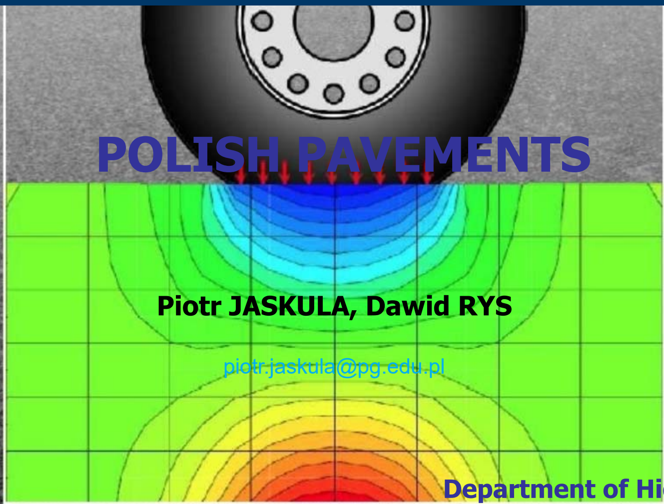
GDAŃSK UNIVERSITY OF TECHNOLOGY



POLISH PAVEMENTS

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Gdansk University of Technology
POLAND

POLITECHNIKA GDAŃSKA

OUTLINE

- Introduction
- Terminology and structure
- Traffic
- Materials
- Subgrade
- Lower layers and improved subgrade
- Calculations of upper layers
- Results – new structures
- Conclusions

Coathors of Catalogue

J. Judycki

Head of the group

P. Jaskuła M. Pszczoła J. Alenowicz

B. Dołżycki M. Jaczewski D. Ryś M. Stienss

Main building of GUT

POLITECHNIKA GDAŃSKA

INTRODUCTION

- Financed by Polish Highway Agency (GDDKiA)
- 2009-2012 (36 months)
- 12 workpackages
- Reviewed by 50 road specialists and institutions
- Recommended for use in 2014
- Implemented by law in 2015
- Obligatory since 2015

Free access to catalogue

https://www.gddkia.gov.pl/userfiles/articles/z/zarzadzenia-generalnego-dyrektor_13901/zarzadzenie%2031%20zalacznik.pdf

POLITECHNIKA GDAŃSKA

PREVIOUS CATALOGUES

Polish Catalogues for Flexible and semi-rigid structures

118 pages with examples

2014 r. **1997 r.** **1983 r.** **1977 r.**

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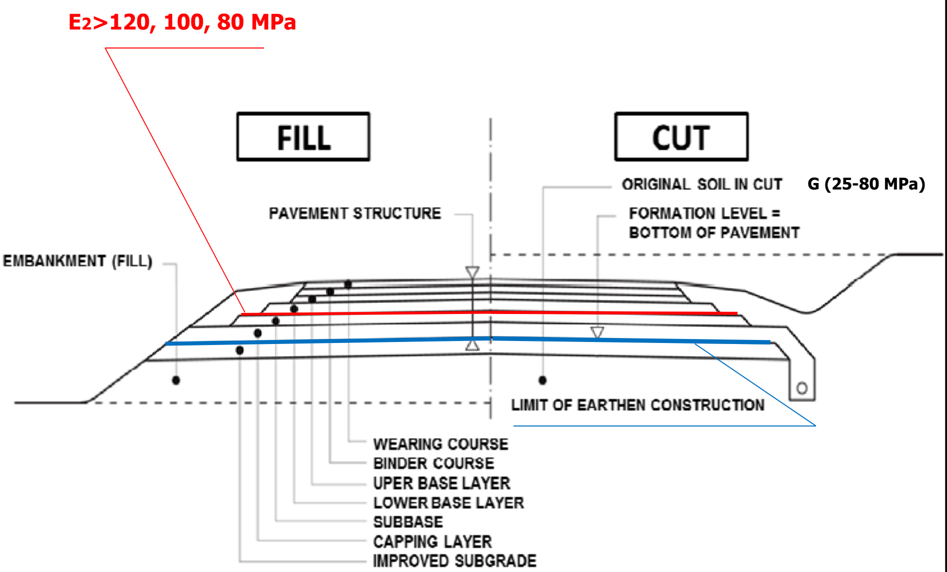
PAVEMENT STRUCTURE

Pavement structure	Upper pavement courses	Wearing course	
		Binder course	
		Base	Upper base layer
			Lower base layer
	Lower pavement courses	Subbase	
		Capping layer	
Subgrade	Improved (stabilised) subgrade		
	Original soil in cut or embankment in fill of bearing capacity class G1-G4		

Fig. 2. Schematic diagram and terms relating to courses of flexible and semi-rigid pavement structures and improved subgrade

PAVEMENT STRUCTURE



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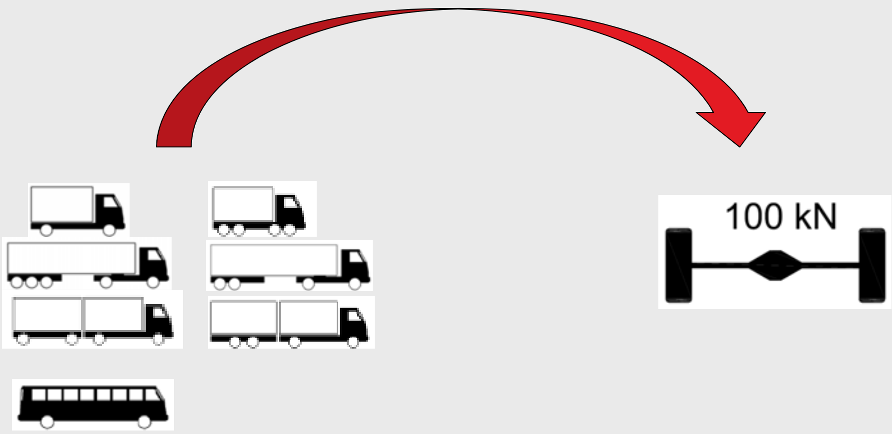
TRAFFIC

- Design life period
  - 30-years for motorways and expressways
  - 20-years for other roads (national, district, local)
- Two classes of allowed load
  - 115 kN – motorways, expressways and national
  - 115 kN or 100 kN other roads – temporarily period
- Equivalent Single Axle Load – 100 kN
  - New equivalency factor: HGV without and with trailer, coaches&buses
  - Factors accounting: lane width and number of lanes, longitudinal gradient
- 7 categories of traffic (KR1-30,000 to KR7-90,000,000 ESAL)

