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MANUFACTURE OF A POROUS ASPHALT MIXTURE WITHOUT ANY NATURAL AGGREGATE

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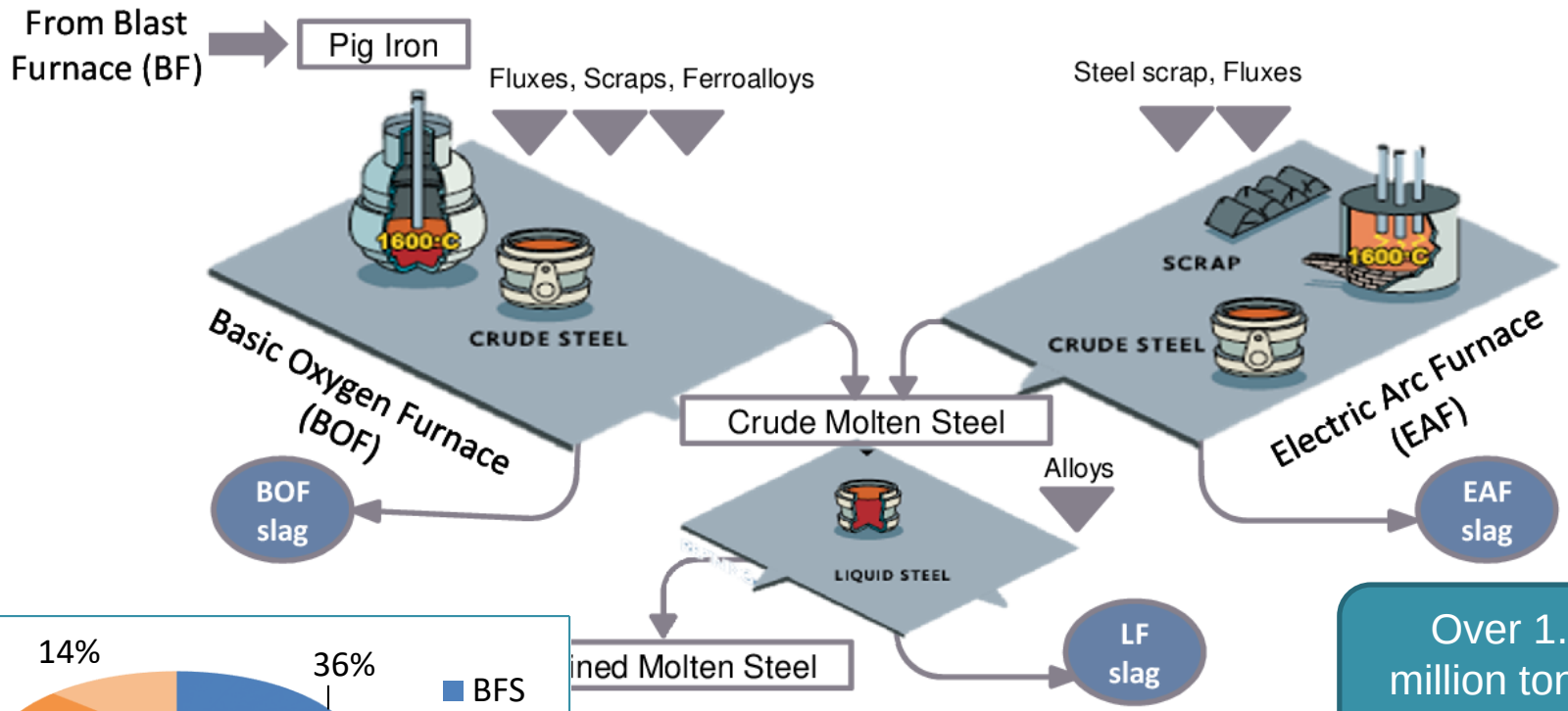
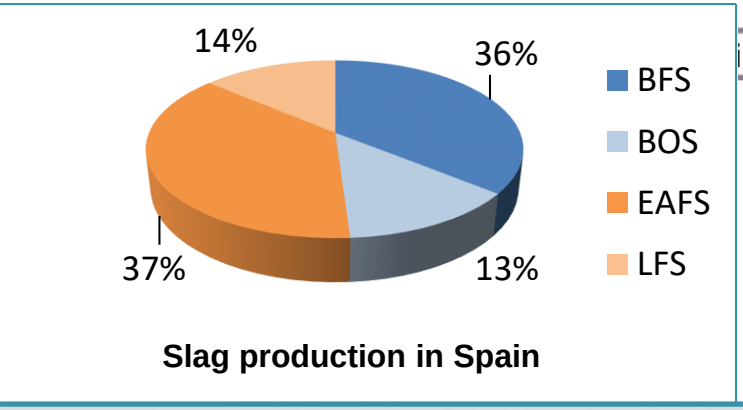
Electric steelmaking in Spain



