

**Projektiranje asfaltnih kolnika za velika
opterečenja**
Design of Heavy Load Asphalt Pavement

Slovenko Henigman

Opatija, April 5th 2019

Content

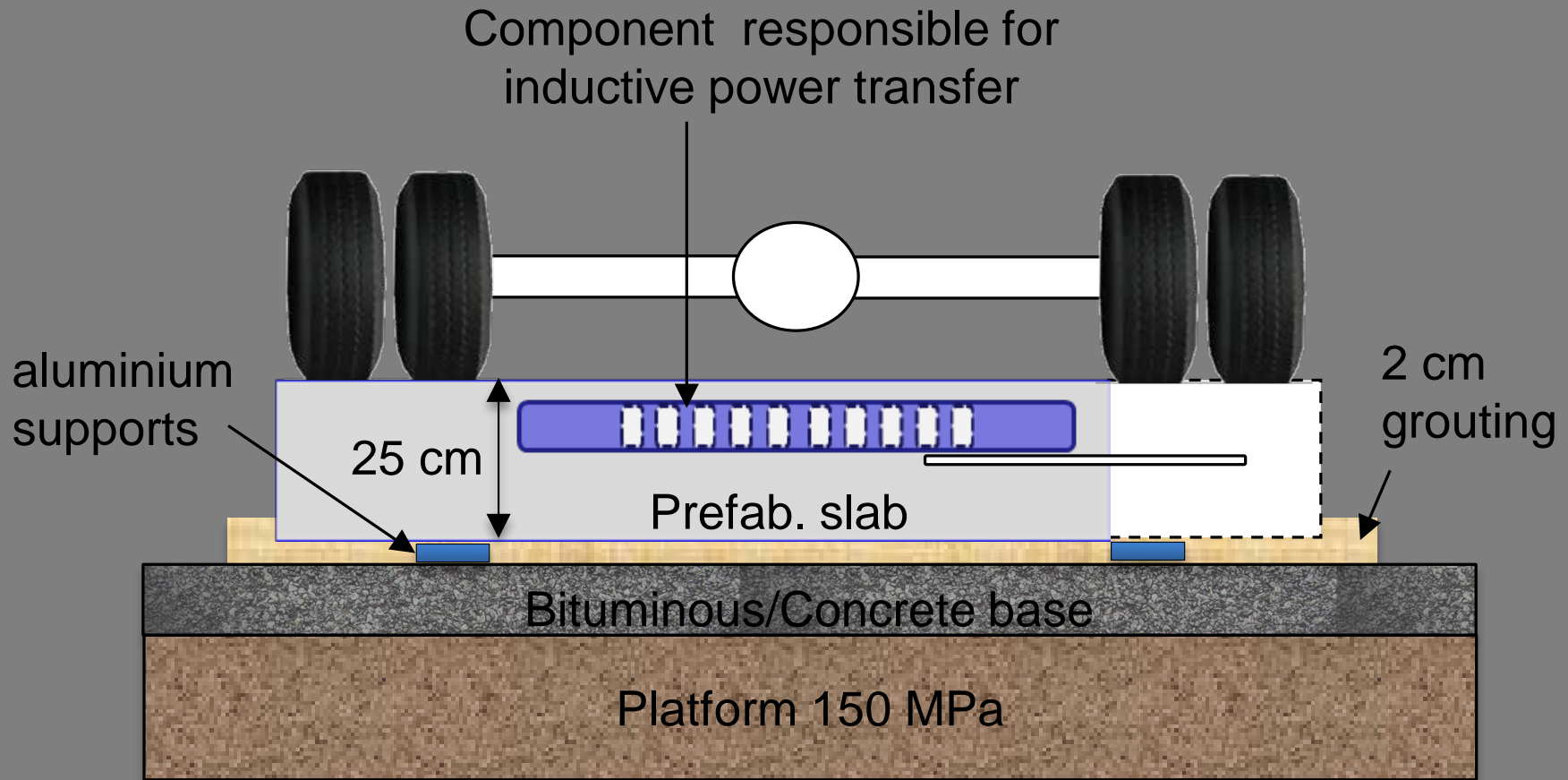
- Introduction and Challenges of the Future
- Pavement design in Slovenia
- Pavement construction on Slovenian highways
- Pavement design for the heaviest traffic loads
- Conclusion

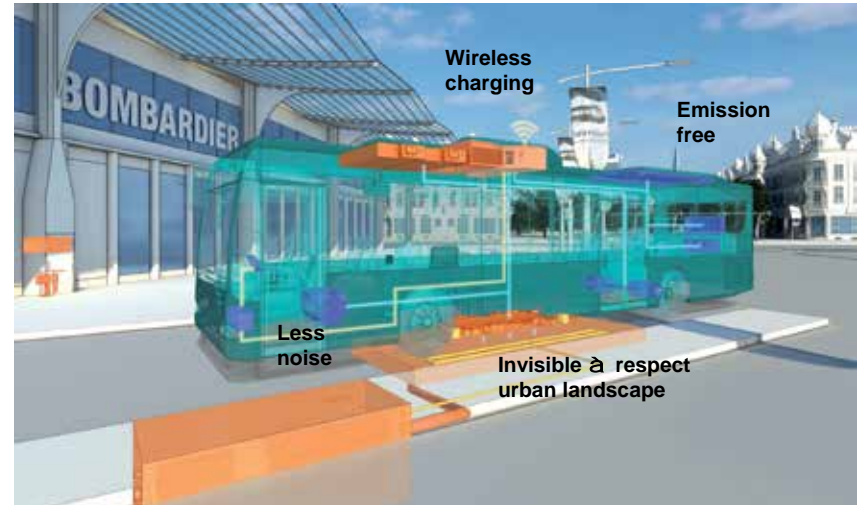
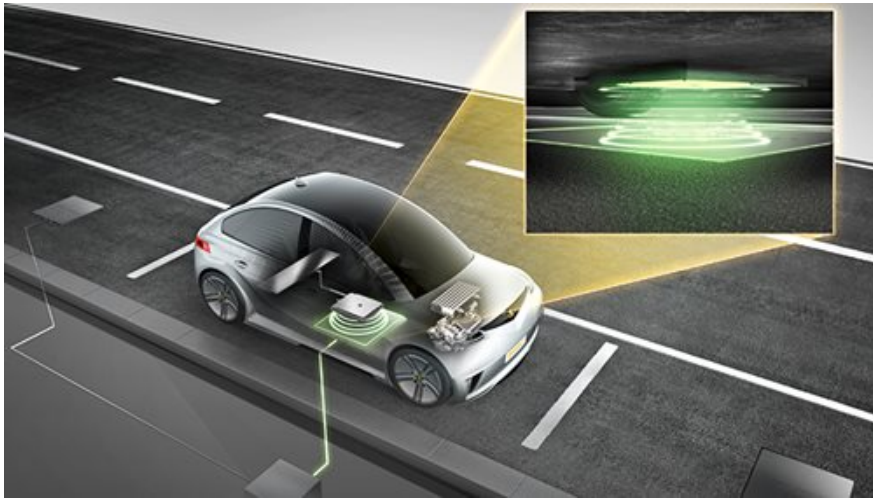
Introduction and challenges for the future

Autonomous driving



Inductive power transfer





Siemens eHighway demonstration in California

First U.S. electrified truck travel project will demonstrate how innovative technology can increase energy efficiency and economically cut harmful emissions on busy truck corridors

10,000

mi could be achieved via Class 8 truck driving rates on highways (news)

1050

1 mile

2x

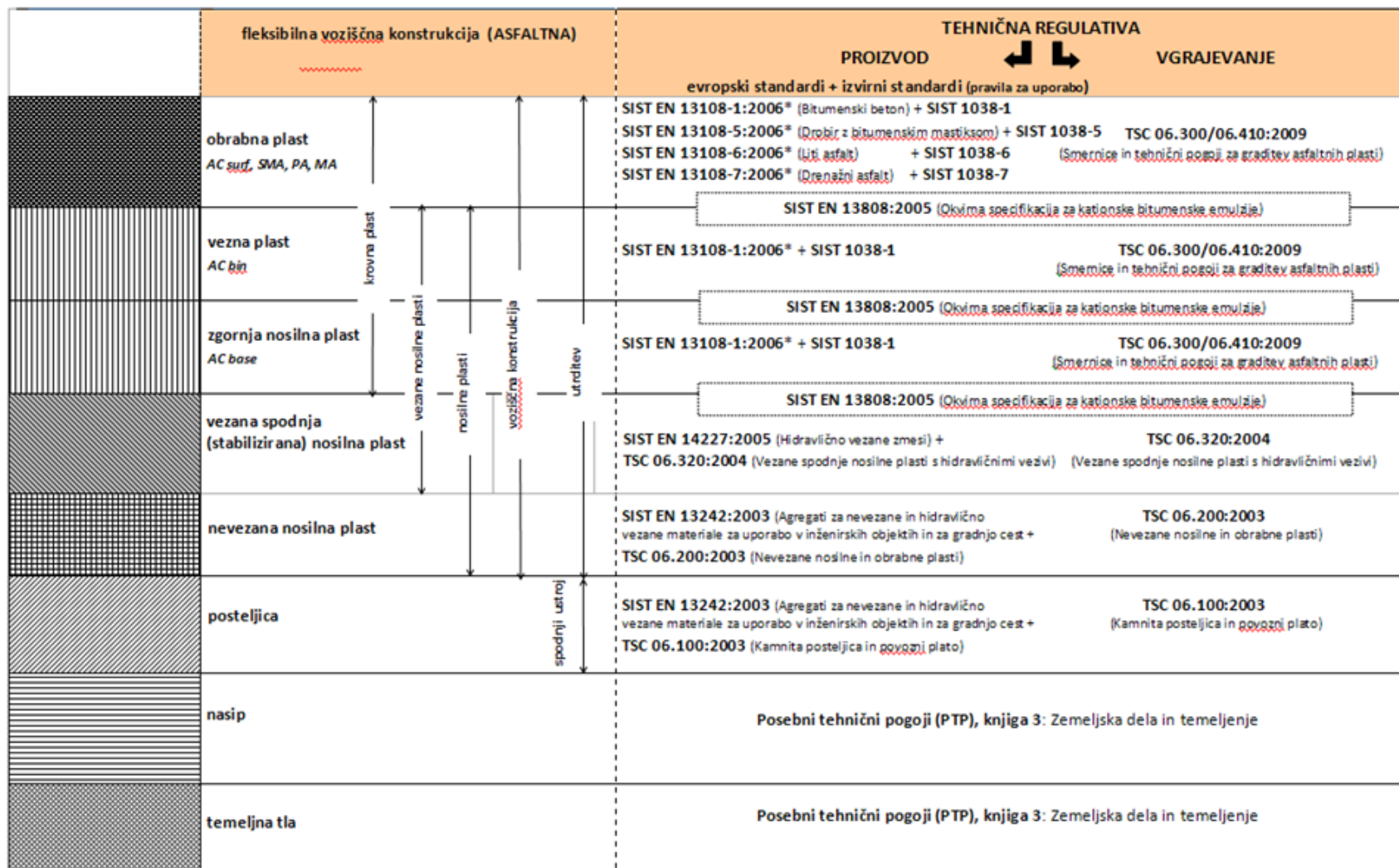
Increase in efficiency compared to conventional combustion engines, cutting energy consumption in half