N_{100}



N_{100}

$$N_{100} = f_1 \cdot f_2 \cdot f_3 \cdot (N_C \cdot r_C + N_{C+P} \cdot r_{C+P} + N_A \cdot r_A) \qquad (1)$$

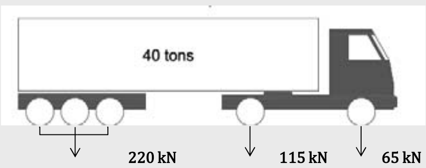
where:

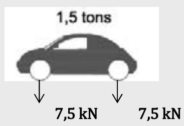
- N_{100} – design traffic being the cumulative number of equivalent standard axles of 100 kN per traffic lane during the design life,
- N_C, N_{C+P}, N_A – cumulative number of HGVs without trailers (C), HGVs with trailers or semitrailers (C+P) and coaches and buses (A) during the design life,
- r_C, r_{C+P}, r_A – load equivalency factors (LEF) to convert the numbers of HGVs without trailers (C), HGVs with trailers (C+P) and coaches (A) to the number of 100 kN ESAL,
- f_1 – load distribution factor of design lane, f_2 – lane-width factor, f_3 – longitudinal gradient factor.

Table 1. Comparison of the load equivalency factors provided in the 2014 and 1997 issues of the Catalogue of Flexible and Semi-rigid Pavements

Vehicle class	2014 issue – Road type and the legal limit of single axle load: Motorways and trunk roads (115 kN)	National roads (115 kN)	Other roads (115 kN)	Other roads (100kN)	1997 issue
HGV without trailer – **C type**	0.50	0.50	0.45	0.45	0.109
HGV with trailer – **C+P type**	1.95	1.80	1.70	1.60	1.245 1.950
Coaches and buses – **A type**	1.25	1.20	1.15	1.05	0.594

N_{100}





$$F_j = \left(\frac{65}{100}\right)^4 + \left(\frac{115}{100}\right)^4 + \left(\frac{220}{263}\right)^4 = 2{,}42$$

$$F_j = \left(\frac{7{,}5}{100}\right)^4 + \left(\frac{7{,}5}{100}\right)^4 = 0{,}00006$$

- 1 x 40t truck == 40 000 passenger cars

POLITECHNIKA GDAŃSKA

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N_{100}

Kategoria ruchu	N_{100} - sumaryczna liczba równoważnych osi standardowych 100 kN w całym okresie projektowym [w milionach osi 100 kN na pas obliczeniowy]
1	*2*
KR1	$0,03 < N_{100} \leq 0,09$
KR2	$0,09 < N_{100} \leq 0,50$
KR3	$0,50 < N_{100} \leq 2,50$
KR4	$2,50 < N_{100} \leq 7,30$
KR5	$7,30 < N_{100} \leq 22,00$
KR6	$22,00 < N_{100} \leq 52,00$
KR7	$N_{100} > 52,00$

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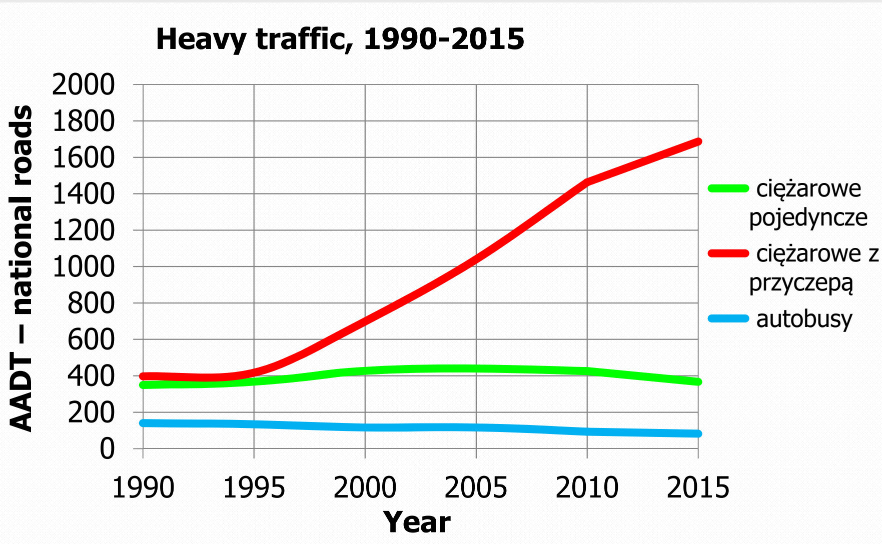
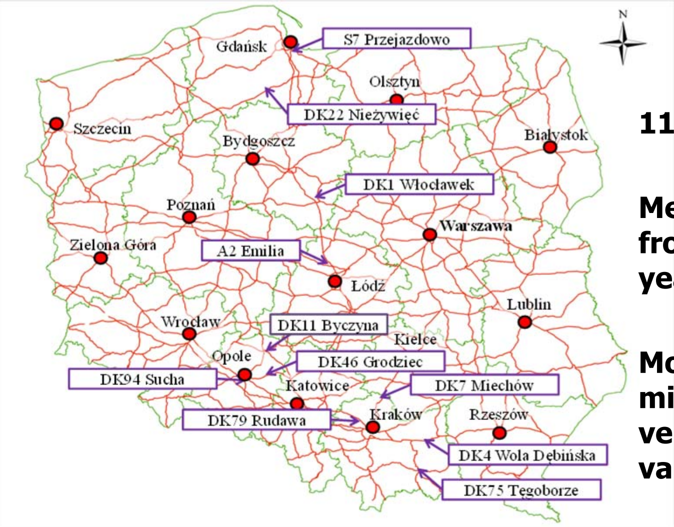
AADTT 1990-2015



TRAFFIC (2)



