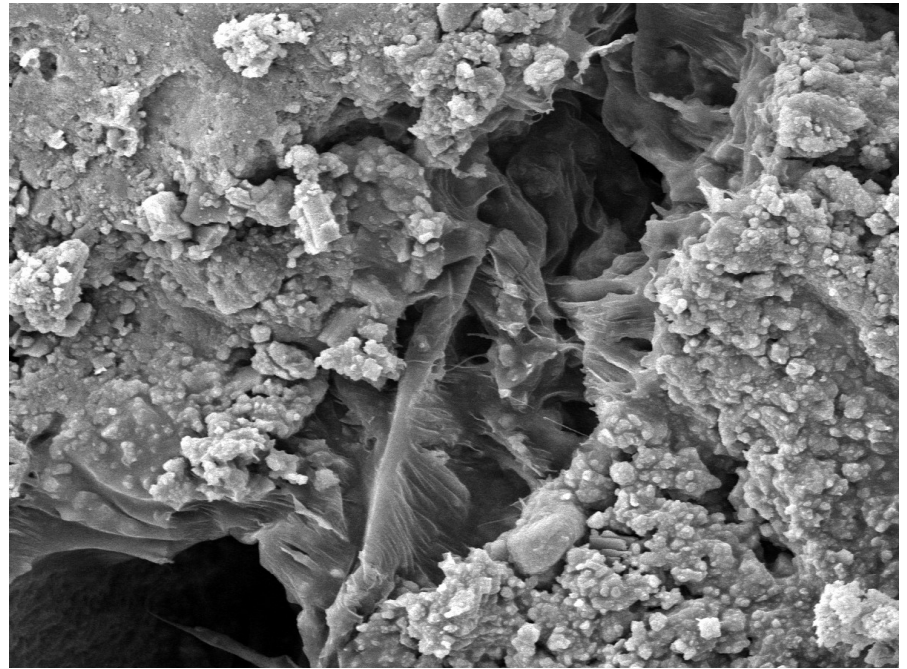


# International Workshop Asphalt Recycling and Materials Re-Use in Asphalt Pavements

## Cold recycling of bituminous mixtures

prof. Ezio Santagata  
Politecnico di Torino



# Cold recycling of bituminous mixtures

## Self introduction

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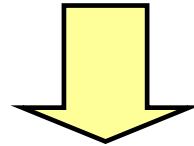


# Cold recycling of bituminous mixtures

## Guidelines for presentation

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



**SPECIFIC AND OPEN QUESTIONS  
RESEARCH NEEDS**

# Cold recycling of bituminous mixtures

## Presentation structure

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

# Cold recycling of bituminous mixtures

## General description

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- 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

# Cold recycling of bituminous mixtures

## General description

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**In-field recycling  
(single or multiple unit)**



**In-plant recycling**

# Cold recycling of bituminous mixtures

## General description

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- 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

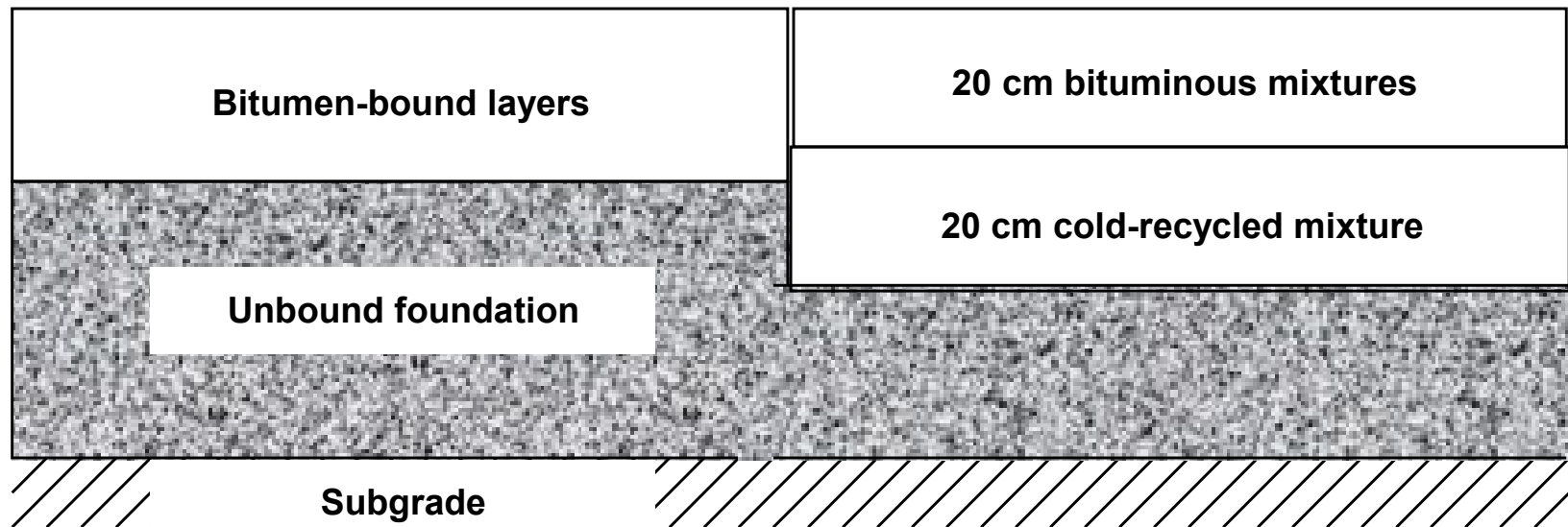
**However, based on engineering experience,  
there are guidelines and specifications!**

# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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



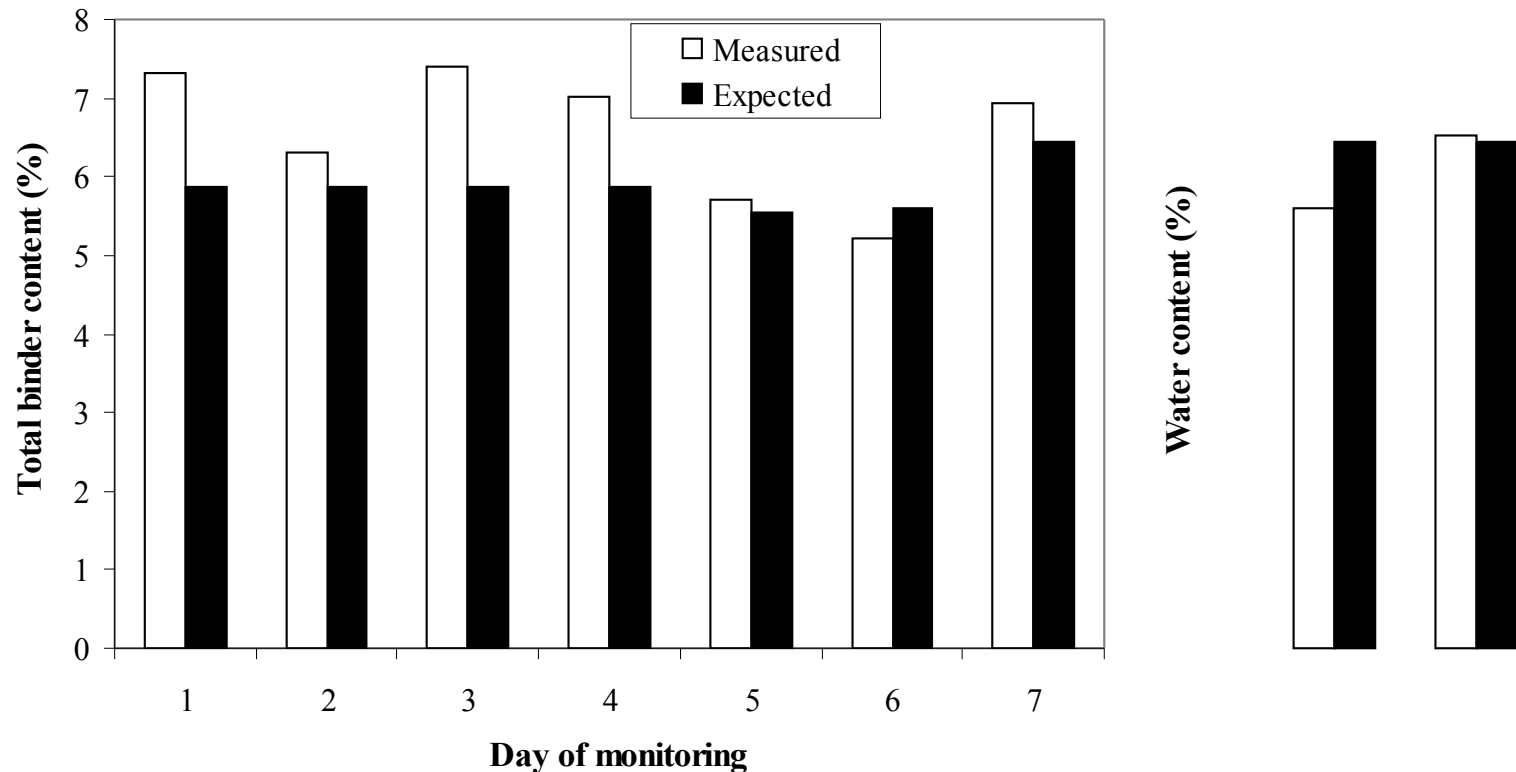


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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