- Pavement design in Slovenija

Asphalt pavement – technical regulations

Vir: Z.Cotič





REPUBLIKA SLOVENIJA
MINISTRSTVO ZA PROMET

TEHNIČNA SPECIFIKACIJA
ZA JAVNE CESTE

TSC 06.520 : 2009

**PROJEKTIRANJE
DIMENZIONIRANJE
NOVIH ASFALJNIH VOZIŠČNIH KONSTRUKCIJ**

Uporaba: ni obvezna

Pripravitel:

Tehnični odbor za pripravo tehničnih
specifikacij za javne ceste TO 06

Soglasje ministra:

Soglasje ministra, pristojnega za promet, je bilo
izdano dne 24. 7. 2009, pod št. 011-3/2007/15-
0032074.

Ključne besede:

asfaltna voziščna konstrukcija, posteljica, merodajna prometna obremenitev, hidrološki pogoji, klimatski pogoji, krovna plast, nosilna plast, doba trajanja, debelinski indeks.

Objava izdaje:

Uradni list RS, št. 65/09, dne 14. 8. 2009.

Izdajatelj:

Tehnično specifikacijo za javne ceste je založila in izdala Direkcija Republike Slovenije za ceste.



REPUBLIKA SLOVENIJA
MINISTRSTVO ZA PROMET

TEHNIČNA SPECIFIKACIJA
ZA JAVNE CESTE

TSC 06.541 : 2009

**PROJEKTIRANJE
DIMENZIONIRANJE OJAČITEV
OBSTOJEČIH ASFALJNIH VOZIŠČNIH KONSTRUKCIJ**

Uporaba: ni obvezna

Pripravitel:

Tehnični odbor za pripravo tehničnih
specifikacij za javne ceste TO 06.

Soglasje ministra:

Soglasje ministra, pristojnega za promet, je bilo
izdano dne 24. 7. 2009, pod št. 011-3/2007/15-
0032074.

Ključne besede:

ojačitev, asfaltna voziščna konstrukcija, ohranitev, prometna obremenitev, doba trajanja, utrditev ceste, nosilnost, podajnost, debelinski indeks.

Objava izdaje:

Uradni list RS, št. 65/09, dne 14. 8. 2009.

Izdajatelj:

Tehnično specifikacijo za javne ceste je založila in izdala Direkcija Republike Slovenije za ceste.

Basics for the dimensioning according to TSC 06.520:2009 design of new pavement constructions

Ø Traffic loads	T
Ø Load bearing capacity of the subgrade	S
Ø Material quality	a_i
Ø Frost protection	h_{\min}

Traffic loads- T_n

Calculation of the total (equivalent) traffic loads according to TSC 06.511/2009
(100 kN)

$$T_n = 365 \times T_d \times f_{pp} \times f_{sp} \times f_{nn} \times f_{dv} \times f_{tp}$$

It means:

T_n – predicted traffic load in –n- years(20 years)

T_d – ekvivalent daily traffic load

f_{pp} - factor for the cross-section of pavement construction

f_{sp} - factor for the width of the traffic lane

f_{nn} - faktor for the longitudinal slope

f_{dv} - faktor for additonal dinamic influences

f_{tp} - faktor for increased traffic load due to traffic growth over the life time

Classification of traffic loads into traffic load groups

Skupina prometne obremenitve	Število prehodov nazivne osne obremenitve 100 kN	
	na dan	v 20. letih
- izredno težka	nad 3000	nad 2×10^7
- zelo težka	nad 800 do 3000	nad 6×10^6 do 2×10^7
- težka	nad 300 do 800	nad 2×10^6 do 6×10^6
- srednja	nad 80 do 300	nad 6×10^5 do 2×10^6
- lahka	nad 30 do 80	nad 2×10^5 do 6×10^5
- zelo lahka	do 30	do 2×10^5

Load bearing capacity of the subgrade S

Determine by the procedures defined in TSC 06.720: 2003 Measurements and tests. Deformation modules of embedded materials

- Probe holes (geological opinion)
- Value of bearing capacity index CBR – California Bearing Ratio

Klasifikacija materiala po USCS	Vrednost CBR ₂ (%)	Modul stisljivosti M _E (MN/m ²)	Deformacijski modul E _{v2} (MN/m ²)
ML, MH, CH	3	4	15
CL, SC	5	8	20
GC, SM	7	13	45
GC, SP	10	20	60
SW, GM	15	35	80
GP, GW	20	50	100

Load bearing capacity of the subgrade S - CBR



Material quality a_i

Average values of the equivalence ratios for basic road construction materials

Vrsta materiala	Količnik ekvivalentnosti a_i
- za obrabno plast:	
- bitumenski beton	$a_o = 0,42$
- drobir z bitumenskim mastiksom	$a_o = 0,42$
- za zgornjo vezano nosilno plast:	
- bituminizirani drobljenec	$a_{zv} = 0,35$
- bituminizirani prodec	$a_{zv} = 0,28$
- za spodnjo vezano nosilno plast:	
- stabilizirana zmes kamnitih zrn	
- z bitumnom	$a_{sv} = 0,24$
- s cementom	$a_{sv} = 0,20$
- za spodnjo nevezano nosilno plast:	
- drobljenec	$a_{sn} = 0,14$
- prodec	$a_{sn} = 0,11^*$

