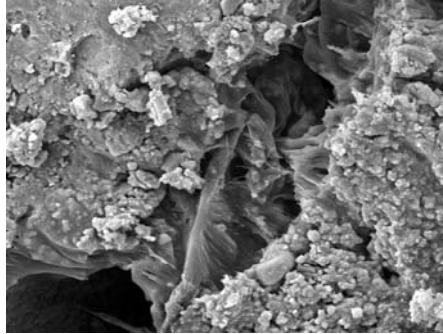


International Workshop Asphalt Recycling and Materials Re-Use in Asphalt Pavements

Cold recycling of bituminous mixtures

prof. Ezio Santagata
Politecnico di Torino



Università di L'Aquila - Facoltà di Ingegneria - 28th June 2007

Cold recycling of bituminous mixtures Self introduction



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Cold recycling of bituminous mixtures

Guidelines for presentation

1. Give general overview of the topic
2. Highlight interest/problems of society, users, road owners, designers and contractors
3. Give some examples about specific solutions or problems
4. Point out main key players in research



SPECIFIC AND OPEN QUESTIONS RESEARCH NEEDS

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Cold recycling of bituminous mixtures

Presentation structure

- General description
- Critical issues derived from research experience
 - Materials
 - Testing
 - Modelling
- Closure = Questions

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Cold recycling of bituminous mixtures

General description

- RAP (reclaimed asphalt pavement)
 - bulk structure
- Bituminous emulsion
 - binder
- Filler (usually Portland cement)
 - filler and stiffening enhancement
- Added water
 - Workability and emulsion dispersion
- Virgin aggregates
 - integration to bulk structure

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Cold recycling of bituminous mixtures

General description



In-field recycling
(single or multiple unit)



In-plant recycling

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Cold recycling of bituminous mixtures

General description

- Advantages:
 - Reduced use of raw materials
 - Reduction of disposal volumes
 - Lower environmental impact
 - Lower energy consumption
 - Reduced impact on labour health and safety
 - Cost reduction
- Disadvantages:
 - Reduced structural performance
 - **Problems in mix design, testing and modelling**

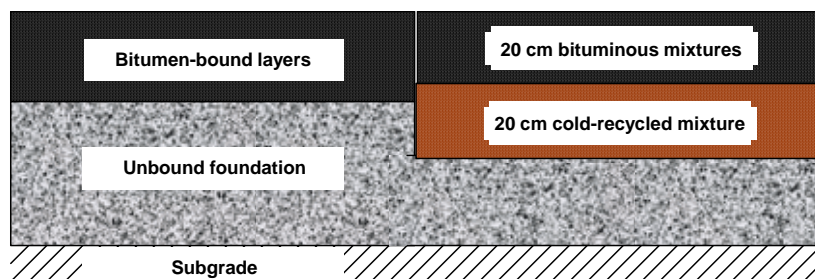
**However, based on engineering experience,
there are guidelines and specifications!**

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Cold recycling of bituminous mixtures

Critical issues derived from research experience

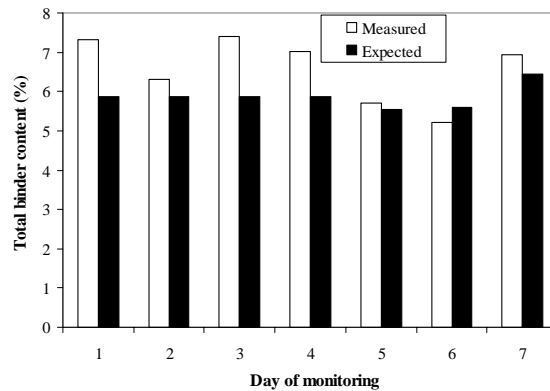
- Rehabilitation of motorway A4 Torino-Milano (1999-2001)



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Cold recycling of bituminous mixtures Critical issues derived from research experience

