

# Application of steel slag aggregate in road construction



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# Damaged building at Hrušica, 1988



## **IMPORTANT TO KNOW!**

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**Slag is a broad term for a particular waste product in the field of metallurgy.**

**Just its name DOES NOT TELL US ANYTHING about the properties of this material.**

**Black steel slag  $\neq$  Siemens-Martin slag.**

# **THE RESEARCH PROJECT**

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**SPENS - Sustainable Pavements for European New Member States (2006-2009)**

**WP 3 - Improvement of pavement structure**

**Task 3.2 - Sustainable road construction processes that include recycling of materials and use of industrial by-products**

# AGENDA

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**Origin of steel slag in electric arc furnace  
and the production of aggregate**

**Test field on a regional road**

**Test field on a main road**

**Test field on the A1 motorway**

# ORIGIN OF SLAG



**Steel scrap**



**Lime**



**Electric Arc Furnace**



**Steel products**



**Liquid slag**

## **Some facts about using steel slag in Europe**

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- **About 150 - 200 kg of slag per 1 ton of steel occur.**
- **Nearly 12 million tons of steel slag are produced annually in the Europe.**
- **About 65 % is used in different applications, mainly as aggregate in road construction.**
- **Some of this aggregate is used as a high-quality aggregate in wearing courses (replacing vulcanic aggregate).**

# Average chemical composition of steel slag



<b>FeO:</b>	<b>30-40</b>
<b>CaO:</b>	<b>20-35</b>
<b>SiO<sub>2</sub>:</b>	<b>5-12</b>
<b>Fe<sub>2</sub>O<sub>3</sub>:</b>	<b>6-9</b>
<b>Al<sub>2</sub>O<sub>3</sub>:</b>	<b>5-7</b>
<b>MgO:</b>	<b>4-12</b>
<b>+ small quantities of other oxides.</b>	



# Mineral composition of steel slag

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**Wustite (FeO),  
Calcium silicates ( $C_3S$ ,  $C_2S$ ),  
Brownmillerite ( $C_4AF$ ),  
Mayenite ( $Ca_{12}Al_{14}O_{33}$ ),**

