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Reuse of Linz-Donawitz (LD) Slag in Asphalt Mixtures for Pavement Application

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IWWATV 2015 Athens, Friday, 22nd

What is LD-Slag?

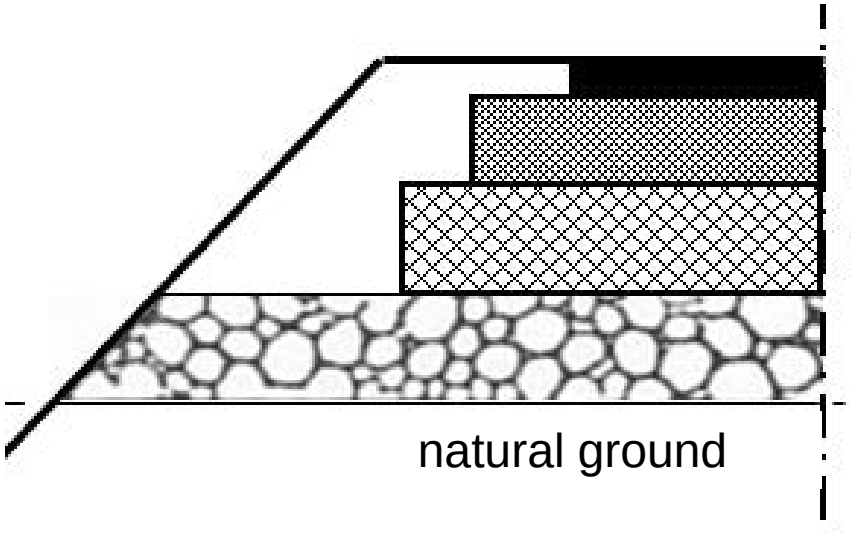
- byproduct of steel production (LD process in particular) as pig iron is processed into crude steel
- slag is separated from the crude steel and separately processed
- main components: iron oxide, calcium oxide and silicon dioxide

Europe: ~ 12 mio. tons of steel slag is produced per year

Objective & Research Approach

How does use of LD slag in asphalt mixtures affects the functional performance of pavement construction compared to asphalt mixtures with natural aggregate Gabbro?

Structure layers of asphalt pavements

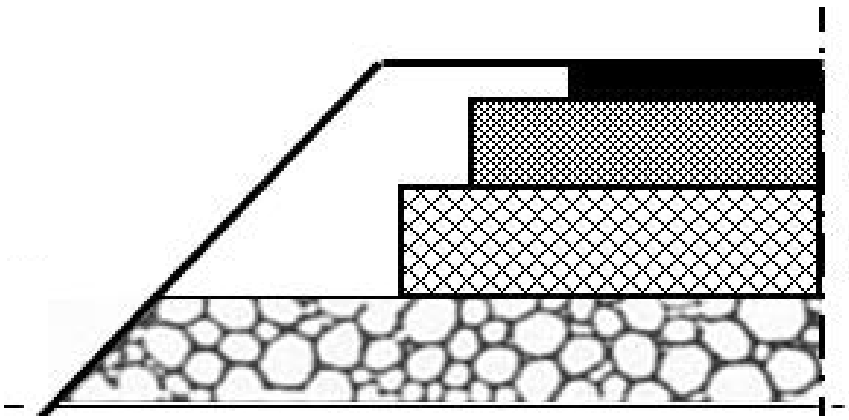


Surface layer
Binder layer
Base layer

Asphalt = mixture of bitumen ("glue") + aggregates

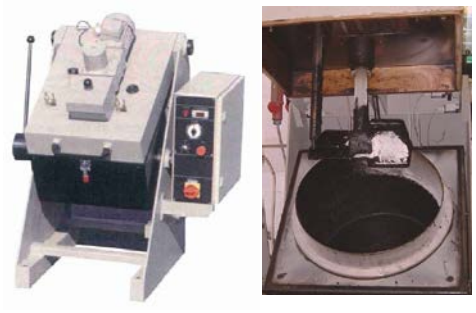
Sub base (unbounded, e. g. Stone)

Objective & Research Approach



Surface layer
Binder layer
Base layer
} Asphalt

Production of asphalt mixture variants with LD slag and natural aggregate Gabbro in the lab:



- MA 11 S (surface layer, mastics asphalt)
- SMA 11 S (surface layer, stone-mastic-asphalt)
- AC 16 B S (binder layer with a maximum aggregate size of 16 mm)
- AC 22 T S (base layer with a maximum aggregate size of 22 mm)

Objective & Research Approach

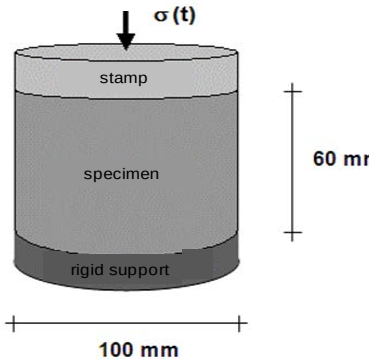
Asphalt properties evaluated in the lab:

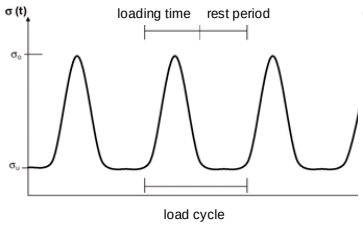
- Resistance to permanent deformation
- Stiffness
- Fatigue resistance
- Resistance to low temperature cracking
- Skid resistance of surface layer

Test Methods - Resistance to permanent deformation

Penetration Test
[EN 12697-25, Pt. A1]

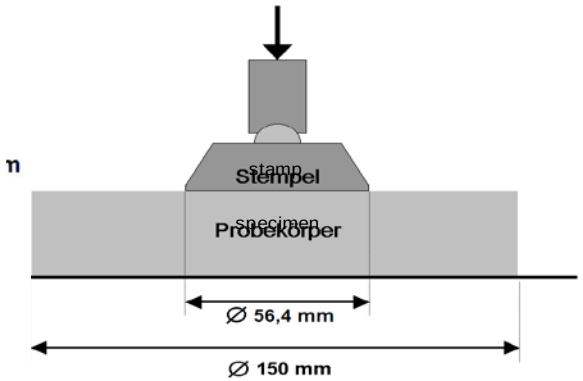
T = +50 °C





Cyclic Compression Test
[EN 12697-25, Pt. B1]