Over 1.3 million tons a year in Spain

Over 0.3 million tons a year in Spain



Slag production in Spain

Uses of slag

EAF slag

- Unbound material in granular layers
- Quality aggregate for bituminous mixes
- Manufacture of concrete

LF slag

- Cement production
- Construction industry:
  - Mortars and concretes
  - Soil stabilization
  - Environmental engin.

Although there are several applications of these materials, there is still an important excess, what leads us to search for new alternatives to reduce waste and prevent landfilling

Our research group

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Asphalt mixes

Bituminous mixes are traditionally made from natural aggregates (from quarries or gravels)

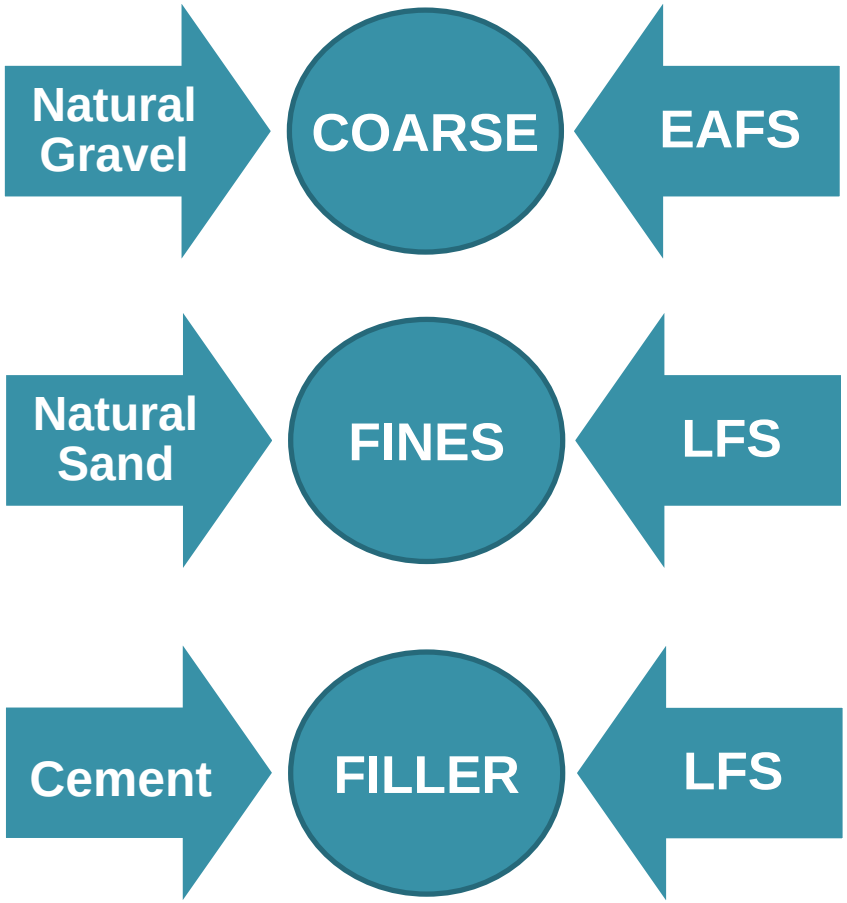
Spanish consumption of aggregates: Over 100 million tons a year

Energy consumption + Resources Exploitation

- **mining**
- **crushing**
- **sieving**
- **washing**
- **transporting**

http://commons.wikimedia.org/wiki/File:Steinbruch_bei_Belgrad.jpg#/media/File:Steinbruch_bei_Belgrad.jpg

