# Sustainable maintenance techniques for wearing courses: different approaches to 100% asphalt concrete recycling.

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1- What is RAP?

2- Ways to recycle RAP: heating or not

3- Hot mixing plants: size and quantity matter

4- 100% RAP in new asphalt concretes: myth or reality?

5- Wearing course spot maintenance: patching

6- Example 1: plant produced hot/warm asphalt mix with 100% RAP

7- Example 2: plant produced cold asphalt mix with 100% RAP

8- Example 3: in situ 100% RAP recycling

9- Example 4: the world of patch asphalts

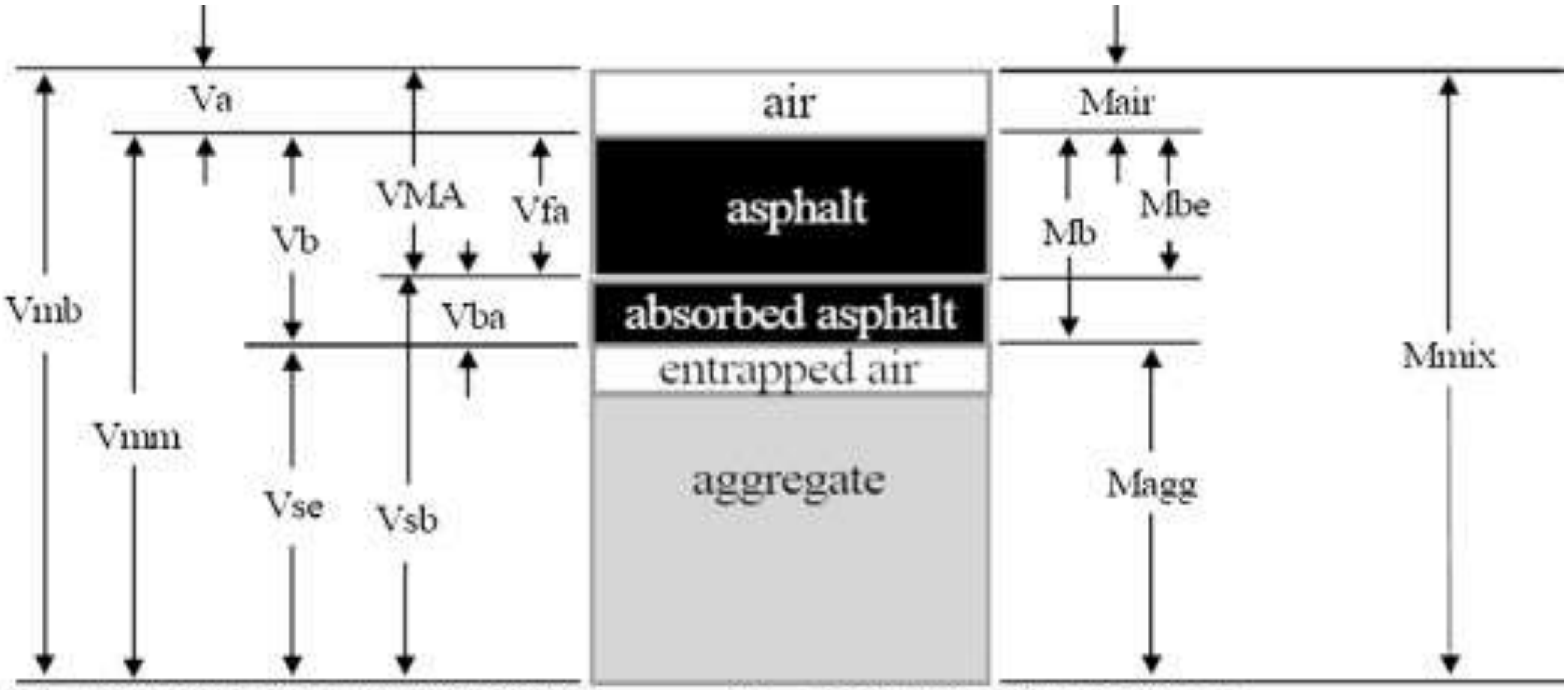
# 1- What is RAP?

Reclaimed asphalt pavement (RAP) is the term given to **removed and/or reprocessed pavement materials containing asphalt and aggregates**. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities. When properly crushed and screened, RAP consists of **high-quality, well-graded aggregates coated by asphalt cement**. (FHWA)

# 1- What is RAP?

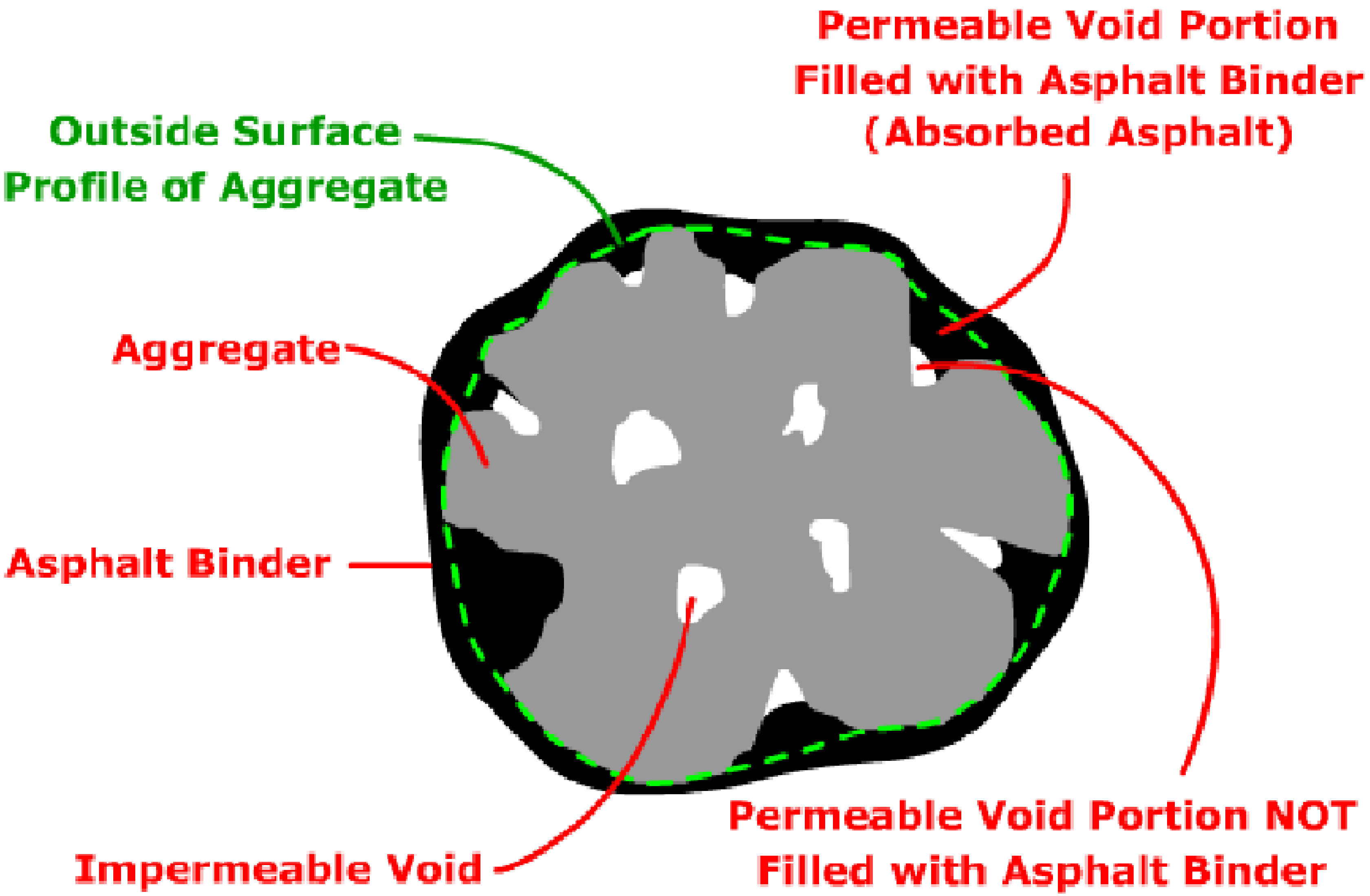
**90% of European roads** are surfaced with asphalt.

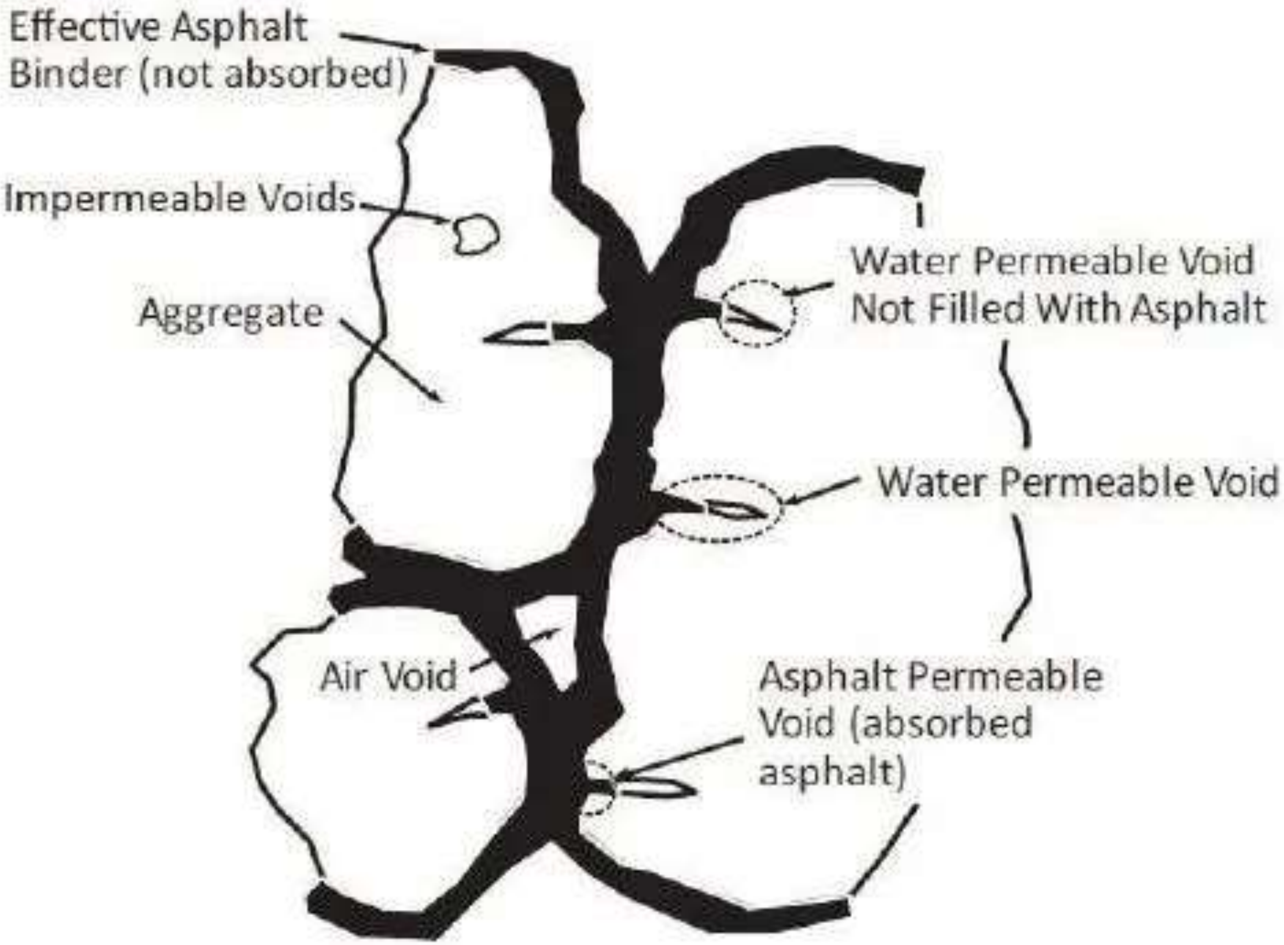
Asphalt materials are almost unique among construction products in that they **can be 100% recycled**, and in many cases re-used directly back into the application and even the site from which they have been extracted. (EAPA)

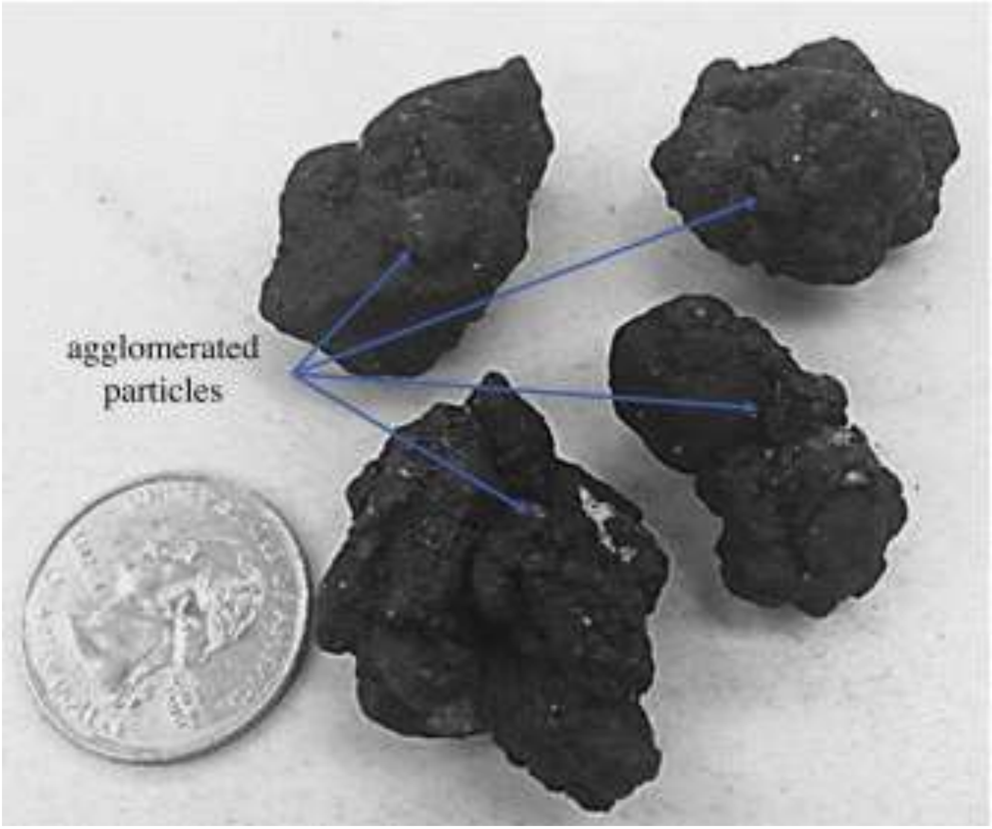


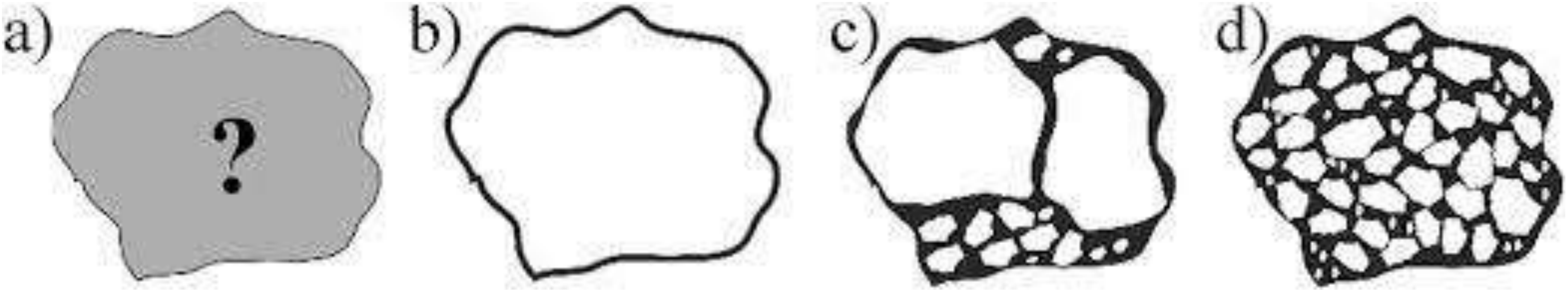

VMA = Volume of voids in mineral aggregate
$V_{mb}$ = Bulk volume of compacted mix
$V_{mm}$ = Voidless volume of paving mix
$V_{fa}$ = Volume of voids filled with asphalt
$V_a$ = Volume of air voids
$V_b$ = Volume of asphalt binder
$V_{ba}$ = Volume of absorbed asphalt binder
$V_{sb}$ = Volume of mineral aggregate (by bulk specific gravity)
$V_{se}$ = Volume of mineral aggregate (by effective specific gravity)

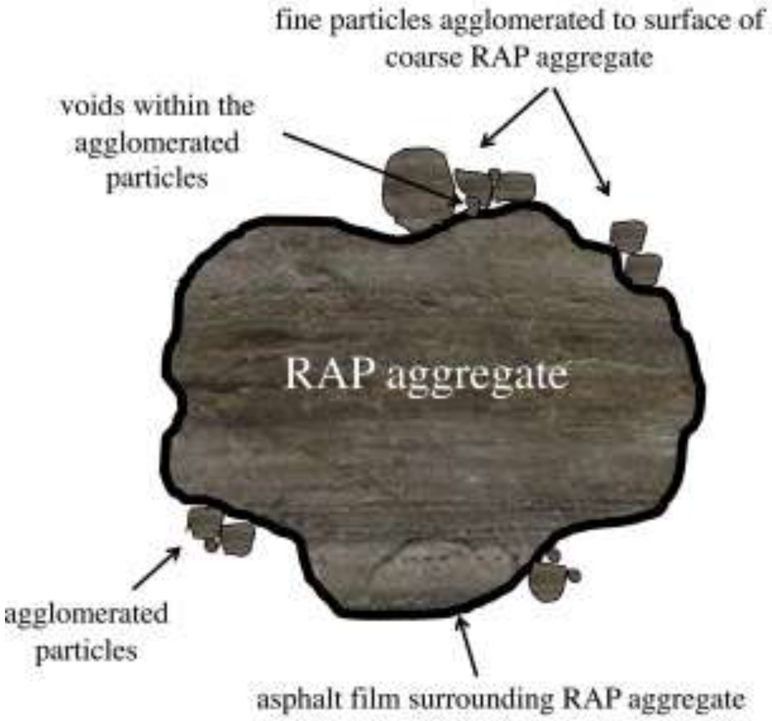
$M_{mix}$ = Total mass of asphalt mixture
$M_b$ = Mass of asphalt binder
$M_{be}$ = Mass of effective aggregate binder
$M_{agg}$ = Mass of aggregate
$M_{air}$ = Mass of air = 0


Permeable Void Portion
Filled with Asphalt Binder
(Absorbed Asphalt)
Outside Surface
Profile of Aggregate
Aggregate
Asphalt Binder
Impermeable Void
Permeable Void Portion NOT
Filled with Asphalt Binder


Effective Asphalt
Binder (not absorbed)
Impermeable Voids
Aggregate
Water Permeable Void
Not Filled With Asphalt
Water Permeable Void
Air Void
Asphalt Permeable
Void (absorbed
asphalt)

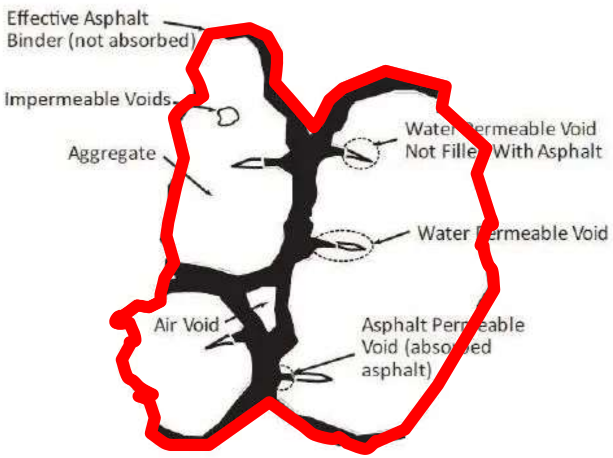

agglomerated
particles

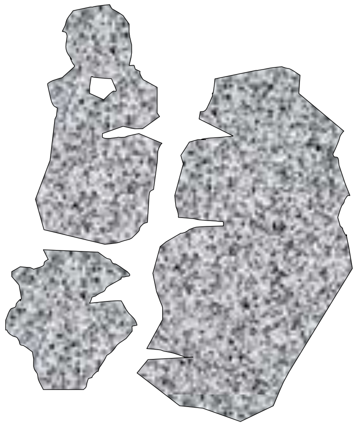

a)
?
b)
c)
d)

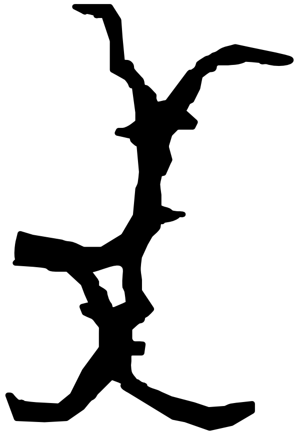

fine particles agglomerated to surface of coarse RAP aggregate
voids within the agglomerated particles
RAP aggregate
agglomerated particles
asphalt film surrounding RAP aggregate

# Air voids in milled RAP: a simple laboratory analysis

| Characteristic | Standard | Unit | Value |
|---|---|---|---|
| Binder on aggregates | (EN 12697-1) | % | 4,74 |
| Particle density of white aggregates | (EN 1097-6) | kg/dm$^3$ | 2,746 |
| Density of bitumen from RAP | (EN 15326) | kg/dm$^3$ | 1,050 |
| Maximum density of RAP: calculated | (EN 12697-5) | kg/dm$^3$ | 2,559 |
| Maximum density of RAP: meas. (as aggreg.) | (EN 12697-5) | kg/dm$^3$ | 2,486 |
| Air voids in RAP | (EN 12697-8) | % | 2,9 |





