Seminário sobre
Valorização de Resíduos em Infra-estruturas de Transportes e ras Geotécnicas

Aplicação a Agregados Siderúrgicos Inertes para Construção (IC)

LISBOA

Caracterização Física e Mecânica dos ASIC da Siderurgia Nacional da Maia e do Seixa

Physical and mechanical Characteristics of AS

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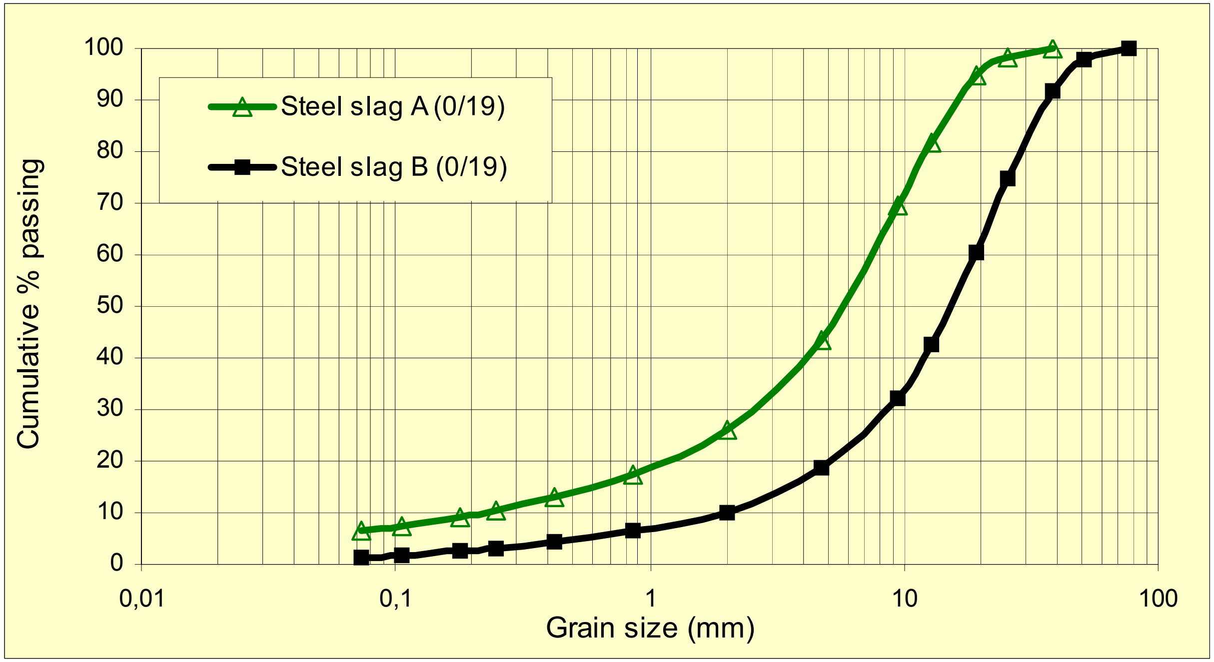
Introduction

- **Aim of study**
- **Studied materials:** Geometric, Physical and Mechanical properties
- **Equipment used to study the stiffness:** Precision triaxial test
- **Test Method to study the stiffness:** State characteristics and confining stresses
- **Results:** Steel slag A (Seixal) and steel slag B (Maia)
- **Comparison of results:** Steel slags and Natural Aggregates
- **Conclusions**

