Changes in binder properties in aging and rejuvenation

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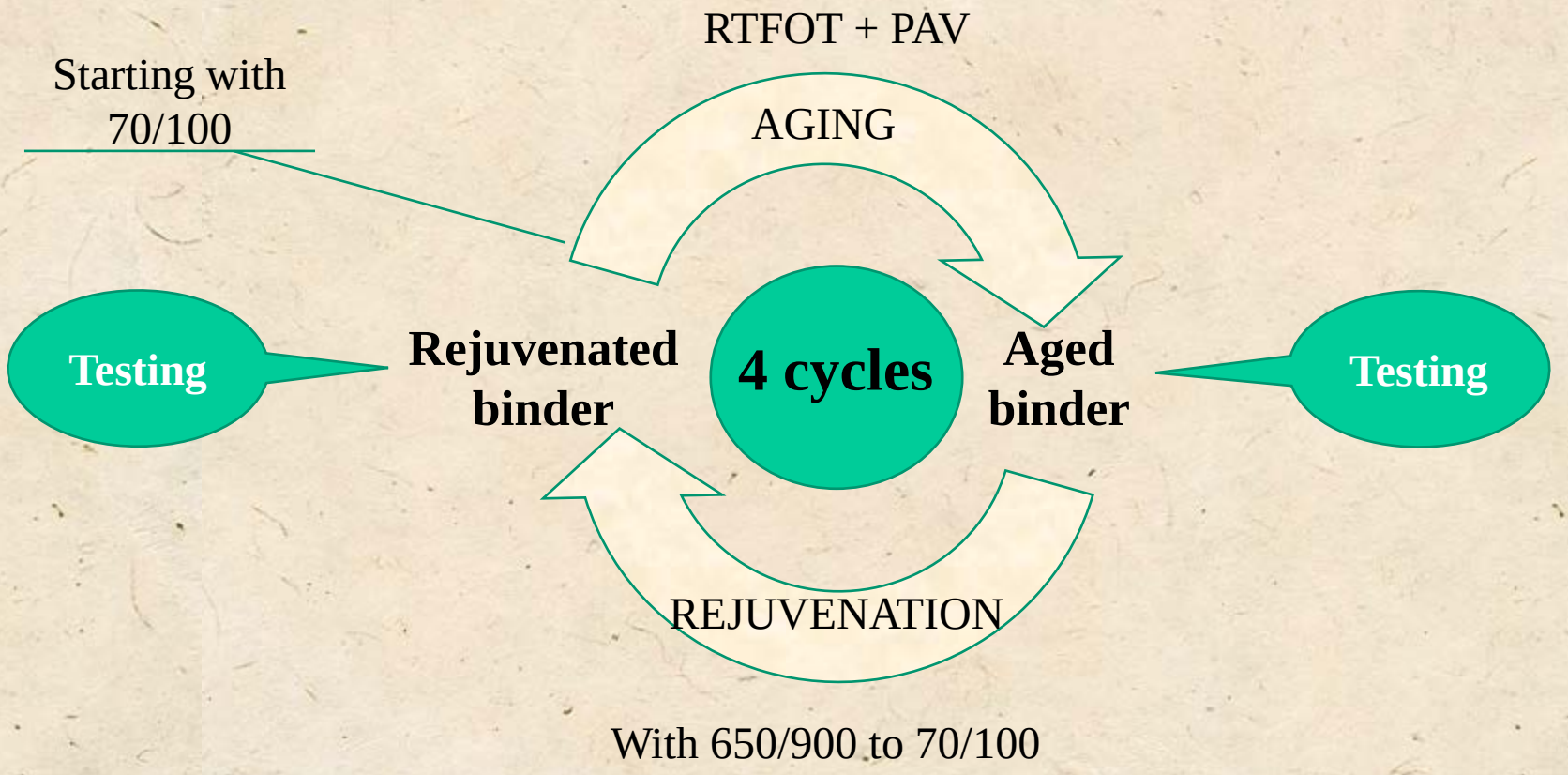
