Hrvatsko asfaltersko društvo   Croatian asphalt association

Laboratorijsko i terensko vrednovanje reciklirane mješavine po hladnom postupku za nosivi sloj izveden u potpunosti od postojećeg asfaltnog kolnika

A laboratory and field evaluation of cold recycled mixture for base layer entirely made with reclaimed asphalt pavement

Dr. Cesare Sangiorgi

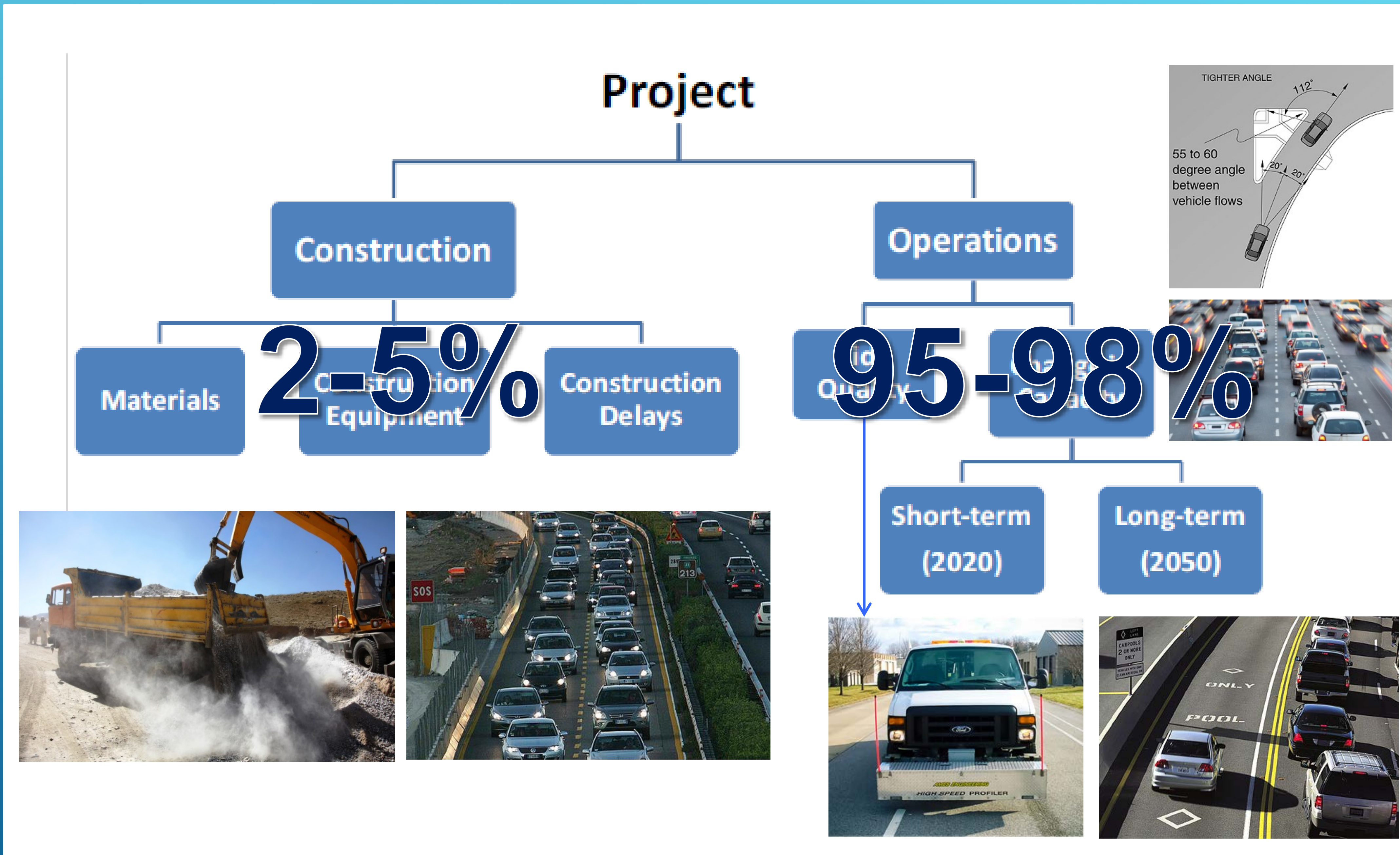
Associate Professor at the University of Bologna, Italy

Međunarodni seminar ASFALTNI KOLNICI 2018

International seminar ASPHALT PAVEMENTS 2018

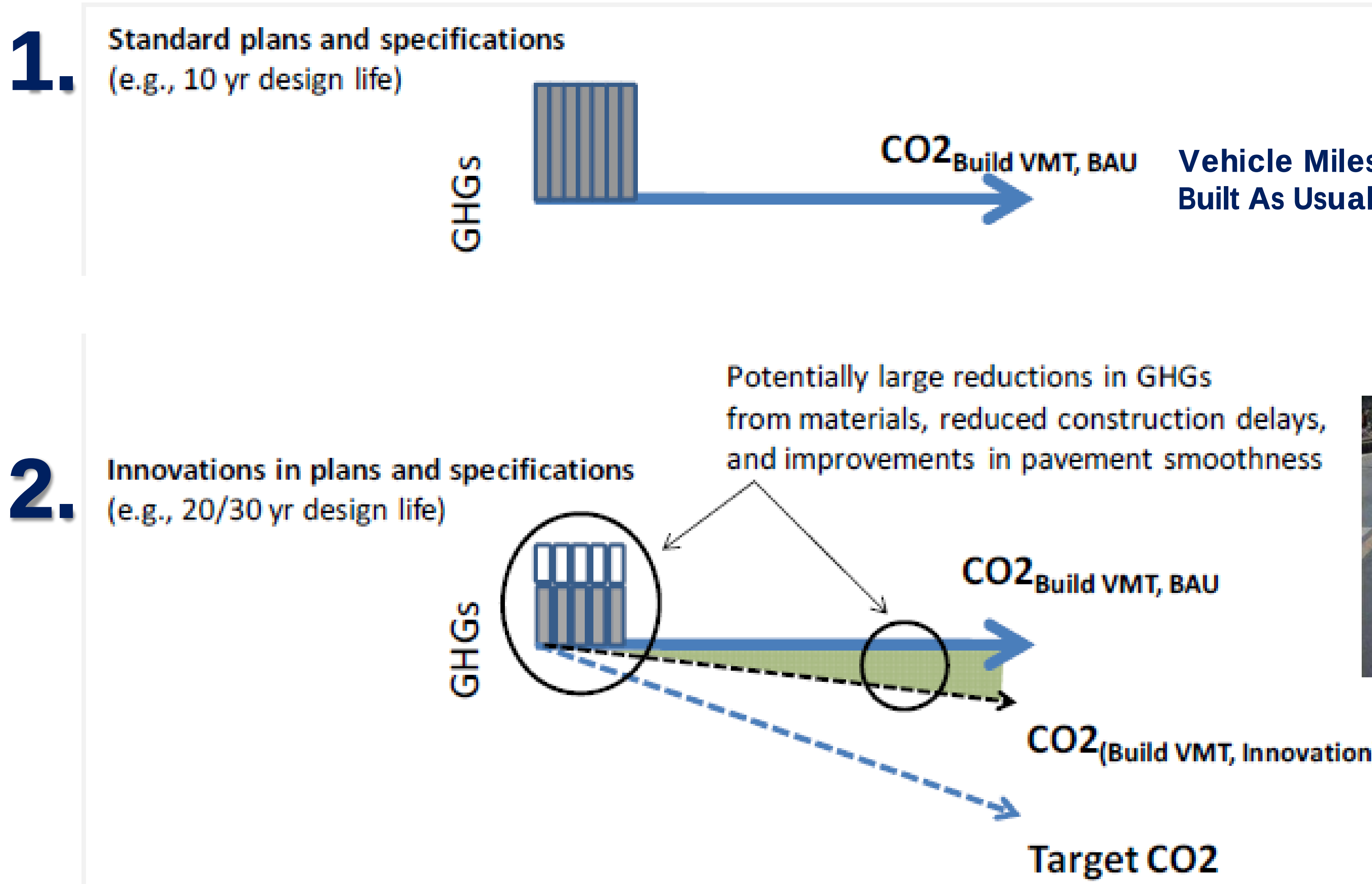
Opatija, 12.–13. 04. 2018.

