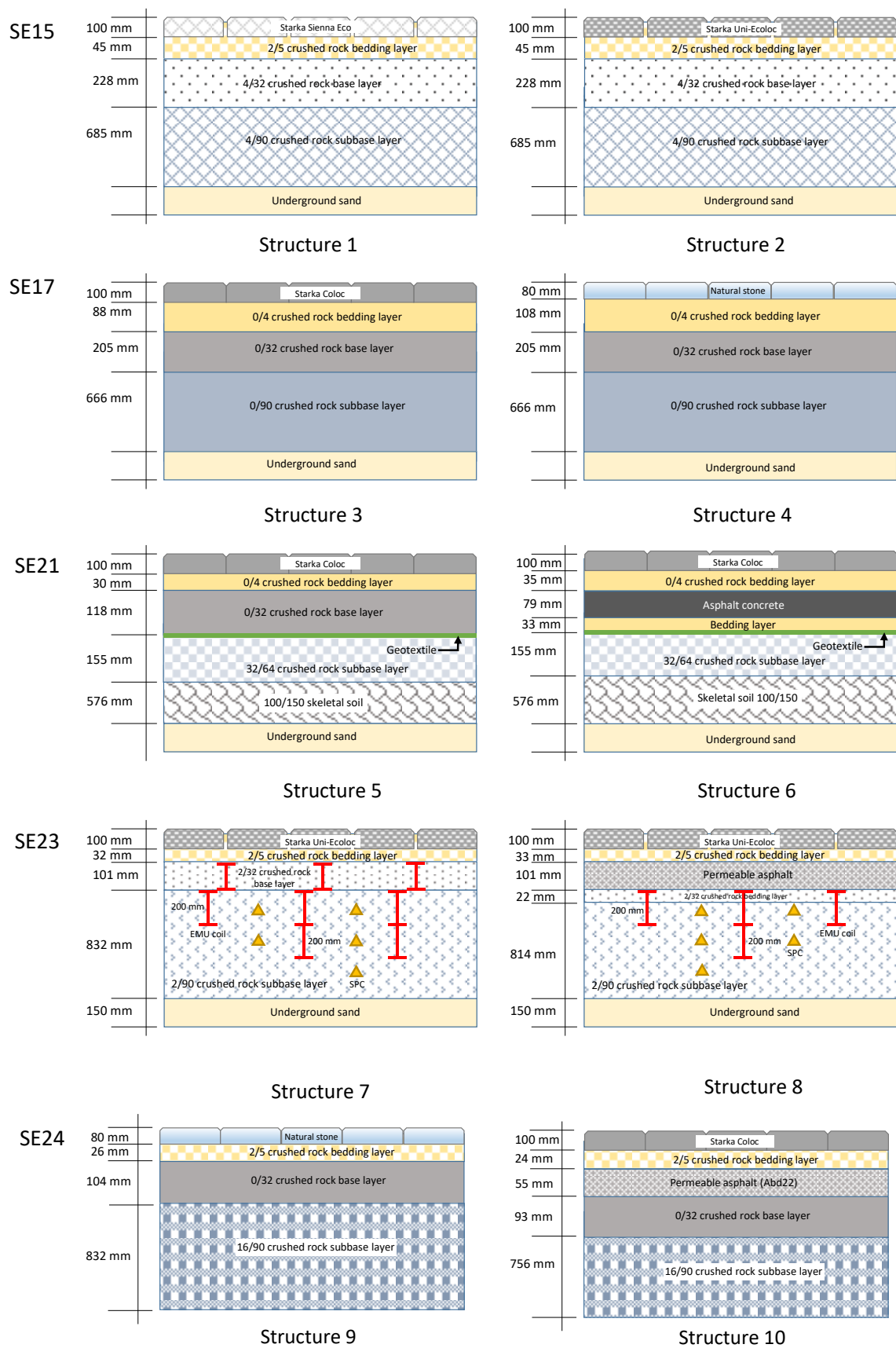


Figure 4. Schematic of the test structures

3.3 Results from the HVS tests

As mentioned earlier, the development of rutting on the surface of the structures were measured along five profiles during the HVS tests. In this report, the average rut depth from these five profiles is reported. The varying wheel loads used during the HVS tests were converted to ESALs of 100 kN using the fourth power rule. Although it is not too difficult to determine a wheel or an axle load for an individual vehicle, it becomes quite complicated to determine the number and types of wheel/axle loads that a particular pavement will be subject to over its design life. Furthermore, it is not the wheel load but rather the damage to the pavement caused by the wheel load that is of primary concern. The most common historical approach is to convert damage from wheel loads of various magnitudes and repetitions (“mixed traffic”) to damage from an equivalent number of “standard” or “equivalent” loads. Therefore, as a rule-of-thumb, the damage caused by a particular load is roughly related to the equivalent load (100 kN) by a power of four as follows:

$$ESAL = \left(\frac{L}{100} \right)^4 \quad (1)$$

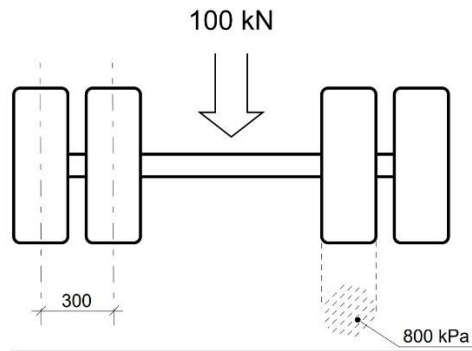


Figure 5. Definition of a standard axle (ref: Trafikverket).