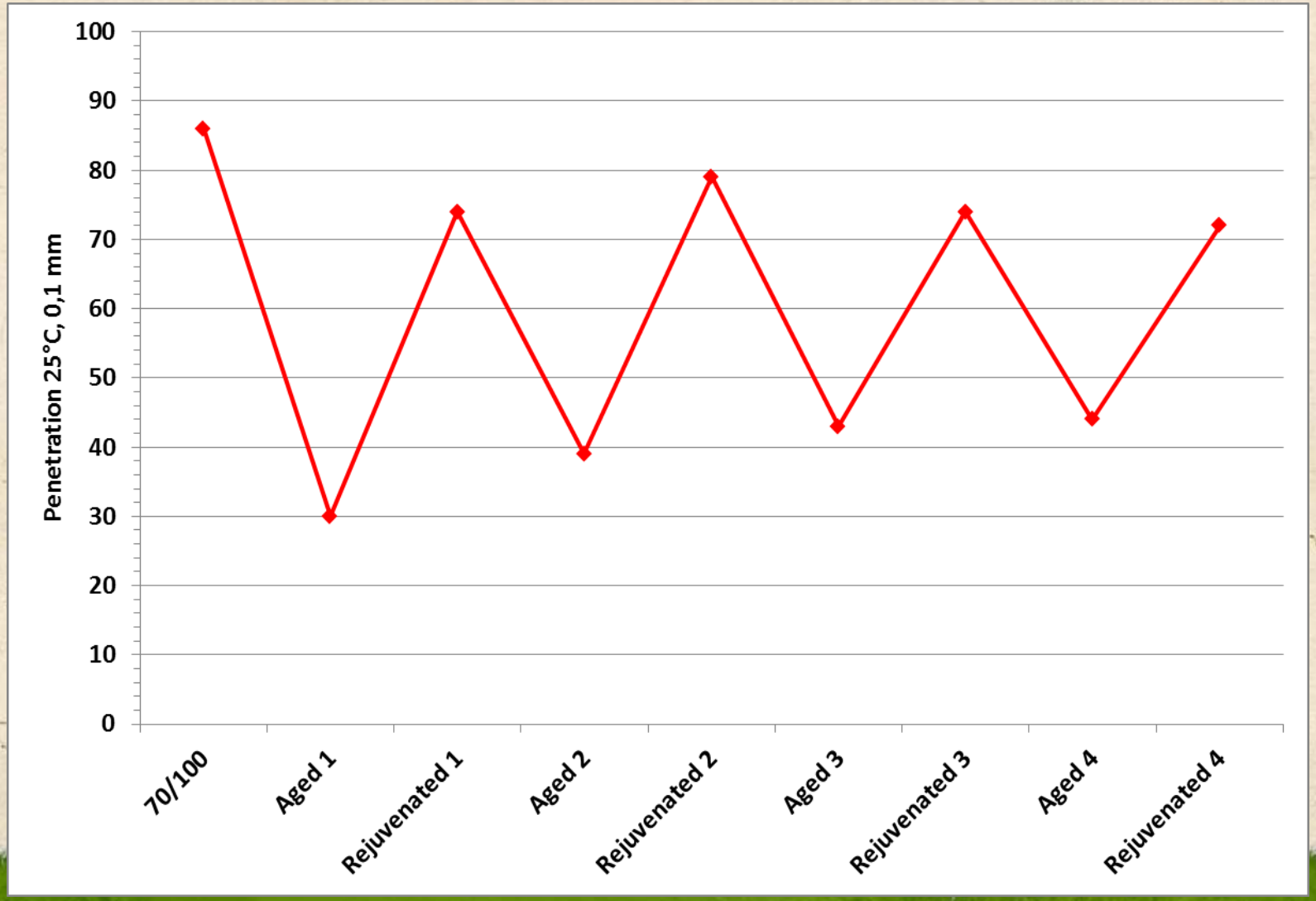
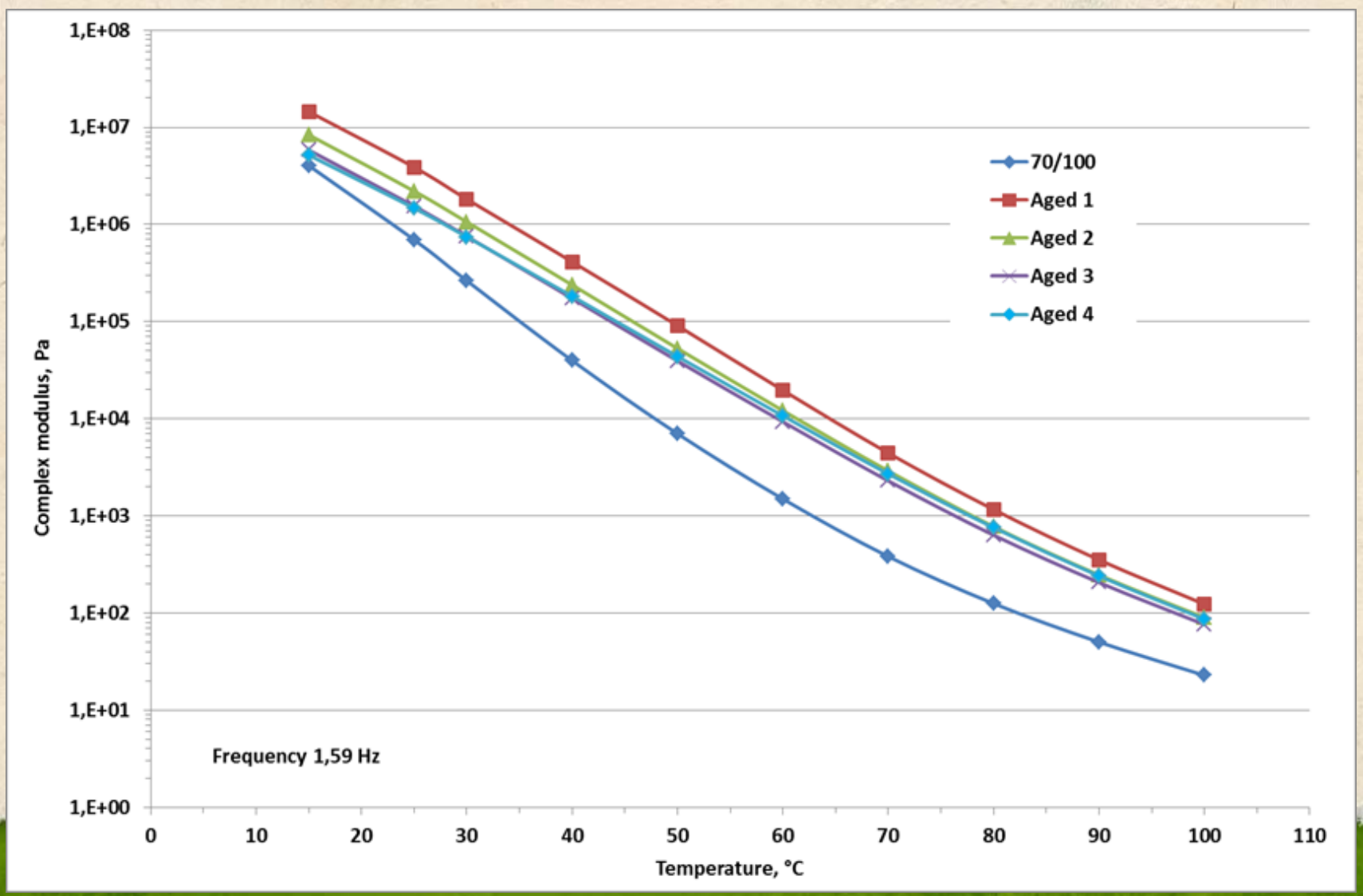
Laboratory aging – rejuvenation