Aim of Study

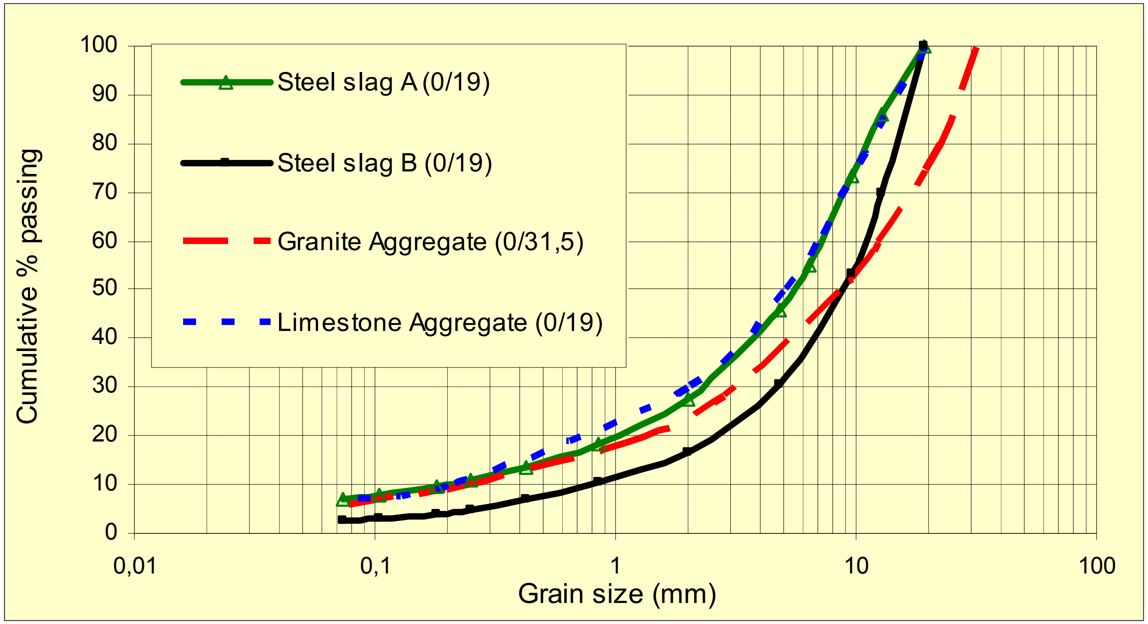
Evaluate the re-use of steel slags produced by the National Industry, designed hereafter of Steel Slag A (Seixal) and Steel Slag B (Maia), in transportation infrastructures and geotechnical constructions

Studied Materials: Geometric properties (integral material)



Material	$D_{máx}$ (mm)	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	C_u	C_c	Index Flakiness	Index Shape
Steel Slag A (Seixal)	38,1	0,22	2,63	7,30	33,2	4,30	5	6
Steel Slag B (Maia)	76,1	1,96	8,50	18,89	9,64	1,95	10	7

Studied Materials: Geometric properties (0/19)



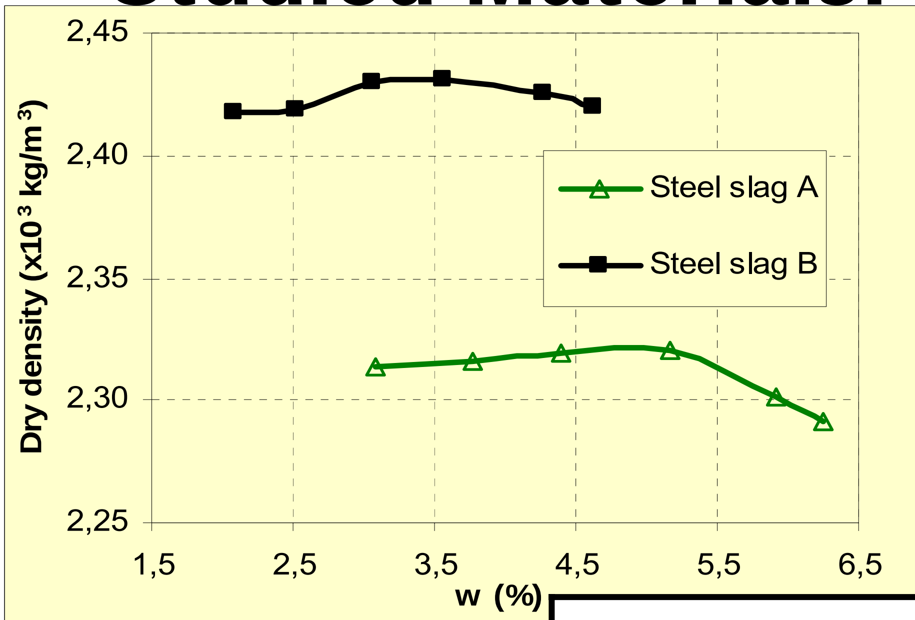
Material	$D_{máx}$ (mm)	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	C_u	C_c
Steel Slag A (Seixal)	19,1	0,20	2,20	7,10	36	3,4
Steel Slag B (Maia)	19,1	0,84	4,60	11,00	13	2,3
Granite Aggregate (0/31,5)	31,5	0,23	3,11	12,14	53	3,5
Limestone Aggregate (0/19)	19,1	0,20	2,00	6,80	34	2,9