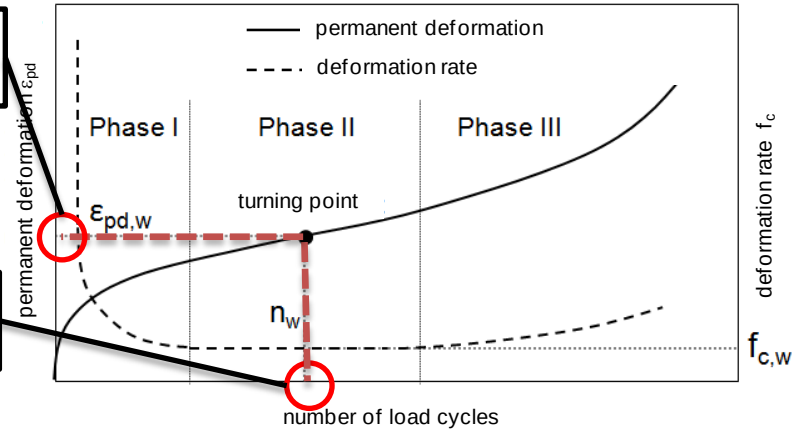
T = +50 °C



penetration depth ET_{dyn}
after 2500 load cycles [mm]

Strain @
turning point [‰]

No. of load cycles @
turning point [-]



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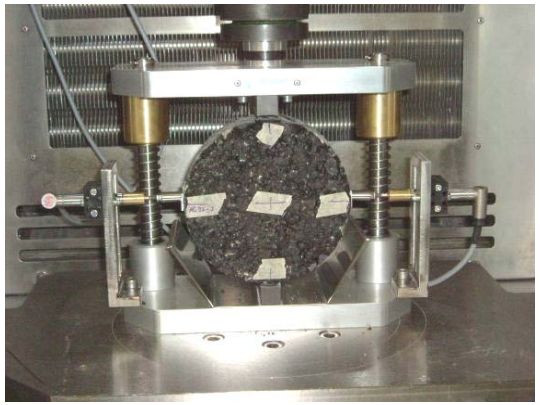
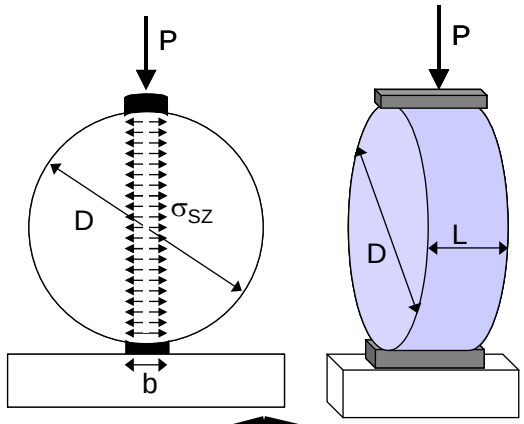
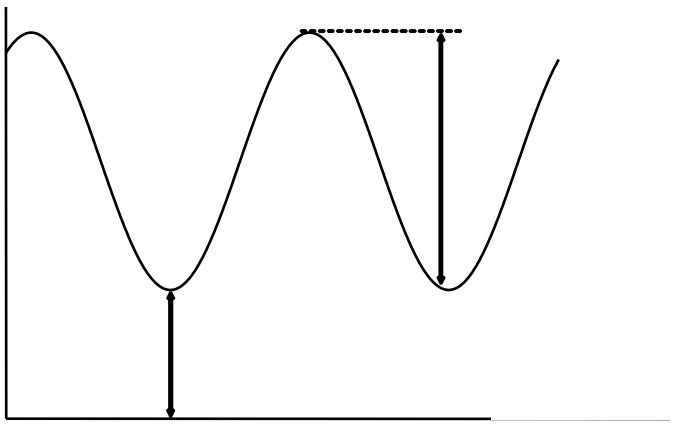
Test Methods - Stiffness and fatigue resistance

Cyclic Indirect Tensile Test [EN 12697-24]





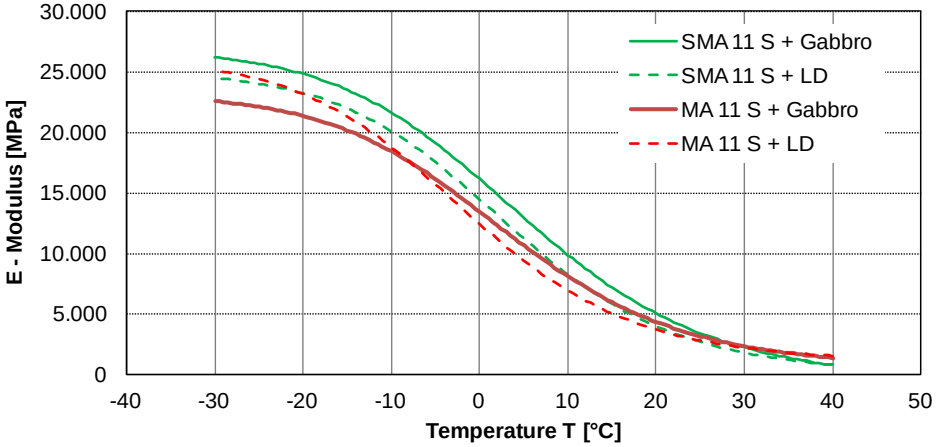


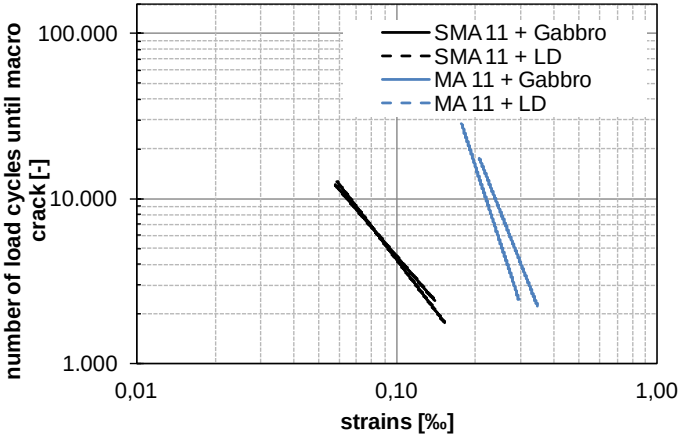
Stiffness

E = f(T)