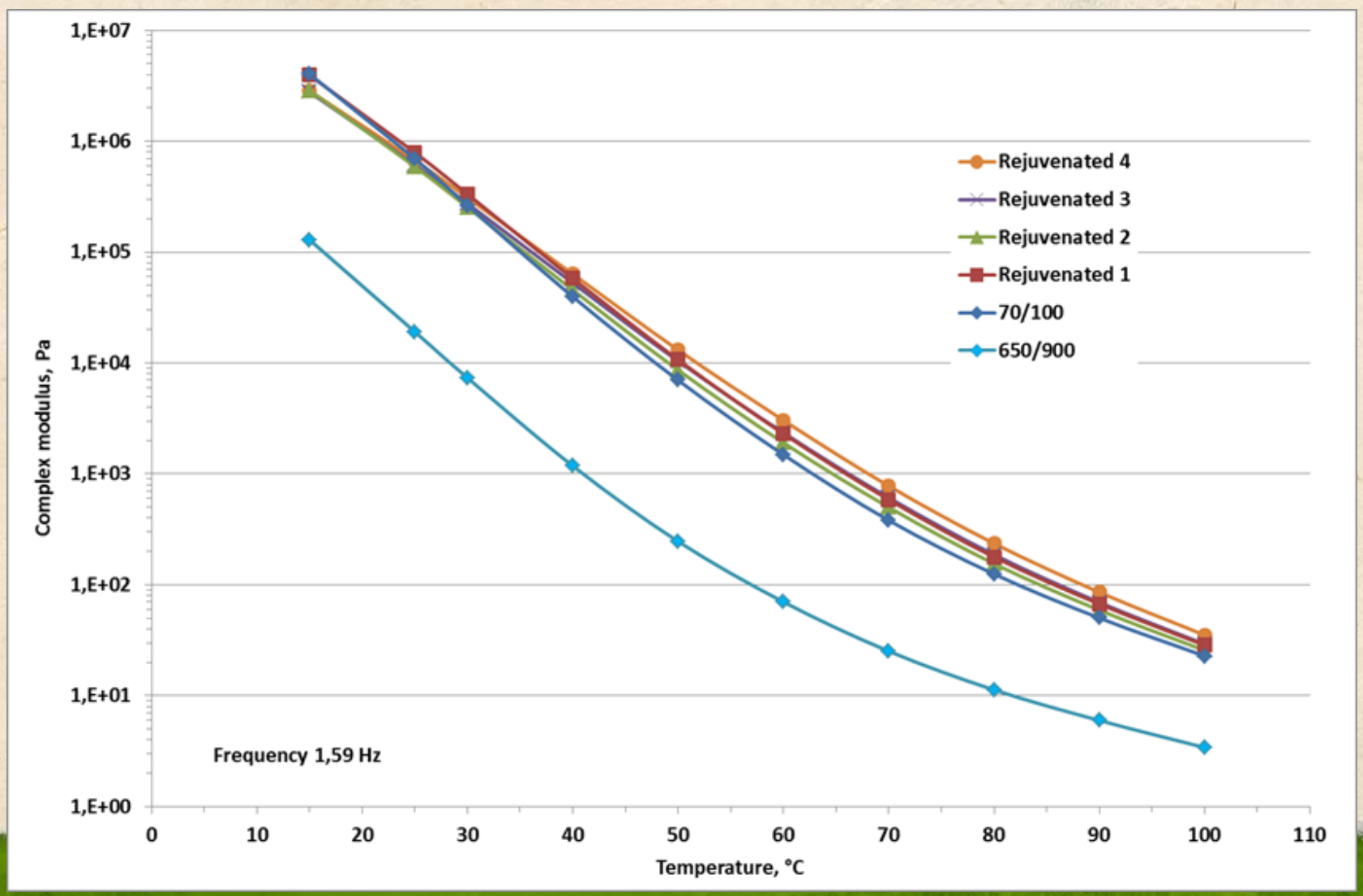
Aging - Rejuvenation cycles



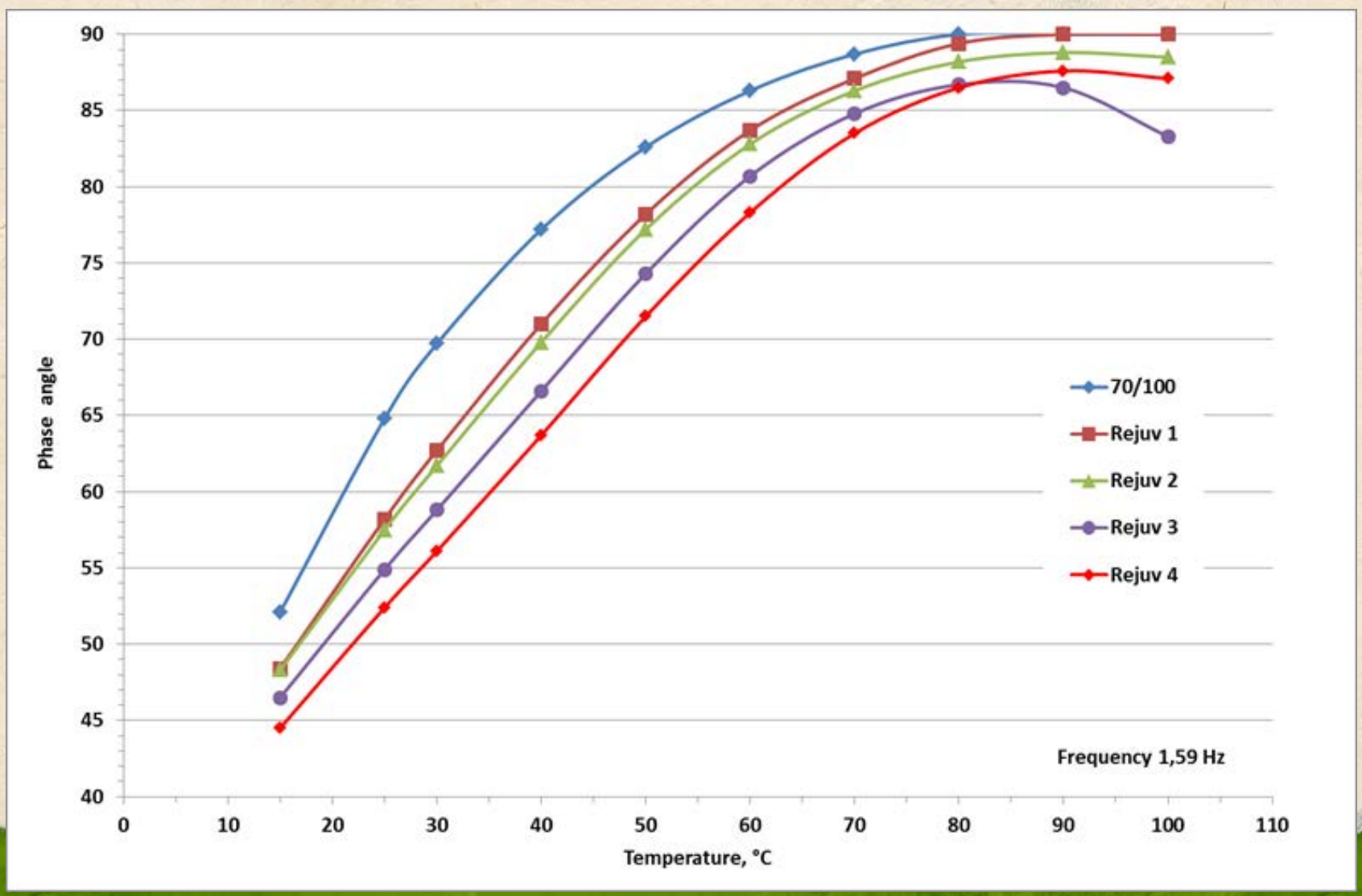
