



Use of rejuvenators in asphalt mixtures

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*Benchmark on rejuvenators, all
rejuvenators are not equal*

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Presentation outline

- Research objectives
- Methods and materials
- Results
- Conclusions
- Discussion

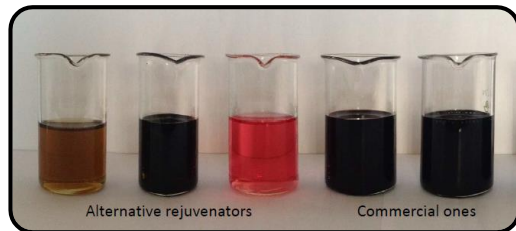
Research objectives – aspects to considered in this presentation

1. HSE & Waste considerations
- 2. Physical properties**
- 3. Influence on aged binder characteristics**
4. Influence on functional behaviour of asphalt mixtures
5. Assessment on full scale trials

Therefore, this presentation is focused on **laboratory results** with the aim to methodologically **evaluate various products.**

Materials (described in this presentation)

- **Rejuvenators** (13 different products)
- **Binders**
 - Recycled binders (includes repeated recycling), **100 % recycling**
 - Paving grade bitumen
 - Reclaimed Asphalt binders



Composition according to Safety Data Sheet

- Refined rapeseed oil
- Mixture of resins, waxes, polymers
- Residues (petroleum), vacuum
- Mixture of vegetable oils
- Fatty acid derivatives
- Rosins esters, fatty acid and vegetable oil
- Mixture of modified alkylamidopolyamine and vegetal oils
- Polyol ester, tall and turpentine oils
- Fatty acid methyl ester
- Aromatic extract
- Mixture of vegetable oils
- Product which contains waxes 1
- Product which contains waxes 2

Not all these are necessarily mentioned in the presentation

Methods (described in this presentation)

- **Testing of rejuvenators**
 - Rejuvenators as such (physical properties)
 - Efficiency (via change of binder rheological properties)
- **Testing of binders**
 - Susceptibility to aging
 - Aging methods (RTFOT, 3xRTFOT, PAV, 2xPAV)

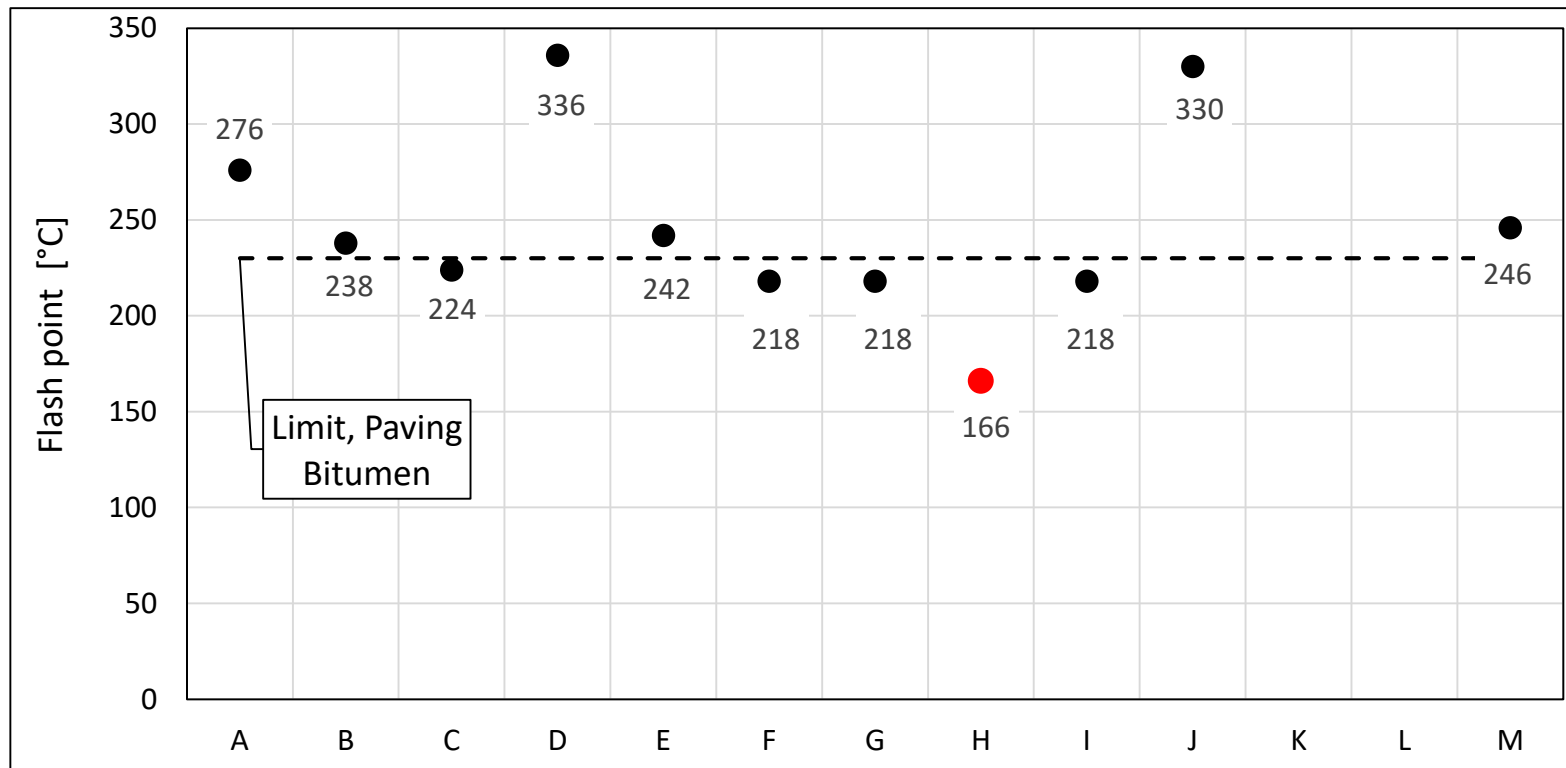
Evaluation of rejuvenators as such

Evaluation of rejuvenators as such

1. Flash point
2. Loss of weight (rejuvenators/binders)
3. Dynamic viscosity
4. Fume emission evaluation
5. HSE – REACH classification
6. ...



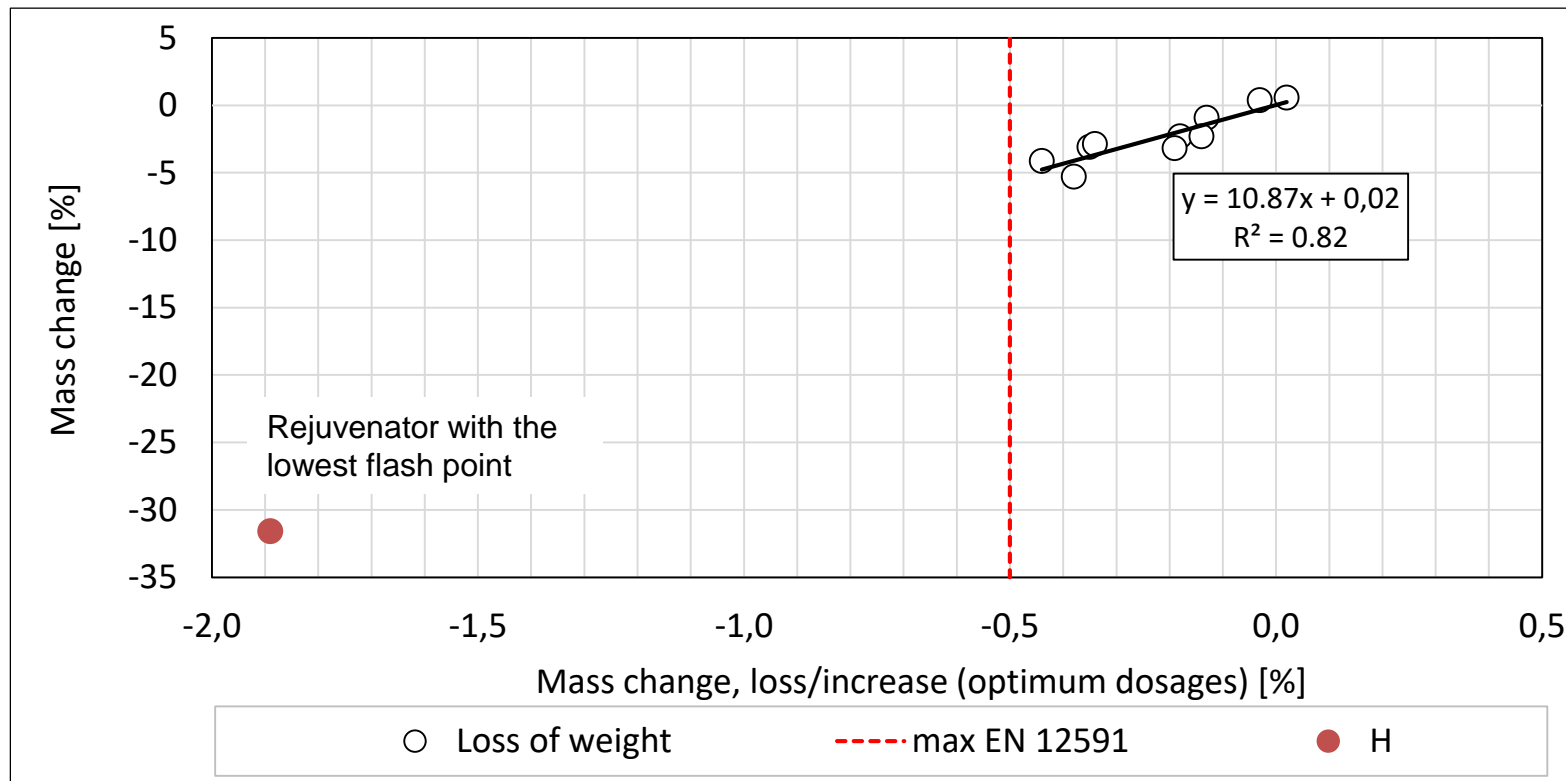
Results – rejuvenators' flash point



There is no requirement or a recommended limit in Europe

Some rejuvenators have lower flash point than required on binders (≥ 230 °C).