Fatigue

$$N_{Makro} = C_1 \cdot \varepsilon_{el,anf}^{C_2}$$





Test Methods – Resistance to low temperature cracking

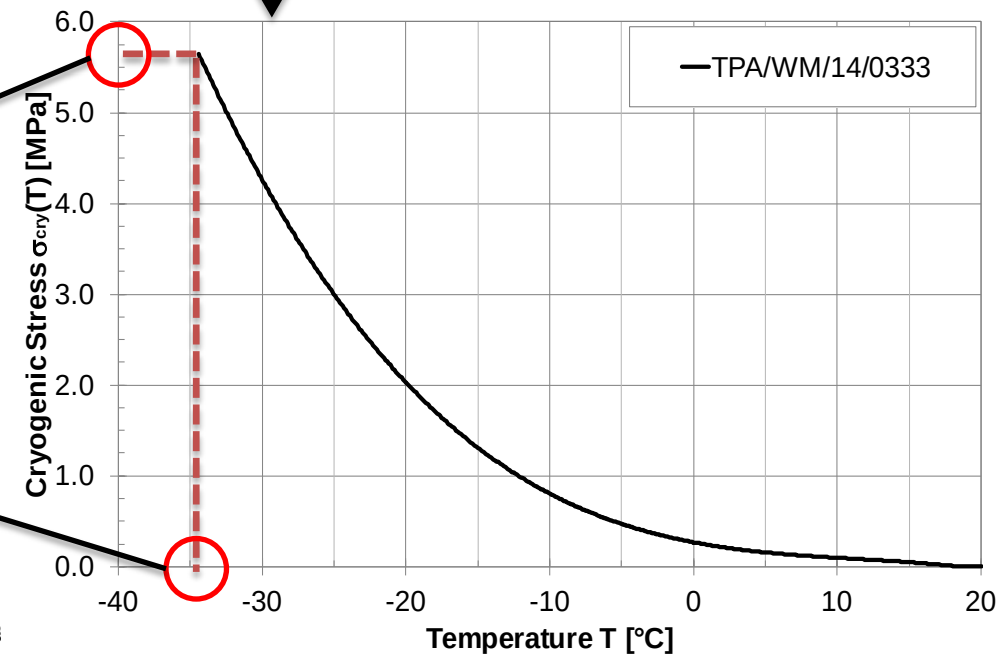
Thermal Stress Restrained Specimen Test [EN 12697-46]

1. Start @ T = 20 °C
2. Cooling Rate ΔT = -10 °C/h
3. Specimen at constant length

Due to prohibited thermal shrinkage

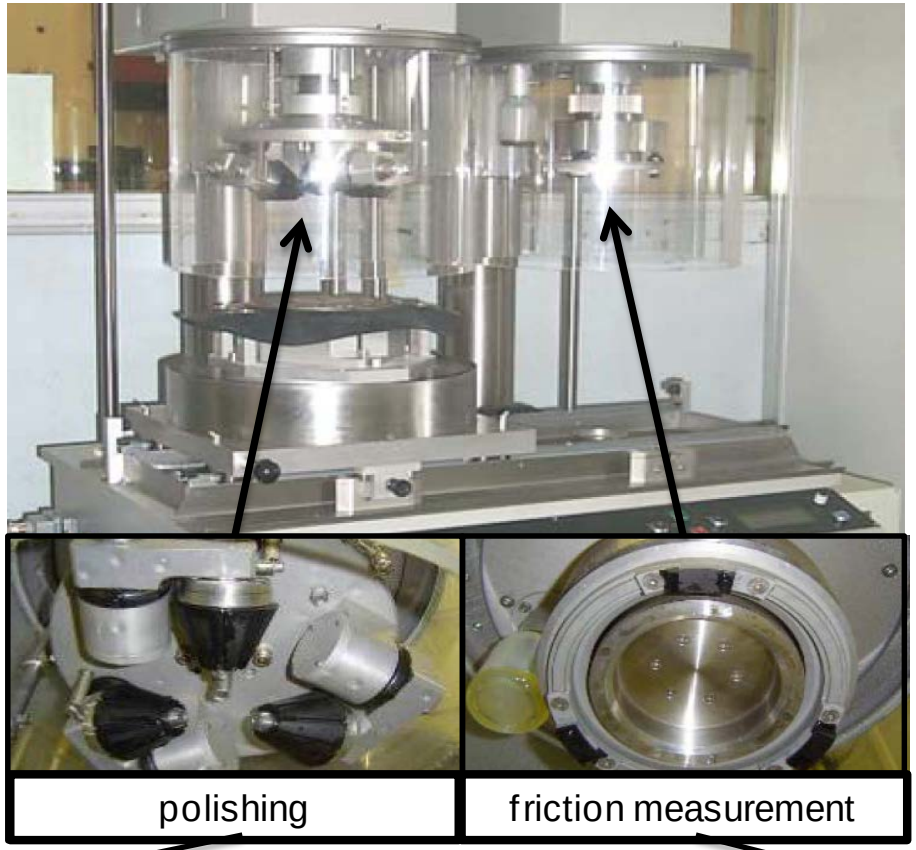
Failure stress σ_F [MPa]

Failure temp. T_F [°C]