GHG EMISSIONS IN ROAD PROJECTS



Operations emissions (95-98%) are much higher than construction ones

WHAT ARE THE EFFECTS OF INNOVATIVE TECHNOLOGIES AND RECYCLING



Vehicle Miles Traveled (VMT)
Built As Usual (BAU)

Innovation reduces emissions in Construction and Maintenance

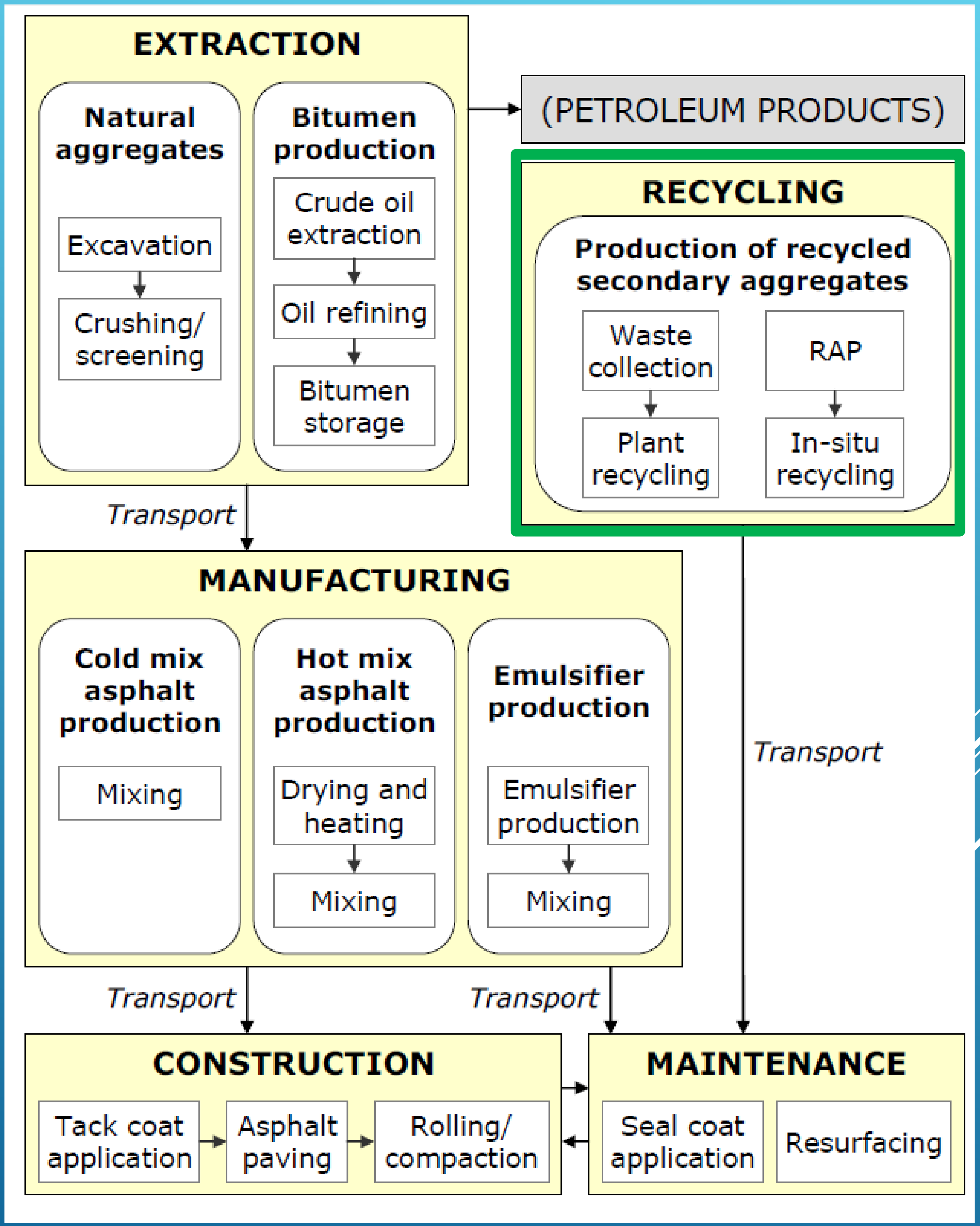
ENERGY, EMISSIONS, & RECYCLING OPPORTUNITIES FOR SUSTAINABLE ASPHALT ROADS

Durable pavements +
Recycling =
Less virgin resources

Research (€) +
Reconversion (€) =
"SUSTAINABLE Growth"

Prof. Hussain Bahia
University of Wisconsin
Madison - USA

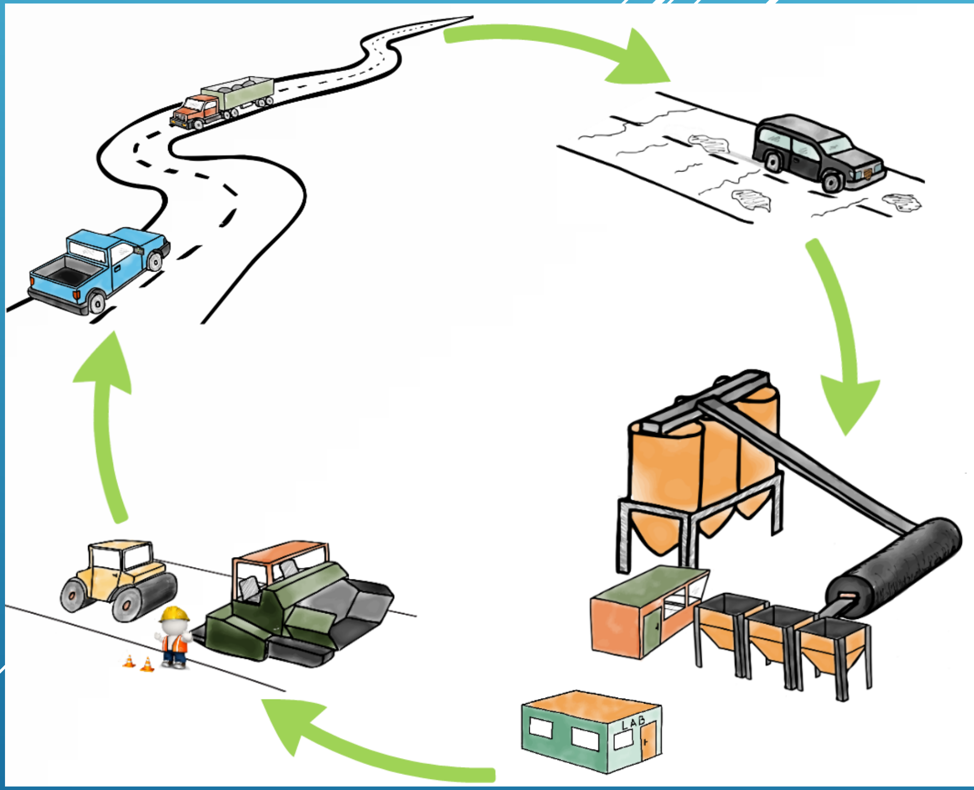
5 PROCESSES WHERE LCA SHOULD BE CONSIDERED FOR ASPHALT PAVEMENTS



RESEARCH ON RAP AT UNIBO

The present research starts form the idea that **100 % RAP can be advantageously used in cold recycling technique** for the production of bituminous mixtures for eco-friendly and durable pavements.