Results – rejuvenators and recycled binders – loss of weight



Clear relationship between rejuvenators' and recycled binders' loss of weight

Note: results are base binder dependent (reference 50/70 – mass loss + 0.04 %)

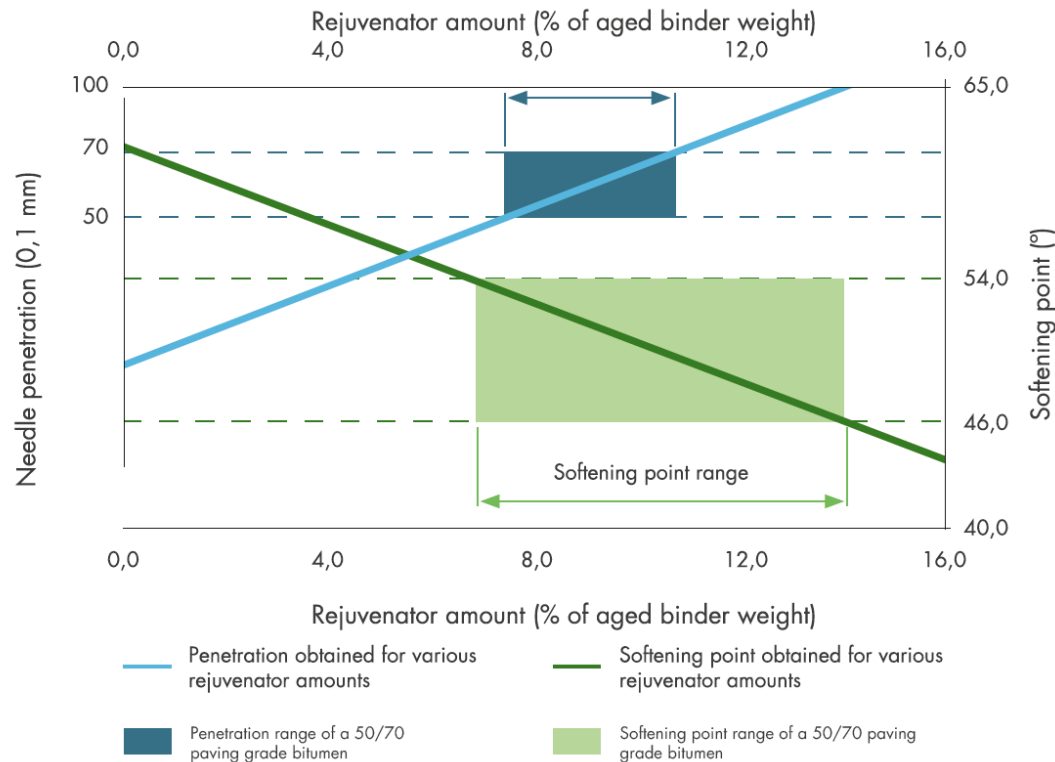
Some rejuvenators emits lots of fumes during RTFOT – organoleptic detection.

Rejuvenators' partial conclusions

- Some rejuvenators have **lower flash point than required on binders** (a need to consider a viable way of dosing. e.g. prior drum, pug mill, binder...)
- Good **correlation on** rejuvenators' and rejuvenated binders' **mass loss**.
- Some rejuvenators can require **constant heating** during pumping at plant.
- Some rejuvenators emits **significant** amounts of **fumes** (health issue).

Rejuvenators' effectiveness

Rejuvenators' effectiveness, general information

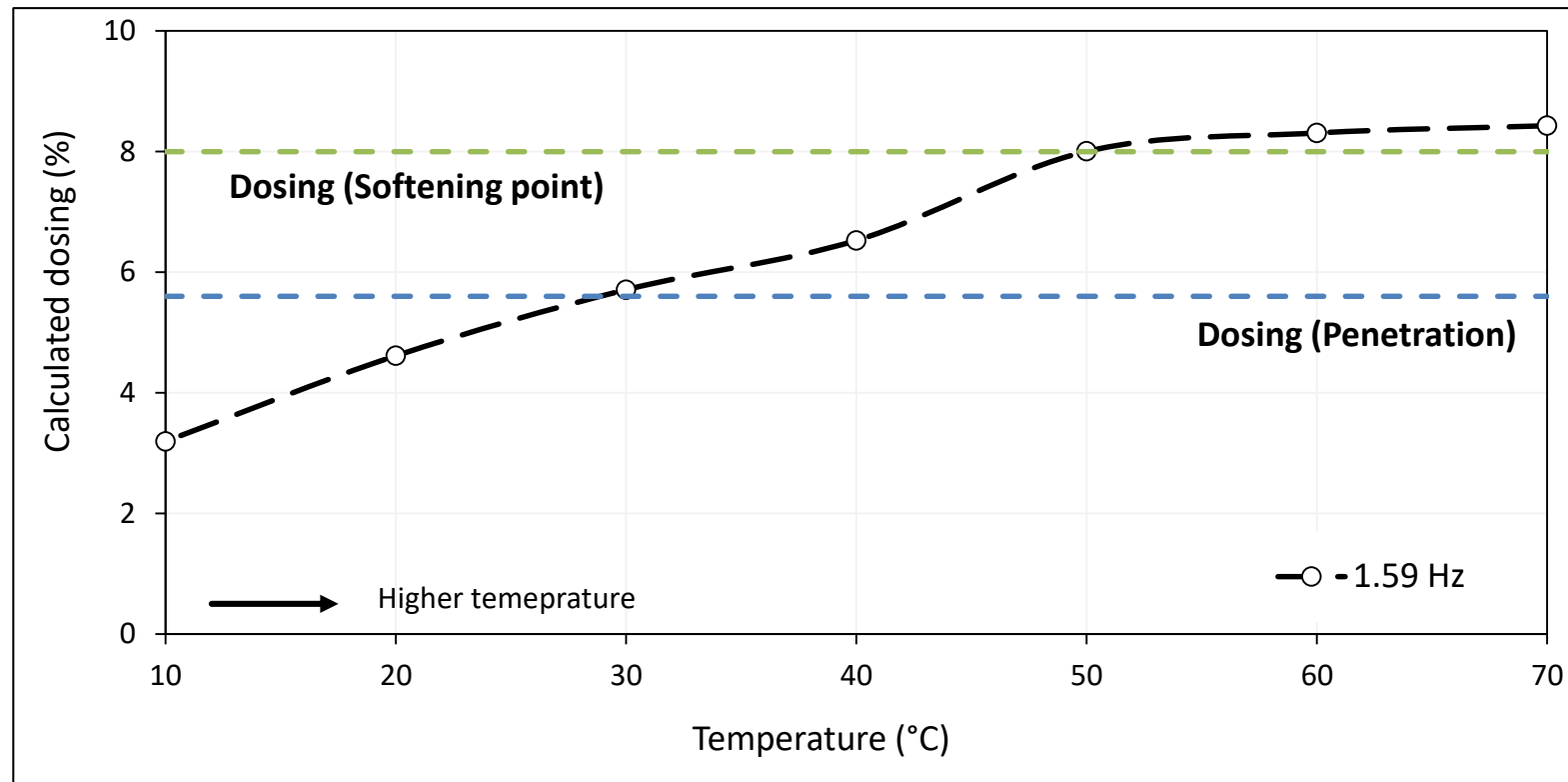


Effectiveness is dependent on the parameter used to assess it.
→ higher dosing generally needed to restore viscous components.

Almost all rejuvenators can restore **empirical properties** (same category after recycling) → **not possible to tell the difference.**

Source: Recommendation for the use of rejuvenators in hot and warm mix asphalt production [EAPA]

Rejuvenators' effectiveness, influence of boundary conditions



Dosages to restore G^* to initial values

Different dosing for each temperature domain

Note: **example of one rejuvenator and one testing frequency**

- Aged binder R&B 61.6°C, pen. 23 (0.1mm)
- Original binder R&B 48.0°C, pen. 56 (0.1mm)

Rejuvenators' effectiveness, influence of boundary conditions

Rej.	Calculated optimum dosages to rejuvenate aged binder		
	Boundary conditions		
	G*, 60 °C, 1.59 Hz	G*, 25 °C, 0.4 Hz	G*, 15 °C, 10.0 Hz
A	8.3	5.8	3.2
B	8.4	7.1	4.9
C	11.9	8.8	4.3
D	8.6	5.5	2.9
E	7.8	5.0	2.7
F	7.9	5.5	3.4
G	8.5	6.1	4.0
H	9.1	6.5	3.5
I	6.8	5.0	3.3
J	8.9	6.0	3.2
M	13.2	11.1	7.8

