Introduction

Università degli Studi di Padova

ICEA

SIIV

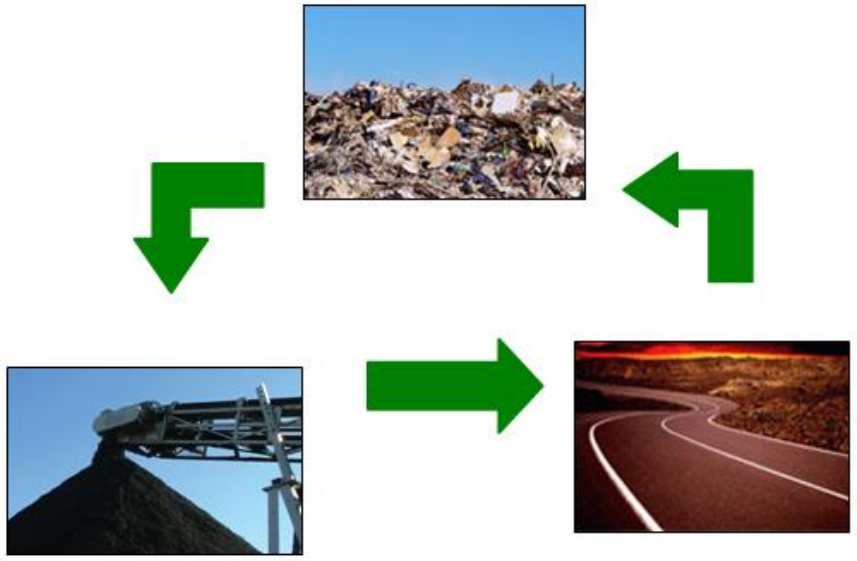
AIIT

Chairman Prof. Marco Pasetto
ICAR/04 Group
Strade, Ferrovie e Aeroporti
Roads, Railways and Airports

2008

1^ Giornata di studio: **COSTRUIRE STRADE CON RIFIUTI?**
DALLA RICERCA ALL'APPLICAZIONE: UTILIZZO DEI MATERIALI MARGINALI NELLA REALIZZAZIONE DI INFRASTRUTTURE VIARIE

Research developments in the sector and analysis of the most recent applications of marginal materials in Italy.



2009

2^ Giornata di studio: **COSTRUIRE STRADE CON RIFIUTI?**
LA NECESSITÀ DEL TOP LEVEL EXPERTISE PER AFFRONTARE LA COMPLESSITÀ NORMATIVA E SVILUPPARE LE POTENZIALITÀ DEI MATERIALI MARGINALI

Legislative implications and regulations that govern the use of waste and raw materials. The “construction of roads with waste” can be done, thanks also to the top-level expertise of research organizations and institutes, including the universities.

2010

3^ Giornata di studio: **COSTRUIRE STRADE CON RIFIUTI? EUROPA ED ITALIA A CONFRONTO**

1st International Workshop: **THE USE OF MARGINAL MATERIALS IN ROAD CONSTRUCTION**

Experimental studies, applications, case histories, environmental analyses and economic valuations demonstrate how non-conventional materials can represent an engineeringly reliable construction solution within a logic of sustainable development.

(Martin F.C. van de Ven, Manfred N. Partl, Hervè Di Benedetto, Dariusz Sybilski, Adriana Martìnez…)







2013

4^ Giornata di studio: **COSTRUIRE STRADE CON RIFIUTI?**

2nd International Workshop: **THE USE OF MARGINAL MATERIALS IN ROAD CONSTRUCTION**

Evolution of research and applications of marginal materials in the recent period. Comparative analysis between Italian and international experiences.

Prof. António Gomes Correia, University of Minho
Dr. Martin Hugener, EMPA
Dr. Gabriele Tebaldi, University of Parma, Adj. Professor Univ. Florida
Dr. Cesare Sangiorgi, University of Bologna
Dr. Andrea Grilli, University of San Marino Republic
Prof. Marco Pasetto, University of Padova

ISAP (International Society for Asphalt Pavements) is a volunteer organization of professionals and experts established to share the latest in leading edge asphalt pavement technology worldwide. The Society's distinctly global and inclusive approach is reflected by the international membership, representing all stakeholders in the asphalt industry - users, producers, professionals, as well as individuals and organizations.
Chair: Jean-Pascal Planche, Western Research Institute (USA)

TC on Asphalt Pavement and Environment (APE): Environmental issues and sustainable development
Chair: Prof. Dr. Manfred N. Partl Chair
Secretary: Prof. Gabriele Tebaldi

WG6 “By-products and Secondary Materials, Recycling in Asphalt Pavements”
Chair: Prof. Marco Pasetto
Secretary: Dr. Eng. Augusto Cannone Falchetto

Use of by-products in road construction

➢ Since 1988, research on marginal materials has been developed at the Road Laboratory of the University of Padua:

T. Pizzocchero, M. Pasetto, A. Friso (1990) - *Utilizzo dei materiali di scarto nelle sovrastrutture stradali. Le scorie d'alto forno*, Galileo - Giornale del Collegio degli Ingegneri della Provincia di Padova, n. 2(July) pp. 25-30.

