**CEDR Transnational Road Research Programme**
**Call 2012: Recycling: Road construction in a post-fossil fuel society**

funded by Denmark, Finland, Germany, Ireland, Netherlands and Norway

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

# AllBack2Pave

## Toward a sustainable 100% recycling of reclaimed asphalt in road pavements

International workshop on Recycling: Road construction in a post- fossil fuel society

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# Objectives

AllBack2Pave is a research project project that will evaluate the feasibility of **going towards 100% recycling of asphalt pavements into surface courses**.

# Objectives

AllBack2Pave is a research project project that will evaluate the feasibility of **maximizing the amount of recycling of asphalt pavements into surface courses**.

The main objectives of the project are:

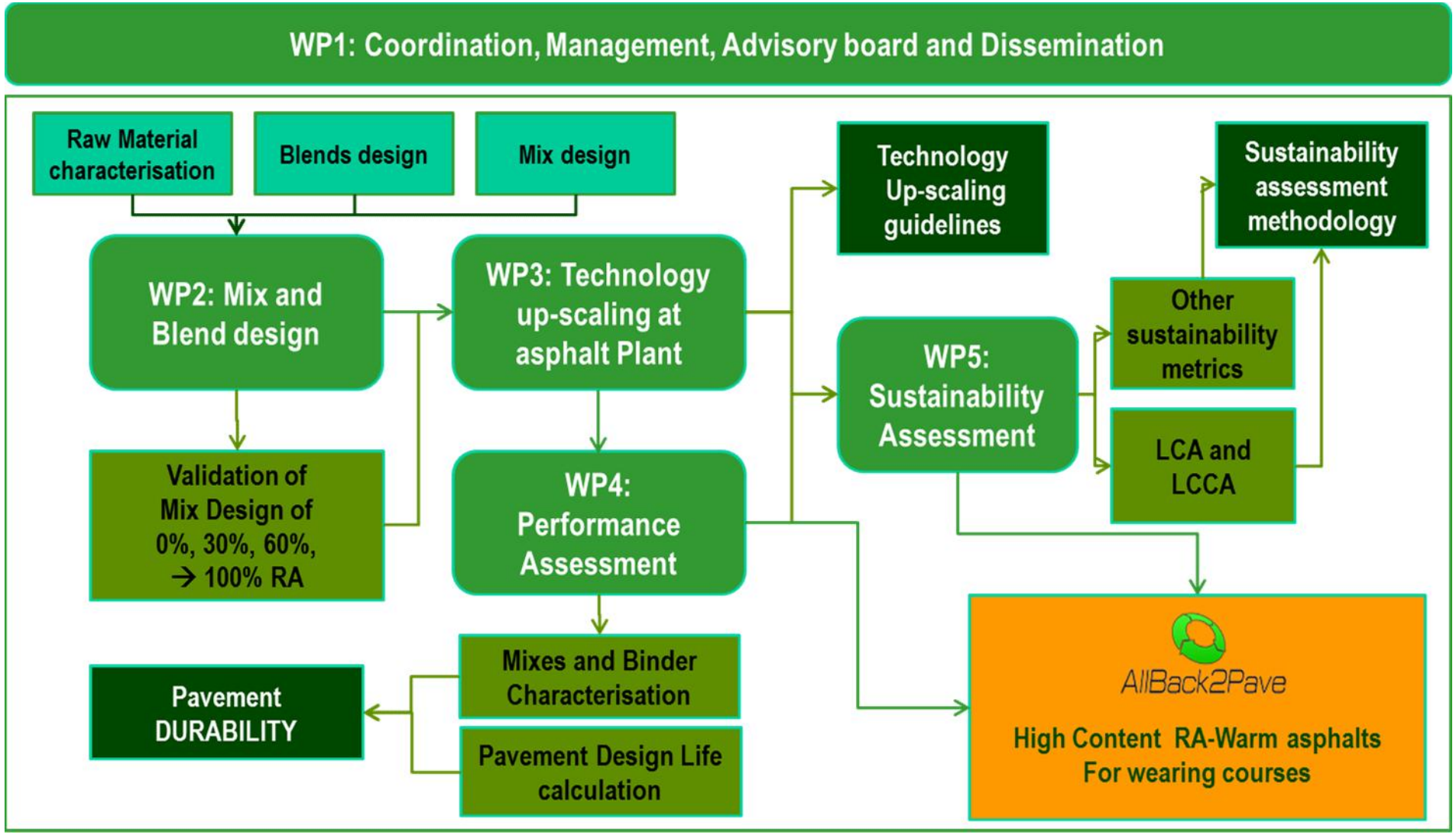
- To establish, through laboratory tests on binders and asphalt mixes, whether the use of high rates of RA is feasible in developing mixes with a high level of performance which do not affect the durability.

- To develop the so-called “AllBack2Pave end-user manual” on how to best produce cost-effective and quality asphalt mixes with high RA content.

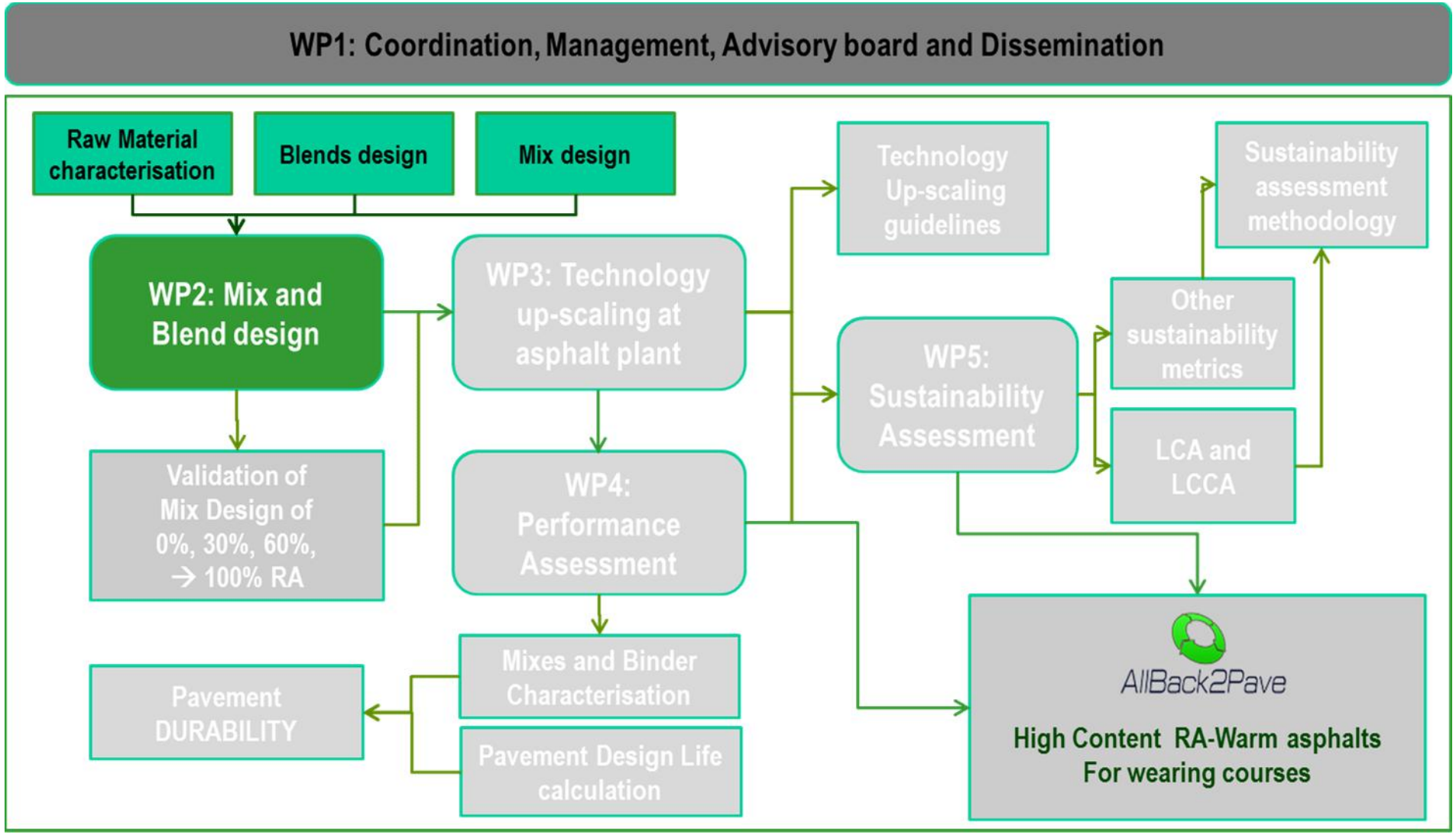
# Consortium

AllBack2Pave

# Project organization



# Project organization



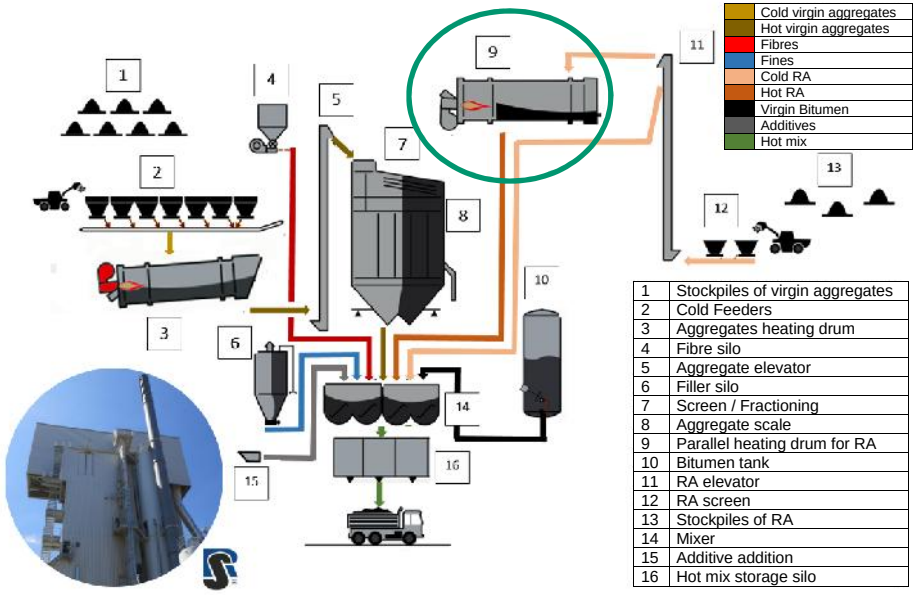
# Methodology

- Two typical asphalt ***surface mixes of high volume*** roads of Germany and Italy.
- Mix design and production following each country regulatory environment.
- Three different amounts of RA in each mix.


| **Control mixes** | **30% RA** | **60% RA** | **Max% RA** |
|---|---|---|---|
| DE: SMA 8S | DE30 | DE60 | DE60+Add. |
| IT: AC 16 | IT30 | IT60 | IT90 |