Fresh binder before aging

G* @ 60 °C a 1.59 Hz ≈ 2.3 kPa

G* @ 25 °C a 0.4 Hz ≈ 266.2 kPa

G* @ 15 °C a 10 Hz ≈ 14170.0 kPa

Aged binder to rejuvenate

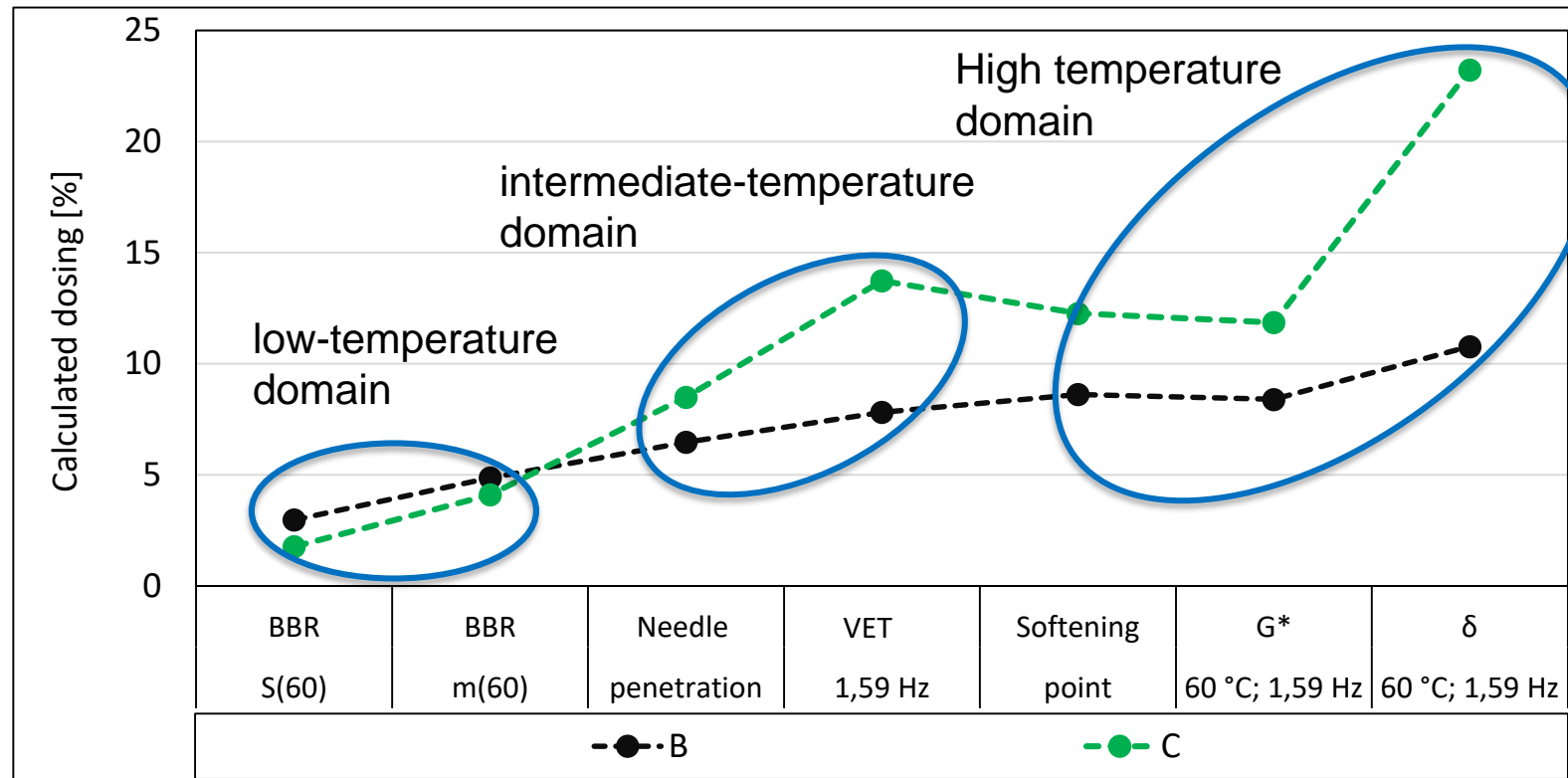
G* @ 60 °C a 1.59 Hz ≈ 16.6 kPa

G* @ 25 °C a 0.4 Hz ≈ 1460.0 kPa

G* @ 15 °C a 10 Hz ≈ 28690.0 kPa

Note: the sequence of rejuvenators is purposely skewed and does not fit the designation in presentation

Rejuvenators' effectiveness, influence of rejuvenator type

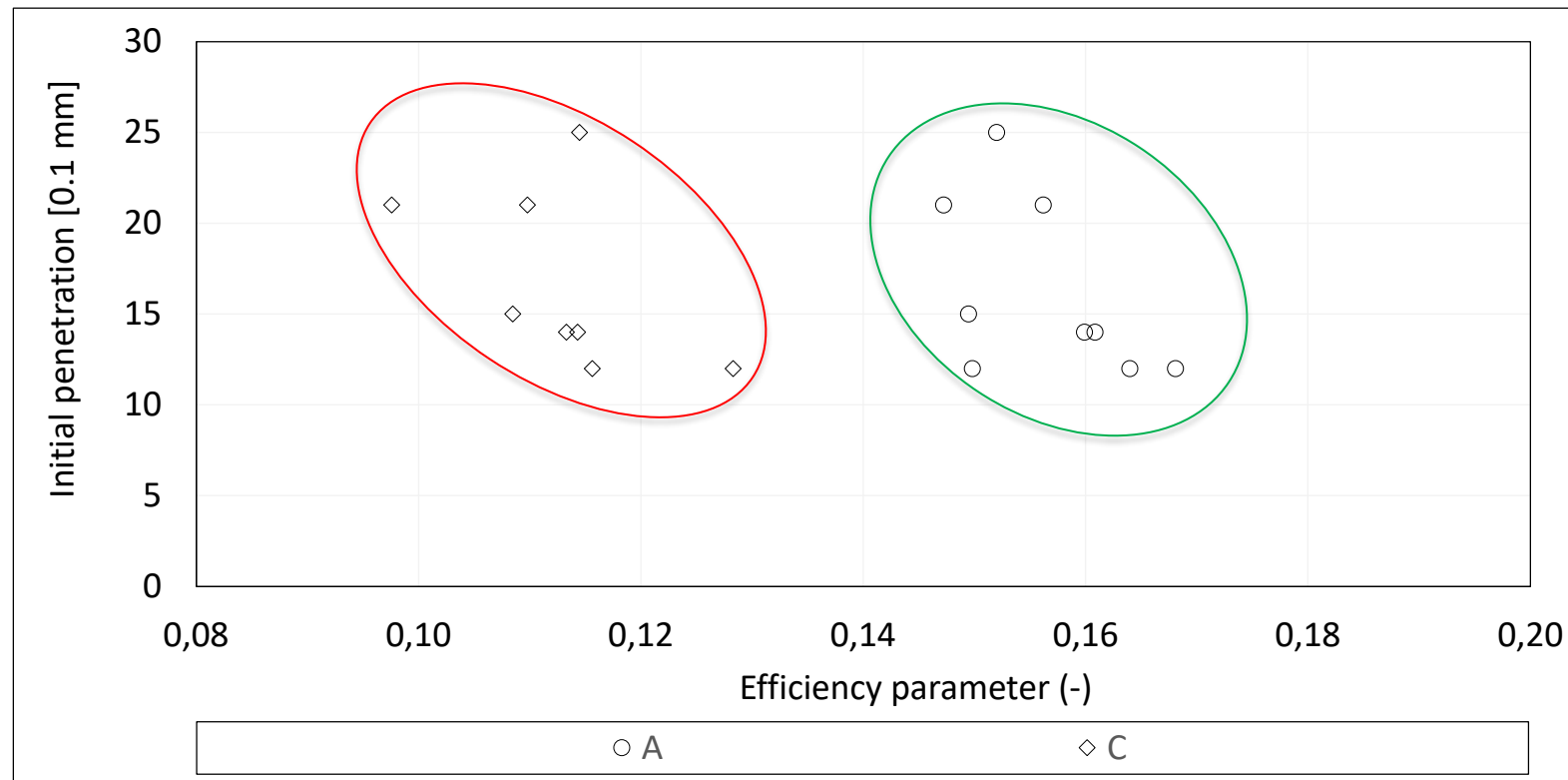


Dosages to restore different rheological parameters

Significant differences between rejuvenators too

- Aged binder R&B 61.6°C, pen. 23 (0.1mm)
- Original binder R&B 48.0°C, pen. 56 (0.1mm)

Rejuvenators' effectiveness, effect of aged binder type



Efficiency parameter – slope of log pen x dosage

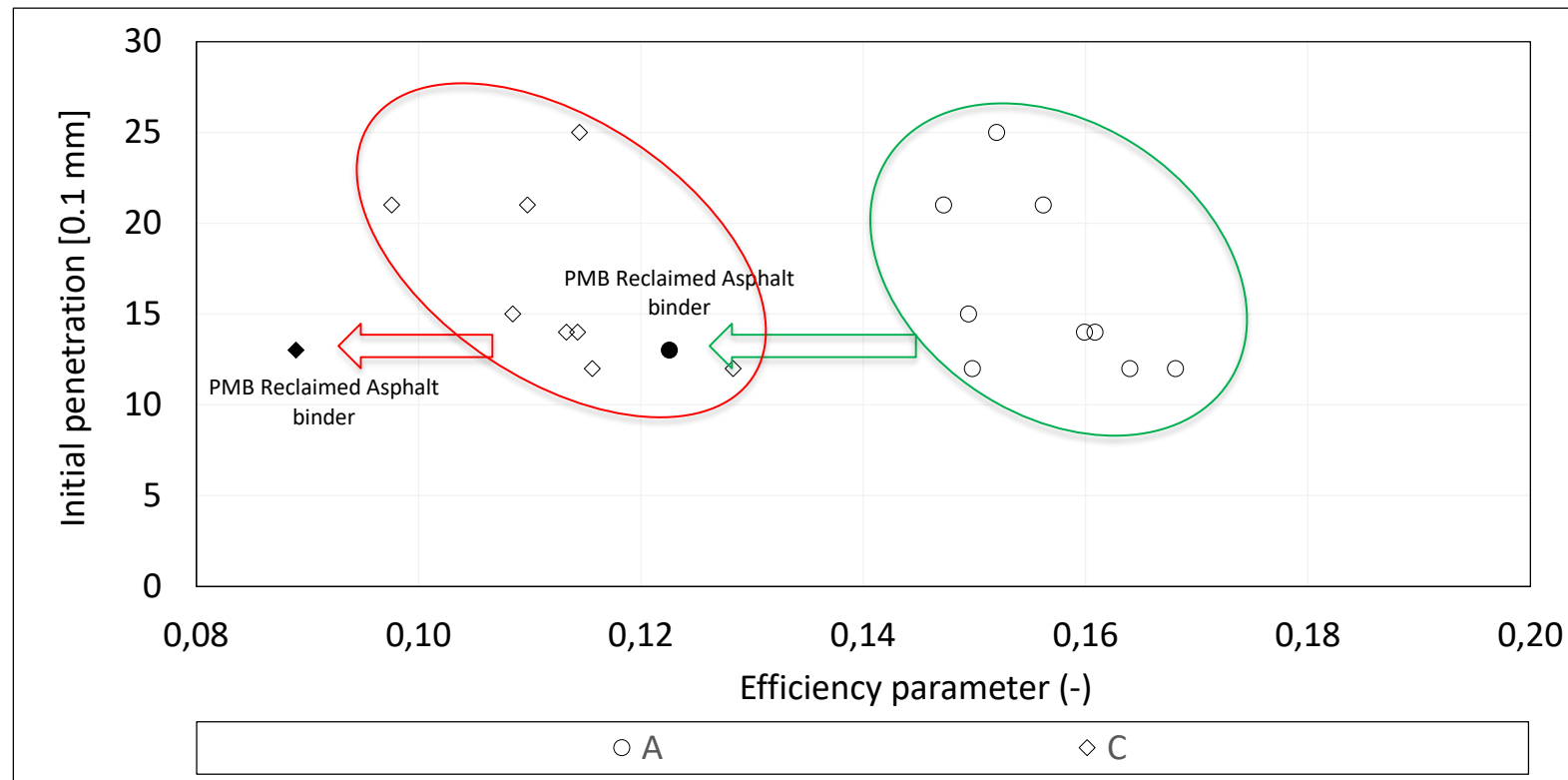
Efficiency not affected by initial penetration