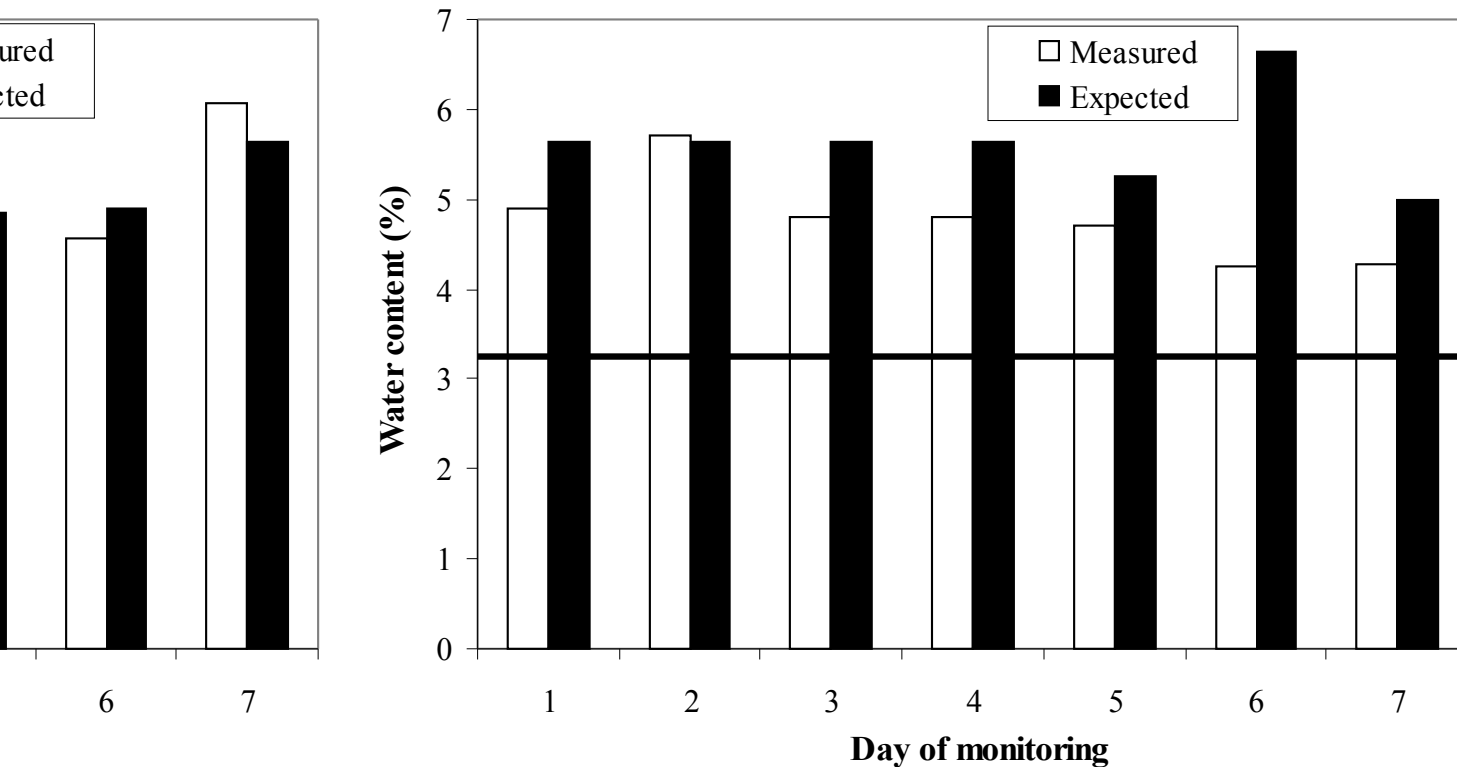


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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



# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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

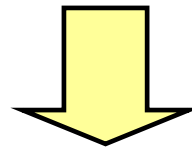
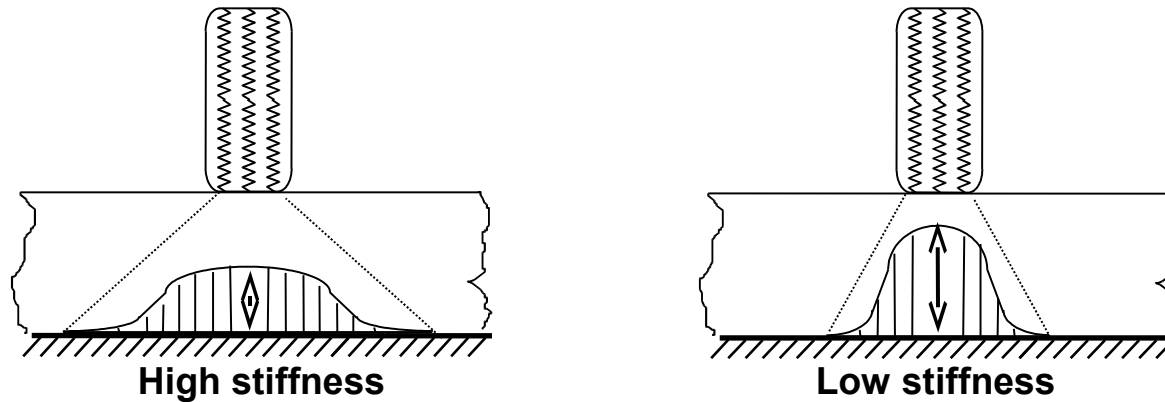


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Load spreading function



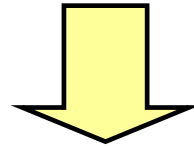
## EVALUATION OF STIFFNESS AND STRENGTH

# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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



**Selection of practical characterization techniques**

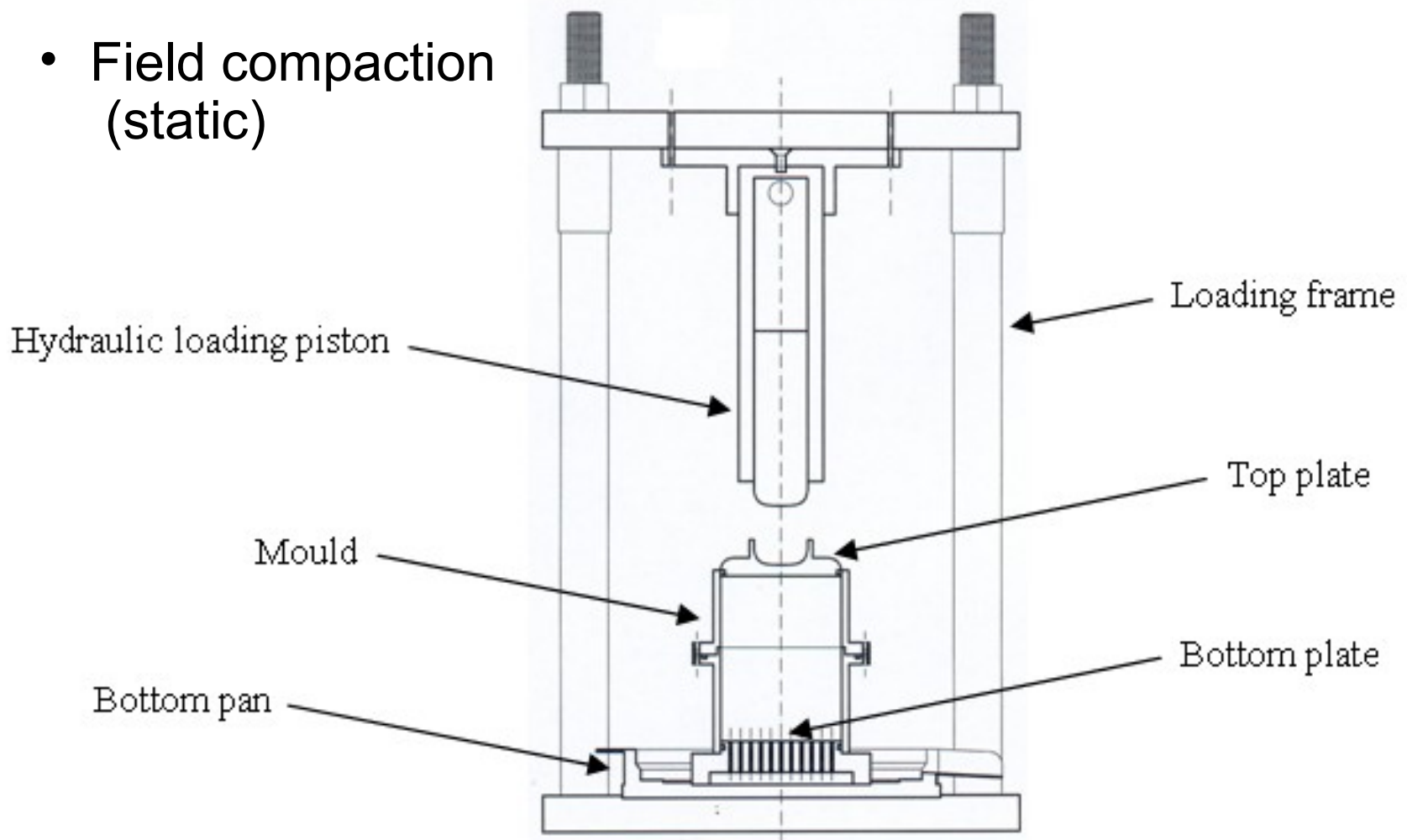
**Development of equipment and procedures**

# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Field compaction (static)

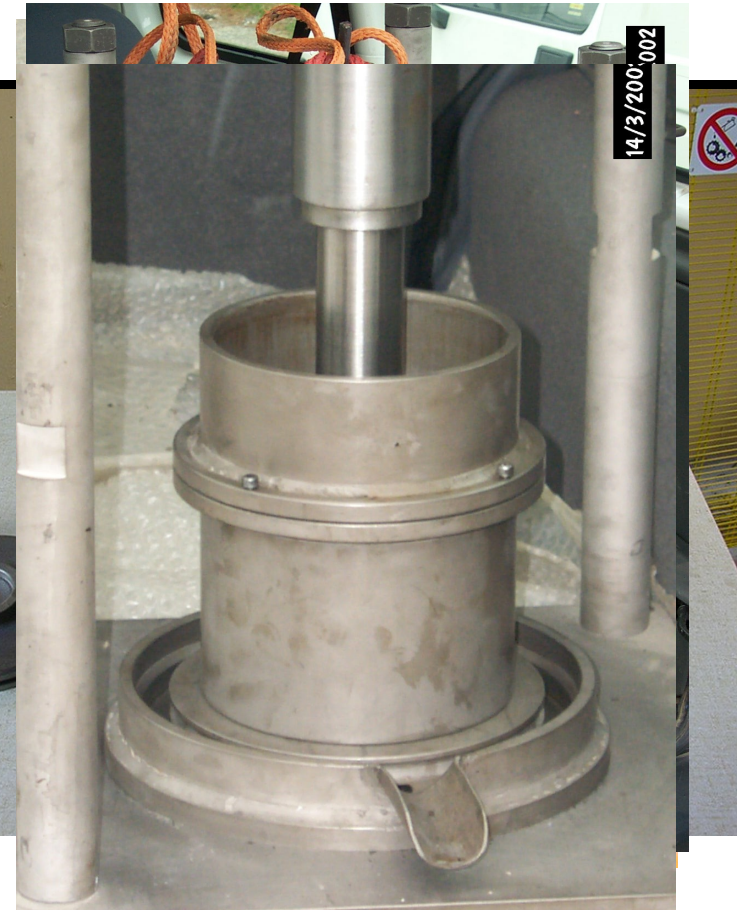


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Field compaction  
(static)



# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Laboratory compaction (gyratory)