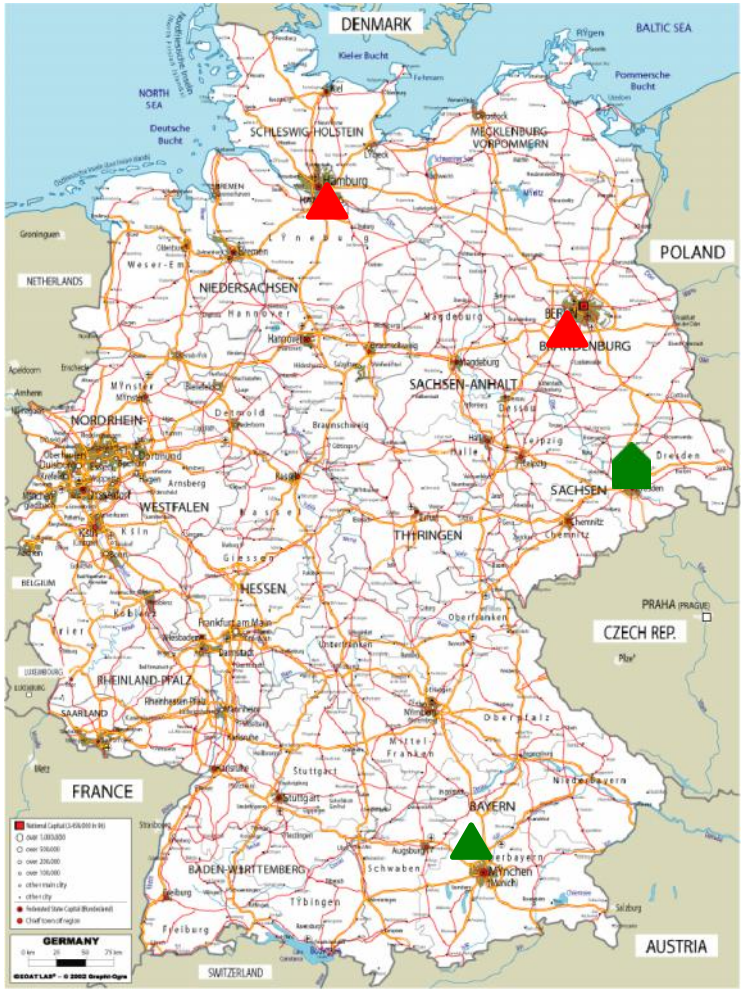
# Materials: DE


| Control mixes | 30% RA | 60% RA | Max% RA |
|---|---|---|---|
| DE: SMA 8S | DE30 | DE60 | DE60+Add. |




| | |
|---|---|
| 1 | Stockpiles of virgin aggregates |
| 2 | Cold Feeders |
| 3 | Aggregates heating drum |
| 4 | Fibre silo |
| 5 | Aggregate elevator |
| 6 | Filler silo |
| 7 | Screen / Fractioning |
| 8 | Aggregate scale |
| 9 | Parallel heating drum for RA |
| 10 | Bitumen tank |
| 11 | RA elevator |
| 12 | RA screen |
| 13 | Stockpiles of RA |
| 14 | Mixer |
| 15 | Additive addition |
| 16 | Hot mix storage silo |

# Materials: DE



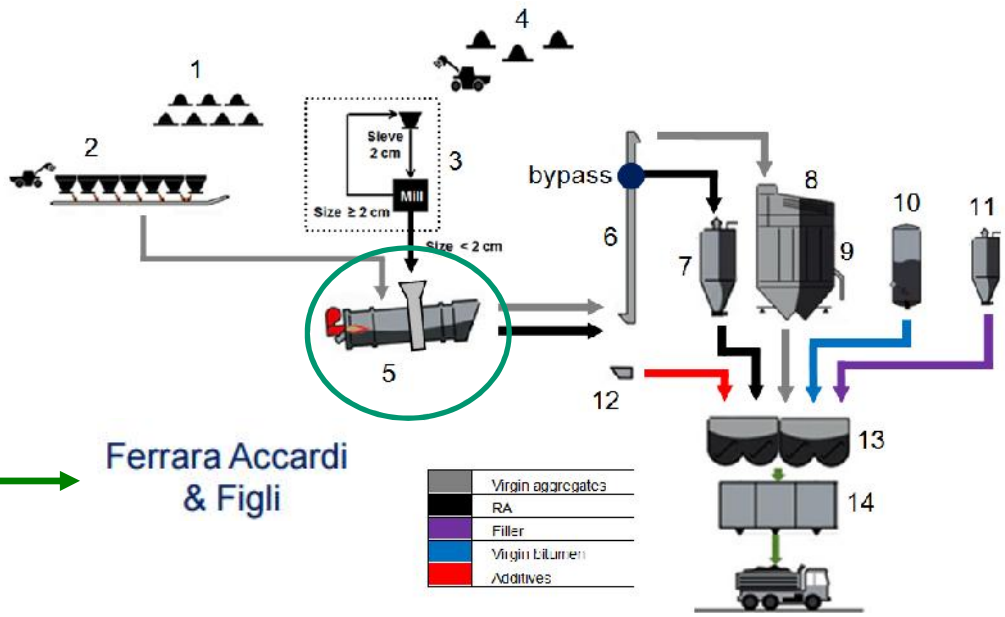

| Virgin minerals | Fibres | Virgin bitumen | Additive | RA |
|---|---|---|---|---|

| | Material | Source / Producer | Sampling |
|---|---|---|---|
| Coarse Aggregates | Crushed stone 8/11 | Quarry in Gilching | 2 buckets of 15kg each for each aggregate. |
| | Crushed stone 8/11 | Quarry in Treidling | |
| | Crushed stone 5.6/8 | Quarry in Gilching | |
| | Crushed stone 5.6/8 | Quarry in Treidling | |
| | Crushed stone 2/5.6 | Quarry in Gilching | |
| | Crushed stone 2/5.6 | Quarry in Treidling | |
| Sand | Sand 0/2 | Quarry in Gilching | 2 buckets of 15kg each |
| Fines | Fines | Quarry in Lauterhofen | 1 bucket of 15 kg |
| Fibres | Fibres | Viatop premium | 1 bucket of 5 kg |
| Virgin Bitumen | Bitumen (PmB 25/55-55) | OMV | 1 bucket of 15 Kg |
| Additives | Blend of rejuvenator and WMA | Storimpex | 1 sample of 5 kg was obtained from the producer |
| RA | Reclaimed asphalt SMA 11S | Rehabilitation of A8 highway near Munich | 10 buckets of 15 kg each. The buckets were filled with RA from 5 random locations of the stockpile |

# Materials: IT


| Control mixes | 30% RA | 60% RA | Max% RA |
|---|---|---|---|
| IT: AC 16 | IT30 | IT60 | IT90 |

| Virgin minerals | Virgin bitumen | Additive | RA |
|---|---|---|---|




Ferrara Accardi & Figli

# Hot mix recycling process

# Reclaim the asphalt

## German RA

- Mill out from the surface layer of a high volume road near Munich (highway A8).
- The RA was made up of a bituminous surface originally designed as a SMA with a nominal grain size of 11mm (SMA 11S) and a Polymer modified bitumen (PmB 25/55-55).
- The original mix design formulas and maintenance history of the RA were not available

## Italian RA

- Mill out from the surface layer of an urban road
- The RA was made up of a bituminous surface originally designed as an AC with a nominal grain size of 16mm
- The original mix design formulas and maintenance history of the RA were not available

# Reclaim the asphalt

## German RA

- Mill out from the surface layer of a high volume road near Munich
- RA properly milled (i.e. layer by layer)
- Mix desing formulas, material and maintenance records of RA
- designed as a SMA with a nominal grain size of 11mm (SMA 11S) and a Polymer modified bitumen (PmB 25/55-55).
- The original mix design formulas and maintenance history of the RA were not available

## Italian RA

- Mill out from the surface layer of an urban road
- RA properly milled (i.e. layer by layer)
- Mix desing formulas, material and maintenance records of RA
- grain size of 10mm
- The original mix design formulas and maintenance history of the RA were not available

# Hot mix recycling process

# Process the RA

## German RA

- RA crushed in the mixing plant to a maximum grain size of 22 mm
- RA stored in stockpiles without further screening
- Open air storage

## Italian RA

- RA crushed in the mixing plant to a maximum grain size of 20 mm
- RA stored in stockpiles without further screening
- Under shelter storage