* omejen z debelino plasti 40 cm

Ø Frost protection h_{\min}

TSC 06.512:Design. Climatological and hidrological conditions

The minimum required thickness of pavement structuree h_{\min}

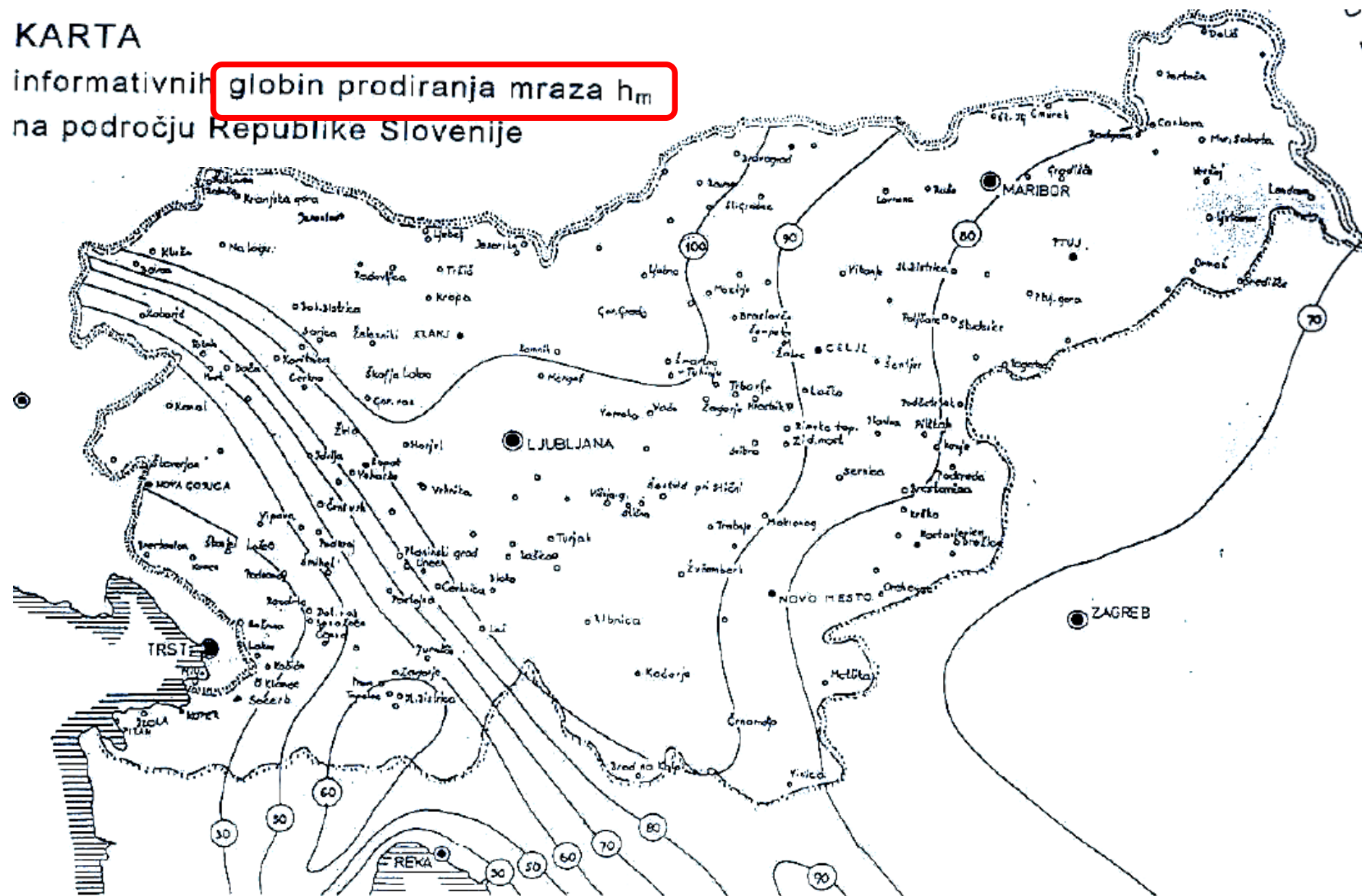
Odpornost materiala pod voziščno konstrukcijo proti učinkom zmrzovanja in odtajevanja	Hidrološki pogoji	Debelina voziščne konstrukcije h_{\min}	
		do nadmorske višine 600 m	nad nadmorsko višino 600 m
odporen	ugodni	$\geq 0,6 h_m$ ¹⁾	$\geq 0,7 h_m$
	neugodni	$\geq 0,7 h_m$	$\geq 0,8 h_m$
neodporen	ugodni	$\geq 0,7 h_m$	$\geq 0,8 h_m$
	neugodni	$\geq 0,8 h_m$	$\geq 0,9 h_m$

Legenda:

¹⁾ h_m – globina zmrzovanja (prodiranja mraza)

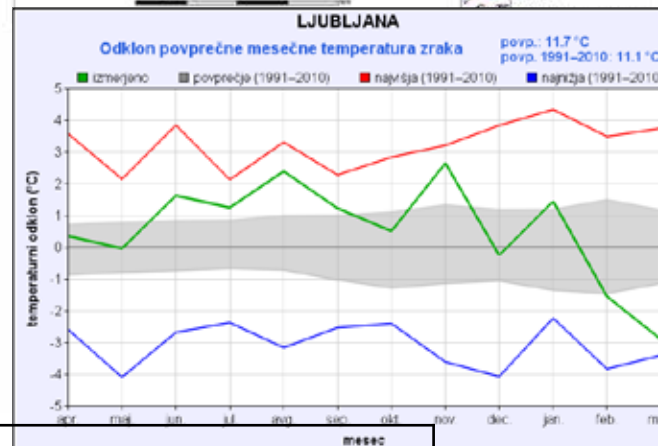
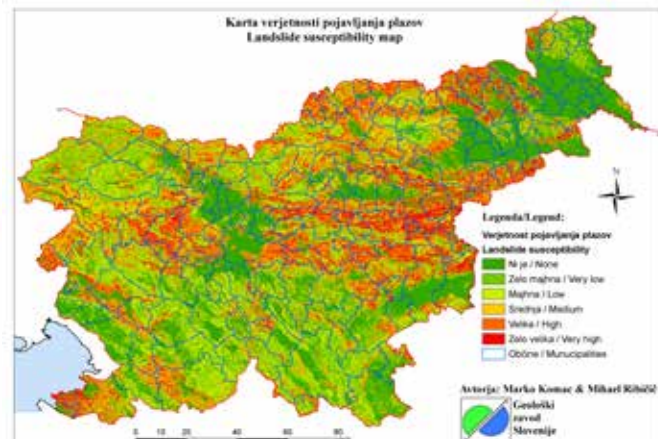
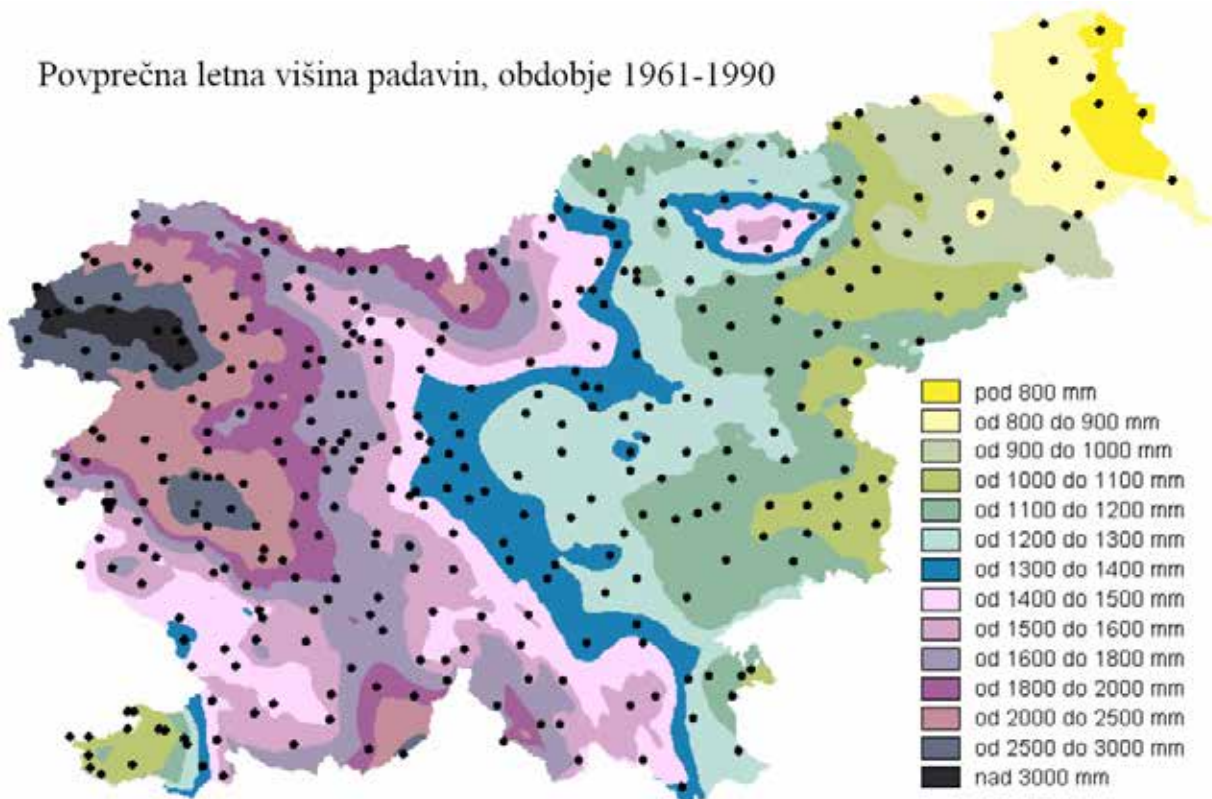
KARTA