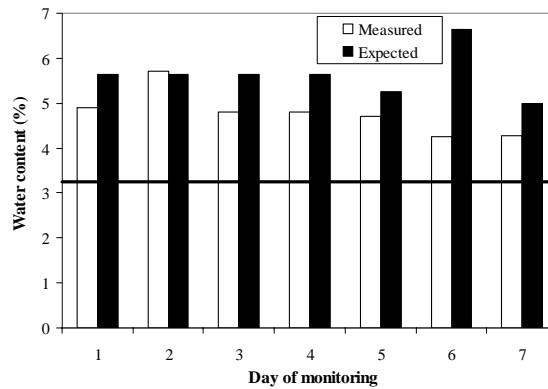
- Rehabilitation of motorway A4 Torino-Milano (1999-2001)
 - Production homogeneity



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Cold recycling of bituminous mixtures Critical issues derived from research experience

- Rehabilitation of motorway A4 Torino-Milano (1999-2001)
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Cold recycling of bituminous mixtures

Critical issues derived from research experience

- Rehabilitation of motorway A4 Torino-Milano (1999-2001)
 - Compaction

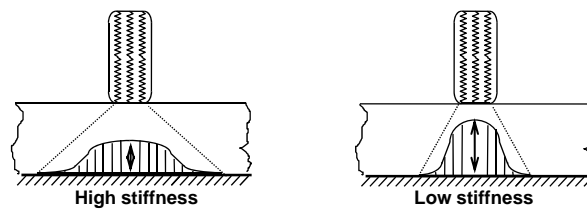


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Cold recycling of bituminous mixtures

Critical issues derived from research experience

- Load spreading function



EVALUATION OF STIFFNESS AND STRENGTH

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Cold recycling of bituminous mixtures

Critical issues derived from research experience

- Problems to solve:
 - Testing technique
 - Sample preparation / coring



Selection of practical characterization techniques

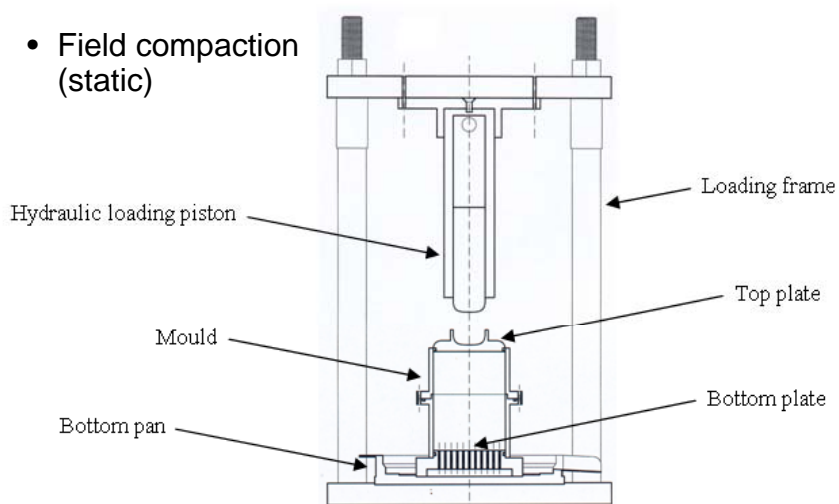
Development of equipment and procedures

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Critical issues derived from research experience

- Field compaction (static)



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Cold recycling of bituminous mixtures

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Critical issues derived from research experience