# Process the RA

## German RA

- ✖ RA properly stored (e.g. under shelter)
- ✖ Fractionation of RA

further screening

- Open air storage

## Italian RA

- ✓ RA properly stored (e.g. under shelter)
- ✖ Fractionation of RA

further screening

- Under shelter storage

# Hot mix recycling process

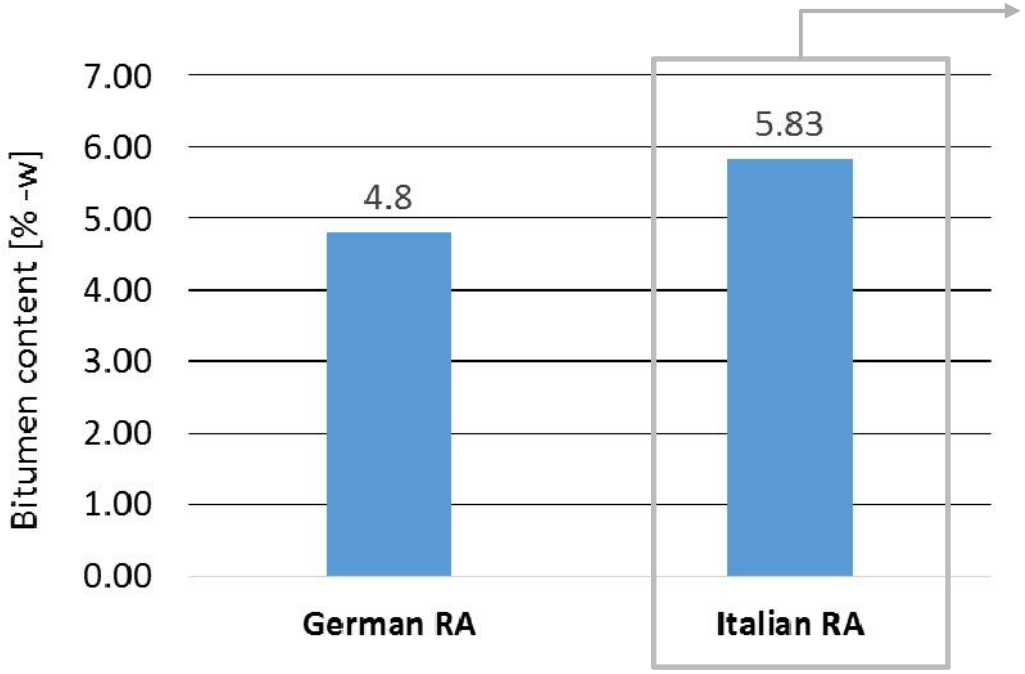
# Characterize the RA

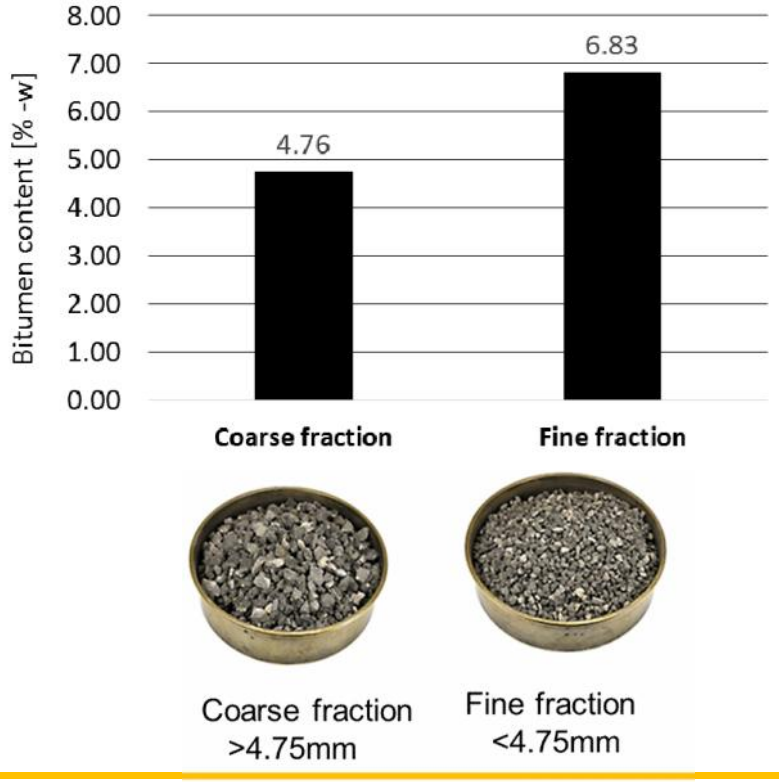
Binder extraction and recovery

Testing of RA aggregates

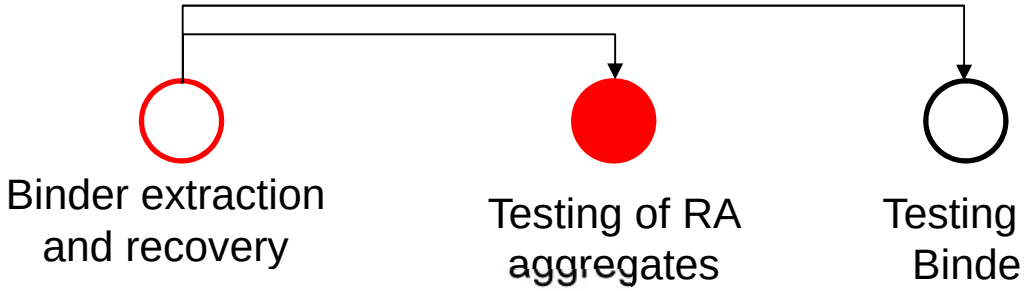
Testing of Binder

Bitumen content

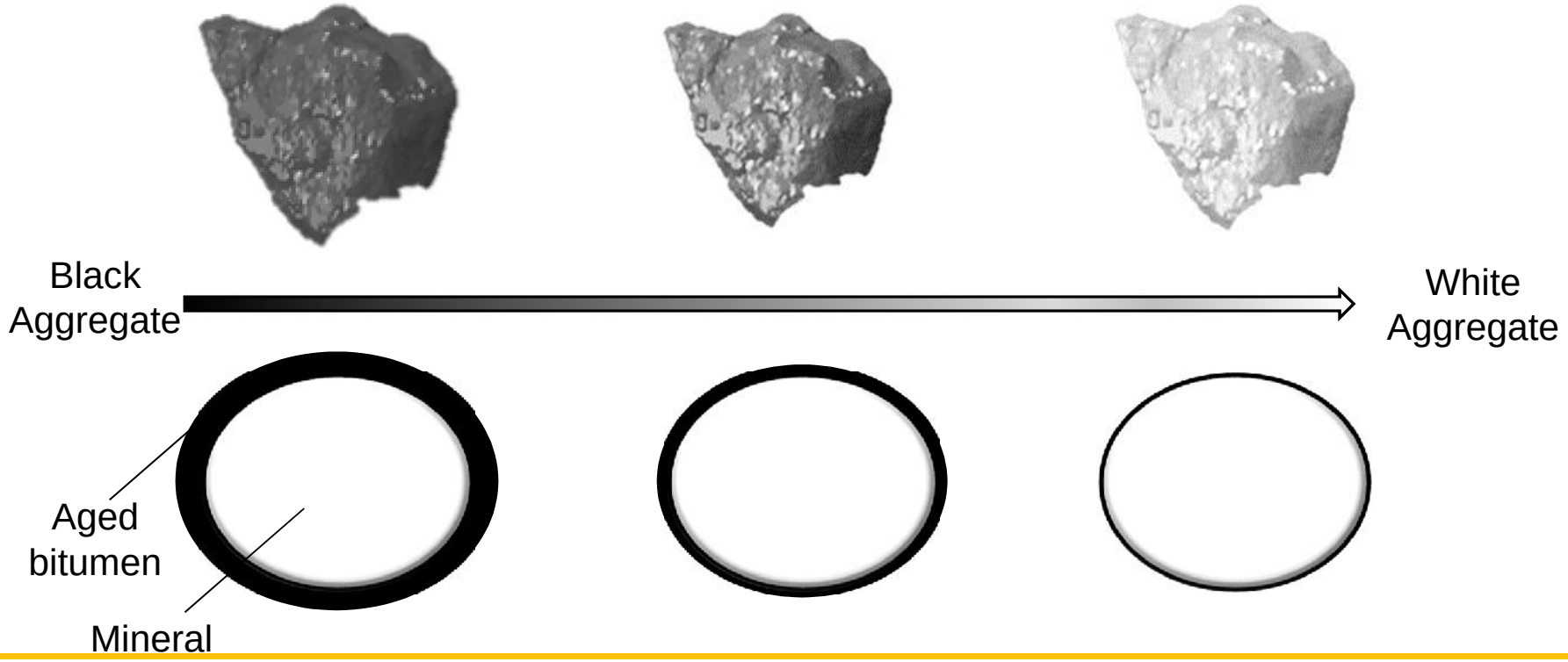


# Characterize the RA




**Partial blending concept**



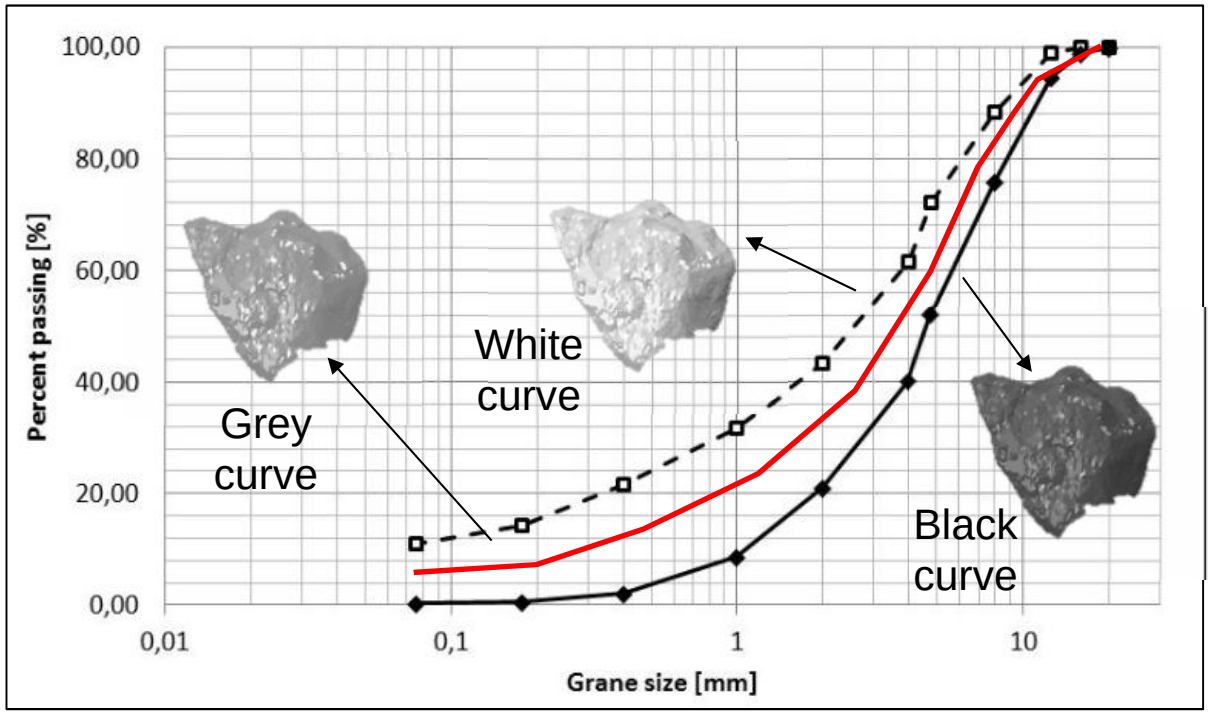