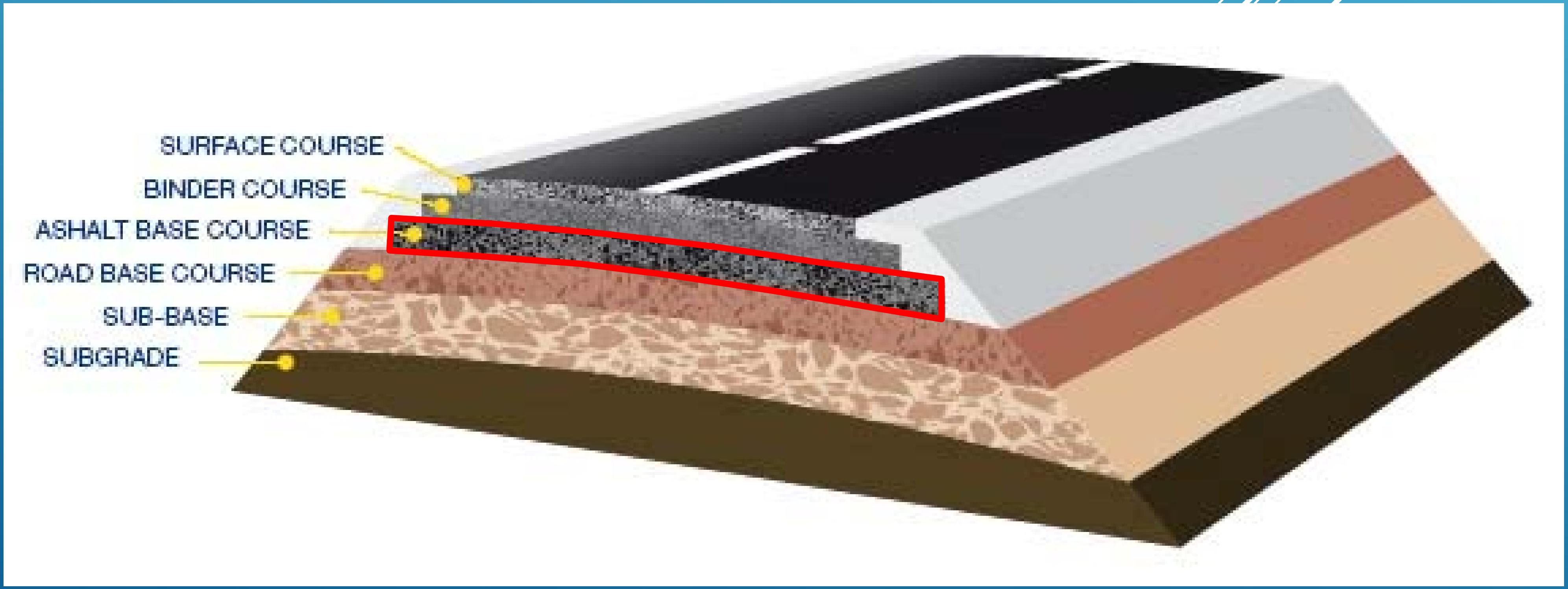
The aim is to evaluate the positive properties conferred to the mixture by using **high amount of recycled materials with bitumen emulsion and cement (CRM).**



Courtesy of Dr. Martins Zaumanis

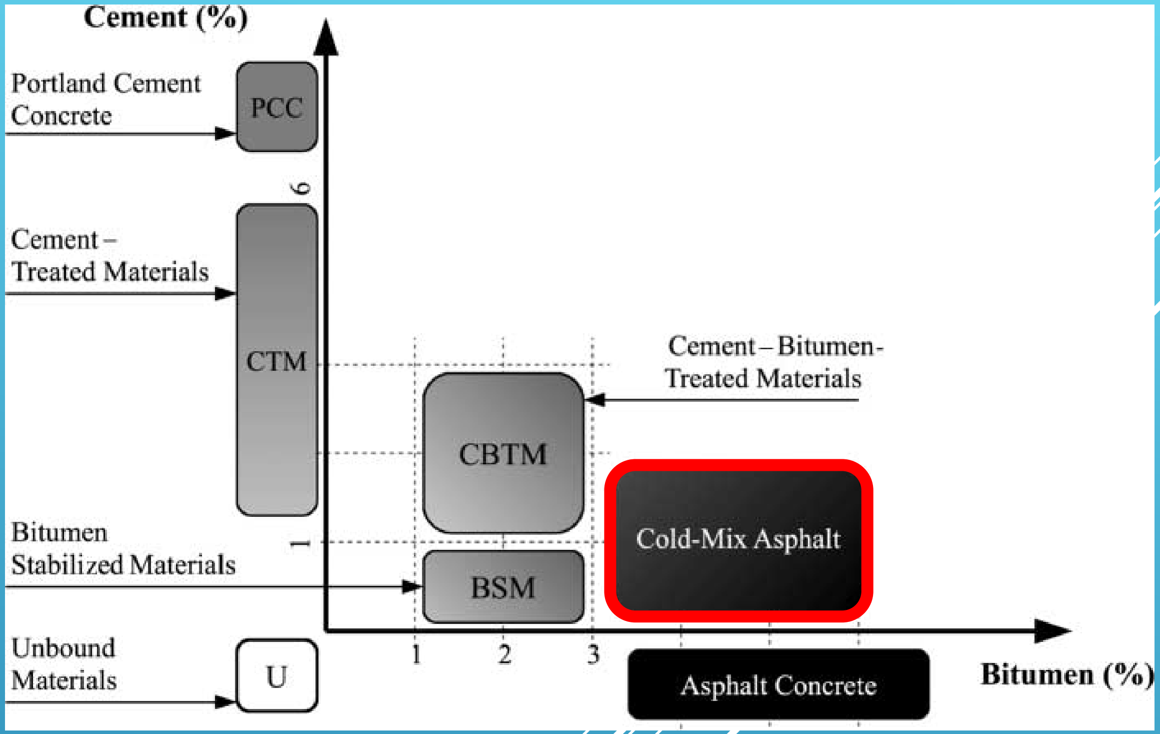
RESEARCH ON RAP AT UNIBO

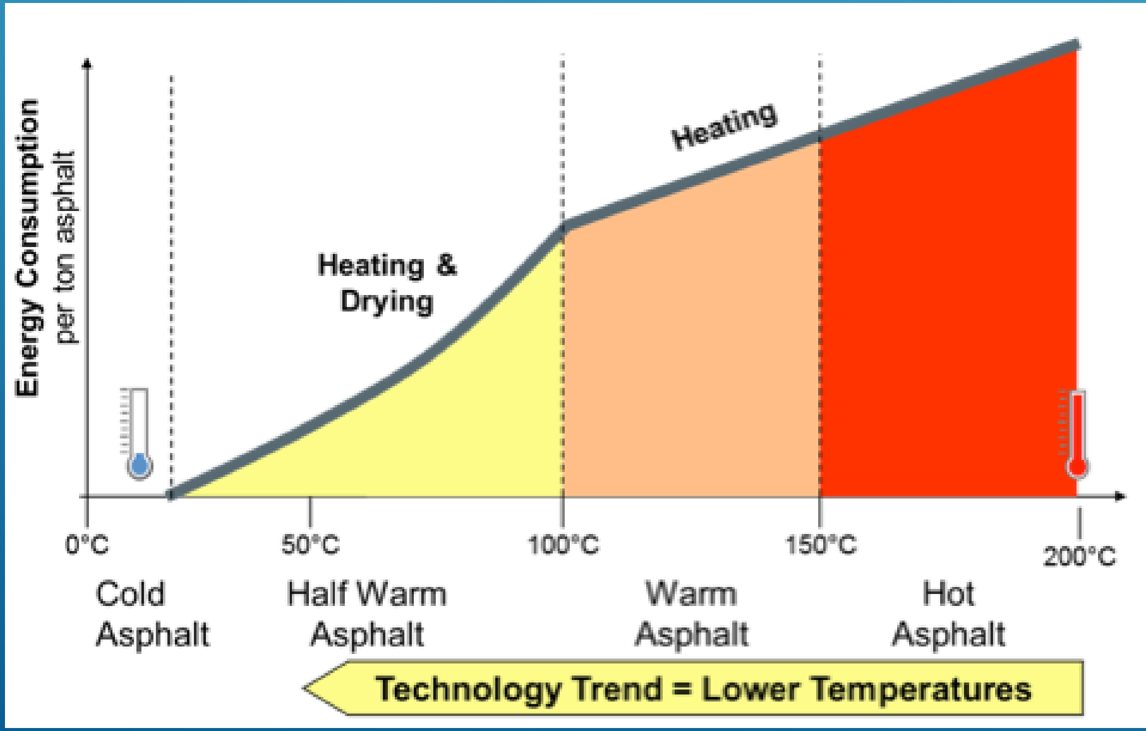
Starting from the **laboratory mix-design** a full scale **trial field** was constructed, to evaluate the development of the mechanical and physical properties of the proposed CRM, when compared to a **high-modulus HMA for base layers.**



RESEARCH ON RAP AT UNIBO

- the possibility of substituting the natural aggregates and part of the virgin binder of an AC mixture, without negatively affecting its mechanical properties.





