



**Hrvatsko asfaltno društvo**



**Croatian asphalt association**

**Projektiranje asfaltnih mješavina s visokim sadržajem recikliranog asfalta**

**Designing HMA Mixtures With High RAP Content**

**Jean-Paul Dupuy, COLAS**

**Međunarodni seminar ASFALTNI KOLNICI 2016  
International seminar ASPHALT PAVEMENTS 2016**

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# Summary

- European standard
- RA identification
- Asphalt mix designs with RAP
- HAMP solutions
- Examples of sites/studies

# European Standard EN 13108-8

Some definitions:

- **site-won asphalt :**

- milled asphalt road layers
- slabs ripped up from asphalt pavements
- asphalt from reject or surplus production.

These materials will require assessment and often processing before being suitable as a constituent material.

- **reclaimed asphalt:**

- Ready for use Asphalt constituent material, obtained after processing site-won asphalt , :
  - ✓ Identification/Selection
  - ✓ Screening
  - ✓ Crushing
  - ✓ Blending

# Site Work Reclaimed Asphalt



# RA identification (13108-8)

- When added to hot asphalt with a ratio of :
  - less than 20 % in base and binder courses and
  - less than 10 % in surface courses,

**a single sample per feedstock** may be specified (whatever the size of the feedstock).
- If one wants to use more %, more controls are necessary and it's producer responsibility to choose the frequency (at least 5 tests per feedstock):

| Level | Tons-test |
|-------|-----------|
| X     | 500       |
| Y     | 1000      |
| Z     | 2000      |

# Which controls ?

- Recovered aggregates: maximum size, grading
- Recovered Binder: content, penetration, softening point

| <u>Example in Croatia</u>                           | Penetration<br>HRN EN 1426 | Ring and ball method<br>HRN EN 1427 |
|---|----------------------------|-------------------------------------|
| Bitumen   | [mm/10]                    | °C                                  |
| Bitumen extracted from the sample of milled asphalt | 24                         | 63,0                                |
| Fresh bitumen 50/70                                 | 61                         | 48,6                                |
| Standard for 50/70                                  | 50 - 70                    | 46 - 54                             |

- Aggregate intrinsic properties (PSV) when used in wearing course

## RAP use : in short

- In wearing course : usually maxi 20-30%
- In binder or in base course: from 0 to 60% , usually ~30%
- For all traffic types (high, medium or low) after pavement design (stiffness modulus and fatigue)
- Need special equipment for HAMPs:
  - If less than 40%, few modifications: feedstock under shelter, special bin for RA, conveyor belt, etc.
  - if more than 40% in the mix, 2 parallel dryers

# Formulation of Asphalt Mix with RAP

if

< 10 % in wearing courses

or

< 20% in base courses

- **No specific study :**
  - ✓ 10% or 20% of virgin aggregates are replaced by the same RA percentage,
  - ✓ correction of bitumen dosage
- Same performances than AC without RAP
  
- Contractor's internal rules (should) demand to make a specific mix design study for controlling all characteristics of the Asphalt Mix are met even at low RAP ratios ⇒ it becomes a new formula



# Formulation of Asphalt Mix with RAP

if

> 10% in wearing courses

or

> 20% in base courses

## ➤ Specific study

- ✓ Specific Additional binder (soft or hard)
- ✓ Mineral fractions mix adaptation
  
- ✓ High importance of a proper identification, and selection, of the RAP stockpiles/origins :
  - Binder type
  - Aggregates type, quality, grading curve
- ✓ Every identified stockpile of RAP is a new constituent of the mix
- ✓ ... and must be properly stored/protected

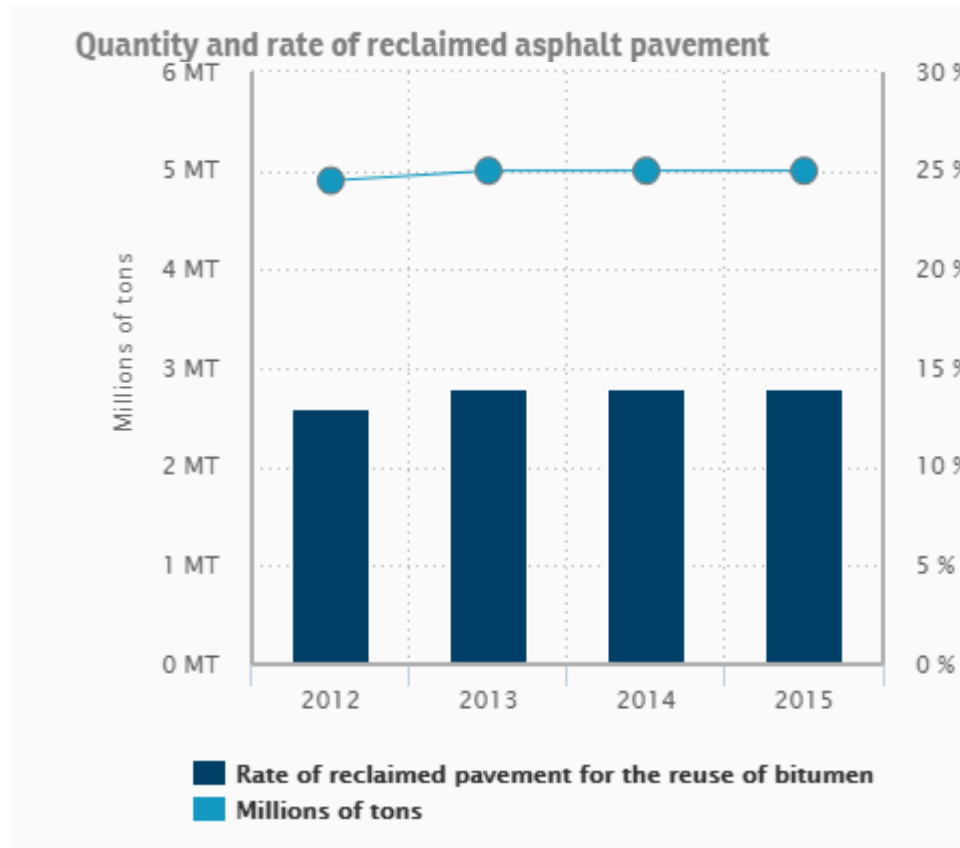
# RAP must be protected against rain and heat