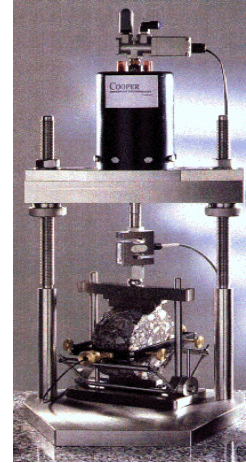
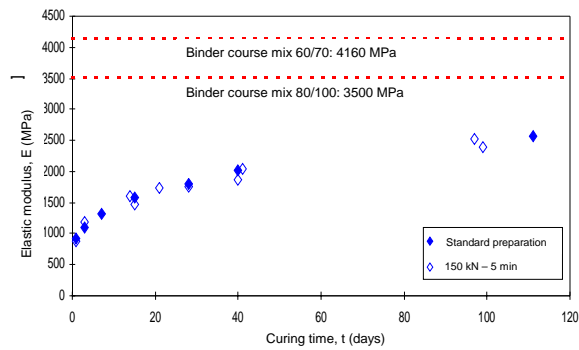
- Laboratory compaction (gyratory)



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Cold recycling of bituminous mixtures Critical issues derived from research experience

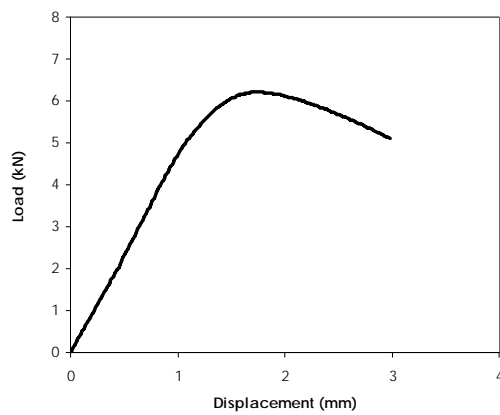
- Elastic stiffness testing (RLIT)



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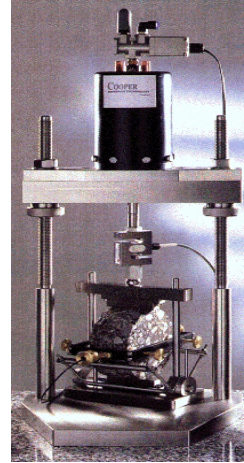
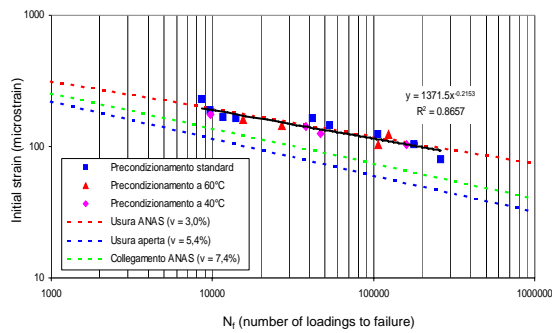
- Indirect tensile strength (ITS) testing (static)



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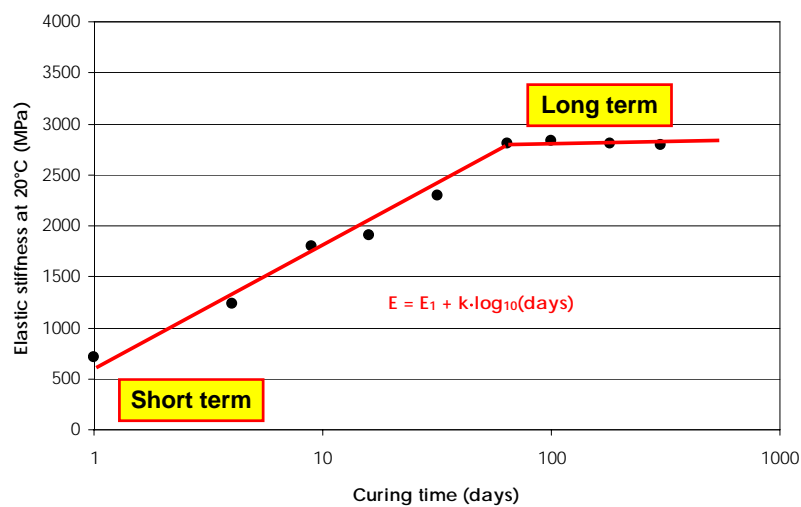
Cold recycling of bituminous mixtures Critical issues derived from research experience