Complex modulus of the aged binders



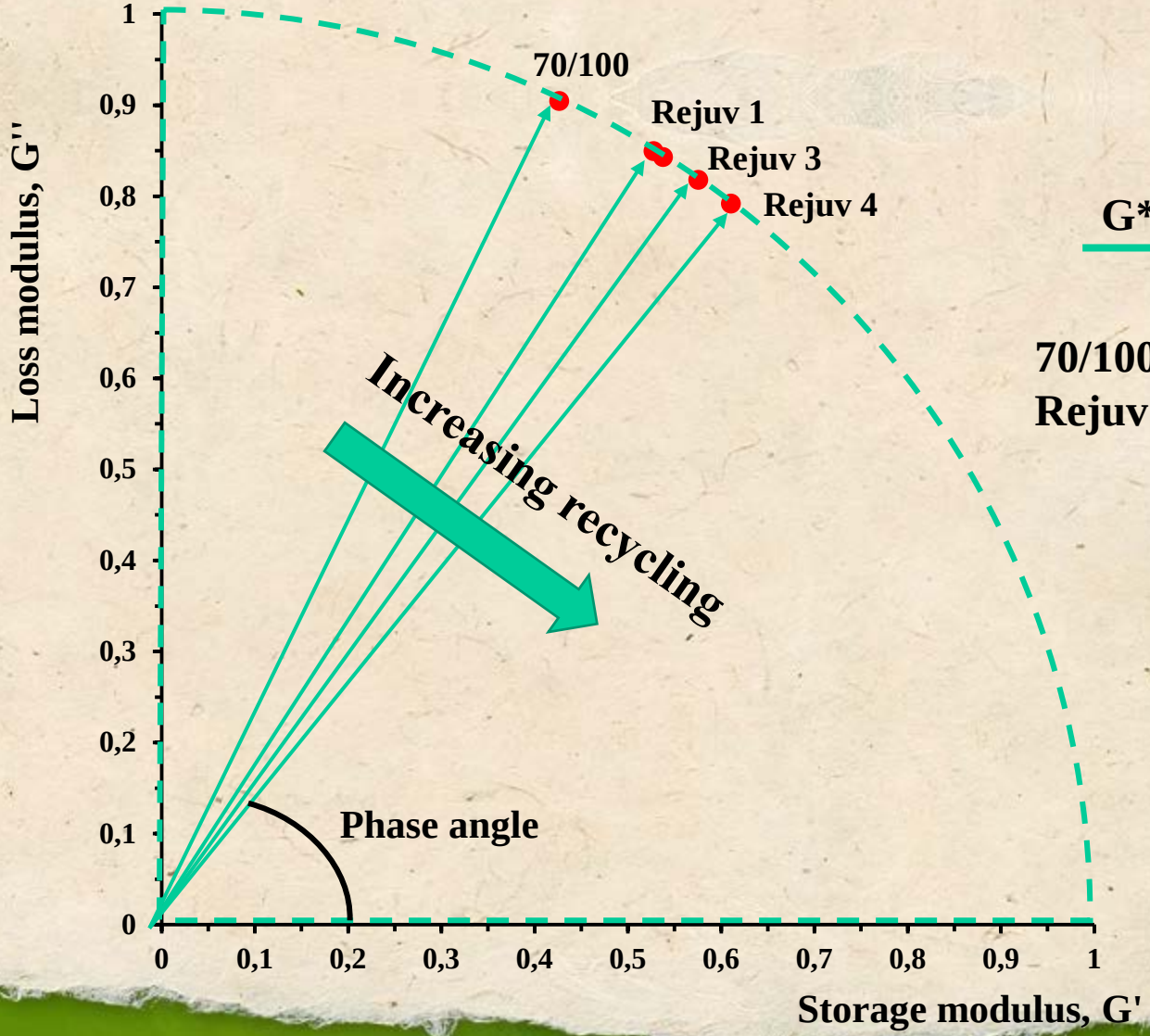
Complex modulus of the rejuvenated binders