➢ Different use of by-products has been analysed (+ 60 papers published):

Cement mixtures

• M. Pasetto (2005) *The use of a new cement mixture made by slags and C&D aggregate in the construction of a urban ring-road*, Proceedings 2nd International Symposium TREMTI (Traitement et Retraitement des Materiaux pour Travaux d'Infrastructures, Parisi, 24-26 October.
• M. Pasetto, N. Baldo (2010) *Recycling of steel slags in road foundations*, Environmental Engineering and Management Journal, TU Iasi, Volume 9, N. 6, pp. 773-778.
• M. Pasetto, N. Baldo (2013) *Cement bound mixtures with metallurgical slags for road constructions: mix design and mechanical characterization*, Inżynieria Mineralna, July-December, pp. 15-20.
• M. Pasetto, N. Baldo (2014) *Experimental analysis of hydraulically bound mixtures made with waste foundry sand and steel slag*, Materials and Structures, 'Online First' 18 May 2014.
• M. Pasetto, N. Baldo (2016), *Recycling of waste aggregate in cement bound mixtures for road pavement bases and sub-bases*, Construction and Building Materials, 108, pp.112-118

Cement and bituminous cold mixtures

• M. Pasetto, N. Baldo (2012) *Laboratory Investigation on Foamed Bitumen Bound Mixtures made with Steel Slag, Foundry Sand, Bottom Ash and Reclaimed Asphalt Pavement*, Road Materials and Pavement Design, iFirst, 2012, Taylor & Francis, pp. 1-22.

Use of by-products in transport infrastructure construction

Asphalt (bituminous) mixtures

• M. Pasetto, N. Baldo (2006) *Electric arc furnace steel slags in "high performance" asphalt mixes: a laboratory characterisation*, Key lecture in Sohn International Symposium on Advanced Processing of Metals and Materials: Principles, Technologies and Industrial Practice, San Diego (USA), 27-31 August, pp. 9.

• M. Pasetto, N. Baldo (2010) *Experimental evaluation of high performance base course and road base asphalt concrete with electric arc furnace steel slags*, Journal of Hazardous Materials, Elsevier, Volume 181, 2010, pp. 938-948.

• M. Pasetto, N. Baldo (2011) *Mix design and Performance Analysis of Asphalt Concretes with Electric Arc Furnace Slag*, Construction & Building Materials, Elsevier, 25, pp. 3458-3468

• M. Pasetto, N. Baldo (2012) *Performance comparative analysis of stone mastic asphalts with electric arc furnace steel slag: a laboratory evaluation*, Materials and Structures, online September 2011, Vol. 45 issue 3.

• M. Pasetto, N. Baldo (2012) *Fatigue Characterization of Asphalt Rubber Mixtures with Steel Slags*, 7th International RILEM Conference on Cracking in Asphaltic Pavements, 20-22 June 2012, Delft (NL), pp. 10

• M. Pasetto, N. Baldo (2013) - *Fatigue performance of asphalt concretes made with steel slags and modified bituminous binders*, International Journal of Pavement Research and Technology, Vol. 6 no. 4/5, Chinese Society of Pavement Engineering, RDC, pp. 294-303.

• M. Pasetto, N. Baldo (2014) *Resistance to Permanent Deformation of Base Courses Asphalt Concretes made with RAP aggregate and Steel Slag,* Asphalt Pavements, Ed. Y. Richard Kim, Chapter 112, CRC Press, Taylor & Francis Group, pp. 1199-1208.

