ISAP TECHNICAL COMMITTEES DAY

Annual meeting (2013) of

Technical Committee on Asphalt Pavements and Environment (APE)

Washington DC, OMNI Shoreham Hotel - Governors Room.
January 13th, 2013

Reuse of by-products in asphalt pavements

Prof. Marco Pasetto

Dept. of Civil, Environmental and Architectural Engineering (DICEA), University of Padova (IT)

Outline

- Alternative materials: what, why, where, how?
- Classification
- Testing
- The Italian experience

Non-traditional/Alternative/Marginal Materials in road construction:

What?

- **Non-traditional natural materials and residuary products (industrial by-products and wastes) , which can be used either to replace traditional aggregates or as hydraulic binders or as fillers in bituminous coated materials**
- **Materials that fall "outside specifications, but which may be utilized provided special care is taken" (PIARC, 1983-1989)**
- **"Marginality" is related to a particular time or place and even sometimes the course in which the material is used (relativity of the definition)**

Non-traditional/Alternative/Marginal Materials in road construction:

Why?

- **Shortage of natural materials**
- **Environment and landscape protection**
- **Savings**
- **Elimination of dumps (pollution, visual impact, etc.)**

Where?

- **Earthworks and subgrades**
- **Sub-bases/foundations**
- **Asphalt (layers)**
- **Etc.**

Non-traditional/Alternative/Marginal Materials in road construction:

How?

- **Technical, economic, environmental evaluation**
  - ✓ **technical :** direct use; quality improvement; with binder; performance-related solutions**;**
  - ✓ **economic:** direct and indirect cost of traditional aggregate; (extra)cost of non traditional materials; costs related to construction solutions**;**
  - ✓ **environmental:** damage to landscape; atmospheric and water-table pollution; etc.

Classification (PIARC) – Earthworks use

MINING AND QUARRY WASTES AND BY-PRODUCTS
Colliery waste materials (baked or unburnt)
Quarry waste materials (from crushing mills, screening, etc.)
Other materials (recycled concrete etc.)

METALLURGICAL WASTES AND BY-PRODUCTS
Blast-furnace slags
Steel slags (BOF)
Non-ferrous slags
Other slags

INDUSTRIAL WASTES AND BY-PRODUCTS
Fly and bottom ash
Calcium sulphate and lime wastes
Sulphur wastes
Other industrial wastes (bauxite, desulphurized gypsum etc.)

Classification (PIARC) – Asphalt pavements

NON –TRADITIONAL NATURAL MATERIALS
Soft mica-schists
Evolutionary schists
Evolutionary marls
Tuff
Traditional materials of poor quality

SOILS
Clay
Silt
Silt-Sand
Pozzolan
Uniform sands
Till

Classification (PIARC) – Asphalt pavements

INDUSTRIAL BY-PRODUCTS (METALLURGICAL INDUSTRY)

Blast furnace slag
Steel slag
Nickel slag
Copper slag
Zinc slag
Lead slag
Ferrochromium slag

INDUSTRIAL BY-PRODUCTS (THERMAL ELECTRIC STATIONS)

Hydraulic fly ash (lignite)
Non-hydraulic fly ash (other coal types)
Bottom ash
Boiler slag

Classification (PIARC) – Asphalt pavements

INDUSTRIAL BY-PRODUCTS (CHEMICAL INDUSTRY)
Phosphogypsum
Lime and cement kiln dust
Hydrated lime by-products
Carbide lime
Oil shale residue
Hydrocarbon refining wastes
Post-refinery sewage wastes

WASTES (MINING AND QUARRYING WASTES)
Slate wastes
Asbestos and bauxite mine wastes
Colliery spoil
China clay sand
Gold and Manganese mine wastes
Lead, zinc, sulphur ore tailings
Stone and gravel pit refuse
Stone screenings