Elasticity increases with A-R cycles



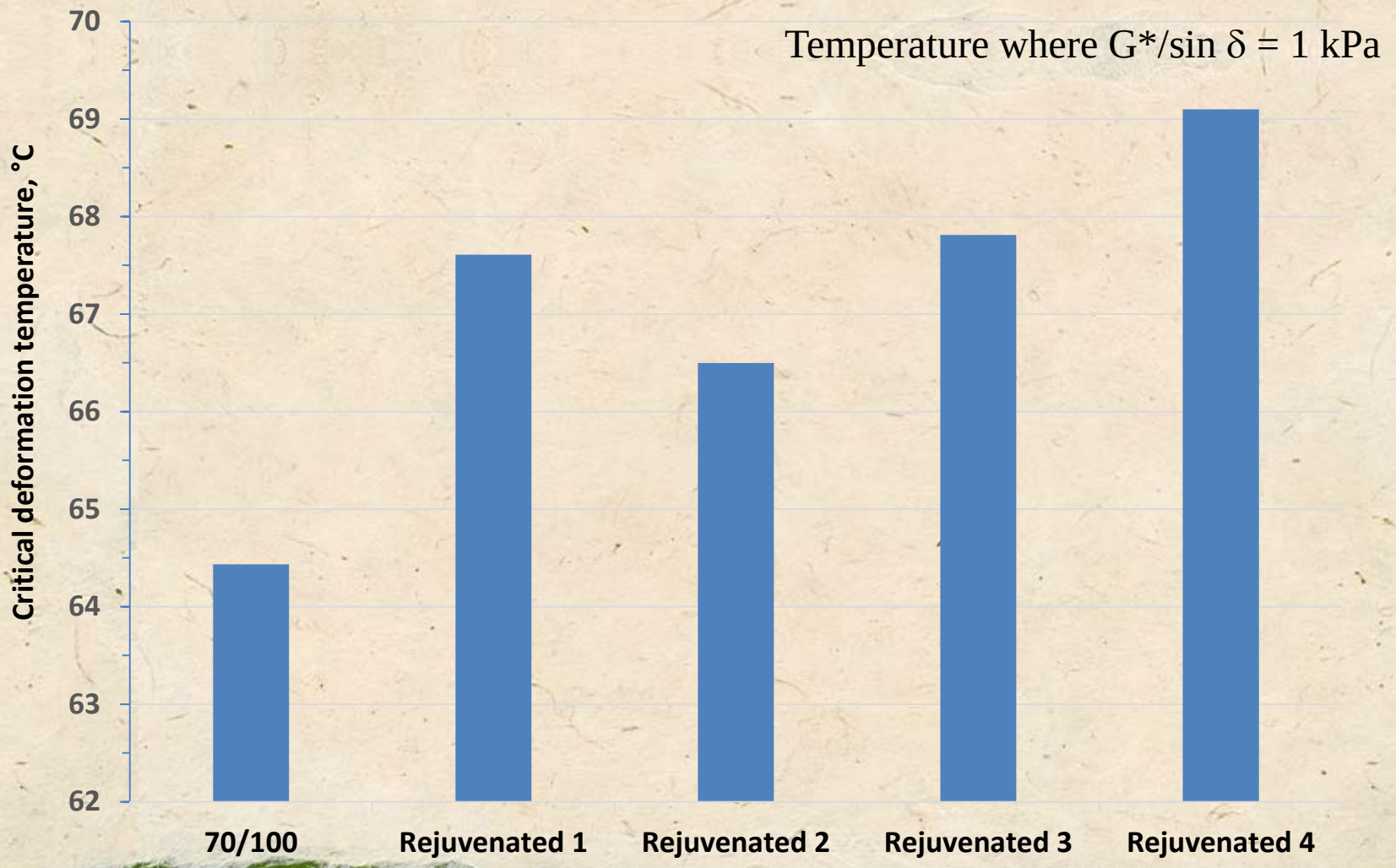
Complex modulus G* ~ 1 MPa at 25 °C



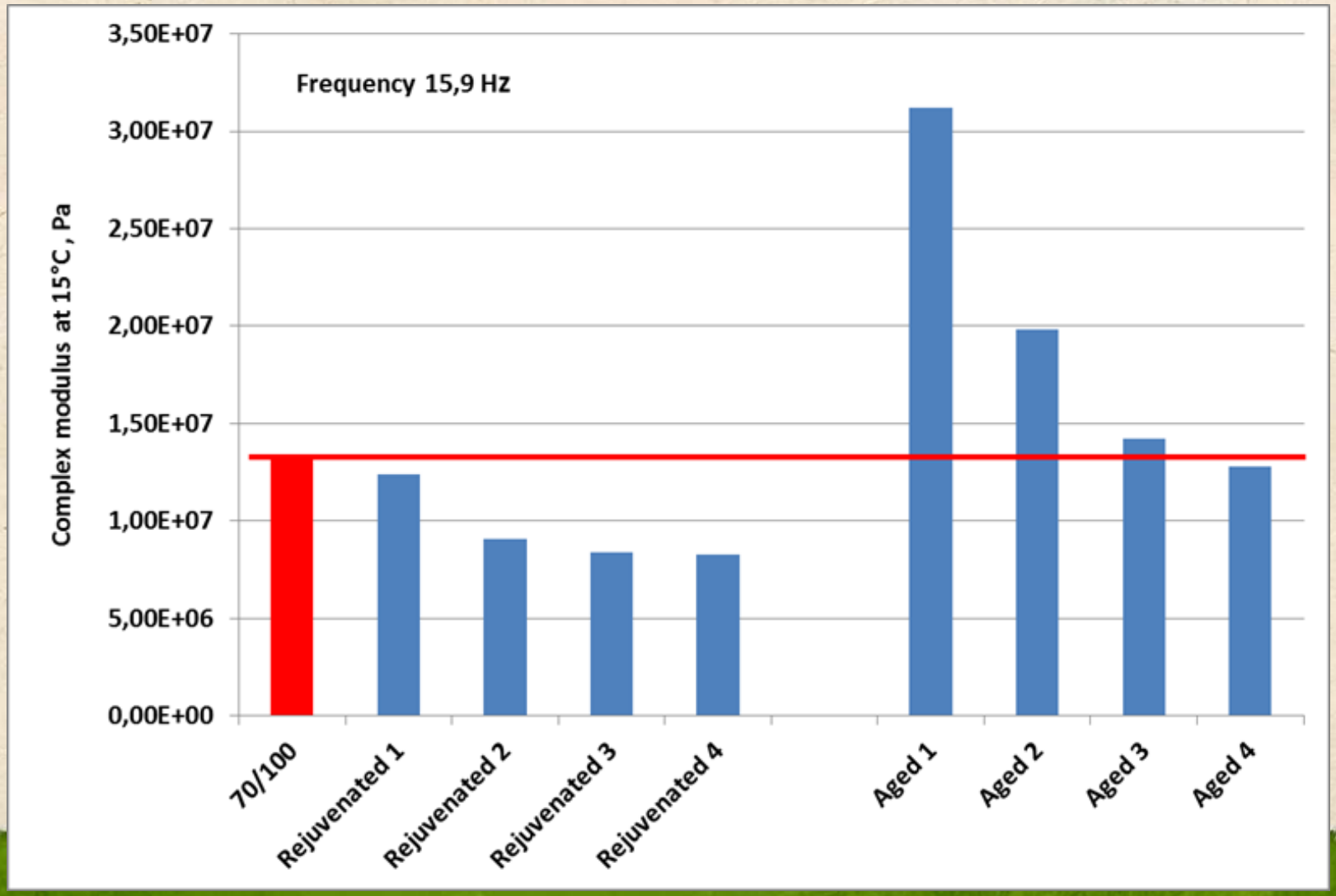
$G^*_{70/100} = G^*_{Rejuv\ 4}$

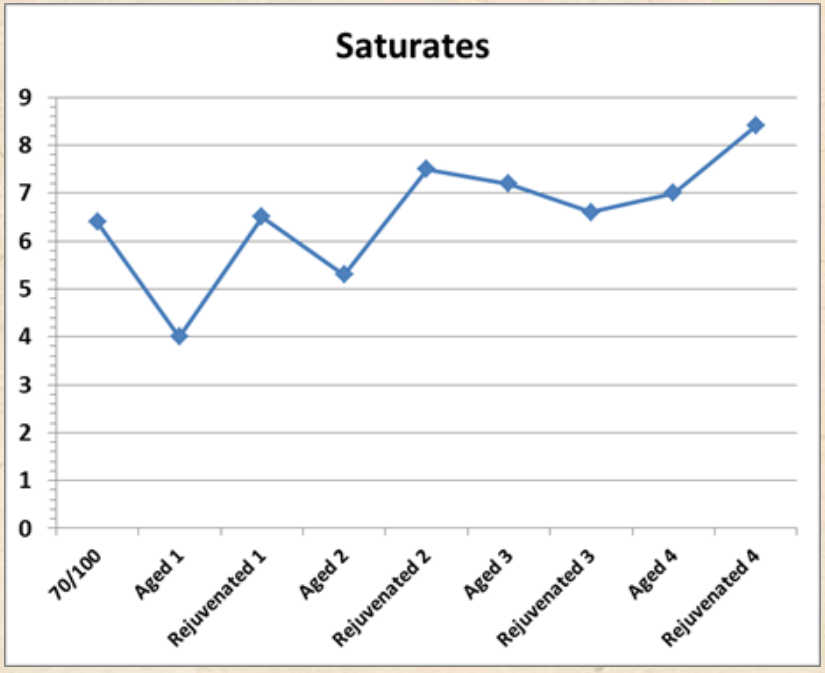
	G’	G”
70/100	= 0,4 G*	0,9 G*
Rejuv 4	= 0,6 G*	0,8 G*