informativnih **globin prodiranja mraza h_m**
na področju Republike Slovenije



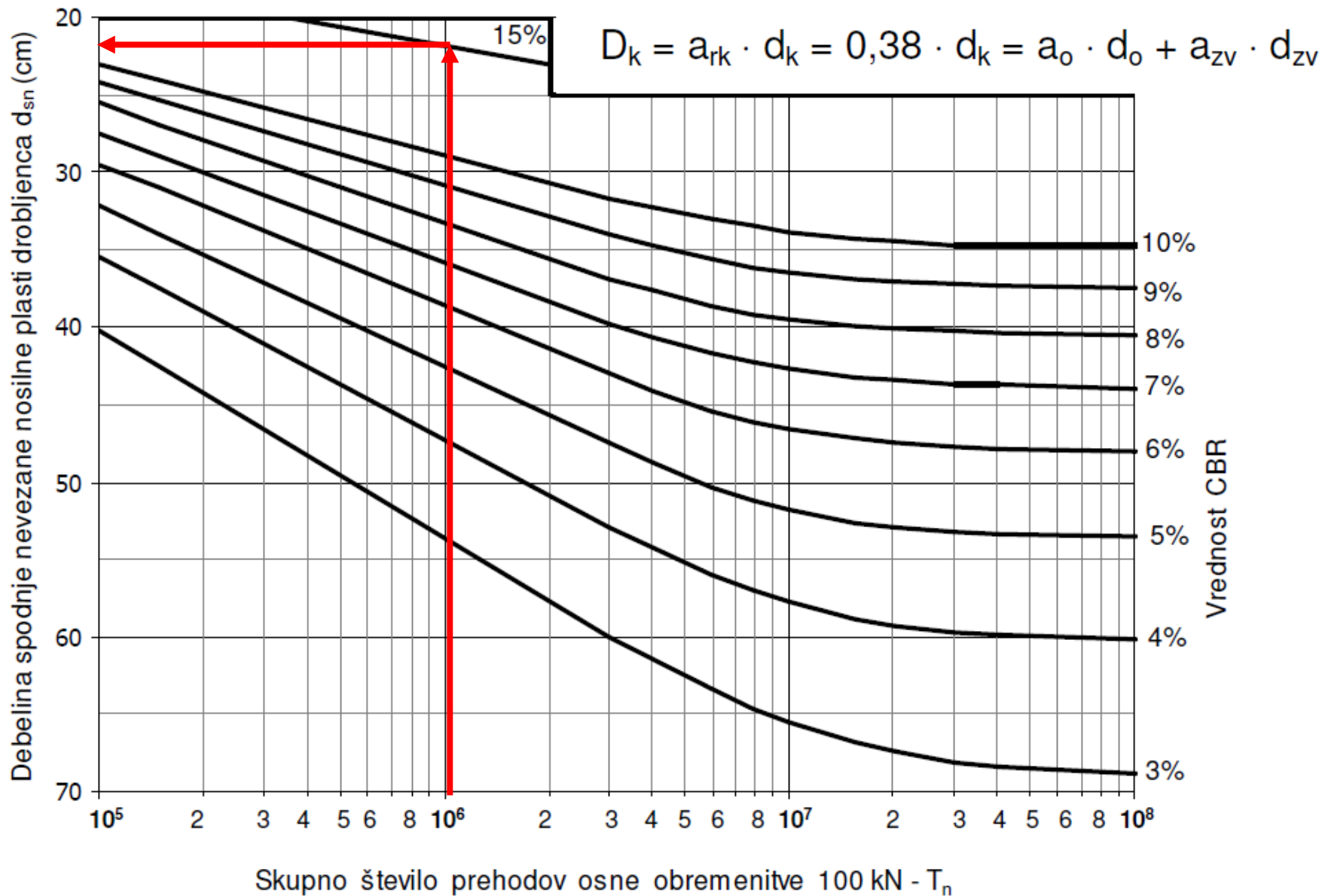
Temperature, precipitation and geological conditions

Povprečna letna višina padavin, obdobje 1961-1990



Temperature	Vremenski monitoring			
	Portorož	Ljubljana	Slovenj Gradec	Murska Sobota
- highest - °C	36,3	37,1	34,5	37,9
- lowest - °C	- 10,3	- 20,3	- 27,0	- 26,9

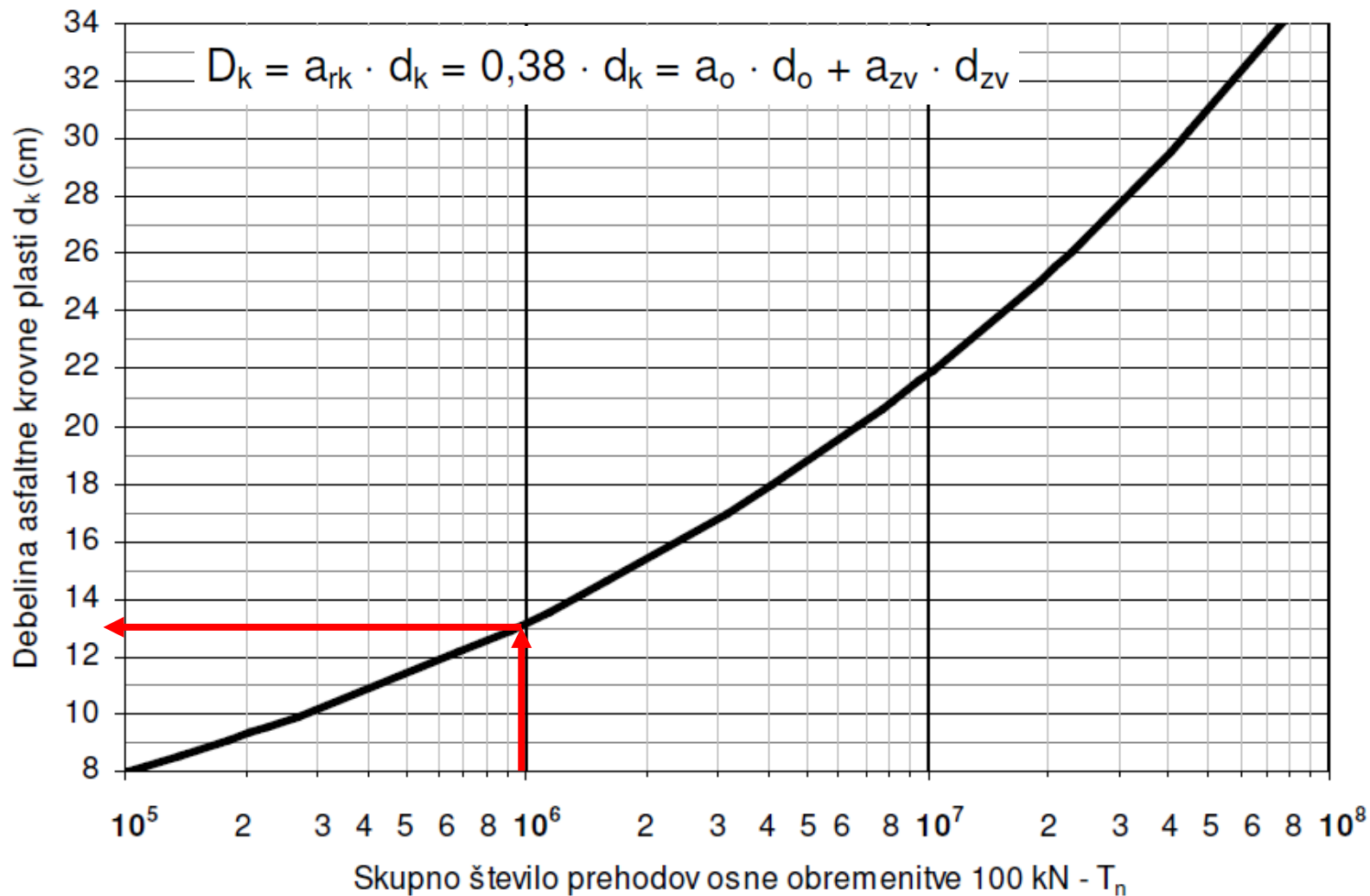
Procedure for dimensioning



Procedure for dimensioning

Ekvivalentna prometna obremenitev

zelo lahka | lahka | srednja | težka | zelo težka | izredno težka



An example of dimensioning

$$d_{\text{potr.}} = 13 \times 0,38 + 22 \times 0,14 = 8,02 \text{ cm.}$$

	d_i	a_i	$a_i d_i$
obrabna plast bitumenskega betona AC 11 surf B 70/100 A3/Z2	4 cm	0,42	1,68
nosilna plast bituminiziranega drobljenca AC 22 base B 50/70 A3/Z5	10 cm	0,35	3,50
drobljenec D 22 (možna ponovna uporaba zmrzlinško odpornega materiala ali stabilizirana zmes obstoječega materiala s cementom) -** <i>po recepturi</i>	18 cm	0,14 do 0,20	2,52 do 3,60
posteljica - reciklaža, stabilizacija in ponovna uporaba ustreznega obstoječega materiala (zagotoviti min. CBR = 15 %) - ** <i>po recepturi</i>	po potrebi - 20do40 cm	(0,18)	(3,60 do 7,20)
obstoječi tampon, kamnita greda ali raščena tla			
Skupaj:	52 cm do 72 cm		min. 11,30

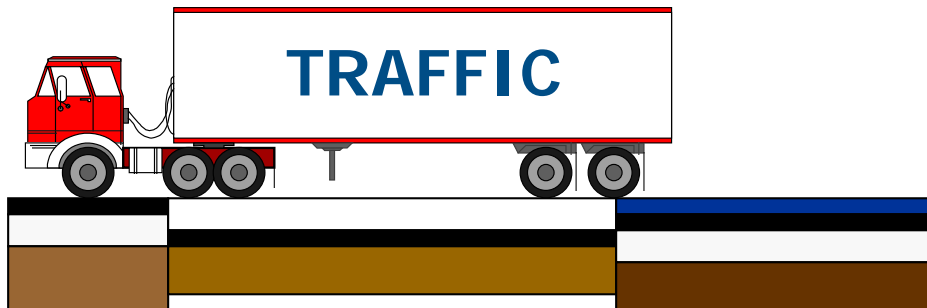
$$\text{Dejanski debelinski indeks znaša: } d_{\text{dej.}} = 11,30 \text{ cm} > 8,02 = d_{\text{potr.}}$$

- Pavement construction on Slovenian highways

IMPORTANCE OF PAVEMENT STRUCTURES



- Level of service for the users (evenness, skid resistance)
- Environment protection (noise)
- Traffic safety (change of transverse slope between two curves)
- Sustainability (cracks, deformations, potholes, wear)