| Moisture             | 1   | 2   | 3   | 4   | 5   |
|----------------------|-----|-----|-----|-----|-----|
| Without shelter in % | 4,1 | 4,1 | 4   | 3,9 | 4   |
| With shelter in %    | 0,8 | 1,1 | 1,3 | 1   | 1,1 |

# RAP use in COLAS Group, World figures 2014

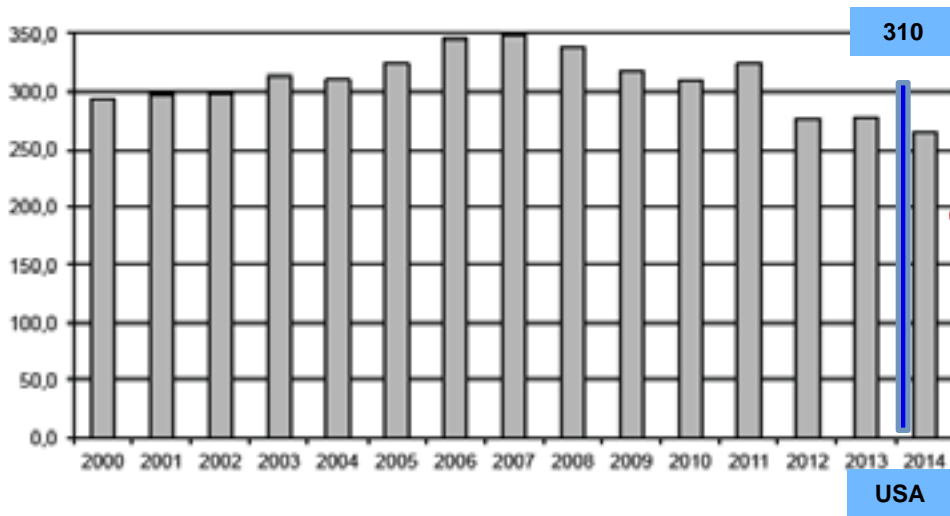
|           | Asphalt Mix  | RAP         | % RAP of total |
|-----------|--------------|-------------|----------------|
| Year 2013 | 35 152 821 t | 4 850 749 t | 13,7 %         |
| Year 2014 | 33 414 393 t | 4 921 176 t | 14,7 %         |



# Asphalt Production world figures

## GRAPH TOTAL PRODUCTION

TOTAL PRODUCTION OF HOT AND WARM MIX ASPHALT IN EUROPE (in million tonnes)