- Fatigue testing



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Cold recycling of bituminous mixtures Critical issues derived from research experience



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Cold recycling of bituminous mixtures

Critical issues derived from research experience

- Elastic stiffness parameters (E_1 and k) extremely sensitive to variations of:
 - Size distribution
 - Emulsion type
 - Compaction

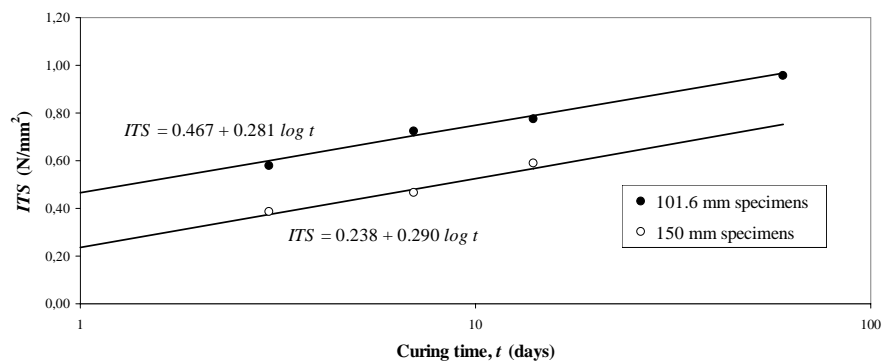
	1999	2000	2001
E_1	1429	569	1256
k_E	1388	921	1591
E_{60}	3897	2206	4084

Lower binder content, coarser RAP, higher air voids

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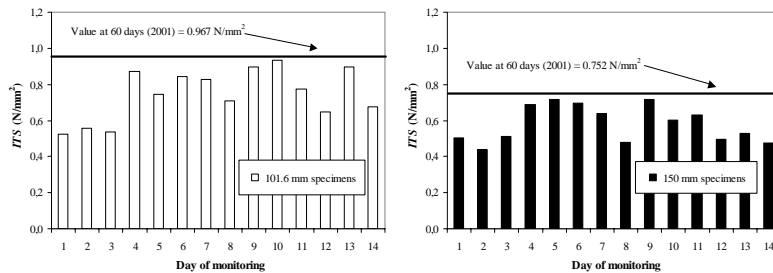
Critical issues derived from research experience



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Cold recycling of bituminous mixtures Critical issues derived from research experience

- ITS parameters (RTI_1 and k_{RTI}) extremely sensitive to variations of:
 - Size distribution
 - Emulsion type
 - Compaction

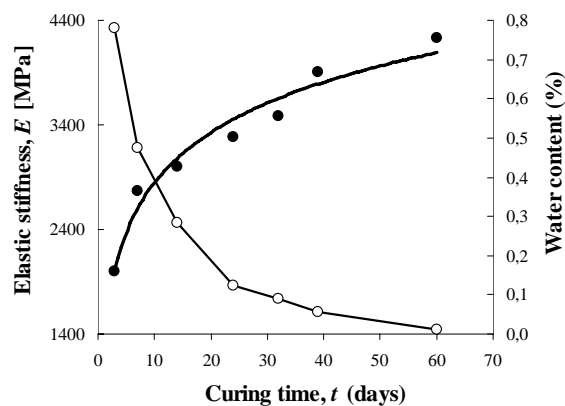


Lower binder content, coarser RAP, higher air voids

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Cold recycling of bituminous mixtures Critical issues derived from research experience