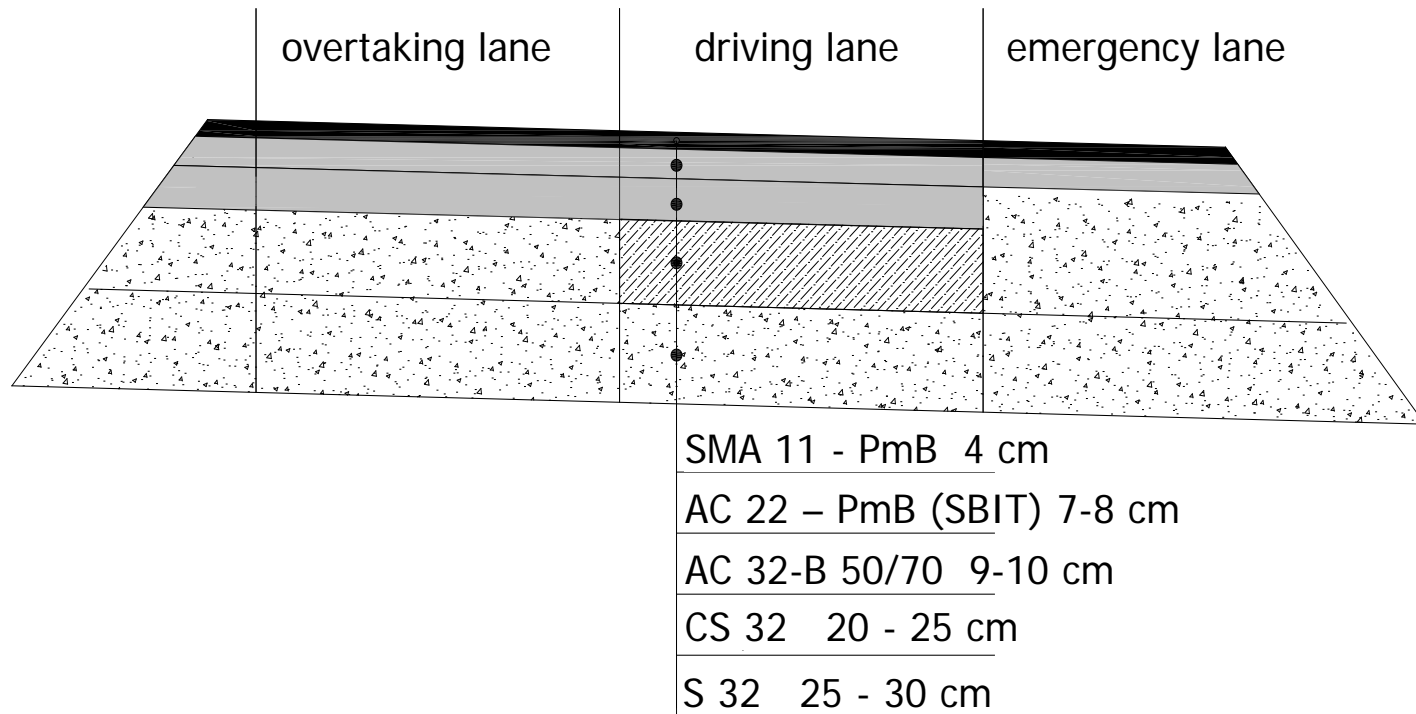


Pavement structure is the most important element of the road

Motorways before 1994



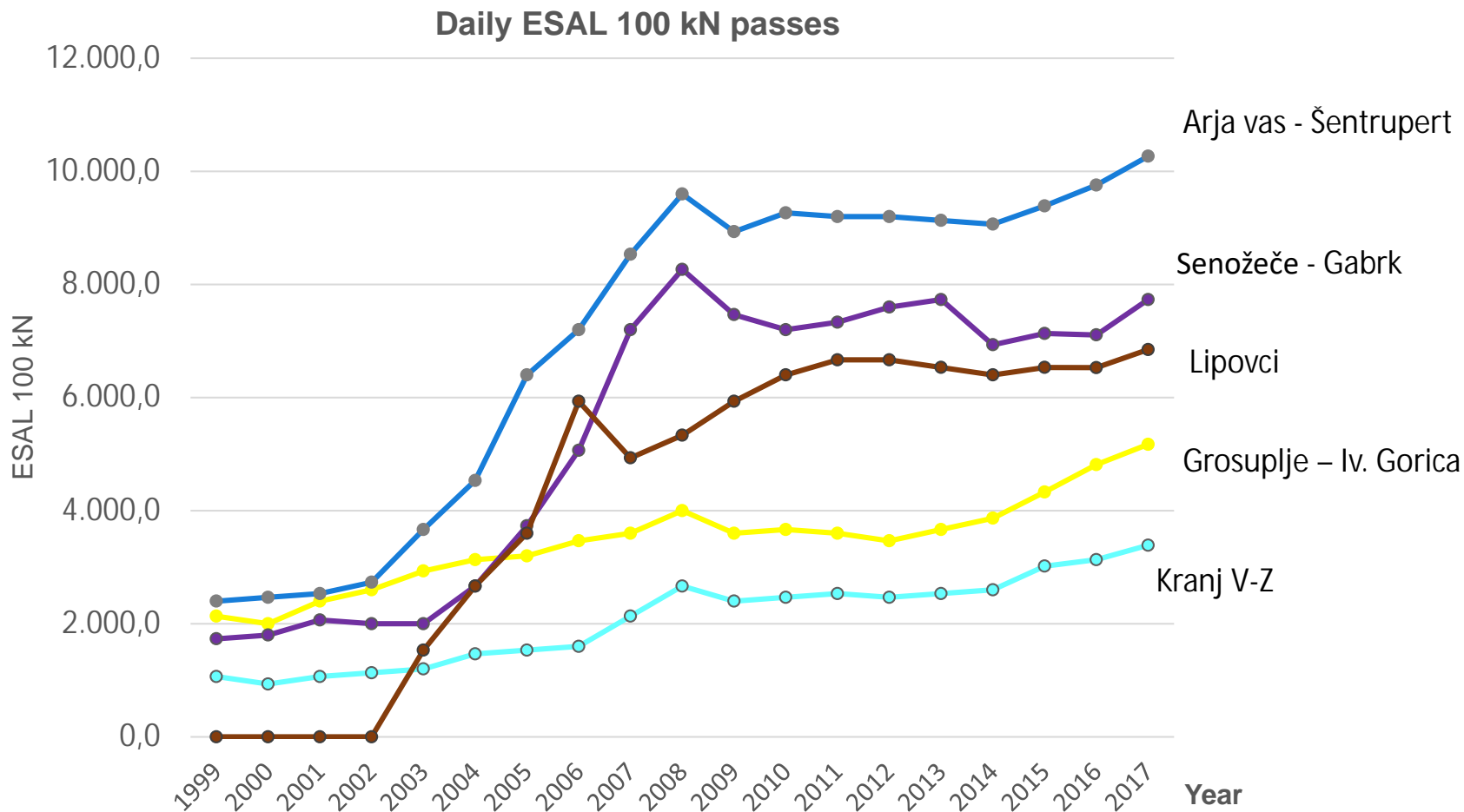
Typical pavement on motorways after Year 2000



Traffic and Traffic Loads

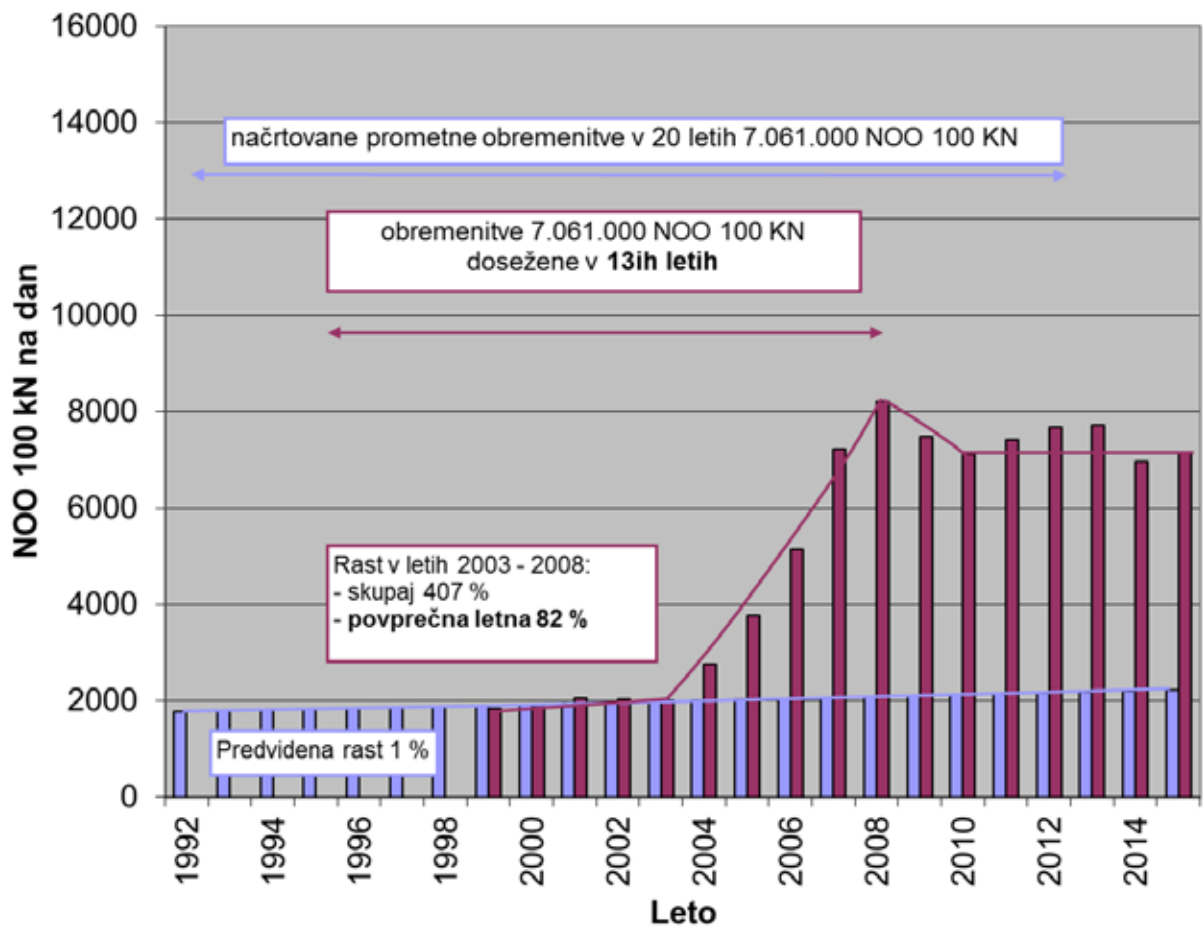


Traffic Loads on motorways in Slovenia



Pavement Design

Prometne razmere na odseku AC - A1/0058 Senožeče - Gabrk



Predvidene prometne obremenitve v 20ih letih (1992-2012):