- reduction in energy consumption and emissions during in plant production and laying, in addition to the actual possibility of achieving durable pavement layers.

RESEARCH ON RAP AT UNIBO

THE EXPERIMENTAL PROGRAM WAS DIVIDED IN TWO CONSECUTIVE PHASES:

A laboratory study in which the mix designs and the physical and mechanical properties of the 2 mixtures were defined: **CRM, made out of 100 % RAP, HMA, a high-modulus mixture for base layers.**

A full-scale test section open to heavy quarry traffic. In situ tests and samples collection were planned at regular intervals, for the evaluation of the development of the mechanical characteristics of each mixture.

MATERIALS

Three materials were used for the recycled mixture: Reclaimed Asphalt Pavement (RAP), Cement (C) and Bituminous Emulsion (EM).

A small amount of water was added to control the workability and aim to the maximum dry density.

	Unit	RAP 20/40	RAP 10/20	RAP 0/10
% Binder	%	3.77	3.82	6.19
Penetration @ 25°C	dmm	9	8	7
Soft. Point	°C	74.7	76.1	79.7
Dynamic Visc. @ 60°C	Pa·s	52265	58051	95219
Heptane insolubles	%	41.5	40.3	38.7

RAP (motorway) was divided in to three different fractions: coarse RAP 20/40 (20-40 mm), coarse RAP 10/20 (10-20 mm) and fine RAP 0/10 (0-10 mm).

MATERIALS

Portland Cement 32.5 and a bituminous emulsion (61% bitumen content) with a 55 pen SBS modified bitumen.

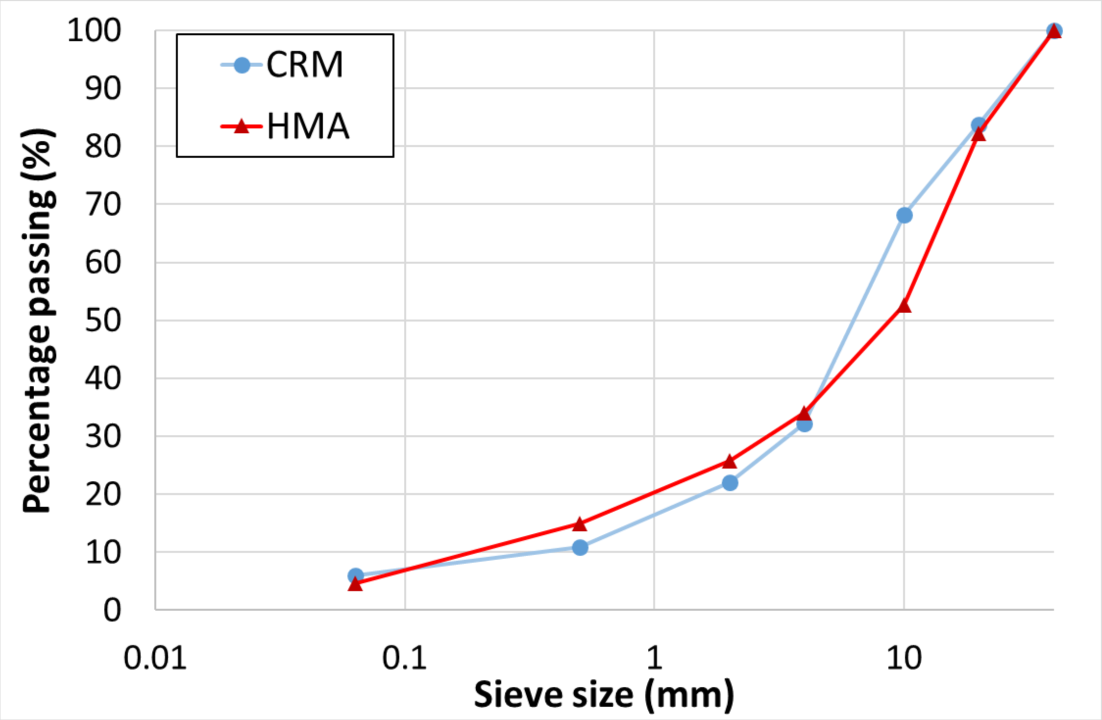
Characteristics of the cationic emulsion			
Characteristics	Unit	Result	Standard
Water content	%	39	EN 1428
pH value	°	4	EN 12850
Settling tendency @ 7 days	%	6	EN 12847
Characteristics of the extracted bitumen			
Penetration	dmm	55	EN 1426
Softening point	°C	62	EN 1427
Fraass breaking point	°C	-16	EN 12593
Elastic recovery @ 25 °C	%	> 50	EN 13398

For HMA mixture, a traditional 50/70 pen bitumen was used according to a dosage of 4.3 % by the weight of aggregates.

LABORATORY MIX DESIGN

CRM was designed on the basis of the characteristics of the available RAP fractions.

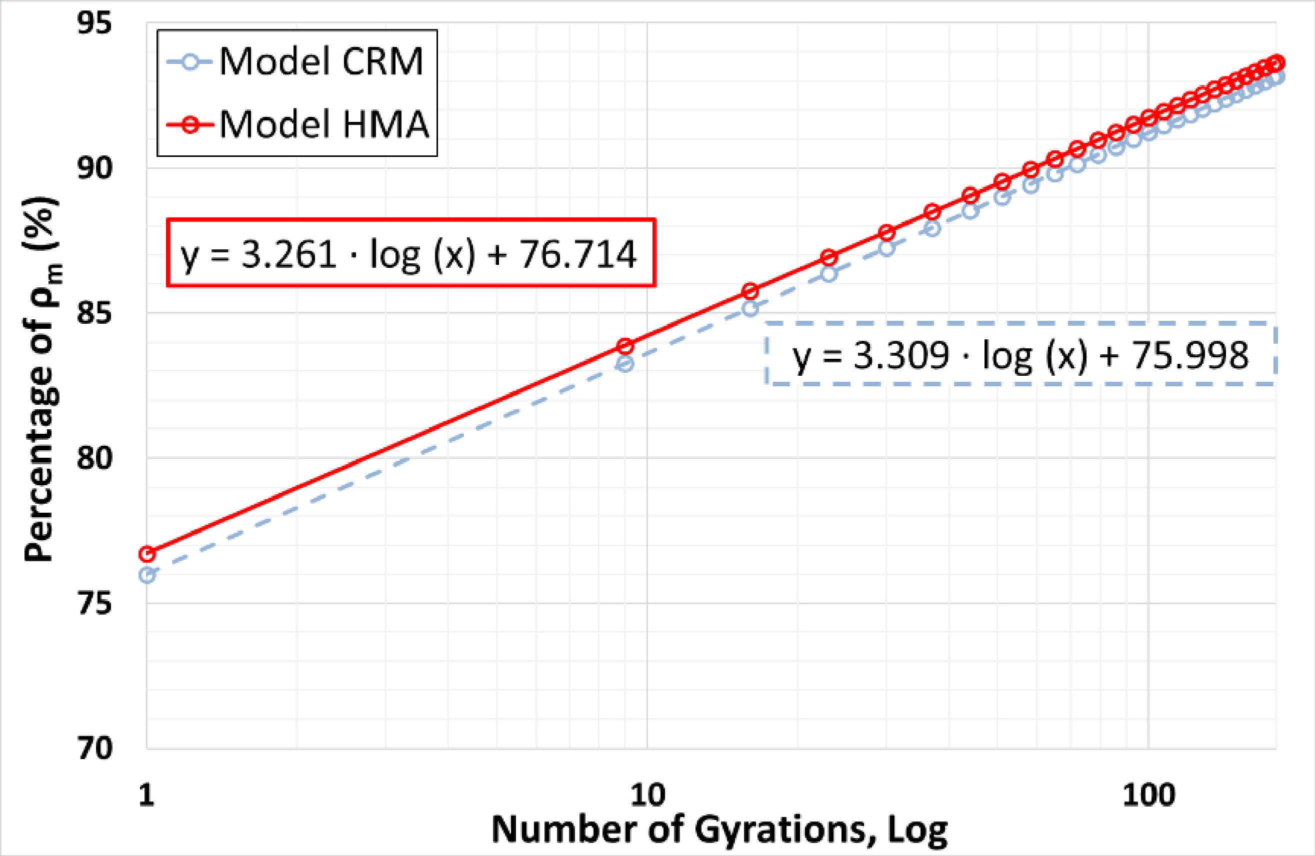
Material	Density (g/cm³)	Mixture
RAP 20-40	2.62	14.0 %
RAP 10-20	2.62	25.0 %
RAP 0-10	2.63	55.0 %
Filler	2.66	4.0 %
Cement	2.95	2.0 %
Bitumen Emulsion (EM)	1.04 (at 25°C)	4.0 %
Additional Water	0.99 (at 25°C)	0.9 %



COMPACTION AND WORKABILITY EVALUATION

Compaction curves: $\%\rho_m = a \cdot ln(x) + b$

where %ρm is the % of maximum densification, *a* is the slope of the compaction curve, *x* is the number of revolutions and *b* is the intercept of the regression curve.