# Characterize the RA

Binder extraction and recovery

Testing of RA aggregates

Testing of Binder

**Partial blending concept**



# Characterize the RA

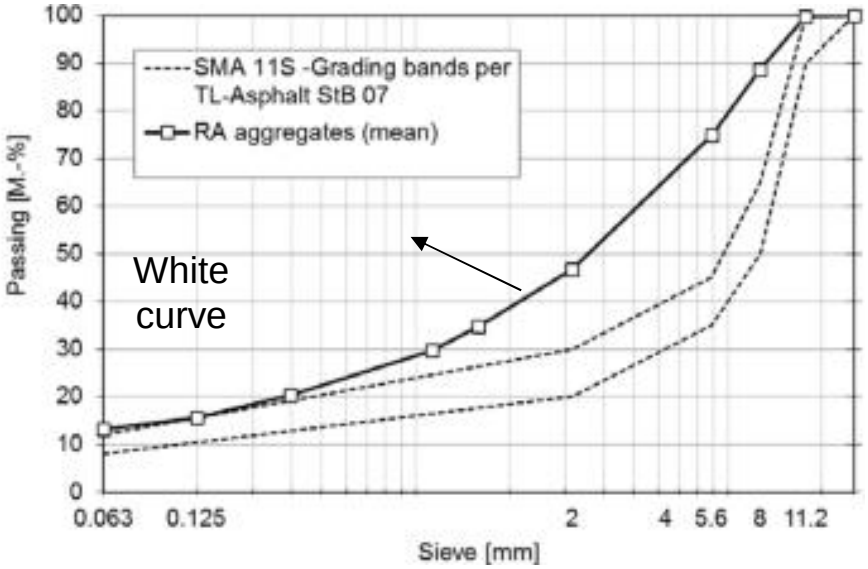
Binder extraction and recovery

Testing of RA aggregates

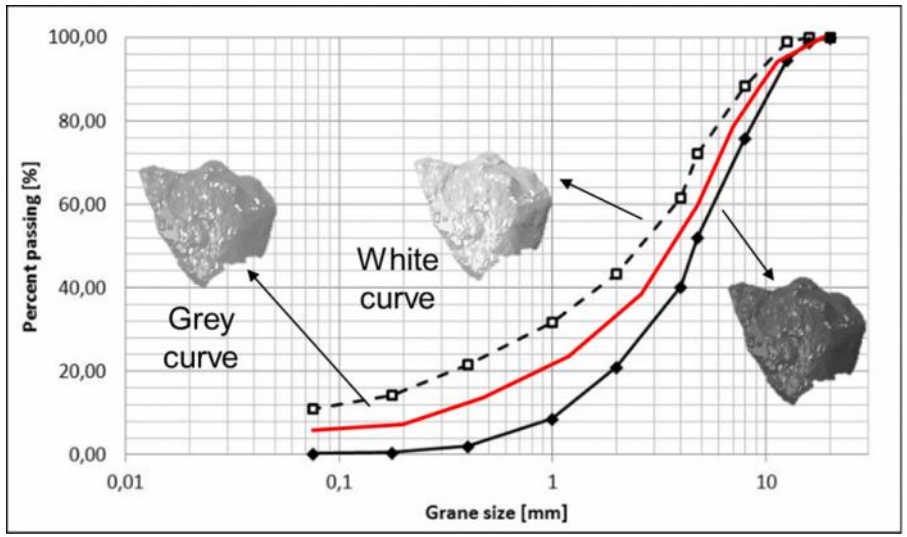
Testing of Binder

Grading

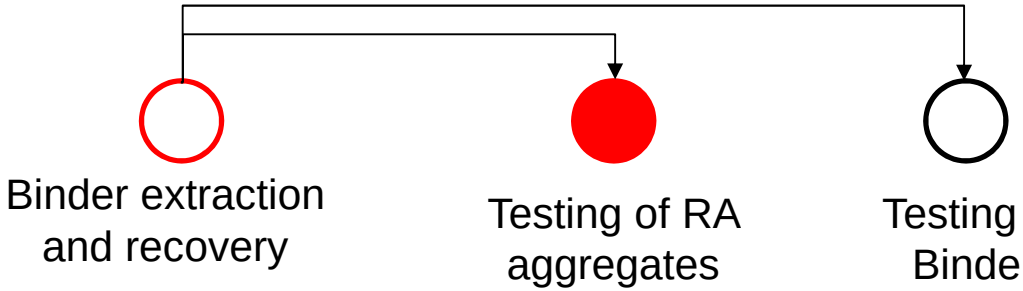
## German RA



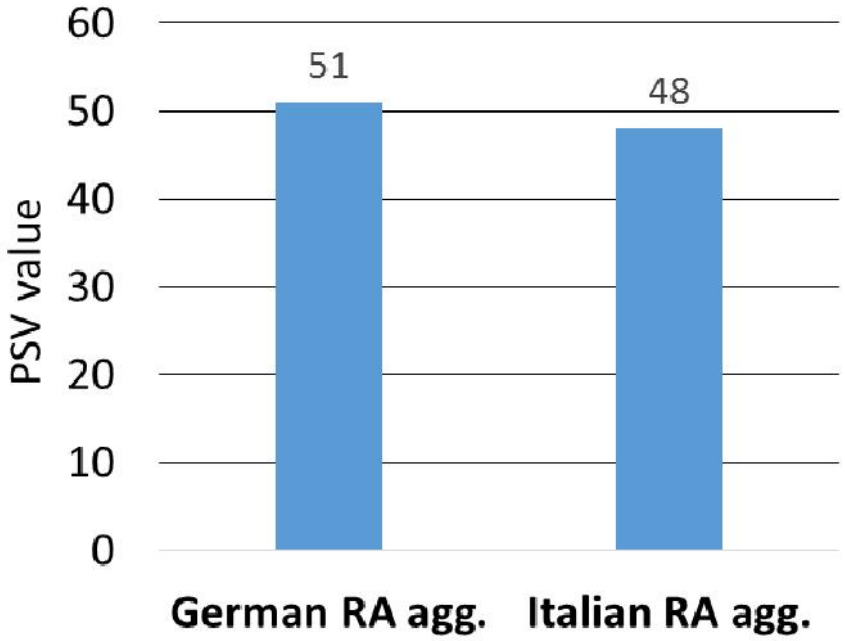

## Italian RA



# Characterize the RA

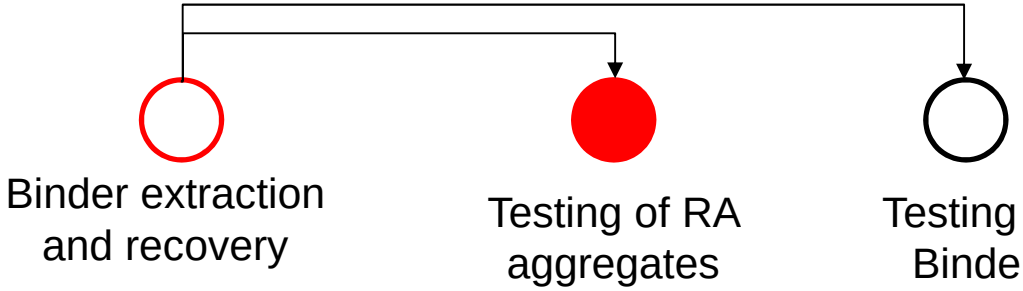



PSV.

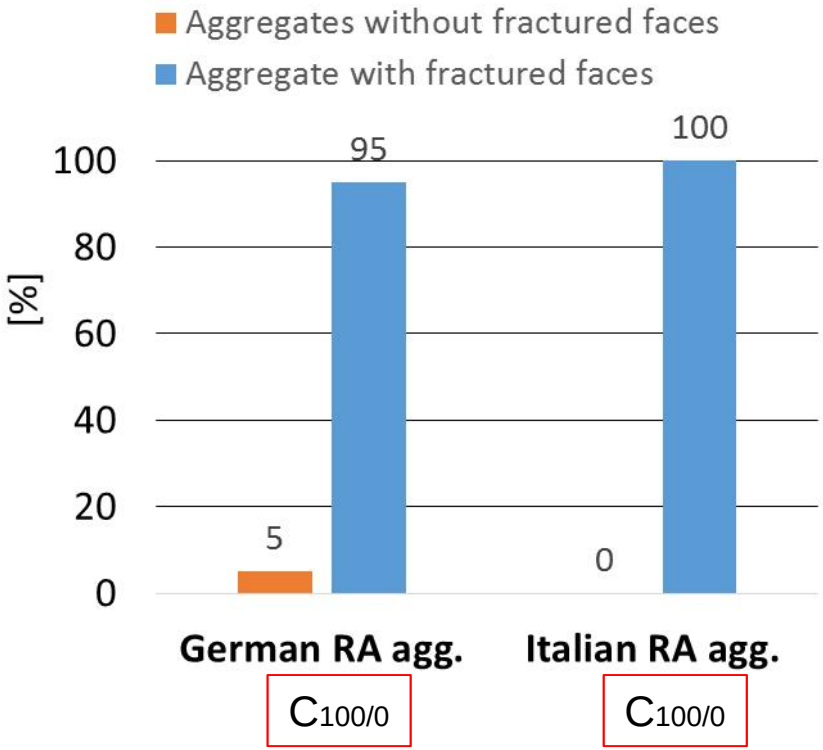



The aggregates ability to resist skidding is crucial when designing wearing course mixes.