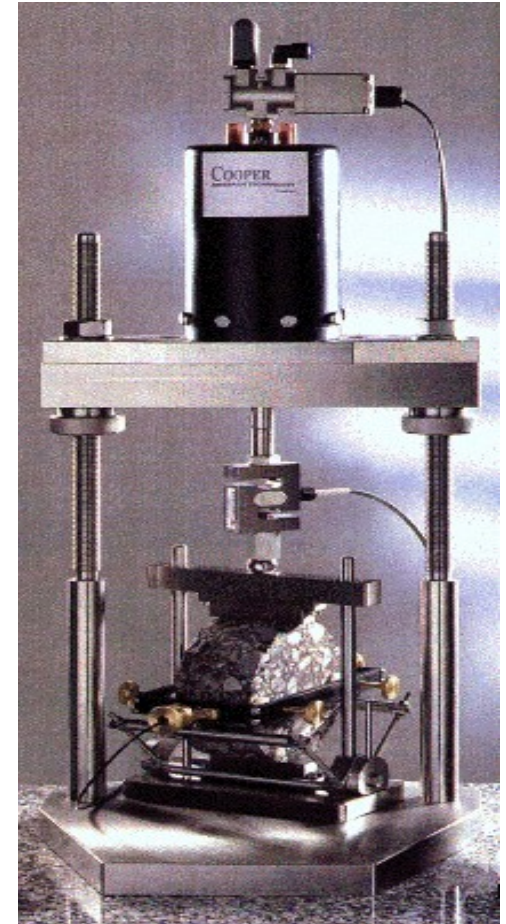
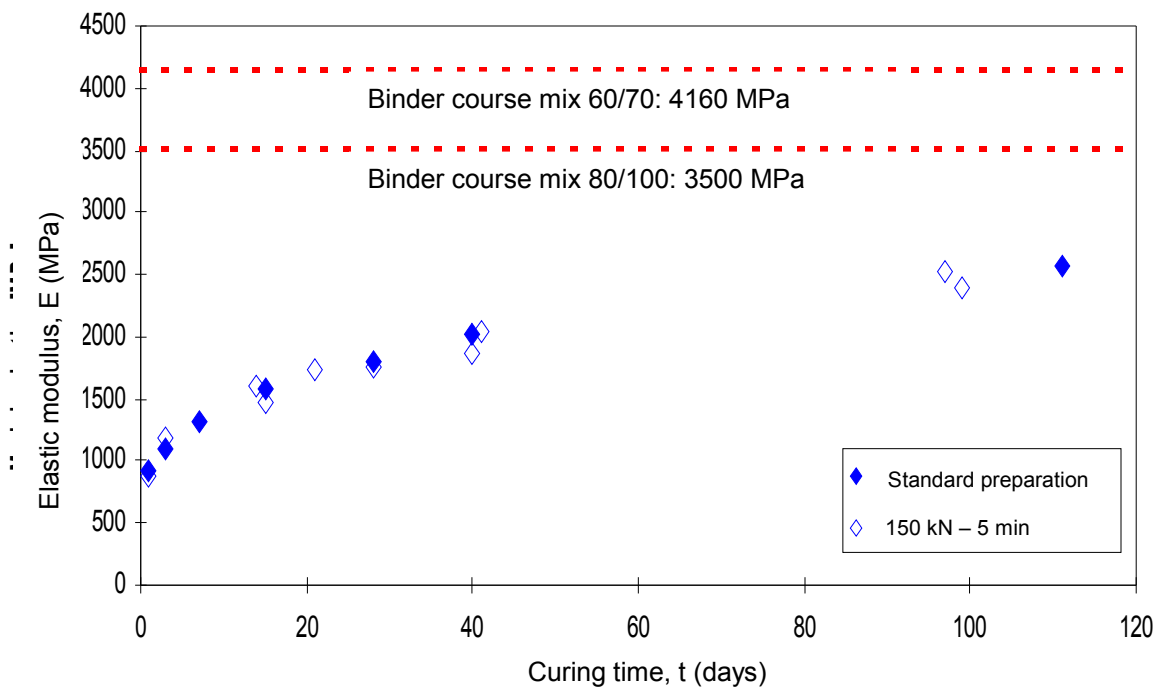




# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

- Elastic stiffness testing (RLIT)

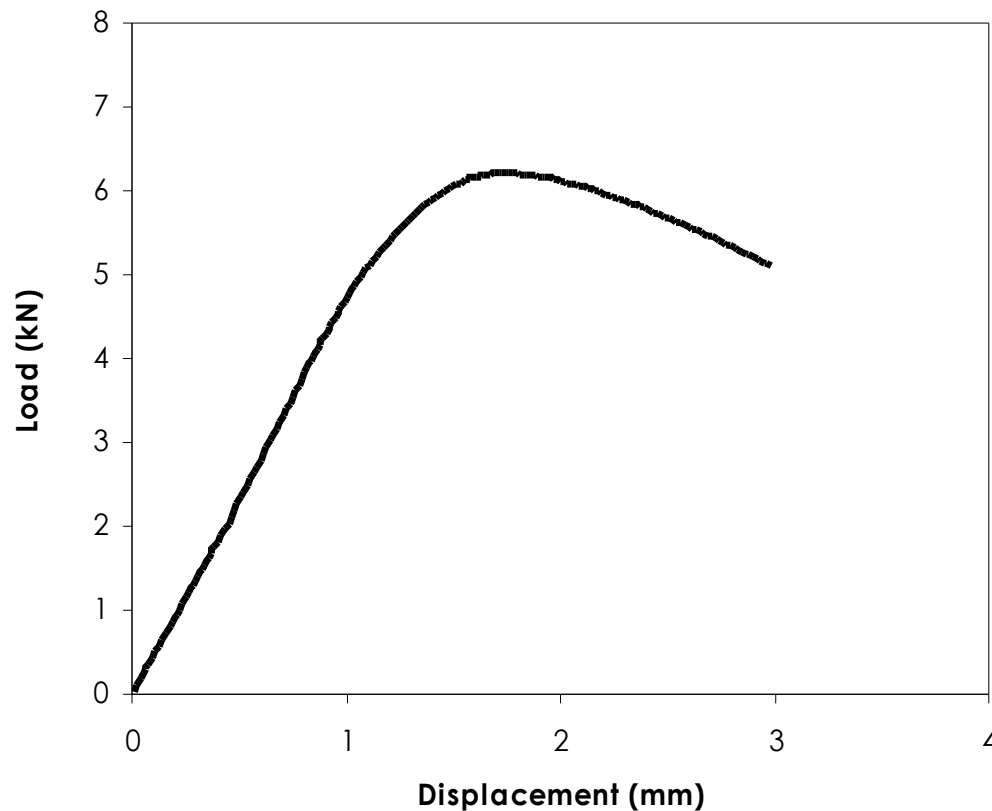


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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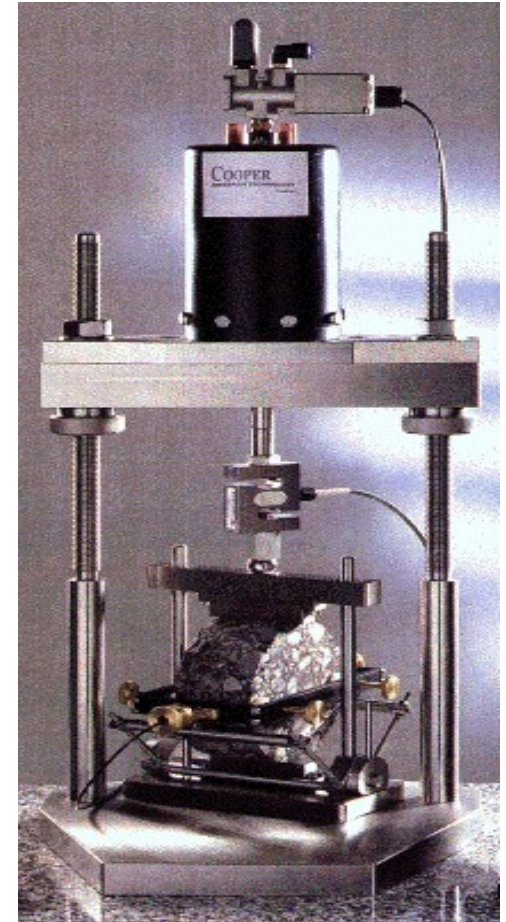
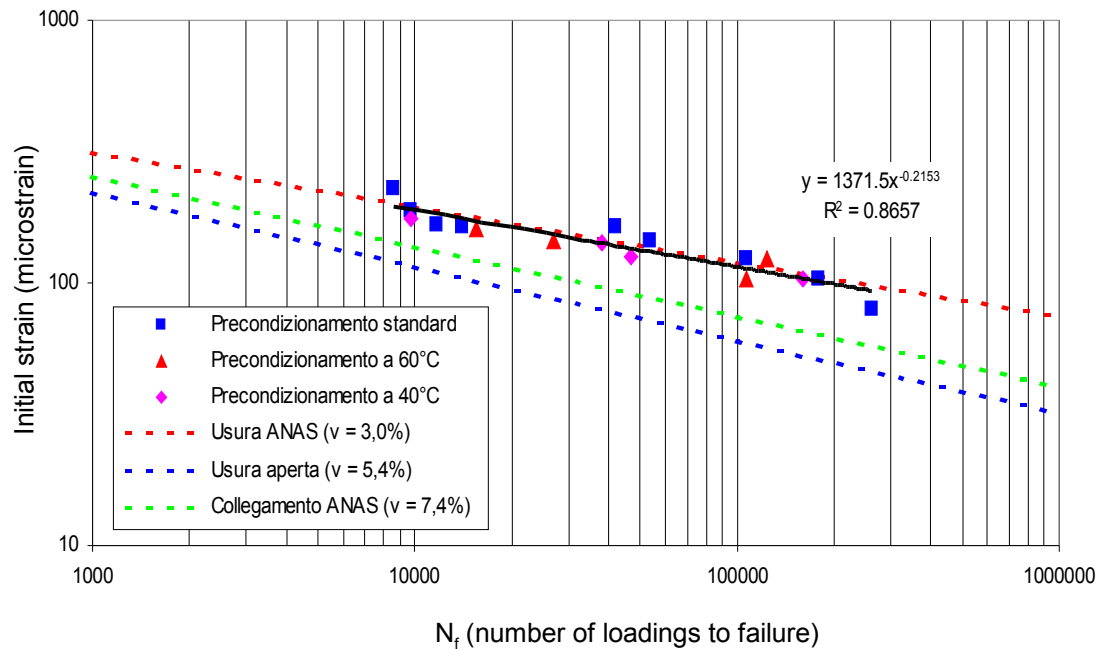
- Indirect tensile strength (ITS) testing (static)