Studied Materials: Physical and Mechanical properties

Material		Steel Slag A	Steel Slag B	Admissible values		
				Capp. layer	Sub-base	Base
Sand equivalent test - EA (%)		80	100	30*	45*	50*
Methylene blue test - VBS (%)		0	0	2,0		-
Atterberg limits		NP	NP	25(1); 6(2)	NP	NP
Density	Impermeable material ($x10^3$ kg/m^3)	3,31	3,45	-	-	-
	Saturated particles ($x10^3$ kg/m^3)	3,05	3,25	-	-	-
	Dry particles ($x10^3$ kg/m^3)	2,94	3,17	-	-	-
Water absorption (%)		3,87	2,59	-	-	-
Specific gravity - Gs		3,07	3,26	-	-	-
Los Angeles test – LA (%)		23	28	40**	45**	40**
Micro-Deval test (%)		11	11	-	-	-
Modified Proctor	Max dry density ρ_{dOPM} ($x10^3$ kg/m^3)	2,32	2,43	-	-	-
	Water content - w_{OPM} (%)	5,0	3,45	-	-	-
California bearing ratio - CBR	quick (%)	100	72	-	-	-
	Standard (%)	51	48	-	-	-
	Expansibility (%)	0	0	-	-	-

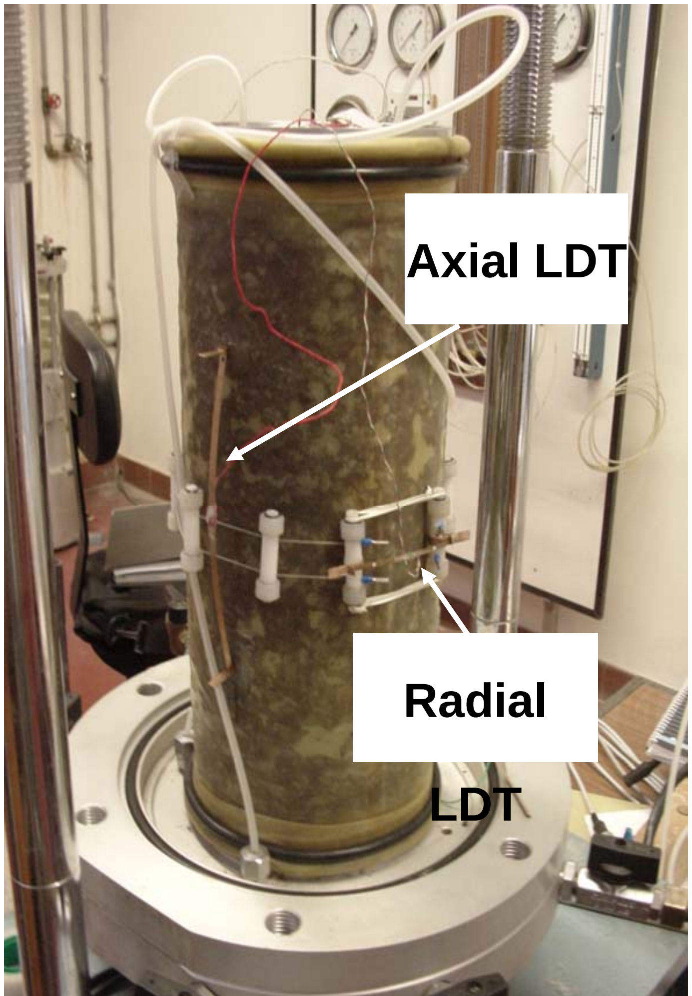
*-minimum value; **-maximum value; (1) – Liquid limit; (2) - Plastic limit

Studied Materials: Modified Proctor curves



Material	ρ_{dopm} ($x10^3$ Kg/m³)	w_{opm} (%)
Steel Slag A (Seixal)	2,32	5,00
Steel Slag B (Maia)	2,43	3,45
Granite aggregate (0/31,5)	2,31	5,90
Limestone aggregate (0/19)	2,20	5,80

Equipment used to study the stiffness: Precision Triaxial Test



INTERNAL INSTRUMENTATION

Displacement Transducers:
LDT (Local Displacement Transducers) manufactured at University of Minho