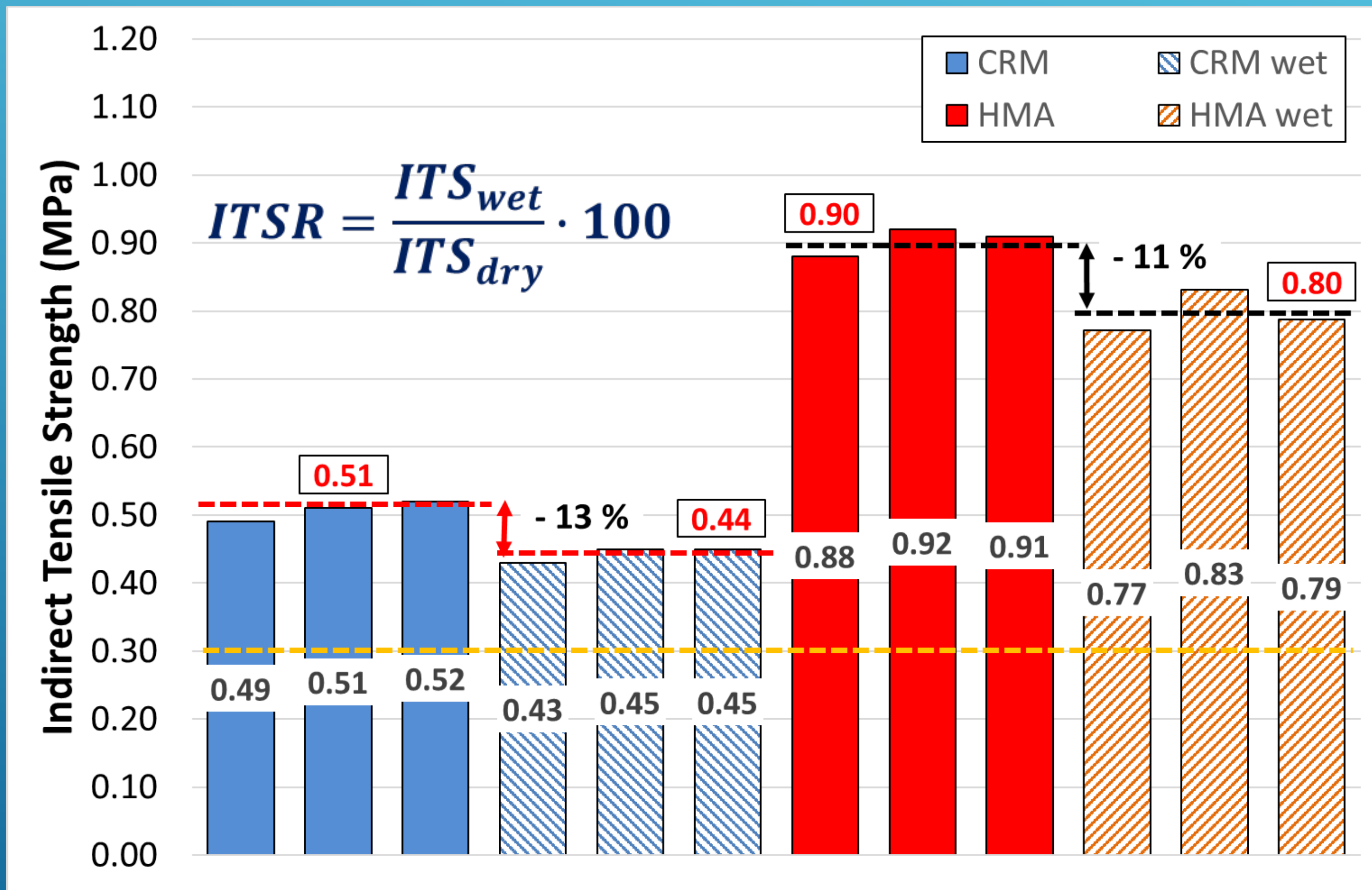


There are no significant differences in terms of workability and maximum density achieved at the end of compaction

Air voids (EN 12697-8) are in line with those recommended for base layers. Compactability is generally one of the weakest points for CRM, if compared to the traditional hot mixing technique.

INDIRECT TENSILE STRENGTH AND ITSR ANALYSIS

Water damage assessment is essential when studying asphalt recycled mixtures, since this property is directly related to the behaviour and durability of these materials