# Cold recycling of bituminous mixtures

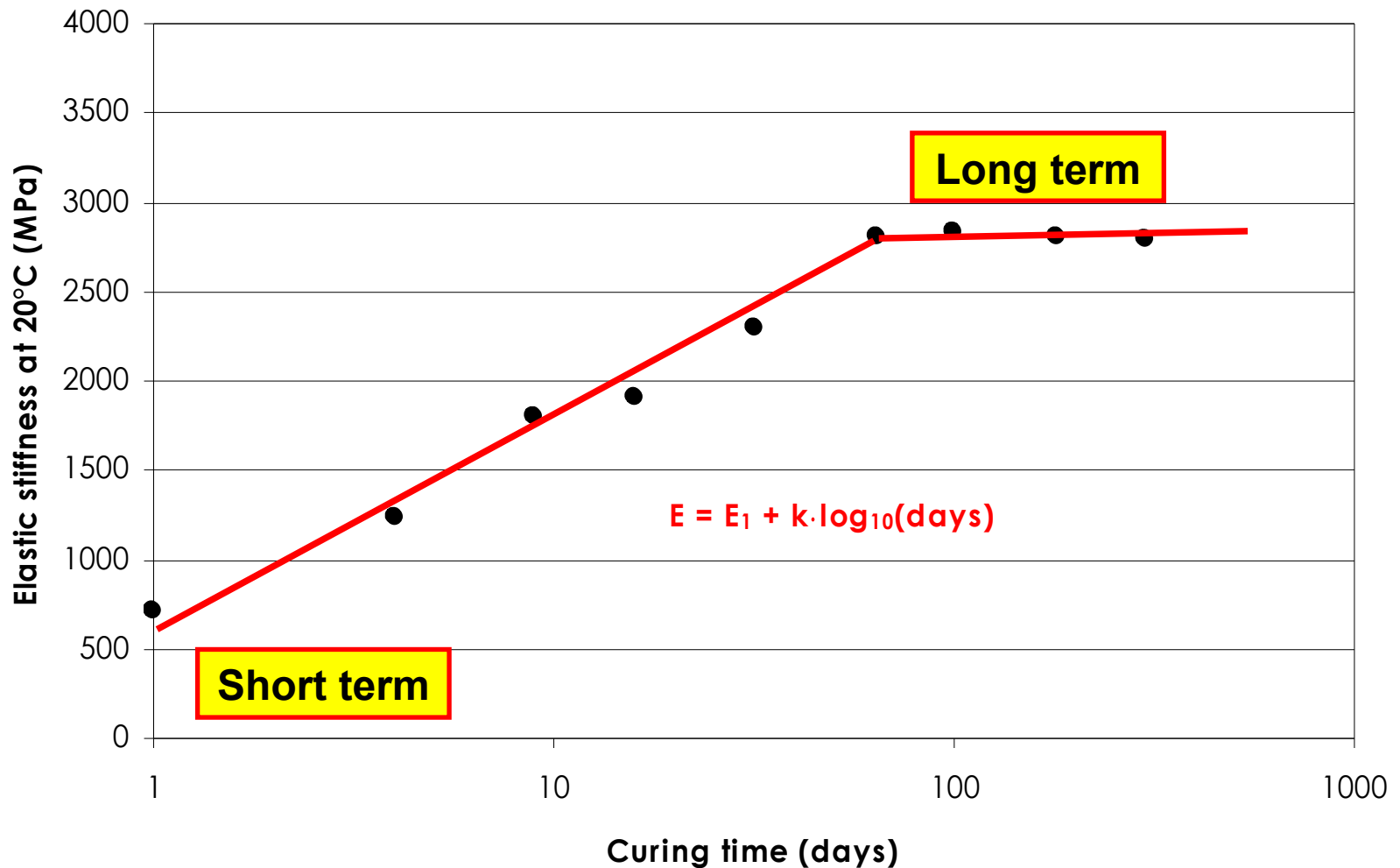
## Critical issues derived from research experience

- Fatigue testing



# Cold recycling of bituminous mixtures

## Critical issues derived from research experience



# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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

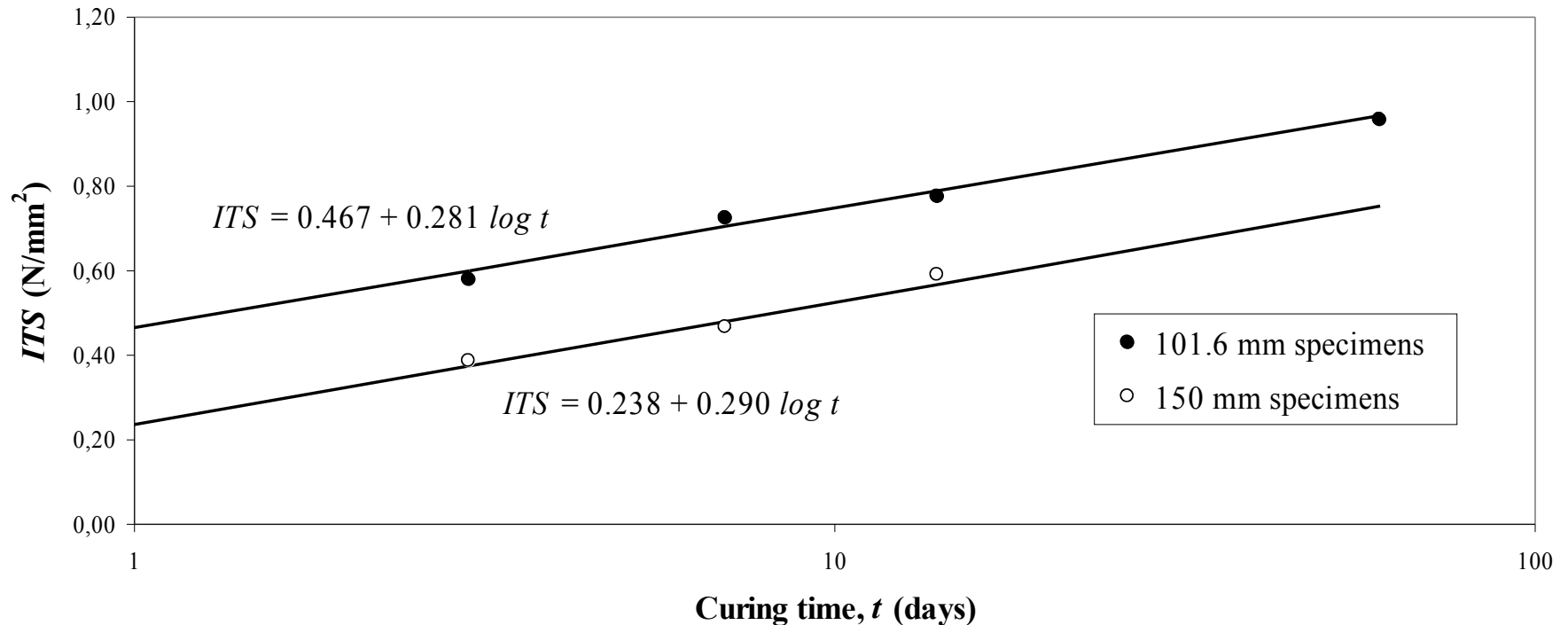
	1999	2000	2001
$E_1$	1429	569	1256
$k_E$	1388	921	1591
$E_{60}$	3897	2206	4084

**Lower binder content, coarser RAP, higher air voids**

# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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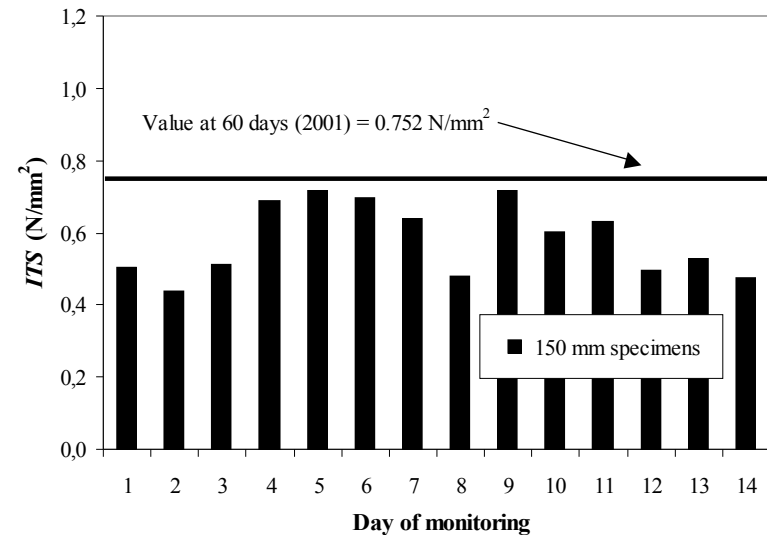
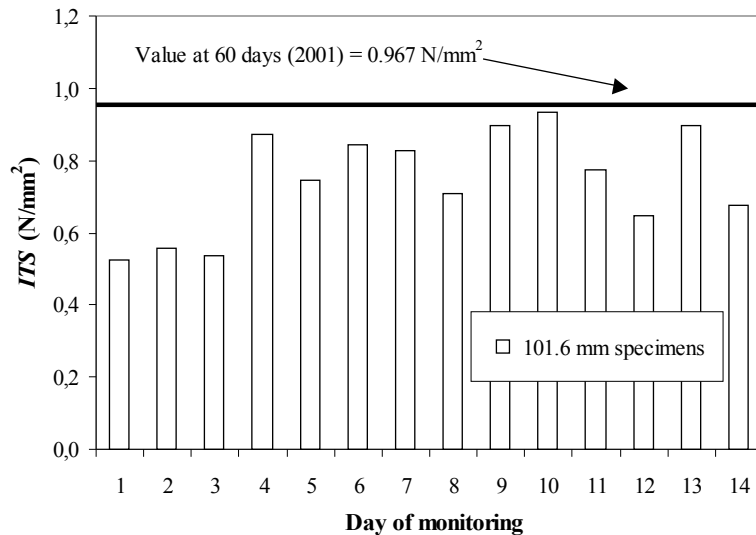


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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