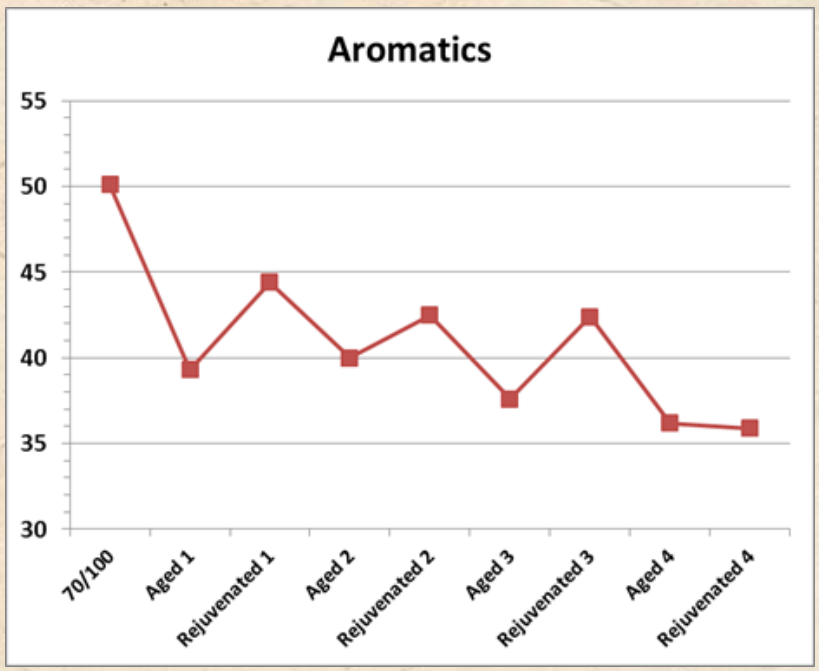
Deformation resistance

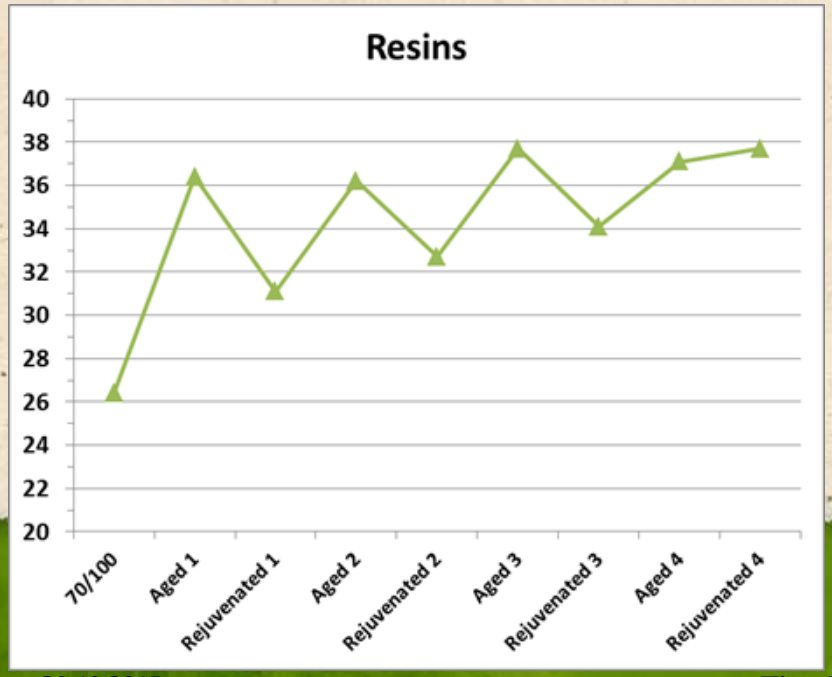


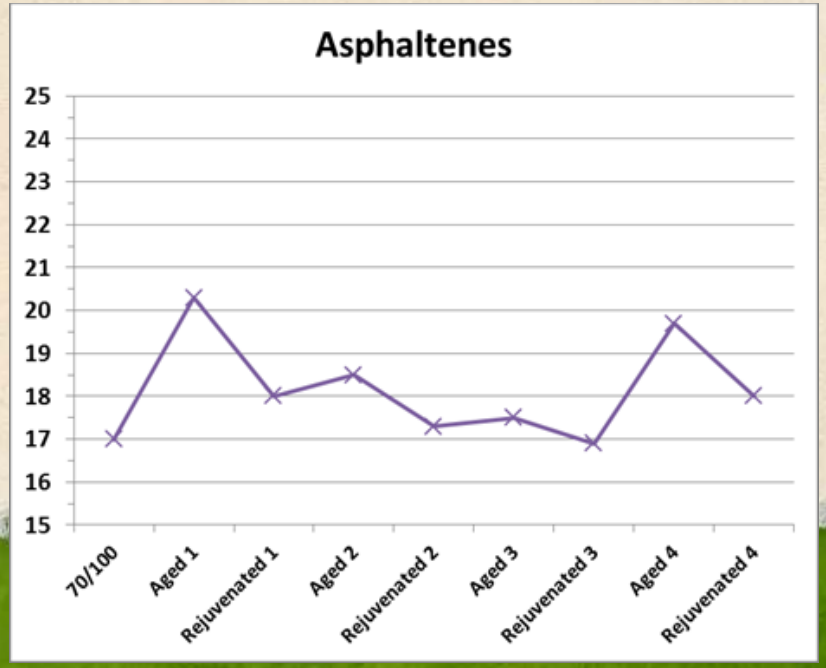
Low temperature properties



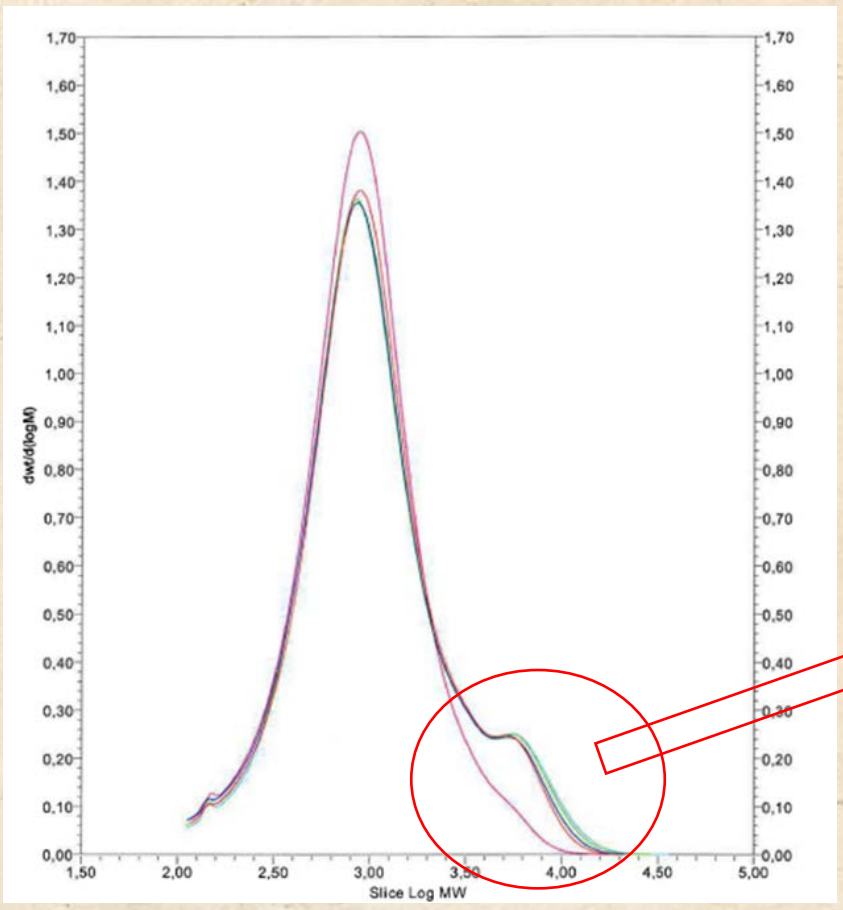

Saturates
9
8
7
6
5
4
3
2
1
0
70/100
Aged 1
Rejuvenated 1
Aged 2
Rejuvenated 2
Aged 3
Rejuvenated 3
Aged 4
Rejuvenated 4

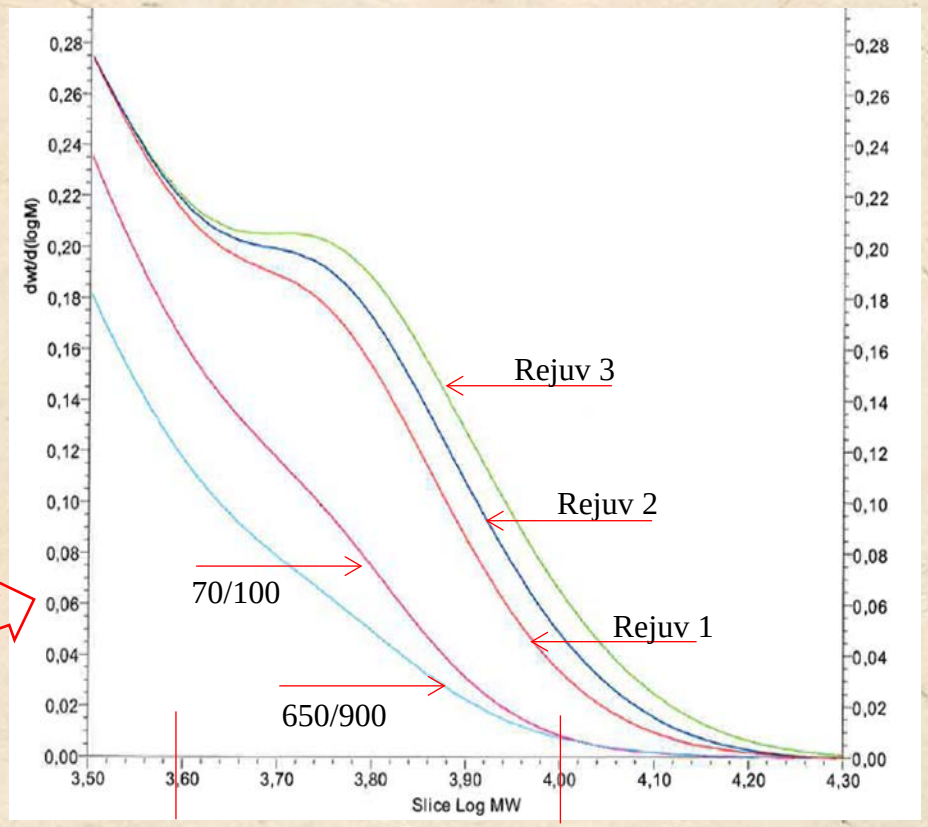

Aromatics
55
50
45
40
35
30
70/100
Aged 1
Rejuvenated 1
Aged 2
Rejuvenated 2
Aged 3
Rejuvenated 3
Aged 4
Rejuvenated 4


Resins
40
38
36
34
32
30
28
26
24
22
20
70/100
Aged 1
Rejuvenated 1
Aged 2
Rejuvenated 2
Aged 3
Rejuvenated 3
Aged 4
Rejuvenated 4


Asphaltenes
25
24
23
22
21
20
19
18
17
16
15
70/100
Aged 1
Rejuvenated 1
Aged 2
Rejuvenated 2
Aged 3
Rejuvenated 3
Aged 4
Rejuvenated 4