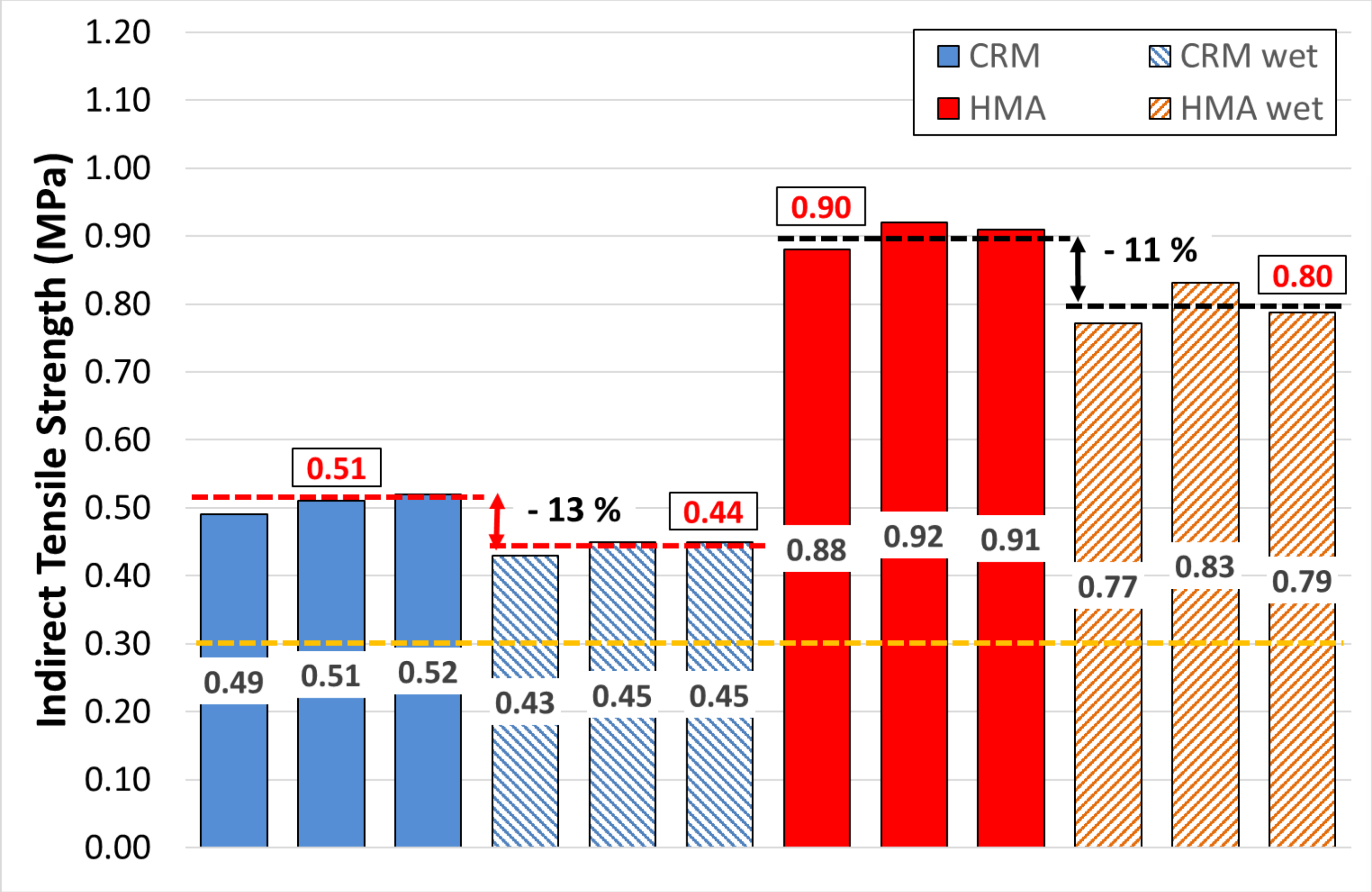


There is a significant difference in terms of ITS between the two mixtures

The ITS for CRM is higher than ITS limit (0.35 MPa) imposed by some Italian technical specifications for CMA for base layer. Notice: these limits are related to mixtures made with <u>less than 30 % of RAP</u>.

INDIRECT TENSILE STRENGTH AND ITSR ANALYSIS

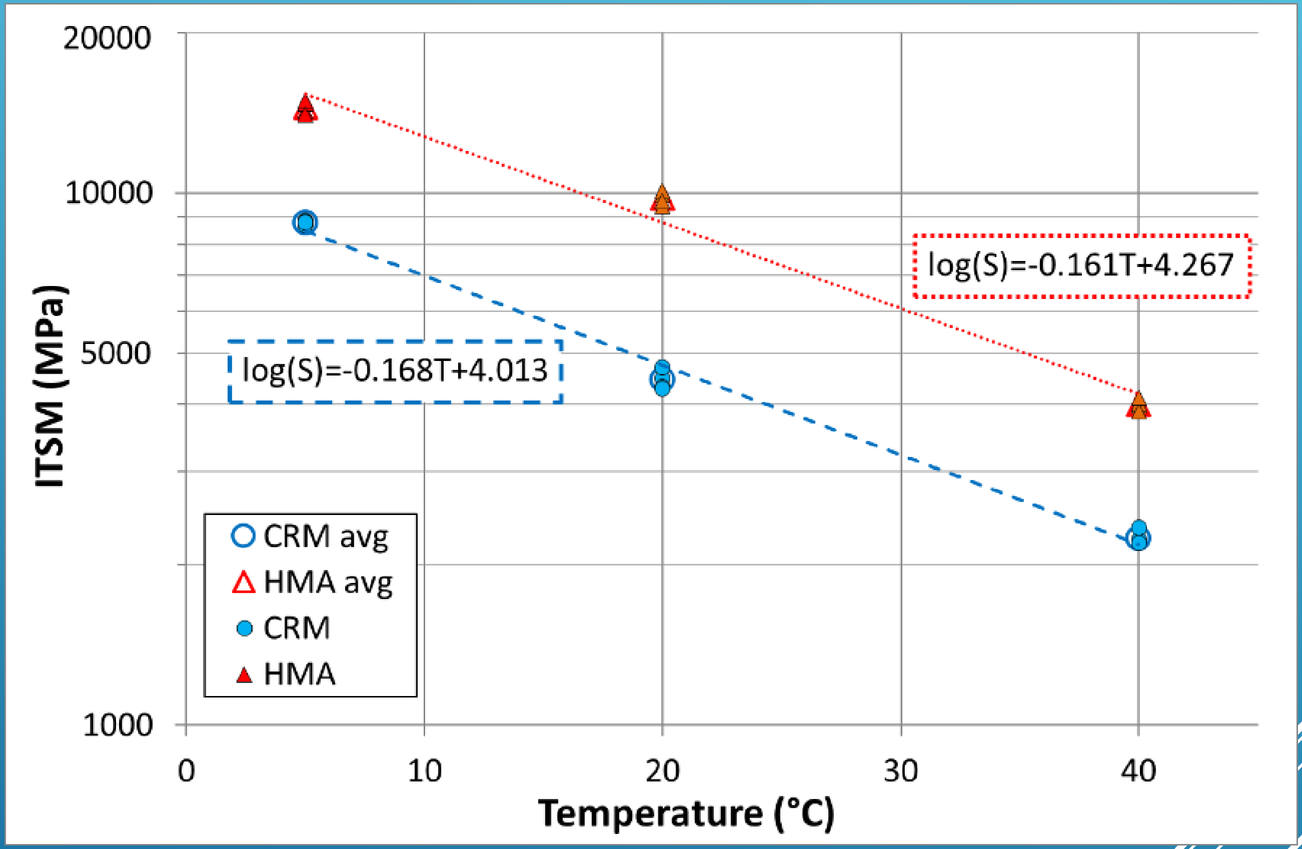
No substantial difference in the reduction of ITS after wet conditioning, between the two compared mixtures



The presence of a <u>very large amount of RAP</u> seems not to affect the water susceptibility of the base mixture.

INDIRECT TENSILE STIFFNESS MODULUS RESULTS

The stiffness modulus was evaluated according to the EN 12697-26 standard, in the indirect tensile configuration



Thermal sensitivity was assessed testing at 5, 20 and 40 ° C

Stiffness values are higher for Hi-HMA at all temperatures

The 2 mixtures show similar variation of stiffness with temp.

The HMA is made of 4.3 % of bitumen on the weight of aggregates. For CRM, only 2.4 % is new binder. However, the ITSM values for CRM are in line with the limit imposed by the technical standard taken as a reference.

TRIAL FIELD PHASE

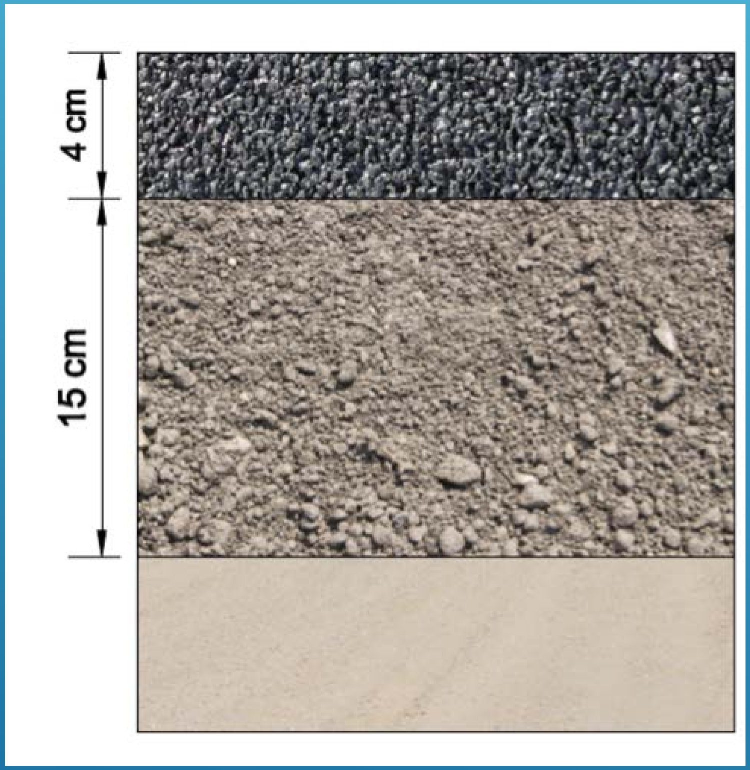
A trial section was built on **an existing road made of unbound granular material**, classified as A1-a according to AASHTO M 145 standard, subject to heavy load traffic due to the proximity of a quarry.

A 60 cm thick layer, characterised by a **measured Light Weight Deflectometer Modulus (E_{LWD}) of 70 MPa**, was considered as foundation for the trial road section.

The foundation was very well compacted by local heavy dumpers traffic.