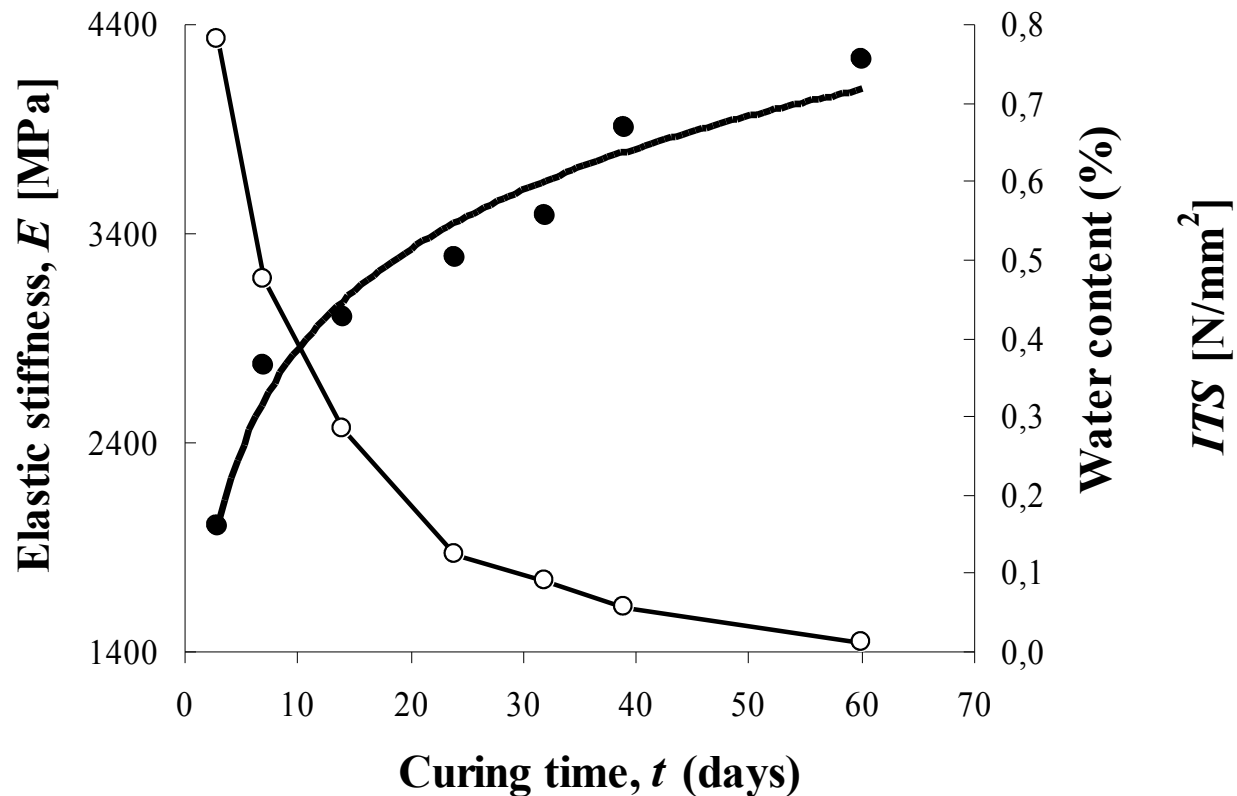
**Lower binder content, coarser RAP, higher air voids**

# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Evolution of water content



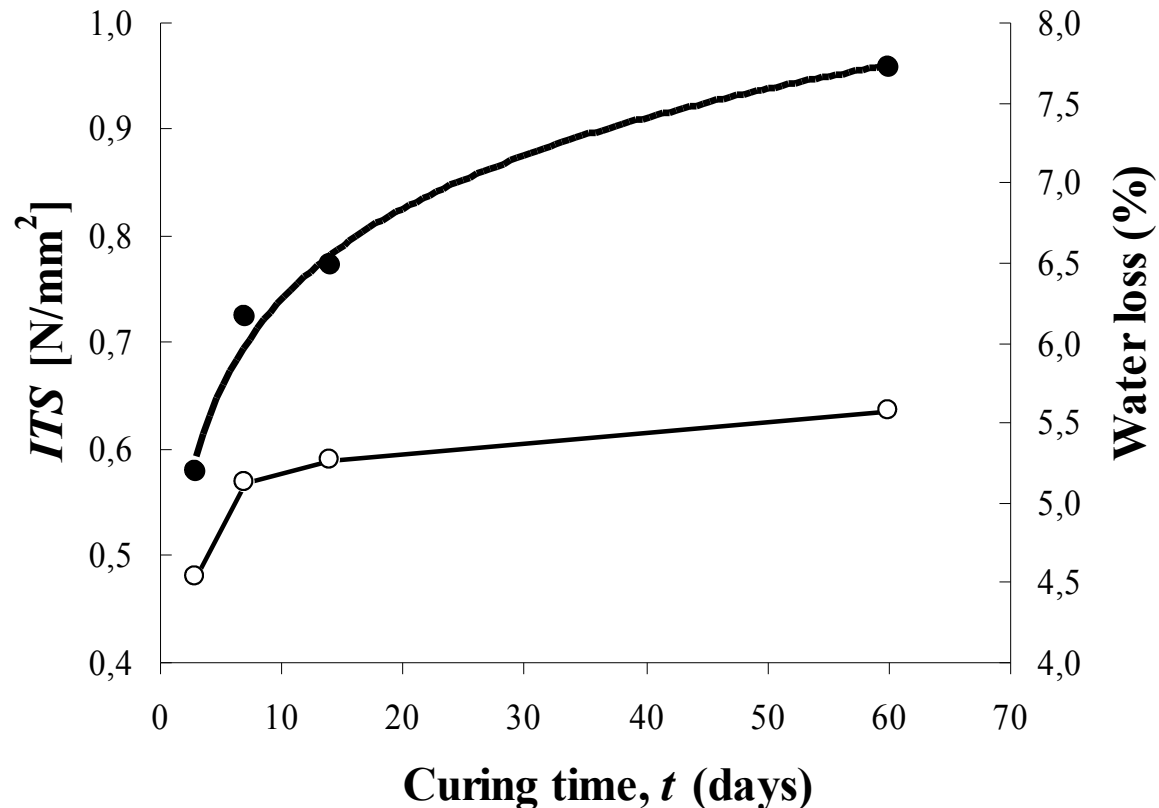


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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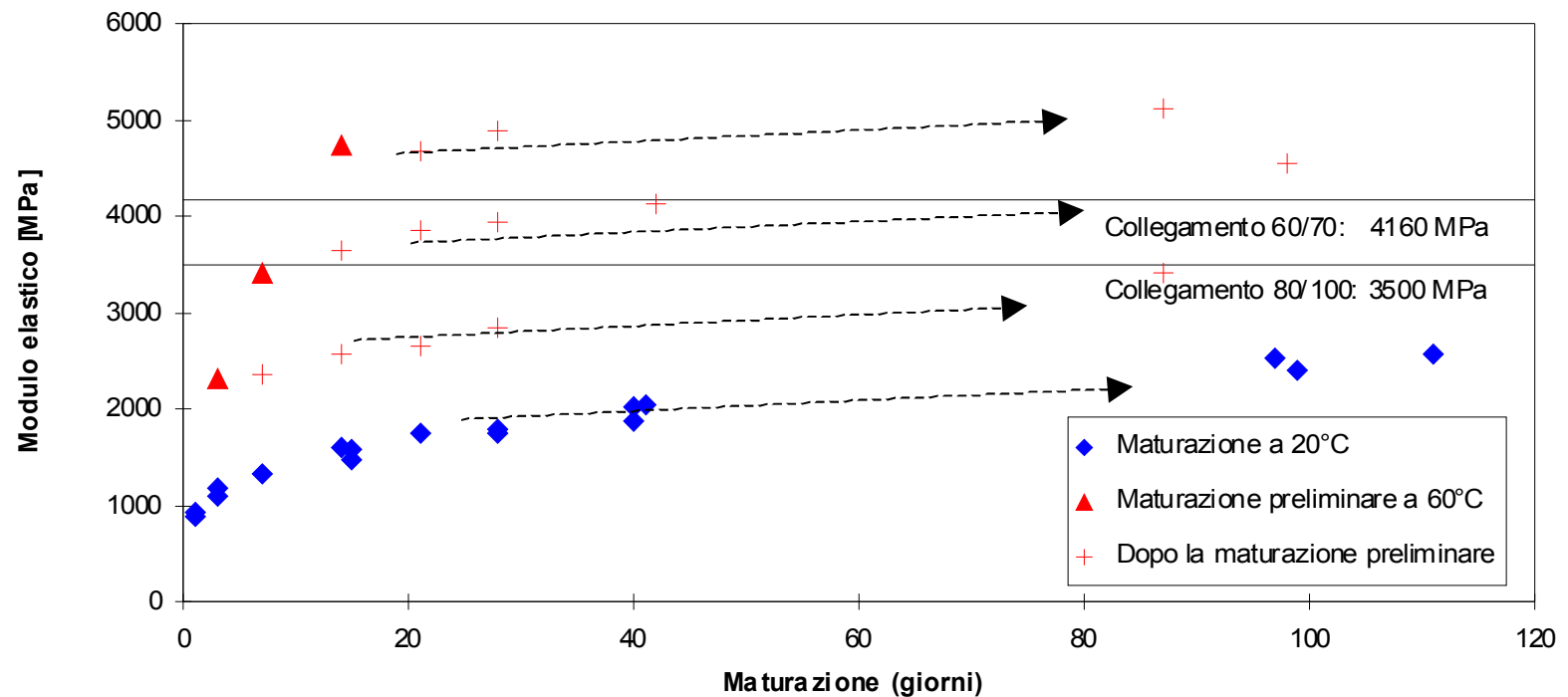
- Evolution of water content



# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

- Effect of curing temperature

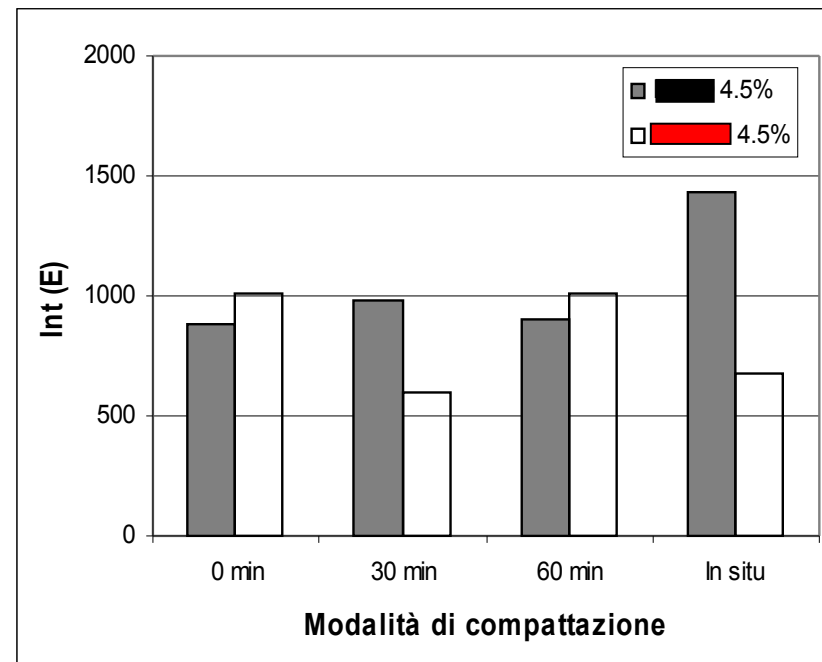
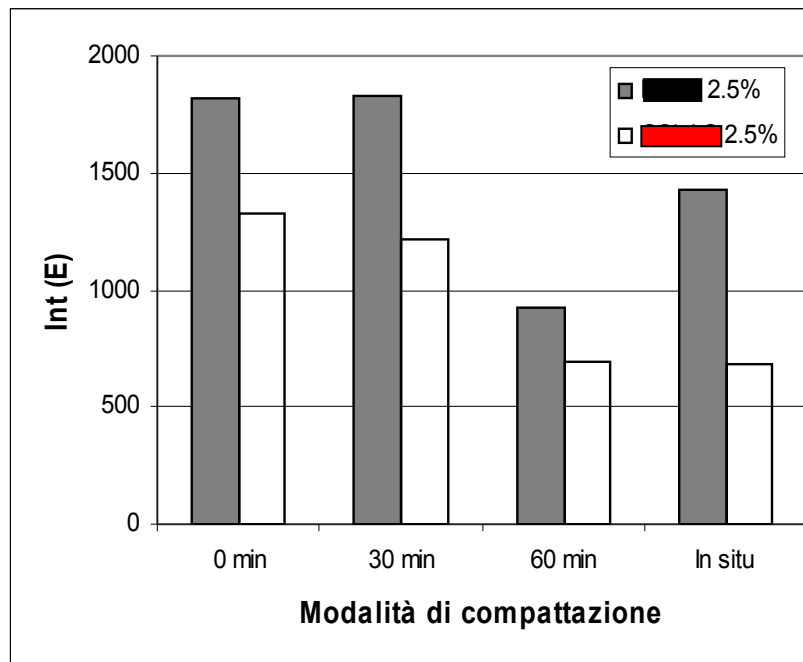