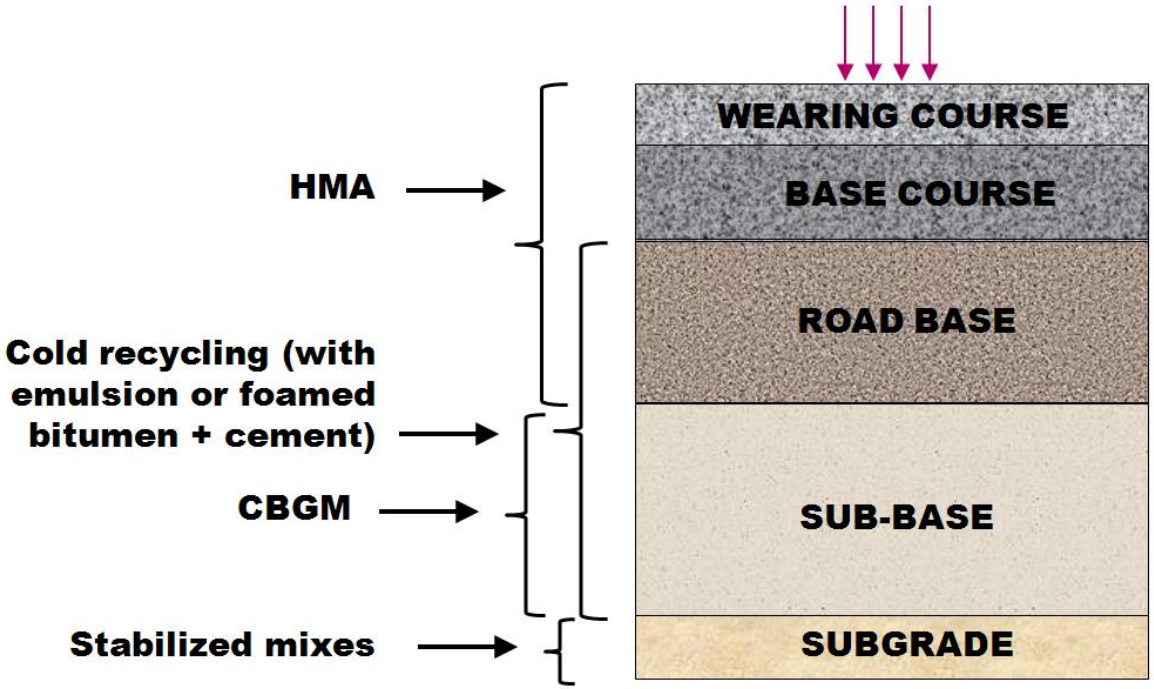
• G. Giacomello, E. Pasquini, F. Canestrari, M. Pasetto, *Effect of warm mix chemical additives on the binder-aggregate bond strength and high-service temperature performance of asphalt mixes containing electric arc furnace steel slag*, . In: Canestrari F, Partl M. (eds.) 8th RILEM Int. Symp. on Testing and Characterization of Sustainable and Innovative Bituminous Materials, RILEM Bookseries, Vol.11, Springer NL; 2015, p. 485-496.

• M. Pasetto, A. Baliello, G. Giacomello, E. Pasquini (2016) *Rheological Characterization of Warm-Modified Asphalt Mastics Containing Electric Arc Furnace Steel Slags*, Advances in Materials Science and Engineering, vol. 2016, Article ID 9535940, pp. 11.

The Italian experience

Electric Arc Furnace (EAF) slag
Spent foundry sand
Municipal Solid Waste Incinerator ash
C&D aggregate
Glass wastes
R.A.P.
Crumb rubber
Plastic wastes etc.

In …
Embankments and subgrades
Foundations / Sub-bases
Road bases
Base courses
Wearing courses



By-products and Secondary Materials (marginal materials)

What?

- Marginal materials are non-traditional natural materials and residuary products (industrial by-products and wastes), which can be used either to replace traditional aggregate or as hydraulic binders or fillers in bituminous materials and cement bound granular mixtures.
- "Marginality" is related to a particular time or place and even sometimes the layer in which the material is used.
- Sometimes these materials fall "outside specifications, but may be utilized provided special care is taken" (PIARC, 1983-1989).

Why?

- Shortage of natural materials.
- Environment and landscape protection (less wastes to landfills, less pollution, less visual impact).
- Savings.

Where?

- Earthworks and subgrades
- Unbound sub-bases/foundations
- Cement bound sub-bases and bases
- Asphalt (bituminous) mixes
- Cement concrete

According to PIARC:

METALLURGICAL WASTES AND BY-PRODUCTS are used for earthworks:
Blast-furnace slags - Steel slags (BOF) - Non-ferrous slags - Other slags

INDUSTRIAL BY-PRODUCTS (METALLURGICAL IND.) for asphalt pavements:
Blast furnace slag - Steel slag - Nickel slag - Copper slag- Ferrochromium slag etc.