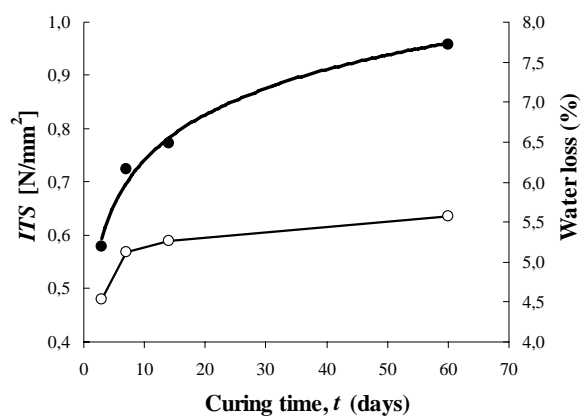
- Evolution of water content



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Cold recycling of bituminous mixtures Critical issues derived from research experience

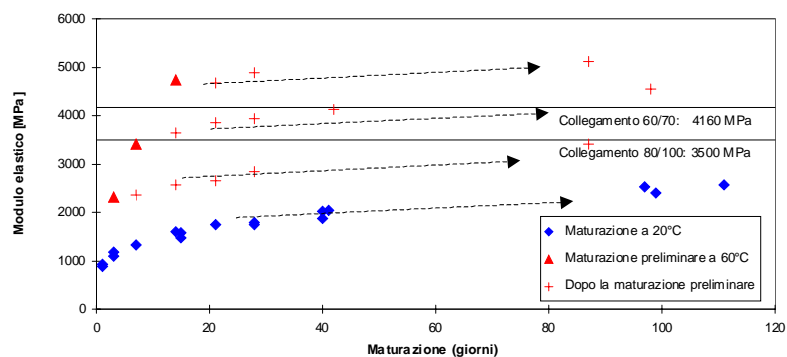
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Cold recycling of bituminous mixtures Critical issues derived from research experience

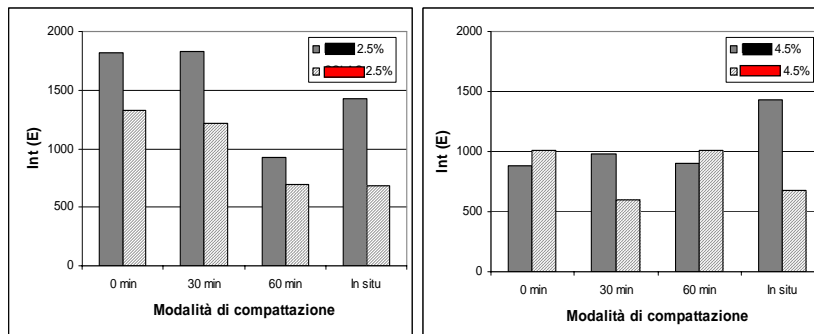
- Effect of curing temperature



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Cold recycling of bituminous mixtures Critical issues derived from research experience

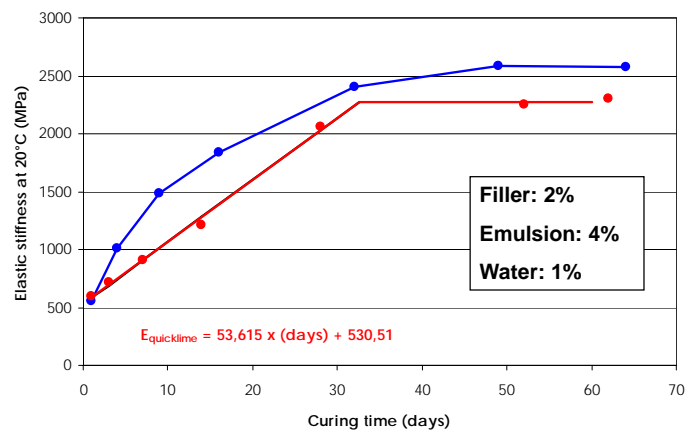
- Effect of emulsion type and quantity



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Cold recycling of bituminous mixtures Critical issues derived from research experience