The development of rutting on the surfaces of the different structures as functions of ESALs is presented in Figure 6. The accumulated rut depths at 50 000 ESALs are presented in Figure 7. 50 000 ESALs equals the design life traffic for traffic class 0 (according to Svensk Markbetong (2002)). Since, for a number of structures, the tests were not terminated at the same accumulated traffic load (i.e. some were terminated at around 250 000 ESALs, corresponding to lower traffic classes), linear extrapolation was applied to estimate the rut depths for those structures in higher traffic classes (corresponding to higher accumulated traffic loads). Furthermore, for the same reason, the performance of the structures was compared in dry states (i.e. prior to raising the ground water level) for fair comparisons and the necessary extrapolations were carried out from the dry parts of the curves. The initial objectives of the HVS tests did not include the development of the design tables. Hence data were not available for all the structures in nearly saturated conditions. Albeit permeable pavements are designed for saturated conditions, the design tables developed here were based on the dry test conditions. The reason is that these design tables were not developed from the scratch. Rather, the proposed design tables are modifications of an existing design table for a

standard concrete block pavement based on comparative performance of various types of structures. Thus, it was assumed that the methodology is independent of moisture conditions provided that

- (a) the design table for the standard structure is suitable for saturated conditions as well and
- (b) the relative performance of the different materials will remain similar in both dry and saturated conditions.

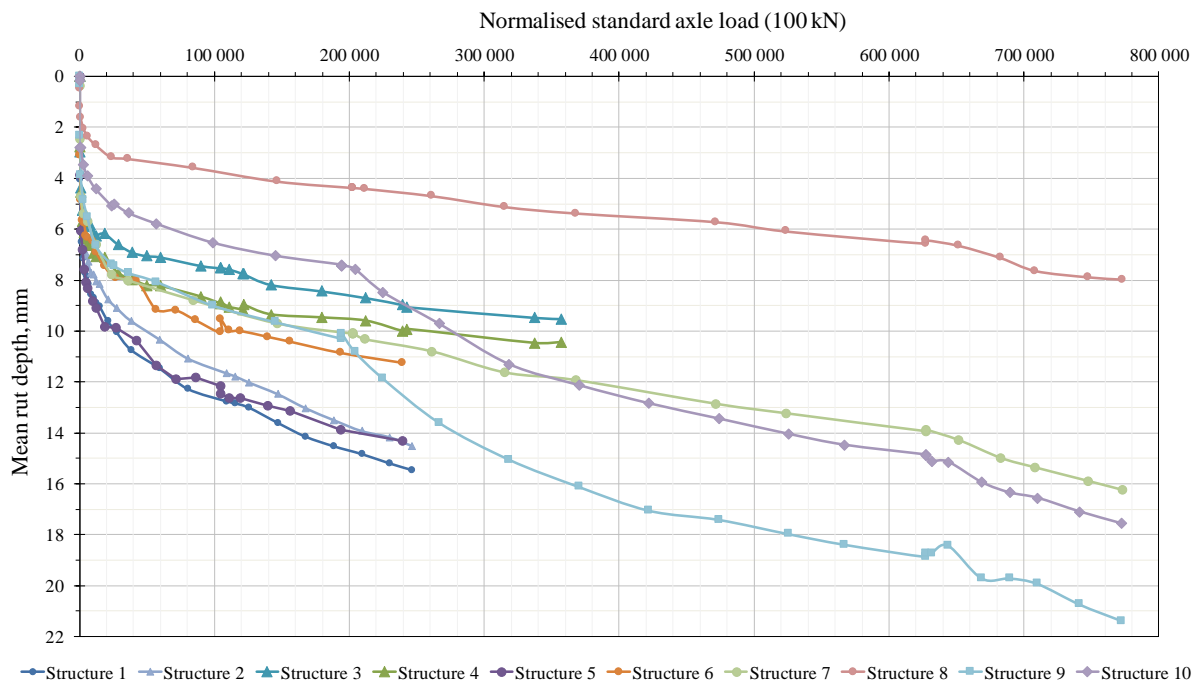


Figure 6. Development of rutting in different structure during the HVS tests as functions of ESALs