Test Methods – Skid Resistance

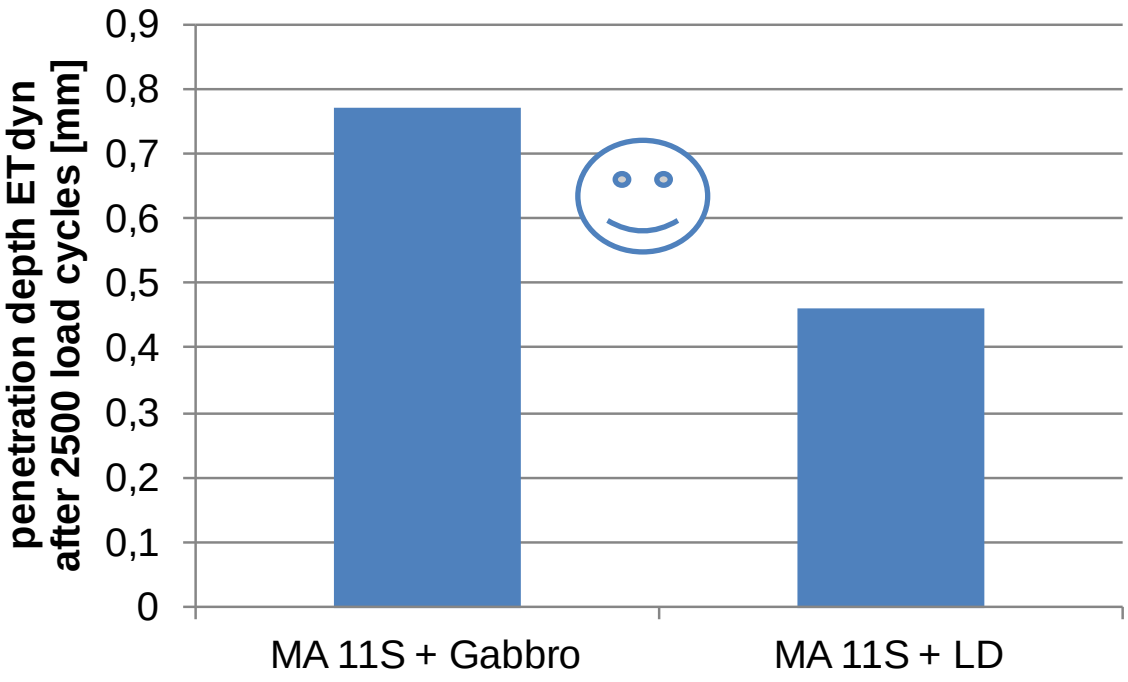
Skid resistance of surface layer [German Standard TP Gestein-StB, Pt 5.4.2]

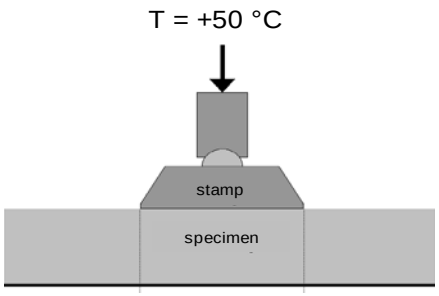


simulation of traffic exposure
1 hour / 500 rpm
Injection water-quartz powder mix

Rotating rubber bodies (100 km/h)
lowered onto specimen surface
thereby braked → friction coefficient

Results - Resistance to permanent deformation
Surface layer: mastic asphalt (MA)



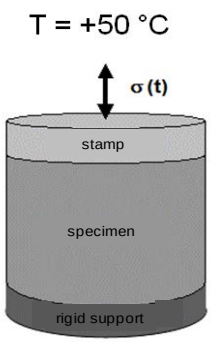


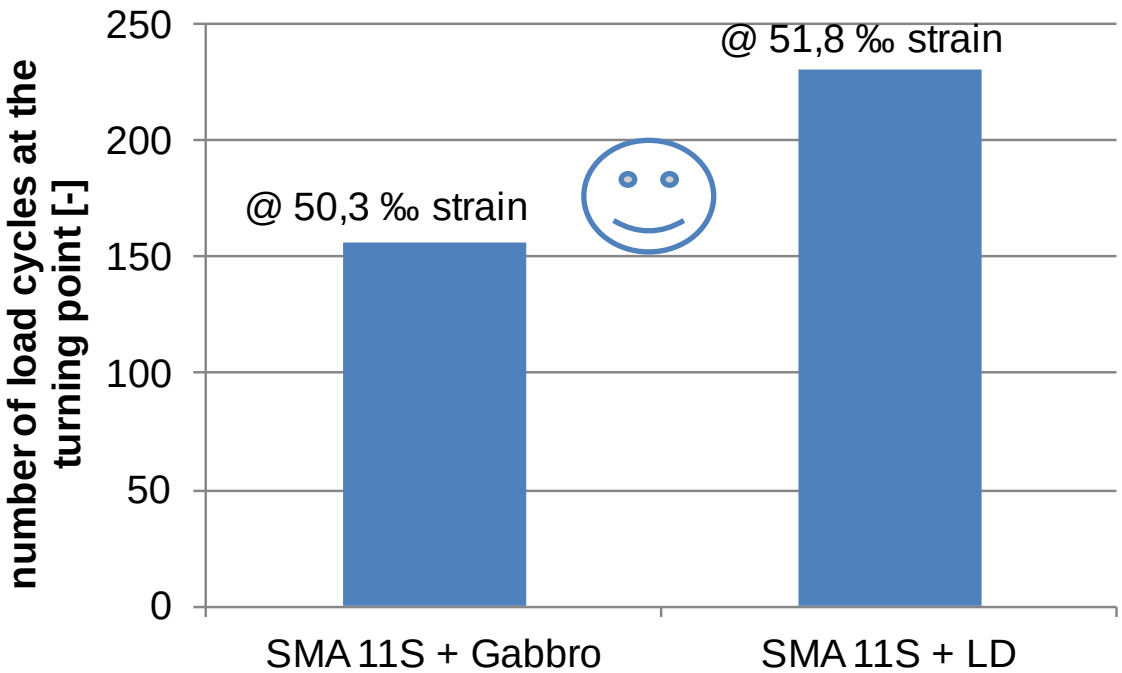
- Slag much lower penetration depth compared MA with natural Gabbro

use of LD slag in mastic asphalt (MA) leads to an advantageous deformation resistance compared to mastic asphalt with natural Gabbro aggregate

Results - Resistance to permanent deformation

Surface layer: stone mastic asphalt (SMA)