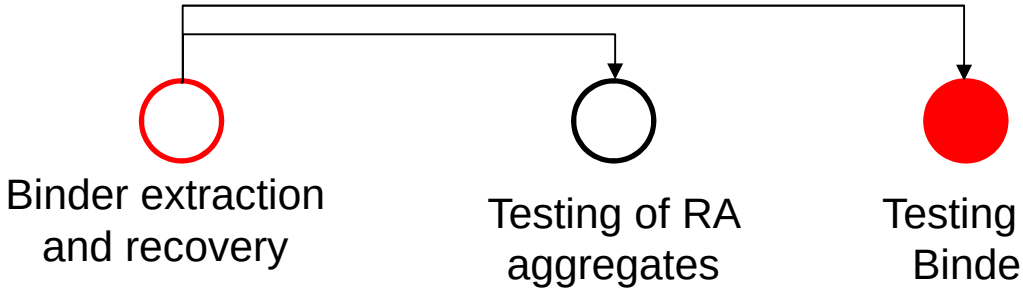
# Characterize the RA



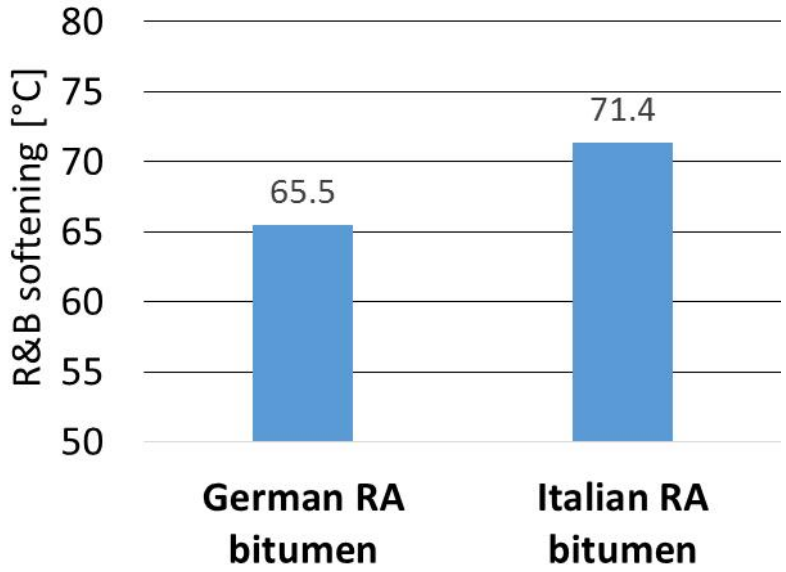

Angularity

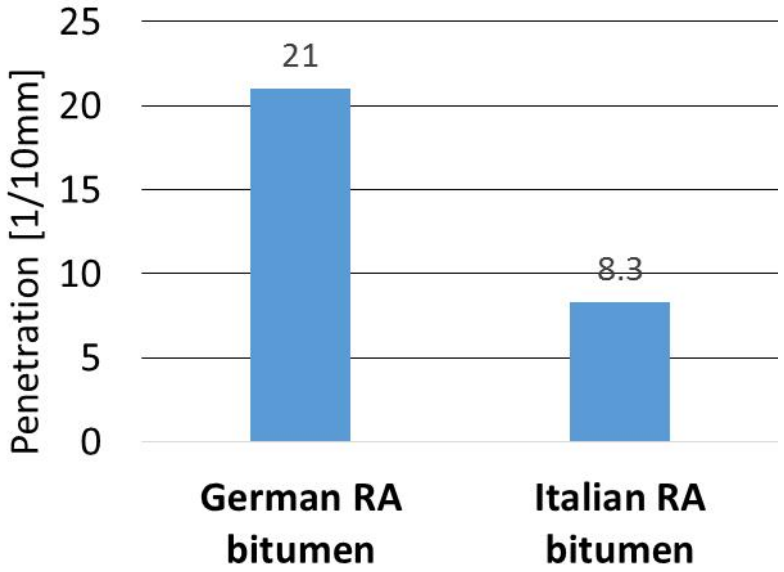



# Characterize the RA

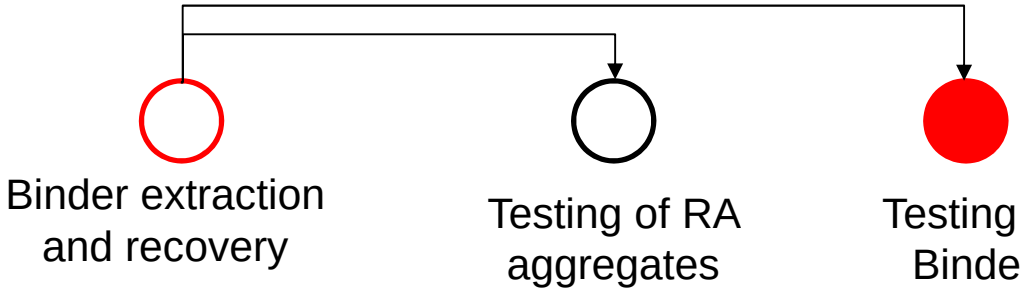



Conventional properties

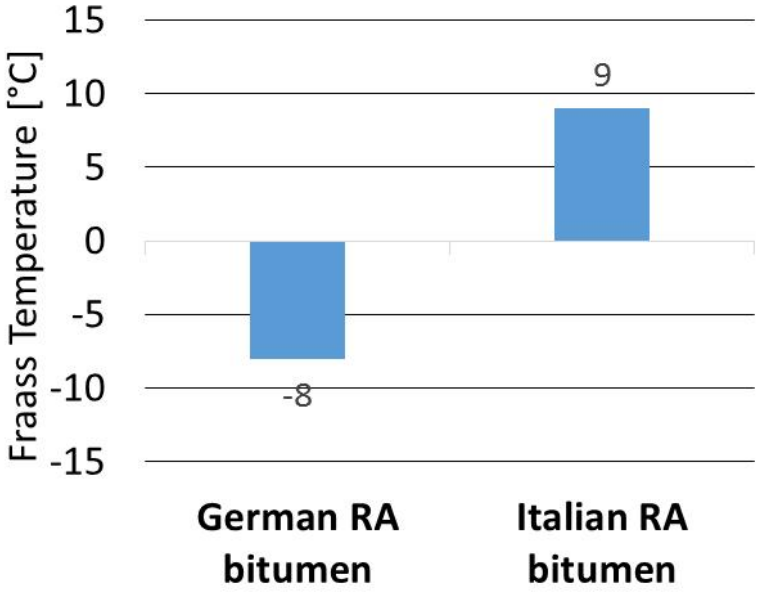


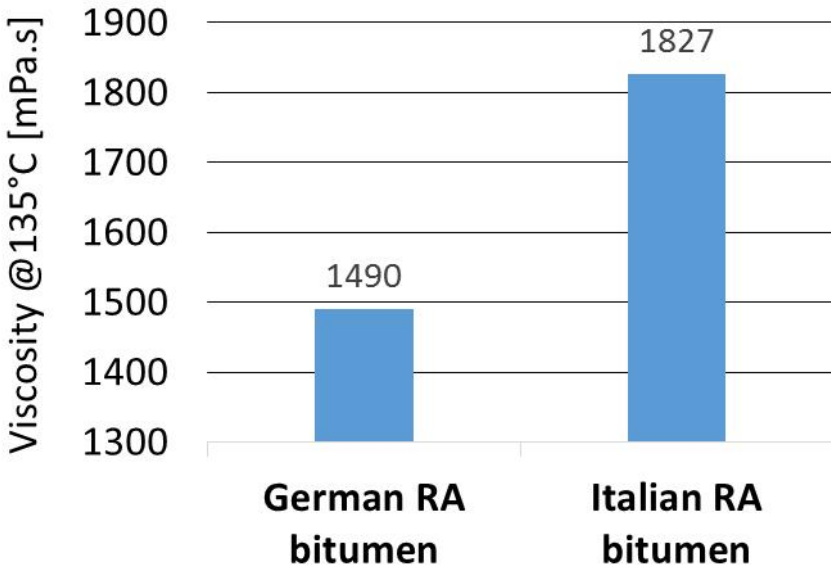



# Characterize the RA

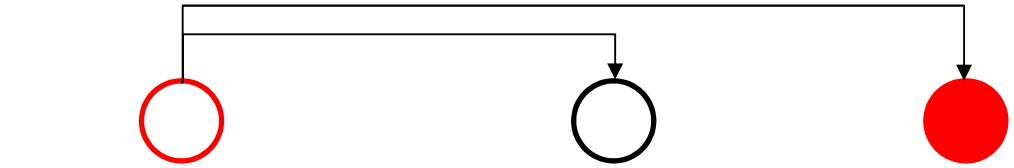



Conventional properties



# Characterize the RA

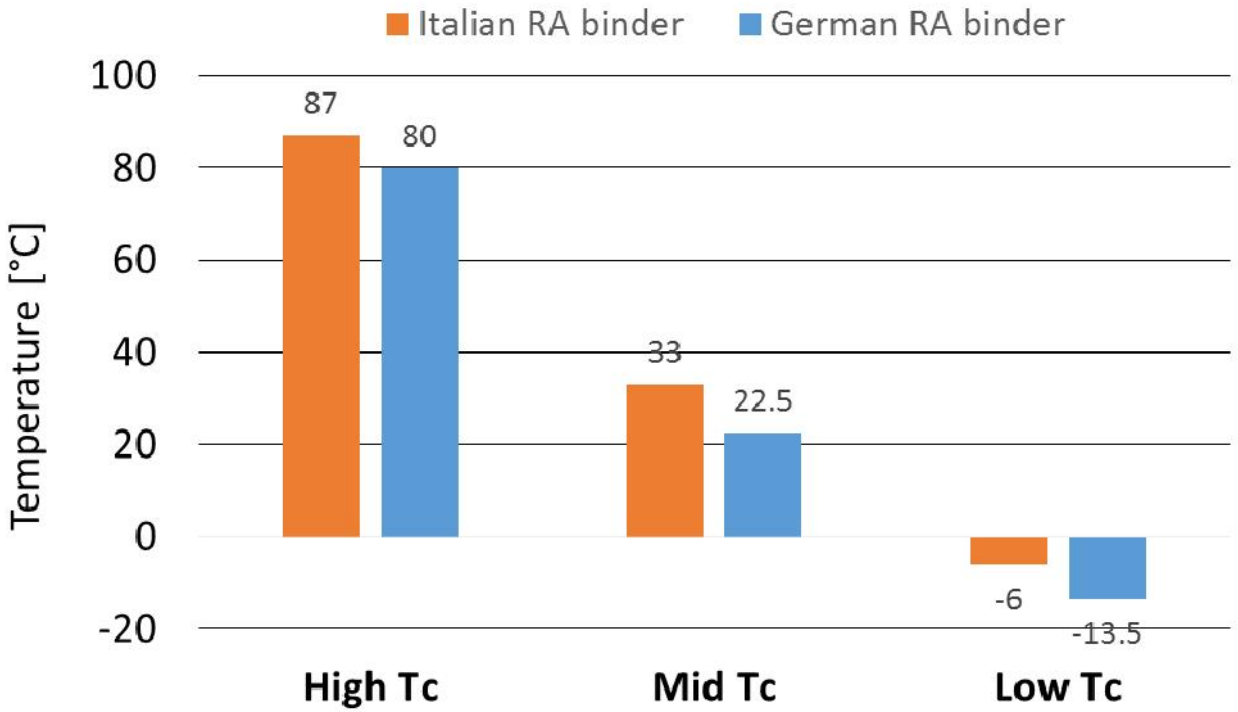


Binder extraction and recovery

Testing of RA aggregates

Testing of Binder

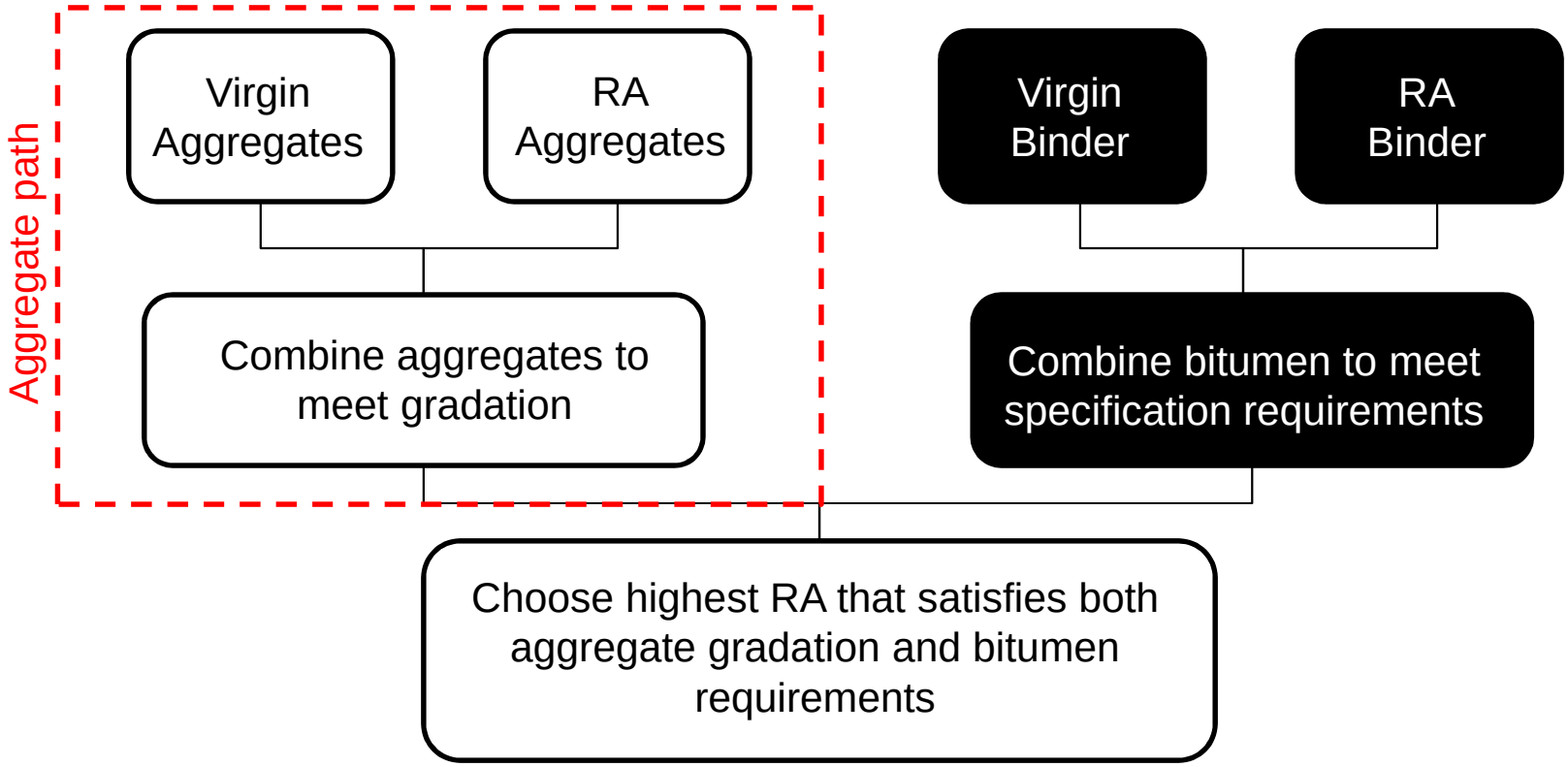