Molecular weight distribution



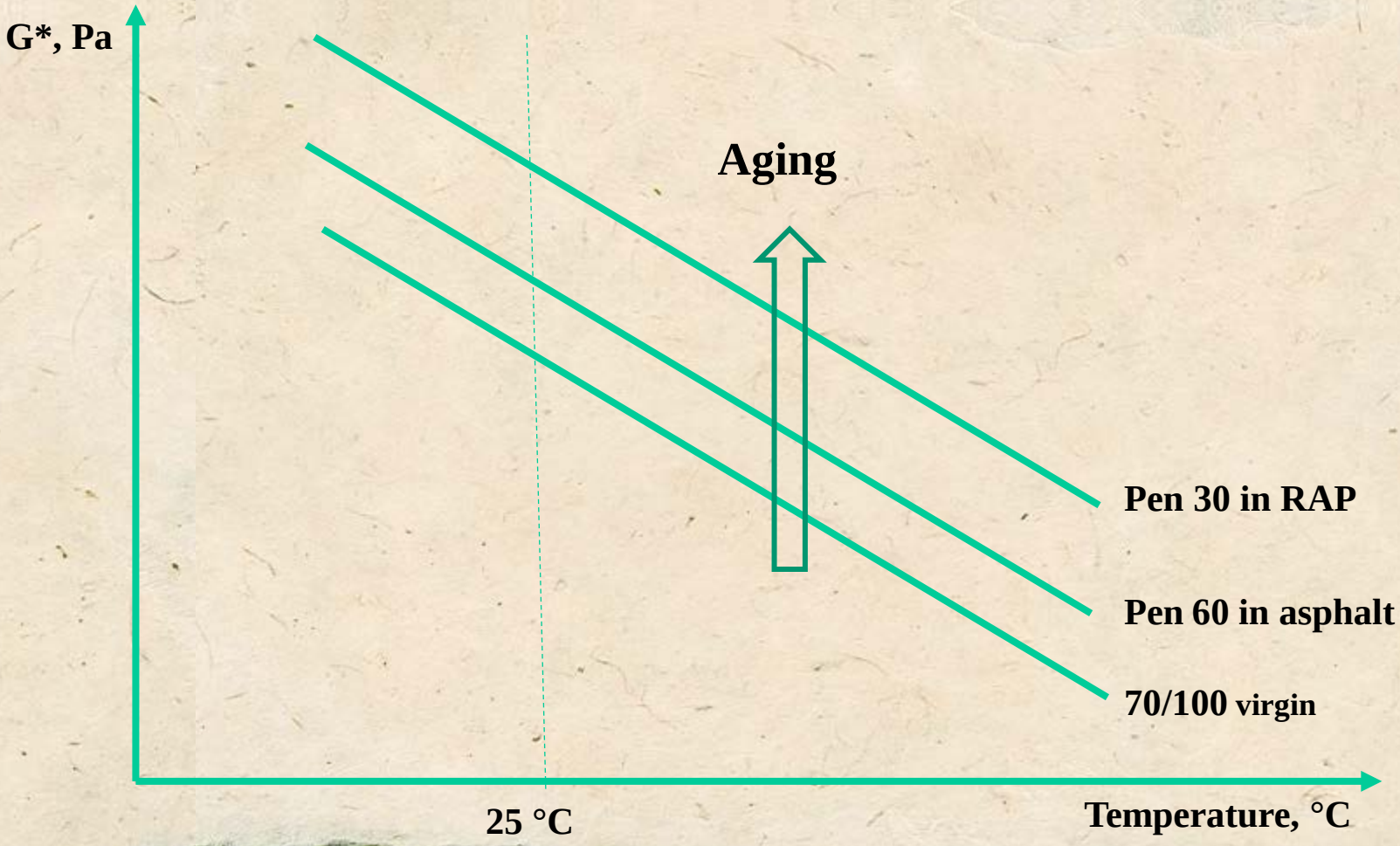


Conclusions

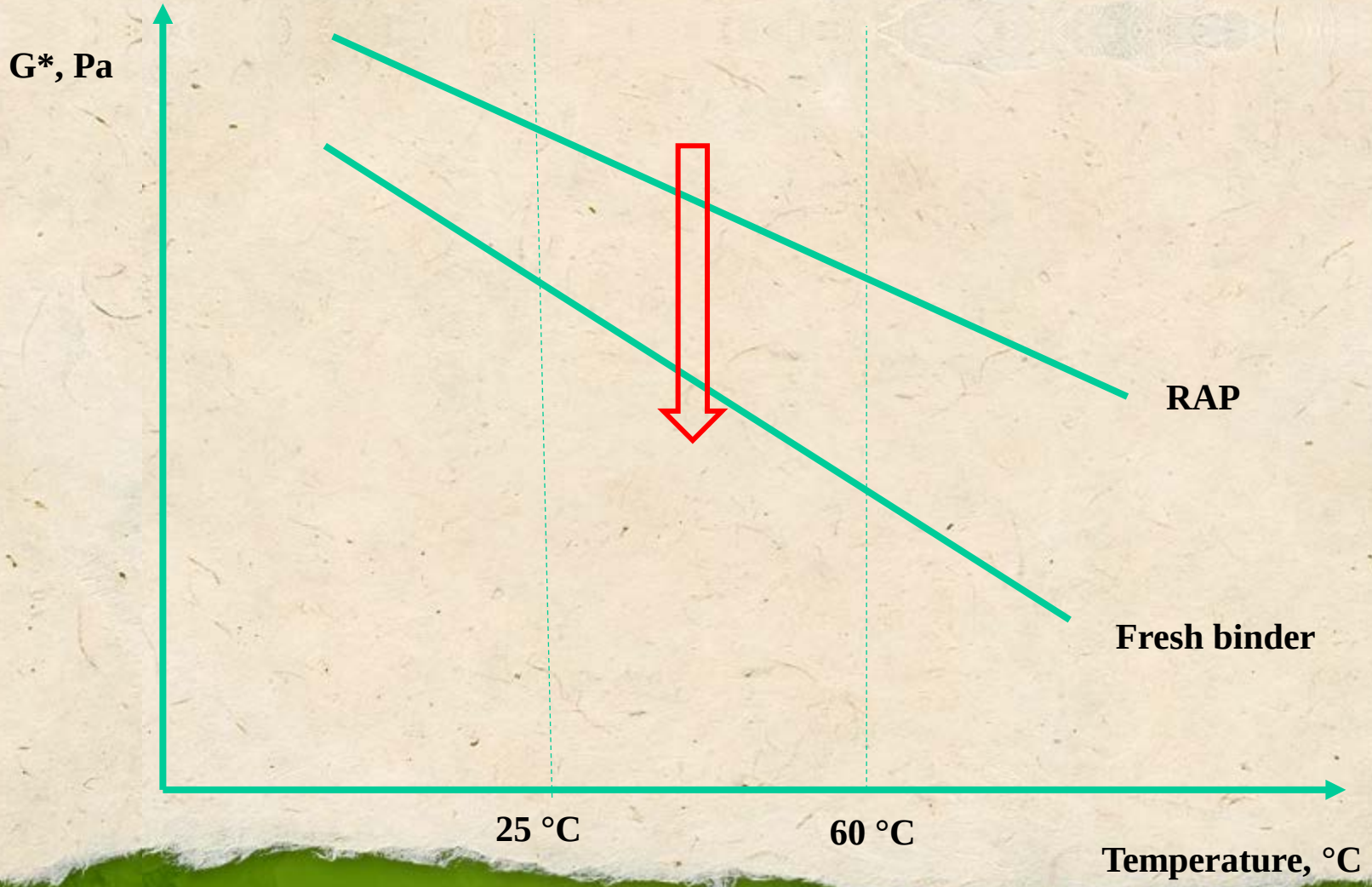
- The original consistency at a selected temperature can be reached, but not the chemistry.
- In aging the binder becomes less temperature susceptible and after each cycle the binder is less temperature susceptible.
  - Equal or better low temperature properties and deformation resistance.
- Binder becomes more elastic, storage modulus increses.
  - Less healing ?
  - Fatigue properties ?
- Blending calculations based on complex modulus.
  - Selection of the reference temperature and frequency is crusal.

Questions?

What should be the target hardness in rejuvenation?
What is the hardening of the rejuvenator in recycling?