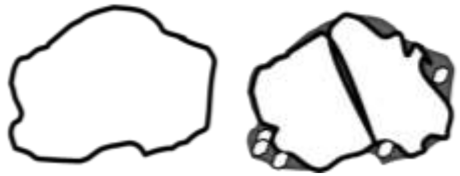
$$\rho_{mc} = \frac{100}{(p_a / \rho_a) + (p_b / \rho_b)}$$

$$\rho_{mv} = \frac{m_2 - m_1}{1000 \times V_p - (m_3 - m_2)/\rho_w}$$

# ACTIVATION OF THE AGED BINDER - from RILEM

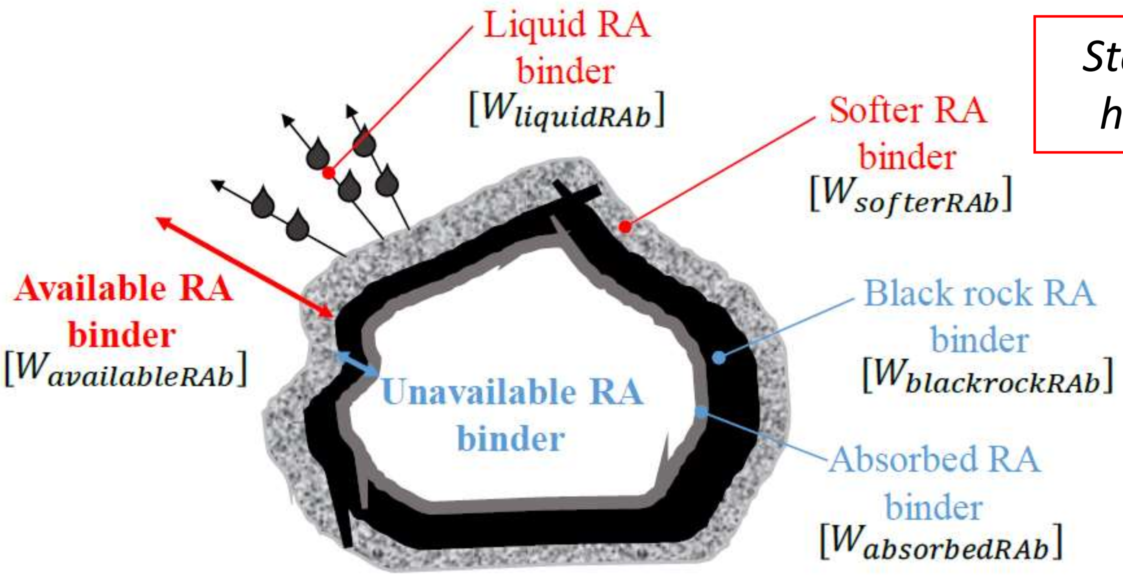
*[Lo Presti et al, 2019]*

**RAP contains aged binder that coates its particles or clusters of particles**



When RAP is used in new mixes, often with *Recycling agents*, and with specific production conditions (temperature and mixing time), a **portion of aged binder can be reactivated and act as binder**

*Liquid bitumen with some mobility*

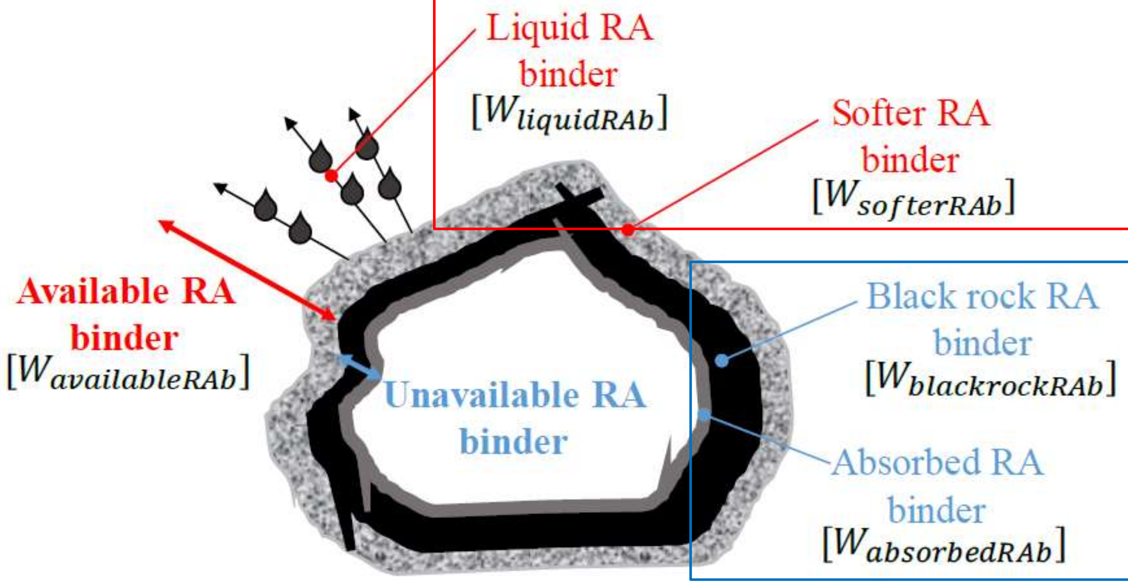



*Stable binder, possible softening if heated and able to act as binder*

*Stiff and brittle bitumen: no softening possible*

*Bitumen absorbed by aggregates*

# ACTIVATION OF THE AGED BINDER - from RILEM




ACTIVE BINDER WHEN RAP IS IN SPECIFIC TEMP and MIXING CONDITIONS

INACTIVE BINDER

**Degree of binder Activity**, (DoA):

is the minimum amount of **active binder** from RAP that a designer can consider for a selected RAP and a selected asphalt manufacturing process. It is not related to the presence of recycling agents and it changes by varying RAP type and processing conditions (i.e time, temperature).

**Only-RA (no Recycling agent) scenario**

**Available binder =**
**Active binder**

**represents the minimum amount of aged binder** that, at specific processing conditions (mixing temperature T, and time t) can be considered available/active in the formulation of recycled asphalt mixtures.

$$W_{activeRAb}(\text{RA type}, \text{t}, \text{T}) = W_{liquidRAb} + W_{softerRAb}$$

**RA + recycling agent scenario**

**Available binder =**
**Active binder**
**+ Activated binder**

The activation of a certain amount of Black rock RA and Absorbed RA binder due to the effect of recycling agent, time and temperature forms the activated binder

$$W_{availableRAb}(RA + rec.ag.) = W_{activeRAb}(\text{RA type}, \text{t}, \text{T}) + $$
$$- W_{activatedRAb}(\text{Rec. ag. type}, \text{RA type}, \text{t}, \text{T})$$

INDEXES:

$$DoA = \frac{w_{activeRAb}(\text{RA type,t,T})}{w_{RAb,total}} \cdot 100\ [\%\ mass]$$

$$DoAv = \frac{w_{availableRAb}(RA+rec.ag.)}{w_{RAb,total}} \cdot 100\ [\%\ mass]$$

**Degree of binder Blending (DoB)** could be defined as: an indicator describing to what extent the aged RAP binder contributes to the final properties of the asphalt mixture’s binder blend composed of aged binder and recycling agent.

# RAP*: characterization according to the EN 13108-8 standard

**RAP**

- Foreign matter in RAP [EN 12697-42]
- Type of binder (technical sheet if available)
- **Particle size distribution – black curve [EN 933-1]**
- Size designation [EN 13108-8]
- *Fragmentation test*
- *Cohesion test*

***RILEM TC-RAP procedures***

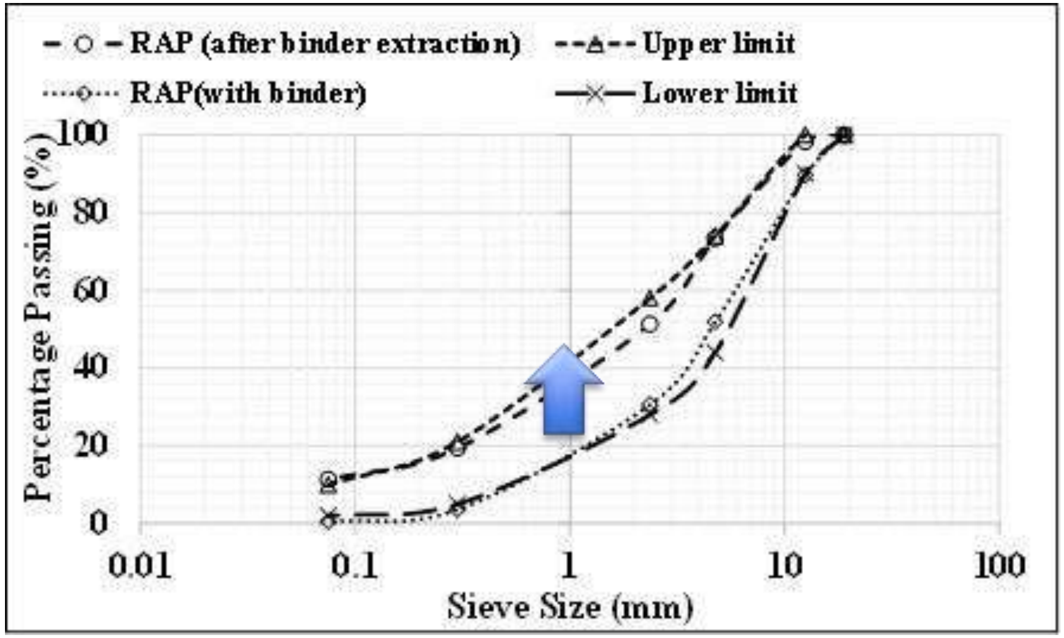
**Binder extraction**

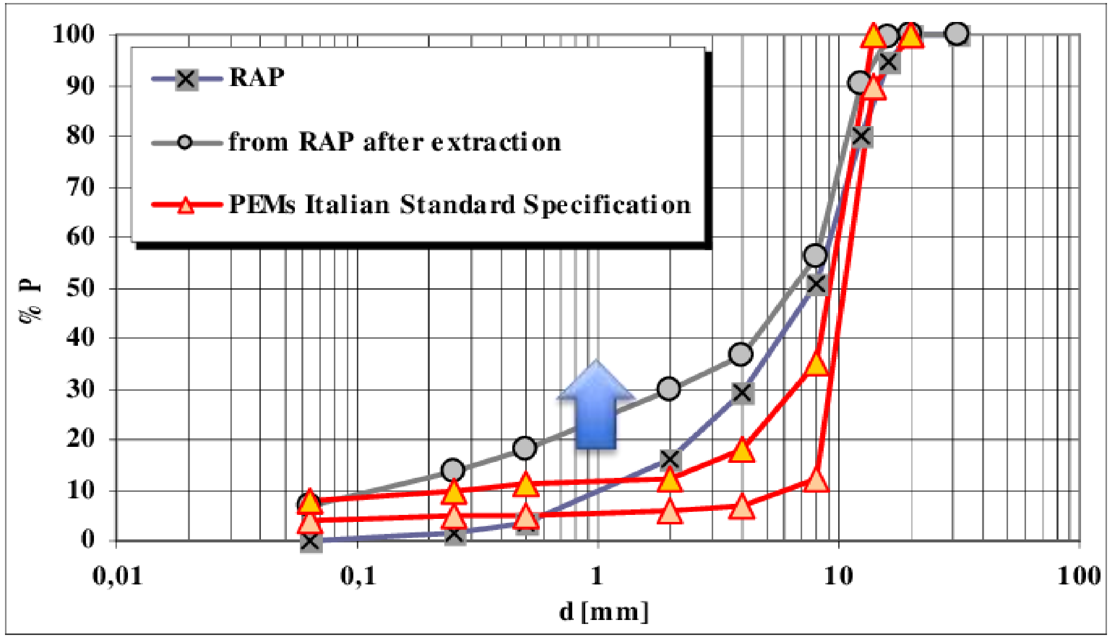
**Aggregates Post-extraction**

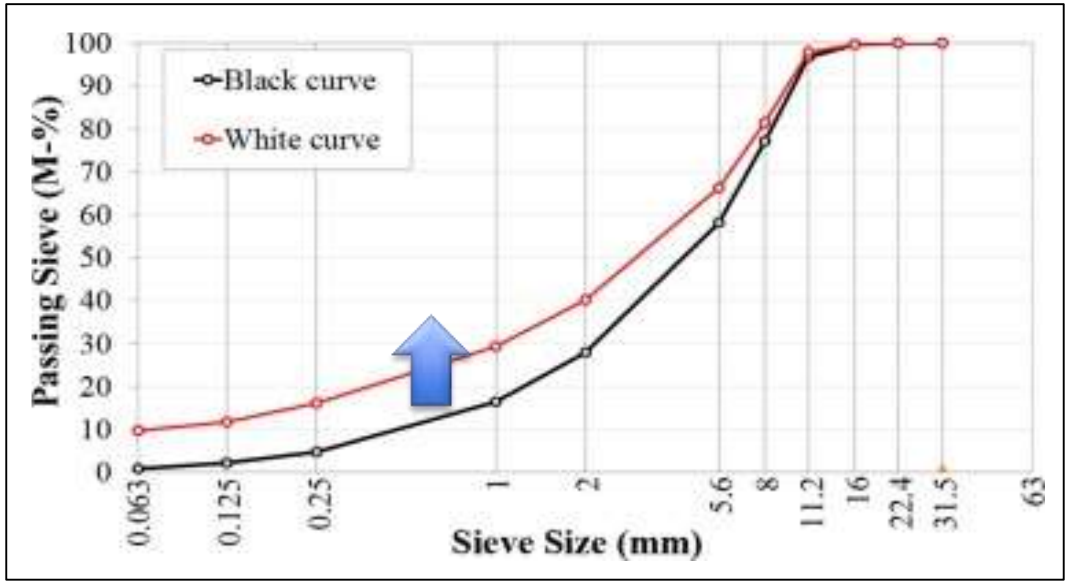
- **Particle size distribution – white curve [EN 12697-2]**
- Aggregates properties [EN 13043]

**Bitumen Post-extraction**

- Penetration [EN 1426]
- Softening Point [EN 1427]
- Viscosity [EN 13302]
- Binder content [EN 12697-1]


RAP (after binder extraction)
Upper limit
RAP(with binder)
Lower limit
Percentage Passing (%)
0
20
40
60
80
100
0.01
0.1
1
10
100
Sieve Size (mm)

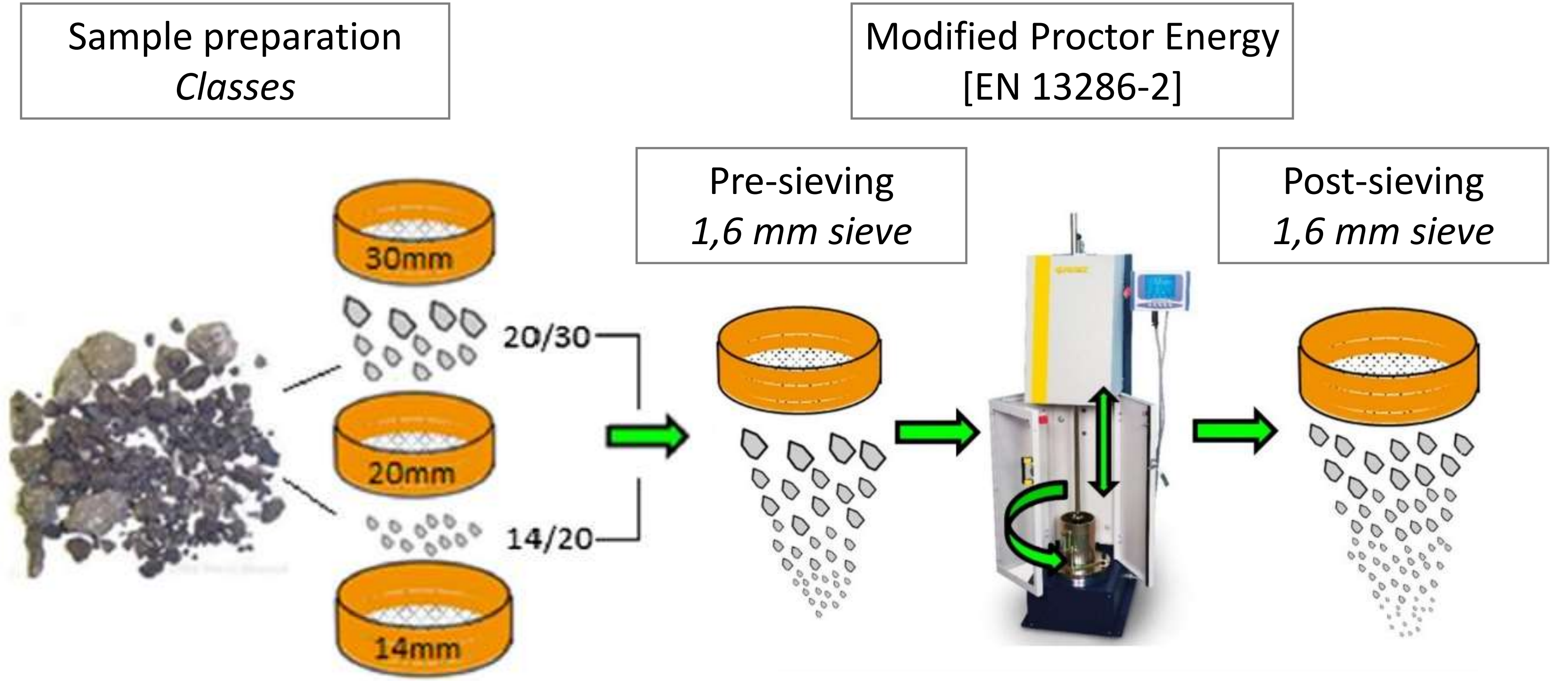

RAP
from RAP after extraction
PEMs Italian Standard Specification
% P
0
10
20
30
40
50
60
70
80
90
100
0,01
0,1
1
10
100
d [mm]


Black curve
White curve
Passing Sieve (M-%)
0
10
20
30
40
50
60
70
80
90
100
0.063
0.125
0.25
1
2
5.6
8
11.2
16
22.4
31.5
63
Sieve Size (mm)

# FRAGMENTATION PROTOCOL (RILEM – Cold Mixes):

*[Tebaldi et al, 2019]*

## Fragmentation of RAP under cyclic impulses with Modified Proctor hammer at 25°C




$$Coefficient\ of\ Fragmentation, PCS\% = \frac{Weight\ passing\ 1.6\ sieve}{Total\ tested\ weight} \cdot 100$$

# COHESION PROTOCOL (RILEM – Cold Mixes):

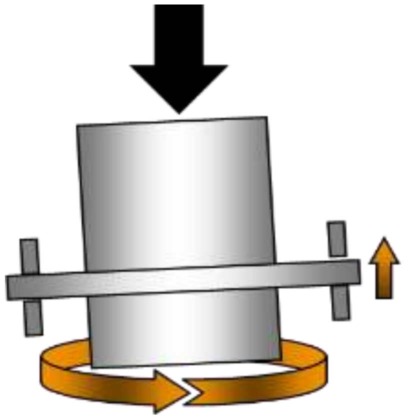
*[Tebaldi et al, 2018]*

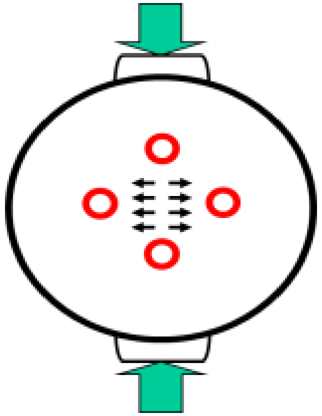
**RAP binder degree of activity after heating and compaction without additional binder.**

Cohesive power is evaluated. No additives.

SGC Compaction [EN 12697-31]
*Diam = 150 mm ; N° gyrations = 30*

Preparation of samples
*Heating temps [20, 70, 140°C]*





ITS [EN 12697-23]
*Air conditioning - 25°C, > 4h*
*Water conditioning - 25°C, 24h*

# 2- Ways to recycle RAP: heating or not

<u>There are two broad classifications of recycling process: **ex-situ** and **in-situ.**</u>

**Ex situ processes** are employed when asphalt materials are excavated from the road and transported (even short distances) <u>to processing units or plants</u> in order to be used as an ingredient in fresh asphalt mixtures.

100%???

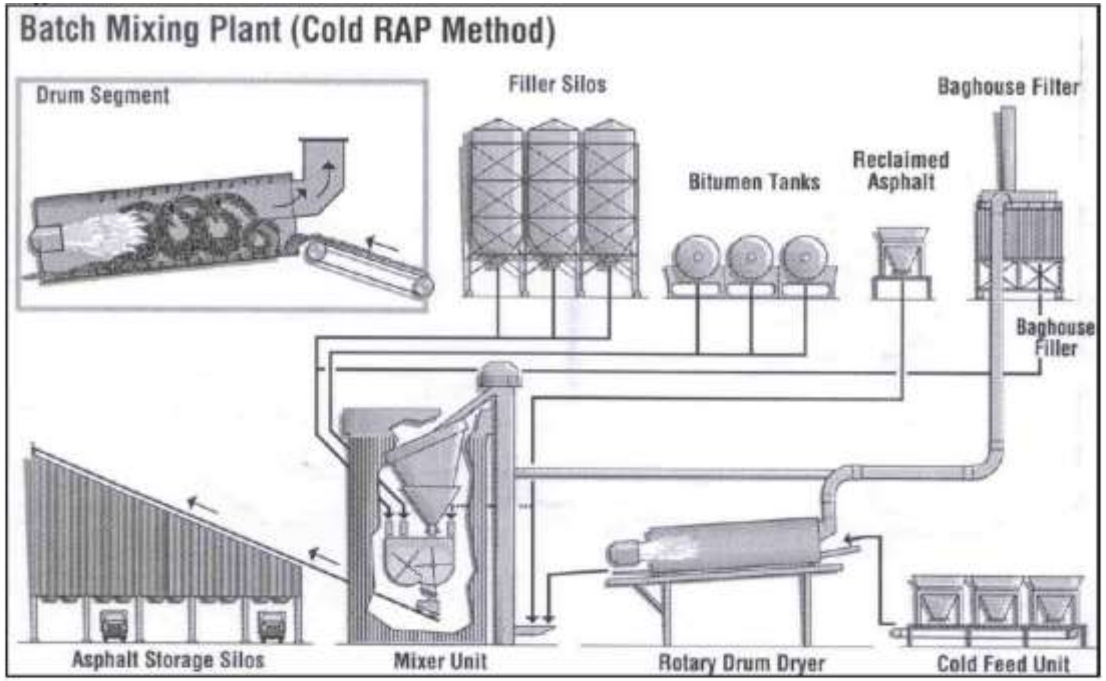
## Hot ex-situ processes – cold RA addition to (batch) mixer

The simplest process is to add cold RA directly to the batches of virgin aggregate, binder and filler, but after the aggregates have been dried.