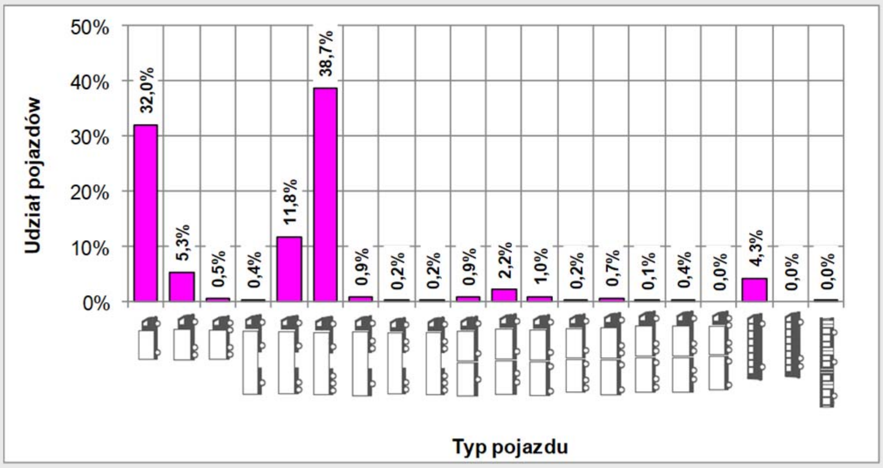
11 WIM stations

Measurement period from 1 to 6 whole years

More than 12 millions heavy vehicles after data validation

WIM – one station

- Example – station at DK94



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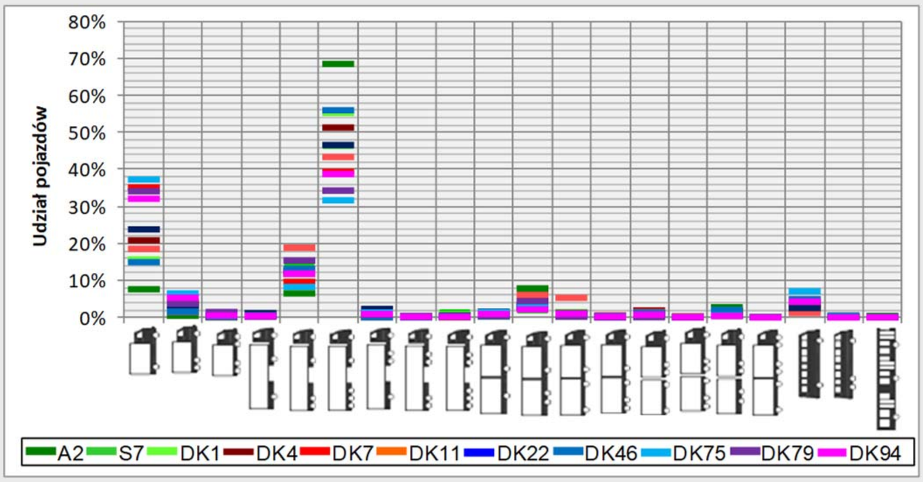
WIM – 11 stations

- WIM data – comparison from 11 stations



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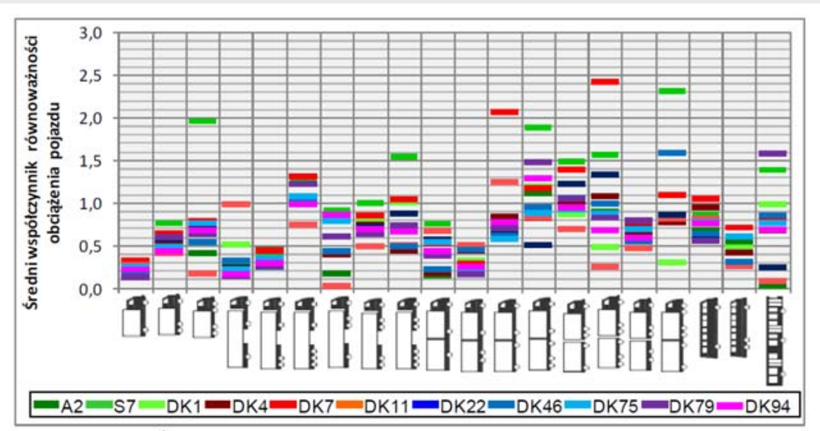
WIM – 11 stations

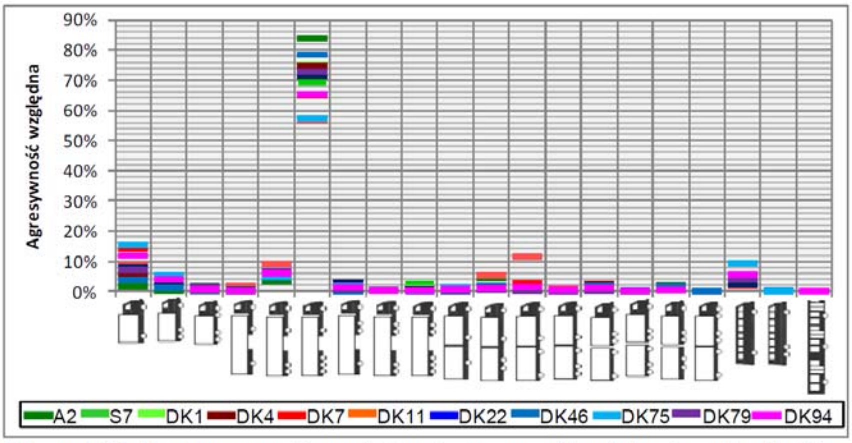
- Load Equivalency Factors (LEF)



Rysunek 3.14. Średnie współczynniki równoważności obciążenia poszczególnych typów pojazdów według wzoru czwartej potęgi

WIM – 11 stations

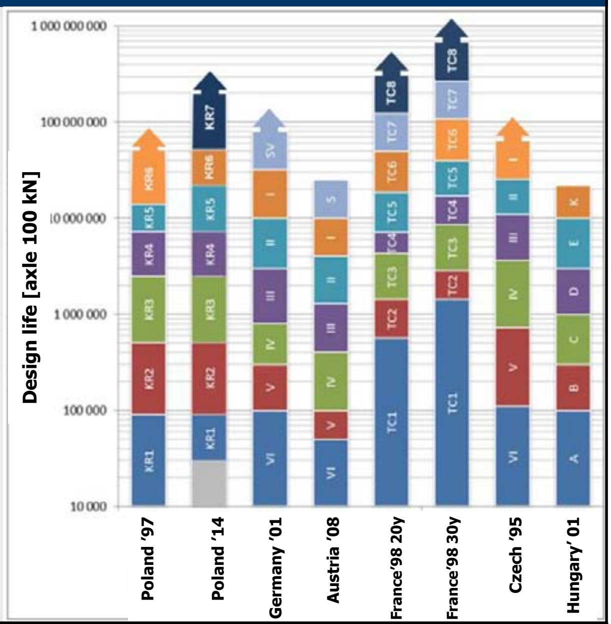
- Relative aggressiveness



Rysunek 3.15. Agresywność względna A_t poszczególnych typów pojazdów t w oparciu o wzór czwartej potęgi

TRAFFIC (3)

Design life:
-all standardized to 100 kN
-20 or 30 years



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MATERIALS

- **Wearing course:** SMA, AC, PA, BBTM
- **Upper base and binder course:** AC (HMAC not included)
- **Lower base course:**
  - Unbound aggregate mixture (**UM**): $C_{90/3}$, $C_{50/30}$, C_{NR}, CBR>80 or 60%
  - Hydraulically bound mixture (**HBM**): $C_{8/10}$, $C_{5/6}$, $C_{3/4}$
  - Hydraulically treated soil (**HTS**): $C_{3/4}$, $C_{1,5/2}$
  - Cold recycling mixture (cement +bitumen emulsion or foam bitumen)