Classification (PIARC) – Asphalt pavements

WASTES (MUNICIPAL WASTES)
Incinerator refuse wastes
Glass and ceramic wastes
Plastic wastes

WASTES (INDUSTRIAL WASTES)
Ceramic and refractory wastes
Cellulosic wastes
Plastic wastes
Tyres and rubber
Resin
Bark and sawdust

WASTES (DEMOLITION WASTES)
Milled pavements
Stones and bricks of demolished buildings
Concrete and reinforced concrete

WASTES (DREDGING MUDS)

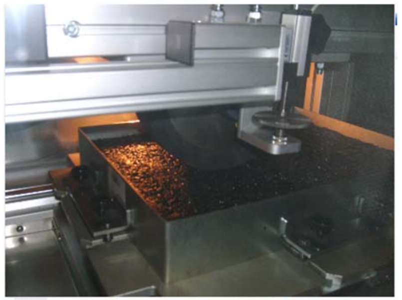
Testing

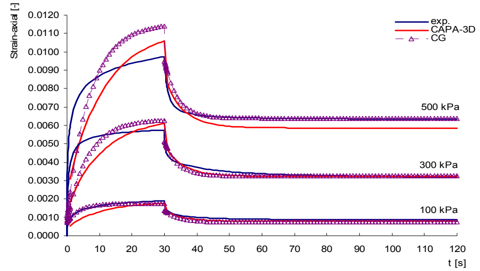
- **Generally, the same as used for traditional materials (see recent Technical Standards, e.g. EN 13242, 13043, etc.)**
- **Specific attention to degradability, free lime content, water absorption, frost susceptibility (swelling, etc.)**
- **High attention to chemical properties (leaching, eco-toxicity,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

… but also…

- **(New) functional, performance based test methods**

are needed.

