How to define High Performance Asphalt Concrete (HPAC), Called "EME" in France, for Cold Regions

Presented at
High Performance Asphalt Materials Symposium

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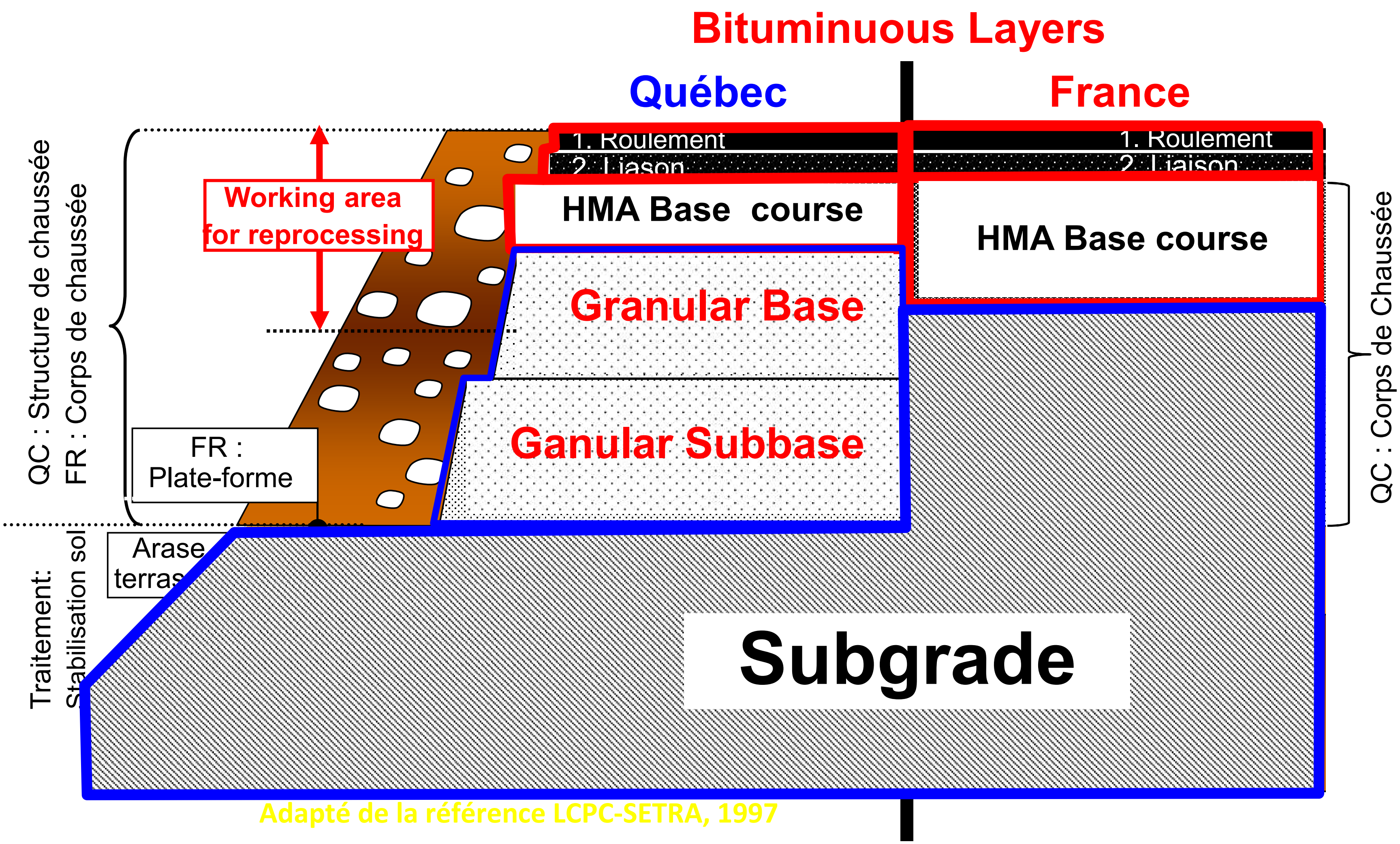
October 2nd, 2019