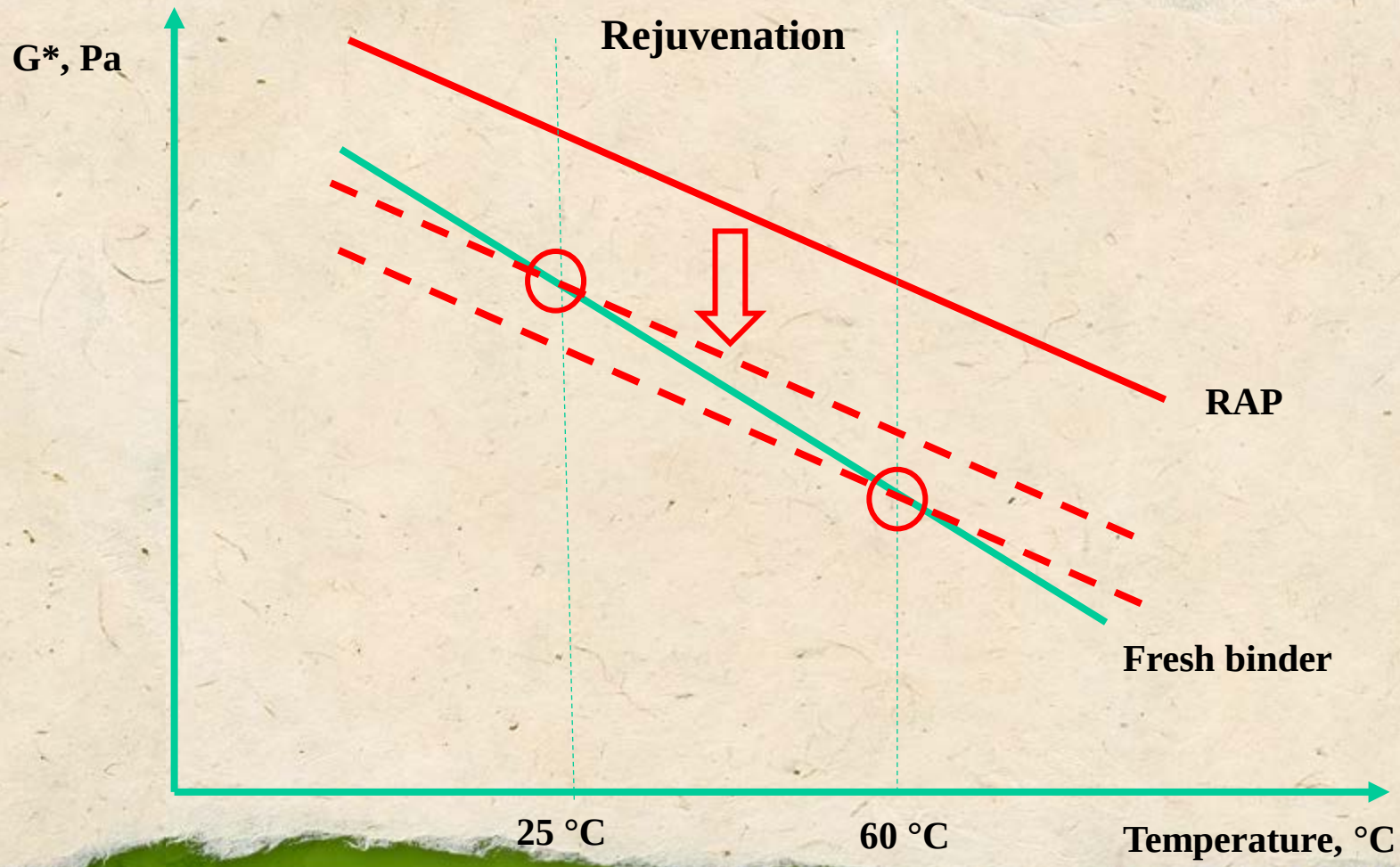


Rejuvenation

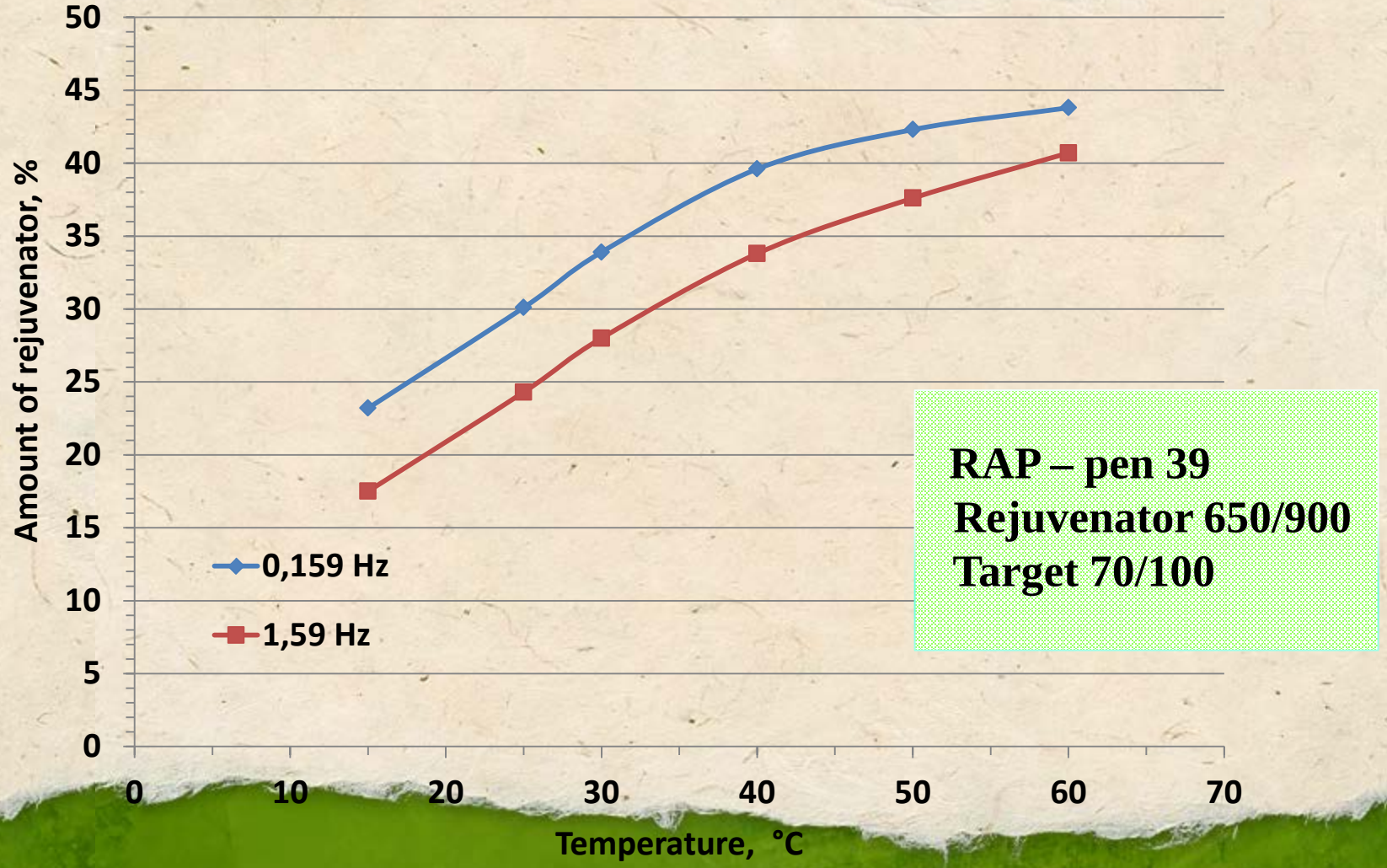


Questions?

What should be the reference temperature?



Effect of the reference temperature and frequency on the amount of rejuvenator



RAP – pen 39
Rejuvenator 650/900
Target 70/100

Do we manage the recycling process ?