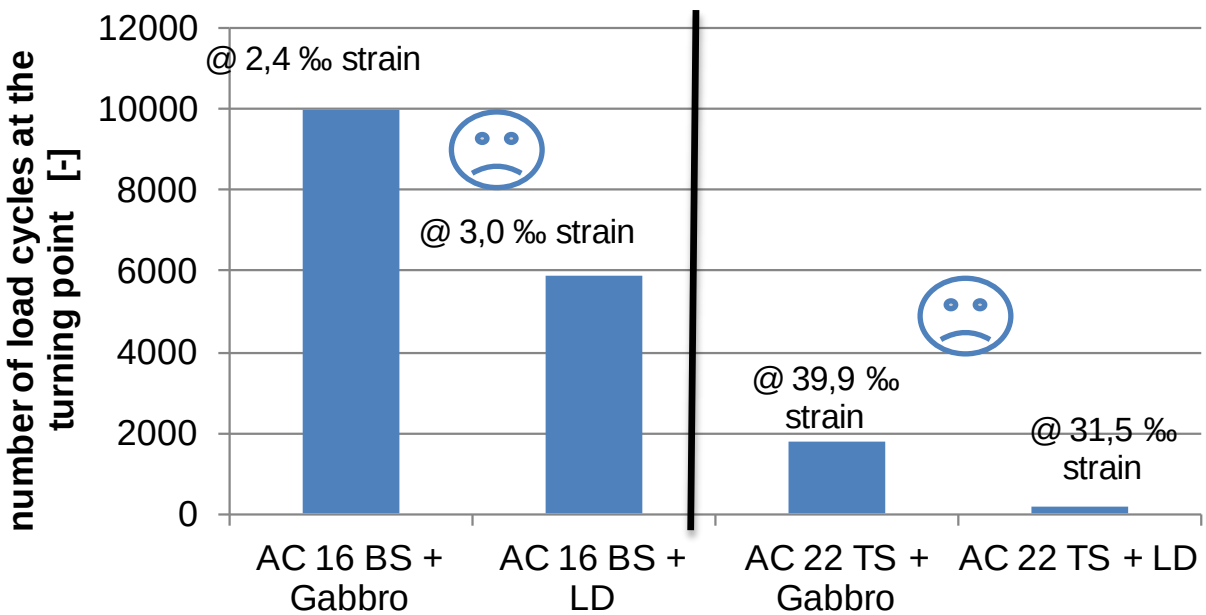


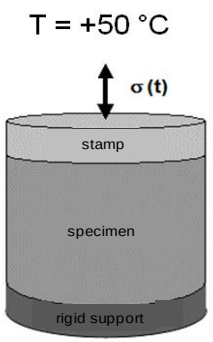
- Slag lead to higher number of load cycles compared to SMA with natural Gabbro

use of LD slag in stone mastic asphalt (SMA) leads to an advantageous deformation resistance compared to stone mastic asphalt with natural Gabbro aggregate (same tendency as for MA)

Results - Resistance to permanent deformation

Binder- & base layer: AC 16 BS & AC 22 TS





- number of load cycles @ turning point much lower for LD slag
- Strains comparable in magnitude

deformation behavior of the asphalt binder and asphalt base mixtures with LD Slag

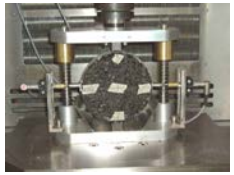
<u>but:</u>

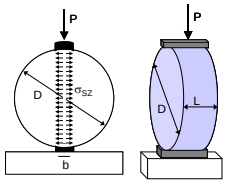
LD slag mixtures showed higher air voids contents (up to 3.0 vol.-%)

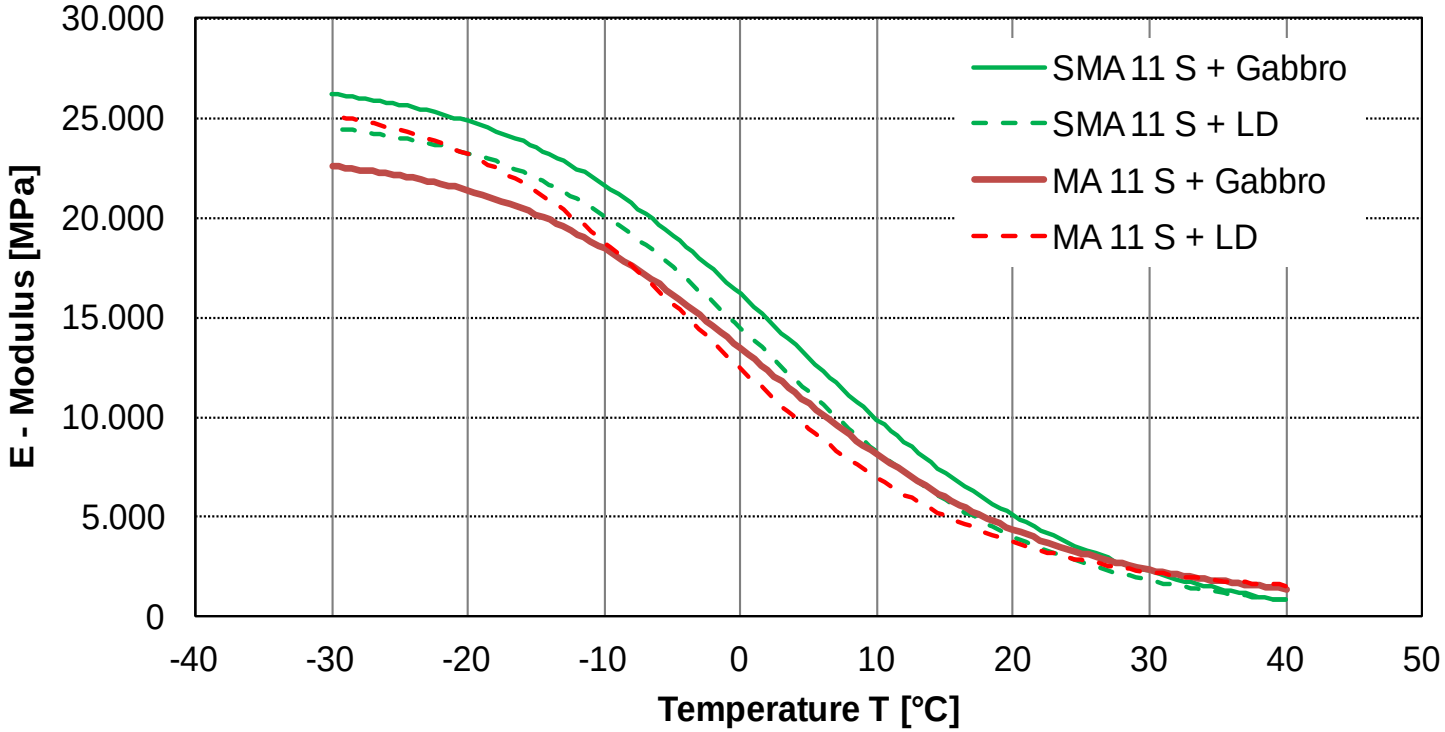
→ affects negatively resistance to permanent deformation