Force Transducer:
Internal Load cell

Test Method to study the stiffness: State conditions and confining stresses

State conditions of tested samples

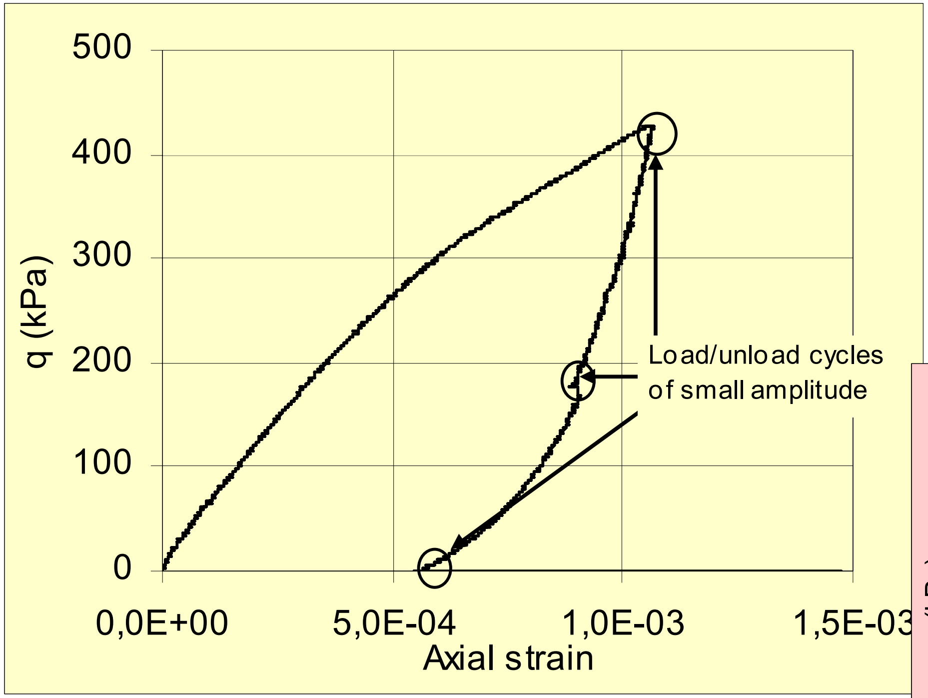
Material	ρ_d (x 10^3 kg/m³)	w (%)
Steel Slag A (Seixal)	2,31	5,8
Steel Slag B (Maia)	2,43	3,5
Granite Aggregate (0/31,5)	2,19	3,9
Limestone Aggregate (0/19)	2,13	3,9