TRIAL FIELD PHASE

The trial field was **divided in 2 sections:** CRM and HMA.
The new road section was formed by **15 cm of CRM or HMA** mixture for the base layer and 4 cm of wearing course made of traditional Asphalt Concrete.



Traditional AC

Experimental layer: CRM or HMA

Exiting C&D unbound foundation

The road pavement **was under-designed on purpose** to promote and accelerate the beginning and development of damage under the heavy quarry traffic load.

TRIAL FIELD CONSTRUCTION

The pavement sections were built with **standard methods**

During paving, **loose samples were collected** at the paver screed and immediately compacted with the gyratory compactor available in the quarry laboratory.

TRIAL FIELD ANALYSIS

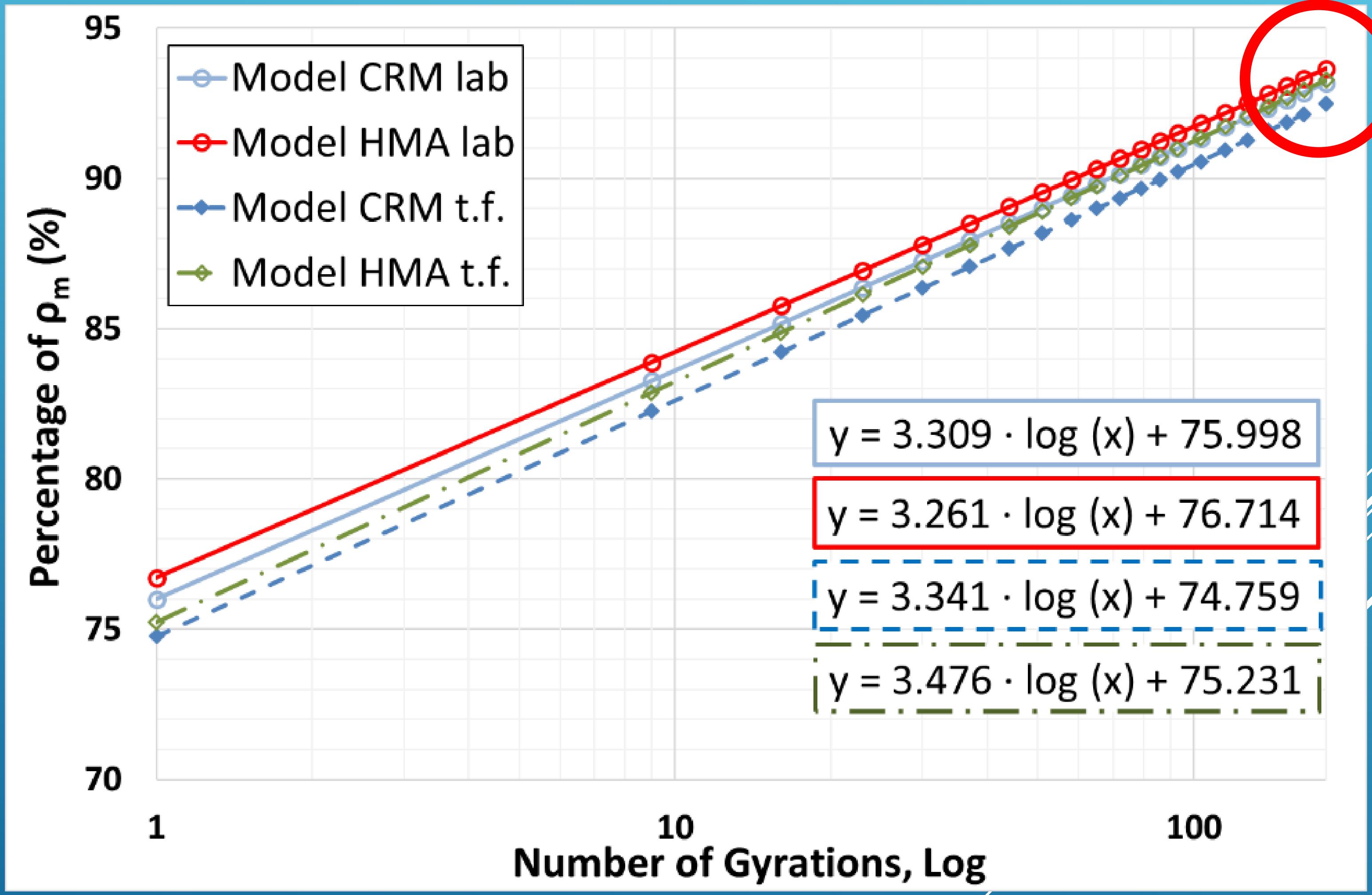
In situ test and samples collection were planned in four dates, corresponding to 0, 60, 180 and 365 days of cumulative heavy traffic. A total of approximately 5000 passes of 42 tons dumpers was measured.

TRIAL FIELD PHASE

The **workability and volumetric characteristics** were analysed by means of the compaction curves and the determination of the air voids content (EN 12697-8). The volumetric analysis was also supported by the **ITS test** (EN 12697-23) at 25 ° C. The development of the mechanical characteristic of the two different mixtures for base layer was evaluated by means of the **ITSM test** (EN 12697-26) at 20 ° C carried out on cores.

TRIAL FIELD PHASE

3 compacted samples for each loose mixture were prepared by gyratory compaction at day 0.



No substantial differences between the compaction curves of the CRM and HMA produced in plant.

TRIAL FIELD PHASE

3 cores were taken from each section. The air voids content was calculated according to EN 12697-8.

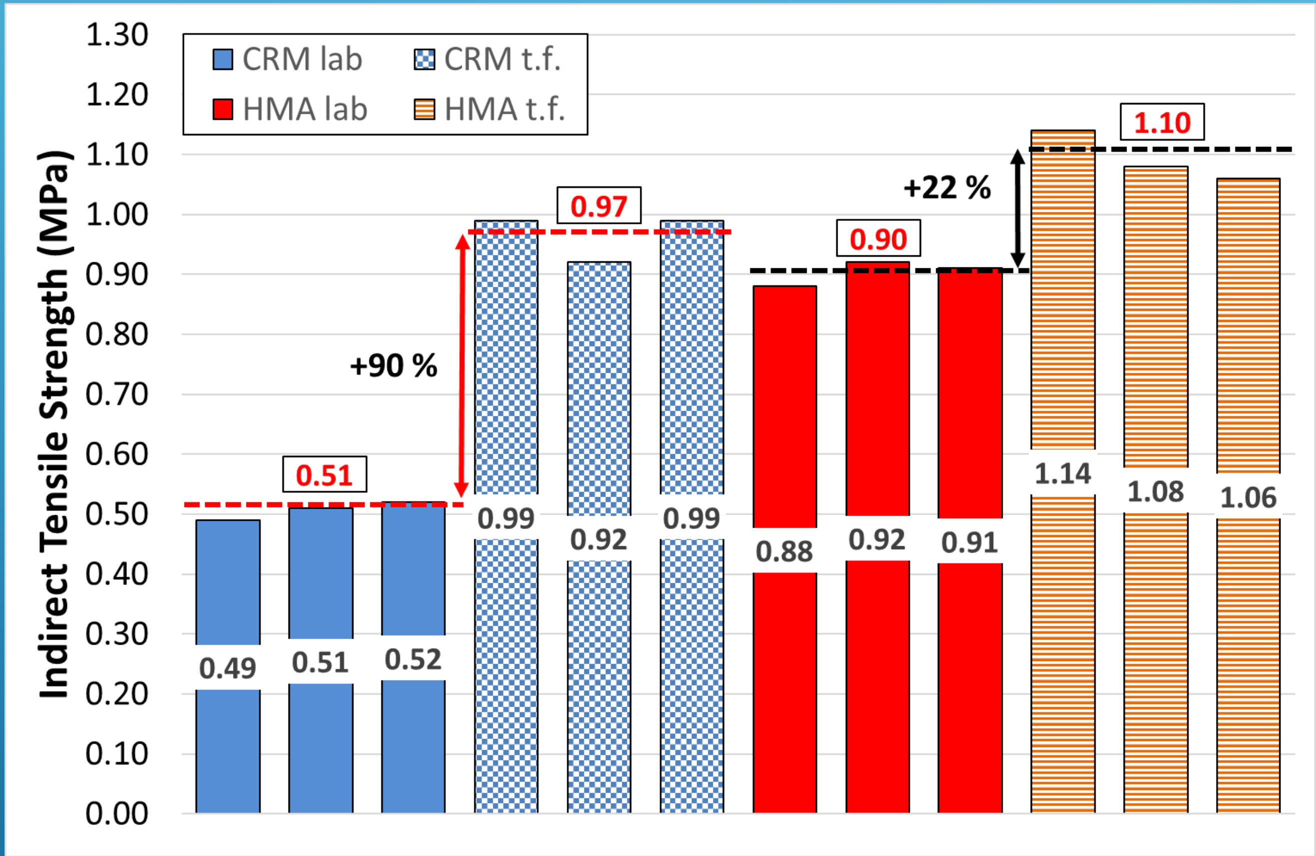
Mixture	Air voids (%)
CRM 1	7.1
CRM 2	6.3
CRM 3	6.3
Avg. CRM	**6.6**
HMA 1	5.8
HMA 2	6.3
HMA 3	6.0
Avg. HMA	**6.0**

Air voids content is in line with the compaction curve results: even if there is no significant dissimilarity between the two mixtures, HMA has a lower air voids content.