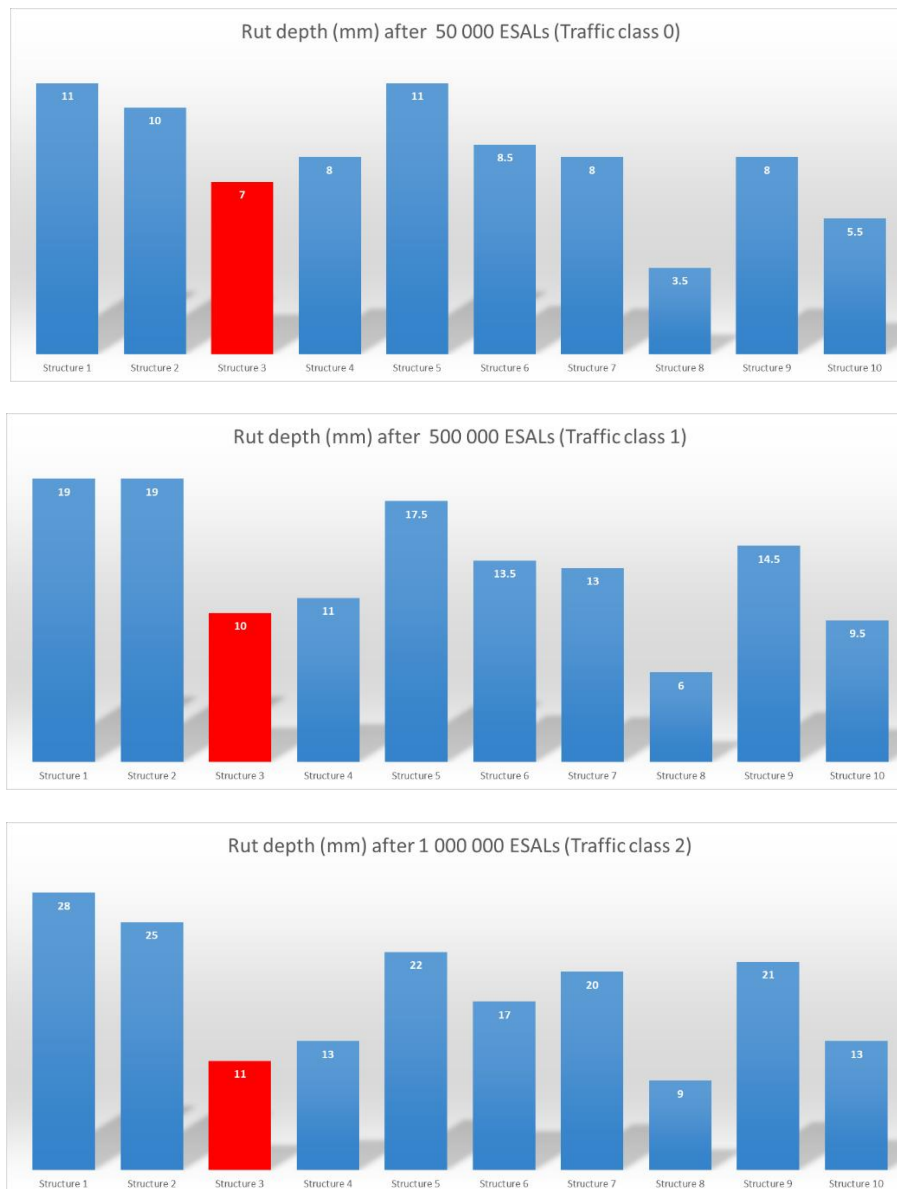


Figure 7. Rut depths of the different structures in HVS tests in different traffic classes

4 Development of the design tables

Comparing the performance of the different kinds of permeable structures in HVS test to that of the standard structure, the existing design table (Svensk Markbetong and Svenska Kommunförbundet, 2002) for standard concrete block pavement structures was modified to generate the design table for the permeable structures. The pavement design software PMS Objekt, developed by the Swedish Transport Administration (Trafikverket) that is commonly used in Sweden, was used for the calculations.

The existing Swedish design table for standard concrete block pavement structures (Svensk Markbetong and Svenska Kommunförbundet, 2002) is presented in Table 2. This table suggests the thicknesses of the different layers of a typical concrete block pavement structure designed for various traffic conditions in Swedish climate zones 1-6 where the subbase layer should consist of crushed rock aggregates.

Table 2. Design table for layer thicknesses of standard concrete block pavements (Table 4.6 in Svensk Markbetong and Svenska Kommunförbundet, 2002)

Klimatzon 1-6, krossat material i förstärklingslagret								
Trafik	Tillåtet antal standardaxlar	0	0	<50 000	50 000-500 000	500 000-1 000 000	1 000 000-2 500 000	2 500 000-5 000 000
	Trafikklas	G*	GC	0*	1	2	3	4
Överbyggnad	Tjocklek[mm]							
	Marksten	50	60	80	80	80	80**	80**
	Sättilager	30	30	30	30	30	30	30
	Obundet bärlager	Hela ÖB	80	80	80	80	80	80
	Förstärkningslagers tjocklek på terrass av materialtyp	1	0	0	70	100	190	250
	2	0	70	70	150	210	290	350
	3	80	70	70	240	290	350	400
	4	100	70	70	270	330	410	470
	5	140	170	170	400	460	580	680
*) Svensk Markbetongs egen definition								
**) Rekommenderad tjocklek på marksten är 100 mm								

4.1 Assumptions and design criteria

For this study, it was assumed that Table 2 should also be applicable to the PCBP counterpart with reasonable/logical adjustments to the thicknesses of the subbase layers. For the PCBP, the allowable rut depth was selected to be 21 mm. Thus, with one maintenance cycle in between, the design rut depth was set to be 42 mm.