Studied confining stresses

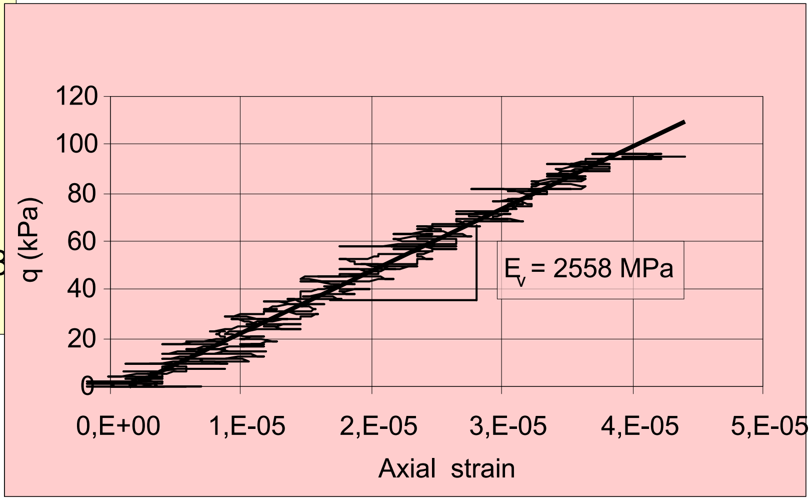
Confining stresses (kPa)		
100	200	300

Test Method to study the stiffness: for each confining stress

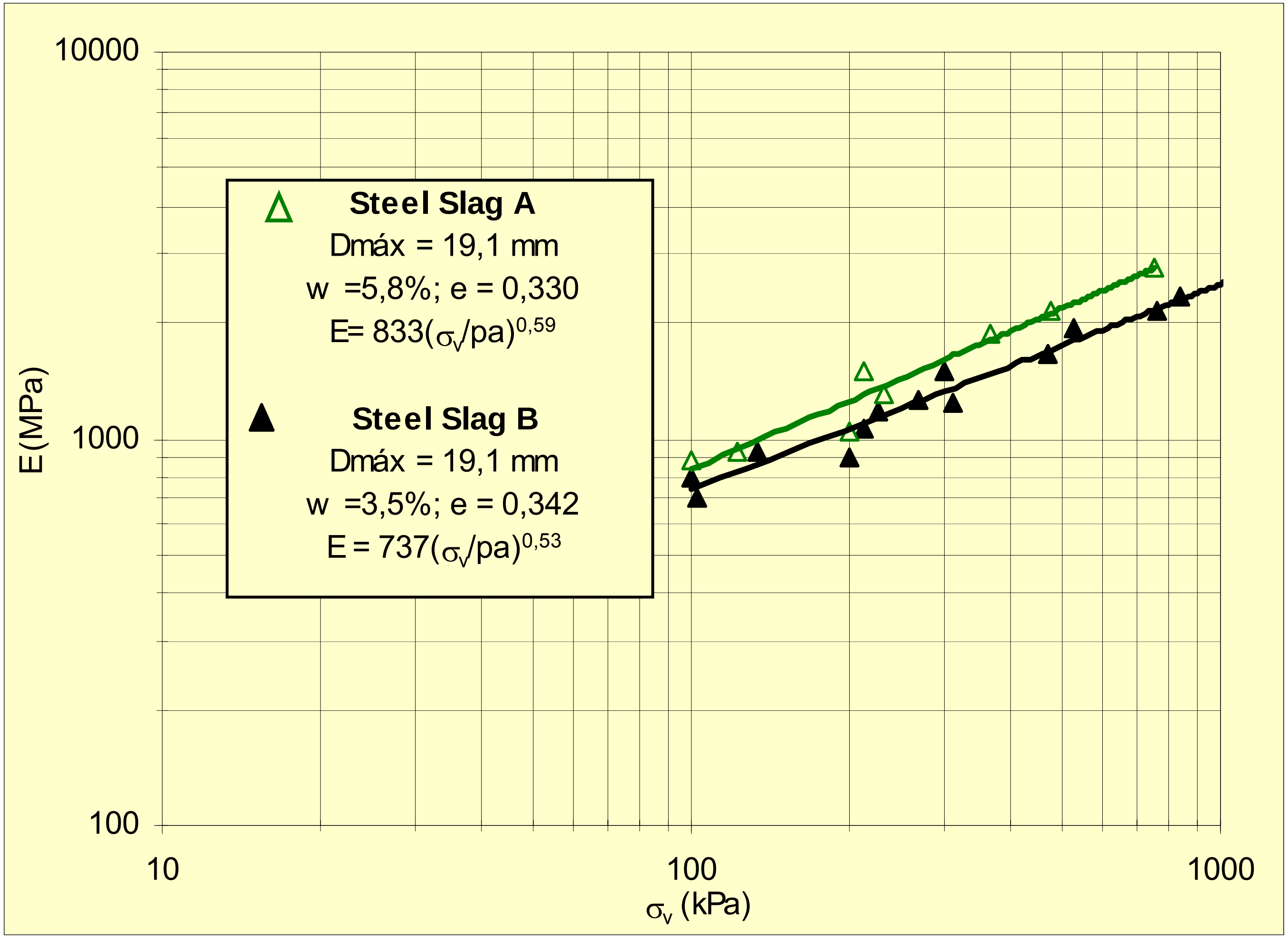
Example of test method for each confining stress