## PRODUCTION SITES

NUMBER OF PRODUCTION SITES

| Country           | Stationary Plants |         |       | Mobile plants |         |         | All plants that are fit for hot and warm recycling <sup>****</sup> |         |         |
|-------------------|-------------------|---------|-------|---------------|---------|---------|--|---------|---------|
|                   | 2012              | 2013    | 2014  | 2012          | 2013    | 2014    | 2012   | 2013    | 2014    |
| Austria           | 112               | 113     | 114   | 1             | 1       |         | 80*  | 75      | 90      |
| Belgium           | 38                | 38      | 38    | 0             | 0       | 0       | 28   | 28      | 28      |
| Croatia           | 32                | 33      | 33    | 3             | 3       | 2       | 5  | 6       | 10      |
| Czech Republic    | 105               | 101     | 101   | 2             | 2       | 2       | 70   | 70      | 70      |
| Denmark           | 40                | 38      | 38    | 3             |         |         | 38   | 36      | 36      |
| Estonia           | 10                | 9       | 9     | 13            | 11      | 10      | 11   | 13      | 13      |
| Finland           | 52                | 59      | 50    | 20            | 22      | 23      | 55   | 62      | 62      |
| France **         | 438               | 434     | 430   | 67            | 62      | 57      | > 300  | > 300   | > 300   |
| Germany           | 635               | 630     | 615   | No data       | No data | No data | 610  | 605     | 600     |
| Great Britain *** | 250               | 240     | 245   | No data       | No data | No data | No data  | No data | 130     |
| Greece ***        | 155               | 195     | 195*  | 5             | 3       | 3*      | 1  | 1       | 1*      |
| Hungary           | 84                | 85      | 87    | 5             | 5       | 6       | 40   | 42      | 48      |
| Iceland ***       | 4                 | 4       | 4     | 4             | 4       | 4       | 2  | 2       | 2       |
| Ireland           | 37                | 37      | 37    | No data       | 0       | No data | 3  | 2       | No data |
| Italy             | 640               | 640     | 640*  | 10            | 10      | 10*     | 300  | 300     | 300*    |
| Lithuania         | 36                | 38*     | 38*   | 3             | 3*      | 3*      | 24   | 24*     | 24*     |
| Luxembourg        | 4                 | 4       | 4     | 0             | 0       | 0       | 2  | 4       | 4       |
| Netherlands       | 41                | 41      | 38    | 1             | 0       | 2       | 40   | 40      | 38      |
| Norway            | 85                | 85      | 85    | 10            | 10      | 10      | 25   | 40      | 3       |
| Poland            | 300               | 300     | 300*  | 35            | 35      | 35*     | 4  | 4       | 4*      |
| Portugal          | 25*               | 25*     | 25*   | 25*           | 25*     | 25*     | 15*  | 15*     | 15*     |
| Romania           | 8                 | 49      | 50    | 2             | 9       | 10      | 8  | 8       | 10      |
| Serbia            |                   |         | 31    |               |         | 2       |  |         | 15      |
| Slovakia          | 54                | 51      | 46    | 0             | 0       | 0       | 22   | No data | 32      |
| Slovenia          | 13                | 18      | 16    | 1             | 1       | No data | 8  | 8       | No data |
| Spain             | 295               | 243     | 243   | 80            | 75      | 75      | 87   | 37      | 16      |
| Sweden            | 87                | 87      | 87    | 10            | 8       | 8       | 80   | 90      | 90      |
| Switzerland       | 147               | 147     | 147   | 0             | 0       | 5       | 78   | 83      | 80      |
| Turkey ***        | 225               | 176     | 104   | 437           | 462     | 449     | 10   | 10      | 12      |
| EU-28             | 3,513             | 3,530   | 3,521 | 266           | 275     | 271     | > 1751   | > 1770  | > 192   |
| Europe            | 3,969             | 3,942   | 3,887 | 729           | 733     | 741     | > 1946   | > 1905  | > 2033  |
| USA               | 137               |         |       | 32            |         |         |  |         |         |
| Japan             | 1,160             | 1,160   | 1,160 | 5             | 4       | 11      | 970  | 974     | 977     |
| New Zealand       | 50                | 50      |       | 6             | 6       |         |  |         |         |
| Ontario - Canada  | 140               | No data | 114   | 22            | No data | 5       | 135  | No data | 100     |
| South Africa      | 28                | 33      | 29    | 23            | 25      | 24      | 32   | 31      | 34      |
| South Korea       | 471               |         |       |               |         |         |  |         |         |

- \*\* One or more plants are operated and owned by the road administration
- \*\*\* One or more plants are operated and owned by the road administration and/or municipalities
- \*\*\*\* This can be all types, e.g. batch plants and/or drum mixer plants and/or plants with parallel drum.