New wearing course

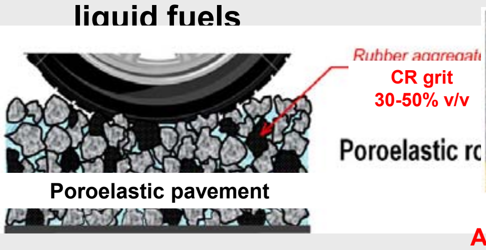
Safe, eco-friendly poroelastic road surface (SEPOR)

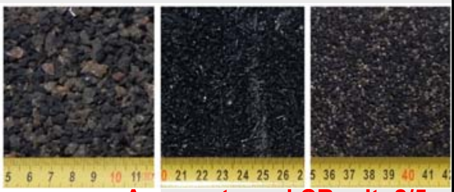
Finansed by NCRD
TECHMATSTRATEG 1/347040/17/NCBR/2018

SEPOR - Aim

Development of innovative poroelastic pavement, where is used crumb rubber grit instead of aggregate which:

- extremly decrease traffic noise (10-12 dB)
- increase safety by high waterpermeability and high skid reisistance
- improve properties of fire suppression from spills of liquid fuels





Aggregate and CR grit: 2/5,
Air voids: 30% Binders: HiMA, epoxy

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MATERIALS (2)

- **Subbase:** UM C_{NR}, CBR>60%, HBM and HTS $C_{5/6}$, $C_{3/4}$, $C_{1,5/2}$
- **Capping layer** – frost layer or drainage layer: HBM or HTS $C_{1,5/2}$, UM CBR>35 or 25% or in case of drainage layer UM, soil n.s.f.h.
- **Improved subgrade:** UM CBR>20%, soil n.s.f.h., HTS $C_{0,4/0,5}$

- n.s.f.h.: non sticky/firm/hard

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Pavement structure	Upper pavement courses	Wearing course	
		Binder course	
		Base	Upper base layer
			Lower base layer
	Lower pavement courses	Subbase	
		Capping layer	
Subgrade	Improved (stabilised) subgrade		
	Original soil in cut or embankment in fill of bearing capacity class G1-G4		

Fig. 2. Schematic diagram and terms relating to courses of flexible and semi-rigid pavement structures and improved subgrade

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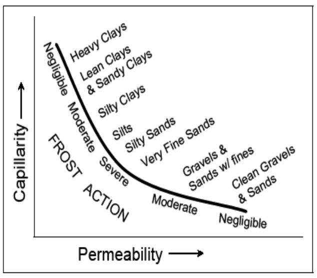
SUBGRADE

- 4 subgrade classes-groups: G1, G2, G3 i G4
- Subgrade classified by bearing capacity: CBR → in situ static plate modulus E_2 and by frost susceptibility

Lp.	Subgrade group Gi	CBR after 4 days soaking [%]	Static plate modulus E2 [MPa]
1	2	3	4
1.	G1	$CBR \geq 10$	$E_2 \geq 80$
2.	G2	$5 \leq CBR < 10$	$50 \leq E_2 < 80$
3.	G3	$3 \leq CBR < 5$	$35 \leq E_2 < 50$
4.	G4	$2 \leq CBR < 3$	$25 \leq E_2 < 35$



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PAVEMENT STRUCTURE

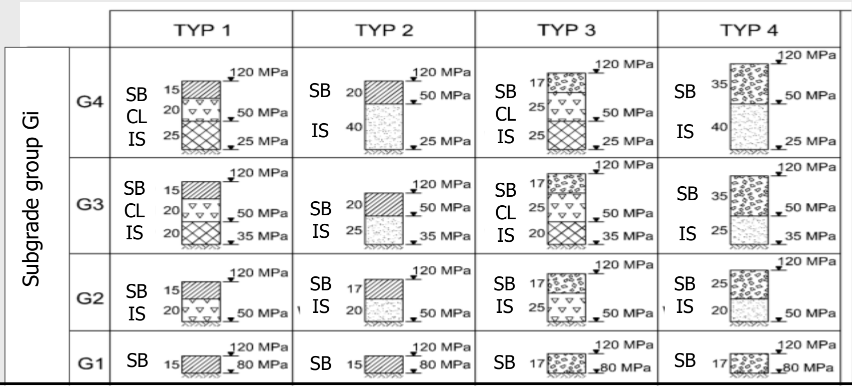
<table>
<tr><td rowspan="6">Pavement structure</td><td rowspan="4">Upper pavement courses</td><td colspan="2">Wearing course</td></tr>
<tr><td colspan="2">Binder course</td></tr>
<tr><td rowspan="2">Base</td><td>Upper base layer</td></tr>
<tr><td>Lower base layer</td></tr>
<tr><td rowspan="2">Lower pavement courses</td><td colspan="2">Subbase</td></tr>
<tr><td colspan="2">Capping layer</td></tr>
<tr><td rowspan="2">Subgrade</td><td colspan="3">Improved (stabilised) subgrade</td></tr>
<tr><td colspan="3">Original soil in cut or embankment in fill of bearing capacity class G1-G4</td></tr>
</table>

Fig. 2. Schematic diagram and terms relating to courses of flexible and semi-rigid pavement structures and improved subgrade

LOWER PAVEMENT LAYERS AND IMPROVED SUBGRADE

- 3 levels of bearing capacity on top of lower pavement layers structure:
  - E_2 = 80 MPa – KR1 i KR2
  - E_2 = 100 MPa – KR3, KR4
  - E_2 = 120 MPa – KR5, KR6 and KR7

SB - subbase
CL – capping layer
IS – improved subgrade



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CALCULATION

1. Mechanistic criteria (IA'81, AASHTO'04, F'94, Shell'77)
2. Empirical method - AASHTO '93
3. Catalogues
   - Austria '08
   - Germany '01
   - Poland '97
   - UK method '06
   - France '98

CALCULATION (2)

- AASHTO 2004 – main criterium (bottom-up cracking)
  - FC=5, 10, 15 i 20%
- IA, Shell – only for comparison
- F – only for HMAC (finally not included)
- University of Illinois (Dempsey) – for semi-rigid
- PCA – for semi-rigid

AASHTO fatigue criterium

$$N_f =$$

$$D * 7{,}3557 * (10^{-6}) \cdot C \cdot k'_1 \left(\frac{1}{\varepsilon_t}\right)^{3{,}9492} \left(\frac{1}{E}\right)^{1{,}281}$$