- Reclaimed Asphalt binders (non-modified) pen 12 to 25 (0.1mm)

- **Possible to use calibration curves**

Rejuvenators' effectiveness, effect of aged binder type



Be aware of different effects on anyhow modified binders

- Reclaimed Asphalt binders (non-modified)
- Reclaimed Asphalt binder modified, pen. 13 (0.1mm)

Rejuvenators' effectiveness, partial conclusions

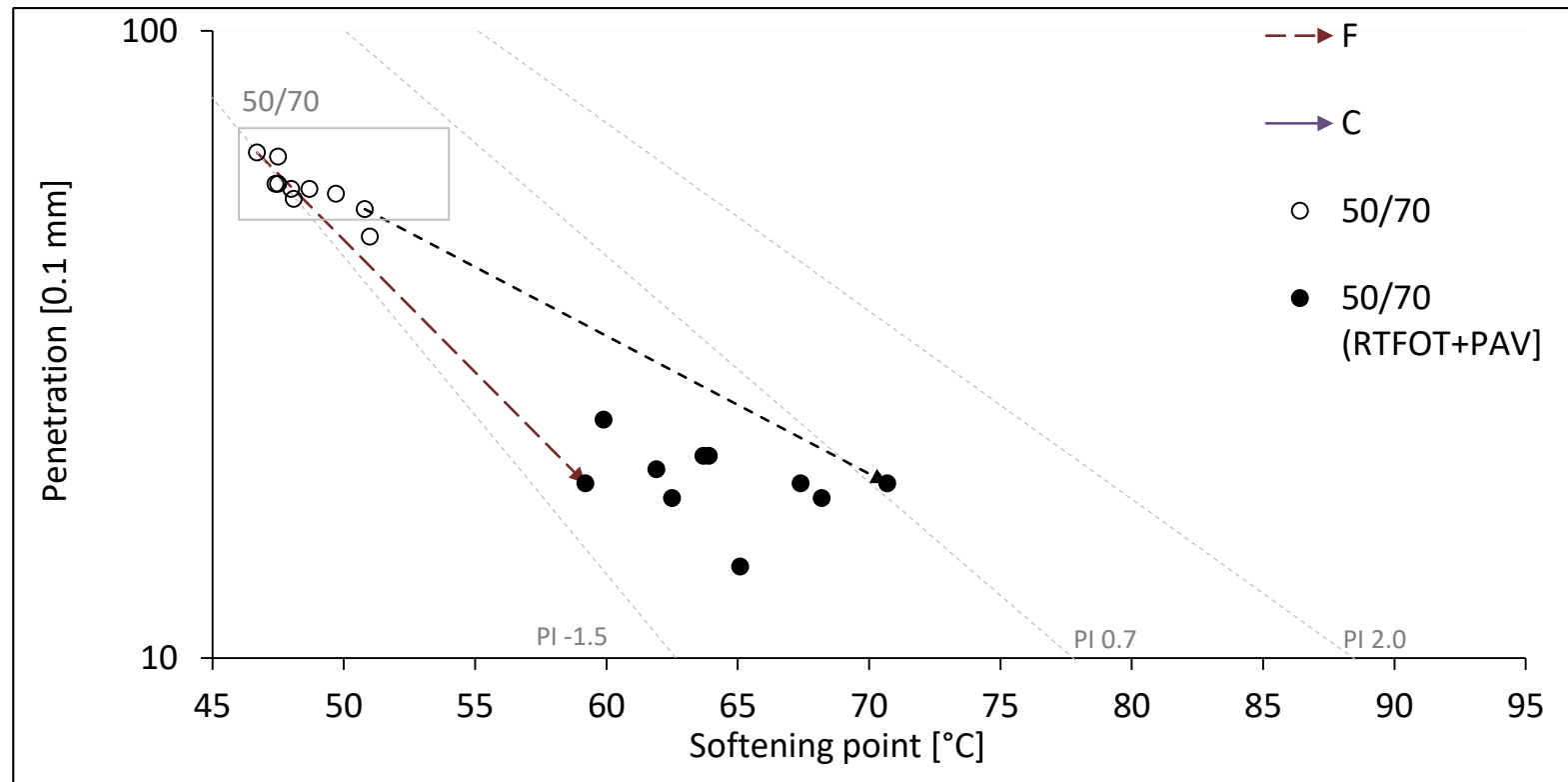
- Rejuvenators have **different ability to restore** visco-elastic **properties**.
- **Rejuvenated binders** might fit 50/70 category, the viscoelastic behavior **can be** very **different** (not necessarily worse) **compared to paving bitumen**.
- **Efficiency not affected** much **by** aged **binder source** (non-modified binders)
- No rejuvenator was able to fully restore the initial properties no matter what dosage used.

Is it at all reasonable to expect or require the full recovery???

It is probably not needed (not possible even), we should look for balance.
Design dosage based on intermediate parameters (penetration, VET, G^*),
keep the benefit of elasticity while having lower stiffness. **Dosing need to be verified and adjusted based on mixture testing.**

Recycled binders' susceptibility to aging

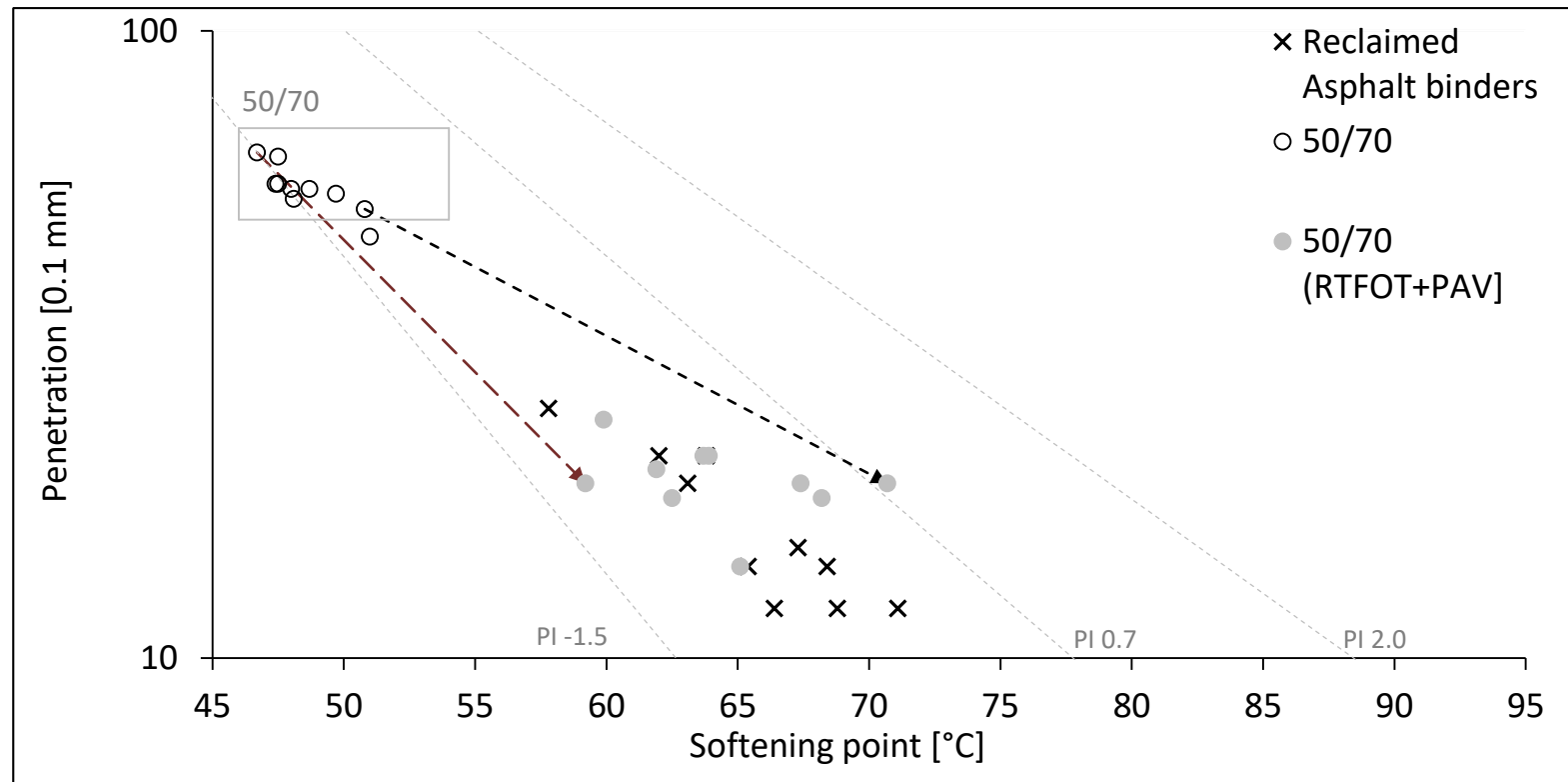
Results – susceptibility to ageing, paving bitumen