Aims and scope

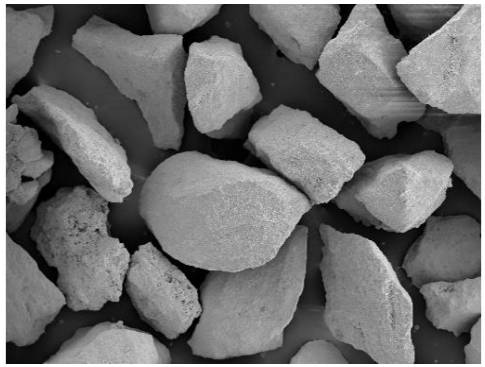


PROVED SUITABILITY ✓

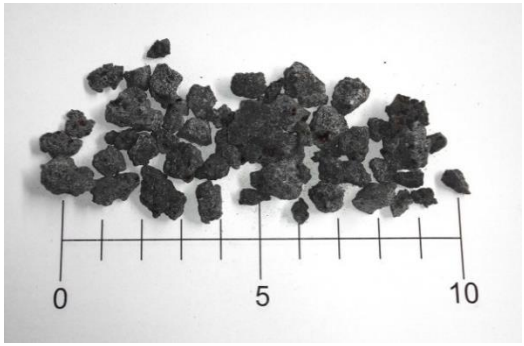
SUITABLE PARTICLE SIZE ✓

CEMENTITIOUS PROPERTIES ✓

Electric Arc Furnace Slag (EAFS)



600 µm. SEM



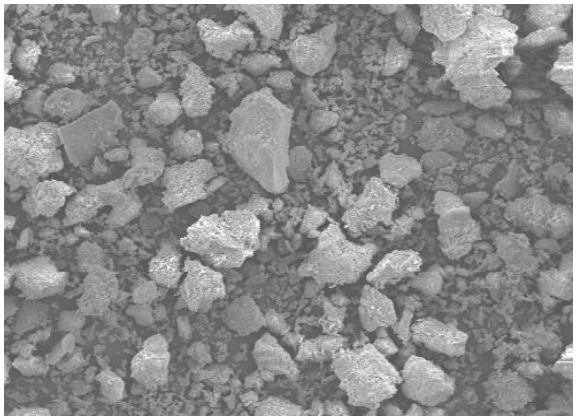
ELECTRIC ARC FURNACE SLAG. DIMENSIONS IN CM.

Component	CaO	SiO_2	MgO	Al_2O_3	Fe_2O_3	MnO
EAFS wt.-%	27.7	19.1	2.5	13.7	26.8	5.3

EAFS Feature	Standard	EAFS
Bulk Density	EN 1097-6	3.6 g/cm^3
Sand Equivalent	EN 933-8	98 %
Water Absorption	EN 1097-6	2.1 %
Los Angeles coefficient	EN 1097-2	23 %
Flakiness index	EN 933-3	3 %
Polished Stone Value (PSV)	EN 1097-8	56 %

Ladle Furnace Slag (LFS)

LADLE FURNACE SLAG.
DIMENSIONS IN CM.

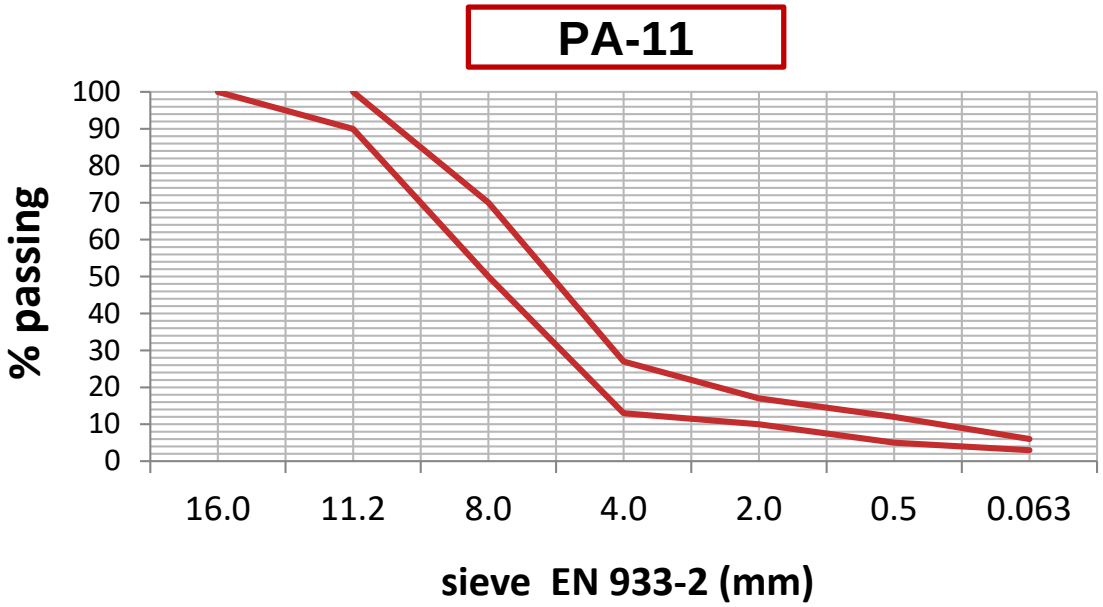


200 µm.