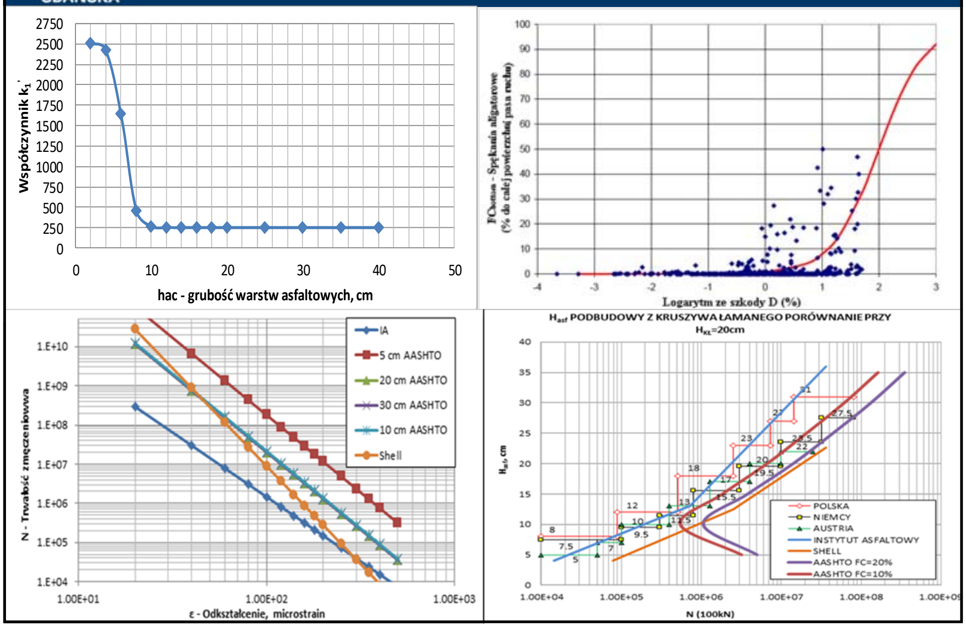
$C = 10^M$

$$M = 4{,}84\left(\frac{V_b}{V_a + V_b} - 0{,}69\right)$$

$$k'_1 = \frac{1}{0{,}000398 + \frac{0{,}003602}{1 + e^{(11{,}02 - 1{,}374 \cdot h_{ac})}}}$$

$$FC_{bottom} = \left(\frac{100}{1 + e^{(-2 \cdot C'_2 + C'_2 \cdot log_{10}(D \cdot 100))}}\right)$$

Criterium AASHTO 2004



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IA deformation criterium

- $N_p = \left(\frac{\varepsilon_z}{0{,}0105}\right)^{\left(-\frac{1}{0{,}223}\right)}$

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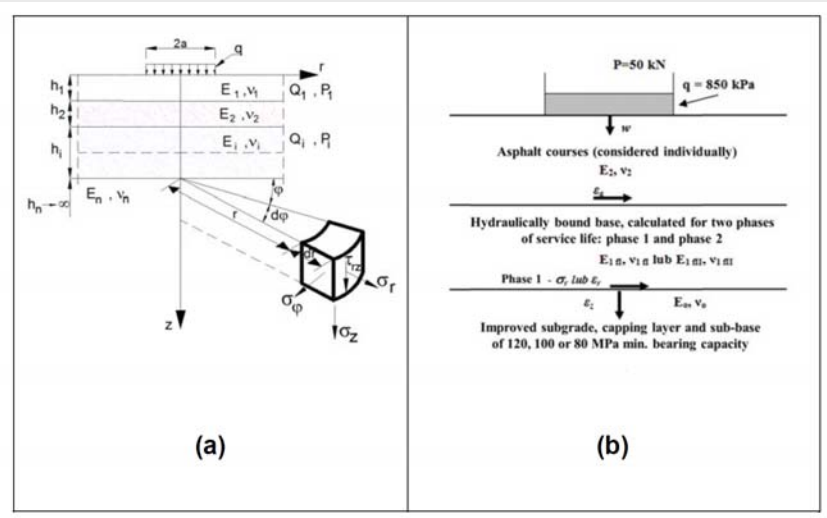
CALCULATION



CALCULATION ASSUMPTIONS

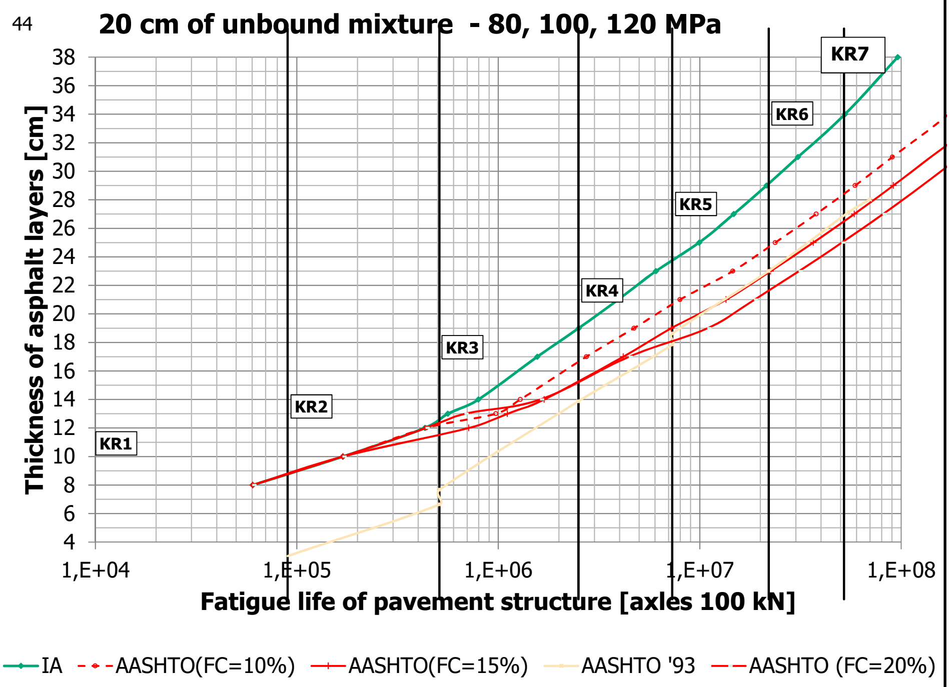
1. Mechanistic calculation of upper pavement layers for support level of 120, 100 and 80 MPa, depending on the traffic class KR
   - solutions for lower pavement layers and improved subgrade were calculated earlier
2. Accepted results
   - according to AASHTO 2004
3. Comparison of accepted results with other catalogues
4. Implementation of technological tolerances for asphalt layers (+1 cm for asphalt layers)