**% max. RAP = 30 ÷ 40 %**

**Pros:**
- Simple plant modifications.

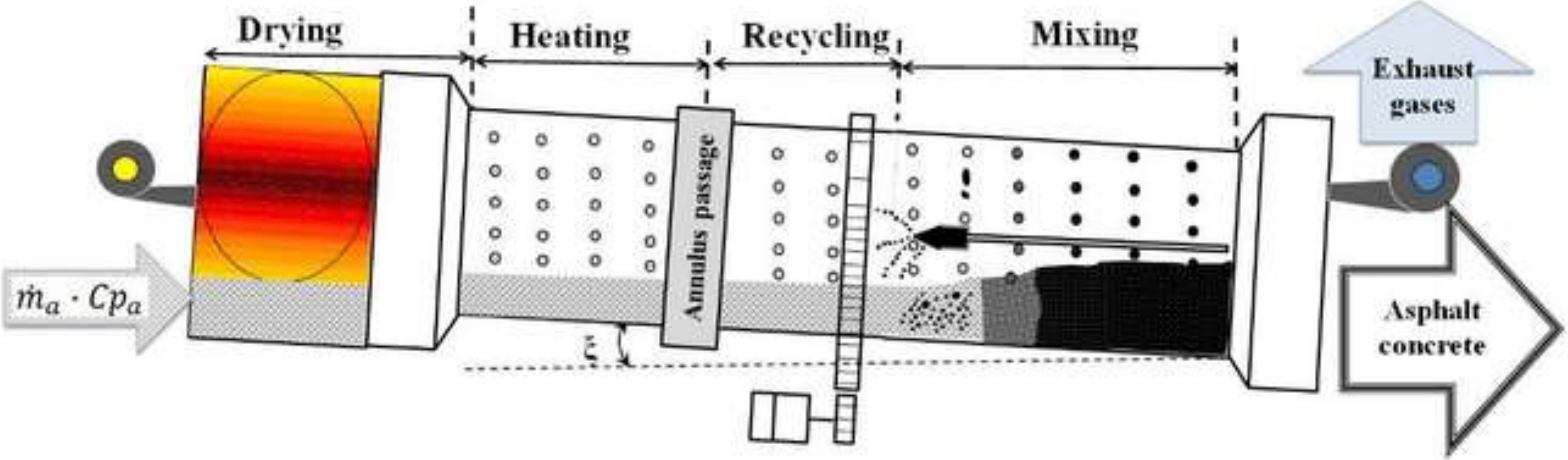
**Cons:**
- RAP with moisture;
- Over heating of virgin aggregates;
- Reduction of production rate;
- Risks of vapours and explosions.



## Hot ex-situ processes – drum mixer

Certain types of asphalt plant have drums, which carry out the drying and mixing process continuously, rather than separately in batches.

**% max. RAP = 50 ÷ 60 %**



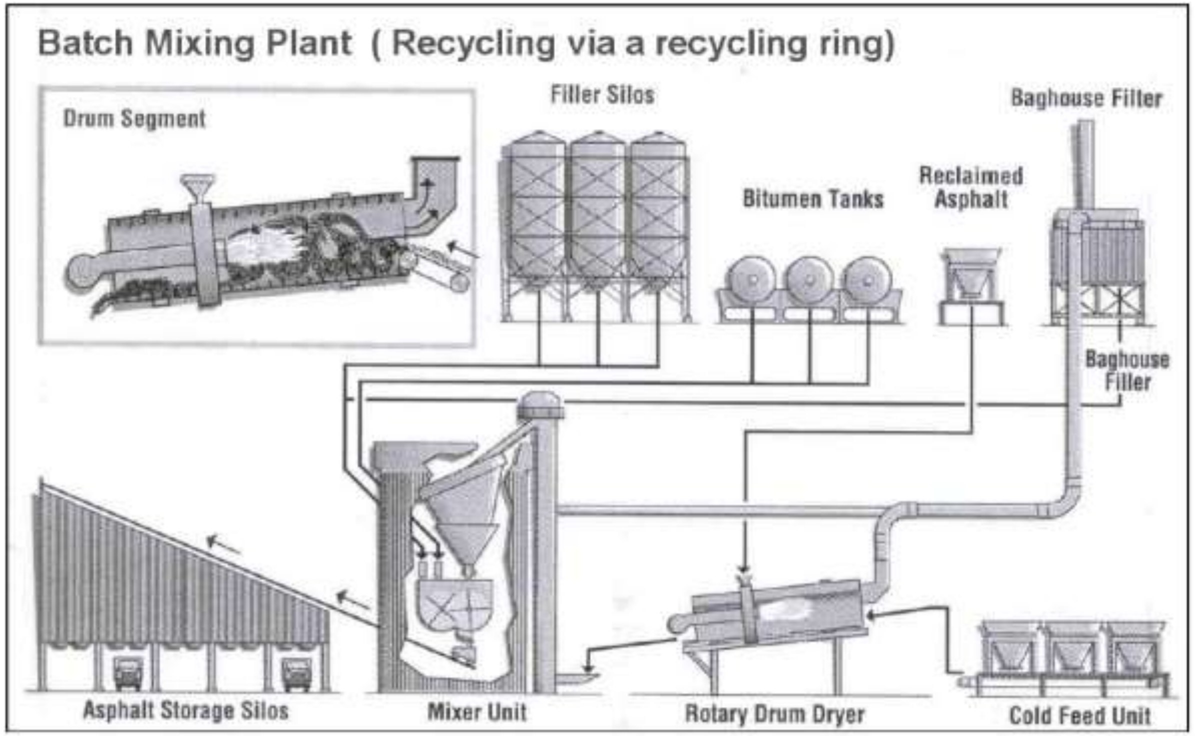
# Hot ex-situ processes – twin drum/ring dryer

Other plants may have a twin drum system, in which the aggregates are dried as normal in the inner drum, while the RA is mixed with dry aggregates, bitumen etc. having been subject (in the outer drum) to radiant heat and hot gases for drying from the inner drum.

**% max. RAP = 30 ÷ 40 %**

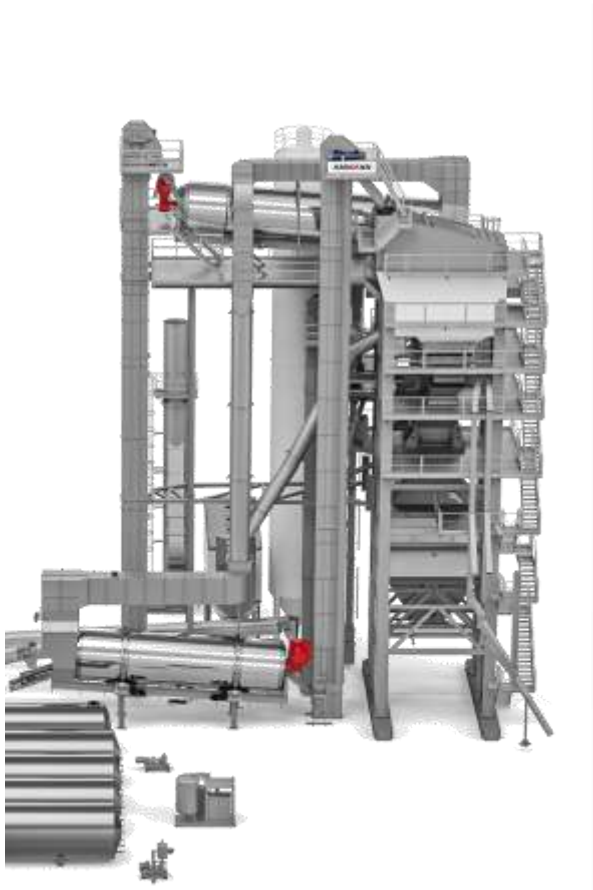
**Pros:**
- RAP moisture removal;
- Reduced overheating of aggregates.

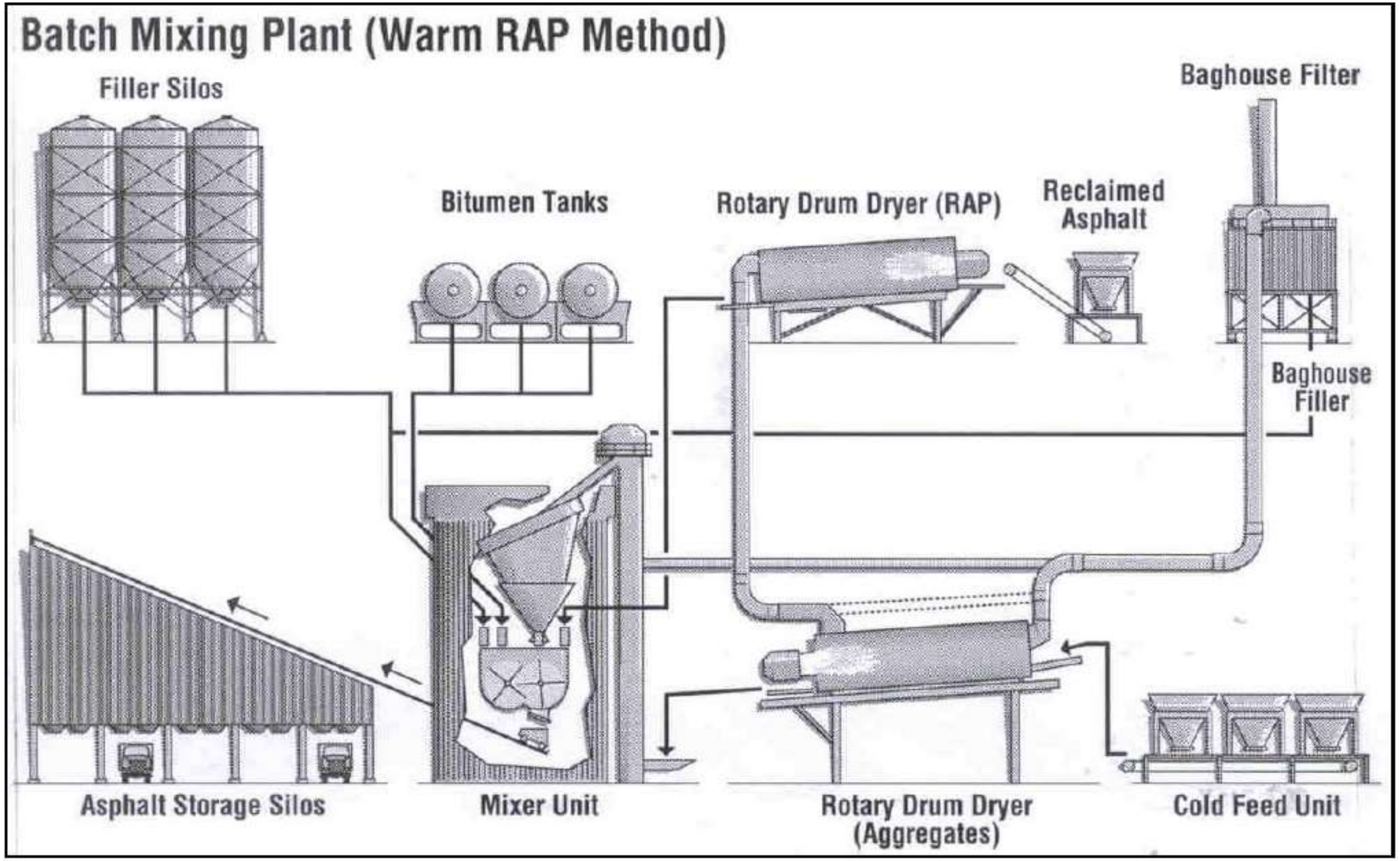
**Cons:**
- Initial plant costs;
- Sieve clogging due to the softened binder.



# Hot ex-situ processes – second drum

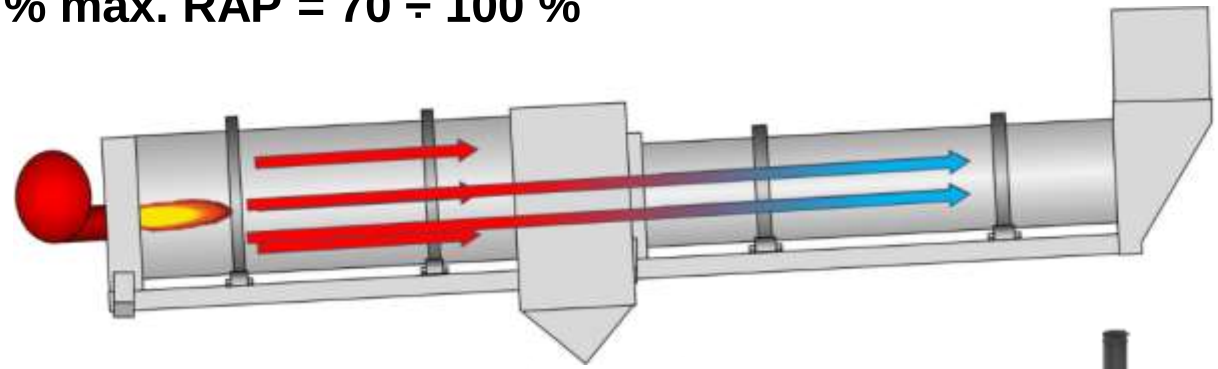
% max. RAP = 50 ÷ 80 %





# Hot ex-situ processes – coupled drums

% max. RAP = 70 ÷ 100 %

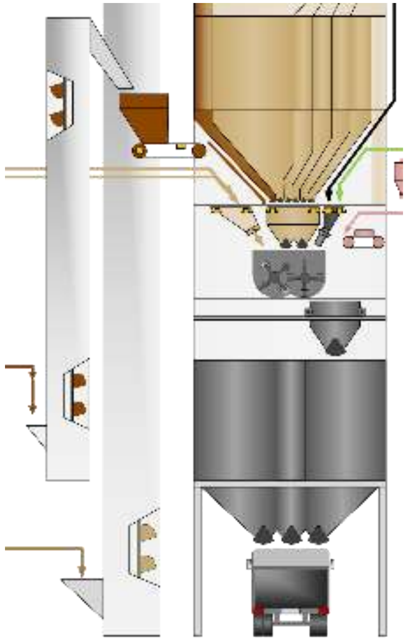


# Hot ex-situ processes – combined ring and mixer

**% max. RAP = 50 ÷ 60 %**

**Pros:**
Combined

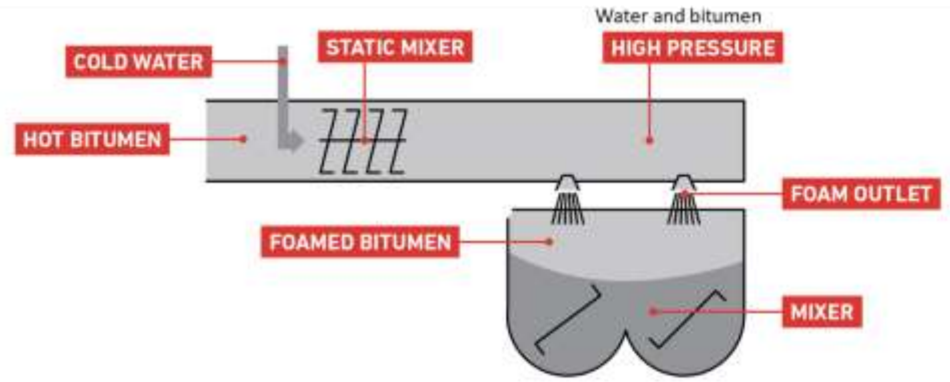
**Cons:**
Combined



# Ex situ processes

## Foaming processes

Foaming is achieved by carefully adding water and air to hot bitumen, resulting in a rapid but temporary expansion of the bitumen, with an associated reduction in the binder film thickness.




## Emulsion processes

Reduced temperature mixtures can also be produced using bitumen emulsions – in which bitumen is chemically encapsulated in water – to reduce viscosity.

## Additives

In some cases, additives are used which release water or other viscosity-reducing agents in the presence of hot bitumen and/or aggregates, and result in a lower overall mixture temperature.

# In situ processes

The road itself can be **recycled in-situ**, thereby reducing the need to remove materials from the site to other locations for processing and inclusion in fresh asphalt.

## "Repave"

Repave-type processes are characterized by the heating and scarifying of the immediate surface of the road to approximately 20-30mm depth.

# In situ processes

## "Remix"

The Remix process is similar to Repave, the main difference being that the existing in-situ material after heating and scarifying, is completely mixed with an appropriate amount of fresh material inside the machine itself.

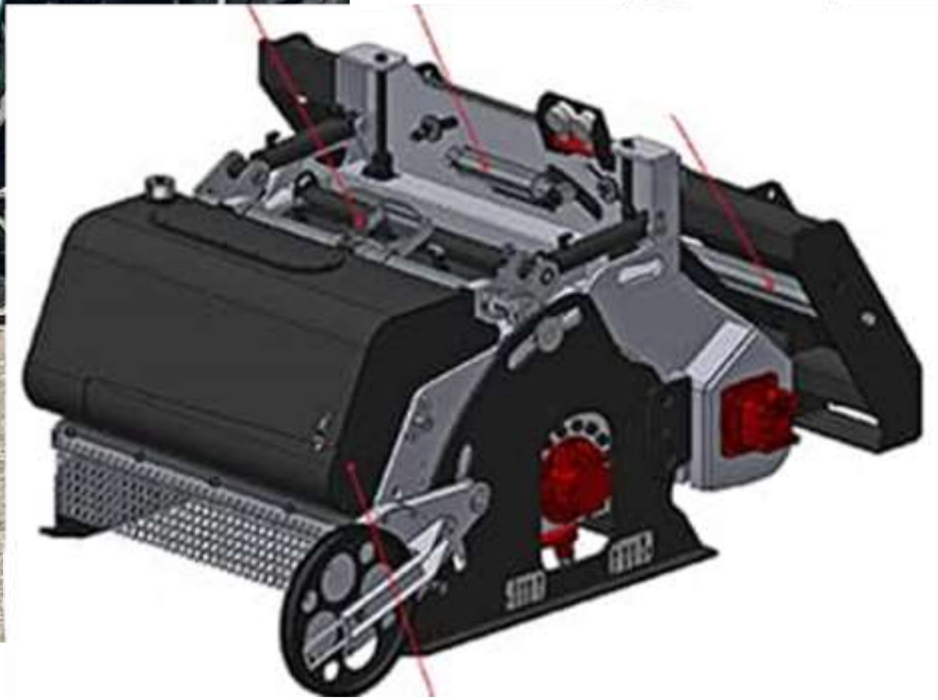
# In situ processes

## “Retread”

The Retread process is carried out to a greater depth than Repave or Remix, typically around 75mm. The road is cold-scarified and the materials homogenised with fresh aggregate and/or binder in the machine before being relaid to full depth.

# In situ processes

## Cold «Repave/ Remix/ Retread»: down to 70-100 mm – 1m width, small areas

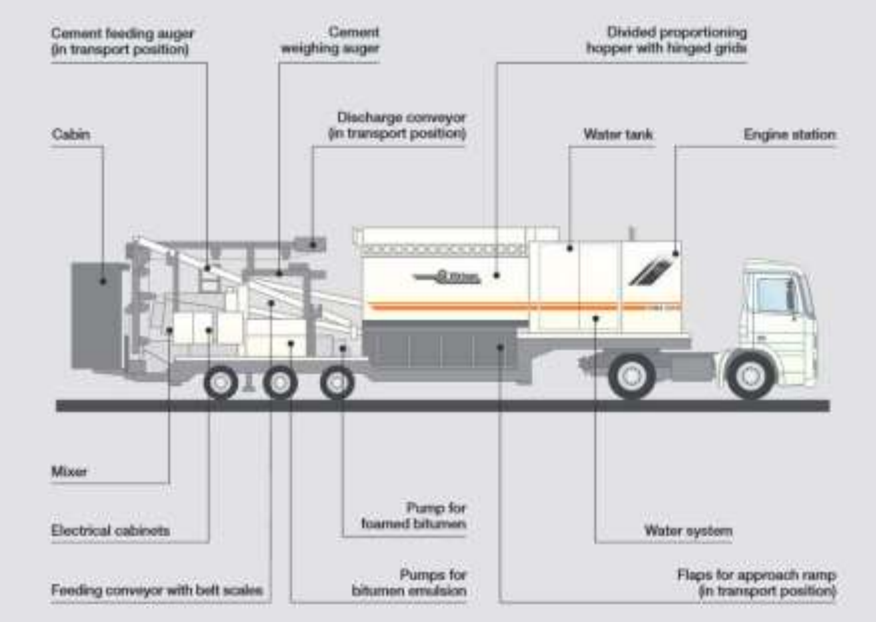



# In situ processes

## Foamed and emulsion in-situ processes / full-depth recycling

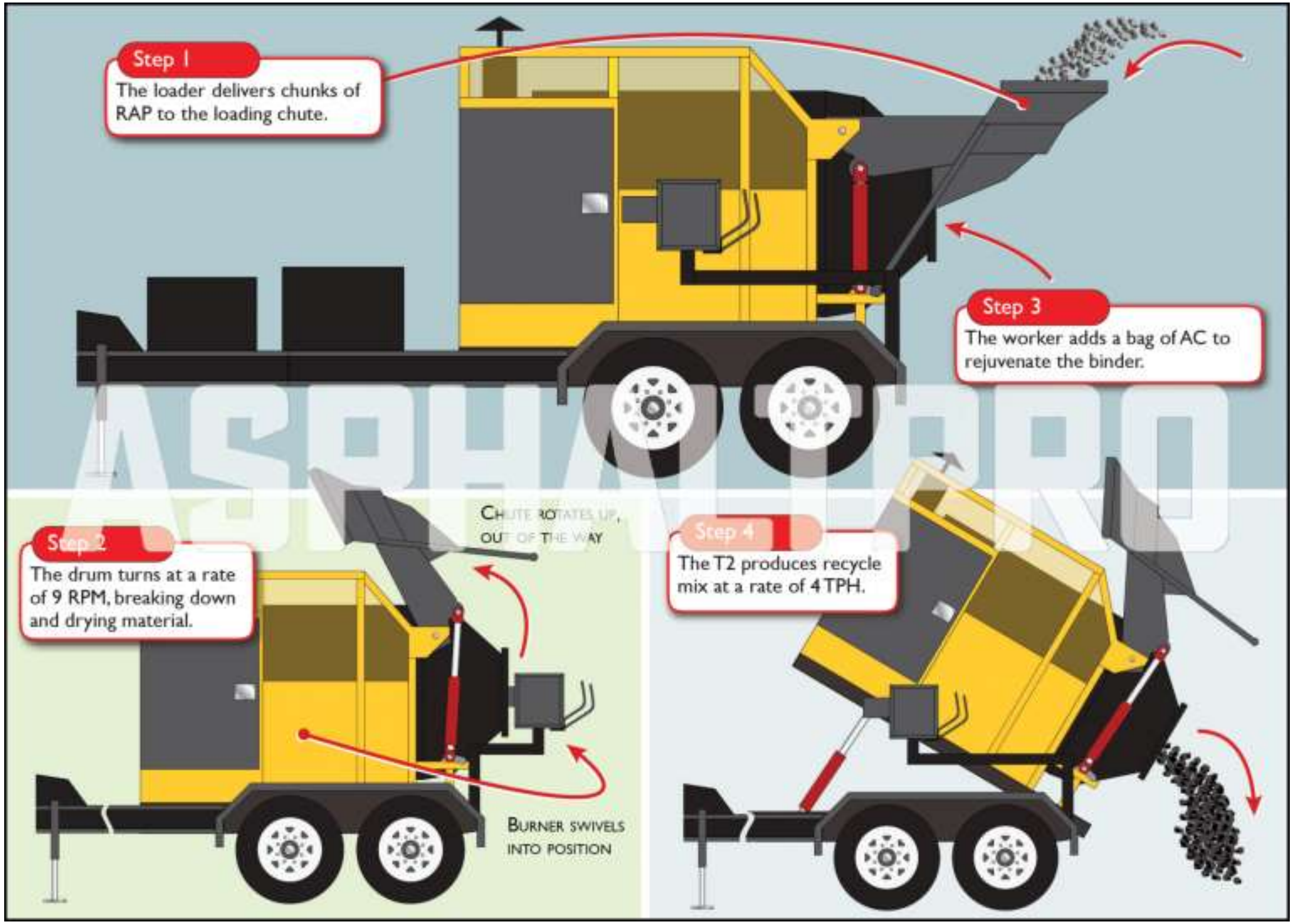
These processes reconstruct the entire road or parts of it to a depth of 150mm to 350mm and <u>involves mixed the existing material in-situ with new binders to form a uniform and strengthened structure</u>.