PG grade testing



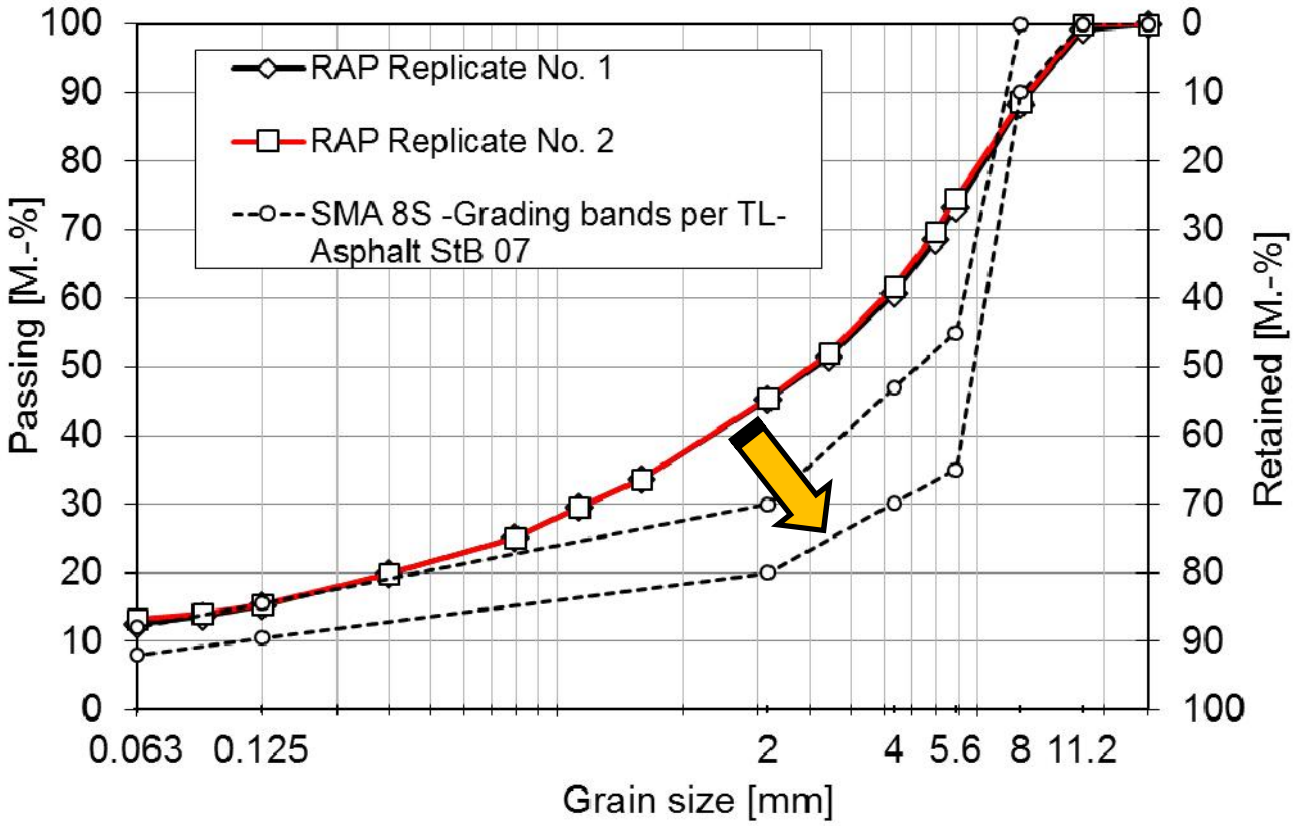
# Hot mix recycling process

# Mix design

## What is the maximum amount of RA that could be allowed in the mix?



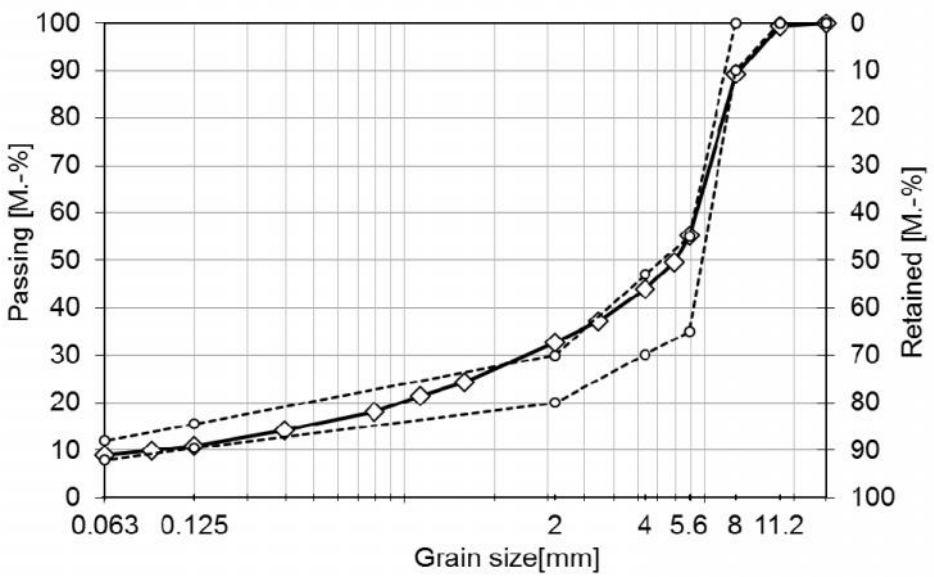
# Mix design




The RA grading needs to be modified by addition of virgin aggregates

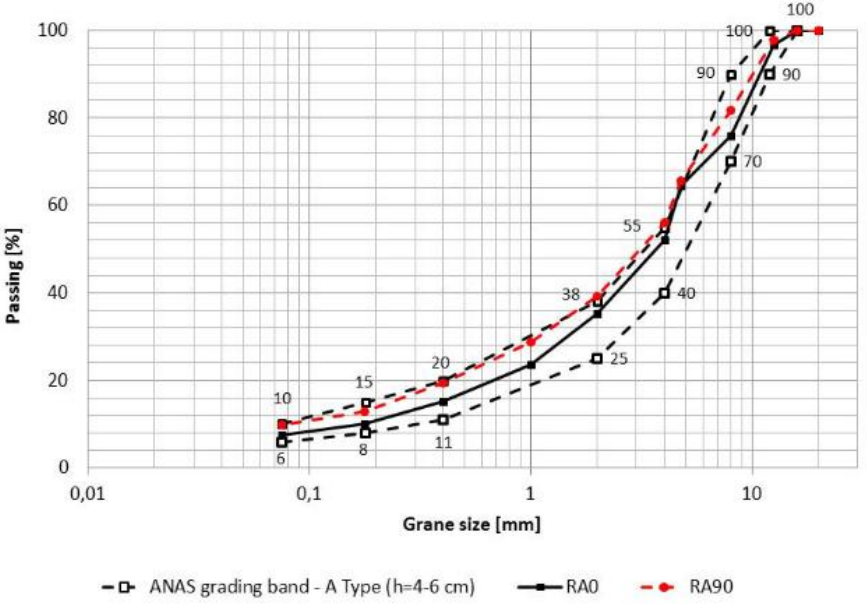
# Mix design

## German Mix




Max RA in mix: 70% -w

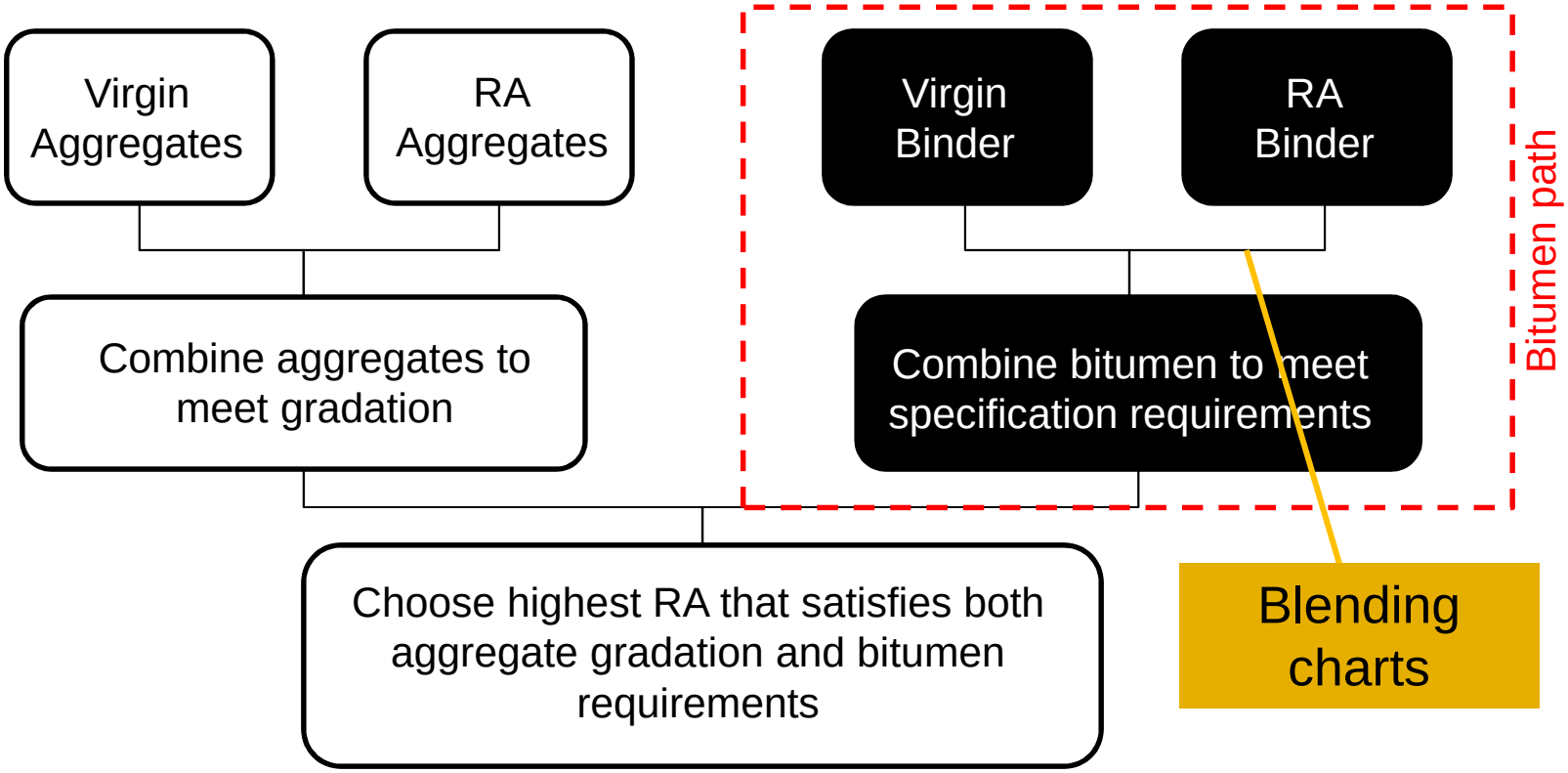
## Italian Mix




Max RA in mix: 100% -w

# Mix design

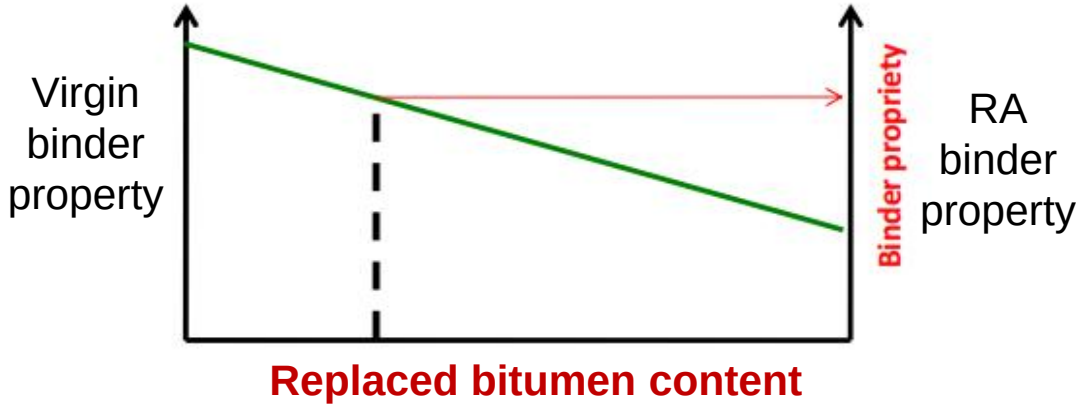
## What is the maximum amount of RA that could be allowed in the mix?