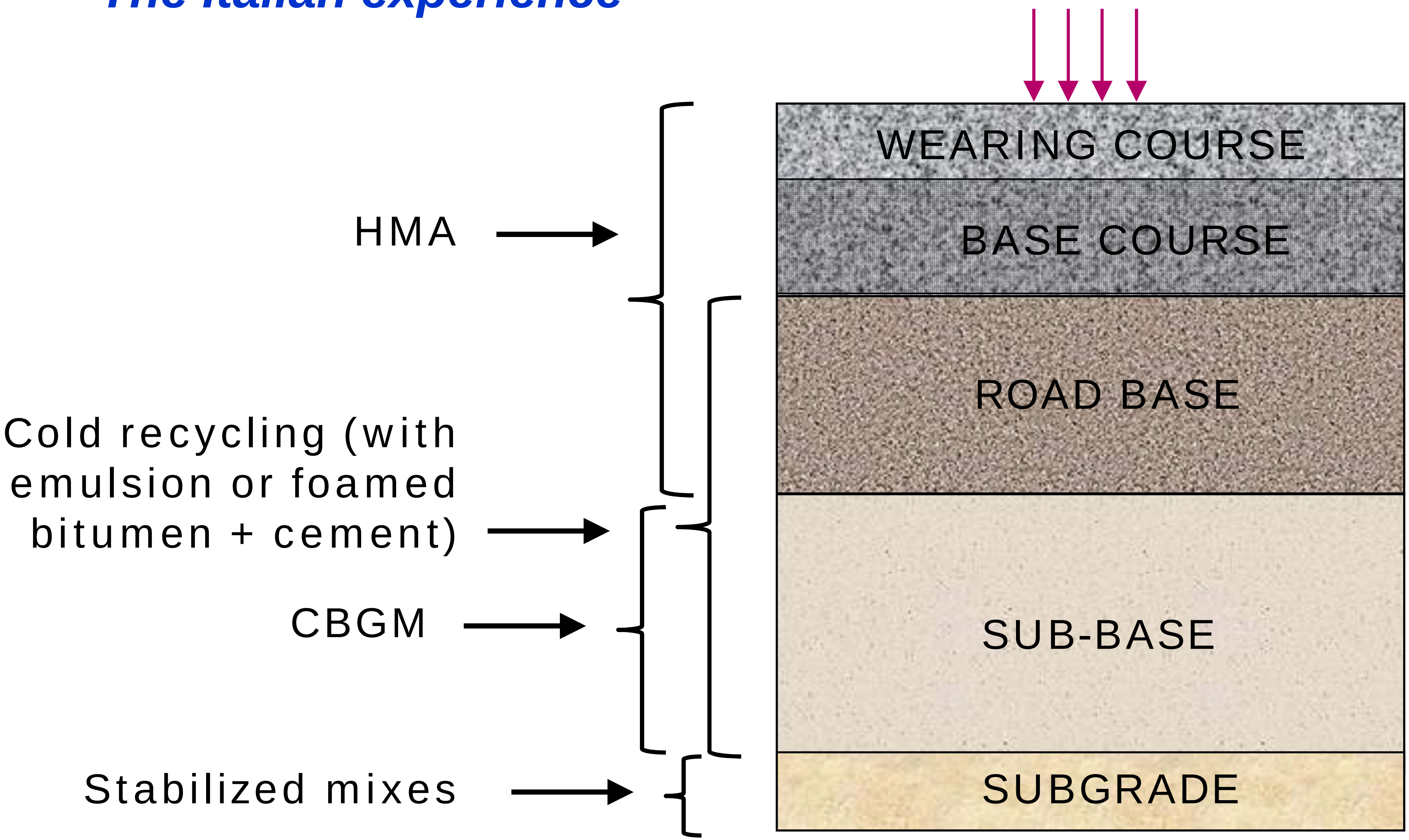


The Italian experience

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

The Italian experience



The Italian experience

3 steps

- **Laboratory testing /materials characterization**
- **Field testing**
- **Construction**

The Italian experience

Background

- **Recent development**
- **No utilization know-how**
- **Infrequent applications**
- **Not updated Specifications and Standards**
- **Law constraints**
- **Aversion from Road agencies, Public Administrations and Contractors**
- **Unfavourable public opinion**
- **Magistrates' inquisitiveness**

The Italian experience, step 1 (lab testing)

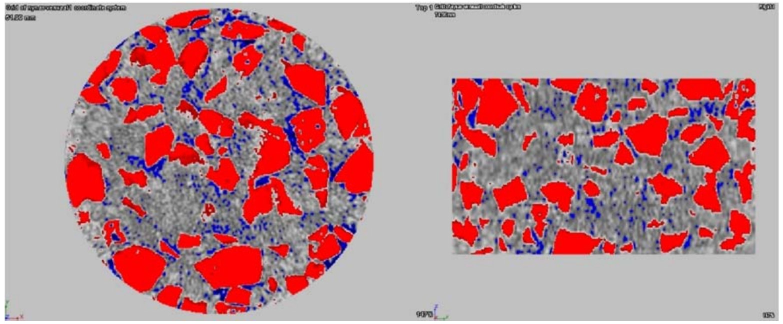
Physical and Mechanical properties	Crushed Limestone	Natural sand	EAF Type A	EAF Type B	RAP aggregates	WF sand	MSWI ash
Grain dry density (g/cm^3)	2.80	2.76	3.97	4.14	2.53	2.76	2.59
Grain bulk density (g/cm^3)	2.72	2.55	3.87	3.92	2.36	2.64	2.53
Plasticity Index (-)	-	0	0	0	0	0	0
Shape Index (%)	2 to 4	-	8	10	10	15	36
Flakiness Index (%)	2 to 5	-	6	12	7	5	39
Equivalent in sand (%)	56	64	79	83	82	27	45
Los Angeles coefficient (%)	23 to 30	-	7	15	27	-	44

The Italian experience, step 1 (lab testing)

- ✓ Four different types of mixtures:
    1. Without EAF slags (natural aggregate)
    2. With EAF slags (25 to 45%)