# RAP world figures

## REUSE AND RECYCLING

RECYCLING IN 2014

| Country        | All available Reclaimed Asphalt in 2014 | % of available reclaimed asphalt used in |                             |                                  |                  |                     |                                      |  | Applied area in m <sup>3</sup> of hot reuse of existing asphalt pavement material in-situ / on the road (Remixing, Repaving, Reshaping, Road Train etc.) | The amount of "only" reheated (reused) asphalt material in-situ / on the road (Remixing, Repaving, Reshaping, Road Train etc.) in metric tonnes |
|----------------|---|--|-----------------------------|----------------------------------|------------------|---------------------|--------------------------------------|--|--|---|
|                |   | Hot Mix Asphalt Production               | Warm Mix Asphalt Production | Half Warm Mix Asphalt Production | Cold Recycling** | Unbound Road Layers | Other Civil Engineering Applications | Put to Landfill / Other Applications / Unknown |  |   |
| Austria        | 1,500,000                               | No data                                  | No data                     | No data                          | No data          | No data             | No data                              | No data  | No data  |   |
| Belgium        | 1,500,000                               | 72                                       | No data                     | No data                          | No data          | No data             | No data                              | No data  | No data  |   |
| Czech Republic | 1,600,000                               | 16                                       | 0                           | 0                                | 30               | 20                  | 10                                   | 24   | 178,400  |   |
| Croatia        | 170,000                                 | 24                                       | 5                           | No data                          | 19               | 10                  | No data                              | No data  |  |   |
| Denmark        | ~1,300,000                              | 54                                       | 0                           | 0                                | 0                | 11                  | 0                                    | 35   |  |   |
| Estonia        | No data                                 | No data                                  | No data                     | No data                          | No data          | No data             | No data                              | No data  |  |   |
| Finland        | 1,000,000                               | 100                                      | 0                           | 0                                | 0                | 0                   | 0                                    | 0  | 9,243,000  |   |
| France         | 7,000,000                               | 64                                       | No data                     | No data                          | No data          | No data             | No data                              | No data  | 637,450  | 114,700   |
| Germany        | 10,900,000                              | 90                                       | 0                           | 0                                | 0                | 10                  | 0                                    | 0  |  |   |
| Great Britain  | 3,350,000                               | 52                                       |                             |                                  | 5                | 0                   | 25                                   | 0  |  |   |
|                | 20,000                                  | 80                                       |                             |                                  | 0                | 10                  | 0                                    | 0  |  |   |
|                | 15,000                                  | No data                                  | No data                     | No data                          | No data          | No data             | No data                              | No data  | 60,000   |   |
|                | No data                                 | No data                                  | No data                     | No data                          | No data          | No data             | No data                              | No data  |  |   |
| Luxembourg     | 285,000                                 | 85                                       |                             |                                  | 10               | 0                   | 0                                    | 0  |  |   |
| Netherlands    | 4,500,000                               | 67                                       |                             |                                  | 15               | 0                   | 0                                    | 15   |  |   |
| Norway         | 837,410                                 | 20                                       |                             |                                  | 3                | 64                  | 9                                    | 4  |  |   |
| Romania        | 20,000                                  | 40                                       | 0                           | 25                               | 25               | 5                   | 5                                    | 0  |  |   |
| Slovakia       | 30,000                                  | 98                                       | 0                           | 0                                | 1                | 1                   | 0                                    | 0  | 60,000   | 7,500   |
| Slovenia       | 40,000                                  | 25                                       | 0                           | 0                                | 0                | 75                  | 0                                    | 0  |  |   |
| Spain          | 390,000                                 | 95                                       | 2                           | 3                                | 0                | 0                   | 0                                    | 0  |  |   |
| Sweden         | 1,200,000                               | 75                                       | 5                           | 5                                | 5                | 10                  | 0                                    | 0  | 4,000,000  | 320,000   |
| Switzerland    | 1,000,000                               | 52                                       | 10                          | 1                                | 2                | 33                  | 0                                    | 2  | 0  | 0   |
| Turkey         | 2,340,000                               | 6  | 0                           | 0                                | 0                | 94                  | 0                                    | 0  |  |   |
| Japan          | No data                                 | No data                                  | No data                     | No data                          | No data          | No data             | No data                              | No data  |  |   |
| U.S.A.         | 68,700,000                              | 95                                       | No data                     | No data                          | No data          | No data             | No data                              | No data  |  |   |
| Ontario-Canada | 2,800,000                               | 95                                       | No data                     | No data                          | No data          | No data             | No data                              | No data  |  |   |

RAP total in tons

% RAP used in Asphalt mix

\*\* Cold recycling includes stabilisation with bitumen emulsion, foamed bitumen and/or cement.