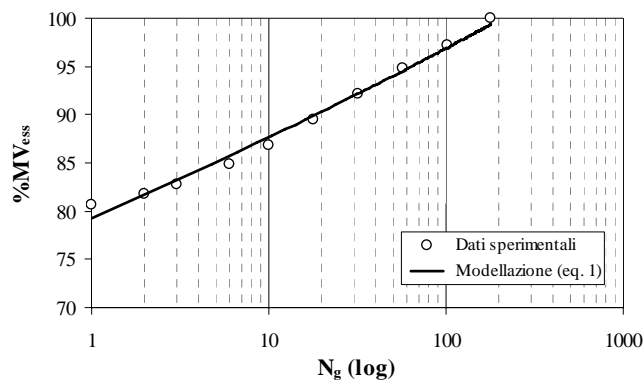
- Effect of filler type (cement vs quicklime)



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Cold recycling of bituminous mixtures Critical issues derived from research experience

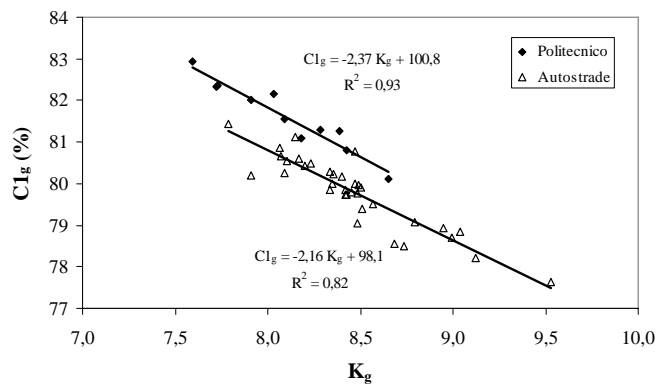
- Compaction properties (from gyratory equipment)



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Cold recycling of bituminous mixtures Critical issues derived from research experience

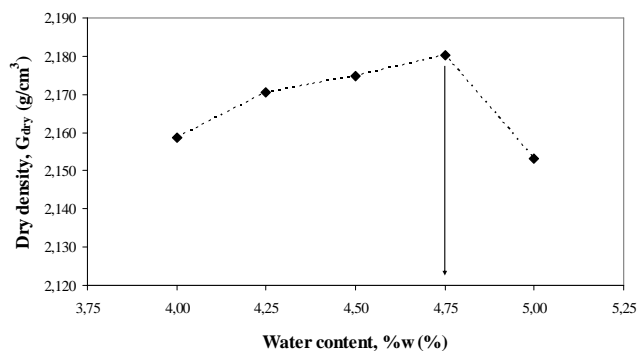
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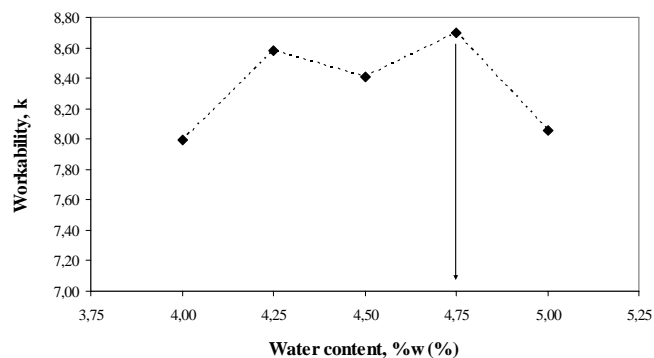
- Mix design



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Cold recycling of bituminous mixtures Critical issues derived from research experience

- Mix design

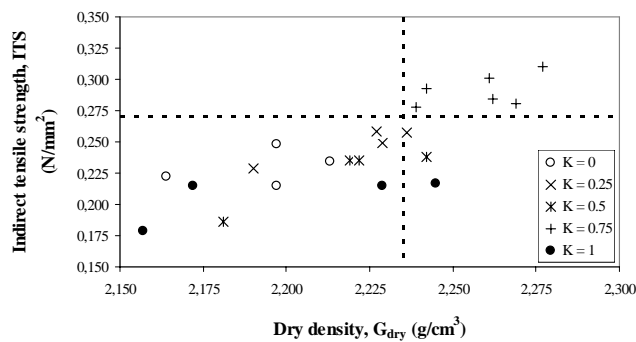


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Cold recycling of bituminous mixtures Critical issues derived from research experience

- Mix design

$$\%FF_{\text{optimum}} = \%W_{\text{added}} + (a+Kb) \cdot \%E$$



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Cold recycling of bituminous mixtures Critical issues derived from research experience

- Short term characterization
 - UNBOUND?