Results - Stiffness

Surface layer: mastic asphalt (MA) & Stone mastic asphalt (SMA)



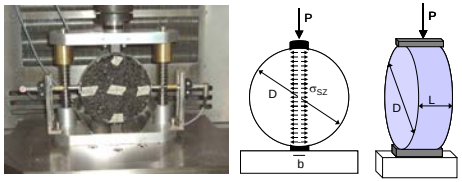


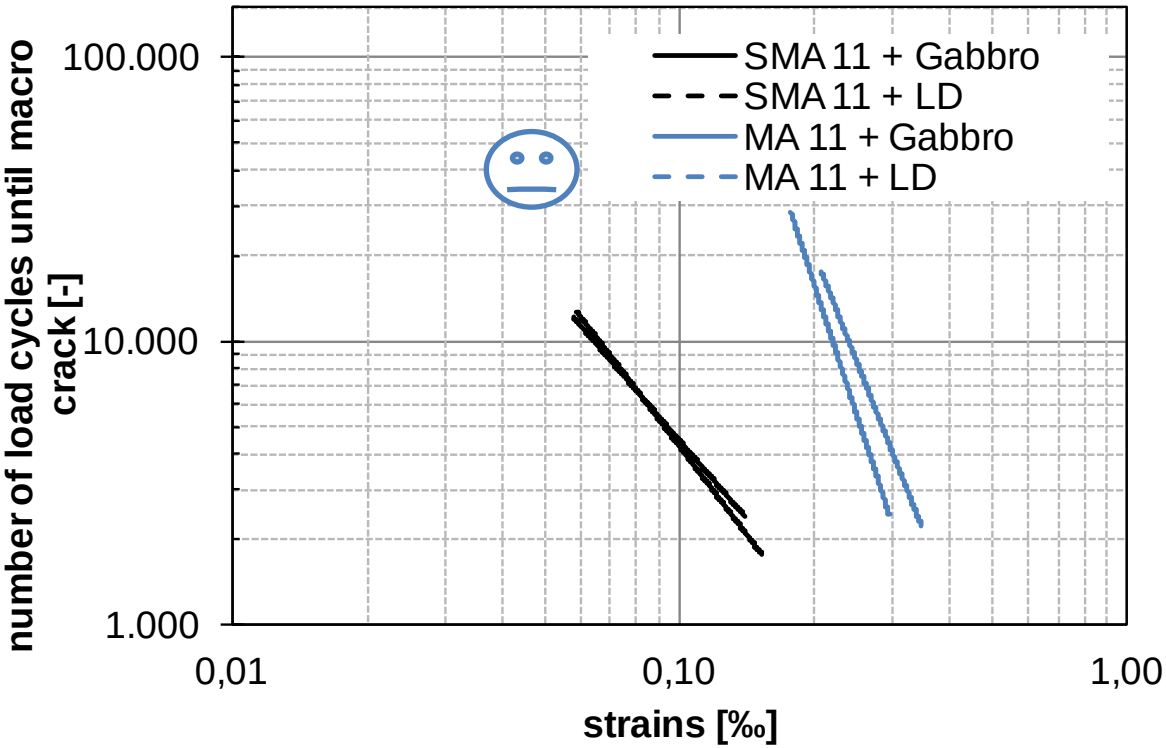


Resulting stiffness is for all asphalt surface mixtures at a comparable level, regardless of whether LD slag or natural Gabbro aggregate was used

Results – Fatigue resistance

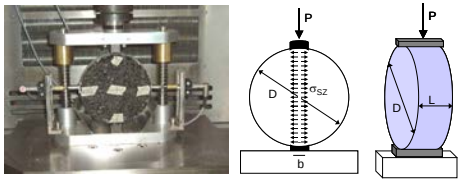
Surface layer: mastic asphalt (MA) & Stone mastic asphalt (SMA)