SCANNING ELECTRON MICROSCOPY

Component	CaO	SiO_2	MgO	Al_2O_3	Fe_2O_3	MnO	CO2	TiO_2	SO_3
LFS wt.-%	56.7	17.7	9.6	6.6	2.2	0.3	1.3	0.3	0.8

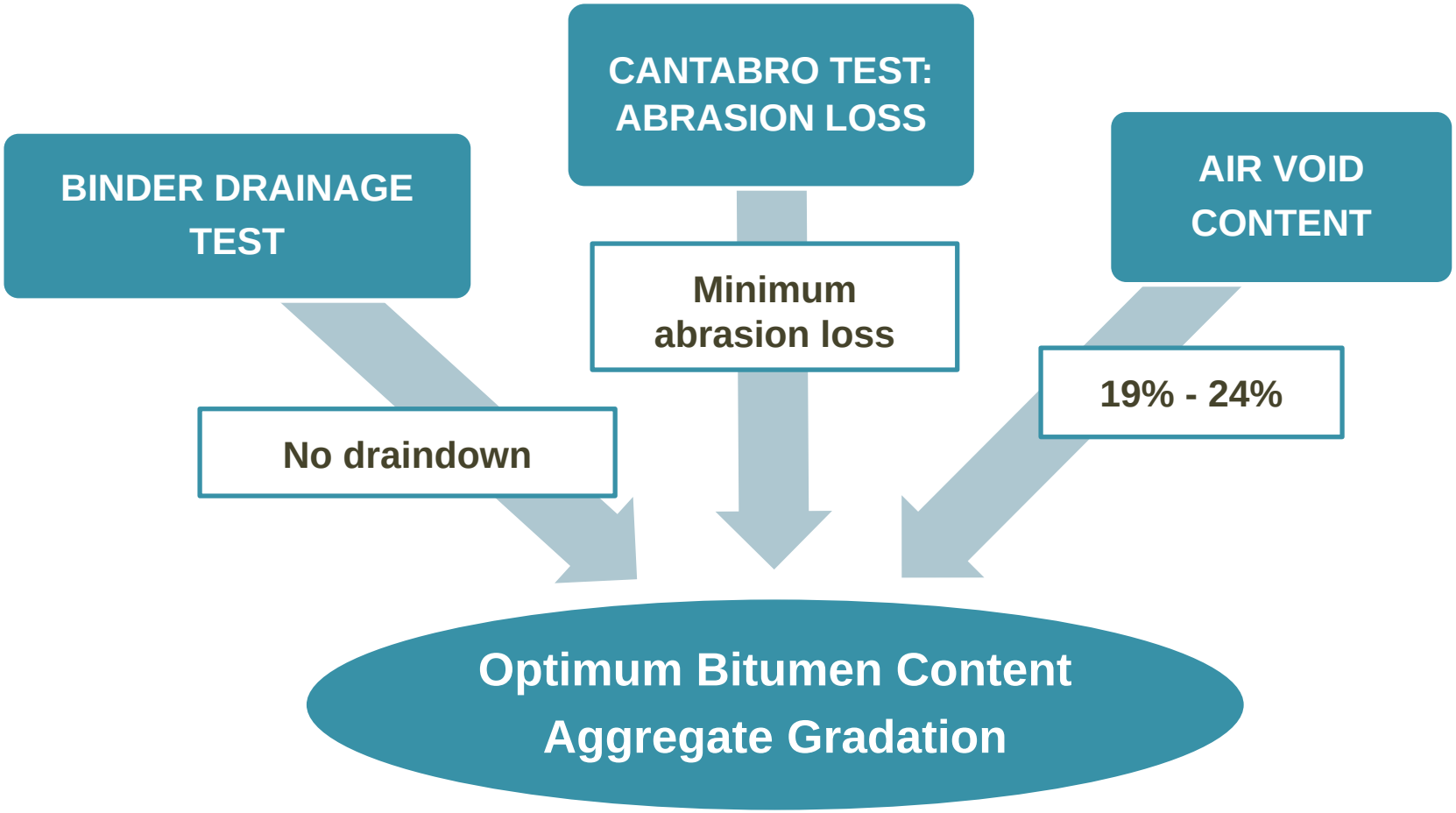
Mix design



http://commons.wikimedia.org/wiki/File:Permeable_paver_demonstration.jpg

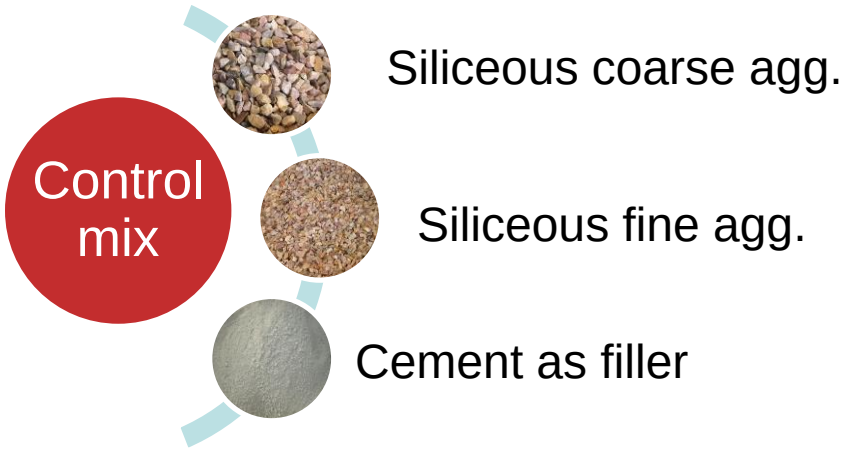