7.061.000

Izvedena debelina asfaltne plasti:

18,0 cm

Revidirane prometne obremenitve v 20ih letih (1995-2015):

16.000.000

Potrebna debelina asfaltnih plasti:

19,5 cm

Pričakovane prometne obremenitve 2015 - 2035:

31.000.000

Potrebna debelina asfaltnih plasti:

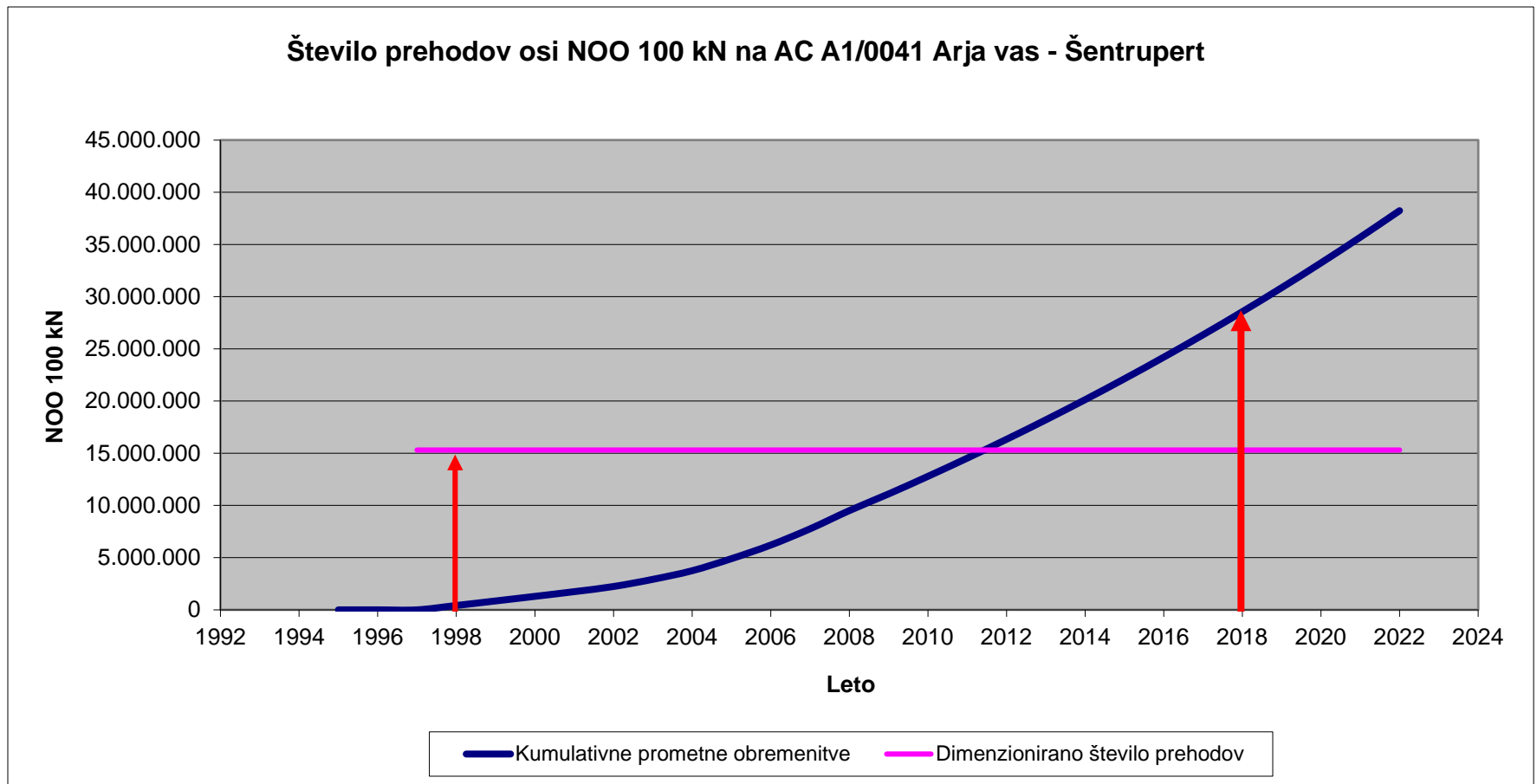
25,0 cm

(28, cm*)

* based on TSC revised in 2009

■ Načrtovano 2001
■ Dejanske obremenitve

Traffic loads in 20 Years



Heavy loaded Roads in Slovenia

	l (km)	w (m)	x (m ²)	% heavy loads	x1 (m ²)
Motorways + Expressways	762	22,00	16.764.000,00	16,00	2.682.240,00
Main and regional roads	5.936	7,00	41.552.000,00	3,00	1.246.560,00
Local roads and public ways	32.224	5,00	161.120.000,00	3,00	4.833.600,00
All together (km):	38.922		219.436.000,00		8.762.400,00
					3,99%

The surface of heavy loaded roads is less than 4 %

Decision on the use of concrete on motorways:

- In tunnels
- Lanes for slow moving traffic and at
- Toll stations

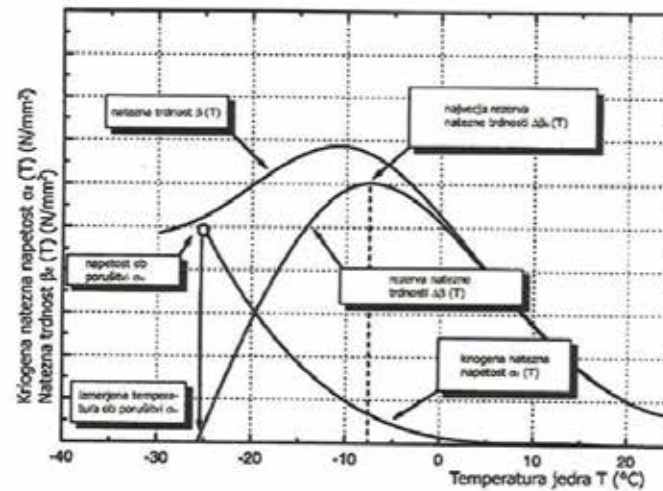
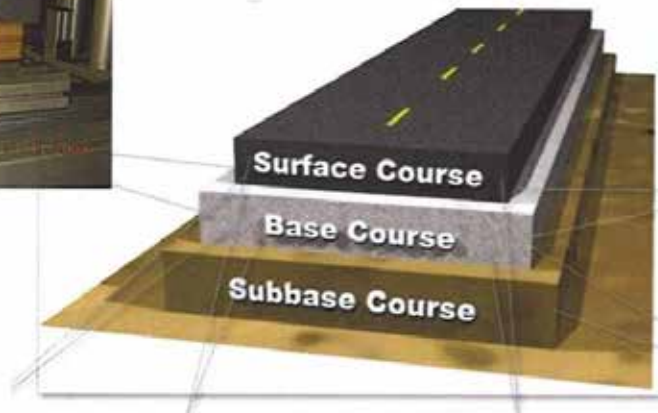
Pavement structures – asphalt : concrete