4.2 Extrapolation of HVS data

Within the scope of the HVS testing of the different structures, attained rut depth for most of the cases were far below the design rut depth. Given the principles adopted for developing the design tables based on pre-existing design tables for standard block pavement structures, it appears that the methodology is fairly independent of the selection of the rut depth. Thus, to minimize the uncertainty in extrapolating the rut depth versus the ESALs data from the HVS trials, a rut depth of 12 mm was selected to compare the different structures. The extrapolation can be done in several ways. However, sufficient data were not available to properly fit a permanent deformation model considering e.g. shakedown behavior or other deterioration model of the structure. Hence, for this study, to be on the conservative side, linear extrapolation through the last few points were selected. As mentioned earlier, the extrapolations were done based on the dry parts of the curves. An example of the extrapolation method used here is shown in Figure 8. In this example, it was found that for 12 mm rut depth the required number of ESALs for structure 3 (reference structure) is 0.94 million (= ESAL1). For the same rut depth, the required number of ESALs for structure 1 or 5 is 0.075 million (= ESAL2). These values were later used for the calculations in PMS Objekt.

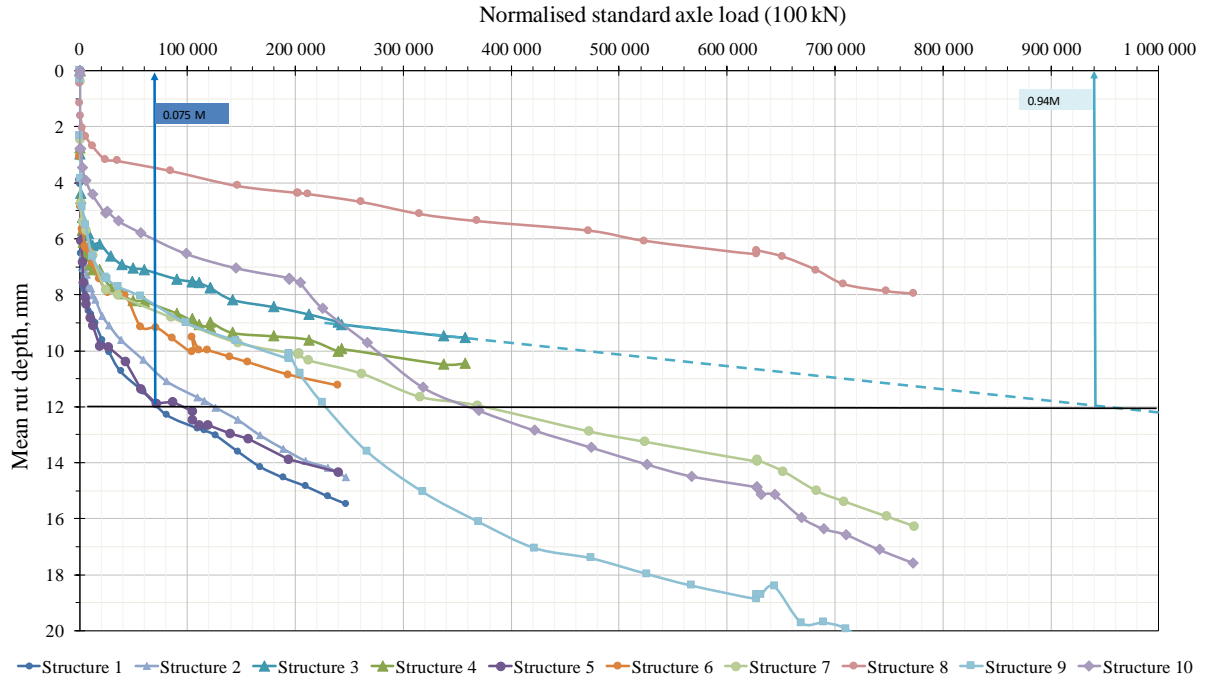


Figure 8. An example of the extrapolation of the HVS data

4.3 Calculations in PMS Objekt

For the calculations in PMS Objekt, the thicknesses of the different layers, except for the subbase layer of a structure in question were used as input values. The subgrade strain criteria in PMS Objekt was used for the calculations. A screen shot of the PMS Objekt interface is shown in Figure 9. The E modulus values of the different layers were assumed based on literature (Judycki et al., 1996; Ahmed and Erlingsson, 2016; Li et al., 2014; Rahman, 2016). Trials with different sets of E modulus values were carried out. Since the design tables were developed based on a comparative performance of the structures, it was assumed that constant values of the E modulus values throughout the year will be sufficient. As shown in Figure 8, the reference value of ESALs or ESAL1 is 0.94 M (here M stands for million) (structure 3, for 12 mm rutting). Thus, in PMS Objekt, the thickness of the subbase layer was adjusted until the design ESALs value was equal to ESAL1. This thickness of the subbase layer, corresponding to the design ESAL, was termed as t_1 . Again, for the structure in question, the number of ESALs required for 12 mm rutting was determined which is termed as ESAL2. For example, in Figure 8, for structure 1, ESAL2 = 0.075 M. Hence for this structure, the subbase layer thickness was adjusted