**and**

**free CaO + free MgO**

**Both can cause expansion of aggregate!  
Quenching and ageing of material is needed!**

# Quenching of slag



**Quenching of fresh  
slag  
(artificial magma)**



**Quenching of cooled  
slag (15 days)**

# Ageing of slag (30 days)

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# Production of aggregate



**Crushing, magnetic separation**

**Sieving**

# Products



**4/8 mm**



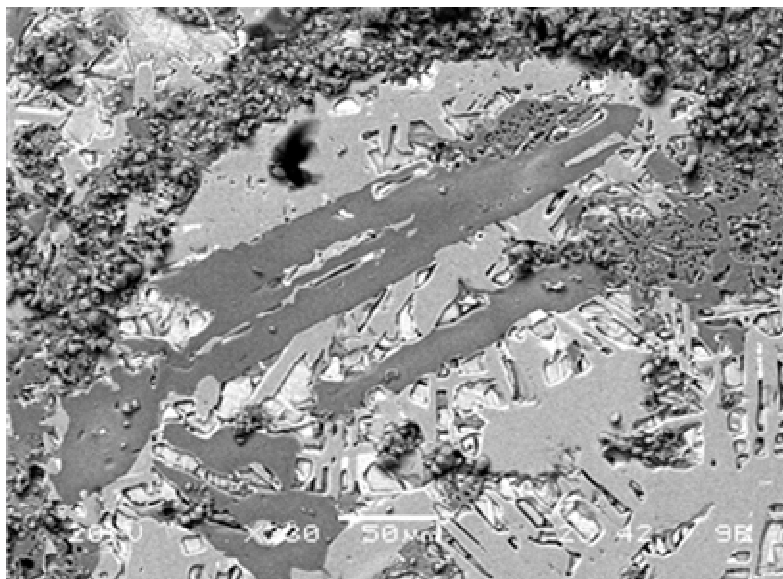
**8/11 mm**

# Characteristics of aggregates



<b>Parameter</b>	<b>Slag aggr.</b>	<b>Natural aggr.</b>
<b>Resistance to fragment. (LA)</b>	<b>16</b>	<b>16</b>
<b>Resistance to abrasion (MD)</b>	<b>8</b>	<b>9</b>
<b>Polish stone value (PSV)</b>	<b>61</b>	<b>57</b>
<b>Frost resistance (MS)</b>	<b>0.0</b>	<b>0.3</b>
<b>Frost resistance (F)</b>	<b>0.0</b>	<b>0.0</b>
<b>Water absorption</b>	<b>0.5</b>	<b>0.7</b>
<b>Bulk density</b>	<b>3.8</b>	<b>2.8</b>
<b>Volume stability</b>	<b>1.6</b>	<b>Not relevant</b>
<b>Eluates</b>	<b>Very low</b>	<b>Not relevant</b>
<b>Radioactivity</b>	<b>Very low</b>	<b>Not relevant</b>

# Comparison between microtextures



**The microtexture of slag**



**The microtexture of volcanic aggregate**

# AGENDA

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**Origin of slag in EAF and production of aggregate**

**Test field on a regional road**

**Test field on a main road**

**Test field on the A1 motorway**



## Purpose of the test fields

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- **Determination of long term behaviour of the wearing course with slag in a continental climate.**
- **Getting experience about the use of slag in road construction with regard to engineering and environmental performance.**

# Test section on a regional road

## Location: Idrijsko- Peršeti



# Bird's-eye view of the test field

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# Test section on a regional road

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**First test field with slag in Slovenia!**

**Annual average daily traffic: 4000**

**Date of reconstruction: 6.6.2007, replacing the wearing course**

**Type of asphalt: AC 11 (asphalt concrete)**

**Width: 6 m**

**Length: 300 m**

**Thickness of asphalt layer: 4 cm**

## Method of construction

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One lane using conventional natural aggregate

(silicate 4/8 and 8/11 mm + carbonate 0/2 mm)

One lane using slag aggregate from Ferriere Nord

(0/4, 4/8, 8/11 mm + carbonate 0/2 mm).

# Construction of the test field

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# The test field after completion

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## Characterization of the asphalt layers

<b><i>SAMPLE</i></b>	<b><i>SAMPLE T (°C)</i></b>	<b><i>SOLUBLE BINDER CONTENT (mas %)</i></b>
<b>Asphalt with slag aggregate</b>	<b>156</b>	<b>5.5</b>
<b>Asphalt with natural aggregate</b>	<b>163</b>	<b>5.4</b>



# HOT MIX ASPHALT



	Density (Mg/m <sup>3</sup> )
Asphalt with slag aggregate	3.124
Asphalt with natural aggregate	2.600

# SURFACE CHARACTERISTICS

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**Equipment: SCRIMTEX measuring device**