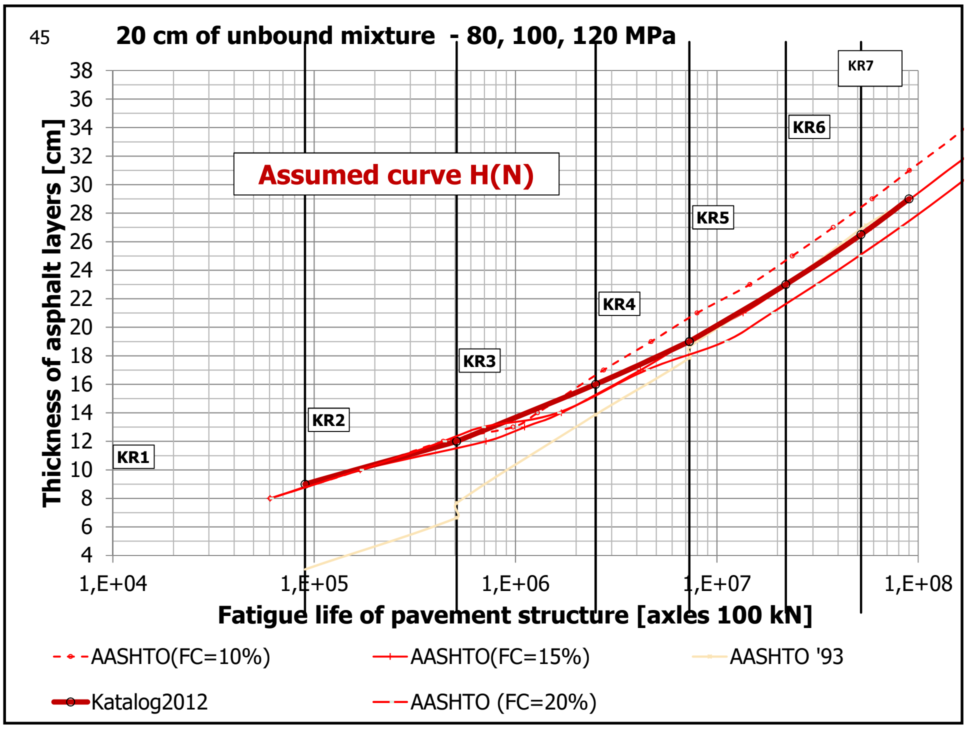
CALCULATION ASSUMPTIONS (2)

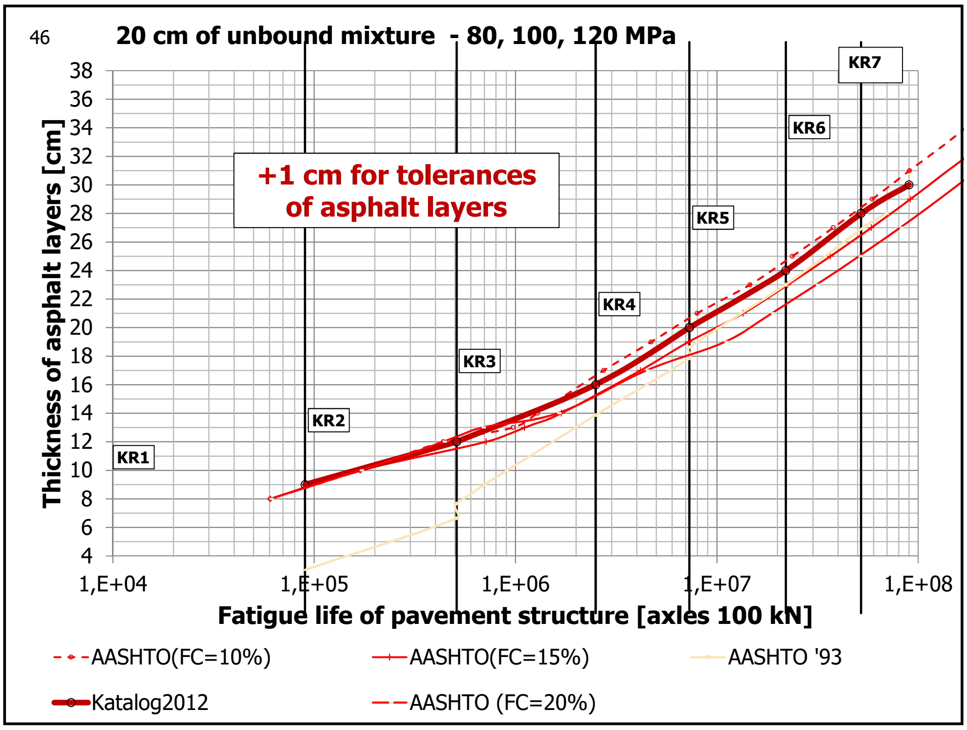
- Wheel load - 850 kPa, 50 kN (650 kPa, 50 kN)
- Stiffness of asphalt layers (Shell method)
  - Bitumen: 35/50 i 50/70 - D50/70
  - New volumetric proportion
  - New equivalent temperature
    - +13°C (+15°C) +2, +10, +23°C

BASE COURSE

(UPPER) AC & (LOWER) UM




45
20 cm of unbound mixture - 80, 100, 120 MPa
Assumed curve H(N)
KR1
KR2
KR3
KR4
KR5
KR6
KR7
Thickness of asphalt layers [cm]
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
1,E+04
1,E+05
1,E+06
1,E+07
1,E+08
Fatigue life of pavement structure [axles 100 kN]
AASHTO(FC=10%)
AASHTO(FC=15%)
AASHTO '93
Katalog2012
AASHTO (FC=20%)


46
20 cm of unbound mixture - 80, 100, 120 MPa
+1 cm for tolerances
of asphalt layers
KR1
KR2
KR3
KR4
KR5
KR6
KR7
Thickness of asphalt layers [cm]
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
1,E+04
1,E+05
1,E+06
1,E+07
1,E+08
Fatigue life of pavement structure [axles 100 kN]
AASHTO(FC=10%)
AASHTO(FC=15%)
AASHTO '93
Katalog2012
AASHTO (FC=20%)