If compared to the volumetric analysis made during the laboratory phase, it can be observed that the air voids content is lower for the core samples.

TRIAL FIELD PHASE

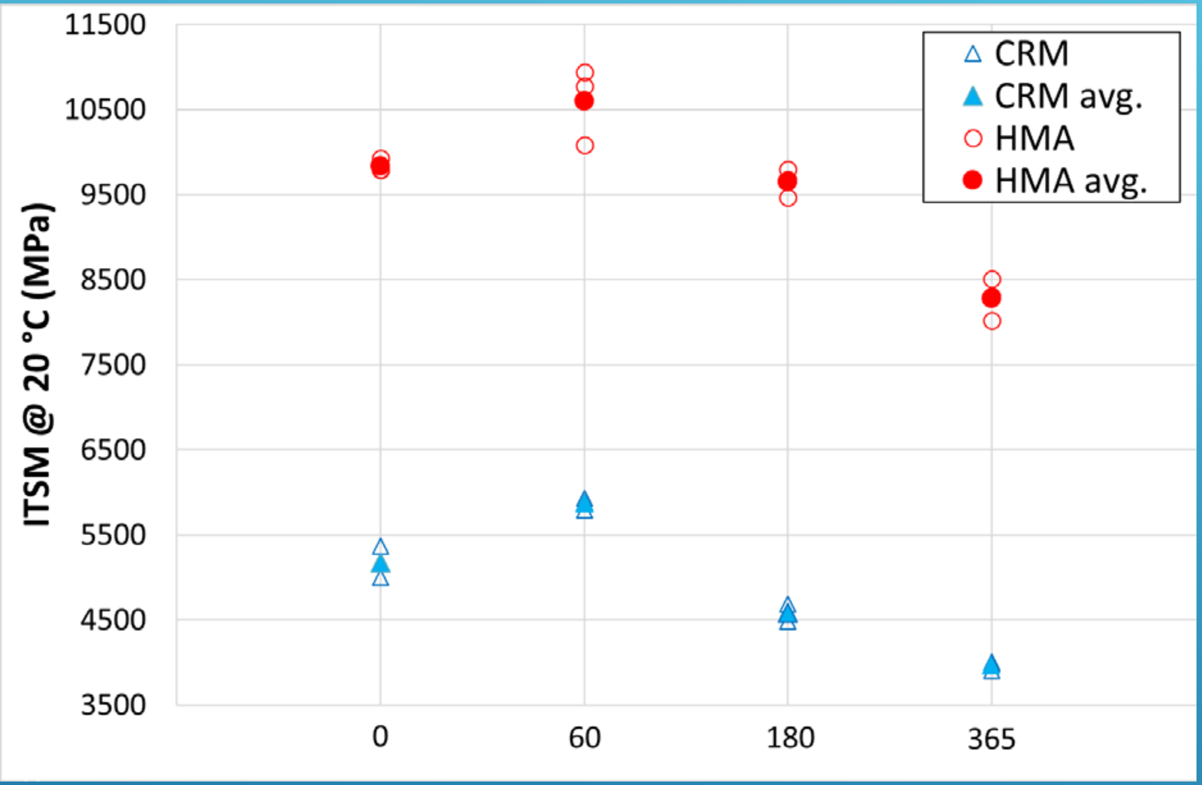
ITS test was also carried out on the same cores. The figure shows ITS values and the comparison between the values obtained **in the lab. and trial field** phase.



The histogram shows higher ITS for cores than laboratory specimens (+90 %). The **ITS values of CRM** are very high considering this type of AC and are similar to those usually obtained from common bituminous mixtures.

DEVELOPMENT OF STIFFNESS MODULUS

The development of the stiffness of the two mixtures under traffic&weather was assessed at: 0, 60, 180 & 365 days



For both mixtures a gradual increase in stiffness from day 0 to 60 was followed by a reduction trend until day 365

The initial rise of the stiffness moduli is probably due to the road pavement settlement given by traffic. After 60 days a gradual decrease in stiffness is recorded: loss of mechanical properties of the layer due to the combined effect of traffic and climate.

TRIAL FIELD PHASE

Cores data are compared with those obtained during the laboratory phase on gyratory compacted samples:

Indirect Tensile Stiffness Modulus (MPa) @ 20 °C										
Mixture	**Lab analysis**		**0**		**60 days**		**180 days**		**365 days**	
CRM	CRM 1	4486	CRM 0.1	4998	CRM 1.1	5795	CRM 2.1	4689	CRM 3.1	4002
	CRM 2	4320	CRM 0.2	5158	CRM 1.2	5935	CRM 2.2	4587	CRM 3.2	3987
	CRM 3	4288	CRM 0.3	5369	CRM 1.3	5888	CRM 2.3	4487	CRM 3.3	3901
	CRM 4	4698								
	Avg. CRM	**4448**	**Avg. CRM**	**5175**	**Avg. CRM**	**5873**	**Avg. CRM**	**4588**	**Avg. CRM**	**3963**
HMA	HMA 1	9898	HMA 0.1	9788	HMA 1.1	10780	HMA 2.1	9802	HMA 3.1	8512
	HMA 2	10083	HMA 0.2	9801	HMA 1.2	10089	HMA 2.2	9471	HMA 3.2	8019
	HMA 3	9425	HMA 0.3	9925	HMA 1.3	10945	HMA 2.3	9678	HMA 3.3	8308
	HMA 4	9645								
	Avg. HMA	**9763**	**Avg. HMA**	**9838**	**Avg. HMA**	**10605**	**Avg. HMA**	**9650**	**Avg. HMA**	**8280**

100% RAP CRM mix design is reproducible in the plant. The values of stiffness for every core sample taken right after the paving process, are always higher than those recorded for the specimens processed in the laboratory.

CONCLUSIONS 1/2

The aim of the present work was to evaluate the physical and mechanical properties of a CRM made with 100 % RAP with bituminous emulsion and Portland cement.

a hi-HMA for base layer, was taken as a reference

- The 100 % RAP in the mix does not seem to worsen the **compactability** of the bituminous mixture.

- There is **no significant difference** in terms of final density and air voids content between the two mixtures.

-Even if CRM shows lower values, its **indirect tensile strength and stiffness modulus are acceptable and higher** than the limits imposed by most common Italian technical specification for Cold Mixes made of up to 30 % of RAP

- The high amount RAP **does not alter the water susceptibility** of the mixture if compared to HMA

CONCLUSIONS 2/2

The results of the trial field phase were very useful for the evaluation of the feasibility of CRM in a cold mix plant.

- The gyratory curves confirm the laboratory phase. There are no evident differences between the volumetric properties of the two mixtures. The analysis of air voids content of the core samples proves the good workability and compactability of CRM.

- The in situ mechanical properties of CRM are higher than those registered in the laboratory phase. The trends of development of stiffness for CRM and HMA are the same for the whole period of analysis. The presence of RAP does not determine an excessive reduction in stiffness after 365 days of dumpers and trucks traffic.

Further work is needed to study the durability and fatigue performance of CRM.

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