**Date of measurement: November 7th 2007**

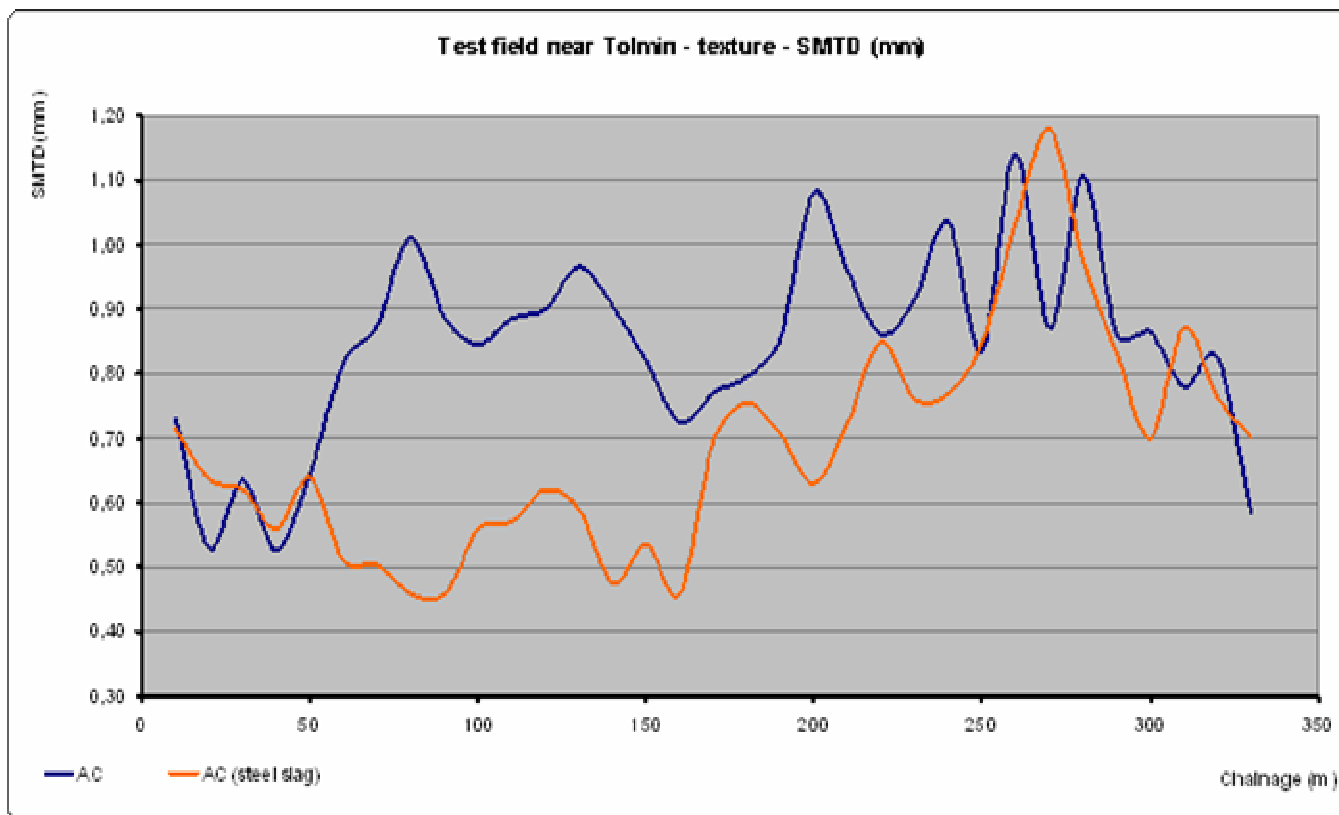


# Comparison of the skid resistance of both lanes



**The levels of skid resistance are similar on both lanes!**

# Comparison of texture on both lanes



**Slight difference in texture on the first half of the test field**

# AGENDA

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# Test field with surface dressing

Location: the main road Ušnik - Plave



# WHAT IS SURFACE DRESSING?



- Bitumen in the form of an emulsion, is sprayed onto the road surface.
- Chippings of aggregate are immediately applied to the bitumen.
- The bitumen part of the surface dressing will seal the old road surface, thus preventing the ingress of water.
- The chippings will restore texture to road surfaces that have become smooth with traffic wear.

# Construction of the test field





# A close-up view

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## Test field with surface dressing

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**Annual average daily traffic (PLDP):  
7000**

**Date of reconstruction: 14.8.2007**

**Width: 7 m**

**Length: 250 m**

**Thickness of asphalt layer: 0.5 cm**

## Method of construction

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**One lane with surface dressing using conventional natural aggregate (silicate 4/8 mm)**

**One lane with surface dressing using slag aggregate from Ferriere Nord (4/8 mm)**

## AGENDA

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# Test field on the A1 motorway

## Location: Postojna - Razdrto



# Bird's-eye view of the test field



## Test field on the A1 motorway

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**Annual average daily traffic:** 30.000

**Date of construction:** 28.4.2008, only replacing the wearing course

**Width:** 6 m

**Length:** 100 m

**Thickness of asphalt layer:** 4 cm

## Test field on the A1 motorway

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**Type of asphalt: SMA 11 PmB 45/80-65**  
**A2**

**Aggregate: slag aggregate from**  
**ACRONI (2/4, 4/8, 8/11 mm)**

+

**limestone aggregate from the Laže**  
**quarry (0/2 mm).**



# Construction of the test field



# Construction of the test field



# Construction of the test field



# Asphalt - resistance to wheel tracking

Rut depth $PRD_{AIR}$	Wheel-tracking slope $WTS_{AIR}$
SIST EN 12697-22	SIST EN 12697-22
<b>3.3 %</b>	<b>0.03 mm/1000</b>

**Excellent results!**

# Asphalt – low temperature test

Tension test	
T (°C)	Tensile strength (MPa)
+ 20	0.59
+ 5	2.07
- 10	6.31
- 25	5.29