# In situ plant processes

# In situ / ex situ processes for small productions

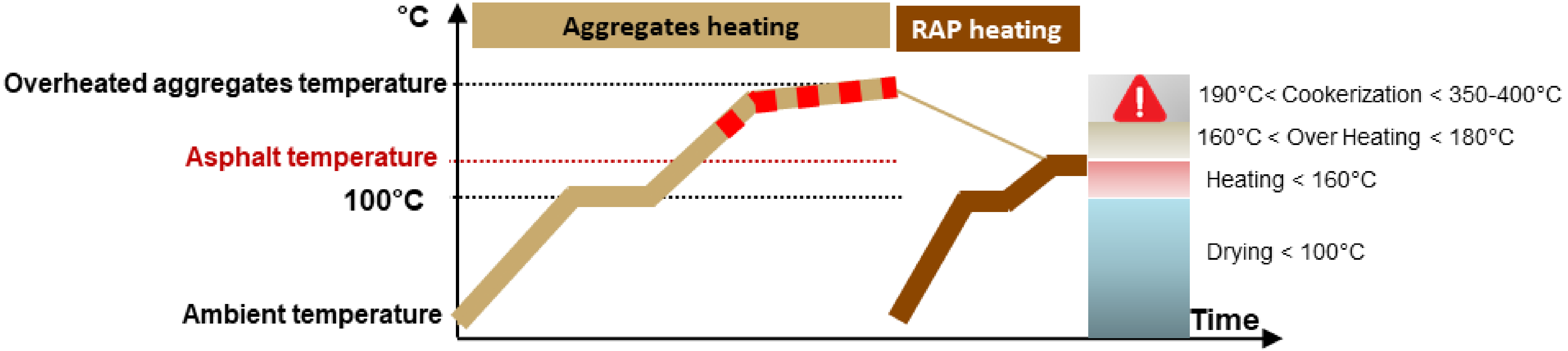

# In situ small recycler processes

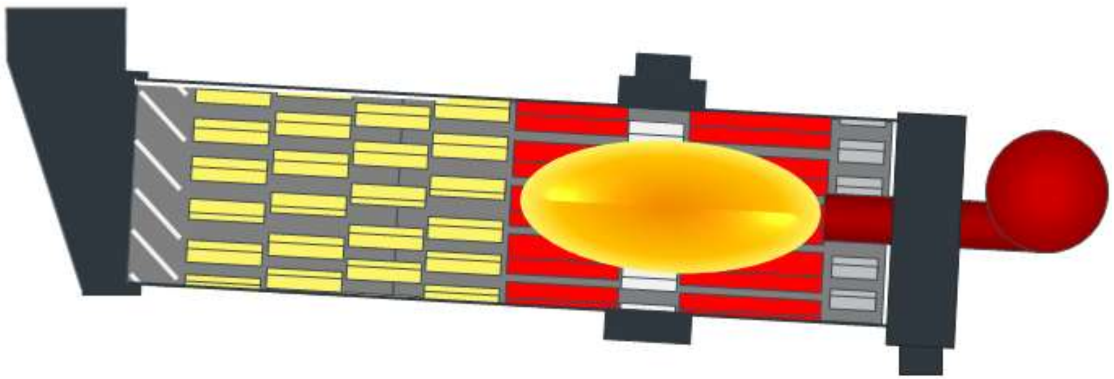


# In situ skid-loeader mounted recycler processes

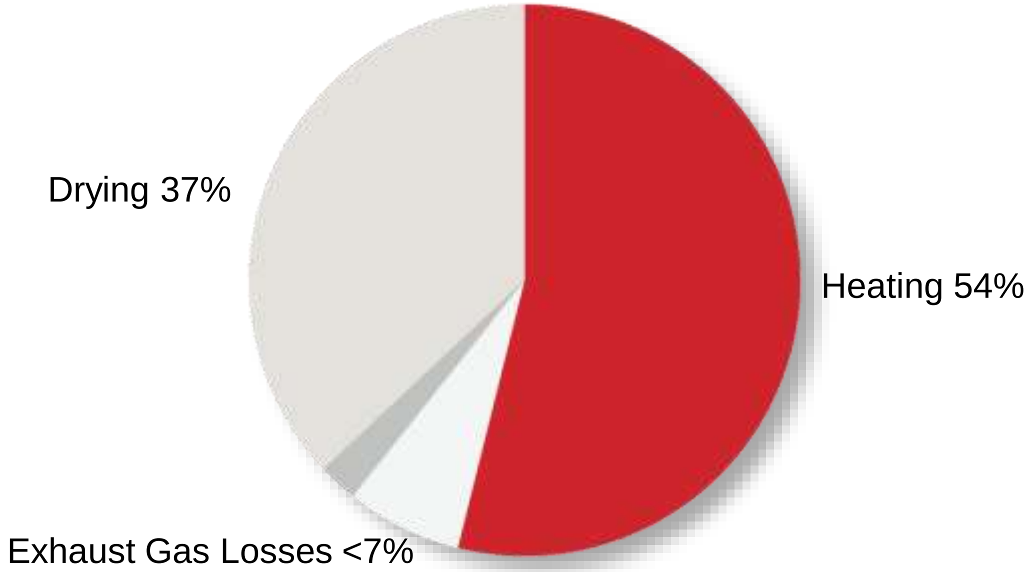
AMERIPATCHER

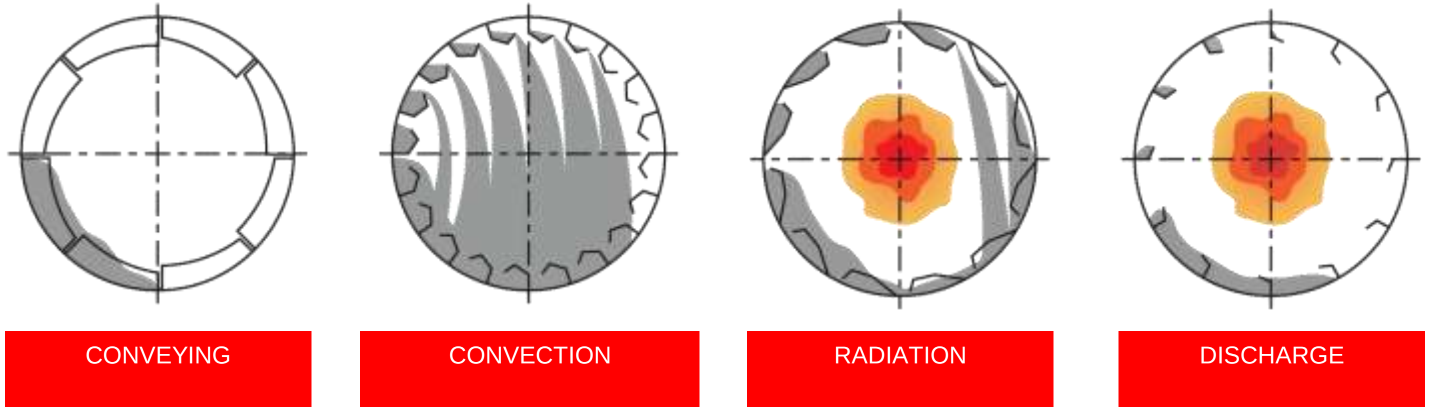
# 3- Hot mixing plants: size and quantity matter

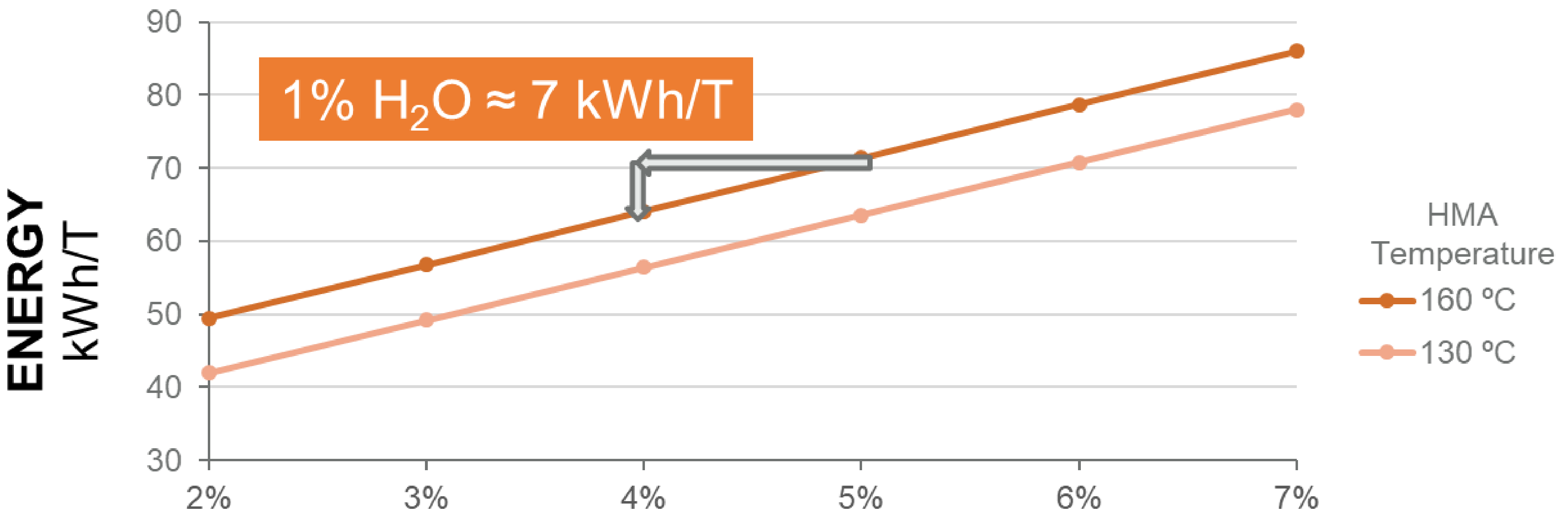



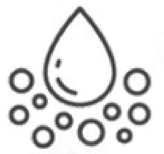
Typical production rates for drum plants **vary between about 100 tons/hr up to over 900 tons/hr** depending upon drum design and moisture content.


Drying 37%
Heating 54%
Exhaust Gas Losses <7%


CONVEYING
CONVECTION
RADIATION
DISCHARGE

# Influence of moisture content in aggregates / RAP on Energy consumption



✓Moisture is the most relevant factor with an impact on production performance and costs

# Minor wearing course maintenance: patching or inlays



D-9
CG123

# Morning patching with the teams of workers:

**Leaving plant at: 8:05 am**
Mix temp at plant: 180°C
Air temp.: 11°C

## Site 1

- **Arrival: 9:50**
- Tack coat: 10:03
- Mix temp: 150°C
- Laying: 10:13
- Layer temp: 115°C
- Surface finish: 10:19

## Site 2

- Arrival: 10:23
- Tack coat: 10:24
- Mix temp: 150°C
- Laying: 10:35
- Layer temp: 110°C
- Surface finish: 10:43

## Site 3

- Arrival: 10:44
- Tack coat: 10:45
- Mix temp: 150°C
- Laying: 10:51
- Layer temp: 108°C
- Surface finish: 10:58

## Site 4

- Arrival: 11.02
- Tack coat: 11:03
- Mix temp: 145°C
- Laying: 11:09
- Layer temp: 105°C
- Surface finish: 11:21

## Site 5

- Arrival: 11:30
- Tack coat: 11:31
- Mix temp: 145°C
- Laying: 11:44
- Layer temp: 105°C
- Surface finish: wth 6

## Site 6*

- Arrival: 11:50
- Tack coat: 11:55
- Mix temp: 140°C
- Laying: 12:00
- Layer temp: 103°C
- **Surface finish: 12:20**

# 4- 100% RAP in new asphalt concretes: myth or reality?

materials

MDPI

*Article*

## Evaluation of Low Volume Roads Surfaced with 100% RAP Millings

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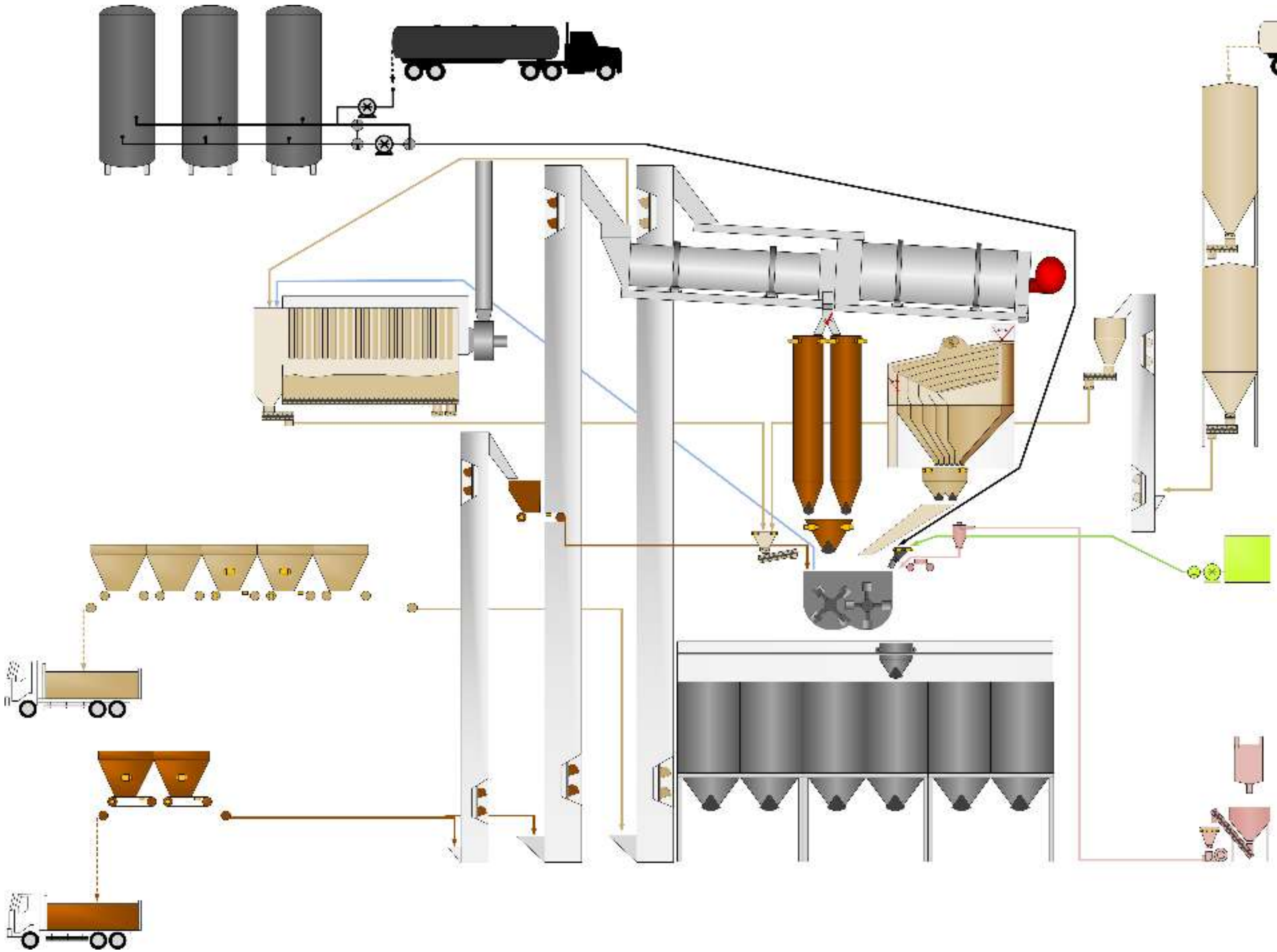
**Abstract:** The sustainability of roadway construction has rapidly been gaining attention within the pavement industry. The pavements examined in this study are in a Northern Nevada county with many of the roadways categorized as low volume roads. The county began surfacing rural roads with 100% Reclaimed Asphalt Pavement (RAP) millings, without any design considerations for decades. These pavements have provided satisfactory performance with little to no maintenance for their intended purpose for 25–30 years. The presented research revealed RAP milling surfaced roads with layer coefficients between 0.18 and 0.30, and design thicknesses ranging from 5 to 11 inches.

**Keywords:** asphalt concrete; low volume roads; reclaimed asphalt pavement; pavement design; cold milling



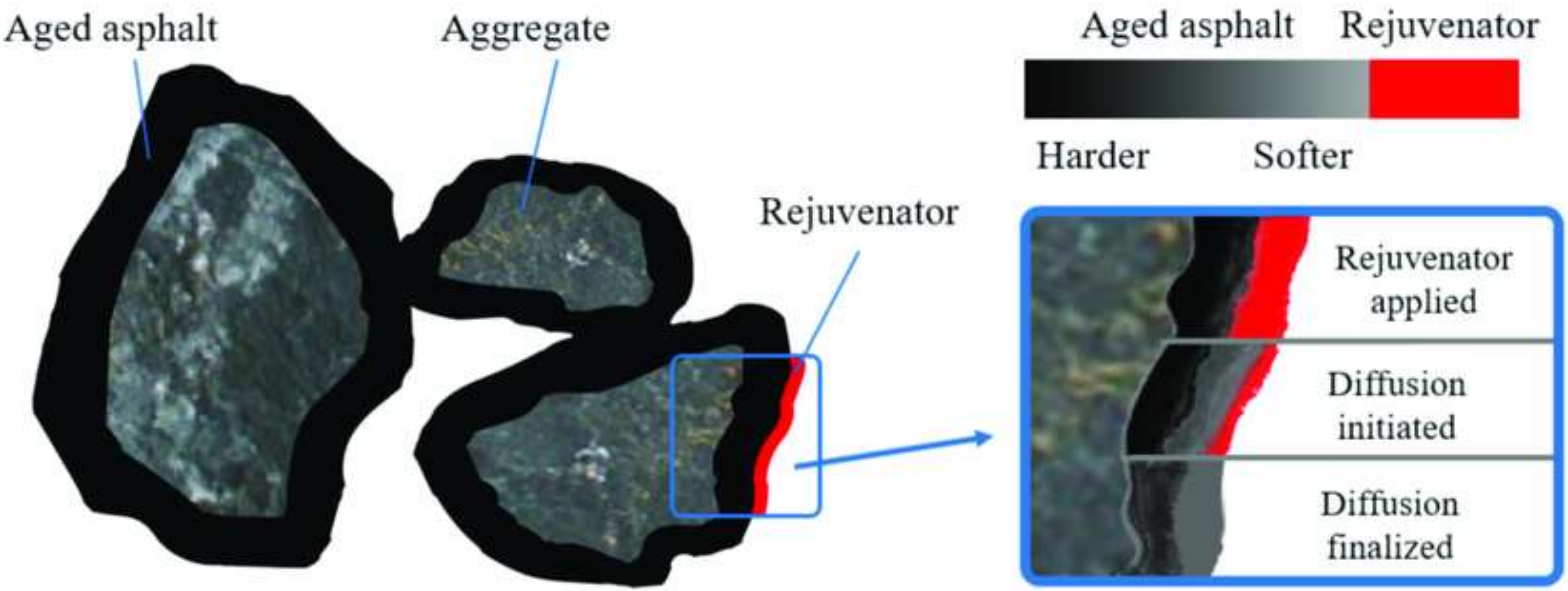

ASTEC
DOUBLE
BARREL
ASTEC

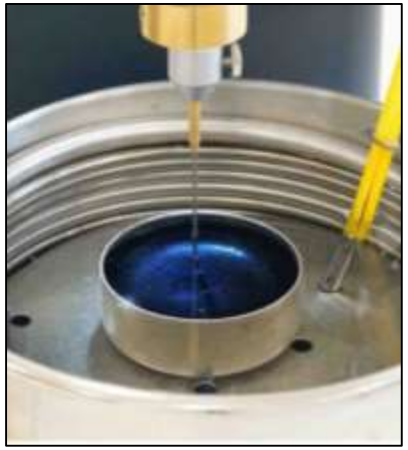
RAH 100 – counter-flow
RAP dedicated drum

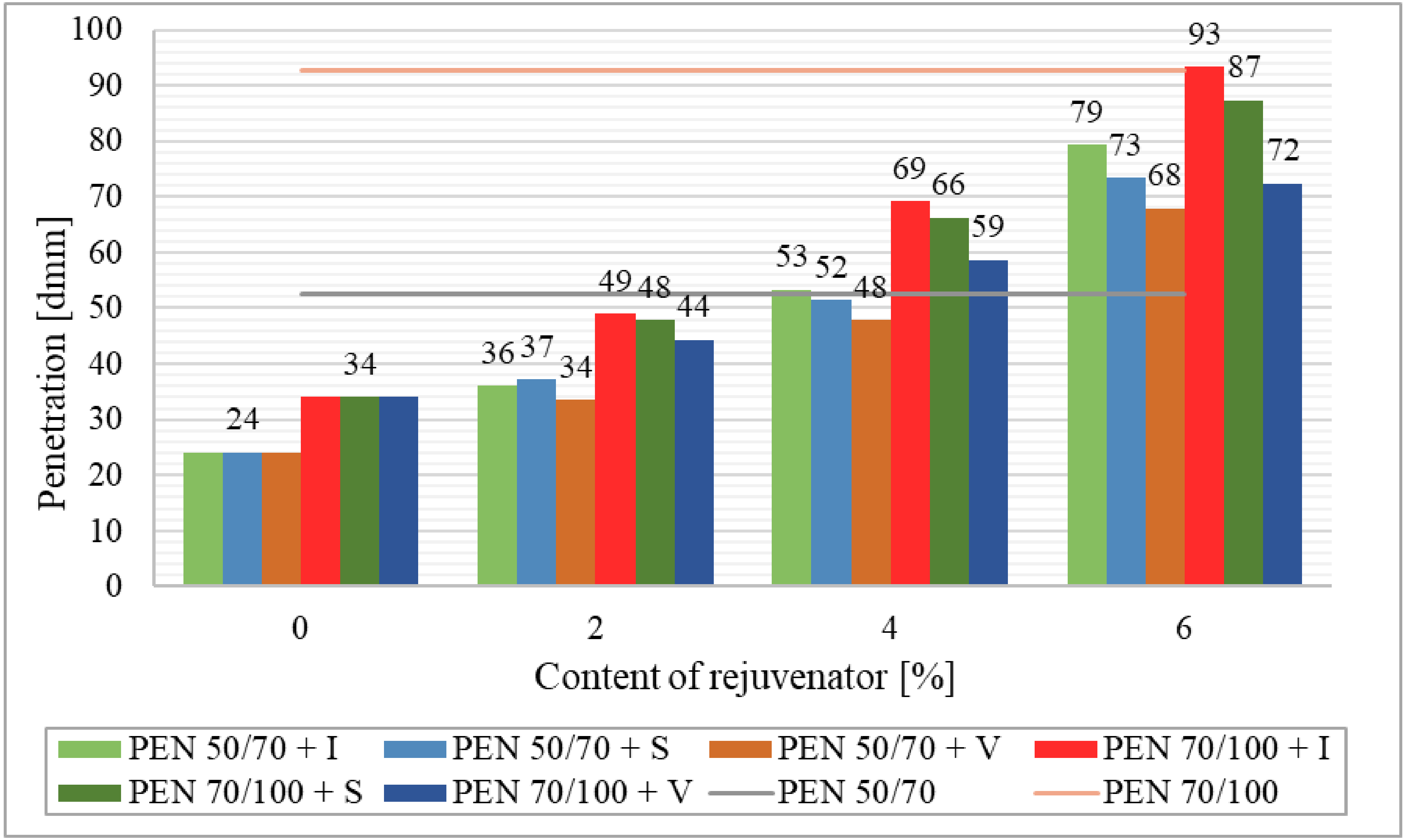

Bagela Asphalt Recycler


SIMEX
CAT

Various types of Recycling Agents have **different impacts on the chemical and physical properties of an aged binder**, and thus the restoring properties of aged binder are a **function of the Recycling Agent type and quantity**.