Aging has different effect on various paving bitumens

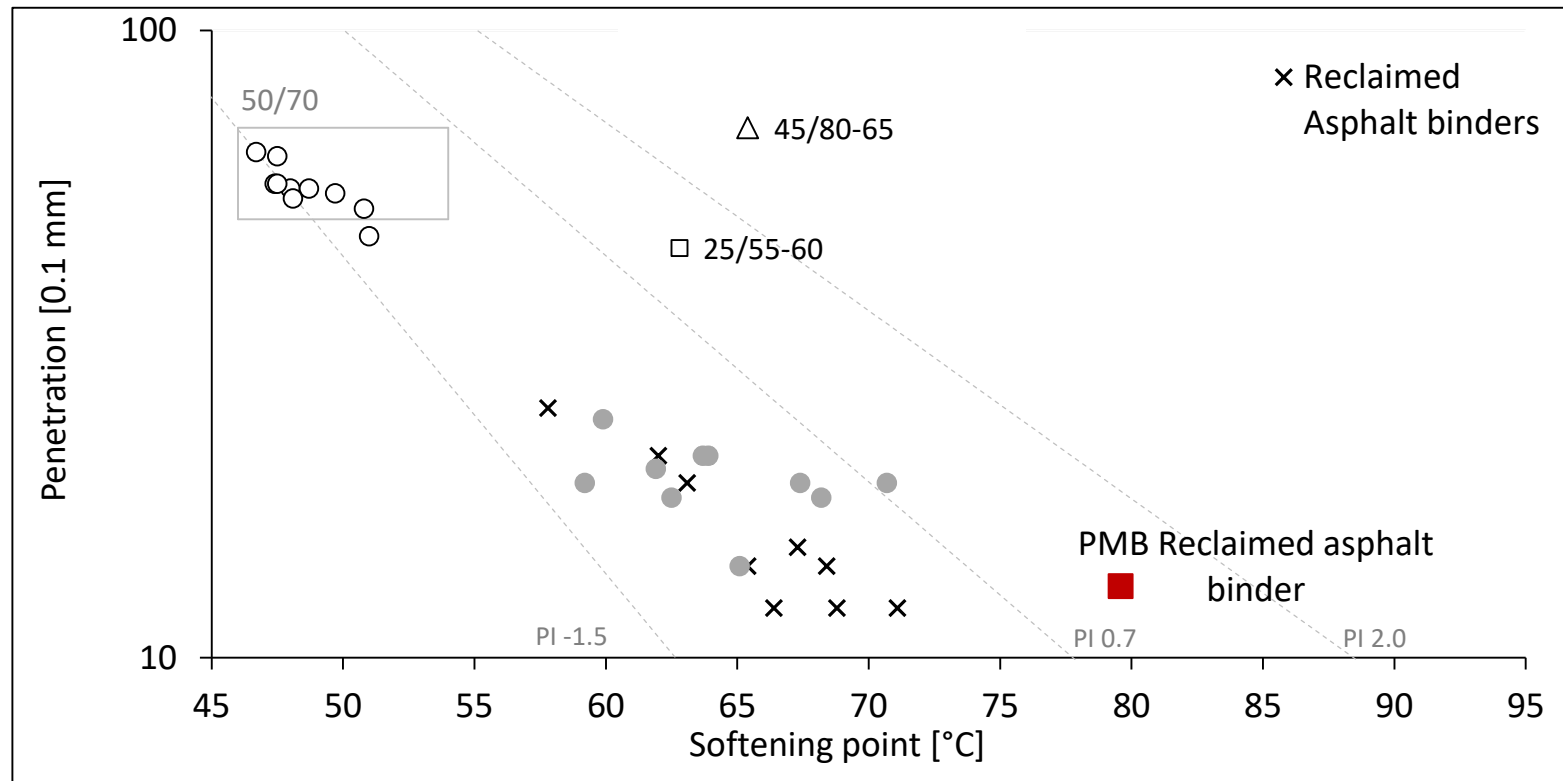
- Most paving bitumens within the PI limits (-1.5 to 0.7)
- PI is an informative parameter in EN 12591 (temperature susceptibility)

Results – susceptibility to ageing, reclaimed asphalt binders



Reclaimed asphalt binders (non-modified) are positioned also within PI limit

Results – susceptibility to aging



Modified Reclaimed asphalt binders can be positioned differently



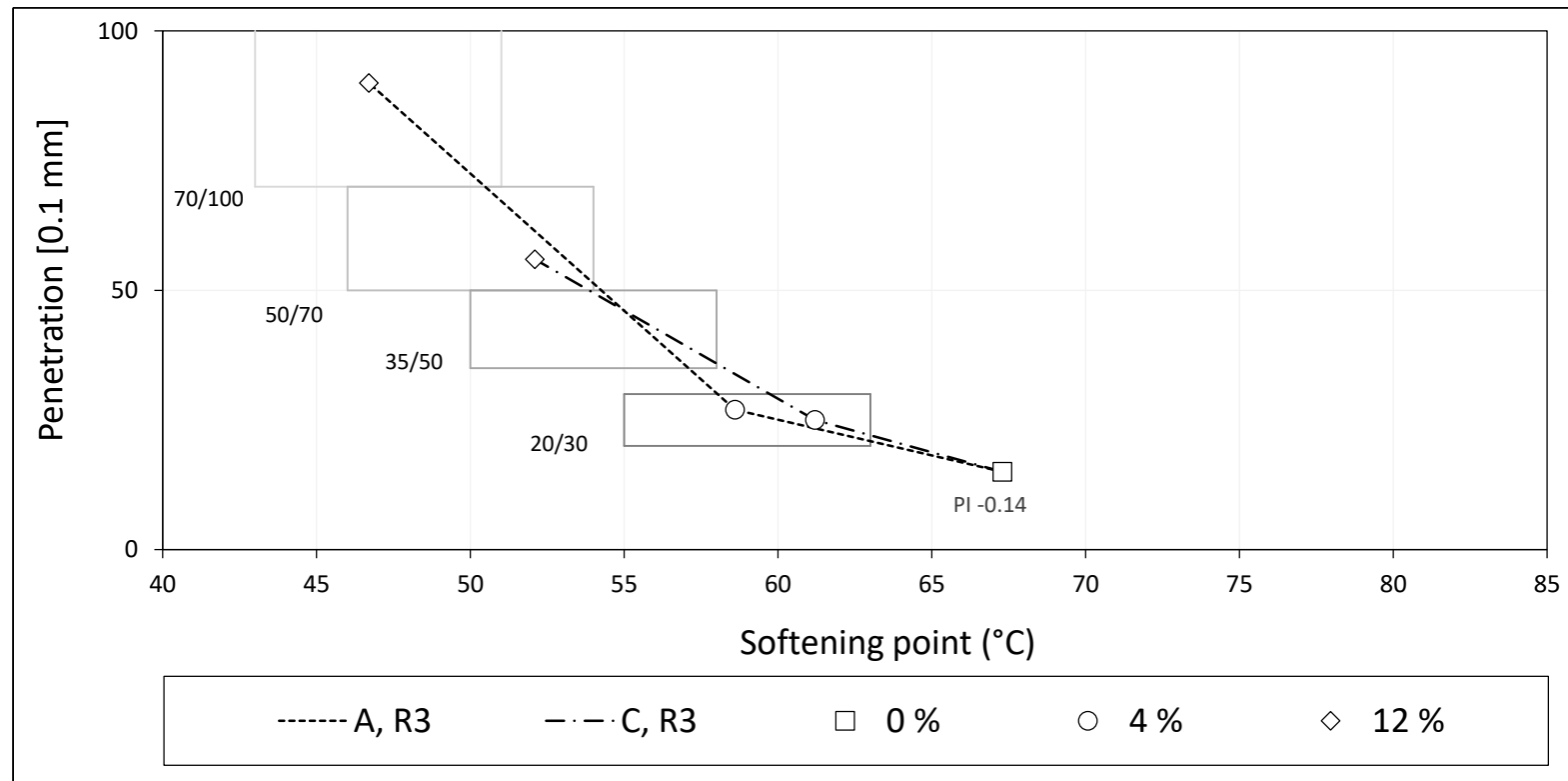
- **Impact on recycling**



- **Impact on binder classification**

Attention should be paid to completely different PI, which remains even after rejuvenation.

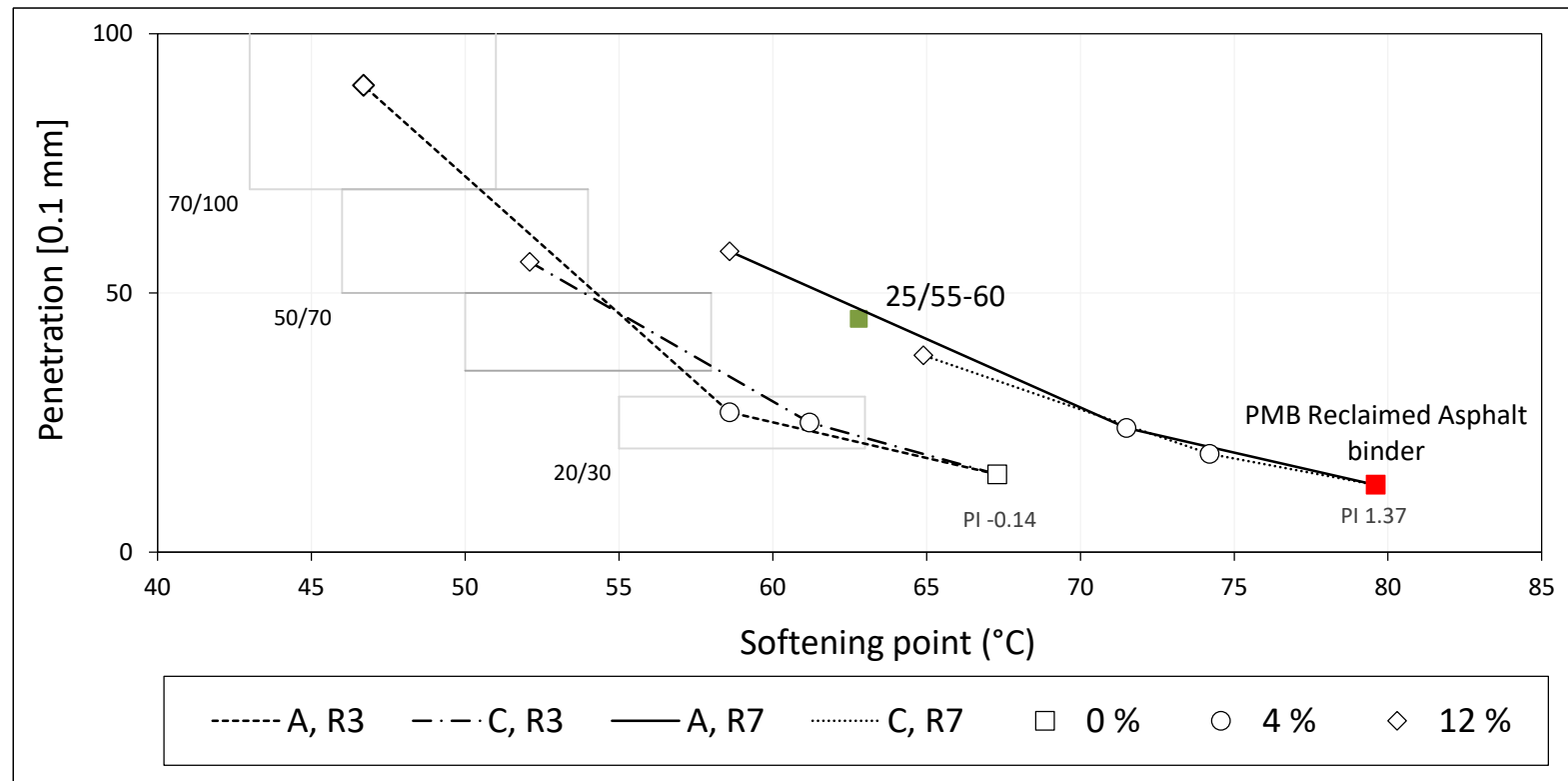
Results – reclaimed asphalt binders recycling