## Blending charts

The charts correlate the **replaced bitumen content** (RBC) with the empirical properties of the blend.

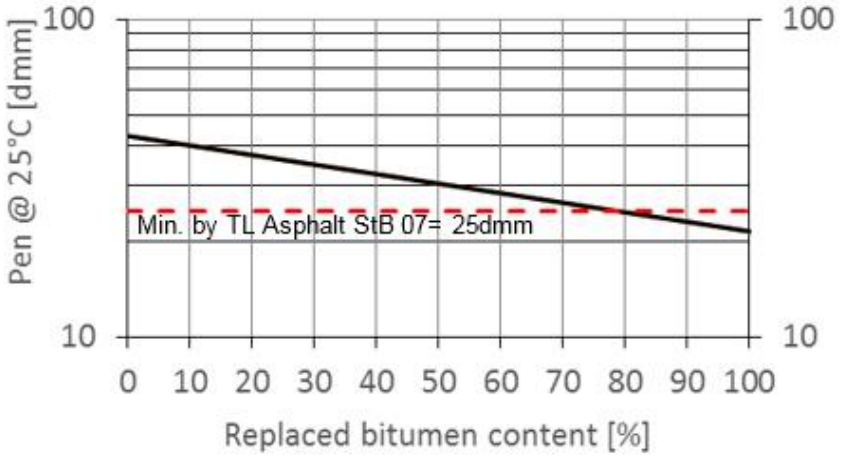
By **replaced bitumen content** it should be understood the percentage of bitumen from the RA in the final blend.

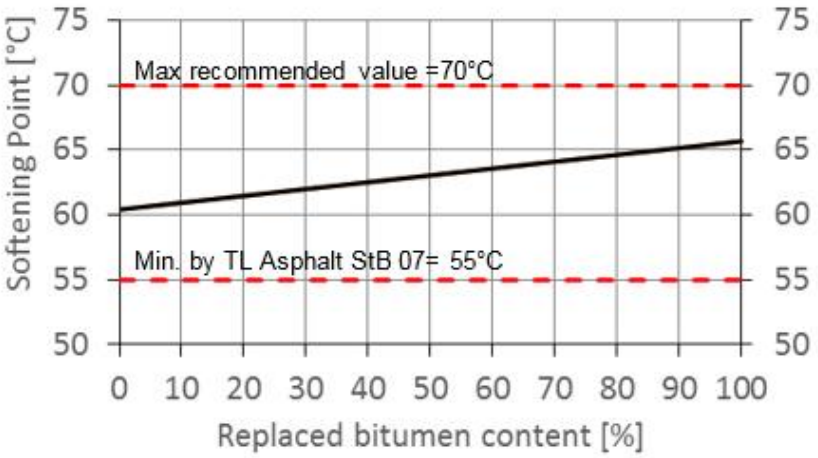


# Mix design

## ***GERMAN CASE:***

- *Use available RA (**short term aged**) and perform the design with and without rejuvenator*
- *Rejuvenator:*
  - *virgin PmB 25/55-55*
  - *partly rejuvenator + warm mix additive (mix)*



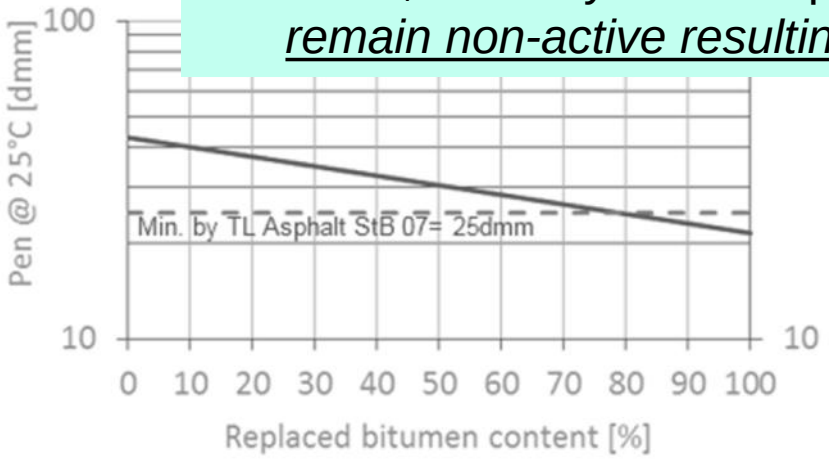
# Mix design

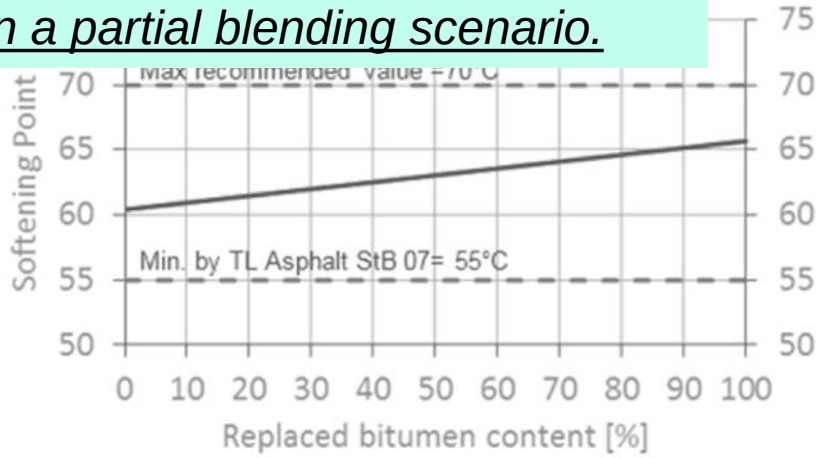
***GERMAN CASE:***

- *Use available RA (**short term aged**) and perform the design with and without rejuvenator*
- *F*

These charts are developed assuming that 100% of the RA binder will be mobilized and become active part of the binder in the new mix.

However, in reality it is also possible that part of the RA bitumen *remain non-active resulting in a partial blending scenario.*



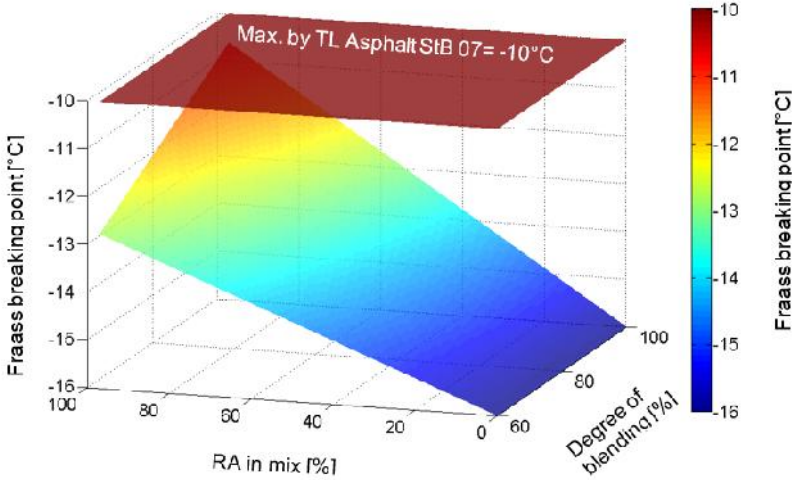



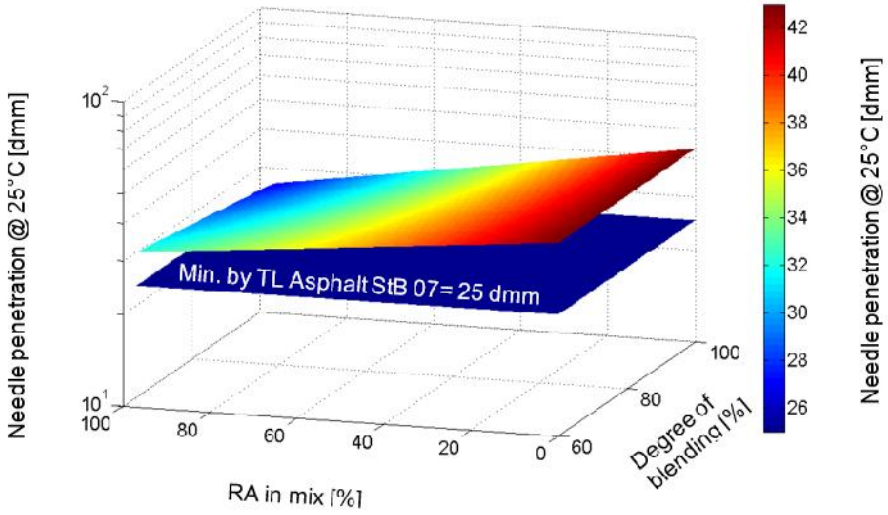
# Mix design

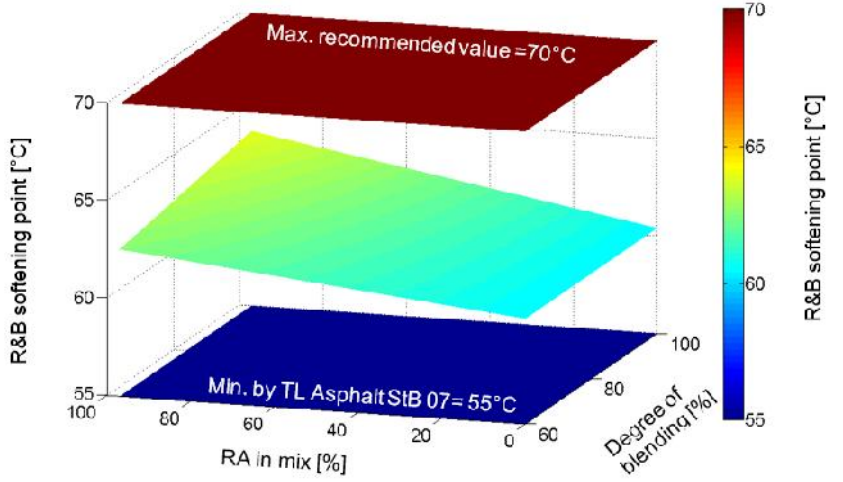
AllBack2Pave

## ***GERMAN CASE:***

Blending charts including degree of blending between 60 % and 100 %



# Mix design

## ***GERMAN CASE:***

- Binder blend design based on conventional properties shows that by using the selected binder PMB 25/55-55 as a virgin binder for the selected RA-mixes (30%,60%, and 70%), it is possible to obtain a final blend whom properties are still within the limits of Pen and SP

| %RA in the mixture | Penetration (25ºC) (d mm) | Softening Point (ºC) |
|---|---|---|
| Final Blend (30% RA) | 37.3 | 61.5 |
| | 39.7 | 61.0 |
| Final Blend (60% RA) | 32.3 | 62.6 |
| | 36.6 | 61.6 |
| Final Blend (70% RA) | 30.8 | 63.0 |
| | 35.7 | 61.8 |
| target | 25-55 | ≥55 |