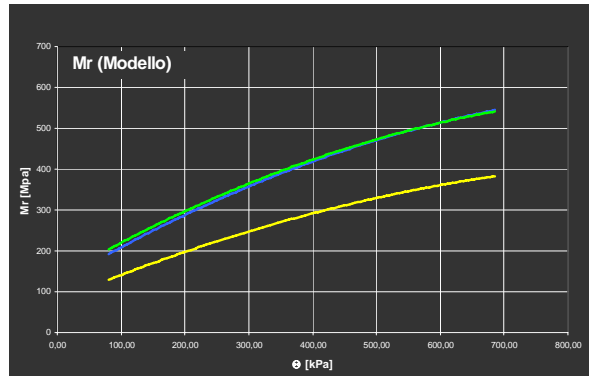
- Resilient modulus M_R
- Failure (p-q) criteria

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Cold recycling of bituminous mixtures

Critical issues derived from research experience

- Short term characterization
 - UNBOUND?

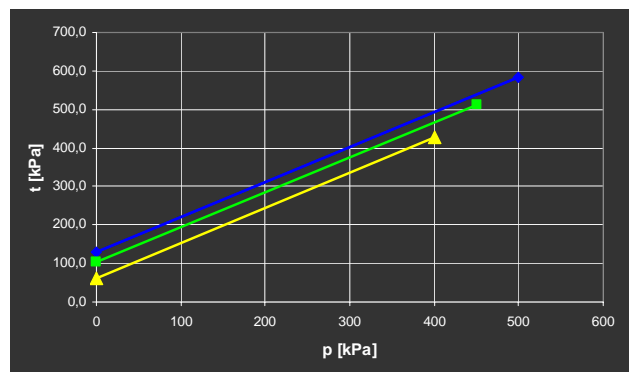


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Cold recycling of bituminous mixtures

Critical issues derived from research experience

- Short term characterization
 - UNBOUND?

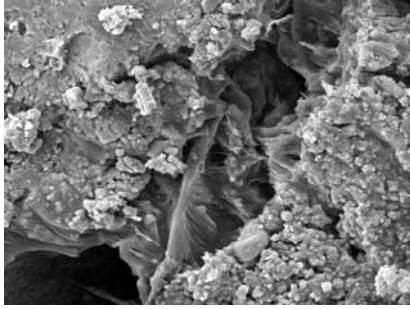


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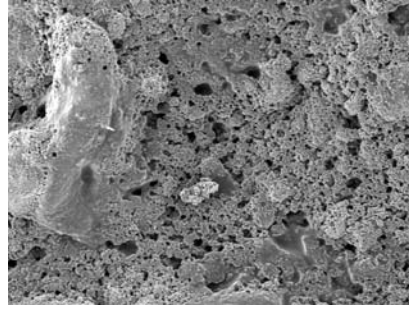
Cold recycling of bituminous mixtures

Critical issues derived from research experience

- Characterization of the emulsion-filler system



Interconnected binding matrix
High modulus, high strength



Porous binding matrix
Low modulus, low strength

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Cold recycling of bituminous mixtures

Closure - Questions

- Can production plants be improved?
- Can compaction techniques be improved?
- Should RAP be separated in fractions to control gradation?
- Are rejuvenators needed?
- Are modified emulsions needed?
- What can of filler should be used?
- How much stiffness is needed?
- Options to mix design?
- Options to performance testing?
- Coring?
- Field testing?

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Thanks for your attention

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