- Rejuvenators A and C
- Dosing 4 % and 12 %
- Reclaimed Asphalt b. R3 (non-modified)

Possible to recycle the reclaimed asphalt binders into paving grade categories

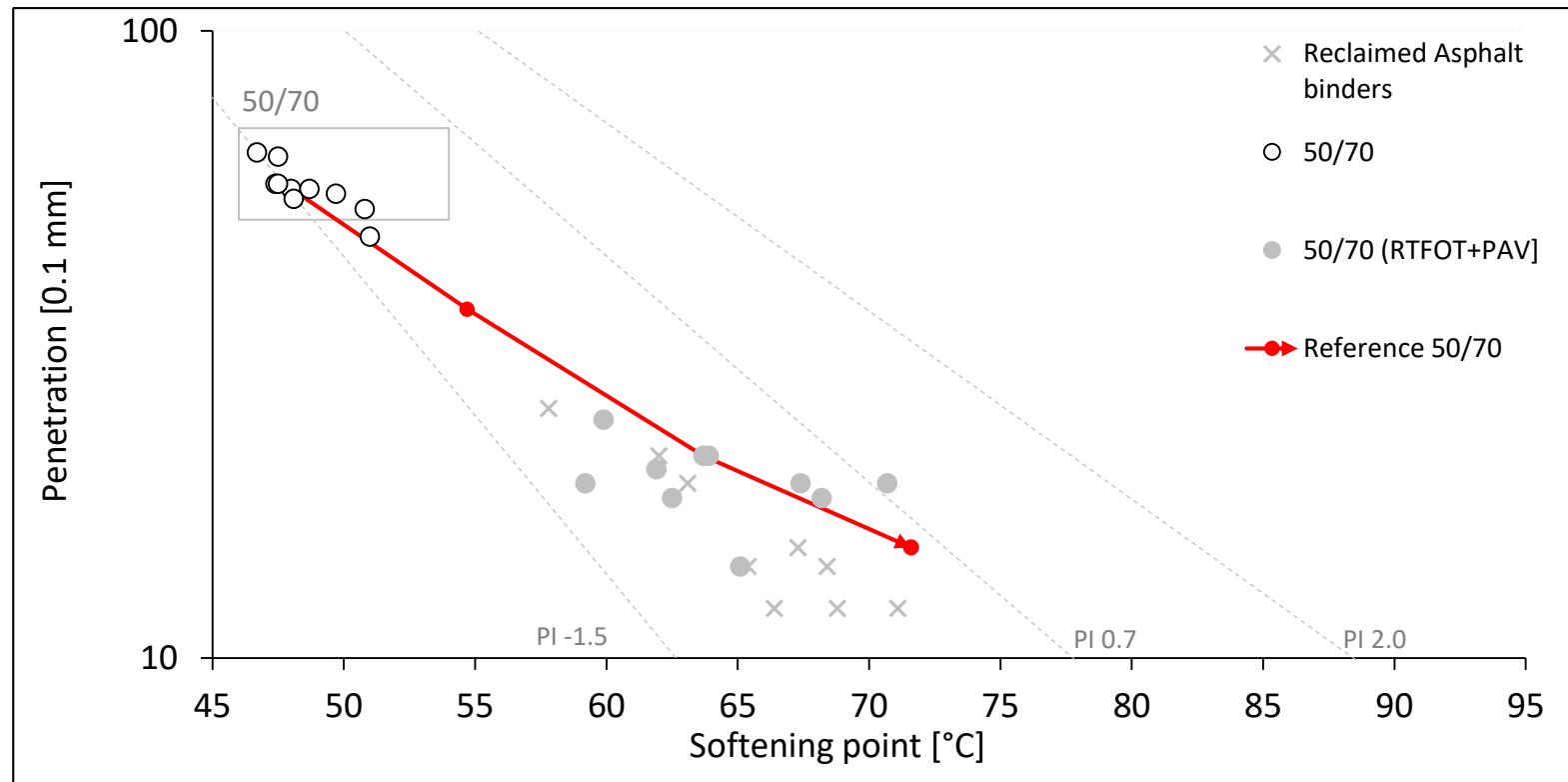
Results – reclaimed asphalt binders recycling



- Rejuvenators A and C
- Dosing 4 % and 12 %
- Reclaimed Asphalt b. R3 (non-modified)
- Reclaimed Asphalt b. R7 (modified)

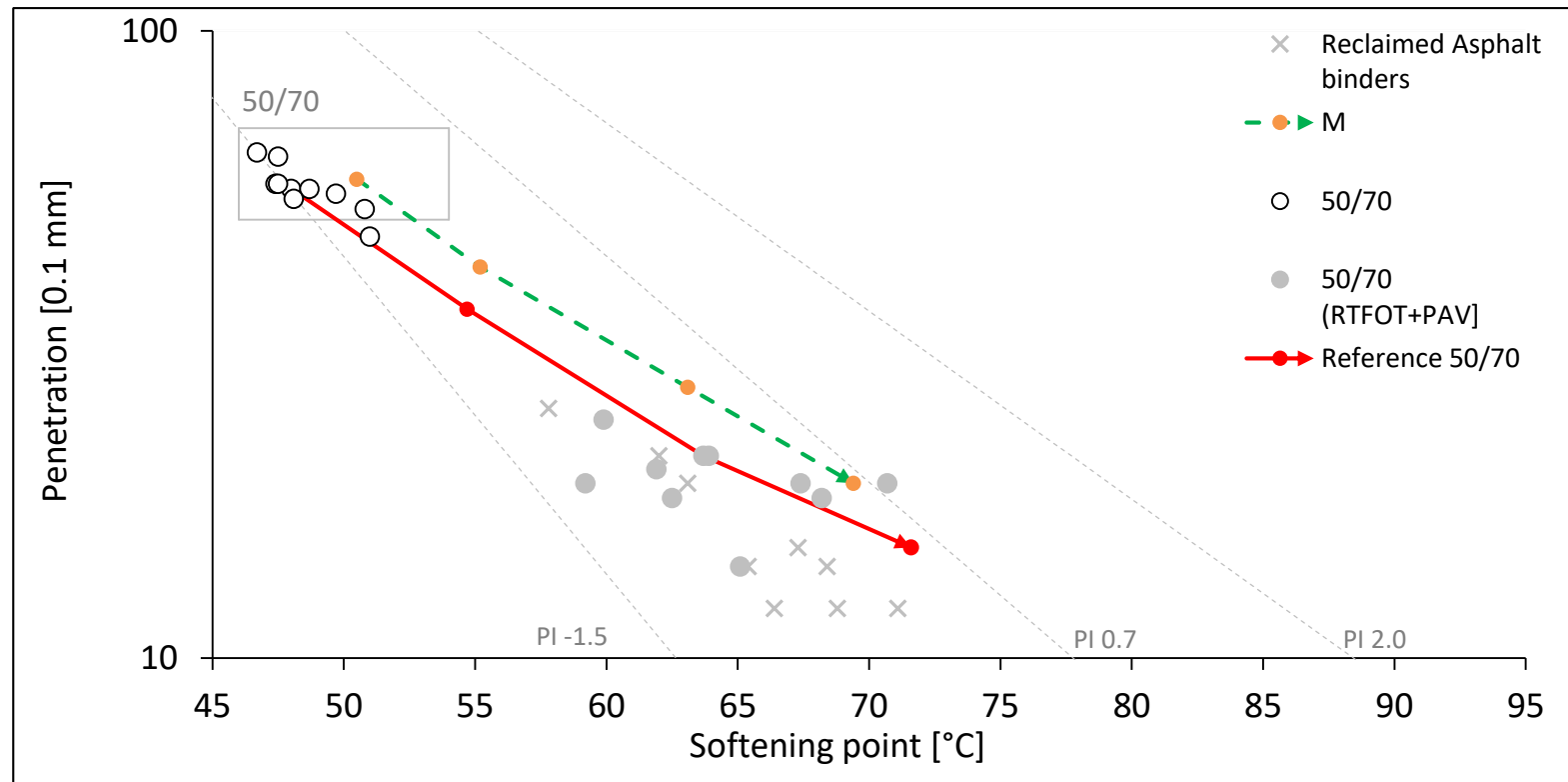
Not possible to rejuvenate into paving grade categories
Rejuvenated PMB classified as PMB??