again in PMS Objekt to get a design ESALs value equal to ESAL2. This thickness was termed as t_2 . Now it was assumed that, for that particular structure, if the subbase layer thickness is changed from t_2 to t_1 , the performance of that structure will be equivalent to the reference structure. Based on this assumption, the materials in Table 2 were changed to the materials used in a structure in question and the thickness of

the subbase layer was adjusted according to the same percentage change required (obtained during the PMS Objekt calculations), that is:

$$\Delta t = \frac{t_1 - t_2}{t_2} \times 100\% \quad (2)$$

where Δt is the percentage change applied to the subbase layer thickness of the standard design table (Table 2).

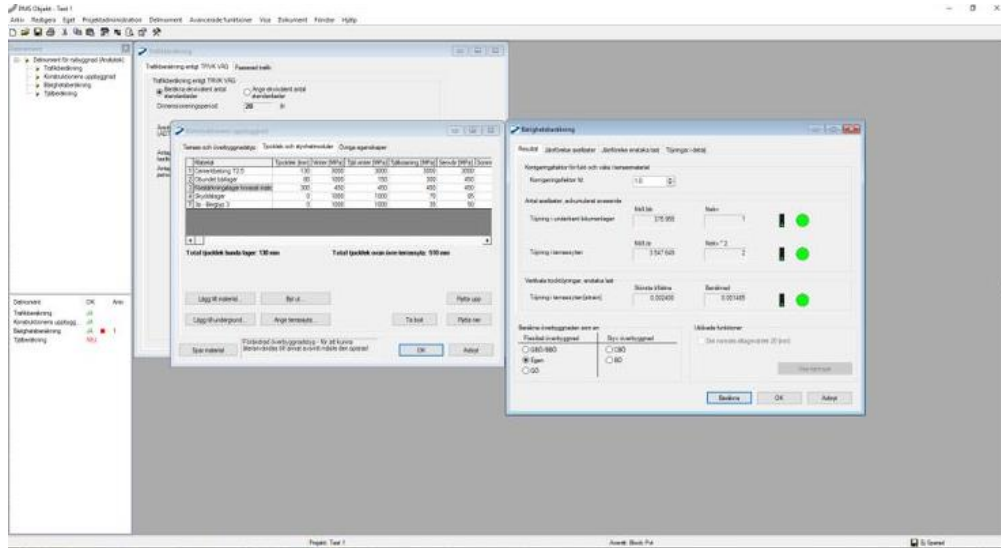


Figure 9. Screen shot of PMS Objekt's interface

An example of trials with different assumed E modulus values of the different layers of structure 1 and the obtained % change required to apply to Table 2 is shown in Table 3. Table 4 presents the summary of the range of subbase layer thickness modifications required to Table 2 for the different structures.

Table 3. An example of trials in PMS Objekt with various E modulus values of different layers.

ESAL1 = 0.94 M, ESAL2 for structure 1 = 0.075 M		
	Trial 1	Trial 2
Assumed E modulus of layer 1	1000	2000
Assumed E modulus of layer 2	100	200
Assumed E modulus of layer 3	200	400
Assumed E modulus of layer 4	200	400
Subgrade type	3a	3a
Subbase thickness t_1	438	321
Subbase thickness t_2	240	153
Δt	198	168
Δt (%)	83	110

Table 4. Obtained % change in subbase layer thicknesses required for the different structures in relation to the standard structure.

Structure no.	Increase subbase thickness by %
1	83 - 110
2	56 - 80
3	0
4	20 - 30
5	65 - 92
6	30-70
7	20 - 25
8	30-40
9	23 - 27
10	4.5 - 6.0

5 Proposed design tables

Based on Table 4, the required modifications to the subbase layer thicknesses were applied to Table 2 and the following design tables were derived for the different structures. To minimize the number of design tables, the structures were grouped in pairs where applicable, and some modifications were suggested to switch between structures within a group. Although the design tables presented here include traffic class 3 and 4, this is for illustrative purposes only. It is not recommended that, without further studies and analysis, permeable structures are subjected to traffic class 3 and 4!

5.1 Structure 1 and 2

This design table (Table 5) was adopted for structure 2 considering 70% increase in subbase layer thickness values in Table 2. Since for structure 1, according to Table 4, 83 to 110 % increase in subbase layer thicknesses in Table 2 is necessary, another 20% increase in those thicknesses were considered when using the following table for structure 1.