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Effect of emulsion type and quantity

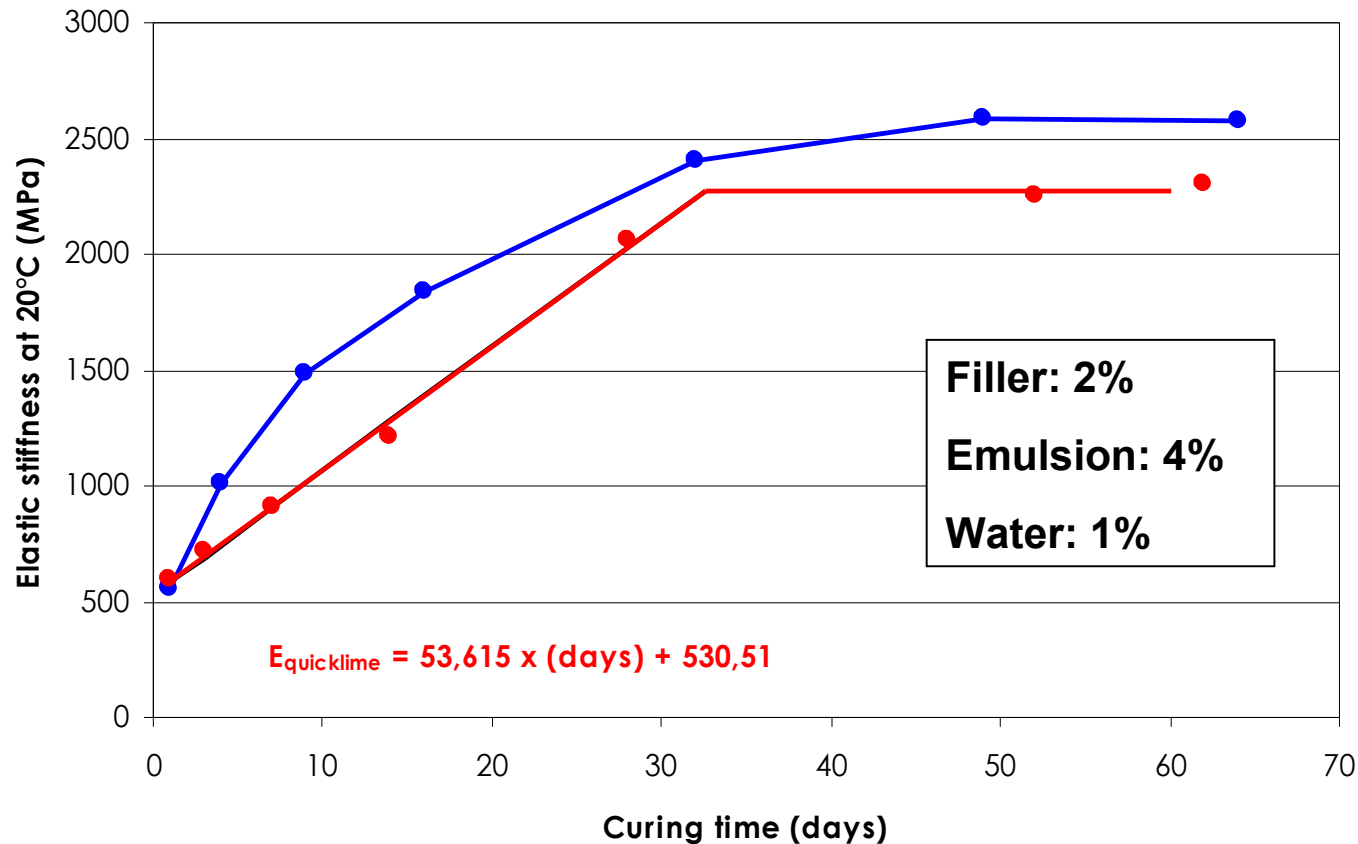


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Effect of filler type (cement vs quicklime)

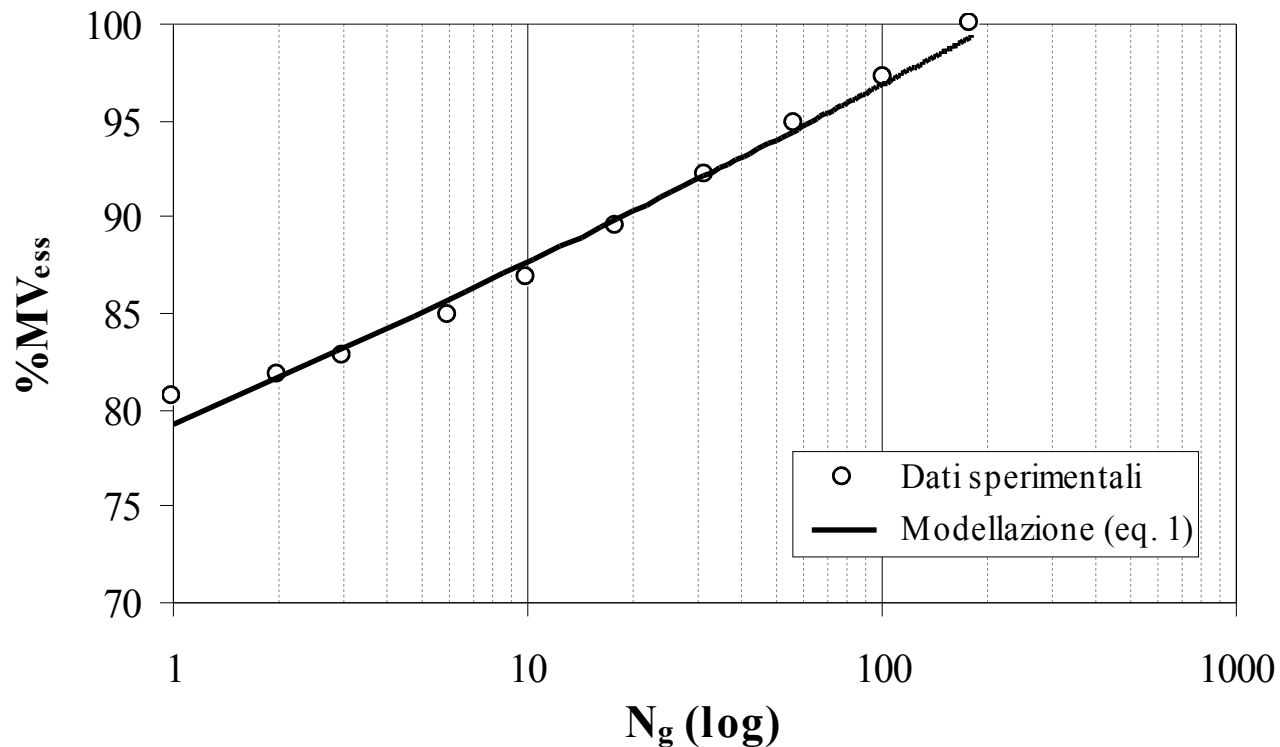


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Compaction properties (from gyratory equipment)

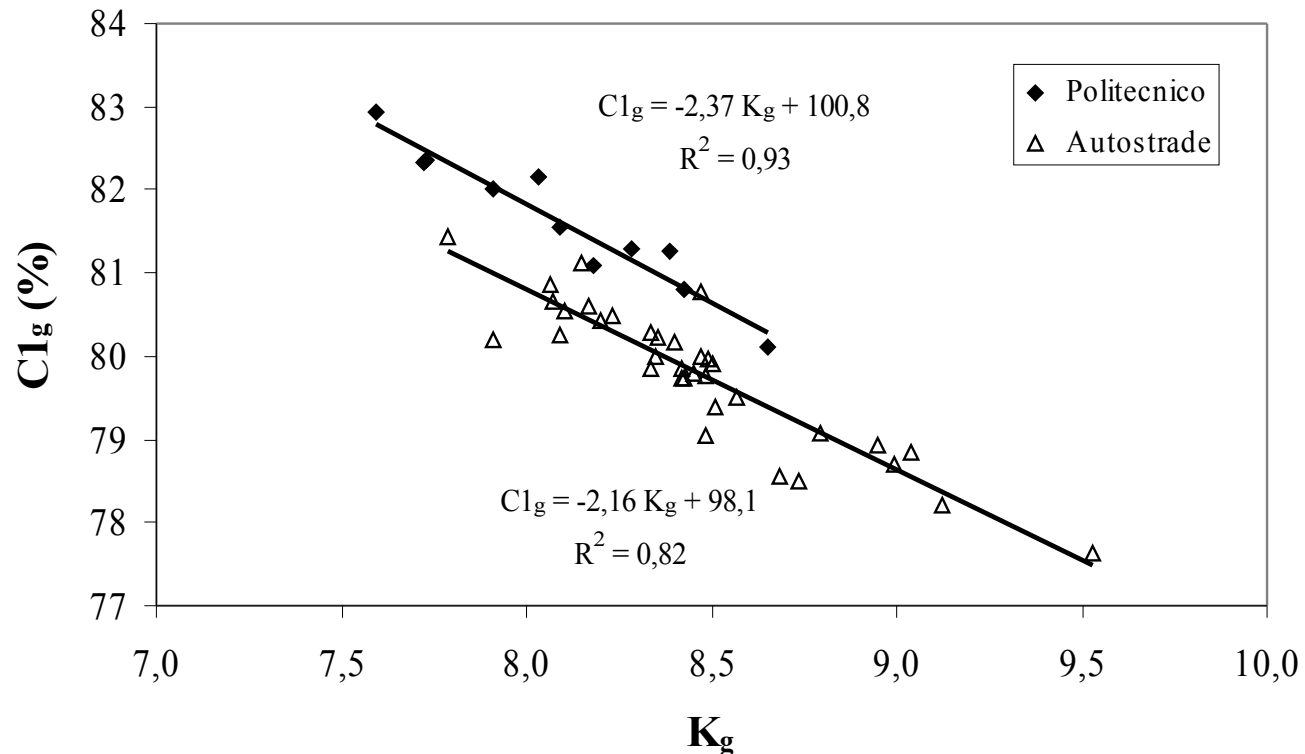


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Compaction properties (from gyratory equipment)