- ✓ Four bitumen contents:
    1. (4.5 to 6%) for AWC, PA and BBM
    2. (5.5 to 7%) for SMA

- ✓ Marshall Test
- ✓ Indirect Tensile Strength Test
- ✓ Stiffness Modulus Test (30°C)



BBM asphalt base course, **AWC** asphalt wearing course, **SMA** Stone Mastic Asphalt, **PA** porous asphalt with EAF slag

n = with natural aggregate

The Italian experience, step 1 (lab testing)

Mix	OBC [%]	MS [daN]	ΔMS [%]	MQ [daN/mm]	ΔMQ [%]	ITs [MPa]	ΔITs [%]	S_m [MPa]	ΔS_m [%]
BBM	4.5	2,637	**+34**	730	**+19**	1.10	**+21**	1,669	**+18**
BBM_n	4.5	1,967		613		0.91		1,414	
AWC	5.0	2,901	**+69**	438	**+34**	0.74	**+3**	1,107	**+8**
AWC_n	5.0	1,713		328		0.72		1,021	
SMA	5.5	1,533	**+2**	360	**+10**	1.13	**+15**	1,622	**+20**
SMA_n	5.5	1,500		328		0.98		1,351	
PA	5.0	868	**+7**	260	**+70**	0.62	**+3**	1,004	**+8**
PA_n	5.0	809		153		0.60		932	

BBM asphalt base course, **AWC** asphalt wearing course, **SMA** Stone Mastic Asphalt, **PA** porous asphalt with EAF slag

n = with natural aggregate

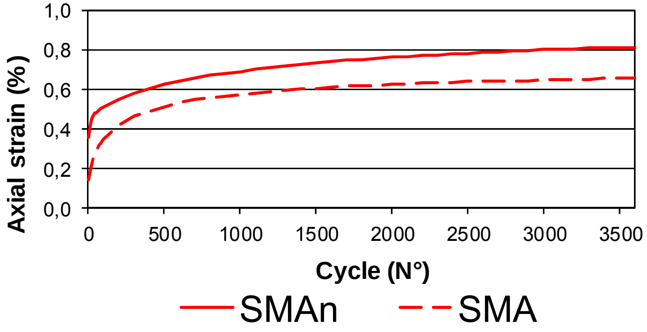
The Italian experience, step 1 (lab testing)

Repeated Load Axial Test (RLAT)

WITH CONFINEMENT

EN 12697/25 – Method A

- **Loading time:** **1 s**
- **Unloading time:** **1 s**
- **Samples (Cylindrical)** **Φ = 150mm, H = 60mm**
- **Temperatures:** **40°C**
- **Stress level:** **100kPa**
- **Loading cycles:** **3600**



Permanent deformation reduction: BBM 10%, AWC 32%, SMA 21%, PA 28%

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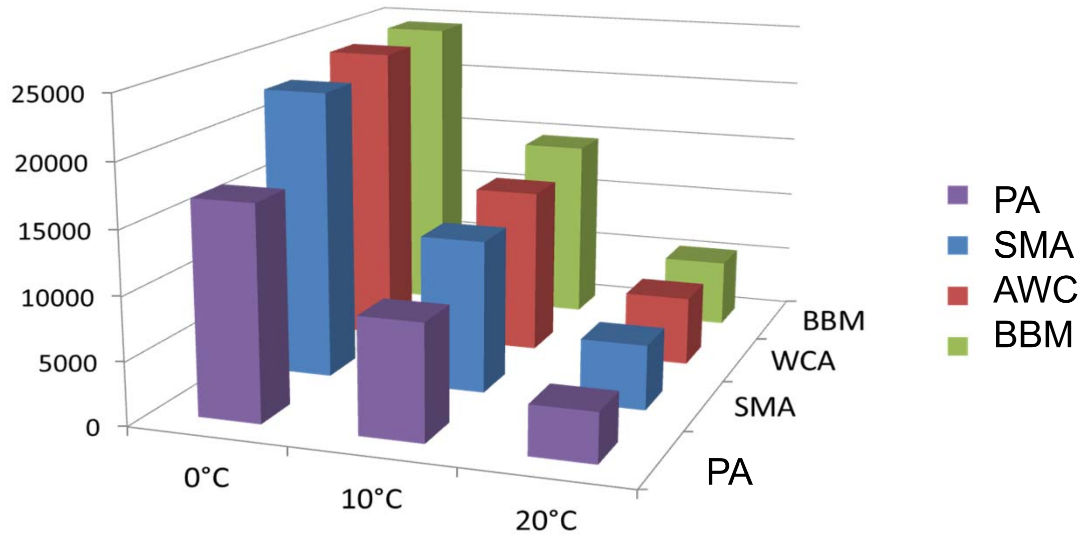
n = with natural aggregate