5.2 Structure 3 and 4

Structure 3 is the standard construction. Hence no changes to Table 2 was necessary. Based on Table 4, to use the following table (Table 6) for structure 4, 30% increase in subbase layer thicknesses was recommended.

Table 5. Design table for structure type 1 and 2 (traffic class 3 and 4 is not recommended!)

Klimatzon 1-6, krossat material i förstärkingslagret								
Trafik	Tillåtet antal standardaxlar	0	0	<50 000	50 000-500 000	500 000-1000 000	1 000 000-2 500 000	2 500 000-5 000 000
	Trafikklas	G*	GC	0*	1	2	3	4
Överbyggnad	Tjocklek[mm]							
	Marksten ¹	50	60	80	80	80	80**	80**
	Sättningslager (2/5)	30	30	30	30	30	30	30
	Obundet bärlager (4/32)	Hela ÖB	80	80	80	80	80	80
	Förstärkningslagers (4/90) tjocklek på terrass av materialtyp	1	0	0	119	170	323	425
		2	0	119	119	255	357	493
		3	136	119	119	408	493	595
	4	170	119	119	459	561	697	
	5	238	289	289	680	782	986	1156

¹ If Siena Eco concrete blocks are used instead of Uni Ecoloc concrete blocks, the thickness of the subbase layer should be increased by 20%.

*) Svensk Markbetongs egen definition

**) Rekommenderad tjocklek på marksten är 100 mm

80 mm

30 mm

80 mm

1.2x mm

Starka Siena Eco

2/5 crushed rock bedding layer

4/32 crushed rock base layer

4/90 crushed rock subbase layer

Subgrade

Structure 1

80 mm

30 mm

80 mm

x mm

Starka Uni-Ecoloc

2/5 crushed rock bedding layer

4/32 crushed rock base layer

4/90 crushed rock subbase layer

Subgrade

Structure 2

Table 6. Design table for structure type 3 and 4 (traffic class 3 and 4 is not recommended!)

Klimatzon 1-6, krossat material i förstärkingslagret								
Trafik	Tillåtet antal standardaxlar	0	0	<50 000	50 000-500 000	500 000-1000 000	1 000 000-2 500 000	2 500 000-5 000 000
	Trafikklas	G*	GC	0*	1	2	3	4
Överbyggnad	Tjocklek[mm]							
	Marksten ¹	50	60	80	80	80	80**	80**
	Sättningslager (0/4)	30	30	30	30	30	30	30
	Obundet bärlager (0/32)	Hela ÖB	80	80	80	80	80	80
	Förstärkningslagers (0/90) tjocklek på terrass av materialtyp	1	0	0	0	70	100	190
		2	0	70	70	150	210	290
		3	80	70	70	240	290	350
	4	100	70	70	270	330	410	
	5	140	170	170	400	460	580	

¹ If natural stones are used instead of interlocking concrete blocks, the thickness of the subbase layer should be increased by 30%.

*) Svensk Markbetongs egen definition

**) Rekommenderad tjocklek på marksten är 100 mm

80 mm

30 mm

80 mm

x mm

Starka Coloc

0/4 crushed rock bedding layer

0/32 crushed rock base layer

0/90 crushed rock subbase layer

Subgrade

Structure 3

80 mm

30 mm

80 mm

1.3x mm

Natural stone

0/4 crushed rock bedding layer

0/32 crushed rock base layer

0/90 crushed rock subbase layer

Subgrade

Structure 4

5.3 Structure 5 and 6

The following table (Table 7) was derived for structure 5. Structure 5 and 6 were very similar in construction except for the asphalt concrete (AC) layer introduced in structure 6 (any contribution of the bedding layer can be neglected). Thus, it was possible to calculate that for 12 mm rutting, if structure 5 has to sustain the same amount of ESALs as structure 6, what should be the thickness of the crushed rock base layer of structure 5. After trials with various *E* modulus values of the different layers, it was estimated that 1 mm AC layer may be replaced with 5 mm of unbound crushed rock layer. Based on this assumption, the following modification was proposed for structure 6:

80 mm asphalt = $5 \times 80 = 400$ mm unbound material.

Structure 5 already contains 120 mm unbound material. Adding an AC layer provides additional $400 - 120 = 280$ mm of equivalent unbound material which can be deducted from the subbase layer.

5.4 Structure 7 and 8

The following table (Table 8) was derived for structure 7. Based on the same assumption as used for structure 5 and 6, the following modification was proposed for structure 8:

55 mm asphalt = $5 \times 55 = 275$ mm unbound material.

Structure 7 already contains 80 mm unbound material. Adding an AC layer provides additional $275 - 80 = 195$ or 200 mm of equivalent unbound material which can be deducted from the subbase layer. Any contribution from the bedding layer can be neglected.

5.5 Structure 9 and 10

This table (Table 9) was developed for structure 9 and the modifications required for any changes here were recommended based on similar arguments as the previous structures.