RAP addition systems in Hot Asphalt Mixing Plants

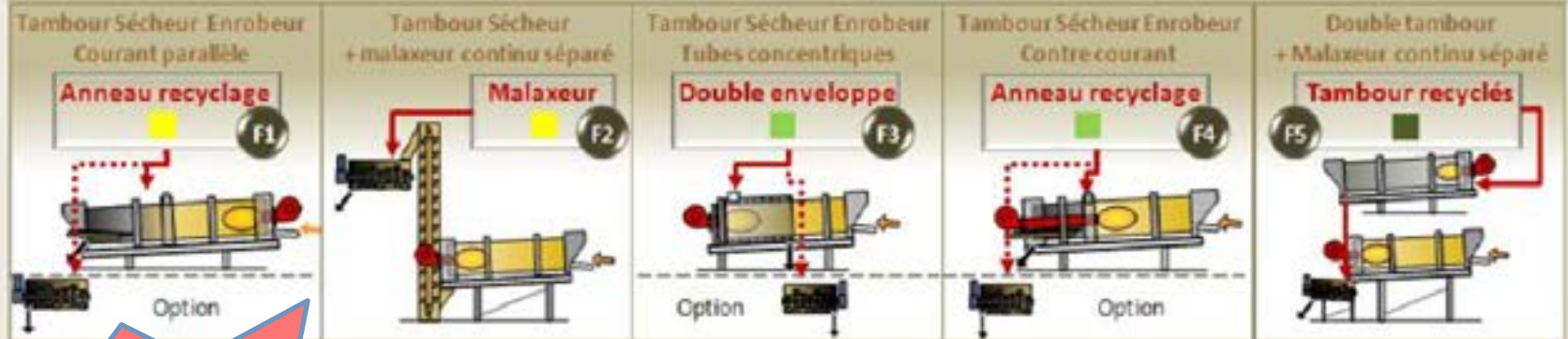
0 à 20%

20 à 40%

40-60%

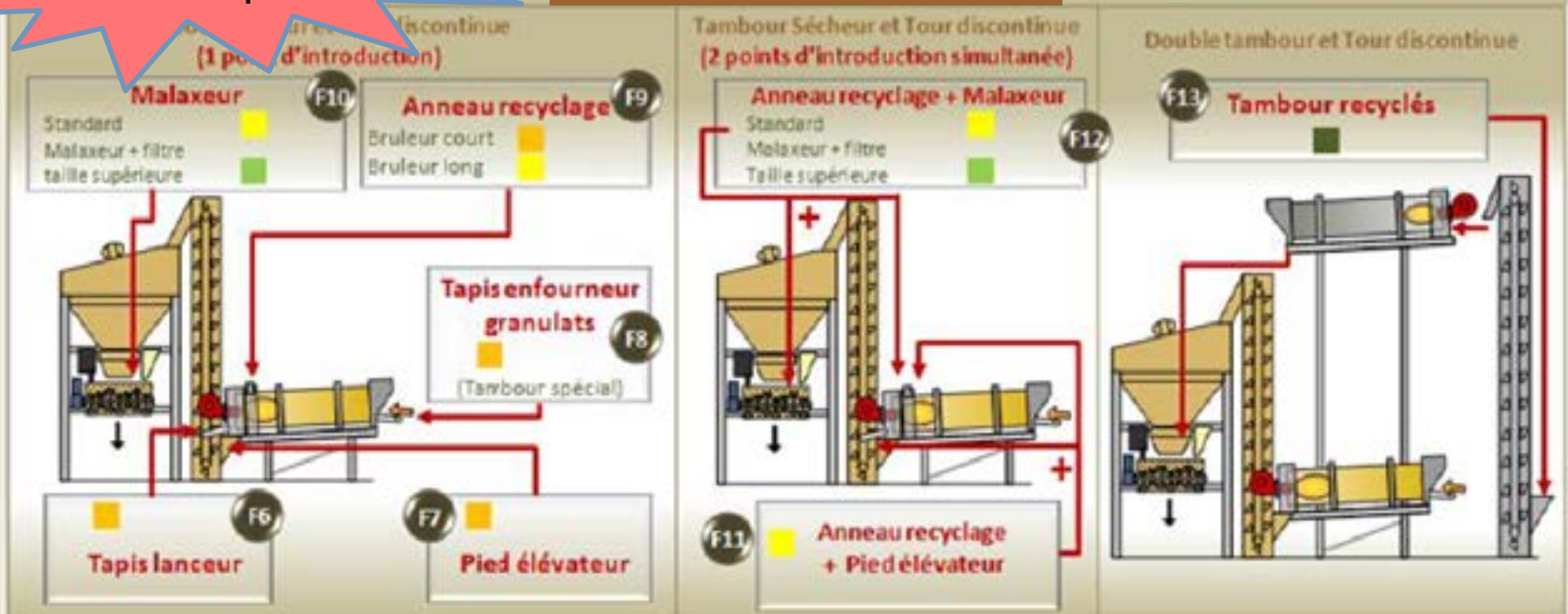
> 60%

## HAMP continuous type



13 Techniques !

## HAMP discontinuous type




# Continuous HAMP

## The most popular techniques

### Recycling ring





RECYCLAGE EN INSTALLATION DE FABRICATION D'ENROBÉS

F1

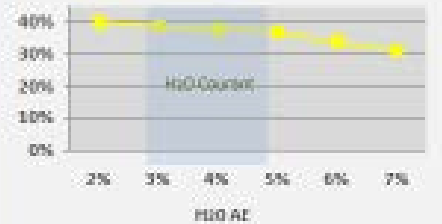
Procédé enrobage : Continu

Technologie : Tambour Secheur Enrobeur Courant parallèle

Technique introduction agrégats d'enrobés : **Anneaux de recyclage**

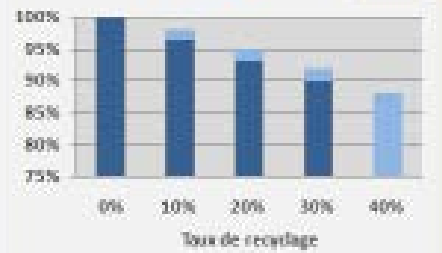
0 à 20 %
20 à 40 %
40 à 60 %
> 60 %

Taux de recyclage généralement constaté en fonction de la teneur en eau des Agrégats d'Enrobés

