Binder properties influence on thermomechanical performance of bituminous mixtures

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Parametric study

Objective : Quantify the influence of binder properties on key thermomechanical performances of bituminous mixtures

Mixture type

- Porphyry rock
- Continuous grading curve
- Targeted 5% void content
- Standard HMA fabrication method

Binders

Bitumen origin (A)

50/70 bitumen B1 ➡ A = -1

50/70 bitumen B2 ➡ A = +1

Polymer modification (B)

Pure ➡ B = -1

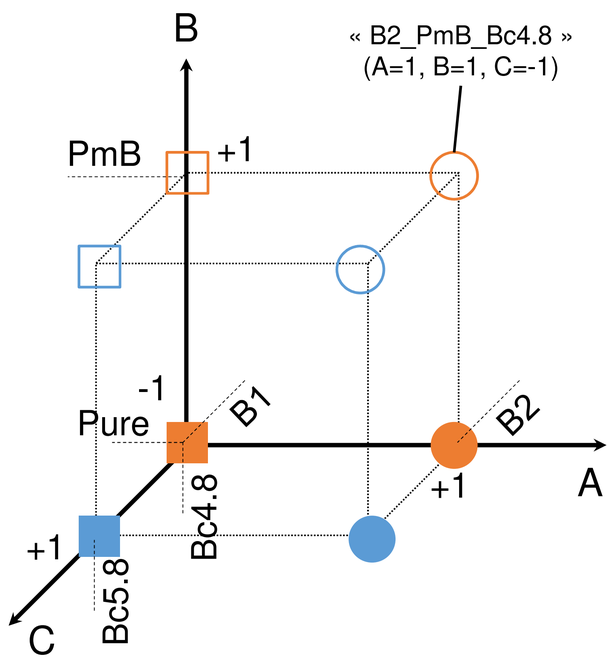
Polymer modified bitumen (PmB) ➡ B = +1

Binder content (C)

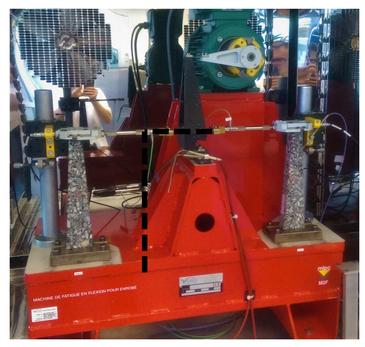
4.8% bitumen content (Bc4.8) ➡ C = -1

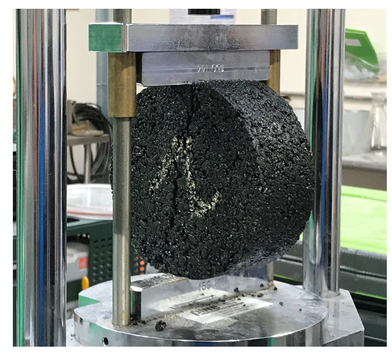
5.8% bitumen content (Bc5.8) ➡ C = +1

2^3 full factorial plan
Total : 8 mixtures



Thermomechanical performances





Complex Modulus
NF EN 12697-26
|E*| (15°C/10Hz)

Resistance to fatigue
NF EN 12697-24
ε_6 and b

Moisture Sensitivity
NF EN 12697-12
ITSR

Regression analysis

$$y = \beta_0 + \beta_A A + \beta_B B + \beta_C C + \beta_{AB} AB + \beta_{AC} AC + \beta_{BC} BC + \beta_{ABC} ABC$$

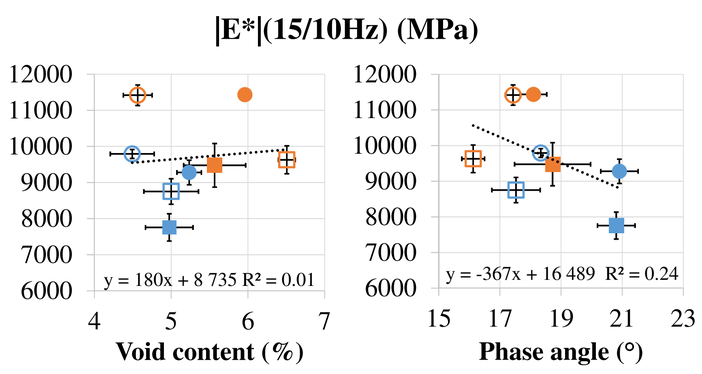
with $\beta_0 = \bar{y}$ (average on all mixtures) and $\beta_X = \frac{\bar{y}_{|X=+1} - \bar{y}_{|X=-1}}{2}$

Results

General observations

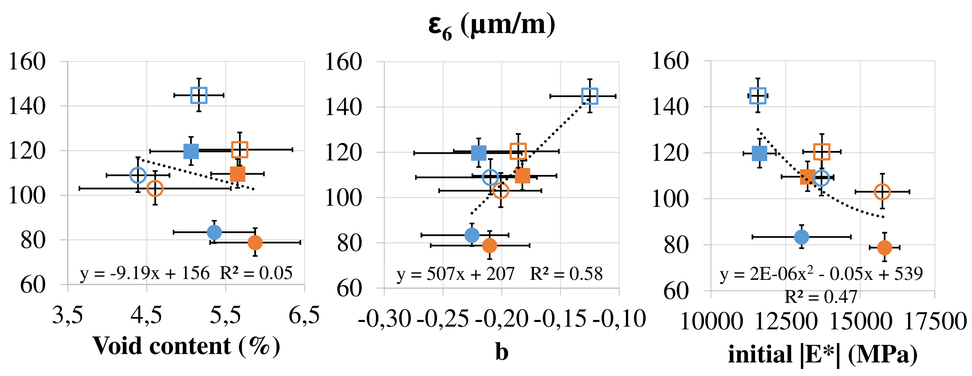
- B1_Bc5.8
- B1_Bc4.8
- B1_PmB_Bc5.8
- B1_PmB_Bc4.8
- B2_Bc5.8
- B2_Bc4.8
- B2_PmB_Bc5.8
- B2_PmB_Bc4.8