Table 7. Design table for structure type 5 and 6 (traffic class 3 and 4 is not recommended!)

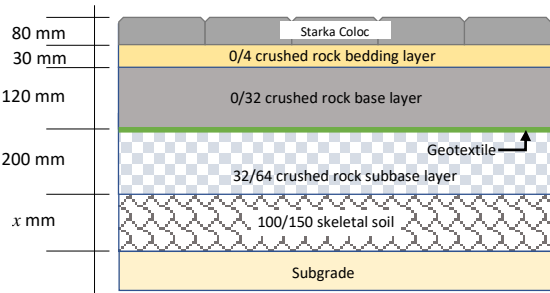
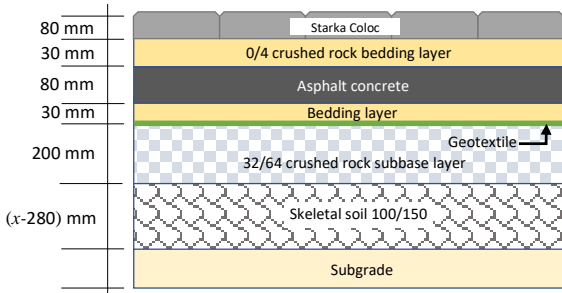
Klimatzon 1-6, krossat material i förstärklingslagret								
Trafik	Tillåtet antal standardaxlar	0	0	<50 000	50 000-500 000	500 000-1 000 000	1 000 000-2 500 000	2 500 000-5 000 000
	Trafikklass	G*	GC	0*	1	2	3	4
Överbyggnad	Tjocklek[mm]							
	Marksten (Starka coloc)	50	60	80	80	80	80**	80**
	Sättningslager (0/4)	30	30	30	30	30	30	30
	Obundet bärlager (0/32)				120	120	120	120
	Obundet bärlager (32/64)	Hela ÖB	200	200	200	200	200	200
	Skeletal soil (100/150) på terrass av materialtyp	1	0	0	122.5	175	332.5	437.5
		2	0	122.5	122.5	262.5	367.5	507.5
		3	140	122.5	122.5	420	507.5	612.5
		4	175	122.5	122.5	472.5	577.5	717.5
		5	245	297.5	297.5	700	805	1015
<p>¹ If 80 mm asphalt concrete is used instead of the 0/32 unbound base layer, the thickness of the subbase may be reduced by 280 mm.</p> <p>*) Svensk Markbetongs egen definition</p> <p>**) Rekommenderad tjocklek på marksten är 100 mm</p> <div style="display: flex; justify-content: space-around; align-items: flex-end;"> <div style="text-align: center;">  <p>Structure 5</p> </div> <div style="text-align: center;">  <p>Structure 6</p> </div> </div>								

Table 8. Design table for structure type 7 and 8 (traffic class 3 and 4 is not recommended!)

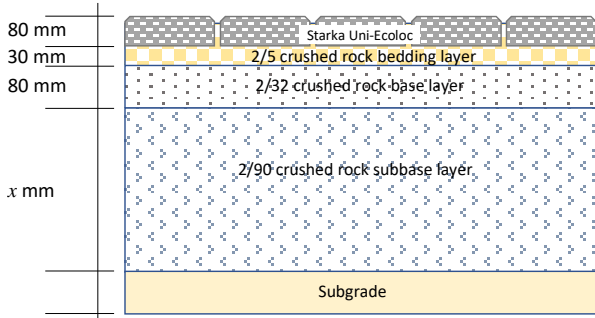
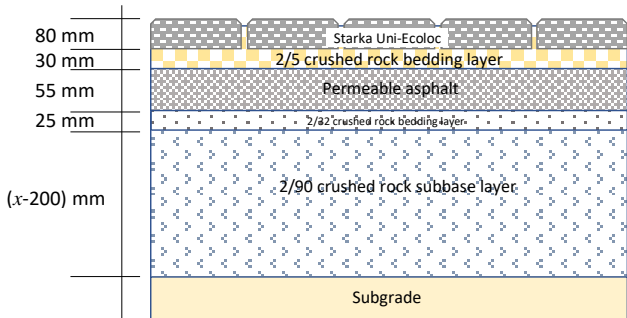
Klimatzon 1-6, krossat material i förstärklingslagret								
Trafik	Tillåtet antal standardaxlar	0	0	<50 000	50 000-500 000	500 000-1 000 000	1 000 000-2 500 000	2 500 000-5 000 000
	Trafikklas	G*	GC	0*	1	2	3	4
Överbyggnad	Tjocklek[mm]							
	Marksten	50	60	80	80	80	80**	80**
	Sättningslager (2/5)	30	30	30	30	30	30	30
	Obundet bärlager (2/32) ¹	Hela ÖB	80	80	80	80	80	80
	Förstärkningslagrets (2/90) tjocklek på terrass av materialtyp	1	0	0	88	125	238	313
		2	0	88	88	188	263	438
		3	100	88	88	300	363	500
		4	125	88	88	338	413	588
		5	175	213	213	500	575	850
¹ If 55 mm permeable asphalt concrete is used instead of the crushed rock base layer, the thickness of the subbase may be reduced by 200 mm.								
*) Svensk Markbetongs egen definition								
**) Rekommenderad tjocklek på marksten är 100 mm								
 <div style="display: flex; justify-content: space-around;"> <div> <p>80 mm</p> <p>30 mm</p> <p>80 mm</p> <p>x mm</p> </div> <div> <p>Structure 7</p> </div> </div>								
 <div style="display: flex; justify-content: space-around;"> <div> <p>80 mm</p> <p>30 mm</p> <p>55 mm</p> <p>25 mm</p> <p>(x-200) mm</p> </div> <div> <p>Structure 8</p> </div> </div>								