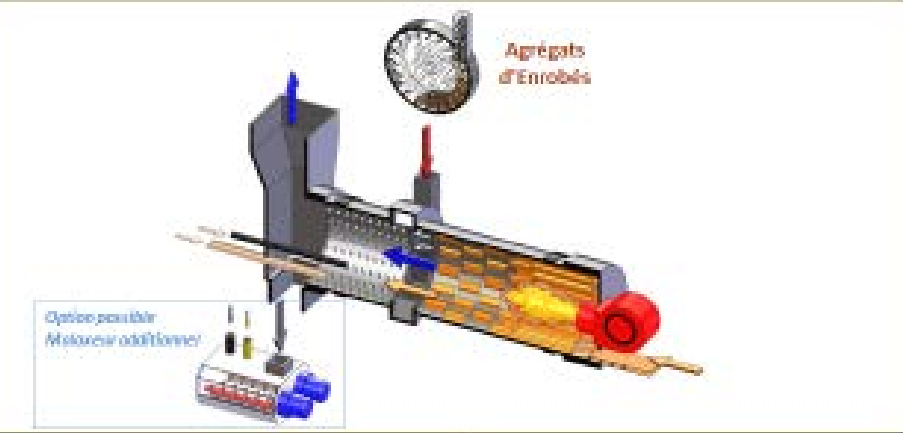


| H2O AC (%) | Taux de recyclage (%) |
|------------|-----------------------|
| 2%         | 40%                   |
| 3%         | 38%                   |
| 4%         | 36%                   |
| 5%         | 34%                   |
| 6%         | 32%                   |
| 7%         | 30%                   |

Variation du débit en fonction du taux de recyclage pour 5% H2O et 2% H2O

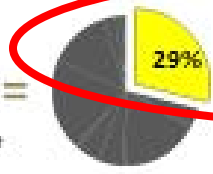


| Taux de recyclage (%) | 5% H2O (%) | 2% H2O (%) |
|-----------------------|------------|------------|
| 0%                    | 100%       | 95%        |
| 10%                   | 98%        | 94%        |
| 20%                   | 95%        | 92%        |
| 30%                   | 92%        | 90%        |
| 40%                   | 88%        | 82%        |



F1

Proportion estimée sur parc France



29%

😊 Filtre de taille supérieure  
Zone de malaxage palettes

☹️



# Discontinuous HAMP

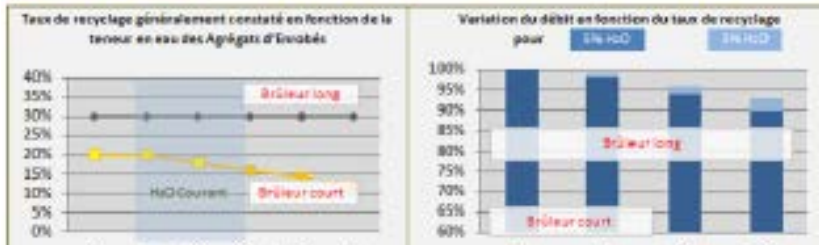
## The most popular techniques

**IDRRIM** RECYCLAGE EN INSTALLATION DE FABRICATION D'ENROBES **F9**

Procédé enrobage : Discontinu

Technologie : Tambour Sécheur et Tour discontinue

Technique introduction agrégats d'enrobés : 1 point d'introduction: Anneau de recyclage

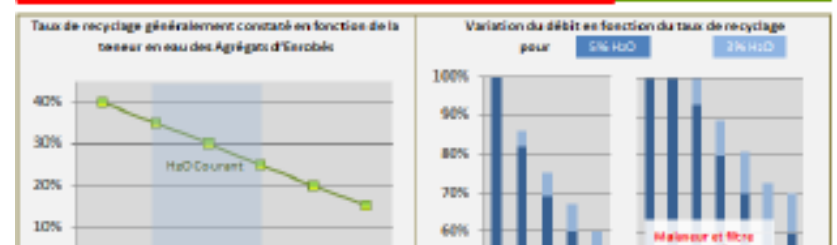
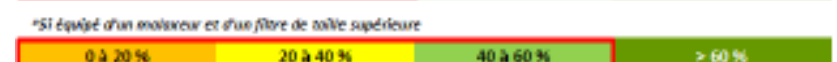


**IDRRIM** RECYCLAGE EN INSTALLATION DE FABRICATION D'ENROBES **F10**

Procédé enrobage : Discontinu

Technologie : Tambour Sécheur et Tour discontinue

Technique introduction agrégats d'enrobés : 1 point d'introduction: Malaxeur



Recycling ring : RAP maxi 20%  
40% with long burner

Directly in the mixer : RAP maxi 40%  
60% with bigger mixer+filter



Very high RAP content > 60% :

Second dryer dedicated to RAP

RECYCLAGE EN INSTALLATION DE FABRICATION D'ENROBES

F13

|   |                                    |
|---|------------------------------------|
| Procédé enrobage :                          | Discontinu                         |
| Technologie :                               | Double tambour et Tour discontinue |
| Technique introduction agrégats d'enrobés : | <b>Tambour recyclés</b>            |

0 à 20%

20 à 40%

40 à 60%

> 60%

**Taux de recyclage généralement constaté en fonction de la teneur en eau des Agrégats d'Enrobés**

| H2O AE (%) | Taux de recyclage (%) |
|------------|-----------------------|
| 2%         | ~70%                  |
| 3%         | ~70%                  |
| 4%         | ~70%                  |
| 5%         | ~70%                  |
| 6%         | ~70%                  |
| 7%         | ~70%                  |