The Italian experience, step 1 (lab testing)

Indirect Tensile Stiffness Modulus (ITSM)

EN 12697/26 - Annex C

- ✓ Test Temperatures: **0°C, 10°C, 20°C**
- ✓ Rise Time: **50 ms**
- ✓ Deformation control procedure (**5 microns**)



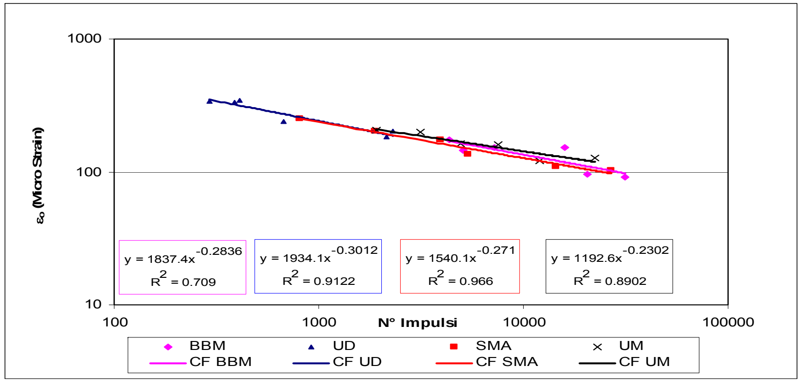
BBM asphalt base course, **AWC** asphalt wearing course,
SMA Stone Mastic Asphalt, **PA** porous asphalt
with EAF slag

The Italian experience, step 1 (lab testing)

Indirect Tensile Fatigue Test (ITFT)

UNI EN 12697/24 - Annex E

- ✓ Repeated (<u>Destructive</u>) Indirect Tensile Test
- ✓ Impulsive loading wave
- ✓ Test Temperatures: **20°C**
- ✓ Stress control procedure (**400, 500, 600 kPa**)



ε6: BBM 37 μm/m, AWC 49 μm/m, SMA 36 μm/m, PA 30 μm/m

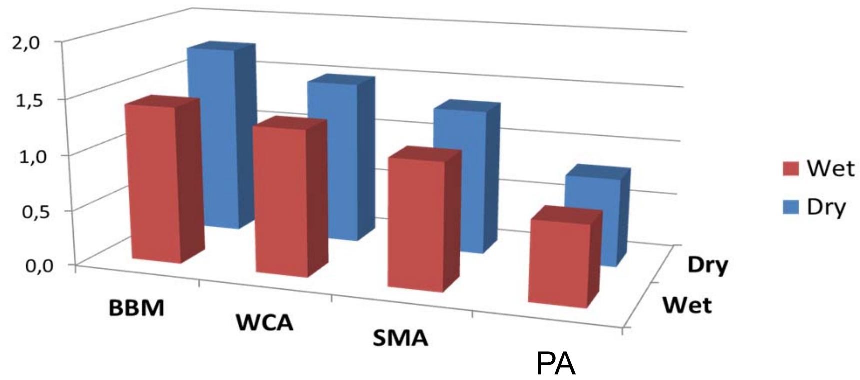
BBM asphalt base course, **AWC** asphalt wearing course, **SMA** Stone Mastic Asphalt, **PA** porous asphalt with EAF slag