Coarse granular skeleton → **High content of connected air voids** → **Drainage properties**

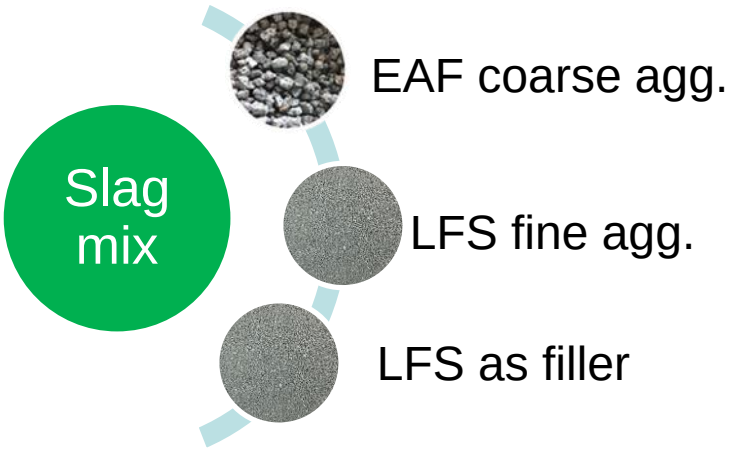
Mix design


BINDER DRAINAGE TEST
CANTABRO TEST: ABRASION LOSS
AIR VOID CONTENT
No draindown
Minimum abrasion loss
19% - 24%
Optimum Bitumen Content
Aggregate Gradation