Complex modulus



➡ Variations of |E*| and phase angle without a general trend

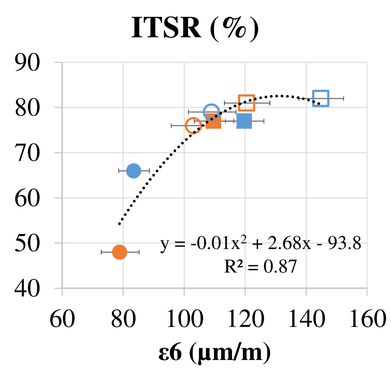
Resistance to fatigue



➡ ε_6 values and confidence interval (with 95% of probability) show different behaviors between mixtures. Less clear with b parameter

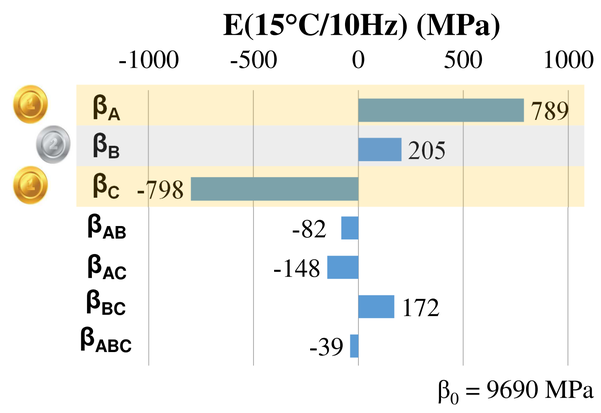
➡ Differences between initial moduli |E*| without a clear trend

Moisture sensitivity



➡ Correlation between high ε_6 and high ITSR values

Regression analysis

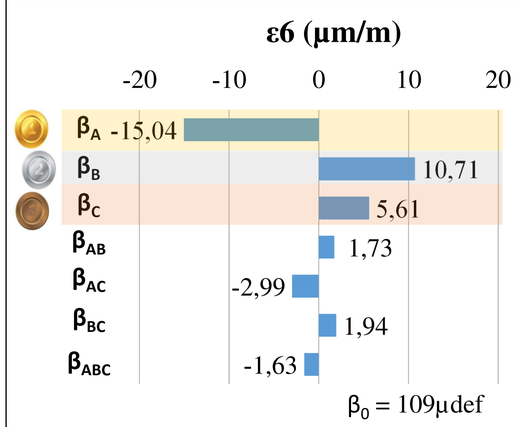


➡ 2 major and comparable parameters : Bitumen origin (A) and binder content (C)

➡ Using B2 over B1 or 4.8% over 5.8% binder content increases |E*| of ≈1600 MPa (≈ +17%)

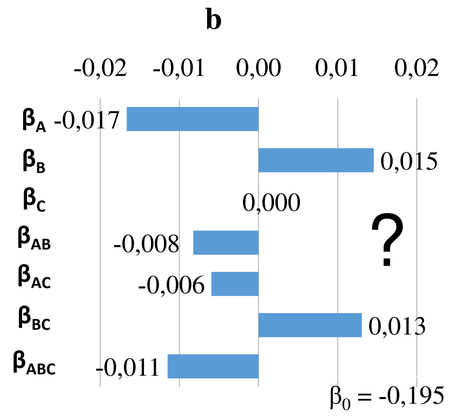
➡ Small effect of polymer modification on |E*|

➡ Little cross effects between parameters

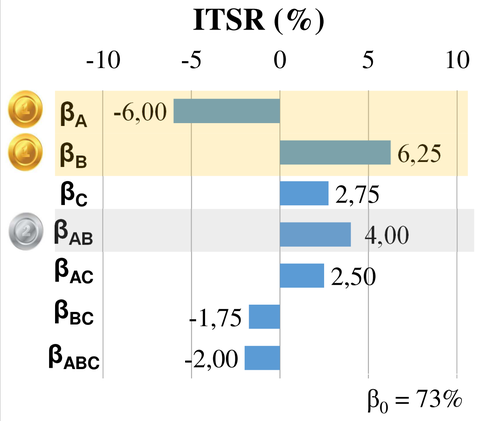


➡ Hierarchy of 3 parameters :
1st Origin of bitumen (A)
2nd polymer modification (B)
3rd binder content (C)

➡ Little cross effects



➡ Unclear role of each parameter, especially because of important cross effects



➡ Major and comparable factors:
Bitumen origin (A)
Polymer modification (B)

➡ Important cross effect (AB)

Conclusion

Full factorial plan regression analysis
=
Powerful predictive tool for mix design

Perspective

The same approach will be applied to isolate and understand the role of binder/aggregate adhesion