The Italian experience, step 1 (lab testing)

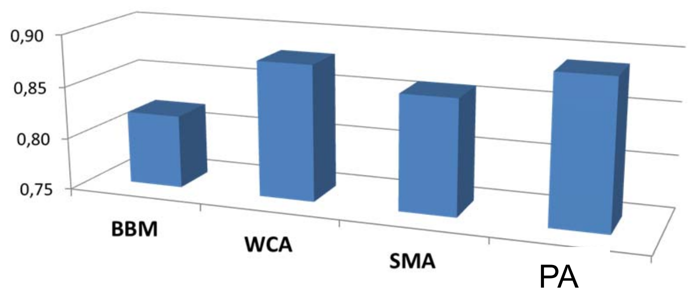
Moisture Resistance – Indirect Tensile Strenght Test (ITT)

CNR 149/92

- ✓ <u>Destructive</u> Indirect Tensile Test
- ✓ Constant strain rate: 0.85 mm/s
- ✓ Test Temperatures: **25°C**
- ✓ Dry & **Wet** conditions (7 days in water)



ITs at 25°C

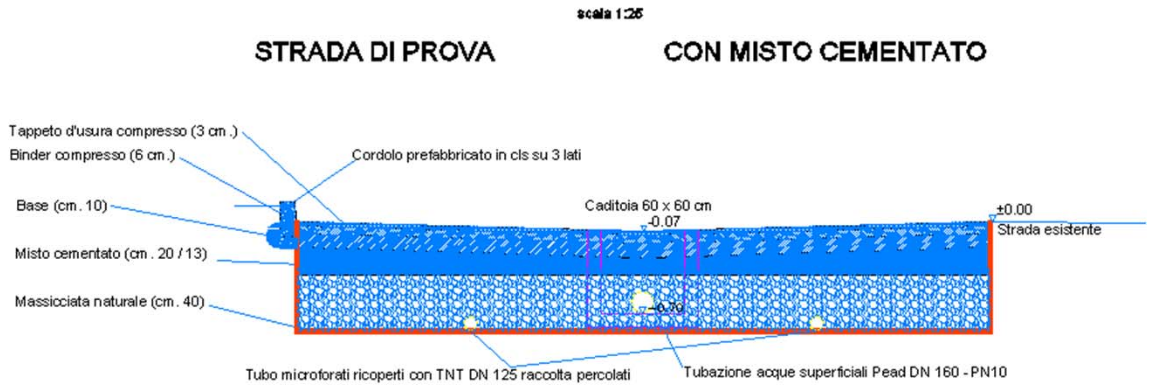


TSR at 25°C

BBM asphalt base course, **AWC** asphalt wearing course,
SMA Stone Mastic Asphalt, **PA** porous asphalt
with EAF slag

The Italian experience, step 2 (field testing)

- MSWI bottom ash



The Italian experience, step 2 (field testing)

- MSWI bottom ash
  - ✓ 100 m (2 different pavements, with/without CBGM sub-base)
  - ✓ 2,350 heavy vehicles in 1 year
  - ✓ 71,130 tons (max weight 46 tons)
  - ✓ Tests on materials (bituminous and cement bound mixes)
  - ✓ FWD and PLFWD
  - ✓ IRI
  - ✓ Coring
  - ✓ Micro/macro-texture (skid test, height in sand)
  - ✓ Drainage
  - ✓ Water analysis

The Italian experience, step 3 (construction)