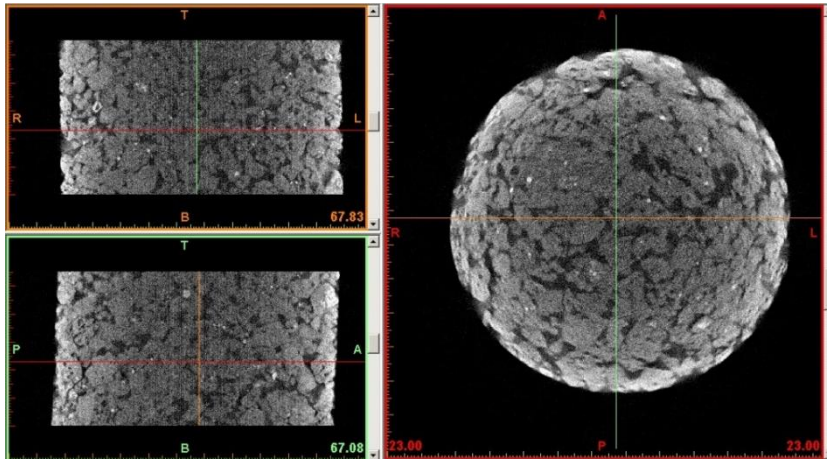
Mix design

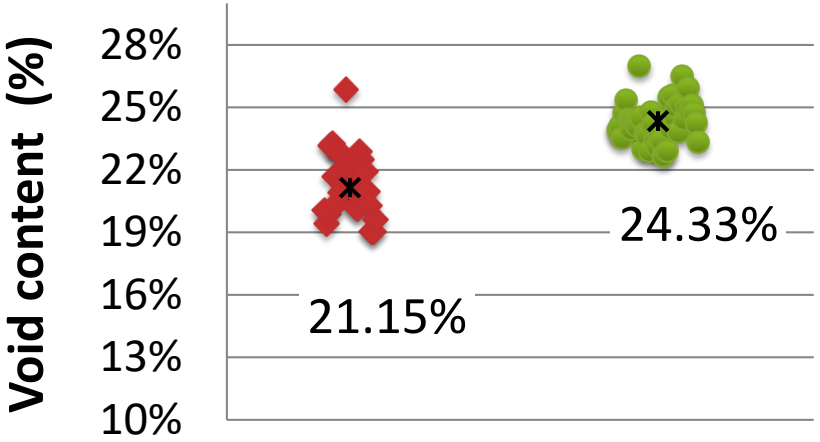
	Coarse aggr. 2/16 mm	Fine aggregate 0.063/2 mm	Filler 0/0.063 mm	Asphalt Binder
	82.2 %	7.8 %	5.0 %	5.0 %
Control mix	Siliceous	Siliceous sand	CEM I/42.5 R	PMB 45/80-60
Slag mix	EAF slag	LF slag	LF slag	PMB 45/80-60

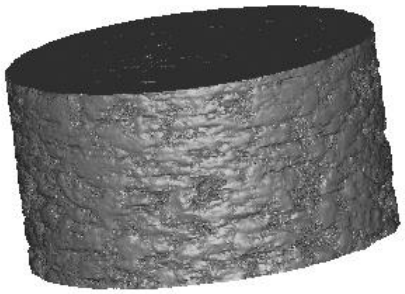




VOLUMETRIC PROPERTIES







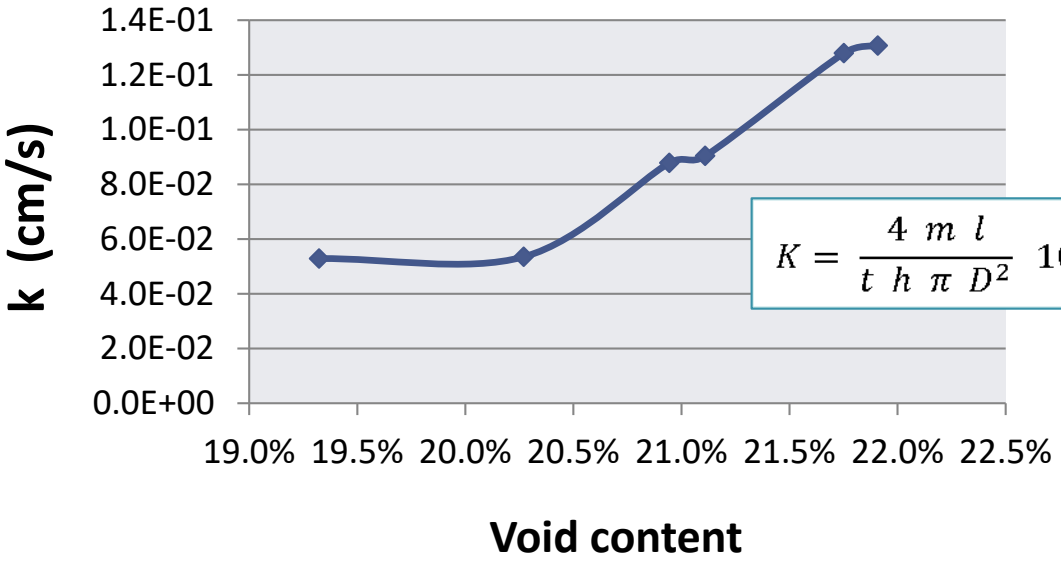
	Control mix	Slag mix
Void content (volumetric)	21.9%	24.6%
Void content (CT)	20.5%	26.4%