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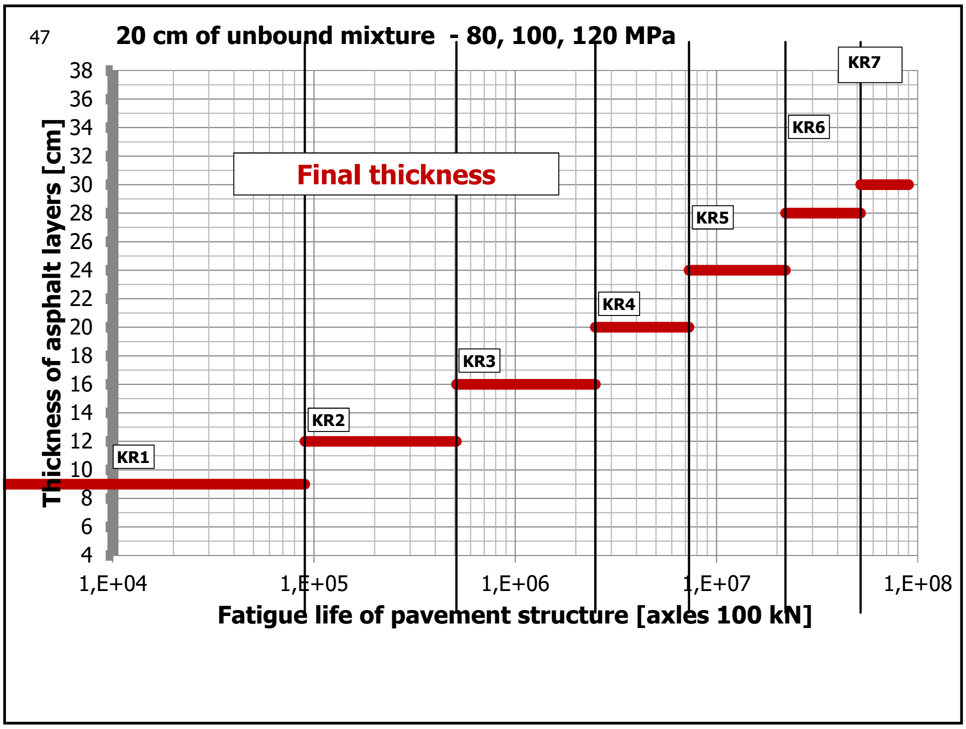
20 cm of unbound mixture - 80, 100, 120 MPa
Final thickness
KR1
KR2
KR3
KR4
KR5
KR6
KR7
Thickness of asphalt layers [cm]
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
1,E+04
1,E+05
1,E+06
1,E+07
1,E+08
Fatigue life of pavement structure [axles 100 kN]

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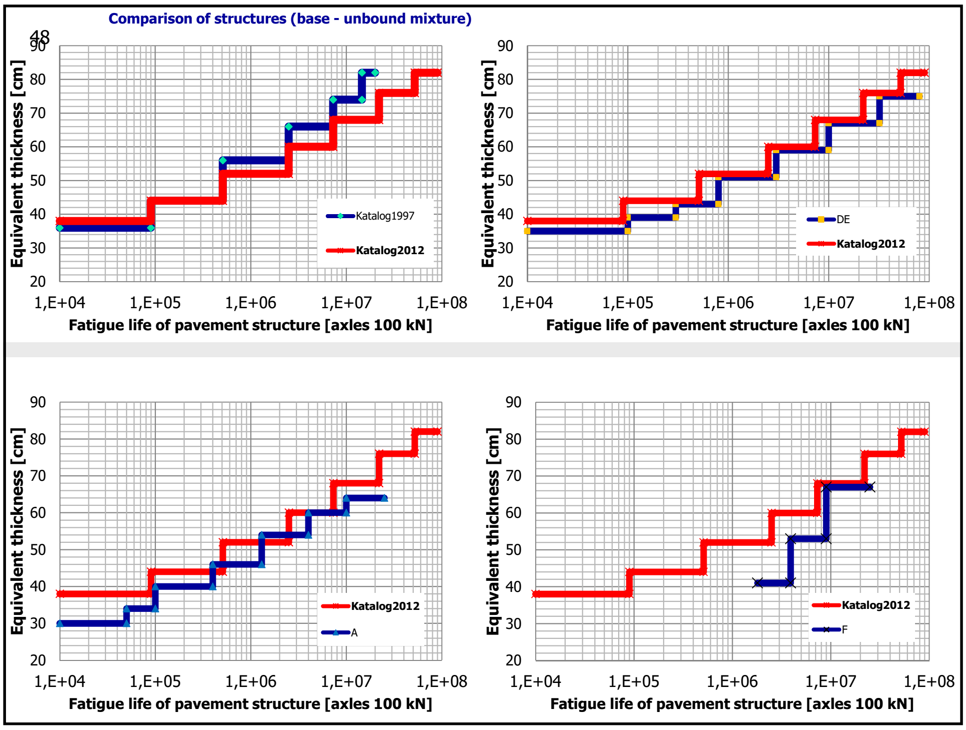
Comparison of structures (base - unbound mixture)
Equivalent thickness [cm]
90
80
70
60
50
40
30
20
1,E+04
1,E+05
1,E+06
1,E+07
1,E+08
Fatigue life of pavement structure [axles 100 kN]
Katalog1997
Katalog2012
DE
Katalog2012
Katalog2012
A
Katalog2012
F

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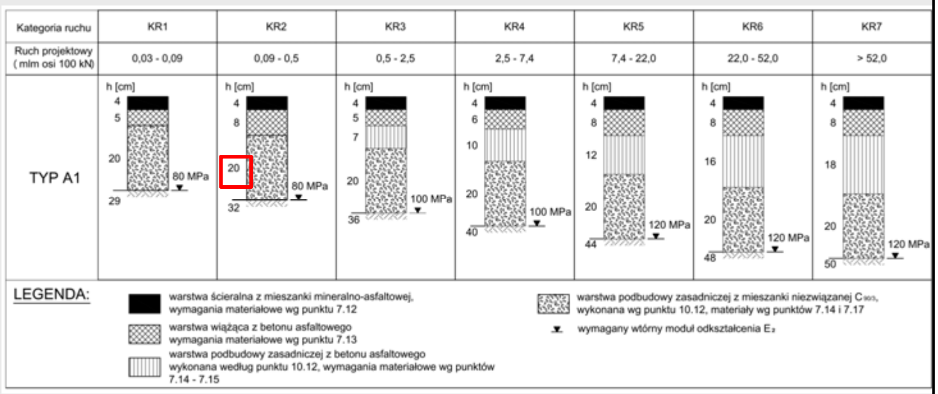
TYP A1: (upper base) - AC, (lower base) – unbound mixture $C_{90/3}$