Cement stabilisation



Dynamic laboratory tests



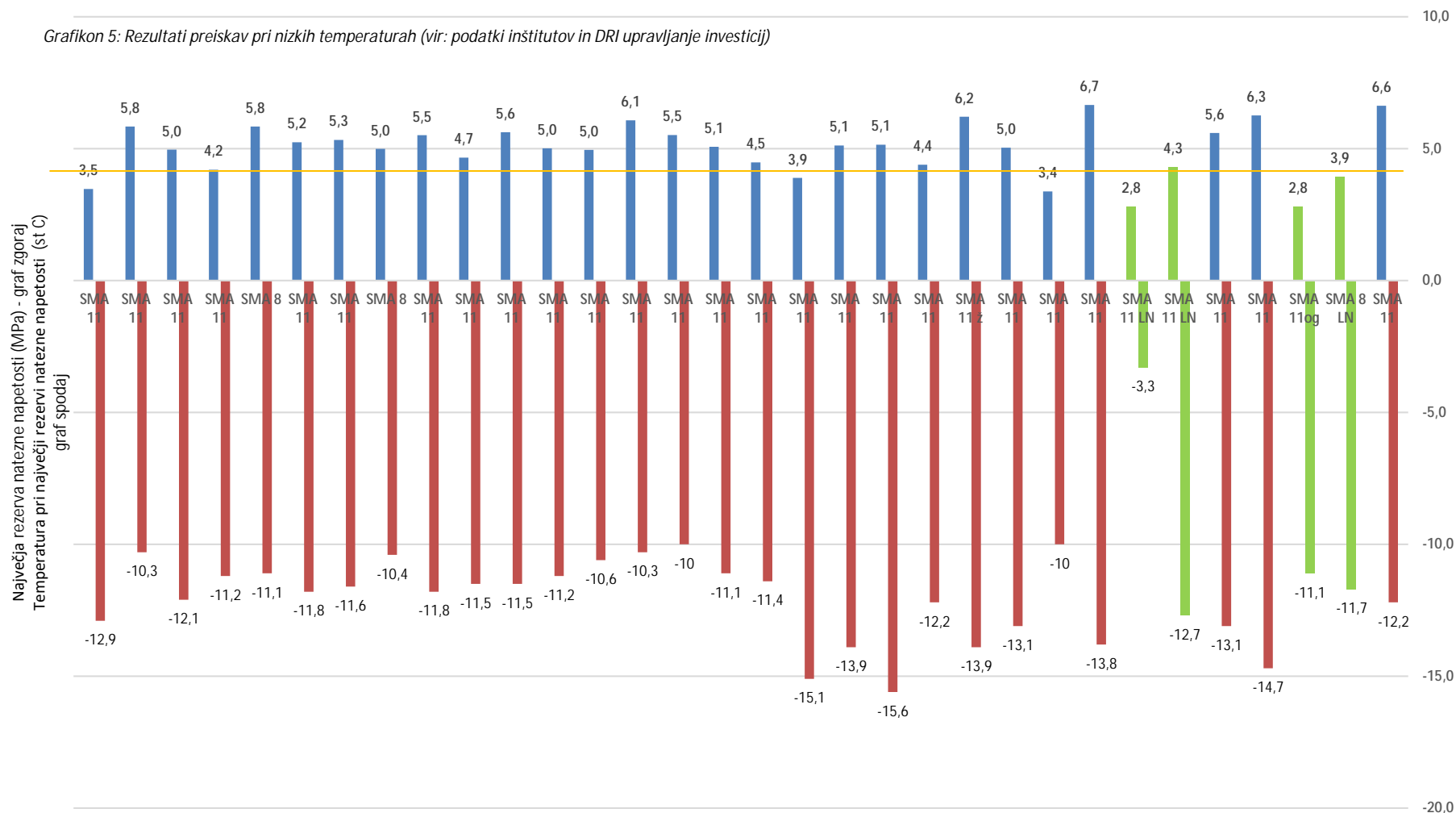
Low Temperature Behavior



Dynamic laboratory tests – Low Temperature Behavior

The max reserve tensile strength stress (in MPa) and the corresponding temperature(st. C)

Grafikon 5: Rezultati preiskav pri nizkih temperaturah (vir: podatki inštitutov in DRI upravljanje investicij)

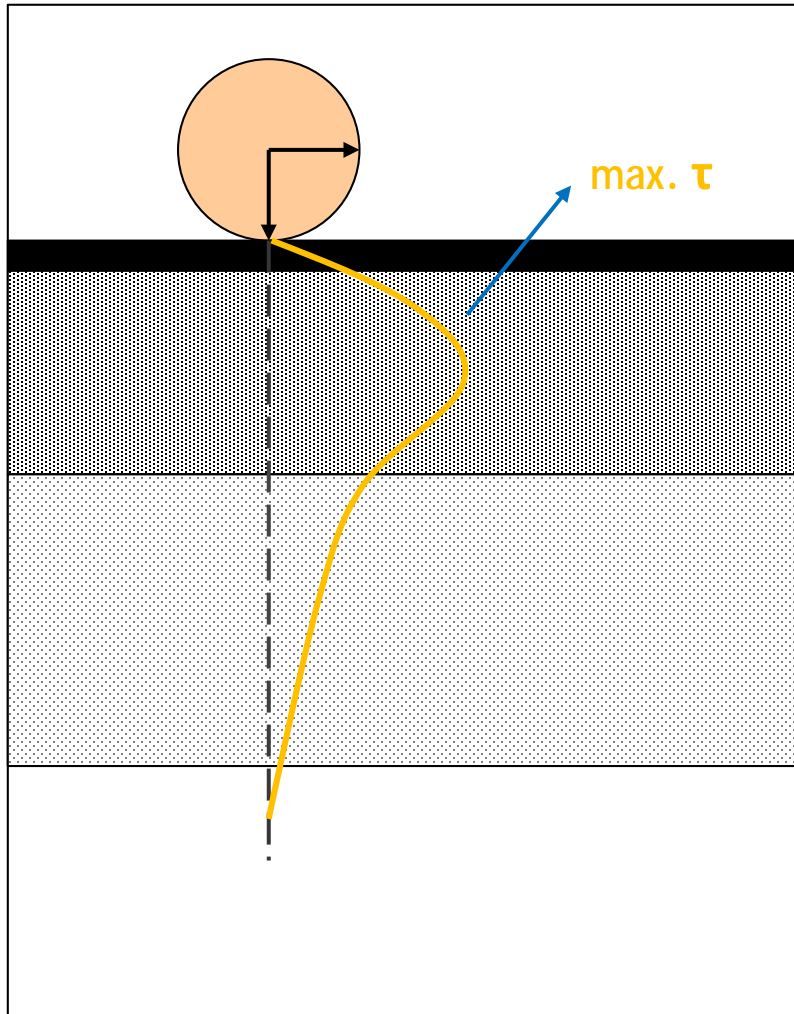


- Pavement design for the heaviest traffic loads

Heaviest traffic loads on pavement structures



How to tackle the challenge of heavy loaded areas at airports, ports...?



Layers in the pavement

- Binder courses mainly absorb the load
- Higher investment in binder will most probably ensure a high durability of the pavement
- However, the design of binder course should be harmonised with other courses
- The value of the layer under the pavement construction

Standard Requirements and practise for heavy loaded asphalt pavement construction (Wearing, binder and base layer)

Standard requirements	Asphalt layer		
	wearing SMA	binder AC	base AC
Vhodni materiali			
KAMENE ZMESI ZRN			
delež drobljenih zrn %	100	100	100
LA	20	30	30
VEZIVA			
PmB	PmB 45/80-65	PmB 10/40-60, PmB 25/55-65 BIT 50/70 + nat. bit.	BIT 50/70
ASFALTNE ZMESI - Marshall			
Proste votline - min %	2,5	4	5
Proste votline - max %	4,5	7	7
Delež bitumna %			
Zapolnjenost votlin z bitumnom %	74-89	55-77	50-68
ASFALTNE PLASTI			
Zlepljenost plasti - Leutner			
debelina mm	30 - 50	70 - 100	80 - 120
zgoščenost %	≥ 98	≥ 98	≥ 98
votline v plasti %	6,5	9	9

Requirements for the asphalt pavement construction on roads

- Wearing, binder and base layer

Test	Asphalt layer		
	wearing	binder	base
High temperature: Wheel tracking	PRD air 5,0 %	PRD air 3,0 %	PRD air 7,0 %
Low temperature: Max Reserve of Tensile Stress	5 Mpa	NR	NR
The whole temperature range: Fatigue	NR	NR	NR
The whole temperature range Stiffness	NR	NR	NR

- Cement stabilization (compressive strength to 5 Mpa)
- A well hardened and high quality subbase layer:

(load capacity, at least 80 -100 Mpa, CBR > 20%)

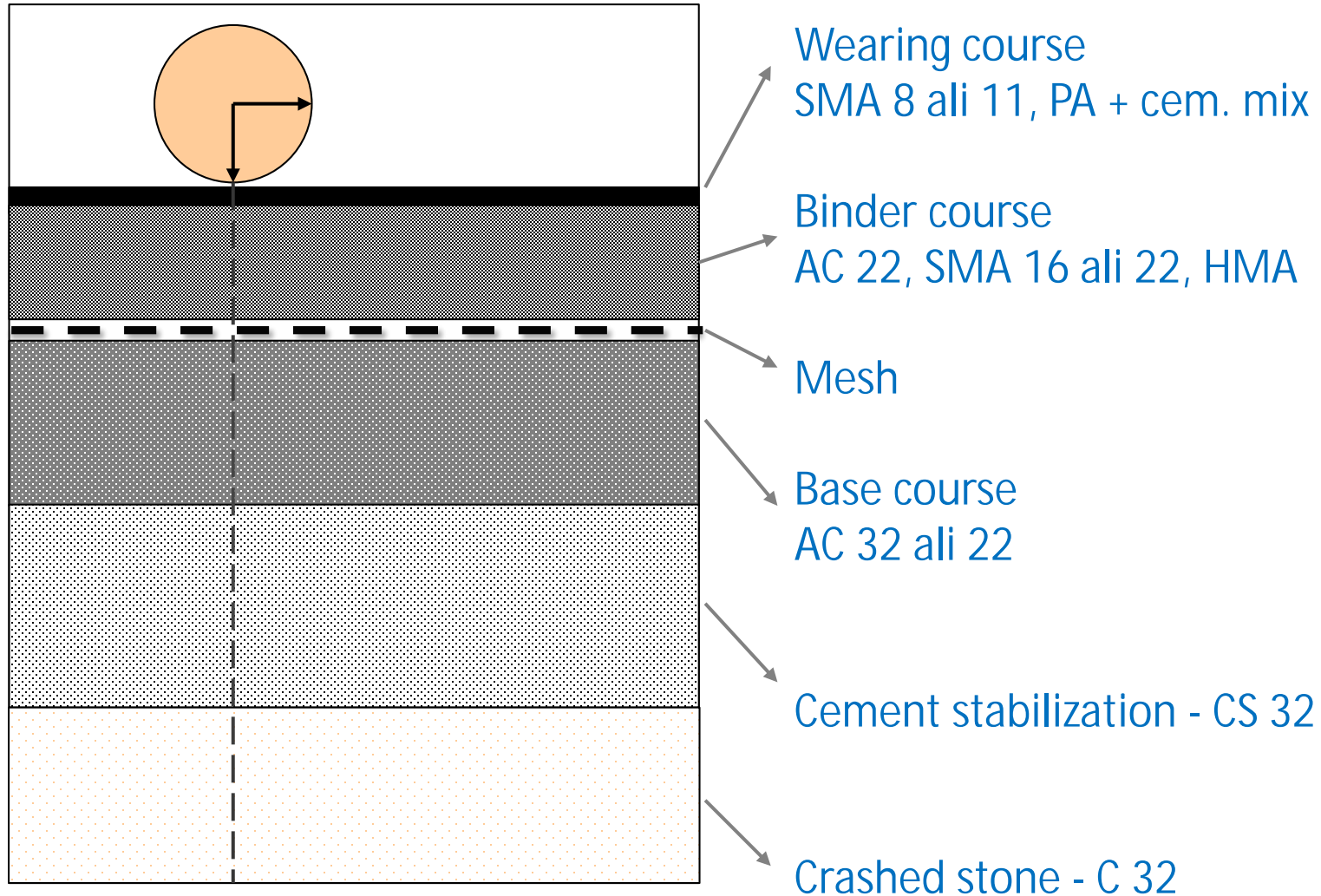
Requirements for the asphalt pavement construction on other surfaces