VERTICAL PERMEABILITY

EN 12697-19

Control mix: $9 \cdot 10^{-2}$ **cm/s**

Slag mix: $15 \cdot 10^{-2}$ **cm/s**



$$K = \frac{4\ m\ l}{t\ h\ \pi\ D^2}\ 10^{-6}$$

ABRASION LOSS

Cantabro Test (EN 12697-17)

- **Control mixes: 8.1 %**
- **Slag mixes: 14.6 %**

DURABILITY

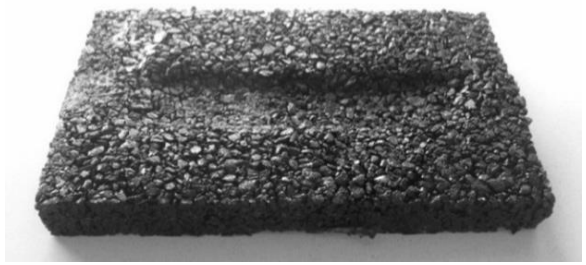
- **Aged Abrasion Loss (ASTM D7064)**
  - **Control mixes: 12.1 %**
  - **Slag mixes: 15.0 %**

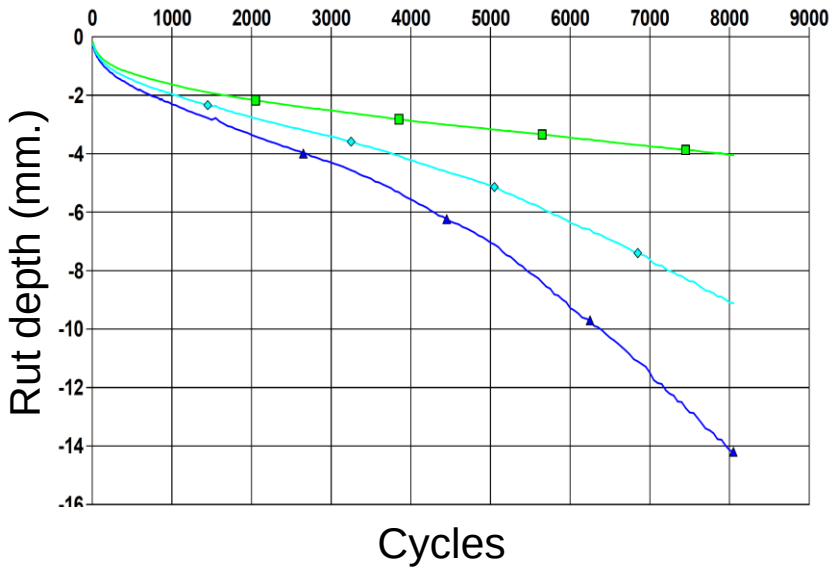
- **Low Temperature Performance**
  - **Control mixes: 23.8 %**
  - **Slag mixes: 29.9 %**