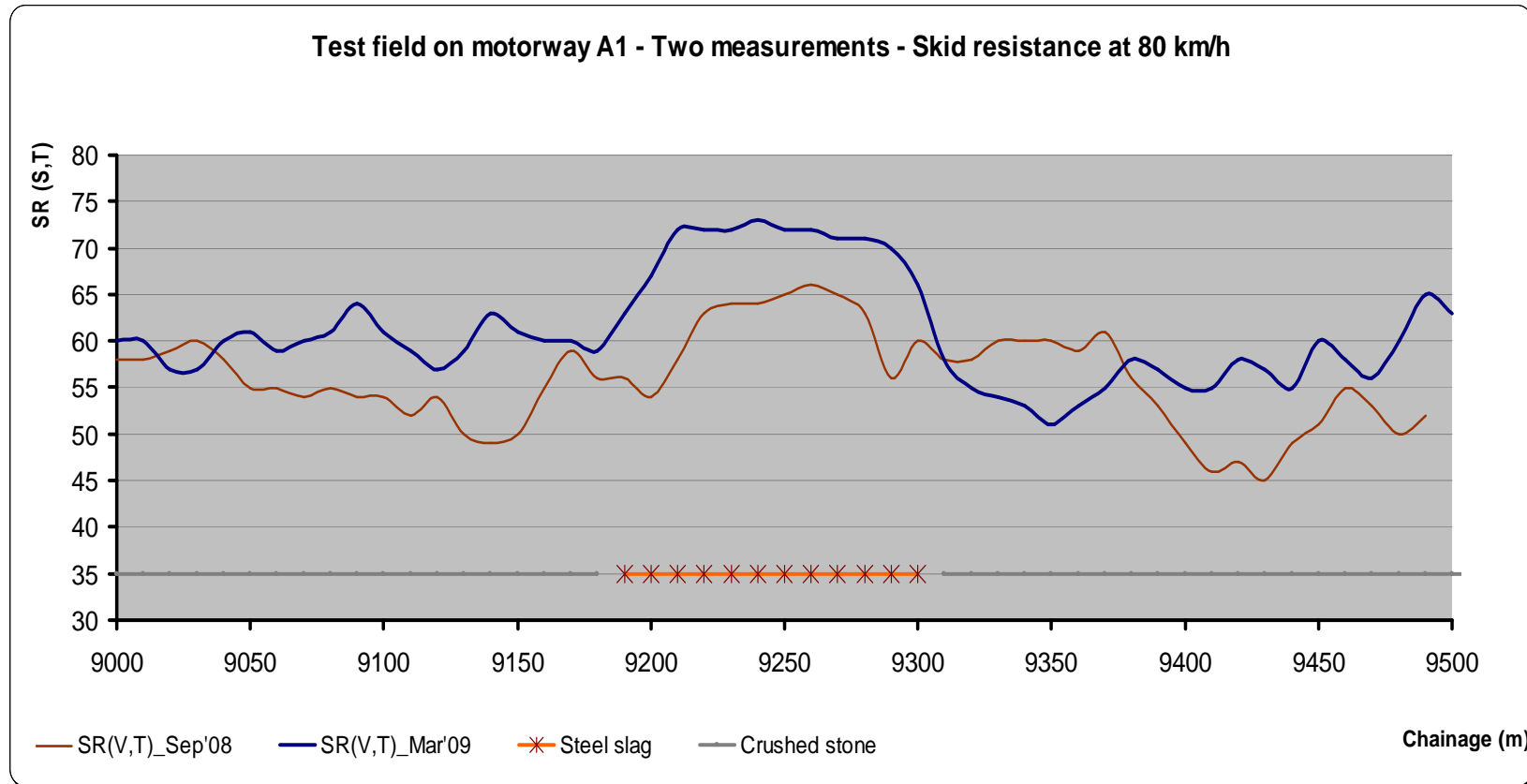
Cooling test	
Failure T (°C)	- 32.57
Failure stress (MPa)	3.90

Tension strength reserve	6,12 MPa at -13.9 °C
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**Excellent results!**