# Mix design

## ***GERMAN CASE:***

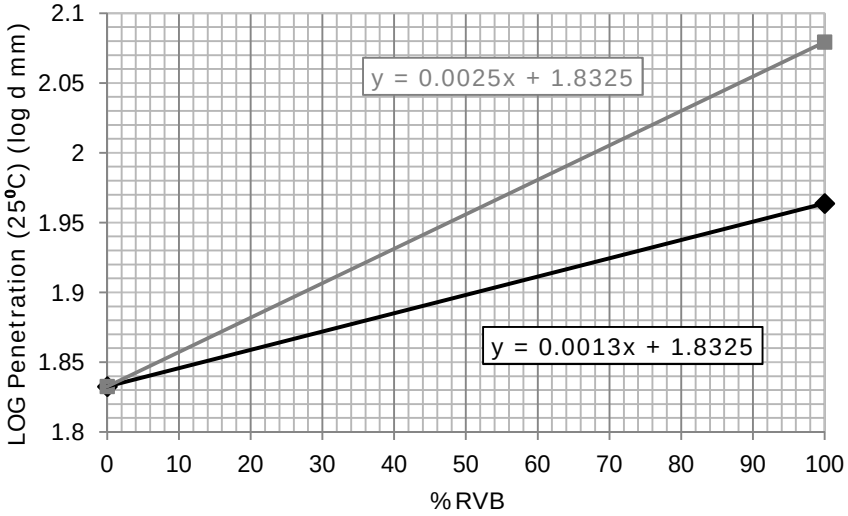
- Binder blend design based on performance-related properties shows that by using the selected binder PMB 25/55 (VB-D) as a virgin binder for the selected RA-mixes (30%,60%, and 70%), it is possible to obtain a final blend whom properties do not differ too much from the selected Virgin binder

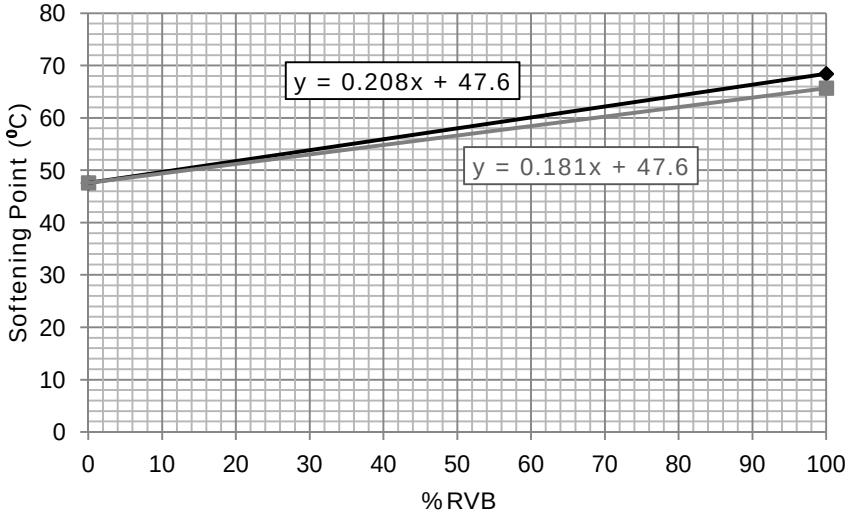
| %RA in the mixture | High Tc (ºC) | Intermediate Tc (ºC) | Low Tc (ºC) |
|---|---|---|---|
| Final Blend (30% RA) | 79.5 | 19.9 | -15.5 |
| | 79.5 | 19.6 | -15.7 |
| Final Blend (60% RA) | 79.7 | 20.6 | -14.9 |
| | 79.6 | 20.2 | -15.4 |
| Final Blend (70% RA) | 79.8 | 20.8 | -14.8 |
| | 79.6 | 20.1 | -15.3 |
| Target (VB-D) | >79.3 | <19.2 | <-16.0 |

# Mix design

## ***ITALIAN CASE:***

- *Use available RA (**long term aged**) and perform the design with rejuvenator*
- *Rejuvenators:*
  - *virgin bitumen 50/70*
  - *rejuvenator + warm mix additive (mix)*



# Mix design

## ***ITALIAN CASE:***

- Binder's blend design based on conventional properties shows that by using the selected binder Pen 50/70 as a virgin binder and RejA and RejB for the selected RA-mixes (30%,60%, and 90%), both Pen and SP values struggle to achieve the target

| %RA in the mixture | Final properties of blend with RejA | | Final properties of blend with RejB | |
|---|---|---|---|---|
| | Penetration ($25^0$C) (d mm) | Softening Point ($^0$C) | Penetration ($25^0$C) (d mm) | Softening Point ($^0$C) |
| 30%RA | 71.0 | 50.5 | 73.7 | 50.2 |
| | 73.9 | 53.3 | 79.5 | 52.6 |
| 60%RA | 70.4 | 53.4 | 79.8 | 52.7 |
| | 80.3 | 59.0 | 92.9 | 57.5 |
| 90%RA | 77.3 | 56.4 | 86.5 | 55.2 |
| | 87.2 | 64.7 | 108.7 | 62.5 |
| target | 50-70 | $\geq$54 | 50-70 | $\geq$54 |

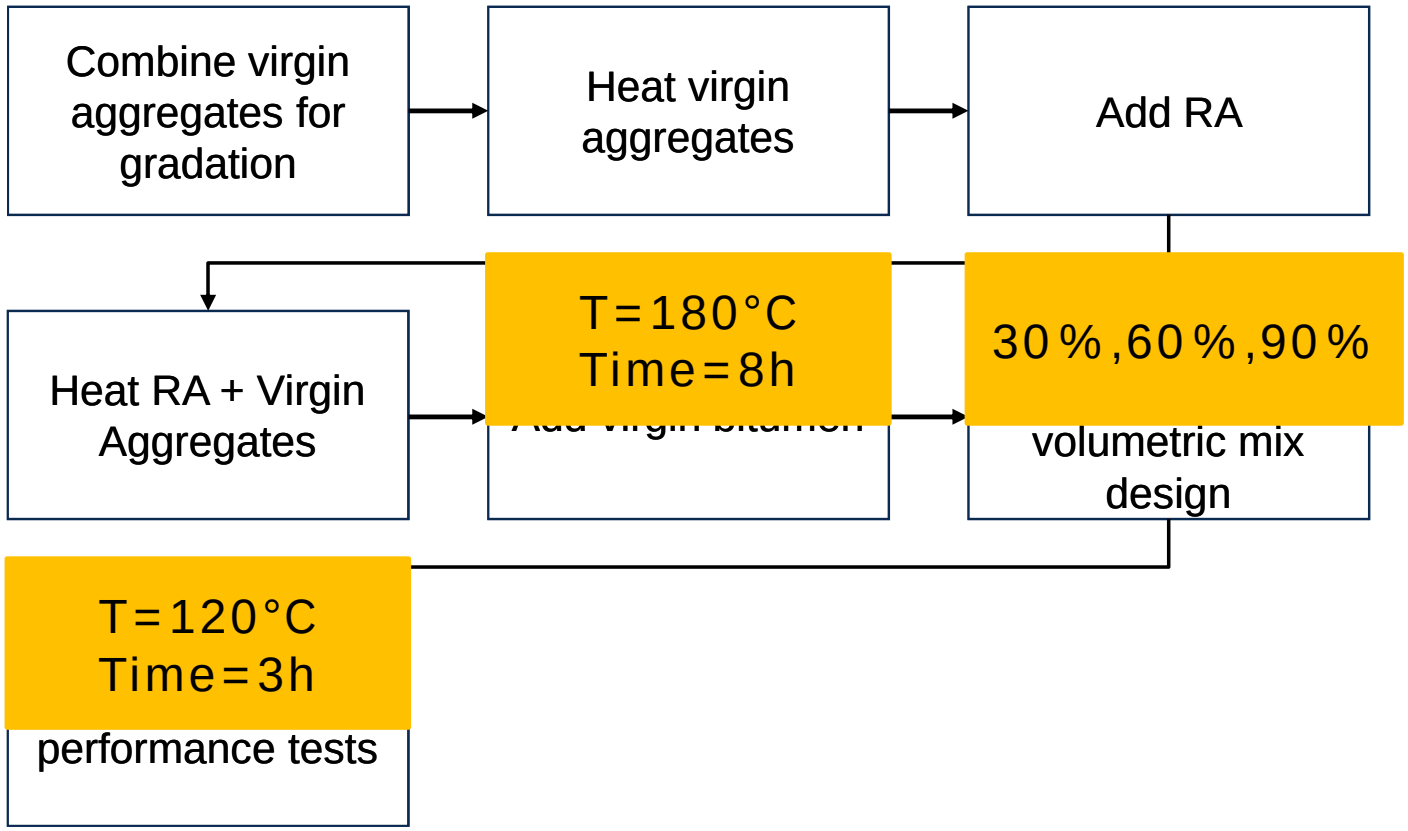
# Mix design

## ***ITALIAN CASE:***

- Blend design based on performance-related properties shows that by using the selected binder Pen 50/70 as a virgin binder and RejA and RejB for the selected RA-mixes (30%, 60%, and 90%), it is possible to obtain a final blend with comparable properties to the target binder VB.

| | Final properties of blend with RejA | | | Final properties of blend with RejB | | |
|---|---|---|---|---|---|---|
| Binder | High Tc ($^0$C) | Int Tc ($^0$C) | Low Tc ($^0$C) | High Tc ($^0$C) | Int Tc ($^0$C) | Low Tc ($^0$C) |
| RAb | 87 | 33 | -6 | 87 | 33 | -6 |
| Final Blend (30% RA – white100) | 67.1 | 16.9 | -16.6 | 67.1 | 16.6 | -14.4 |
| Final Blend (60% RA – white100) | 68.5 | 14.8 | -18.1 | 68.4 | 14.2 | -13.9 |
| Final Blend (90% RA – white100) | 69.8 | 12.7 | -19.7 | 69.7 | 11.8 | -13.3 |
| target (VB) | $\geq$66 | $\leq$19 | $\leq$-16 | $\geq$66 | $\leq$19 | $\leq$-16 |

# Mix design process in lab



# Conclusions

- The heterogeneity of the RA aggregates plays an important role when designing asphalt mixes for wearing courses where high quality aggregates with high resistance to wear/abrasion (polishing) are needed.

- Properly milled (i.e. layer by layer) and stockpiled RA is a mandatory prerequisite in order to produce durable asphalt wearing courses with high content of RA.

- The RA must be treated as a valuable material

- In order to produce mixes with high RA content, a balanced mix design approach must be followed.

- One possible solution is to allow the use of high percentage of RA in wearing courses only if the RA material proceeds from the same location and layer where the new mix will be placed.