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RESULTS – NEW STRUCTURES

- Type A1 – **AC + UM $C_{90/3}$ – KR1-7**
- Type A2 – **AC + UM $C_{50/30}$ – KR1-7**
- Type A3 – **AC + UM C_{NR} – KR1-2**
- Type B – **AC (full depth) – KR1-7**
- Type C – **AC+HBM $C_{8/10}$, $C_{5/3}$, $C_{3/4}$ – KR1-7**
- Type D – **HTS $C_{1,5/2}$ – KR1-2**
- Type E – **CRM – KR1-4**

RESULTS – NEW STRUCTURES

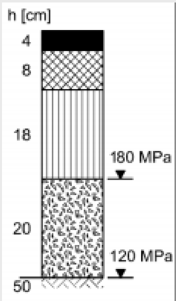
Table 3. Thicknesses of the upper courses of typical pavement structures given in [11]

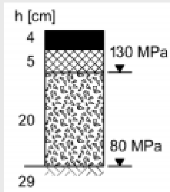
No.	Type of pavement	Pavement course	Thickness of the upper courses of pavement, cm						
			Traffic class						
			KR1	KR2	KR3	KR4	KR5	KR6	KR7
1.	Flexible	Asphalt layers	9	12	16	20	24	28	30
		Unbound base, $C_{90/3}$	20	20	20	20	20	20	20
2.	Flexible	Asphalt layers	9	12	16	20	24	28	30
		Unbound base, $C_{50/30}$	22	22	22	22	22	22	22
3.	Flexible	Asphalt layers	9	12	-	-	-	-	-
		Unbound base, C_{NR}	25	25	-	-	-	-	-
4.	Flexible	Asphalt layers and base	14	18	22	26	30	34	36
5.	Flexible	Asphalt layers	8	12	12	16	-	-	-
		Mineral/cement/emulsion/ FBit base	15	15	20	20	-	-	-
6.	Semi-rigid	Asphalt layers	9	11	15	18	20	22	24
		Hydraulically-bound base	18	20	20	22	22	24	24
7.	Semi-rigid	Asphalt layers	9	11	-	-	-	-	-
		Hydraulically treated soil base	18	20	-	-	-	-	-

STRUCTURE EXAMPLES

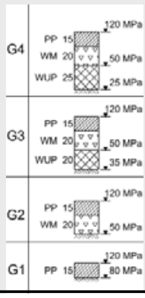
KR7 – 52-90 mln 100 kN   KR1- 0,03-0,09 mln 100 kN

Upper layers -





Lower layers and improved subgrade -

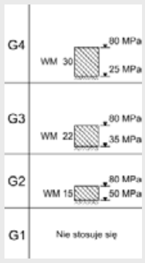


Very weak subgrade (E2>25 MPa or 2<CBR<3%)

Weak subgrade (E2>35 MPa or 3<CBR<5%)

Quite good subgrade (E2>50 MPa or 5<CBR<10%)

Strong subgrade (E2>80 MPa or CBR>10%)



OUTLINE

- Introduction
- Terminology and structure
- Traffic
- Materials
- Subgrade
- Lower layers and improved subgrade
- Calculations of upper layers
- Results – new structures
- **Conclusions**

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CONCLUSIONS

- New Polish Catalogue covers:
  - new extended traffic loads and design life period, EU standard materials
- Safety margins:
  - traffic calculation, mechanical properties of materials (conservative), tollerances of asphalt layers
- It was implemented to official use by government in 2015

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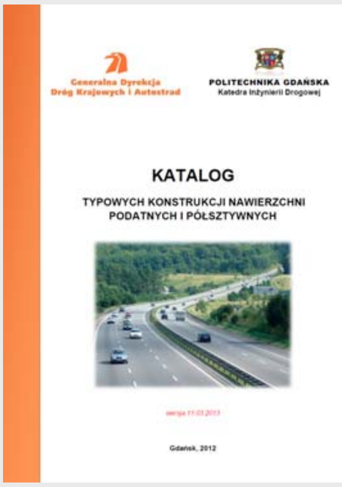
Catalogue

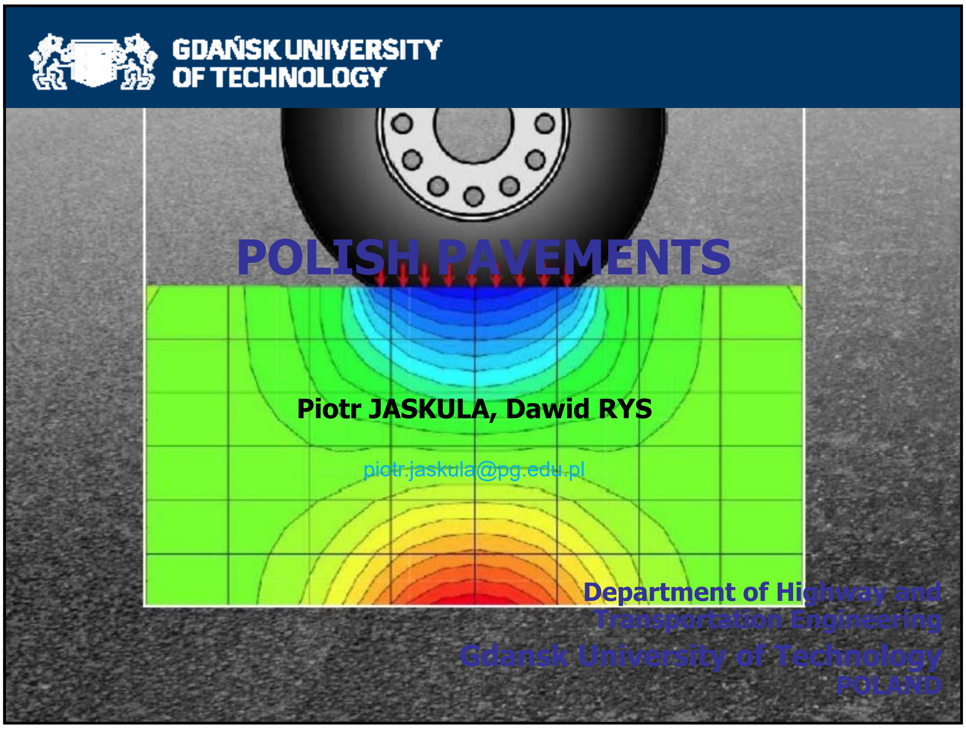

Generalna Dyrekcja Dróg Krajowych i Autostrad

POLITECHNIKA GDAŃSKA
Katedra Inżynierii Drogowej

KATALOG

TYPOWYCH KONSTRUKCJI NAWIERZCHNI PODATNYCH I PÓŁSZTYWNYCH

Gdańsk, 2012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Thank you!
fot. Michał Czacharowski
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