Moreover:

METALLURGICAL WASTES+INDUSTRIAL BY-PRODUCTS for cement concrete

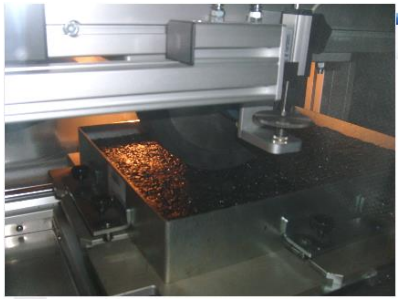
Testing

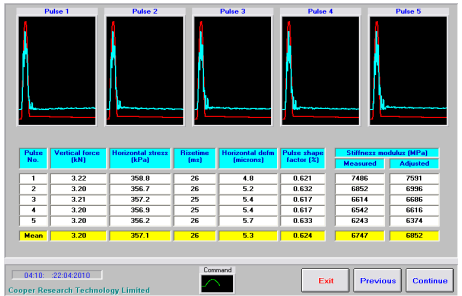
- Generally, the same used for traditional materials (see European Technical Standards, e.g. EN 13242, 13043, etc.)
- Specific attention to degradability, free lime content, water absorption, frost susceptibility (swelling, etc.)
- High attention to chemical properties (leaching, eco-toxicity, etc.)

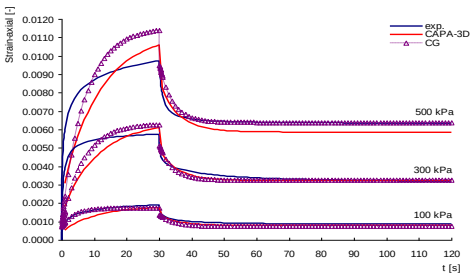
… but also…

- (New) functional, performance based test methods

are needed.







Recent and… future Italian Standards: Tecniche di impiego delle terre UNI 11531-1/2

CNR UNI 10006

- Strade
- Classificazione
- Instabilità
- Opere di difesa
- Rilevati/trincee
- Sottofondi
- Stabilizzazioni

→

UNI 10006

- CNR UNI 10006
- Appendice A
- Appendice B

Aggregati da C&D in mix rifiuti minerali
Produzione

→

CEN Standardization

UNI EN 13285
UNI EN 13242
UNI EN 14227-1/5
UNI EN 14227-15

UNI EN ISO 14688-1/2

→

UNI 11531-1

- Infrastrutture
- Classificazione
- Rilevati/trincee
- Sottof.+anticap.
- Aggregati n+a+r
- Miscele granulari
- Posa
- Controlli

→

UNI 11531-2

- Infrastrutture
- Legante idraulico
- Mix migliorate
- Mix stabilizzate
- Bonifiche
- Fondazioni
- Posa
- Controlli

→ ?

From RESEARCH …

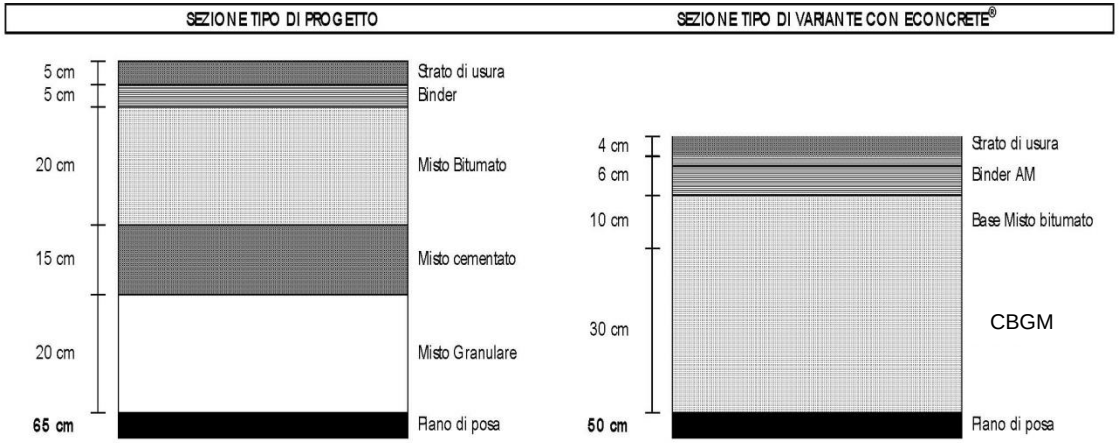





… to APPLICATION

The Italian experience - construction

- **Mestre-Venice ring-road (2006-2008)**
  - ✓ 36 km motorway, 3 lanes x 2 separate carriageways



4 cm bituminous wearing course with EAF slag, also used in 30 cm CBGM base and porous foundation