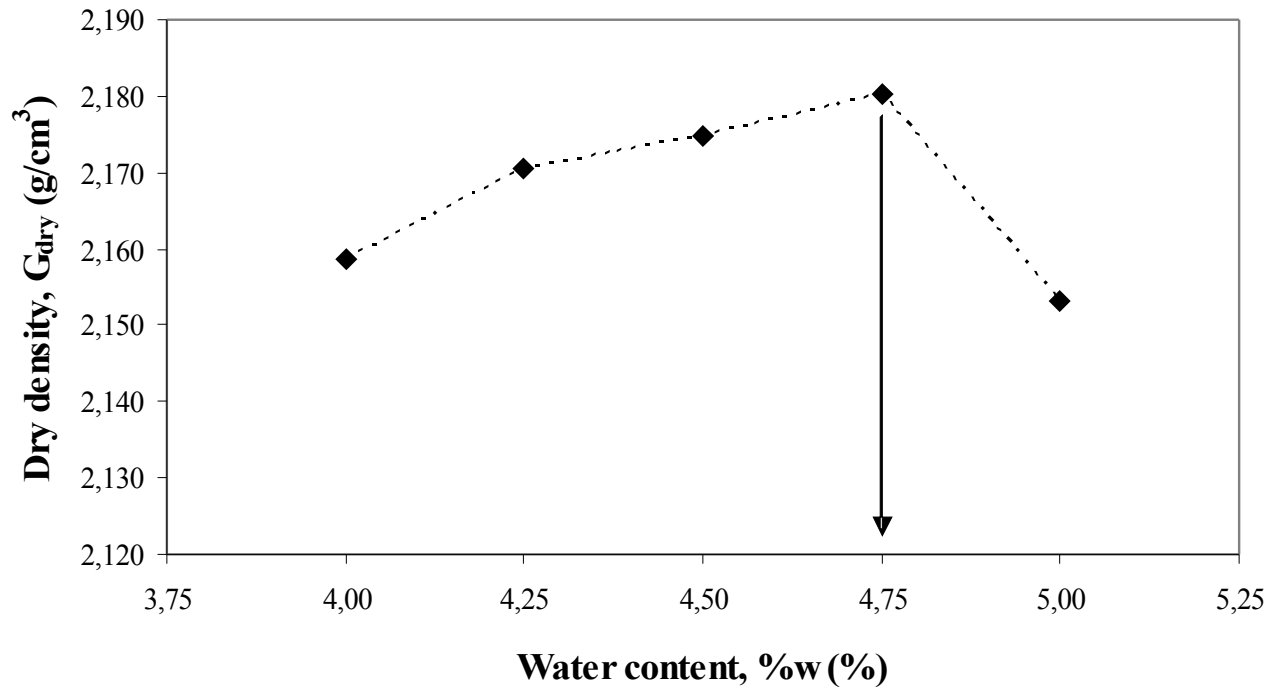


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Mix design

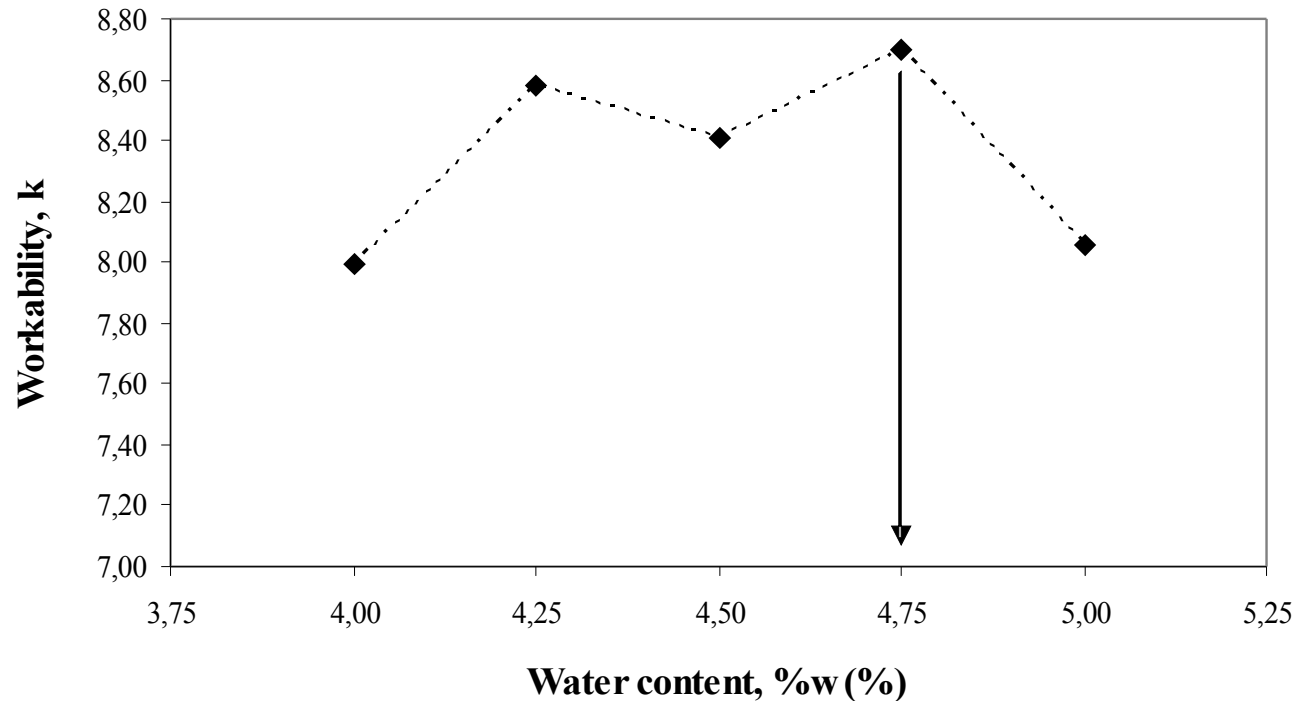


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Mix design





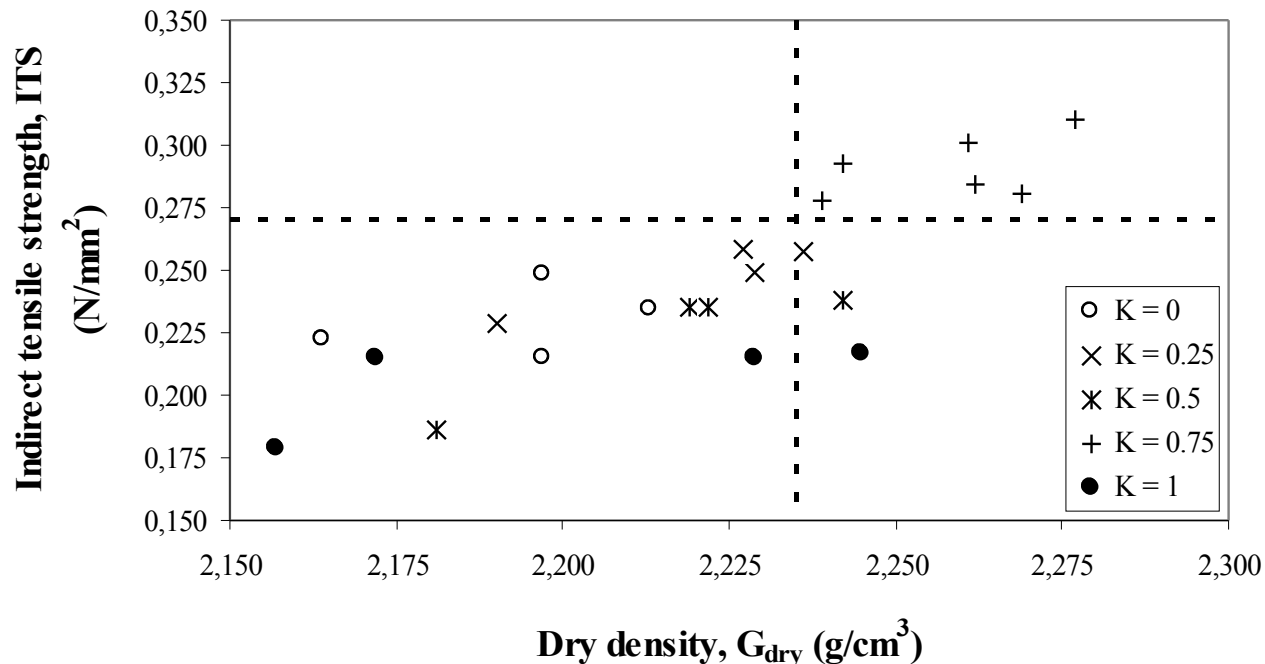
# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Mix design

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

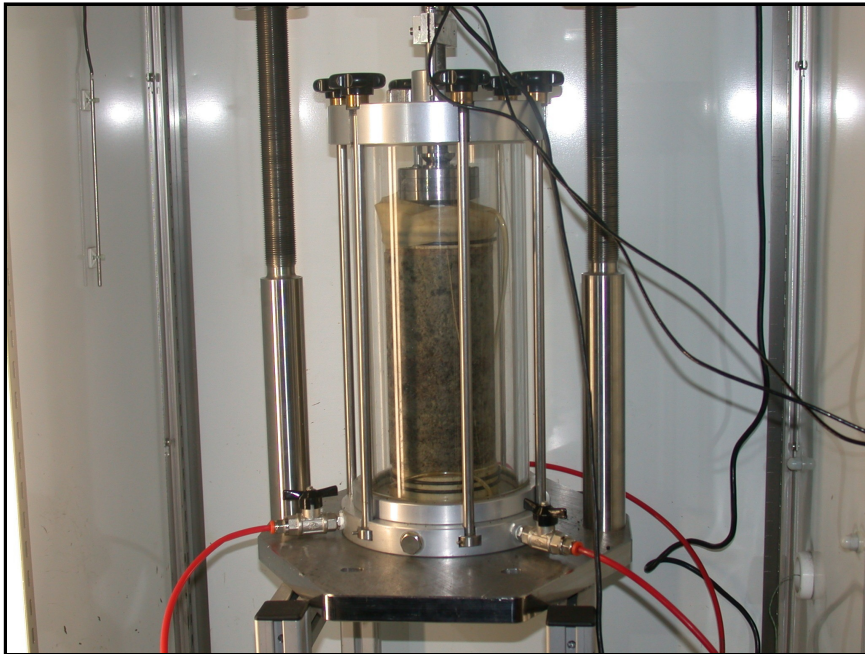


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Short term characterization
  - UNBOUND?