**Variation du débit en fonction du taux de recyclage pour 5% H<sub>2</sub>O et 3% H<sub>2</sub>O**

| Taux de recyclage (%) | 5% H <sub>2</sub> O (%) | 3% H <sub>2</sub> O (%) |
|-----------------------|-------------------------|-------------------------|
| 0%                    | 100%                    | 100%                    |
| 10%                   | 100%                    | 100%                    |
| 20%                   | 100%                    | 100%                    |
| 30%                   | 100%                    | 100%                    |
| 40%                   | 100%                    | 100%                    |
| 50%                   | 100%                    | 100%                    |
| 60%                   | 100%                    | 100%                    |
| 70%                   | ~85%                    | ~70%                    |
| 80%                   | ~70%                    | ~55%                    |

Agrégats d'Enrobés

by pass pour teneur < 20%

F13

Proportion estimée sur parc France

0,9%

😊 Prévoir dispositif complémentaire pour faible taux de recyclage

☹️ Attention au dimensionnement du sécheur AE pour atteindre des taux > 70%



Very high RAP content > 60%

# Mixing plants with 2 dryers

Second dryer dedicated to RAP



## Overview in France in 2013

- 300 HAMPs equipped for RAP use
- Average possible recycling ratio 35 %  
(3% moisture)
- Only 3% of them can recycle more than 60%
- Recycling technologies :
  - Recycling ring : the most frequent , continuous and discontinuous
  - Introduction in the mixer : frequent for discontinuous

## Some comments/recomendations

- Consider how much RAP is available :
  - Better (and safer) to make many tons with 20 % RAP
  - Than few tons with 60% RAP
- Influence of the binder from RAP :
  - Little influence if  $RAP \leq 30\%$  : use a normal new binder
  - Always check the recovered binder from RAP : expert's assessment for defining the added binder, % of RAP, properties of the targeted asphalt mix design
- Always control the asphalt mix properties
- High RAP content with one dryer : be careful with overheating of the virgin aggregates

# Examples of Mix design study

- Example 1 : Pardines
  - Influence of the RAP pre-heating temperature
  - For 40% and 70% of RAP
- Example 2 : Motorway A54, Arles – Nimes
  - High modulus asphalt with 70% of RAP
  - Influence of RAP binder characteristics
  - Control of site values versus lab study

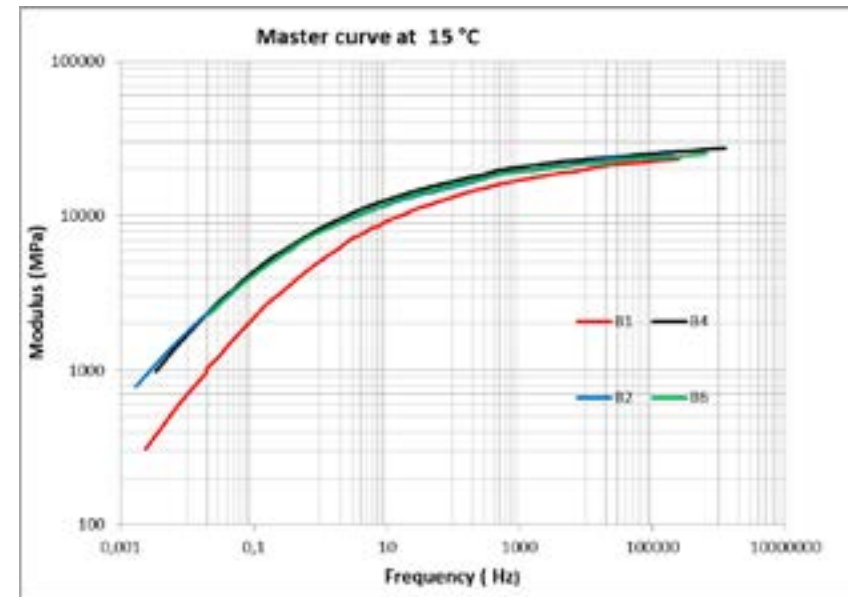


# Example study 1 : 40% and 70% of RAP : Influence of RAP pre-heating temperature

Tests on the building site in Pardines, France

RGRA | N°924 • décembre 2014 - janvier 2015

| Reference | Formula                                  | Production temp (°C) |
|-----------|--|----------------------|
| B1        | AC 14 base course 50/70                  | 150                  |
| B2        | AC 14 BC 50/70 R40 (cold RAP)            | 160                  |
| B3        | AC 14 BC 50/0 R40 (RAP at 101°C)         | 160                  |
| B4        | AC 14 BC 50/70 R40 (RAP at 134°C)        | 160                  |
| B5        | AC 14 BC 50/70 R70 (RAP at 130°C)        | 165                  |
| B6        | AC 14 BC 50/70 foamed R40 (RAP at 120°C) | 132                  |