The Italian experience - construction

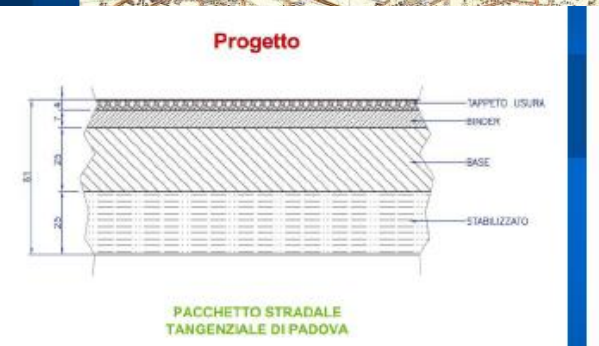
- **Padova Northern by-pass (2004-2005)**
  - ✓ 7 km major road, 2 lanes x 2 separate carriageways

73,000 m^3 capping layer : sand -> lime stabilization of soil

102,000 m^3 embankment: natural aggregate -> lime stabilization of soil

10,000 m^3 sub-base: unbound mixtures -> 14,000 m^3 CBGM (slag+C&D+foundry sand)

36 cm bituminous layers -> 23 cm bituminous layers with EAF slag

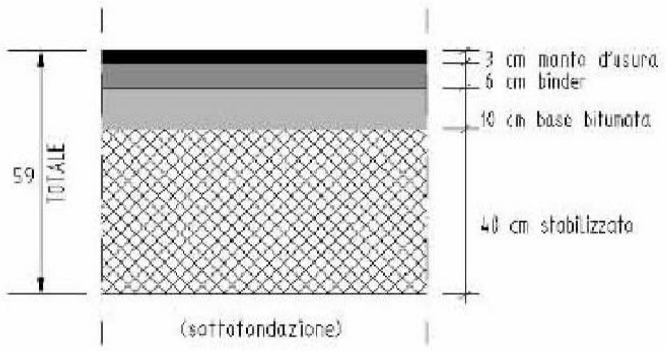


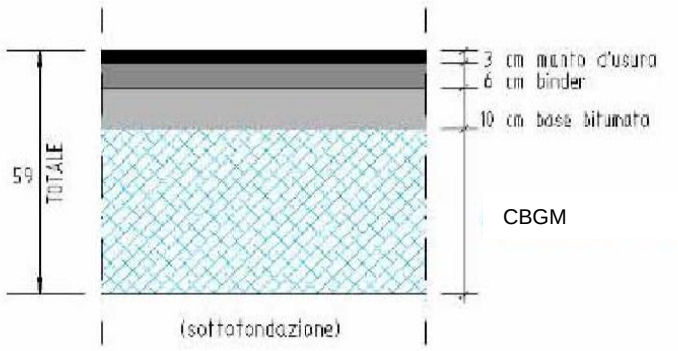
The Italian experience - construction

- **National Road SS 246 Var. Montecchio M. (2005-2006)**
  - ✓ 10 km major road, 2 lanes x 2 separate carriageways

150,000 m^2 capping layer sub-base: unbound mixtures -> 14,000 m^3 CBGM (slag+C&D+foundry sand)

27 cm bituminous layers -> 19 cm bituminous layers with EAF slag





Use of by-products in transport infrastructure construction

The Italian experience

Background

- Quite recent development
- Limited utilization know-how
- Infrequent applications
- Not always updated Specifications and Standards
- **Law constraints**
- **Aversion from Road agencies, Public Administrations and Contractors**
- **Unfavourable public opinion**
- **Magistrates' inquisitiveness**

9.45
Workshop opening
Prof. Marco Pasetto
Authorities

10.00
Activities of Rilem TC Waste and Marginal Materials for Roads (WMR)
Prof. Lily Poulikakos
EMPA - Switzerland

10.30
Experimental investigation on the use of Linz-Donawitz steel slag in asphalt mixture
Dr. Augusto Cannone Falchetto
Technische Universität Braunschweig - Germany

11.00 Coffee break

11.15
The latest developments on the use of secondary cementitious materials in road constructions
Prof. Hassan Al Nageim
Liverpool John Moores University - United Kingdom

11.45
Innovation in cold recycling technologies
Prof. Gabriele Tebaldi
Univesity of Parma - Italy, University of Florida - USA

12.15
Manufacture of a porous asphalt mixture without any natural aggregate
Dr. Marta Skaf
Univeristy of Burgos - Spain

12.45
Multiscale analysis of warm mix asphalt containing EAF steel slags
Dr. Emiliano Pasquini
Univeristy of Padua - Italy

13.15 Workshop closing
Chairman **Prof. Marco Pasetto**

Thank You,

Marco Pasetto, marco.pasetto@unipd.it