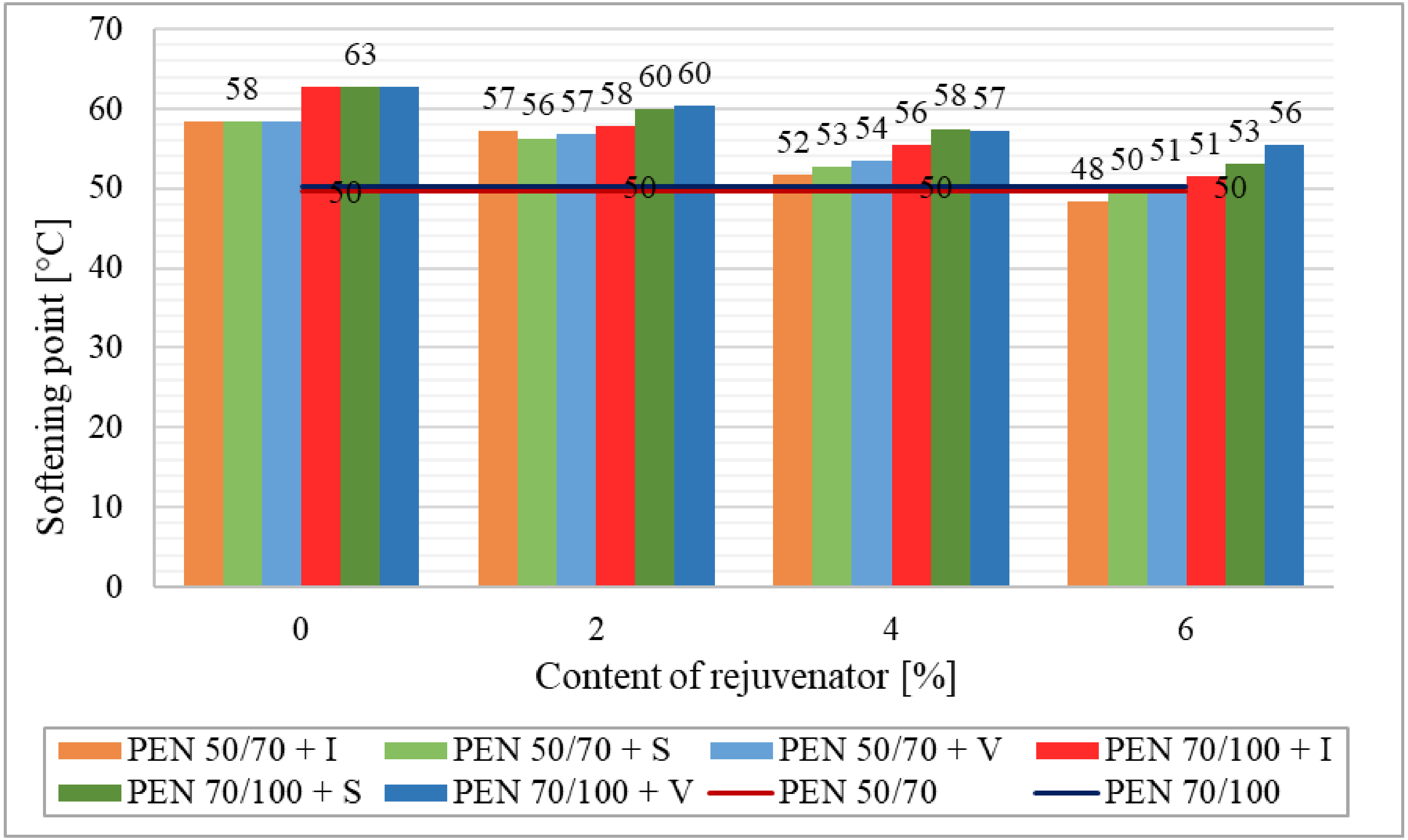


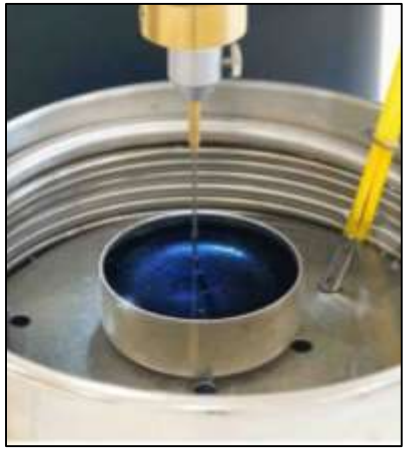


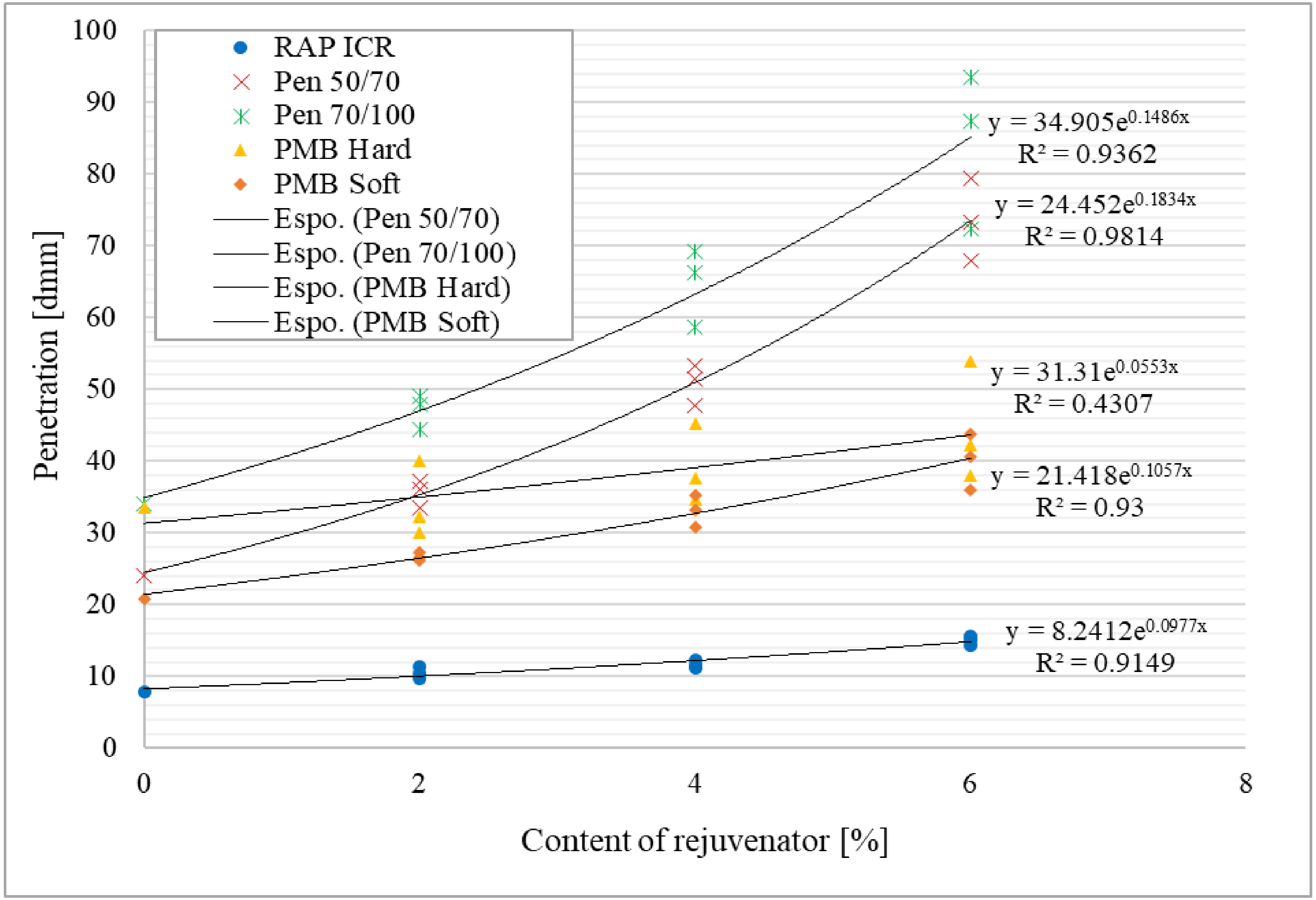


Penetration [dmm]
100
90
80
70
60
50
40
30
20
10
0
24
34
36
37
34
49
48
44
53
52
48
69
66
59
79
73
68
93
87
72
0
2
4
6
Content of rejuvenator [%]
PEN 50/70 + I
PEN 50/70 + S
PEN 50/70 + V
PEN 70/100 + I
PEN 70/100 + S
PEN 70/100 + V
PEN 50/70
PEN 70/100

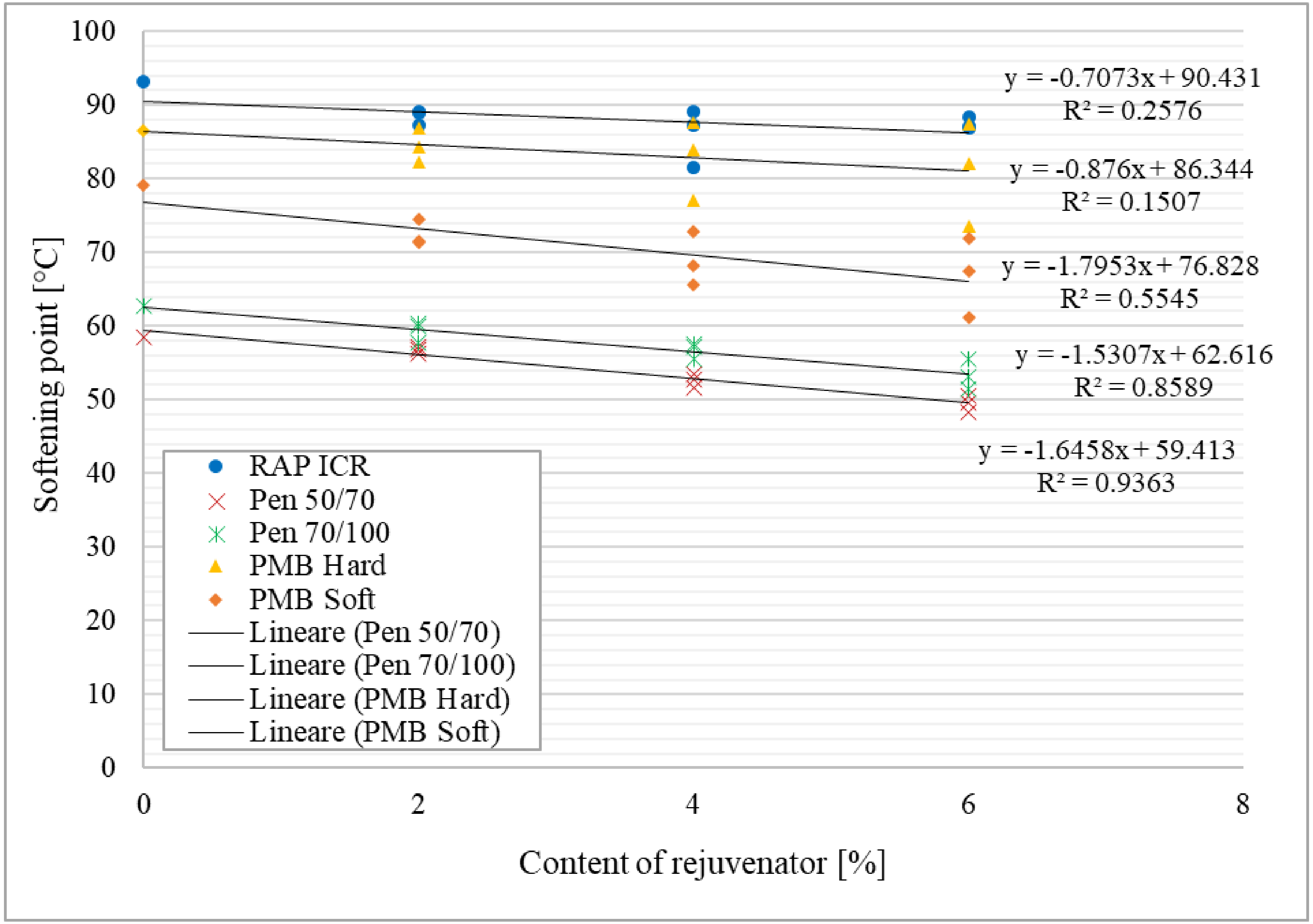

100


Softening point [°C]
70
60
50
40
30
20
10
0
58
63
57 56 57 58 60 60
52 53 54 56 58 57
48 50 51 51 53 56
50
50
50
50
0
2
4
6
Content of rejuvenator [%]
PEN 50/70 + I
PEN 50/70 + S
PEN 50/70 + V
PEN 70/100 + I
PEN 70/100 + S
PEN 70/100 + V
PEN 50/70
PEN 70/100

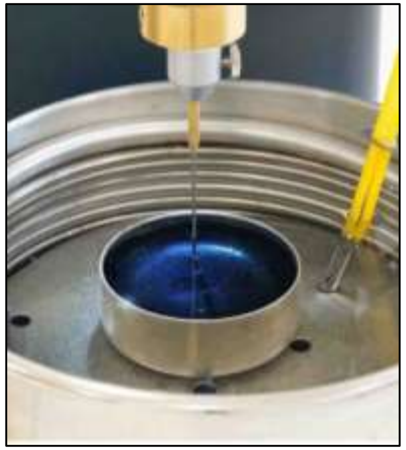


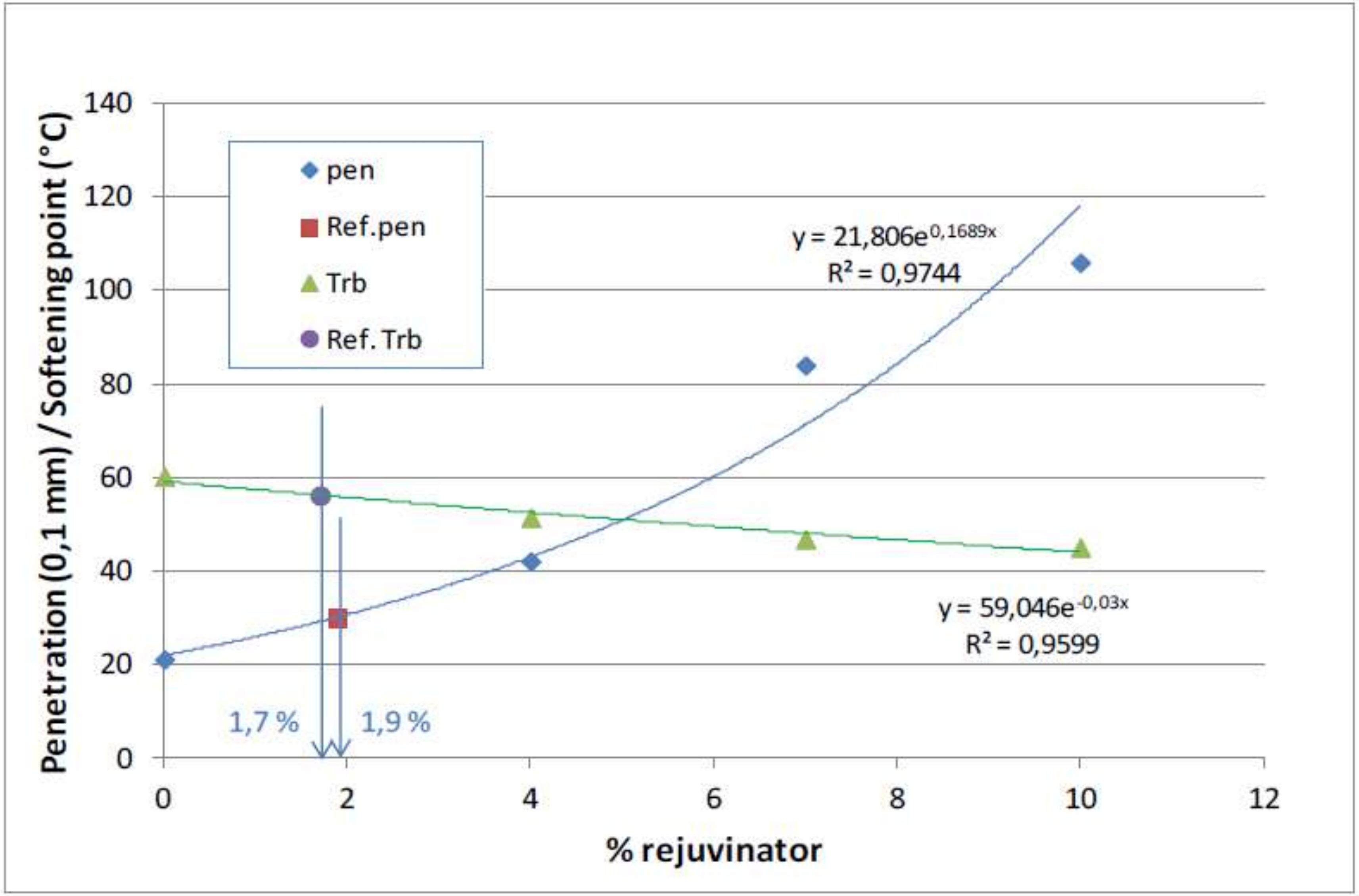


Penetration [dmm]
Content of rejuvenator [%]
RAP ICR
Pen 50/70
Pen 70/100
PMB Hard
PMB Soft
Espo. (Pen 50/70)
Espo. (Pen 70/100)
Espo. (PMB Hard)
Espo. (PMB Soft)
y = 34.905e0.1486x
R² = 0.9362
y = 24.452e0.1834x
R² = 0.9814
y = 31.31e0.0553x
R² = 0.4307
y = 21.418e0.1057x
R² = 0.93
y = 8.2412e0.0977x
R² = 0.9149



Softening point [°C]
Content of rejuvenator [%]
y = -0.7073x + 90.431
R² = 0.2576
y = -0.876x + 86.344
R² = 0.1507
y = -1.7953x + 76.828
R² = 0.5545
y = -1.5307x + 62.616
R² = 0.8589
y = -1.6458x + 59.413
R² = 0.9363
RAP ICR
Pen 50/70
Pen 70/100
PMB Hard
PMB Soft
Lineare (Pen 50/70)
Lineare (Pen 70/100)
Lineare (PMB Hard)
Lineare (PMB Soft)





Penetration (0,1 mm) / Softening point (°C)
140
120
100
80
60
40
20
0
pen
Ref.pen
Trb
Ref. Trb
y = 21,806e^0,1689x
R² = 0,9744
y = 59,046e^-0,03x
R² = 0,9599
1,7 %
1,9 %
0
2
4
6
8
10
12
% rejuvinator

# 5- Wearing course spot maintenance: patching/inlays

Patching and filling potholes – small areas of defects.

**Potholes** are typically ‘small’ areas (< 300mm maximum dimension) and/or shallow (< 50mm depth) defects in the surface course of a road, but if left untreated they will expand in both area and depth, often combining with other defects nearby to become more like ‘trenches’.

Sometimes as a matter of road user safety, **potholes are filled temporarily until an effective permanent repair can be put in place**. These temporary treatments are carried out using asphalt mixes that have been **specially designed to be workable for long periods of time** for ease of application and compaction to profile. (EAPA).



WHAT?

# Inlay treatments are similar to patch repairs, but carried out over a more extensive area

They are made typically in or between wheel tracks but **not to the full width of the pavement**, e.g. one (or part of one) lane of a multiple lane road. Inlays should be excavated and reinstated following the **same principles as patches, but with the awareness that the material failure may be to a greater depth**.