Results – susceptibility to aging, empirical properties



50/70 prolong aging period (RTFOT+2xPAV)

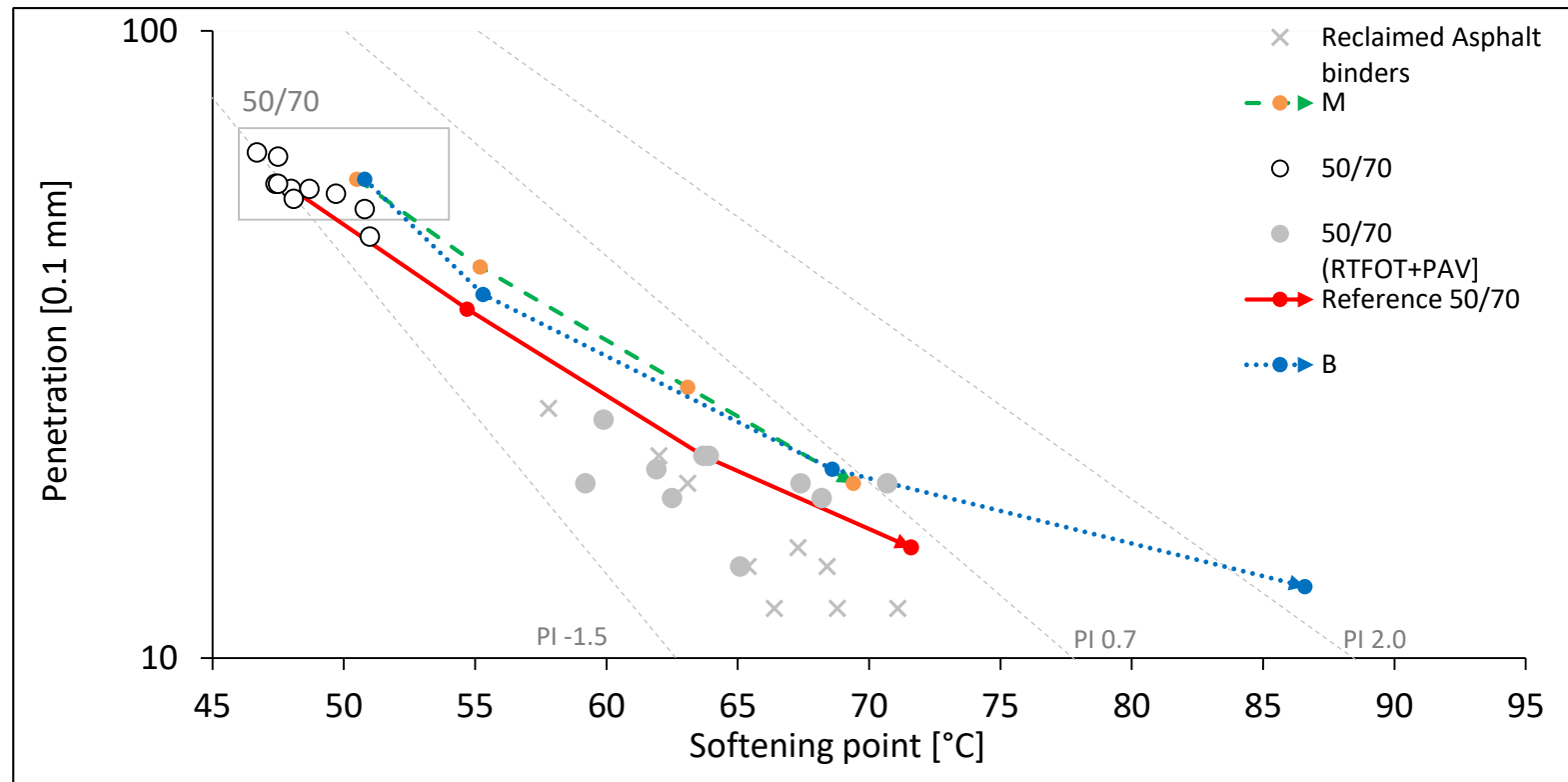
Results – susceptibility to aging, empirical properties



- Rejuvenator M
- Dose 10.9 %
- RTFOT+2xPAV

Recycled binder can maintain the PI limits after aging, even lessen the impact of aging (lower SP, higher penetration)

Results – susceptibility to aging, empirical properties



- Rejuvenator B
- Dose 6.5 %
- RTFOT+2xPAV

Recycled binder can be positioned very differently and even propagate aging

Rejuvenated binders' aging, partial conclusions

- **Long-term aging** is needed to **differentiate** rejuvenators (RTFOT alone is not sufficient).
- Some rejuvenators **accelerates aging**.
- High aged PMB might not be possible to rejuvenate into paving grade categories – use of **PMB classification**.

Remarks

- Be aware that these information are based on 100 % recycling.
- Functional properties of asphalt mixtures are decisive for the industry.

Discussion

- Industry shall define **what is expected from rejuvenators**. (position paper – a good step taken)
- Should be introduced **any requirements on rejuvenators** in Europe?
- Should be define **what is** considered as rejuvenators' **optimum dosage**?



Thank you

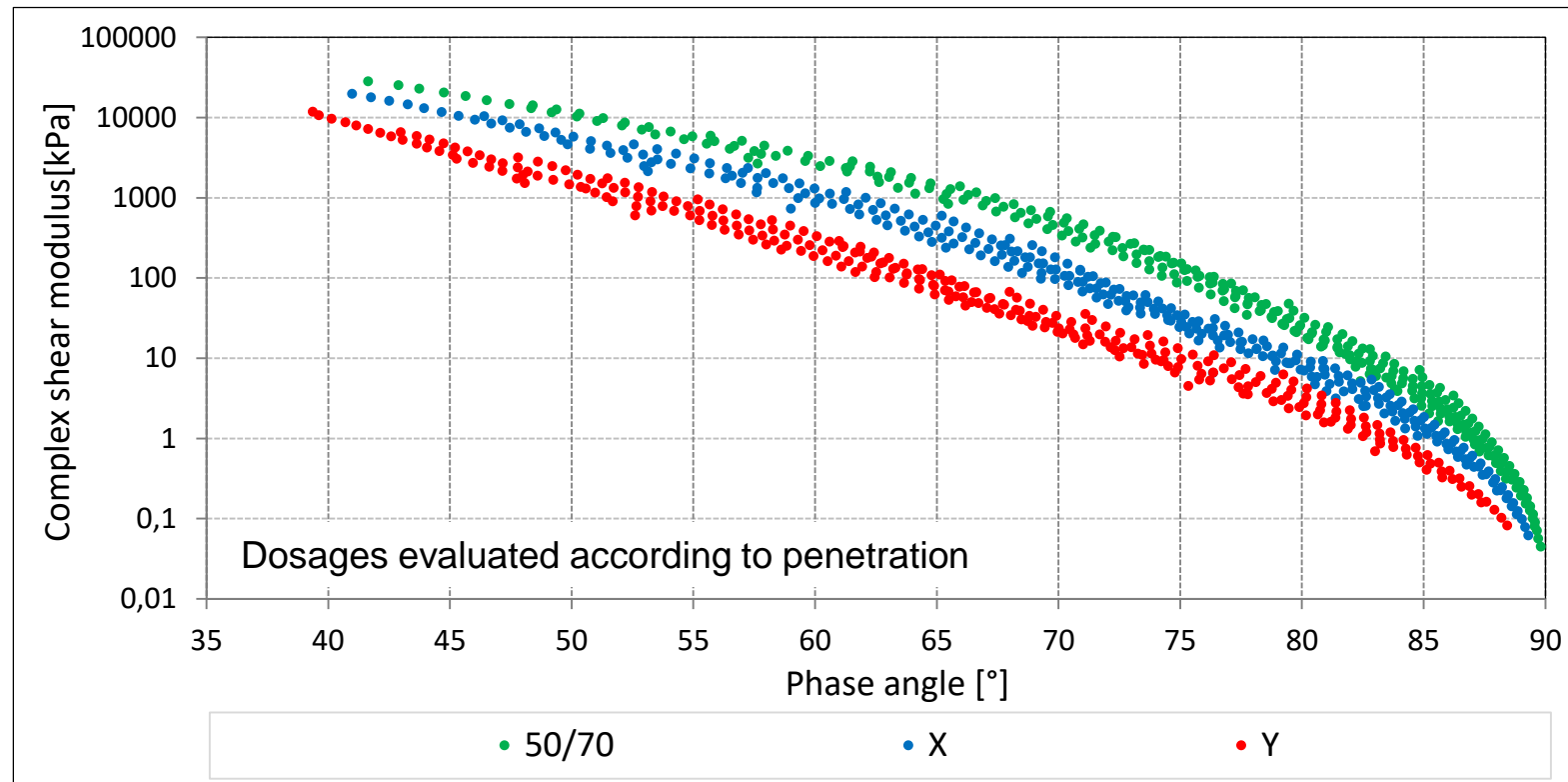
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My colleagues without whom this presentation could not be made are Ms. Iva Coufalikova, Mr. Pavel Coufalik and the head of the department of road structures Mr. Varaus

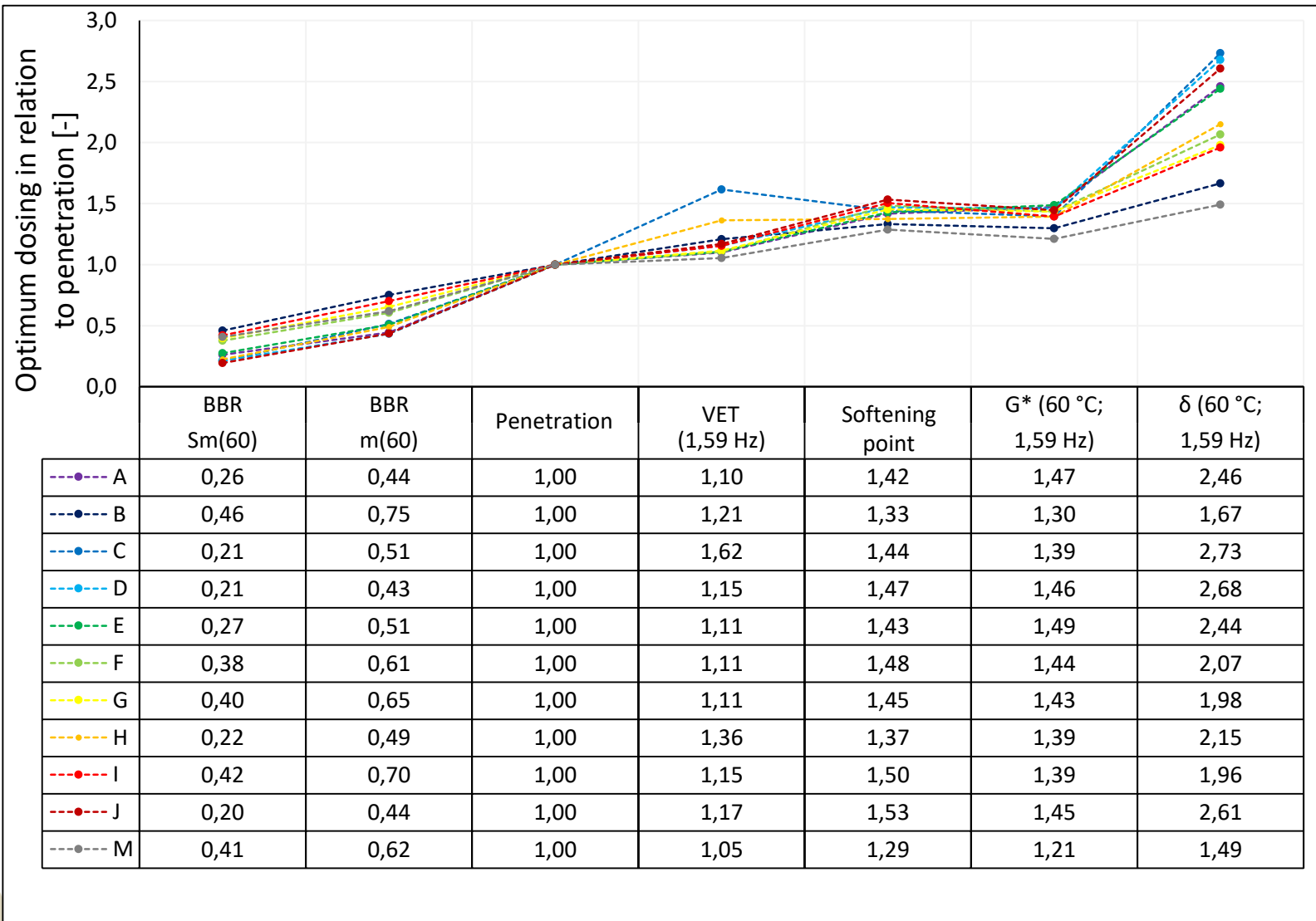
Rejuvenators' effectiveness, evaluation via functional approach