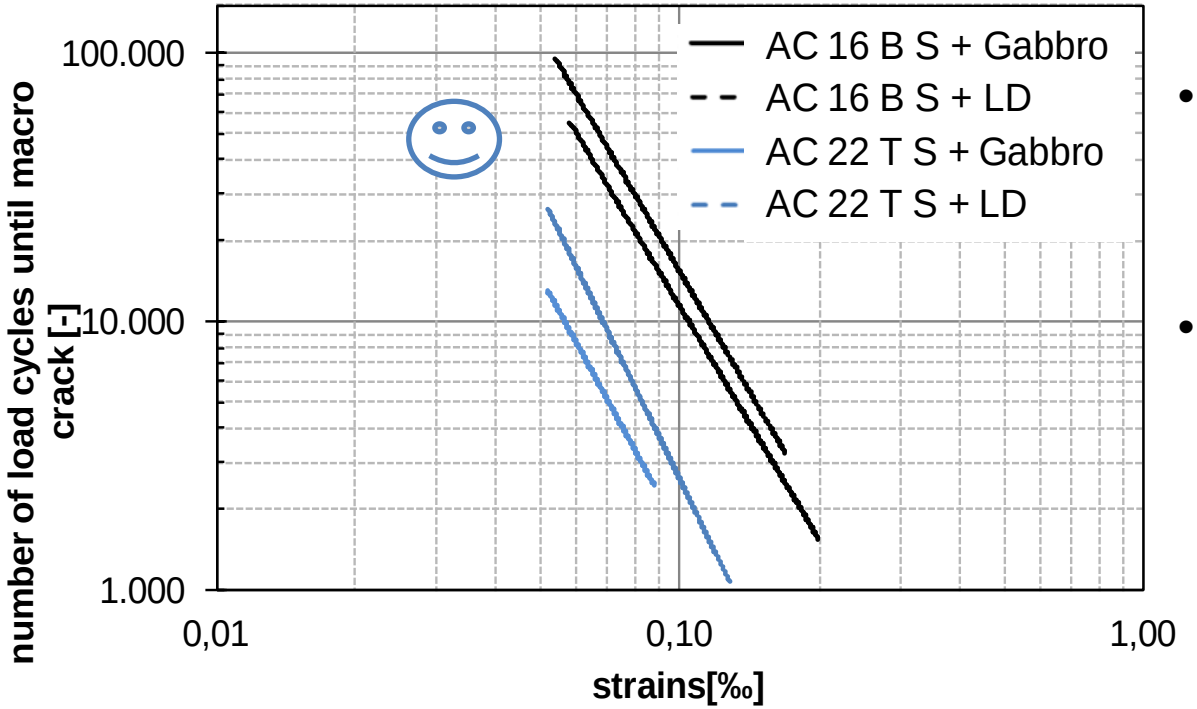




Similar fatigue resistance for mixtures with natural aggregate Gabbro and LD slag

Results – Fatigue resistance
Binder- & base layer: AC 16 BS & AC 22 TS



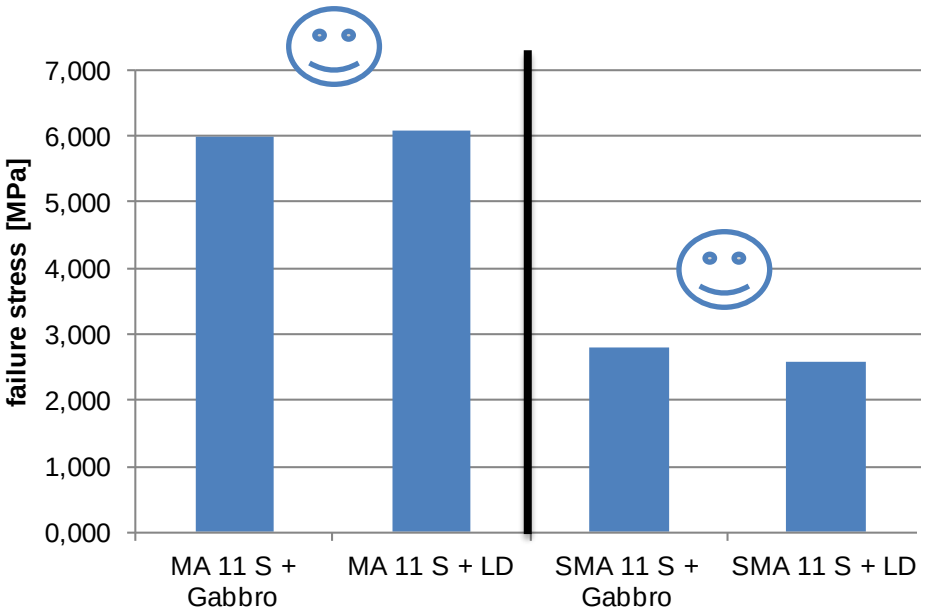


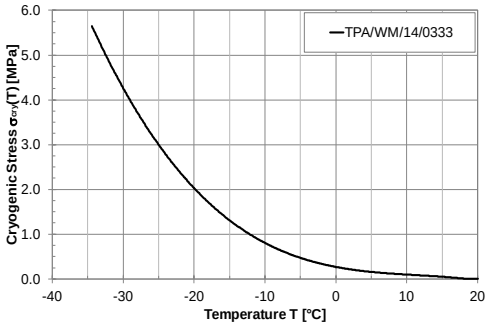
- Wöhler curves of asphalt binder and asphalt base mixtures with LD slag are shifted upwards
- for the same elastic strain, mixtures with LD slag can sustain a higher number of load cycles before a macro crack

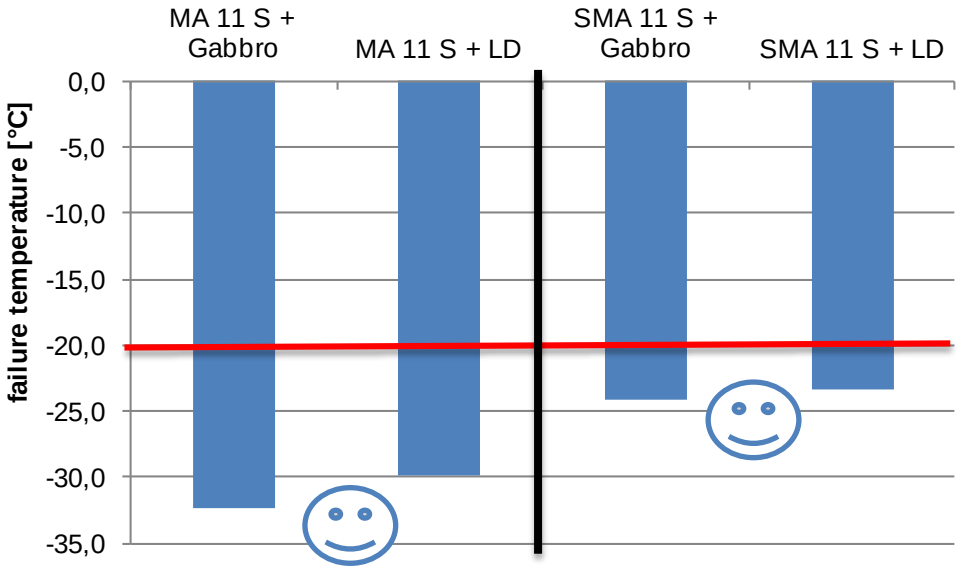
Use of LD slag in asphalt binder and asphalt base course mixtures leads to a higher fatigue resistance in comparison to mixture with natural Gabbro

Results - Resistance to low temperature cracking

Surface layer: mastic asphalt (MA) & Stone mastic asphalt (SMA)