# Traditional hot-mix pothole pathing procedure


1. On-site production of mixtures

2. Crush the pothole area

3. Primer coating application

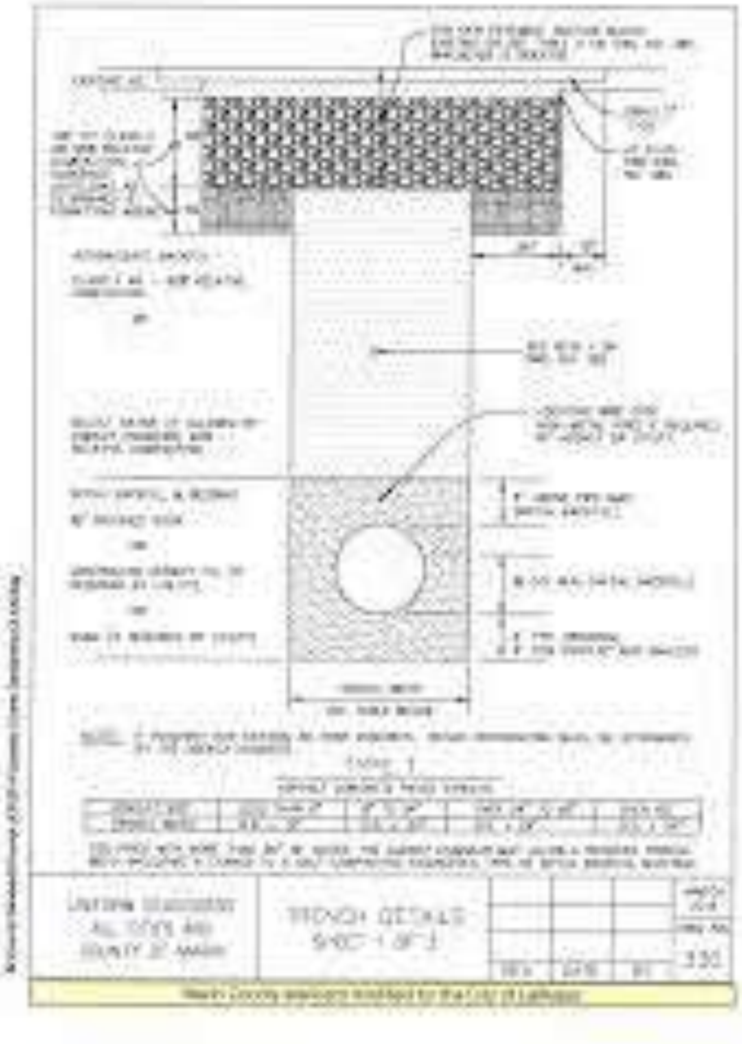
4. Applying of the mixture

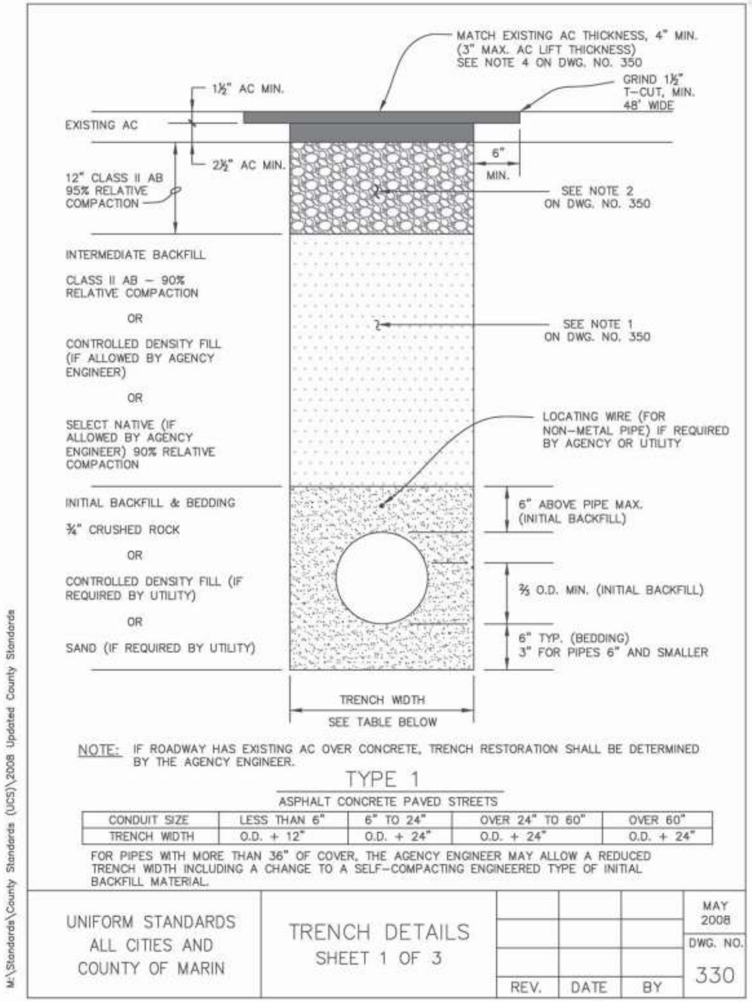
5. Compaction of laying surface

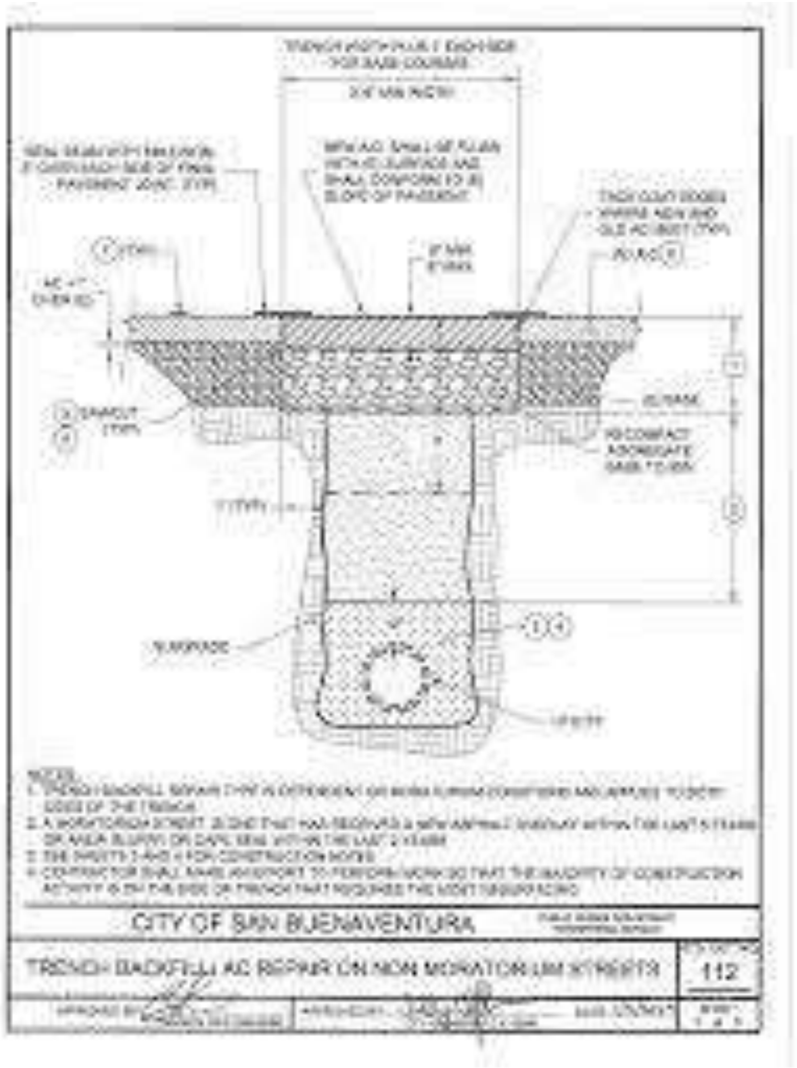
# Cold patching products: often 100% recycled materials (various)




# Repairing trenches: a lot of specifications



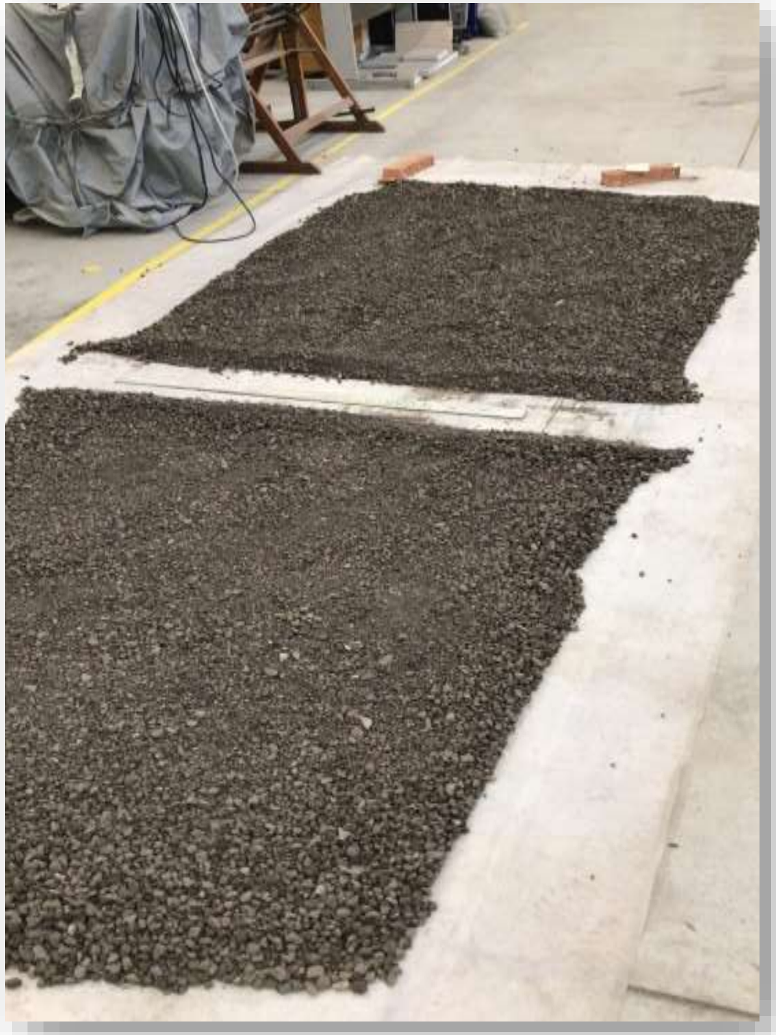



Existing pavement
Patch
Existing pavement
Existing base
Backfill
Existing base


WHAT?

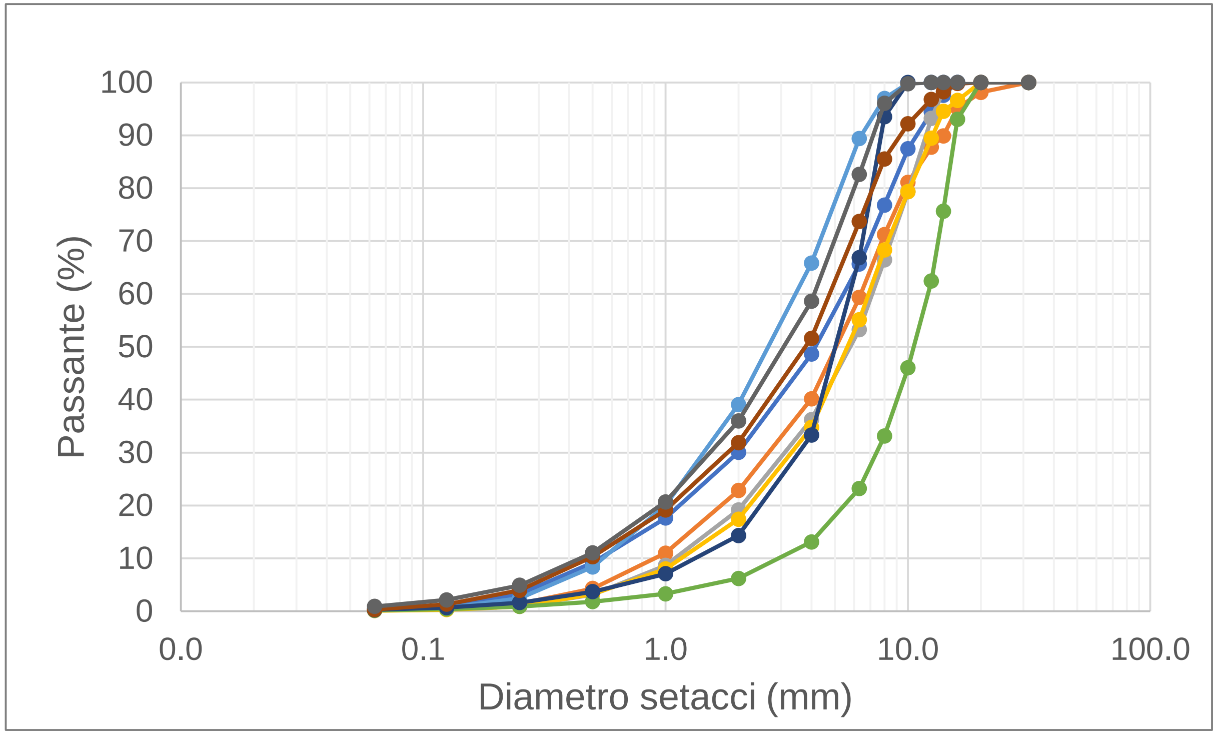
# 6- Ex 1: plant produced hot/warm asphalt mix with 100% RAP



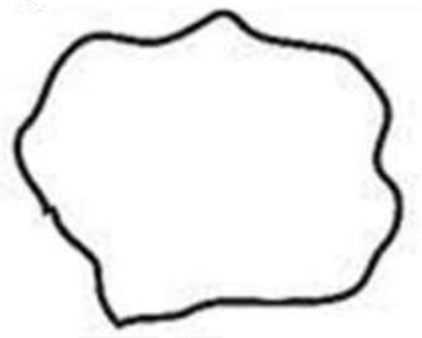
- **Material F1**, sieved and treated RAP 0/20;
- **Material F2**, RAP;
- **Material F3**, sieved RAP 0/20;
- **Material F4**, mix 73% F1 + 23% F3;
- **Material F5**, sieved and treated RAP 0/10;
- **Material F6**, sieved and treated RAP 0/20;
- **Material F7**, sieved and treated RAP 0/10;
- **Material F8**, sieved and treated RAP 0/20;
- **Material F9**, sieved and treated RAP 0/10;

307 Samples

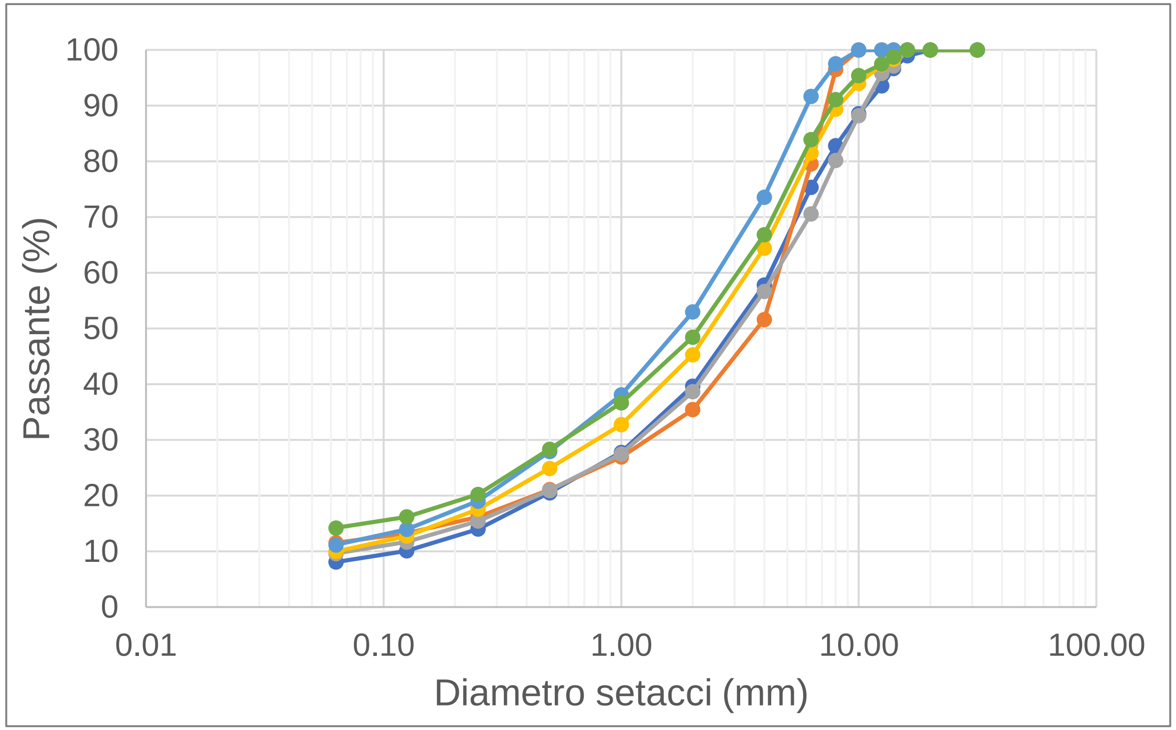
790 Tests




Black gradation



White gradation



# Lab testing procedures:

SGC Compaction
110°C-50 grts (EN 12697-31)

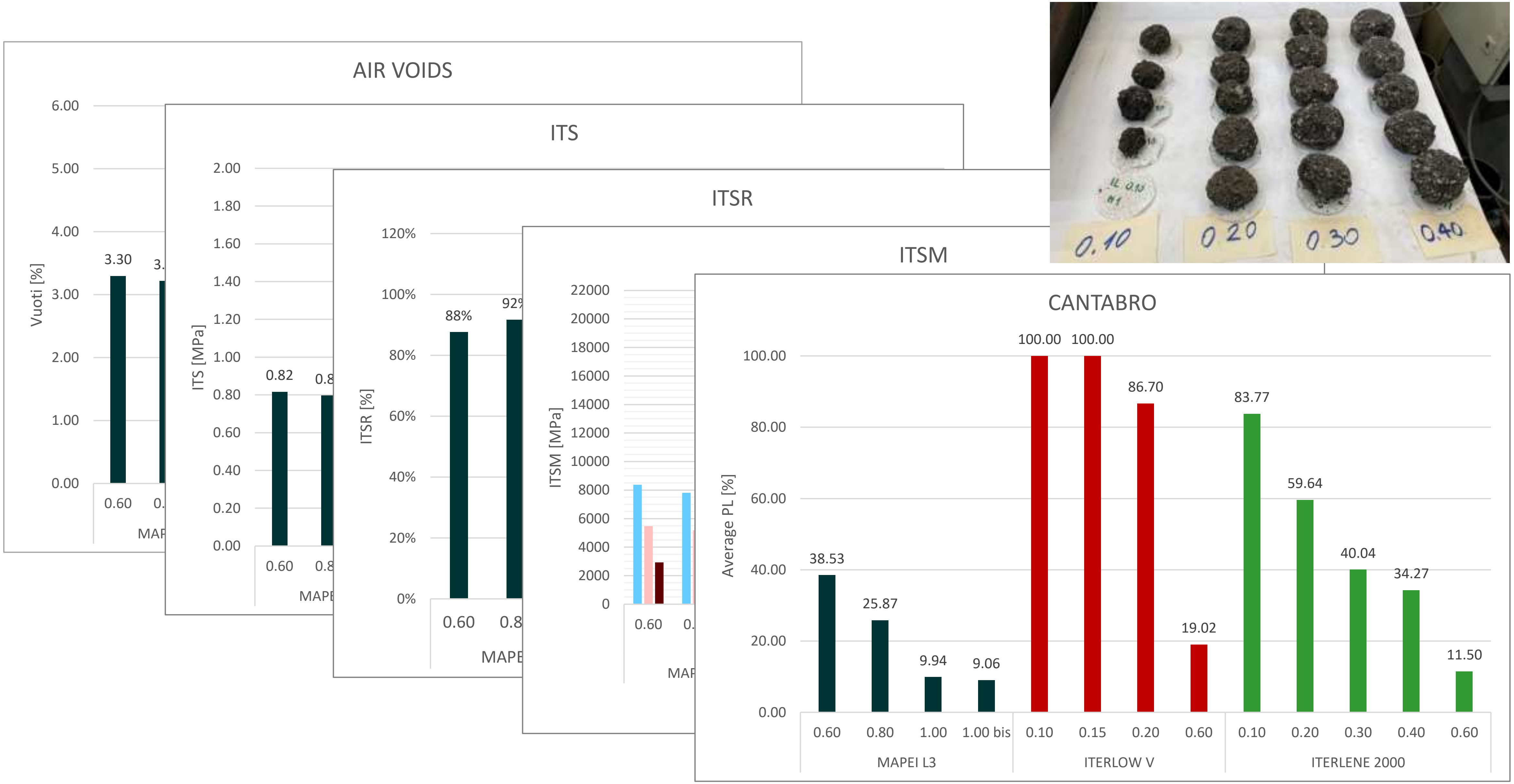

Air voids
(EN 12697-8)

ITS
(EN 12697-23)

ITSM
(EN 12697-26)

ITSR
(EN 12697-12)

Cantabro
(EN 12697-17)


AIR VOIDS
Vuoti [%]
3.30
ITS
ITS [MPa]
0.82
ITSR
ITSR [%]
88%
ITSM
ITSM [MPa]
CANTABRO
Average PL [%]
38.53
25.87
9.94
9.06
100.00
100.00
86.70
19.02
83.77
59.64
40.04
34.27
11.50
0.60
0.80
1.00
1.00 bis
0.10
0.15
0.20
0.60
0.10
0.20
0.30
0.40
0.60
MAPEI L3
ITERLOW V
ITERLENE 2000
0.10
0.20
0.30
0.40