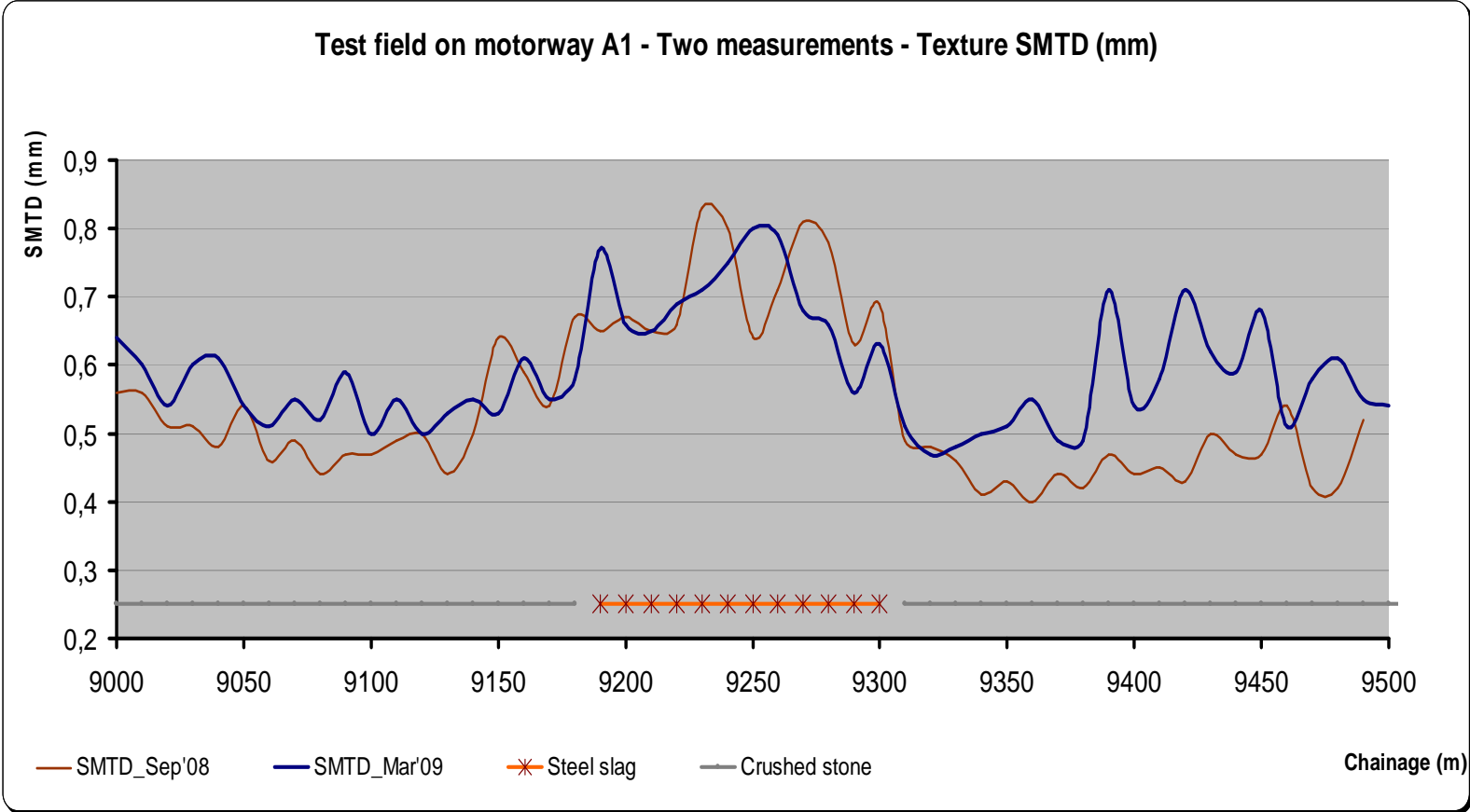
# Skid resistance measurements

## September 2008 versus March 2009



# Texture measurement

September 2008 versus March 2009



## Conclusions

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During the construction of the test fields, no problems occurred (design of the mix, transport to the site, placing of the asphalt).

The test fields are stable, and show no signs of degradation.

The surface properties appear to be better on the field with slag aggregate.



# Conclusions

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## Further work

**Monitoring of all the test fields.**

**Focus mainly on surface (safety) characteristics.**

**Performance of asphalt concrete during service life.**

## Conclusions (for Slovenia)

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**The use of steel slag in asphalt is everyday practice in the developed countries.**

**The successfully constructed test fields are proof that Slovenia can follow these trends.**

**Fear of the use of steel slag is unnecessary.**

**There are opportunities for designers, investors and producers of asphalt mixes.**