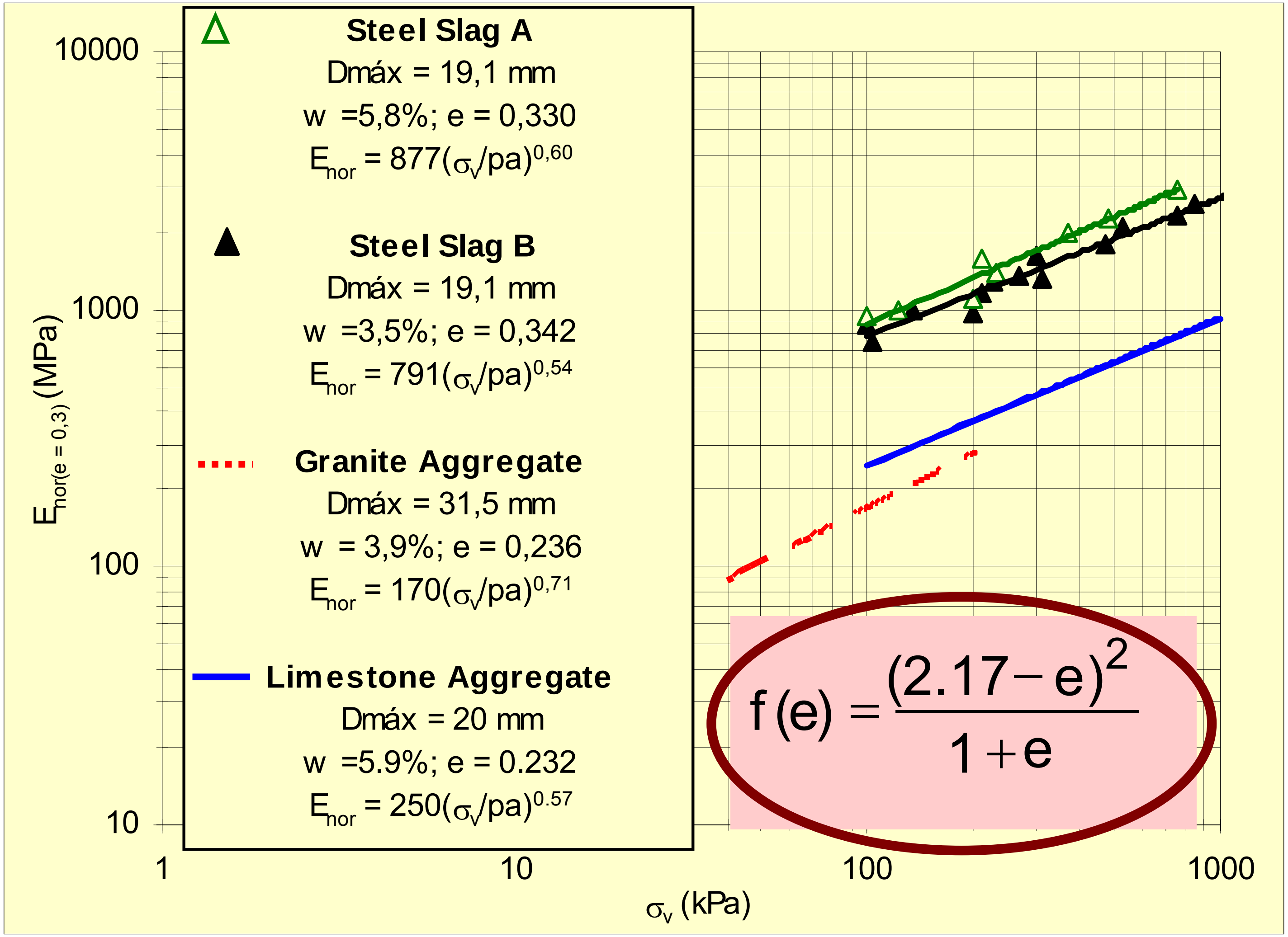
Example of a load/unload cycle of small amplitude