Table 9. Design table for structure type 9 and 10 (traffic class 3 and 4 is not recommended!)

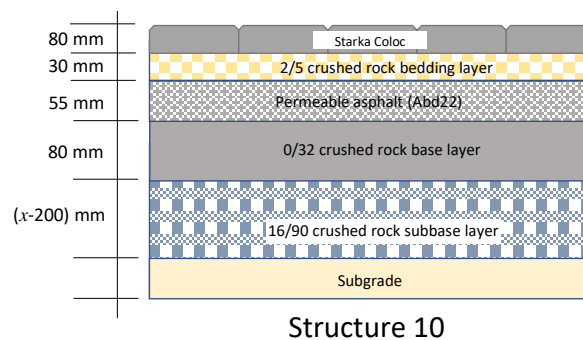
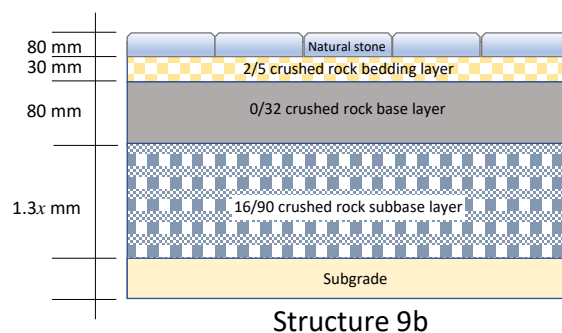
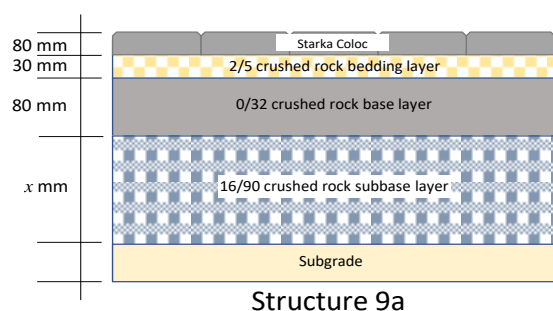
Klimatzon 1-6, krossat material i förstärkingslagret								
Trafik	Tillåtet antal standardaxlar	0	0	<50 000	50 000-500 000	500 000-1 000 000	1 000 000-2 500 000	2 500 000-5 000 000
	Trafikklas	G*	GC	0*	1	2	3	4
Överbyggnad	Tjocklek[mm]							
	Marksten ¹	50	60	80	80	80	80**	80**
	Sättningslager (2/5)	30	30	30	30	30	30	30
	Obundet bärlager (0/32) ²	Hela ÖB	80	80	80	80	80	80
	Förstärkningslagrets (16/90) tjocklek på terrass av materialtyp	1	0	0	77	110	209	275
		2	0	77	165	231	319	385
		3	88	77	264	319	385	440
		4	110	77	297	363	451	517
		5	154	187	440	506	638	748

¹ If natural stones are used instead of interlocking concrete blocks, the thickness of the subbase layer should be increased by 30%.

² If 55 mm permeable asphalt concrete is used instead of the crushed rock base layer, the thickness of the subbase may be reduced by 200 mm.

*) Svensk Markbetongs egen definition

**) Rekommenderad tjocklek på marksten är 100 mm



6 Conclusions

The structural design tables for the 10 different types of structures were developed based on their rutting performance in HVS testing. Hydraulic and water storage design is not included in this report. The underlying assumption was that the existing design table for the standard construction may be modified based on their comparative performance employing a pavement design software. The design tables presented here may act as guidelines for designing similar pavement structures bearing in mind the empirical nature of the methodology adopted here. Since there are a few uncertainties and assumptions involved in the process of the construction of the test structures and in the theoretical development of the design tables, some of the design tables for a few structures may be more reliable than the others. For example, design table for structure 1 and 2 is more reliable than the design table for structure 5 and 6. Comparing the derived design tables with design tables for similar constructions in other countries (Judycki et al., 1996; Li et al., 2014; Beeldens et al., 2009) is not straight forward due to differences in material characteristics, traffic loading and climatic conditions. However, the closest match may be a few structures from the Belgian design table (Beeldens et al., 2009) which are very similar to the design tables derived here.

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