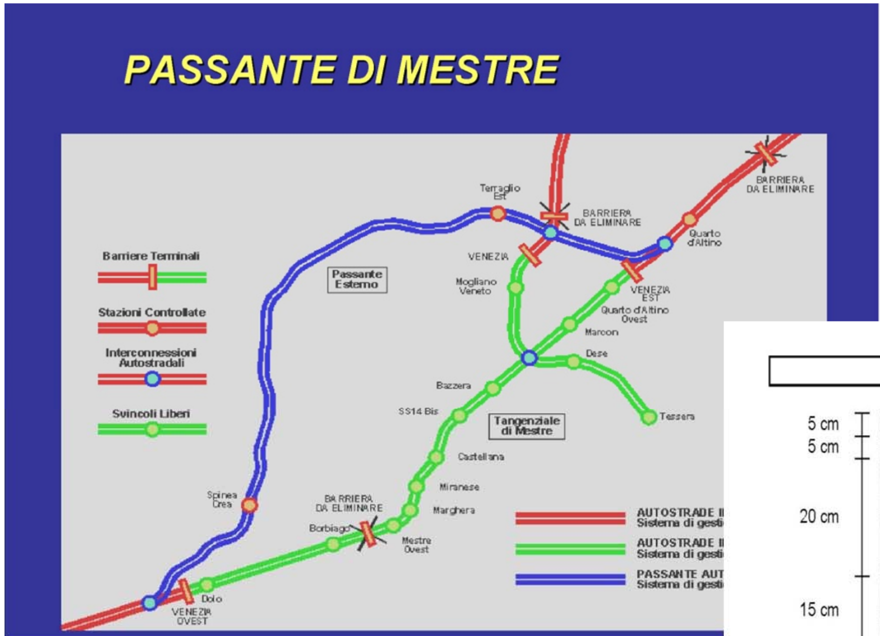
- **Applications concerning**
  - ✓ embankments (1)
  - ✓ hydraulically bound foundations (2)
  - ✓ cement and bituminous draining layers (3)
  - ✓ bituminous wearing courses, base courses, road bases (4)

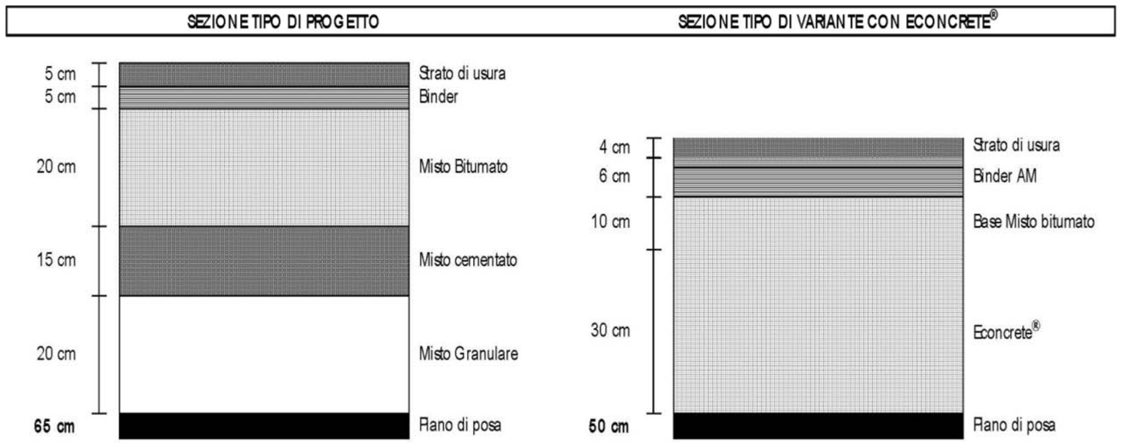
with

- ✓ EAF slag (1) (2) (3) (4)
- ✓ Spent foundry sand (2) (3)
- ✓ C&D aggregate (1) (2)
- ✓ crumb rubber (4)
- ✓ RAP (4)

The Italian experience, step 3 (construction)