# Plant hot production:

RAP from Stockpile

↓

Recycling Agent

↓

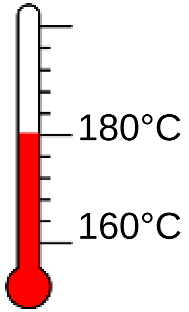
Heating and Mixing

↓

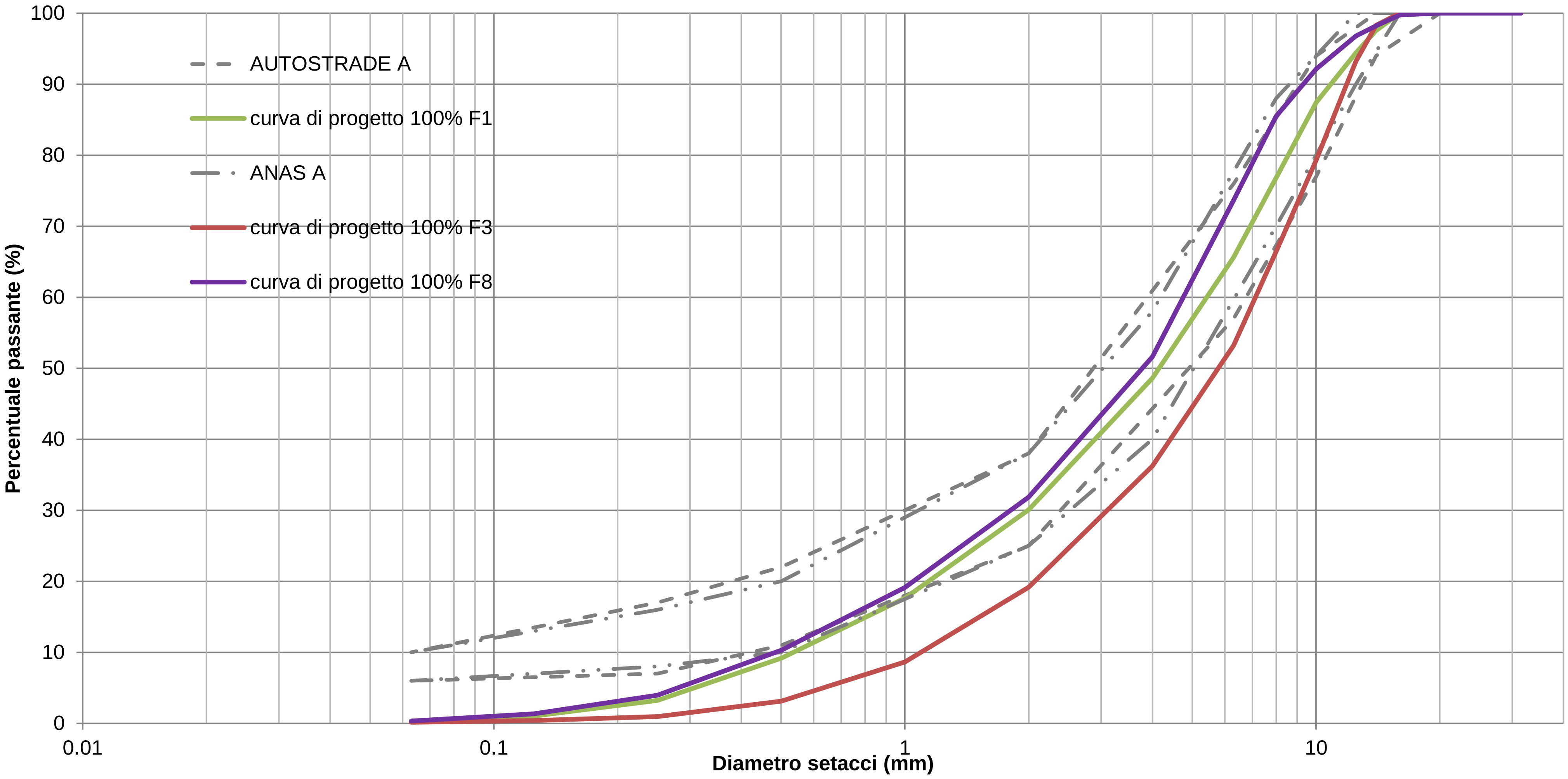
Loading on truck

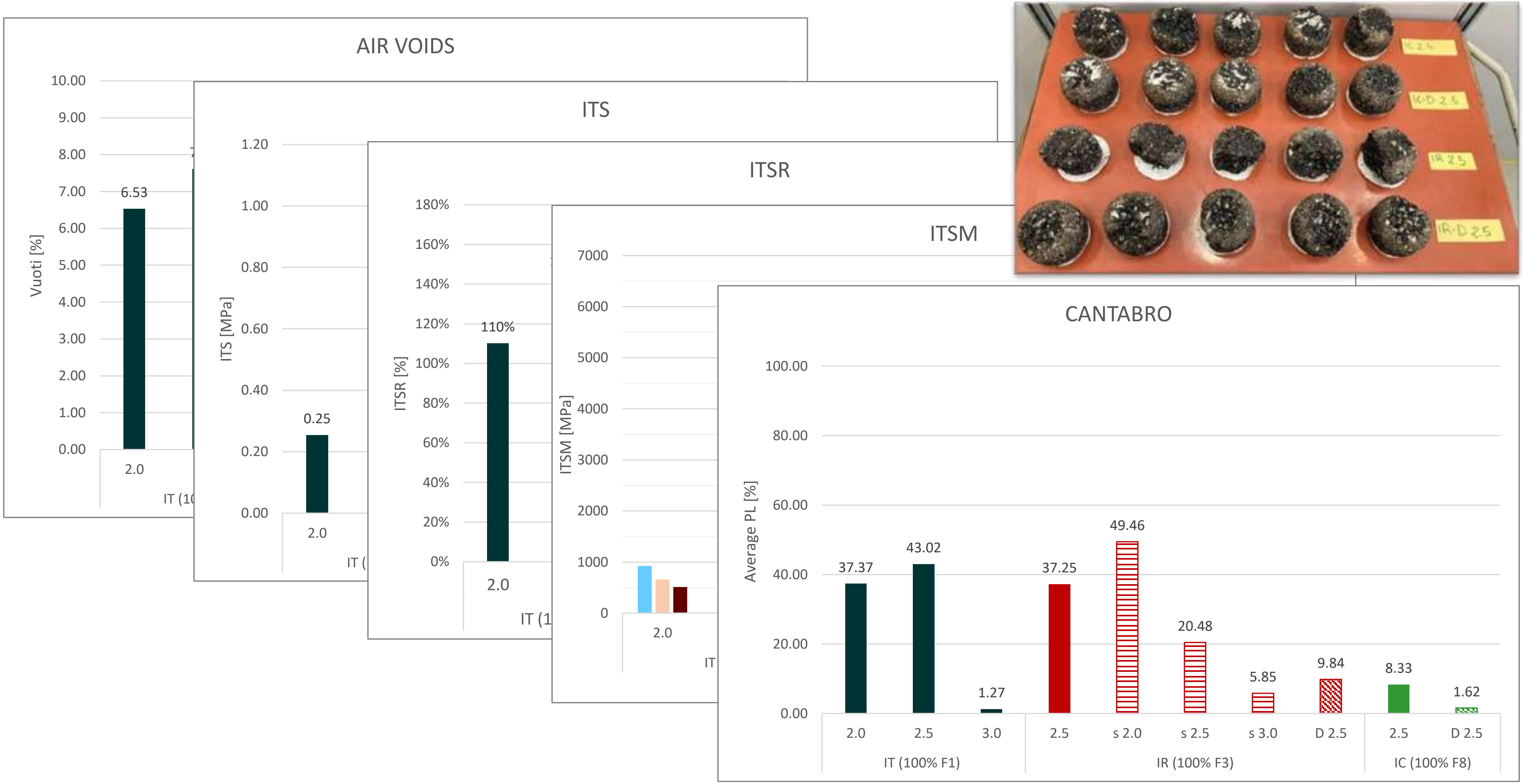
↓

Work site

# 7- Example 2: plant produced cold asphalt mix with 100% RAP




AIR VOIDS
Vuoti [%]
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
6.53
2.0
ITS
ITS [MPa]
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.25
2.0
ITSR
ITSR [%]
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
110%
2.0
ITSM
ITSM [MPa]
7000
6000
5000
4000
3000
2000
1000
0
2.0
CANTABRO
Average PL [%]
100.00
80.00
60.00
40.00
20.00
0.00
37.37
43.02
1.27
37.25
49.46
20.48
5.85
9.84
8.33
1.62
2.0
2.5
3.0
2.5
s 2.0
s 2.5
s 3.0
D 2.5
2.5
D 2.5
IT (100% F1)
IR (100% F3)
IC (100% F8)

# Plant cold production:

Stockpile

↓

BLEND truck mixer

↓

Recycling Agent

1-2 days? ↓

Cement binder and mixing

↓

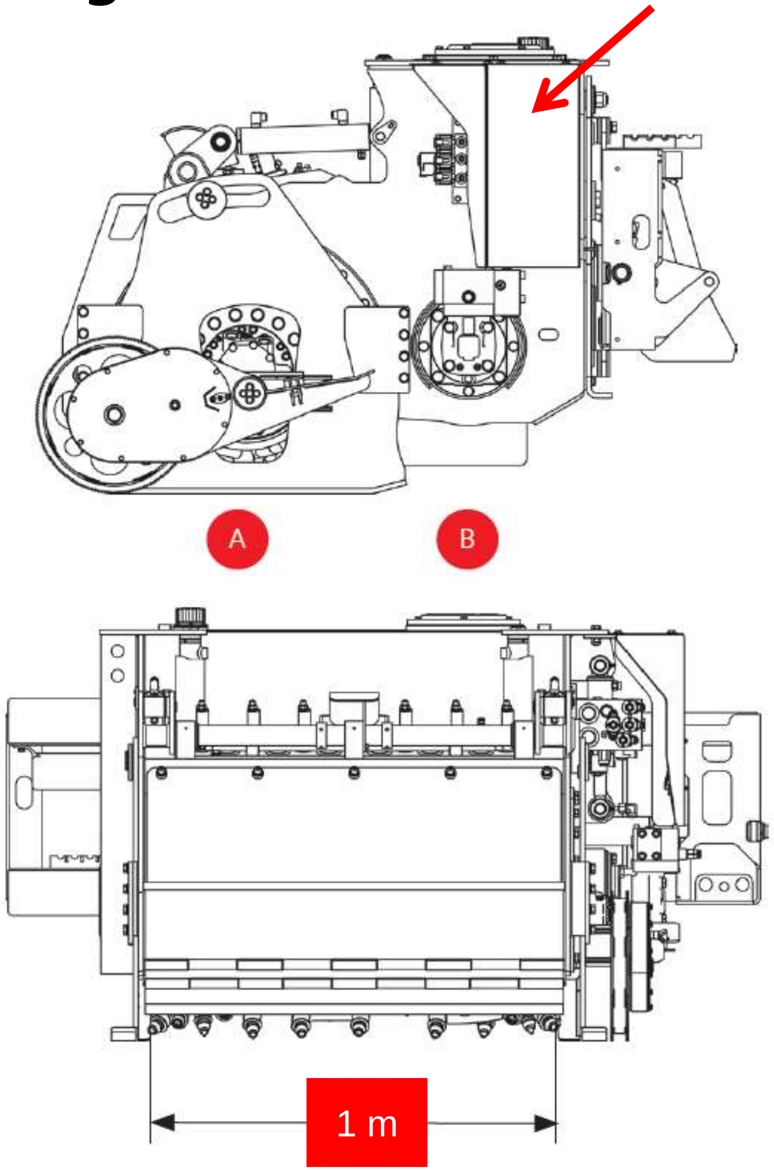
Loading on truck

↓

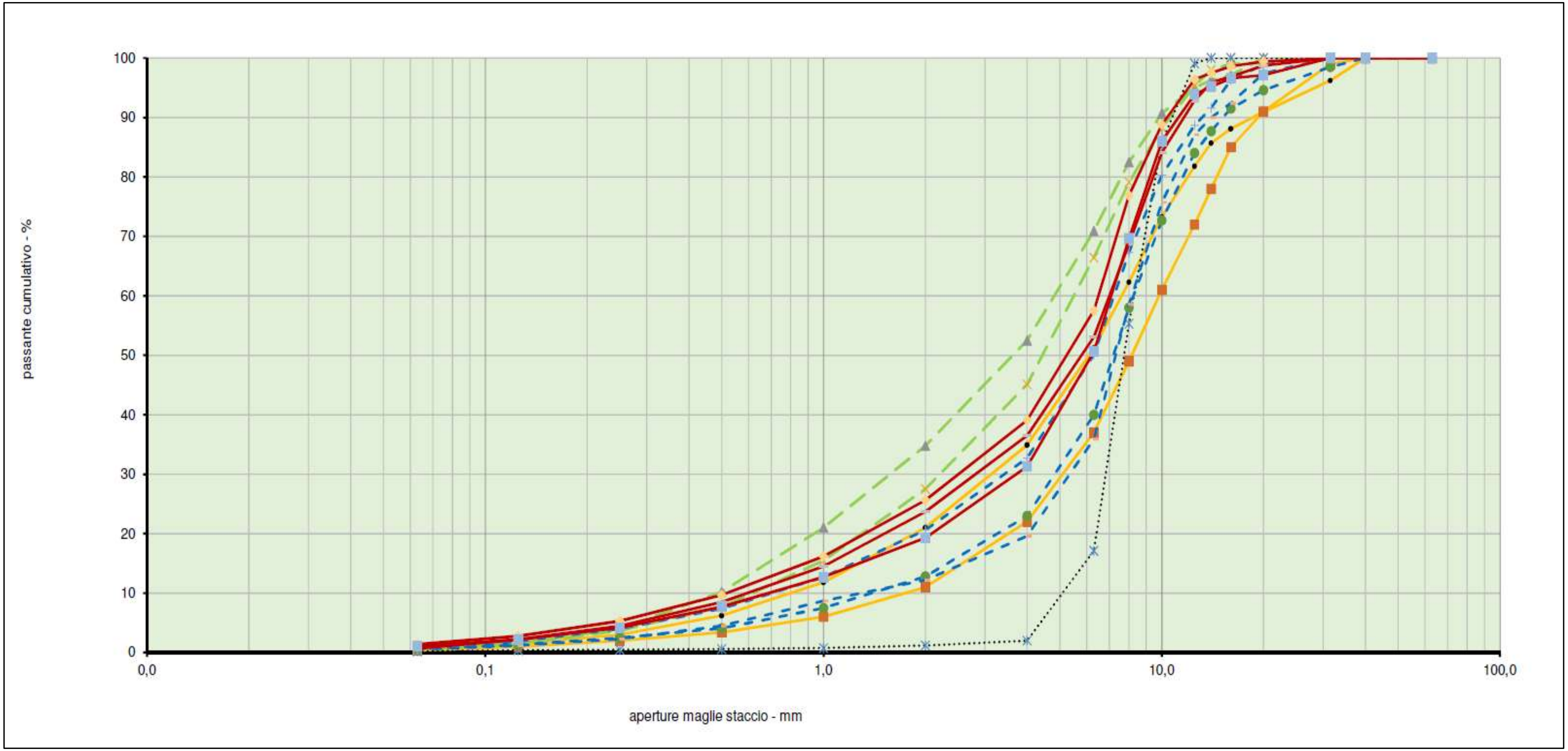
To work site

# 8- Example 3: in situ 100% RAP recycling with milling machine

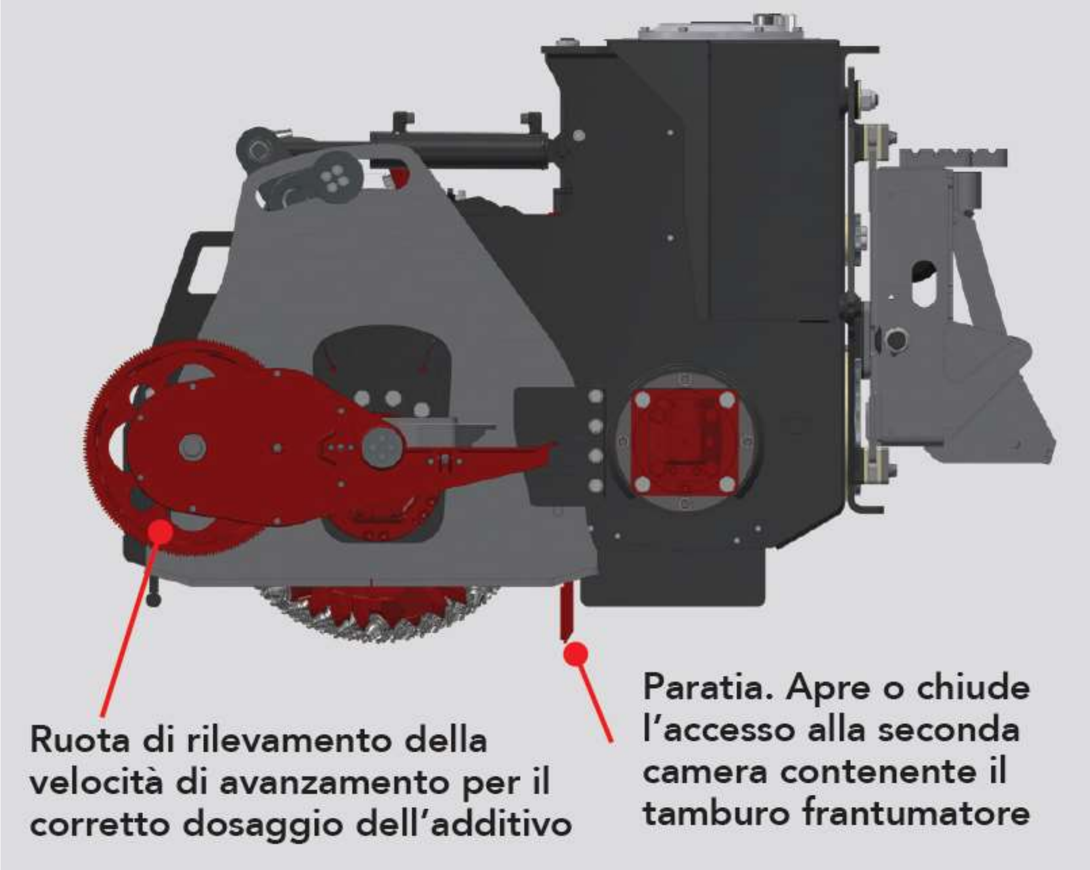
# *Wearing course in situ recycling: 100% RAP + additive*

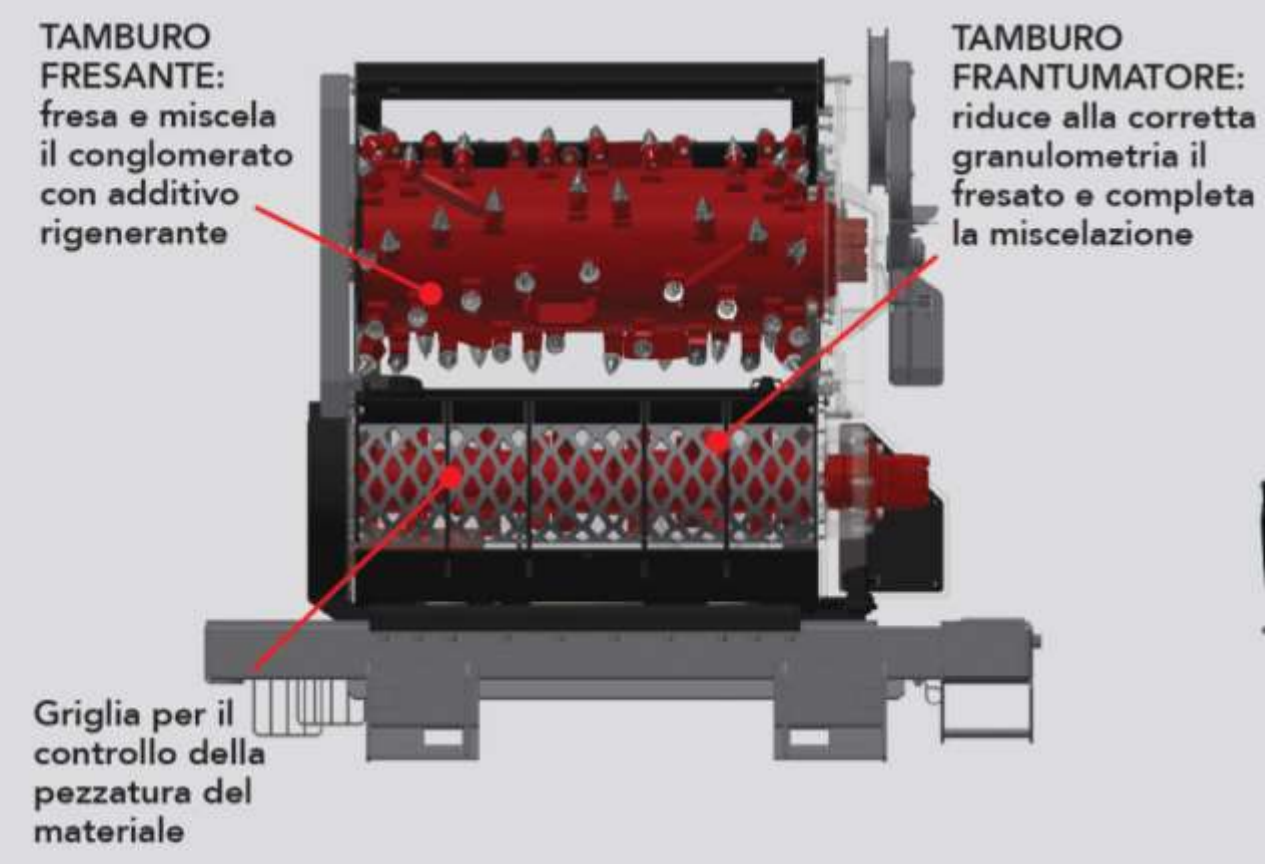



# Setting up the milling, crushing and screening system



# Double drum, mobile partition and sieving grid



# Optional: additional binder and/or RAP

# *1 m width recycling and multiple sections*

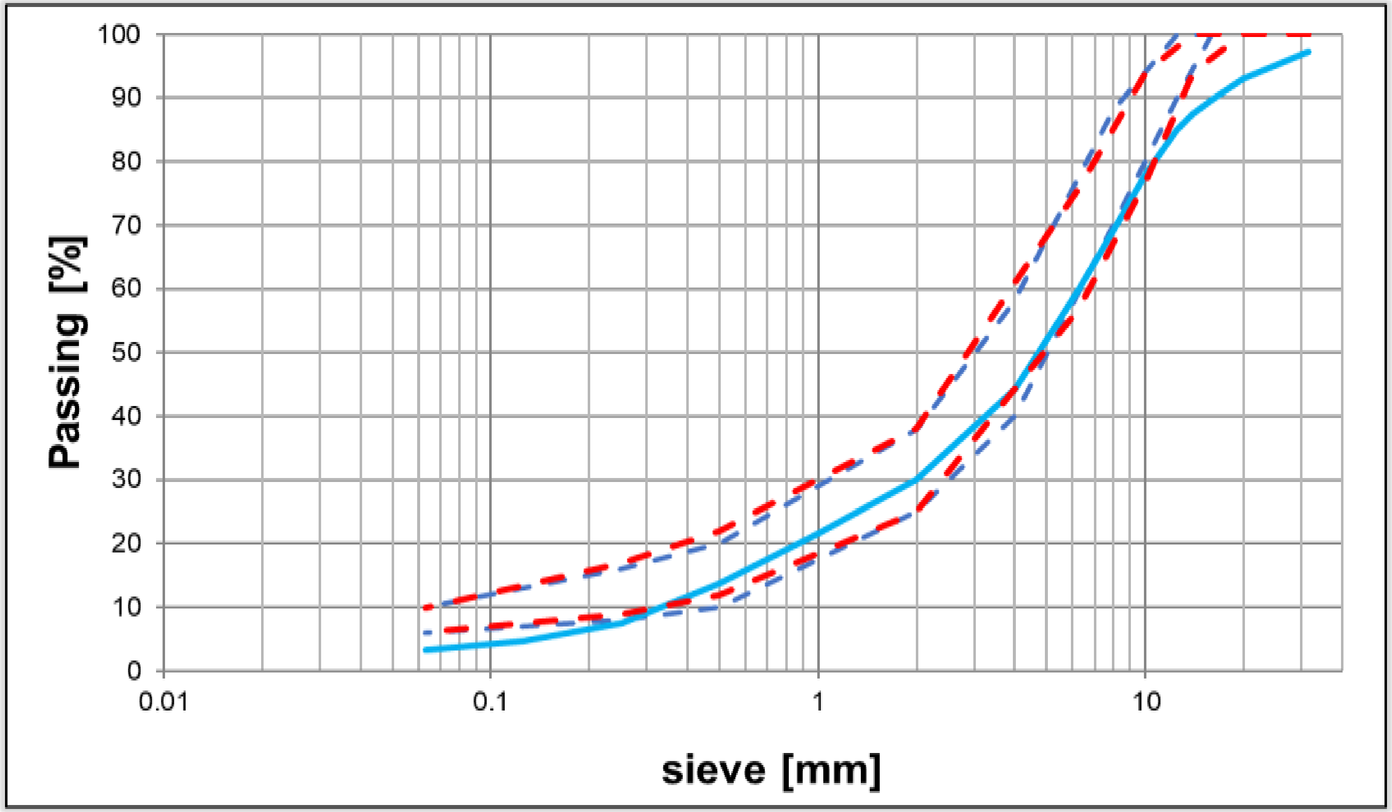
# Recycled material: ready for compaction