- Wearing, binder and base layer

Test	Asphalt layer		
	wearing	binder	base
High temperature: Wheel tracking	PRD air 3,0 %	PRD air 2,0 %	PRD air 4,0 %
Low temperature: Max Reserve of Tensile Stress	5 Mpa	NR	NR
The whole temperature range: Fatigue	NR	NR	NR
The whole temperature range Stiffness	NR	NR	NR

- Cement stabilization (compressive strength to 5 Mpa)
- A well hardened and high quality subbase layer:
(load capacity, at least 80 -100 Mpa, CBR > 20%)

Recommended pavement design for the heaviest traffic loads



Requirements for asphalt layers and materials

- Types of materials in wearing layer
 - Type of mixutre: SMA, PA + cement mort (half rigid system)
 - Binder + additive: PmB 45/80-65, rubber, waxes,...
 - Agregat: 100% crushed, light
- Requirements for binder layer
 - Type of mixutre : AC, SMA, HMA
 - Binder (and additives): PmB 10/40-60, PmB 25/55-65, B50/70 + natural bitumen, waxes
 - Agregat: 100% crushed
- Requirements for base layer
 - Type of mixutre: AC
 - Binder: B 50/70, B50/70 + natural bitumen, B70/100 + natural bitumen
 - Agregat: 100% crushed

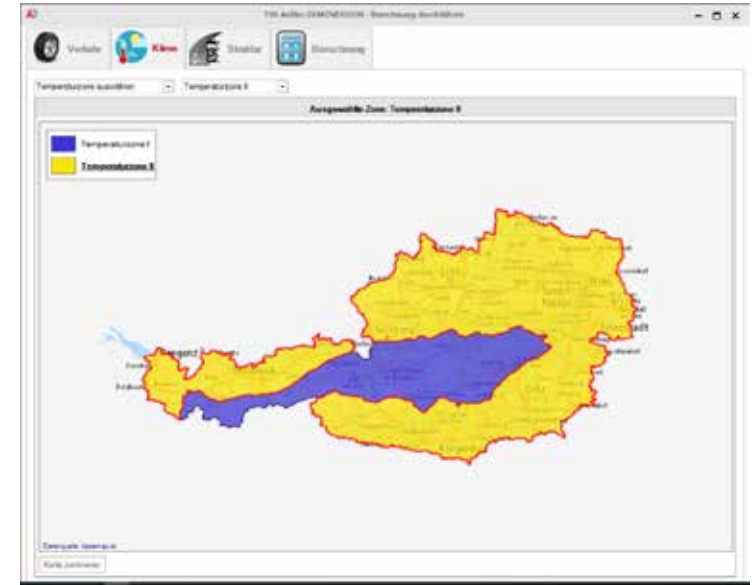
ASDIM (FSV-Austria)

Veränderliche Lastungen

Datum (Länge, Breite)	GTZ (MS/G)	Art der Fahrzeuggruppe (%)	Art der Richtungs-fahrtrichtung	Fahrerzahl (Stk)	Bemessungs-gewicht (Stk)	Durchm. (mm)	Lastwechsel N (Stk)	Bemessungs-nachweis	Technische Lebensdauer (J)	RIV (Stk)	Anmerkung
21.09.2018 18:07:38		LKW 2	1,75	80	1,00	88.200	340.130	0,96	10,30	1.97.2019	

Einblick in ausgewählte Bauteile

Material	Stärke	Streckgrenze (N/mm²)	Stoßzähigkeit	Stummel-Verspannung (N/mm²)	Stoß (N/mm²)
Deckschicht	4,2	510 N/mm²	Polymersulfid (Stärke 0,1, 480)		
Bodenschicht	8,0	510 N/mm²	Polymersulfid (Stärke 0,1, 500)		
Tragschicht	10,0	510 N/mm²	Stahlsulfid (Stärke 0,1, 1000/180)		
Tragschicht unter Tragstuhl	10,0				
Tragschicht unter Tragstuhl	10,0				



Limited values for stiffness and fatigue (4PB).

Ergebnisse			
Lastwechsel N		Bemessungsnachweis	Technische Lebensdauer
Erwartet	Zulässig		
16.162.914	16.919.369	0,96	20,77 Jahre

Abbildung 20: Bericht - Bemessungsnachweis erfüllt

Ergebnisse			
Lastwechsel N		Bemessungsnachweis	Technische Lebensdauer
Erwartet	Zulässig		
16.162.914	10.748.966	1,50	14,14 Jahre

Abbildung 21: Bericht - Bemessungsnachweis nicht erfüllt

PaDeSto (Primia - Germany)

Pavement Design Tool - slovenia1.bem

File Options Window ?-Help

Project data

Basic information

Loading

Trafficloading

Climate

Frost damage protection and Temperatures

Construction

Drillcores

Thickness measurement

Layerdefinition

Materialdatabase

Calculationvalues

Table 1

Table 2

Analyzing

Result

Graphics

Variants

Asphalt layers Select structure from the RStO...

1	DS	AC 8 D S 25/55	6,0 cm	100 %
2	BS	AC 16 B S	8,0 cm	100 %
3	TS	AC 22 TS	16,0 cm	
4				
5				
6				

Start layer thicknesses

Layer bonding

Asphalt overall thickness 30,0 cm

7 **Cement stabilized base course / Stabilization**

Layer module

Hydraulically bound basecourse 500 MPa 30,0 cm

Bonding to layer above

8 **Base course(s) without binder**

Ev2 value

MPa

MPa

9 **Formation**

Ev2 value

45 MPa

Illustration of the selected structure

6,0 cm

8,0 cm

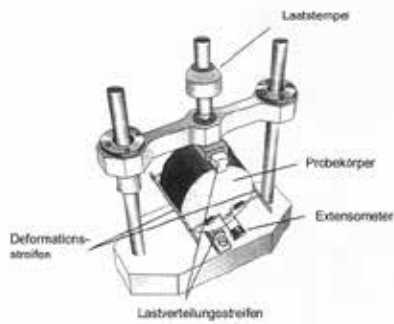
16,0 cm

30,0 cm

60,0 cm (30,0 cm + 30,0 cm)

Prüfvorschriften Dimensionierung AL-SP - ASPA-HLT 08 (Stand 20.03.2008)

Temperaturzonenkarte



Pavement construction on the roads with the haviest traffic loads

When dimensioning is completed and the contractor has been chosen, the following is recommended

- Execution of test fields and
- On the basis of the result of the test fields, the final implementation can start.

RECOMMENDATIONS TO THE CLIENTS

- Research & development
- Analytic verification of dimensioning (npr. AsDim, Padesto,...)
- Constant monitoring of experimental fields

Conclusion

Conclusion

1. Heavy loaded asphalt surfaces are small in comparison to all asphalt surfaces
2. Heavy loaded asphalt surfaces are a challenge for asphalt industry
3. The requirements for the quality of heavy loaded surfaces will increase in the future - for example, self driving vehicles.
4. Dynamic tests in the entire temperature range and advanced software are available, but without proper requirements
5. What is our task?
 - a) Determine the requirements for a certain test.
 - b) Define the expected warranty period with the requirements.

4. Workshop Pavement Design, Croatia 2020 ?



3. workshop

PAVEMENT DESIGN

*unique meeting of European experts
on Pavement design*

Term: 15–16 November 2018

Place: Hotel Galant Lednice, Southern Moravia



- Prepared by – SLOMAN d.o.o.

SLOMAN company activities

- Consulting and leading of projects and supervision in traffic infrastructure
- Preparing of professional assignments, studies and reports
- Leading of professional associations
- Preparing of technical and project design for road and traffic infrastructure
- Implementation of new technologies in building and maintenance of road infrastructure
- Pavement measurements and measurements of road surroundings
- PMS - Pavement Management System
- Preparation and executing of environmental projects
- Organising and preparing of technical regulations, ensuring system and quality control for traffic infrastructure
- Organising of specialized technical events, round tables and conferences
- International projects and cooperation





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*Thank you for your attention!
Questions?
info@sloman.eu*