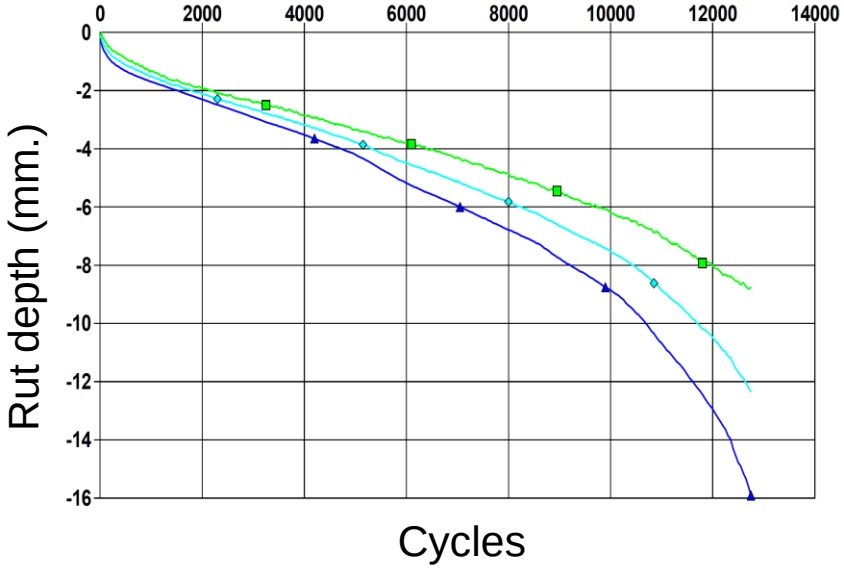
RESISTANCE TO PERMANENT DEFORMATION

WHEEL TRACKING MACHINE

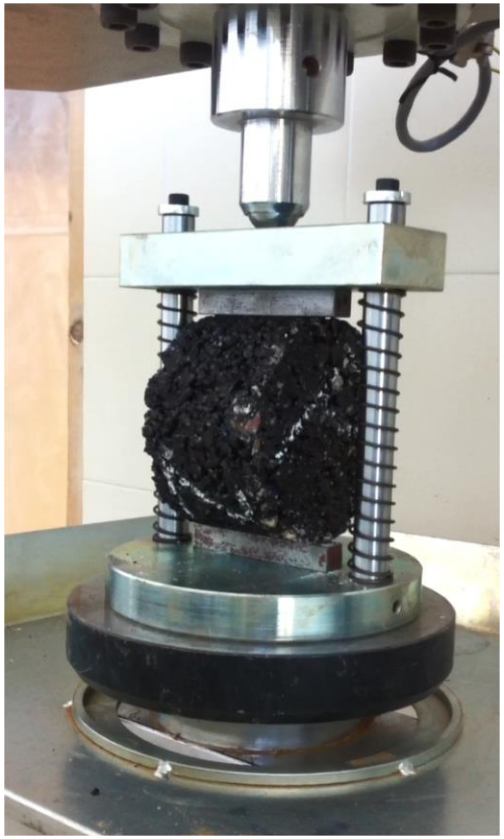
EN 12697-22







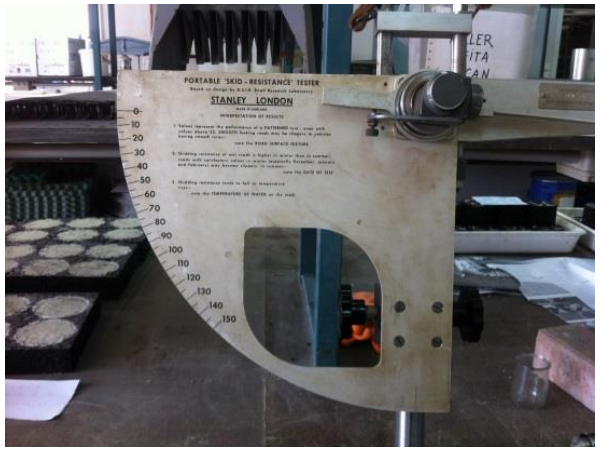
MOISTURE SUSCEPTIBILITY



Tensile Strength Ratio (EN 12697-12)

- **Control mixes: 75.5 %**
- **Slag mixes: 79.2 %**

SKID RESISTANCE



Skid resistance (MICROTEXTURE)

(EN 13036-4)

Control mixes: BPN= 61

Slag mixes: BPN= 77

Skid resistance (MACROTEXTURE)

(NLT-335)

Control mixes: 1.5 mm.

Slag mixes: 1.9 mm.

Conclusions

- **The void content was higher → superior angularity of the slag → difficulties in compaction → more porous mixture.**
- **Mechanical behavior - abrasion loss:**
  met the requirements for heaviest loads, but significantly worsened the conventional results → higher void content of the slag mixtures.
- **Moisture susceptibility was improved → better affinity of the binder with the slags / siliceous aggregate + the rougher texture of slag enhances adhesion.**

Conclusions

- **Aging produced similar effects on both mixtures → far exceeding the standard requirements.**
- **Resistance to permanent deformation: much better in slag mixtures → excellent properties of the EAF slag as coarse aggregate (angularity, hardness, shear strength, resistance to wear and polishing).**
- **Skid resistance: optimal for the slag pavements → excellent performance against slipping and skidding → rougher texture and higher permeability: perfect for rainy regions → high PSV of EAF slag aggregates also ensures excellent long term performance.**

Junta de Castilla y León

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMIA Y COMPETITIVIDAD

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THANK YOU FOR YOUR ATTENTION

Any questions or comments are welcome:
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