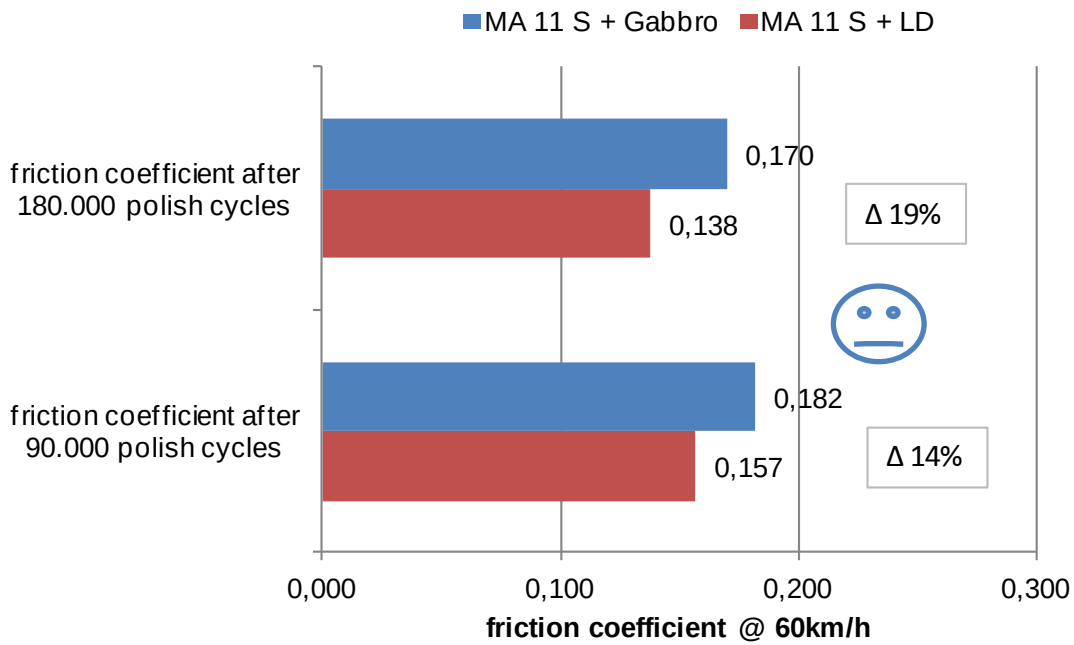


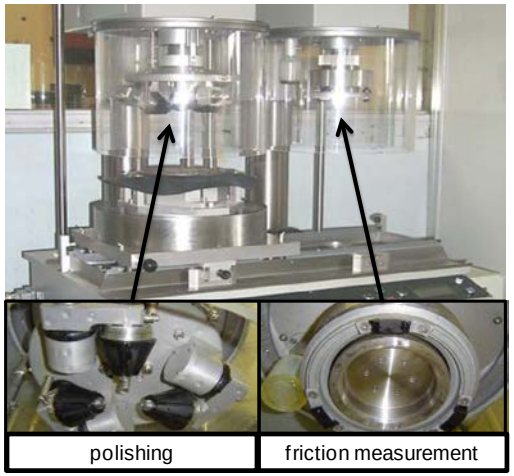


- Comparable resistance to low temperature cracking
- Failure stresses at a high (good) level

→ typical for commonly used asphalt pavement surface layers in Europe

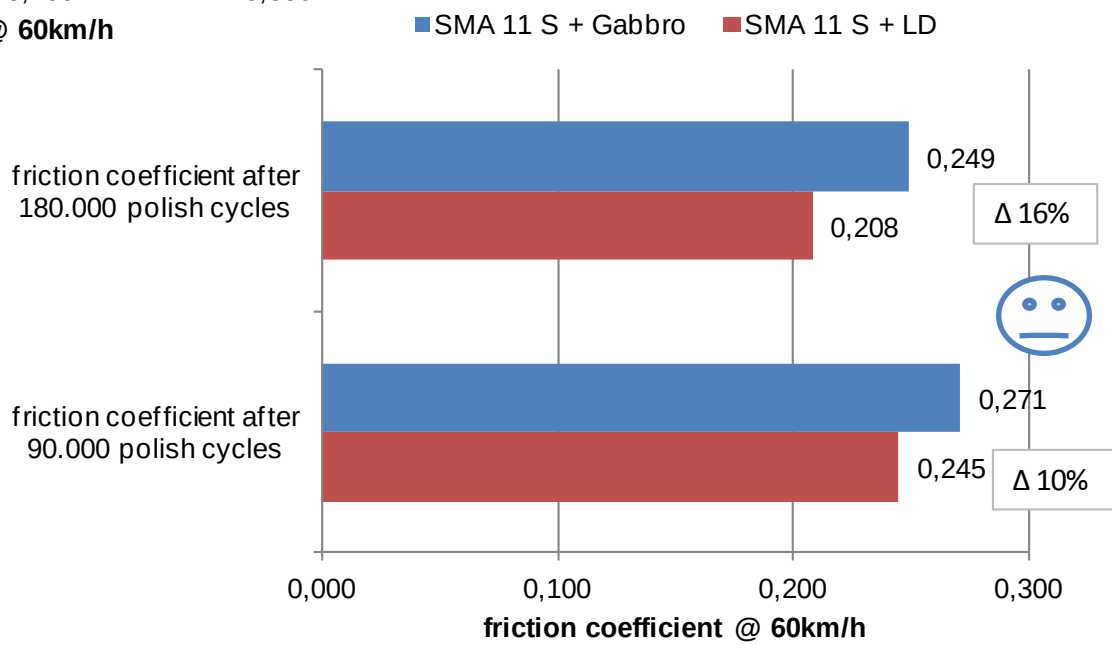
Results – Skid Resistance of surface layer





- friction coefficients of the mixtures with LD about 15 to 20% lower compared to Gabbro

→ Nevertheless high level of friction (satisfactory for safety purposes)



Summary and conclusions

How does use of LD slag in asphalt mixtures affects the functional performance of pavement construction compared to asphalt mixtures with natural aggregate Gabbro?

☹ disadvantageous 😐 comparable (good!) level ☺ advantageous

Resistance to permanent deformation ☺ surface

☹ binder, base → voids!

Stiffness 😐

Fatigue resistance 😐

Summary and conclusions

☹ disadvantageous 😐 comparable (good) level ☺ advantageous

Resistance to low temperature cracking 😐

Skid resistance of surface layer 😐

1. asphalt mixtures with LD slag are suitable for asphalt pavement construction
2. performance as good as or even better than conventional asphalt mixtures prepared with natural aggregate Gabbro

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Thank you !

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