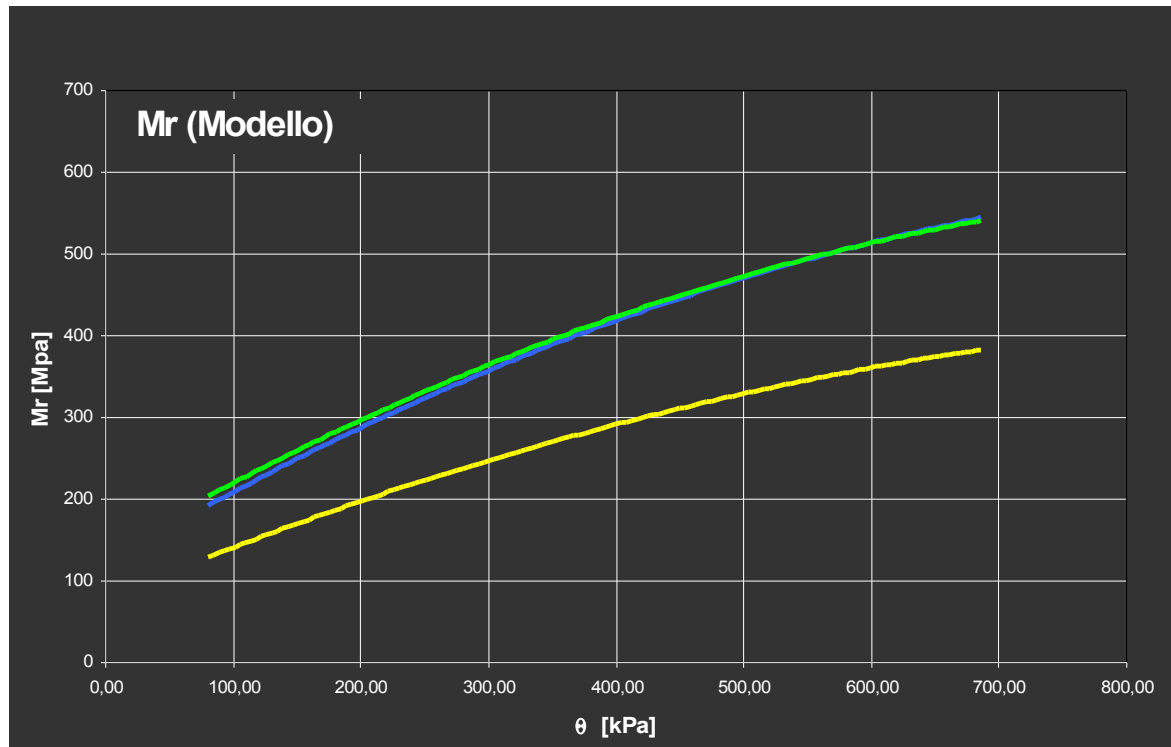
- Resilient modulus  $M_R$
- Failure (p-q) criteria

# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Short term characterization
  - UNBOUND?

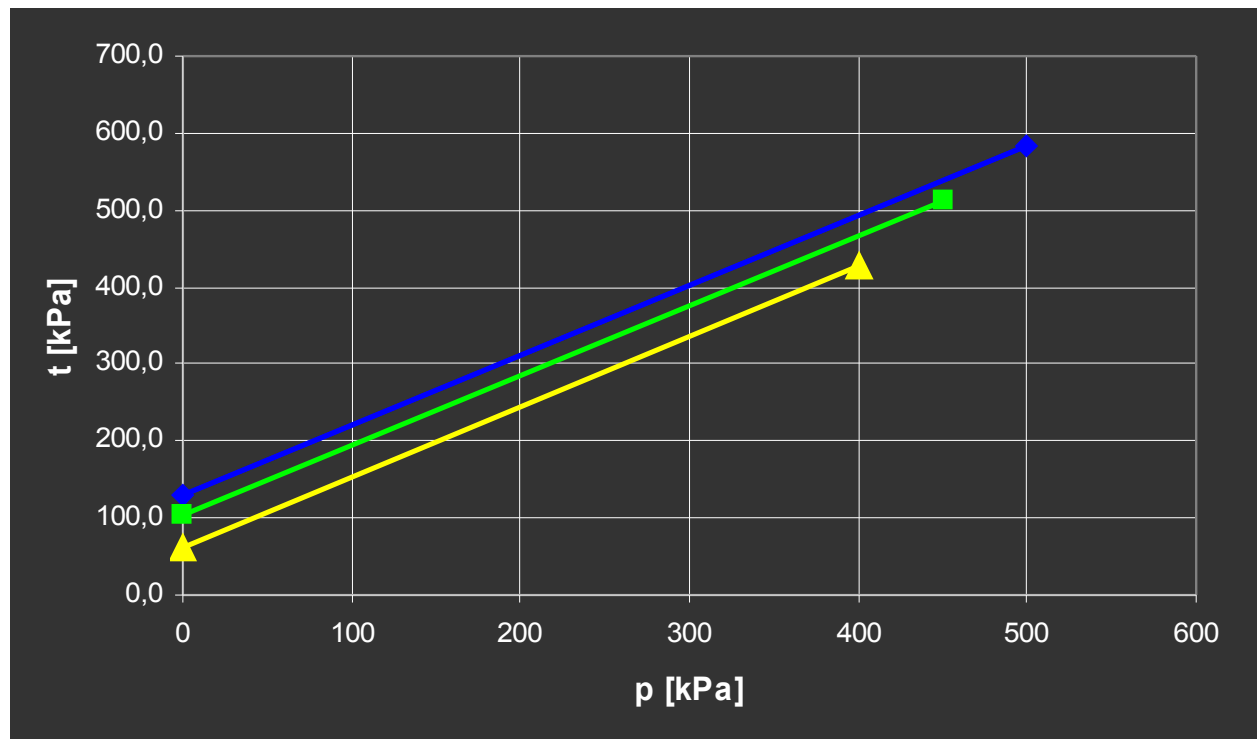


# Cold recycling of bituminous mixtures

## Critical issues derived from research experience

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- Short term characterization
  - UNBOUND?

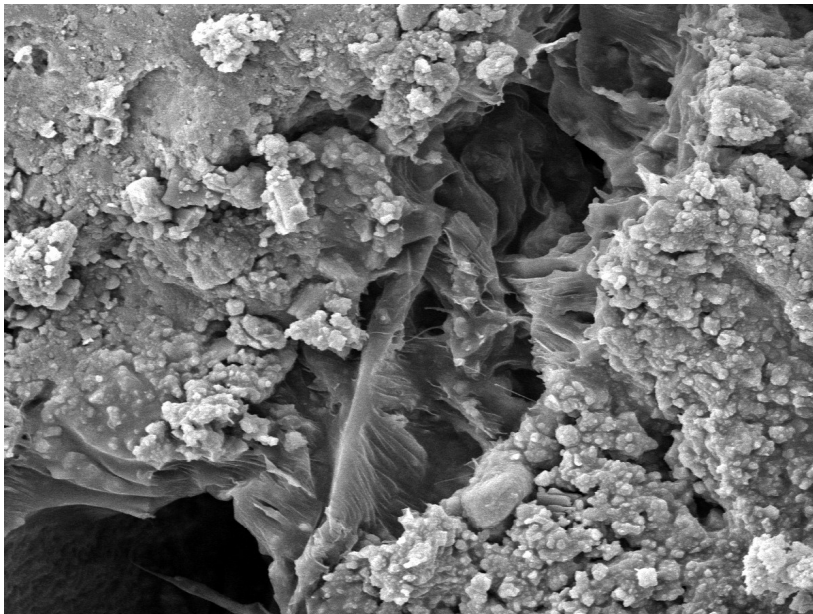


# Cold recycling of bituminous mixtures

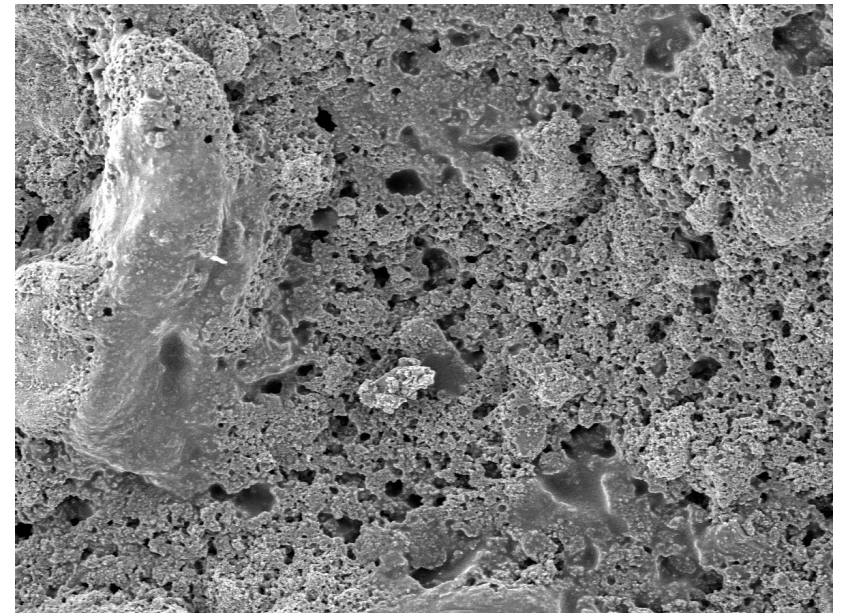
## Critical issues derived from research experience

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- Characterization of the emulsion-filler system



**Interconnected binding matrix**  
**High modulus, high strength**



**Porous binding matrix**  
**Low modulus, low strength**

# Cold recycling of bituminous mixtures

## Closure - Questions

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- 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?

**Thanks for your attention**

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