Use of Black Space to evaluate the behavior

- Green – **50/70** paving bitumen, pen 56 (0.1 mm)
- Blue (X) – recycled (6.5 %), categorized as **50/70**, pen 58 (0.1 mm)
- Red (Y) – recycled (8.5 %), categorized as **50/70**, pen 58 (0.1 mm)

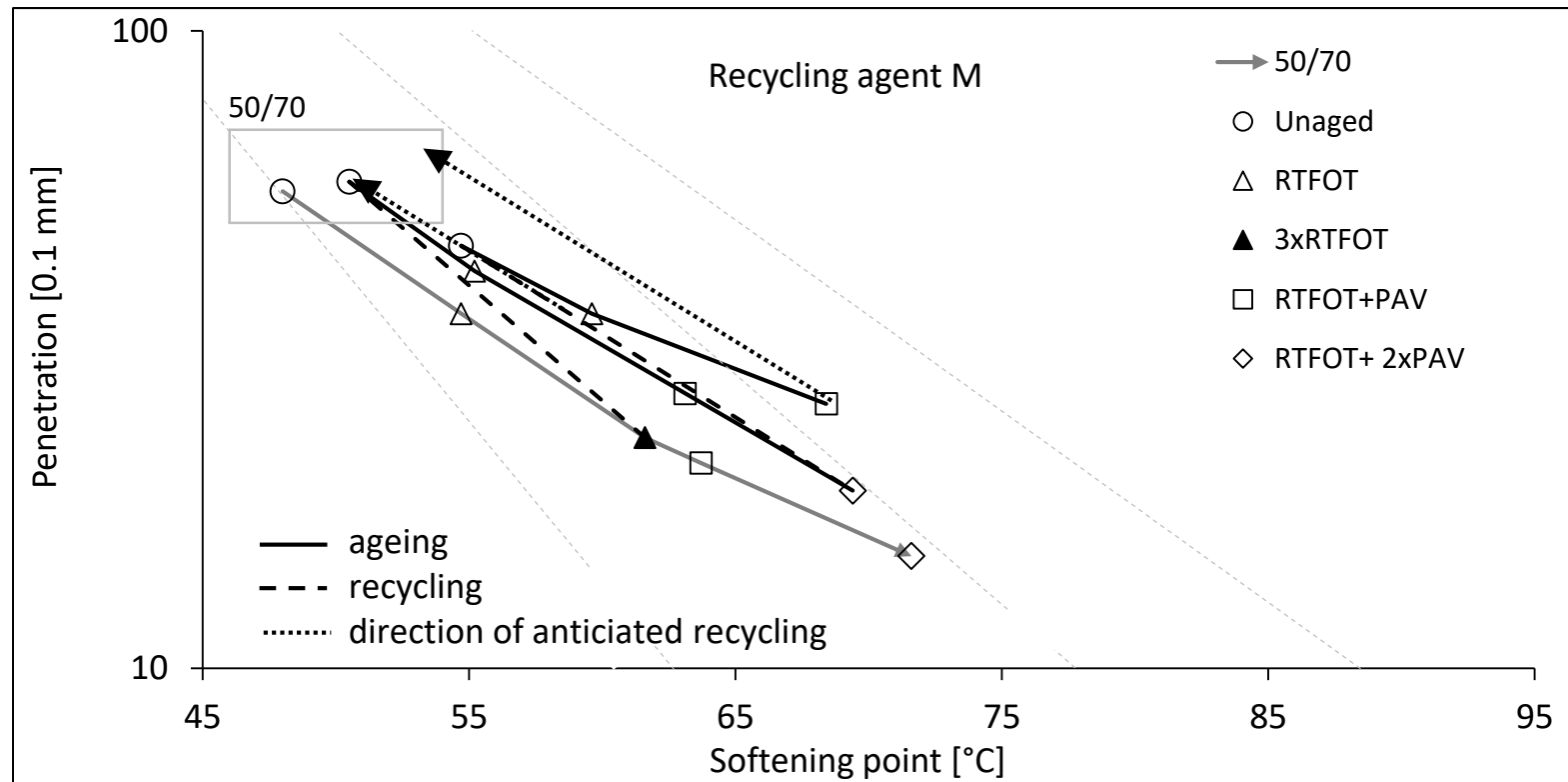
Rejuvenators' effectiveness, influence of rejuvenator type



Interrelation
between dosing
according to
different parameters

Penetration is
reference = 1.0

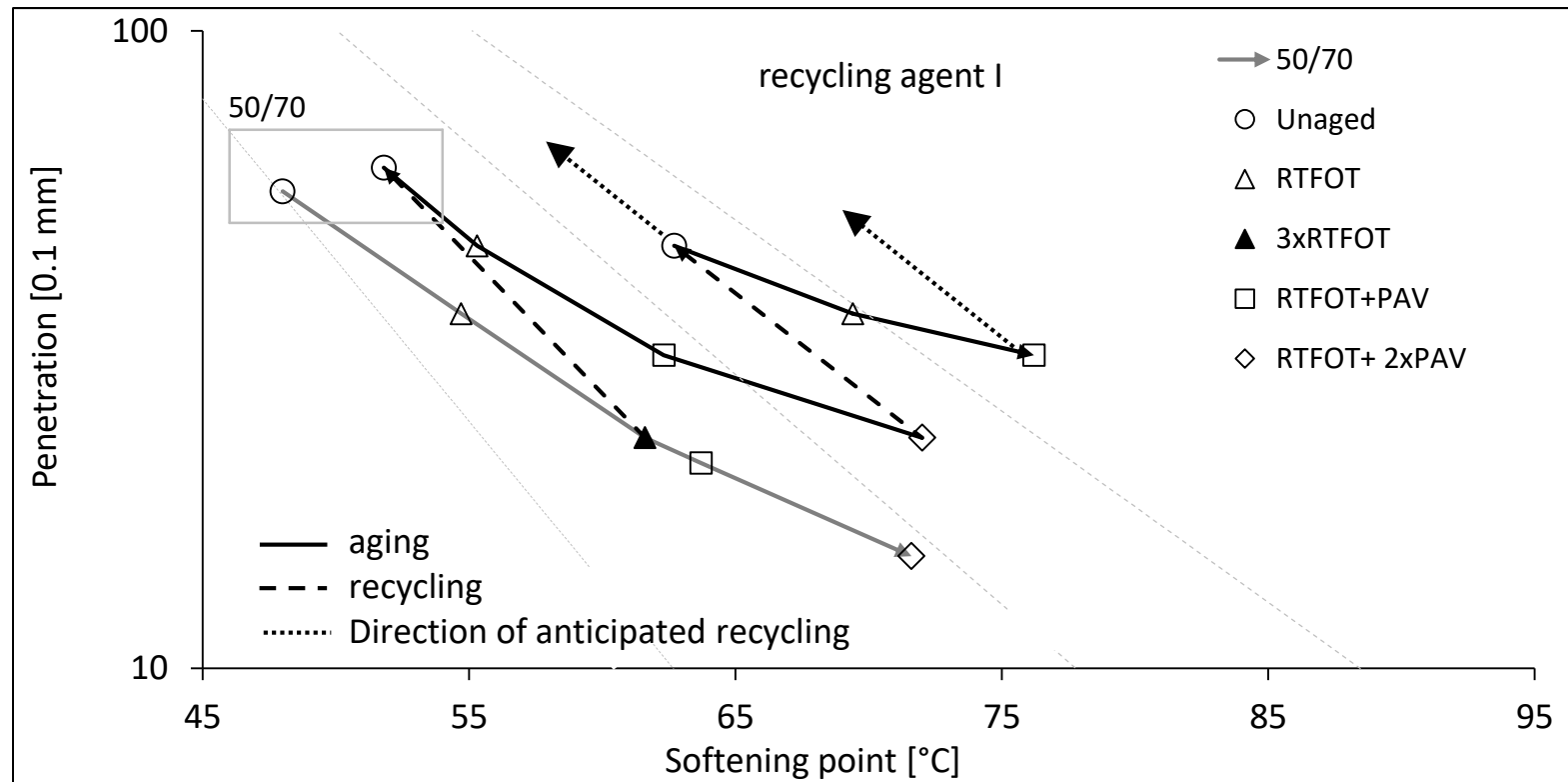
Results – re-recycling



- Rejuvenator M
- Dose 10.9 % (1st)
- Dose 13.2 % (2nd)

Comparable behaviour compared to paving bitumens

Results – re-recycling



- Rejuvenator I
- Dose 6.2 % (1st)
- Dose 6.3 % (2nd)

Completely different behaviour compared to paving bitumen