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





The Italian experience, step 3 (construction)

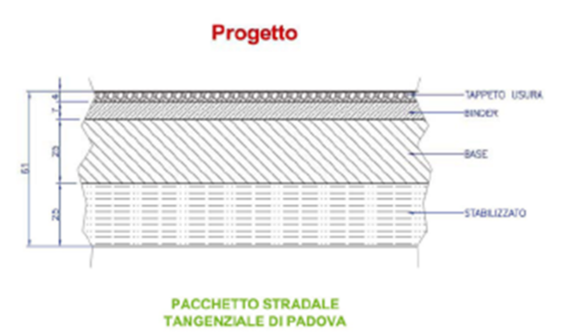
- **Padova Northern by-pass**
  - ✓ 7 km major road, 2 lanes x 2 separate carriageways

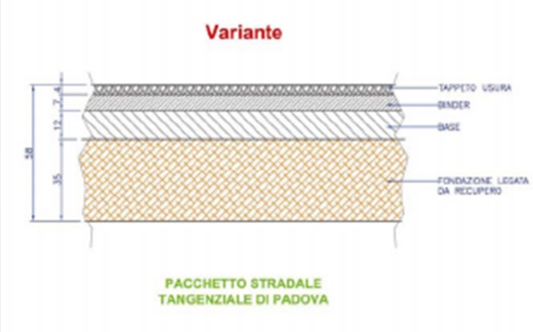
73,000 m^3 capping layer : sand -> lime stabilization of soil

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



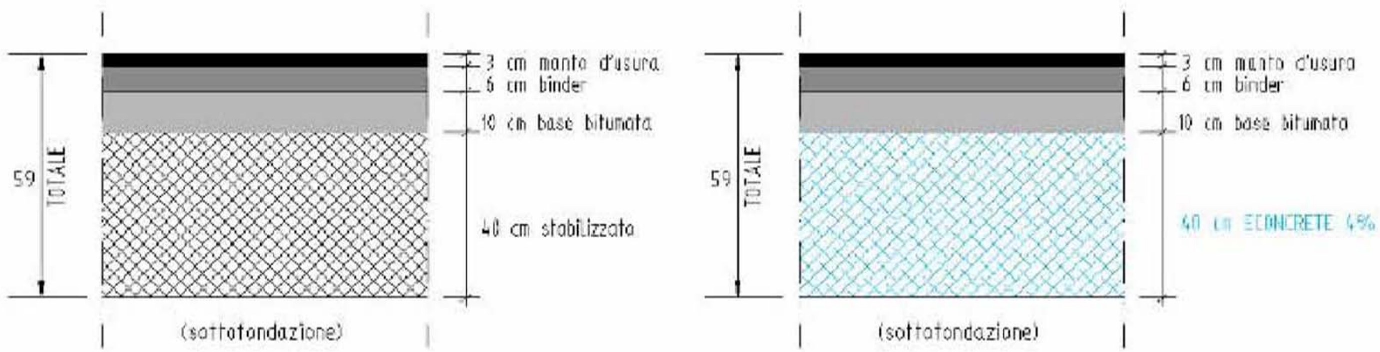


The Italian experience, step 3 (construction)

- **National Road SS 246 Var. Montecchio M.**
  - ✓ 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



Conclusions

- ✓ Several marginal materials show physical, geotechnical and mechanical characteristics that make them suitable for producing asphalt mixtures as well as CBGM and unbound mixes. Their use has been also tested in cold recycling.
- ✓ New tests could be useful in order to analyze the performances.
- ✓ Field tests are useful in order to understand the critical aspects related to the utilization of these aggregates in real pavements.
- ✓ In different countries the alternative materials are being used in road construction.
- ✓ Specifications and technical Standards are needed.
- ✓ Leaching and eco-toxicity should be continuously monitored before and after any application.

Thank You,

Marco Pasetto
marco.pasetto@unipd.it