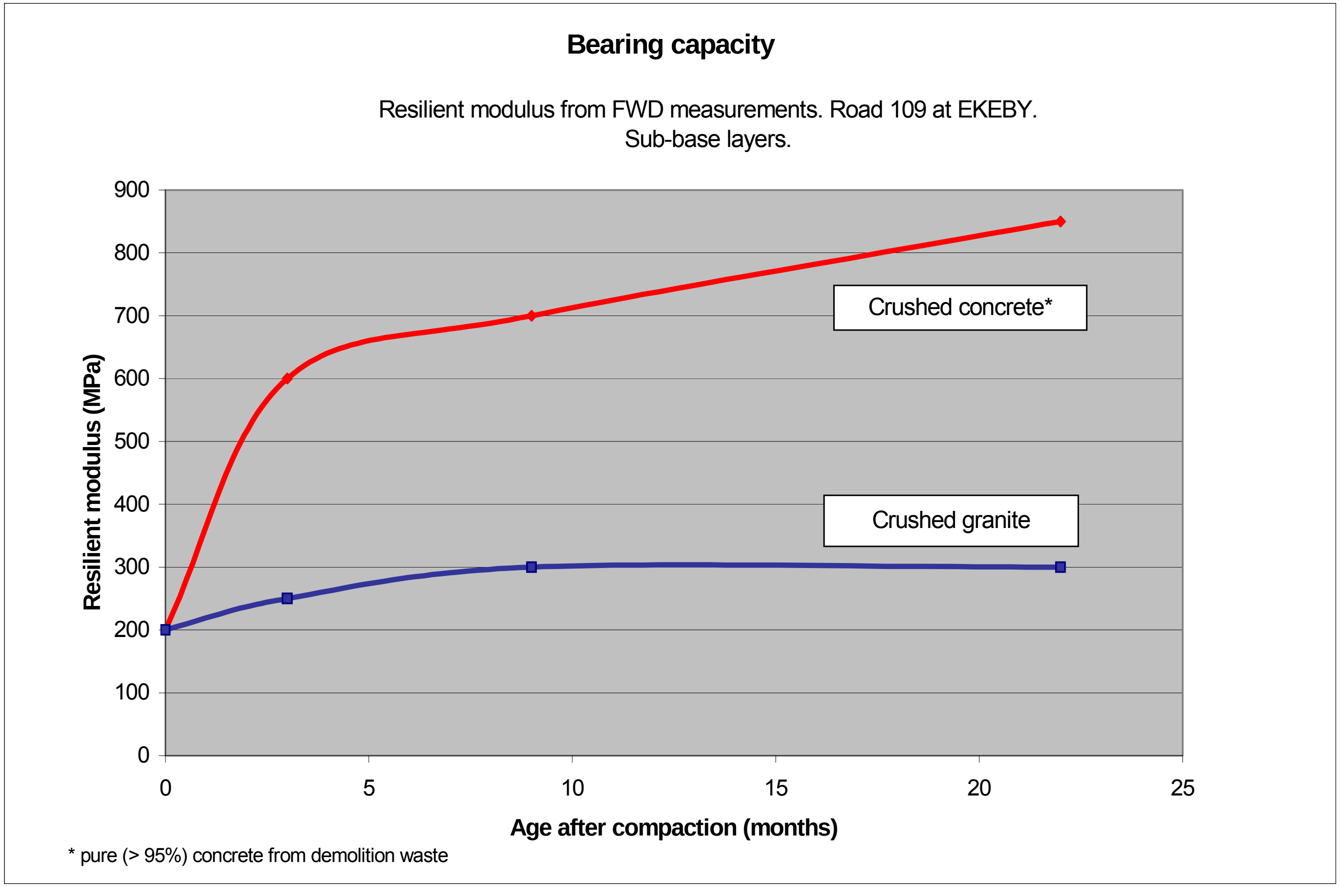
Results: Steel Slag A (Seixal) and Steel Slag B (Maia)



Comparison of Results: Steel Slags and Natural Aggregates



….. Other Recycled Materials Can Give Better Properties



Dr Mike Winter
Regional Director, Scotland
TC3 Workshop, Madrid
23 September 2007

Conclusions

- This research work aims to promote the re-use of steel slags as a substitute for natural aggregates or traditional materials used in transportation infrastructures and geotechnical works
- Steel slags have allowed values for environmental characteristics, and good performance in compactation
- The stiffness of steel slags is described by a power law given by equation $E_v(\sigma_v)$, like for natural materials.
- Steel slags have better mechanical properties than standard base course materials (granite aggregate 0/31,5 and limestone aggregate 0/19)

Conclusions: *Cont*

The re-use of steel slags will be possible if:

1 - Economical benefits are met

2 - The material satisfies engineering and environmental specifications

3 - Its performance in the field is as good as that of traditional materials

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Attending to experience in other countries, as well as to the technical database already collected in an European framework project there are reasons to expect that these requirements will be fulfilled by these materials.

Summary (adapted from Winter, 2007)

- We can reuse Steel Slags
- This requires the skills of Geotechnical Engineers
- Benefits to clients
  - – Less expenditure on disposal costs
  - – Less expenditure on construction of tips
- Benefits to society
  - – Less waste / more sustainable society
- Benefits to Geotechnical Engineers
  - – We get paid for
    - Interesting and innovative work
    - Improves public perception of what we do

Acknowledgements

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