# *Recycled material: compacted surface*

# Test sections: machine set up and mix proportions

| N° OF SITE | SECTION | DEPTH OF MILLING | N° OF STEPS (without compaction) | % OF CHEMICAL ADDITIVE | NOTES |
|---|---|---|---|---|---|
| 1st SITE | 1 | 5 cm | 4 + compaction | 2% + water | Two milling process to obtained the desired material but the chemical additive is less than the expected |
| | 2 | 5 cm | 4 + compaction | 3,5% + water | Same milling process as section 1 but the chemical additive seems the optimal one |
| | 3 | 5 cm | 4 + compaction | 4,5% + water | Same milling process as previous sections but the material is too oily |
| 2nd SITE | 4 | 5 cm | 4 + compaction | 3,5% + water | After the optimization of the milling machine it is decided to develop this section as the second one |
| | 5 | 5 cm | 3 + compaction | 2,5% + water | It is characterized by one milling process to open the sectiont with two milling drums working |
| 3rd SITE | 6 | 5 cm | 3 + compaction | 2,5% + water | It is noted from the first two section of the third site that the quantity of chemical additive it is not compliant to the expected one. The material seems darker and oilier. |
| | 7 | 5 cm | 3 + compaction | 3,5% + water | |
| | 8 | 5 cm | 3 + compaction | 4,5% + water | Too much additive is present in this two last section of the third site. The nozzle do not spray the required doasge. |
| | 9 | 5 cm | 3 + compaction | 5,5% + water | |
| 4th SITE | 10 | 5 cm | 3 + compaction | 2,5% | The fourth site is developed the same day as the third. The chosen dosage of chemical additive is the one of section 6 and 7. Instead of adding the cement and the water , in these two sections is added the filler. |
| | 11 | 5 cm | 3 + compaction | 3,5% | |

# *Variability of RAP: controlling gradation*




RAP is made of particles or clusters of particles. Milling operations can significantly. **change the original gradation curve of the recycled material**

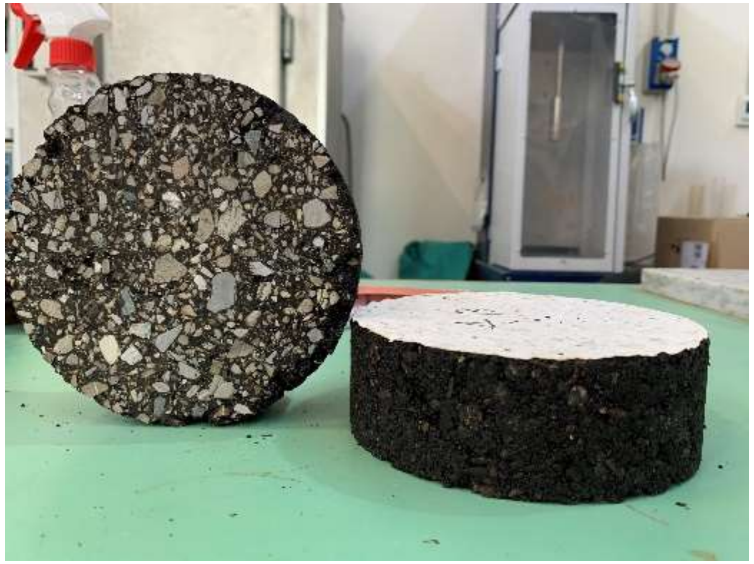
In situ a simple/reliable check can be made on the **amount of fines passing the 1 mm sieve**. It should range bewteen 20 and 30%.

# *Laboratory testing and upscaling to a real trial site*

LABORATORY

***Tests***

- *Va (EN 12697-8)*
- *ITS (EN 12697-23)*
- *ITSR (EN 12697-12)*
- *ITSM (EN 12697-26)*



TRIAL SITES

***San Giovanni in Persiceto (BO)***

- *1st site via Astengo*
- *2nd site via Astengo*
- *via Einstein x 2*


***Zola Predosa (BO)***

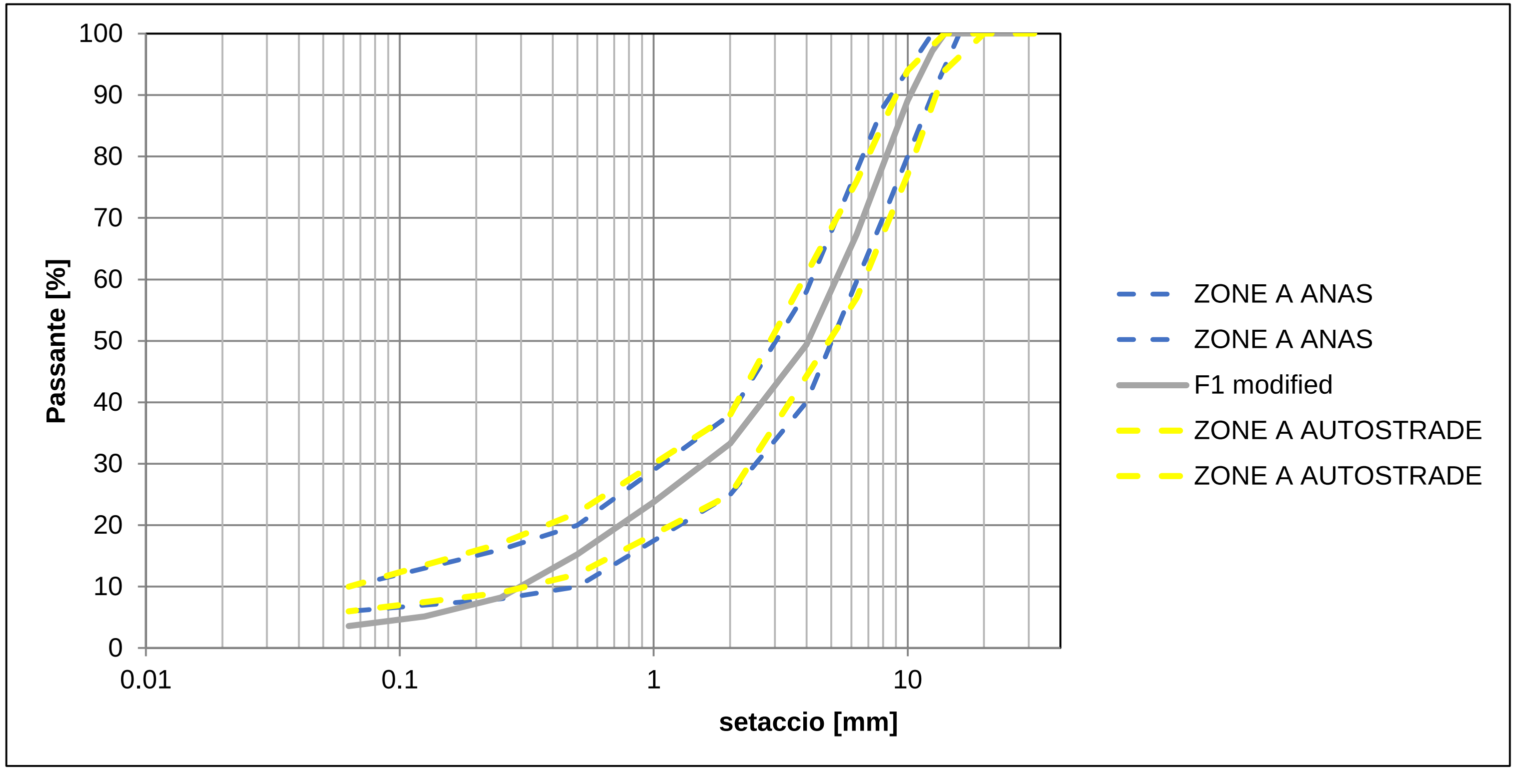
- *via Piemonte*
- *via Masetti*

***In situ tests***

- *Skid resistance (UNI EN 13036-4)*
- *Sand patch (UNI EN 13036-1)*
- *Bonding: 100 mm cores*

# *Example of optimized mix with recycling agent and cement*

*RAP GRADATION (EN 933-1)*




*MIX DESIGN*

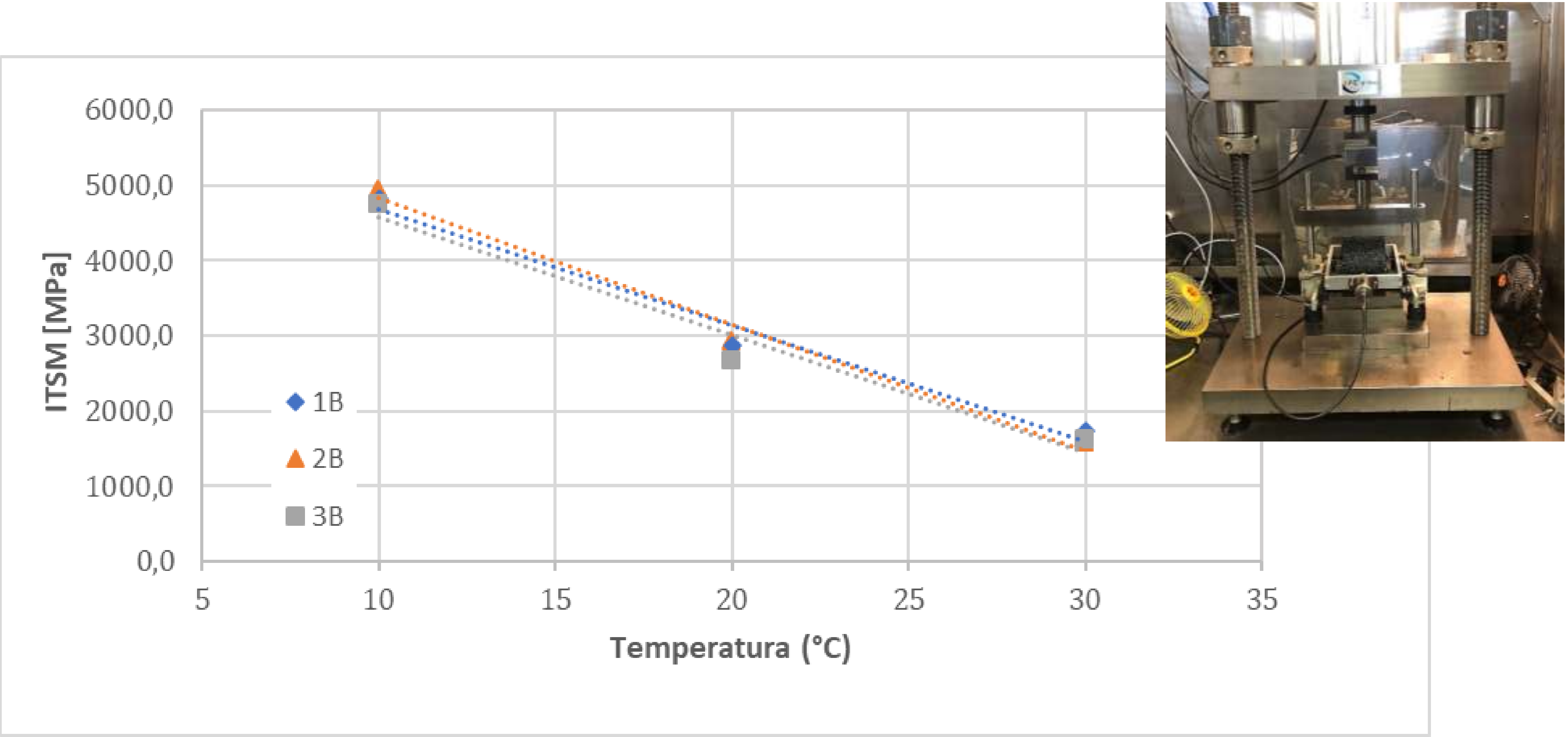
**1,5% Cement (Portland 32,5)**

**2,0% Recycling agent**

| TEST | AVG RESULTS |
|---|---|
| **Air voids** | 12.92 [%] |
| **ITS dry** | 0.59 [MPa] |
| **ITS wet** | 0.30 [MPa] |
| **ITSM (10 °C)** | 4837 [MPa] |
| **ITSM (20 °C)** | 2820 [MPa] |
| **ITSM (30 °C)** | 1639 [MPa] |

***150 diam and 100 mm thickness***
***SGC compaction: 30 gyrations***
***Room temperature***

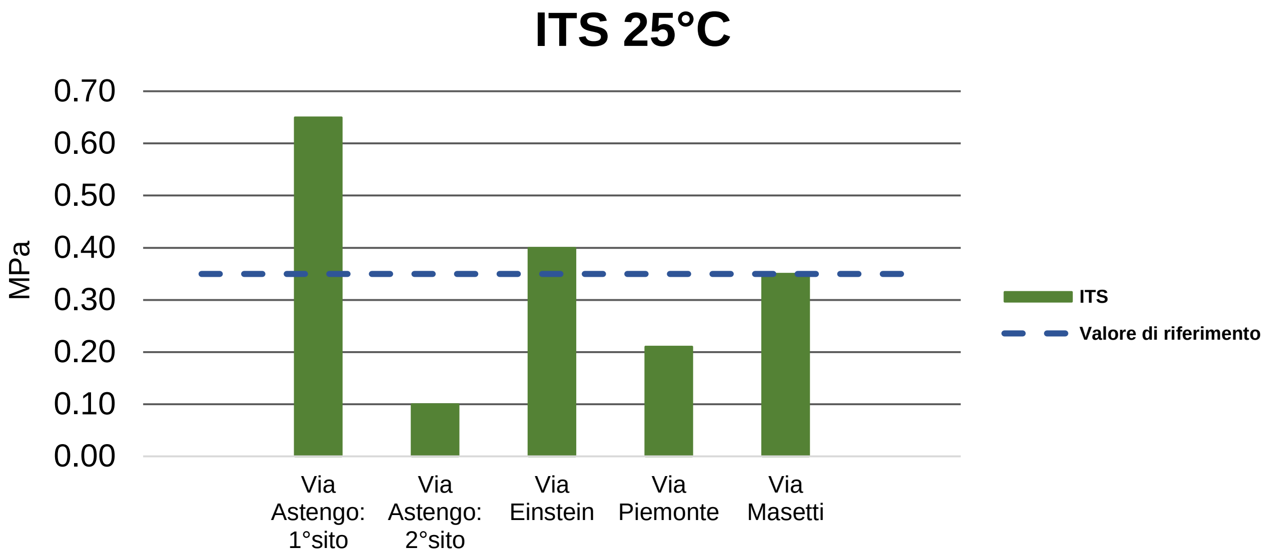
# *ITSM at different temperatures*



# Testing cores from different trial sites

*ITS – EN 12697-23*

| Site | ITS [MPa] | Ref. value [MPa] |
|---|---|---|
| *San Giovanni in Persiceto* | | |
| 1°sito via Astengo | 0.65 | **> 0.35** |
| 2° sito via Astengo | 0.10 | |
| via Einstein | 0.40 | |
| *Zola Predosa* | | |
| via Piemonte | 0.21 | **> 0.35** |
| via Masetti | 0.35 | |




*Va% – Voids*

| Site | Va% | Ref. Value [%] |
|---|---|---|
| *San Giovanni in Persiceto* | | |
| 1°sito via Astengo | 2.5 | **< 4.0** |
| 2° sito via Astengo | 1.8 | |
| via Einstein | 14.8 | |
| *Zola Predosa* | | |
| via Piemonte | 7.9 | **< 4.0** |
| via Masetti | 11.1 | |

# *Very good bond at interface*

# *In situ surface characterization*

## Skid resistance EN 13036-4

| Site | PTV | Ref. value |
|---|---|---|
| *San Giovanni in Persiceto* | | |
| 1°sito via Astengo | 72 | **> 55** |
| 2° sito via Astengo | 66 | |
| via Einstein | 79 | |
| *Zola Predosa* | | |
| via Piemonte | 66 | **> 55** |
| via Masetti | 65 | |

## Sand patch EN 13036-1

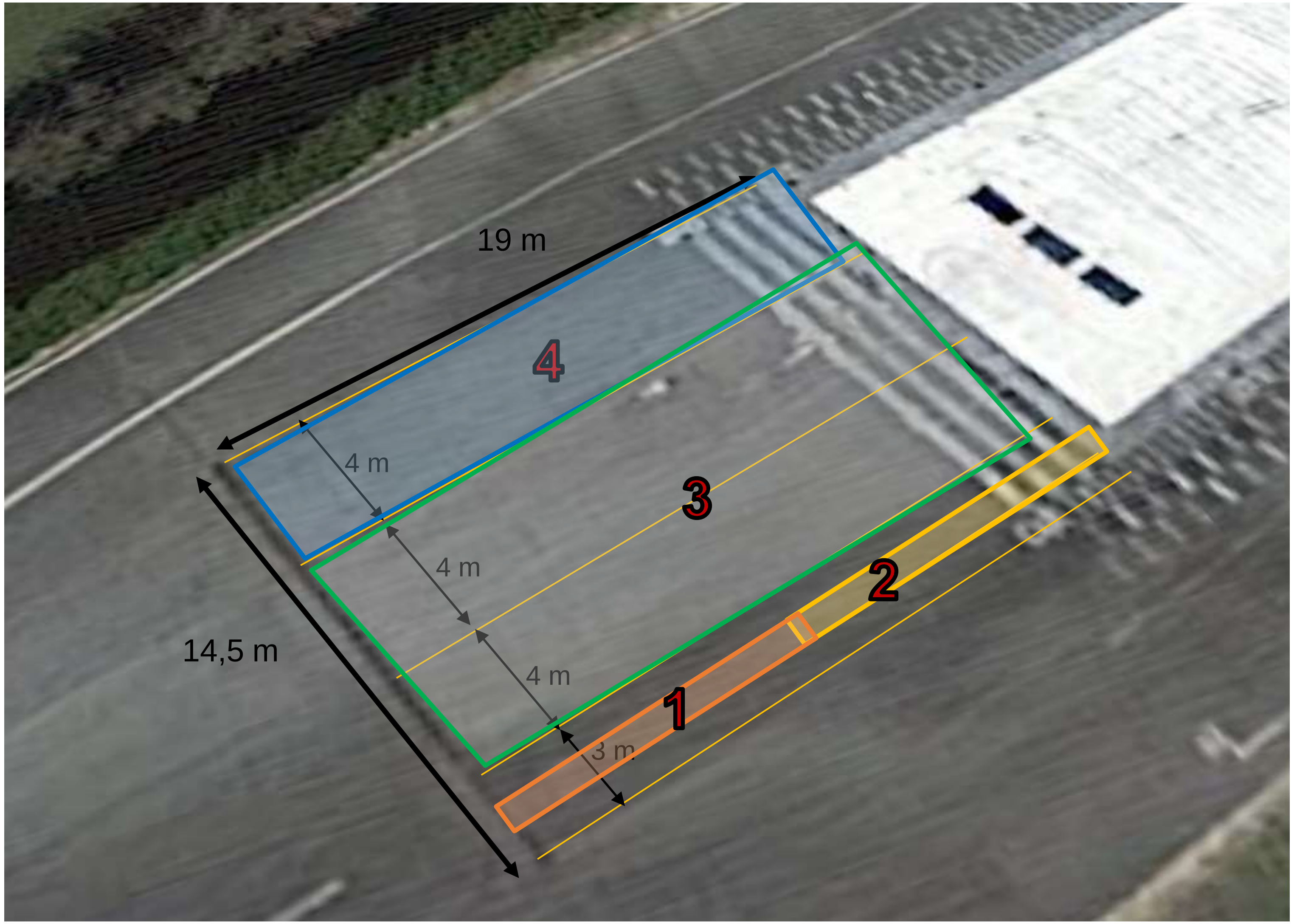
| Site | HS | Ref. value |
|---|---|---|
| *San Giovanni in Persiceto* | | |
| 1°sito via Astengo | 0.37 | **> 0.40** |
| 2° sito via Astengo | 0.25 | |
| via Einstein | 0.51 | |
| *Zola Predosa* | | |
| via Piemonte | 0.60 | **> 0.40** |
| via Masetti | 0.55 | |

# *Some remarks on the in situ 100% recycling of wearing course layers*

- Lab preliminary testing showed that **it is possible to produce cold asphalt mixes with good performance** for their intended use.
- Alike full depth recycling, the surface recycling technology is a **valid and sustainable solution for pavement maintenance**. The mechanical and functional performance are good. Bonding, without tack coat, is also very good.
- A number of different **recycling agents are being tested** to assess their use with the recycling machine.
- Larger surfaces can be treated with the **use of a traditional paver**.

# Road Safety Training Centre: Vallelunga (ROME)

# Road Safety Training Centre: Vallelunga (ROME)



# Road Safety Training Centre: Vallelunga (ROME)


# *Road Safety Training Centre: Vallelunga (ROME)*

# Thanks!
# CS