## Main results

| Reference | Formula AC 14 BC                | Modulus            |          |         | Modulus              |          |         |
|-----------|---------------------------------|--------------------|----------|---------|----------------------|----------|---------|
|           |                                 | Laboratory studies |          |         | On site measurements |          |         |
|           |                                 | % voids            | Cd (MPa) | I/C (%) | % voids              | Cd (MPa) | I/C (%) |
| B1        | 50/70                           | 6.5                | 9489     | 92      | 8.9                  | 7717     | 89      |
| B2        | 50/70 R40 (cold RAP)            | 4.6                | 12611    | 93      | 7.3                  | 9983     | 90      |
| B4        | 50/70 R40 (RAP at 134°C)        | 4.7                | 15040    | 96      | 7                    | 11013    | 96      |
| B6        | 50/70 foamed R40 (RAP at 120°C) | 4.3                | 14259    | 92      | 6.4                  | 11453    | 90      |

# Example study 2 : High Modulus Asphalt Binder characteristics for formula with 60 % of RAP

- Rules for mixes with > 40% of RAP : Binder study
  - Preliminary investigation (before milling) and identification

| Prélèvements       | Penetration | R & B       | G* des valeurs à 15 °C -10 Hz (MPa) |
|--------------------|-------------|-------------|-------------------------------------|
| Sens Nîmes - Arles | 12 à 20     | 62,6 à 68,2 | 48,5 à 82                           |
| Sens Arles - Nîmes | 5 à 11      | 69 à 88,5   | 80 à 88                             |

- Laboratory study & trial productions

| Essais                  | Liant 20/30 neuf d'apport | Liant extrait des AE | Calcul dans l'hypothèse d'un mélange parfait |
|-------------------------|---------------------------|----------------------|--|
| Pénétrabilité (1/10 mm) | 28                        | 12                   | 18   |
| TBA (°C)                | 60,8                      | 70,8                 | 66   |
| G* 15 °C -10 Hz (MPa)   | 33                        | 84                   | 54   |

Tableau 3  
 Caractéristiques du liant neuf d'apport et du liant des AE  
 Characteristics of new binder added and of asphalt aggregate binder

Penetration

R & B

G\*



# Example study 2 : Motorway A54, Arles – Nimes, France : Special study for High Modulus Asphalt with 60 % of RAP

RGRA | N° 920 • avril - mai 2014

## AUTEURS

Xavier Carbonneau  
Chef du Service enrobés  
Campus scientifique et technique (CST)  
Colas

Emilie Cornibes  
Cadre technique  
Service Enrobés  
CST Colas

Frédéric Gileni  
Directeur technique adjoint

| Liants analysés           | Histoire thermique                                      | Penetration | R & B | G*, 10°C,<br>15 Hz |
|---------------------------|---|-------------|-------|--------------------|
| Liant neuf d'apport 20/30 |   | 28          | 61,4  | 33                 |
| Liant extrait des AE      | séchage   | 13          | 72,4  | 86                 |
| Mélange théorique         |   | 18          | 67,6  | 57                 |
| Fabrication laboratoire   | Séchage @50 °C<br>+ 2h à 110 °C<br>+ granulats à 240 °C | 16          | 71,8  | 66                 |

| Essais   | EB 14 assise<br>10/20<br>Laboratory<br>study | EB 14 assise<br>10/20<br>Site control<br>Plot A | EB 14 assise<br>10/20<br>Site control<br>Plot B | Spécifications<br>EN 13108-1<br>pour EME<br>classe 2                 |
|--|--|---|---|--|
| Stiffness modulus<br>(NF EN 12697-26 Annexe A) | V = 3,7 %<br>17 916 MPa                      | V = 4,4 %<br>15 351 MPa                         | V = 4,2 %<br>15 230 MPa                         | V <sub>i</sub> = 3 % V <sub>s</sub> = 6 %<br>S <sub>min</sub> 14 000 |
| Fatigue<br>(NF EN 12697-24 Annexe A)           | V = 3,8 %<br>137                             | V = 4,6 %<br>134                                | V = 3,9 %<br>137                                | V <sub>i</sub> = 3 % V <sub>s</sub> = 6 %<br>ε <sub>G</sub> 130      |

Colas

Tableau 8  
Vérification des performances en module et fatigue sur les prélèvements et comparaison aux caractéristiques déterminées à l'étude de formulation  
Checking modulus and fatigue performance on samples and comparison with characteristics determined during mix design study

# Using RAP in hot, warm or cold asphalt mixes :

- Is good for the Planet :
  - Less GHG emission
  - Less energy consumed
    - ... saved from :
  - Prime materials : extraction, processing, delivery
  - Energy consumed, mainly for transport
- Is good for Investors :
  - Less construction costs
  - Sustainable construction policy
- Is good for Contractors :
  - More competitive offers
  - But demands :
    - ✓ (proper) investments
    - ✓ High level technical know-how



**Hrvatsko asfaltno društvo**

**Croatian asphalt association**

**Hvala na pažnji**