Plan

- Context and Problematic
- Purpose and Methodology
- Some results
- Conclusions

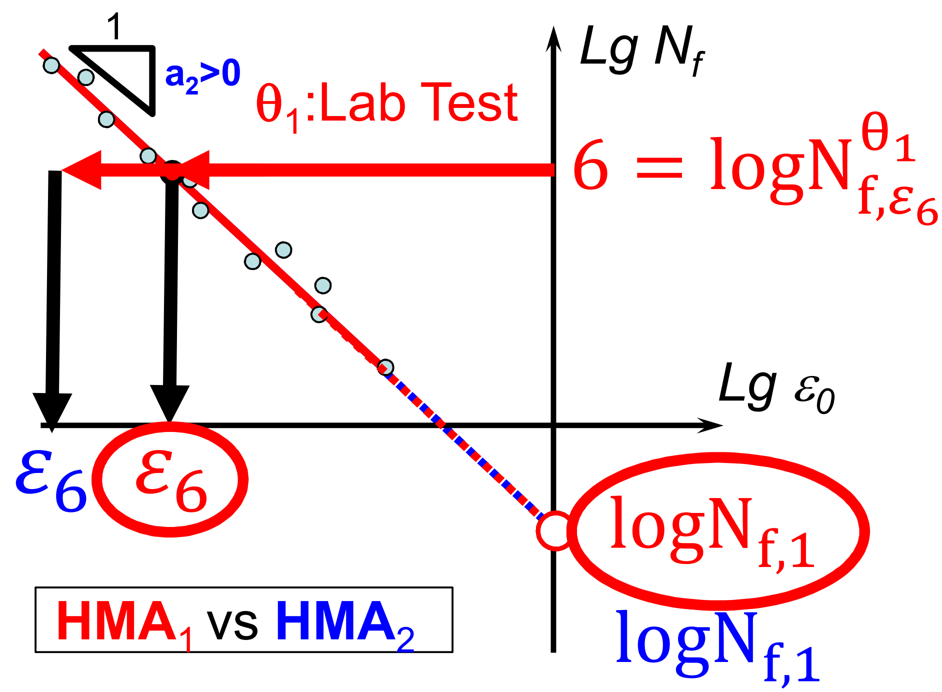
Context and Problematic:

Definitions – Sectional View of Pavement Structure



Context and Problematic:
Definitions – Fatigue resistance

From many testing samples:
Duration life (N_f) is changing with the strain amplitude (ε_0)



Context and Problematic

EME Technology

- EME mixes are used on base asphalt course to:

1. Improve fatigue performance of pavements;
2. Reduce pavement thickness for a given traffic condition;

- Typically EME mixes are made with hard bitumen

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Context and Problematic

EME Technology

- In cold region, HMA made with hard bitumen will crack at low T°C : Thermal cracking;
- To apply EME technology in cold region, HMA shall conform to local needs as regard low temperature requirement;
- To that end, new bitumen grades are being developed;

Context and Problematic

EME Technology : France vs Québec

EME2 (EN 13108-1) (2PB)		EME-BQ (introduced in 2013) (TC)	
E (15°C; 10Hz)	>14,000 MPa	E (15°C; 10Hz)	>11,000 MPa
ε_6 (10°C; 25Hz)	>130 x 10^{-6} m/m	ε_6 (10°C; 10Hz)	>130 x 10^{-6} m/m
Low T° need	n/a	Low T° need	PG88-**28**
EME		**HPAC**	

- Can we say that **EME-BQ (HPAC-QC)** meet EME Technology as introduced in France?

Problematic
EME Technology for Cold Region

- However, the question arises:

  Which properties should be target for cold region to reach a pavement performance level as defined for EME technology in France?

- How could EME technology be defined?

Purpose and Methodology

EME Technology for Cold Region

- Our thinking was done in three steps:

1. Define a **“ Fatigue Life Gain”** at the pavement level when using EME mixes as base course;
2. Point out HMA properties to target EME performance when using different fatigue life bituminous materials;
3. Figure out set of twin properties as regards stiffness/fatigue resistance (E, ε_6) to reach equivalent “Fatigue Life Gain” of a given pavement structure using different HMA base course.

Fatigue Life "Gain" of Pavement Using EME2 Mix as Asphalt Base Course

- In France, there are mainly 2 types of EME mix

	ε_6[(1)] $(\theta_{test}, f_{test})$ (µm/m)	$E(\theta_{test}, 10Hz)$ (MPa)	$E^{(2)}(\theta_{Design}, 10Hz)$ (MPa)
EME1	**100**	**16,940**	**14,000**
EME2	**130**	**16,940**	**14,000**

(1) Test result from 2PB test; θ_{test} = 10°C; f_{test}=25Hz; a_2 = -1/b = 5

(2) θ_{Design} = 15°C

4 times!

- We focus our investigation on the EME2 mix type

Fatigue Life "Gain" of Pavement Using EME2 Mix as Asphalt Base Course

- For a given HMA base course thickness (e_{Base}), the fatigue life ($N_{f,\theta}^{Site}$) of pavements using either EME2 or GB3 were compared.

	k_C ⁽¹⁾	ε_6 ⁽²⁾(θ_{test}, f_{test}) (µm/m)	E(θ_{test},10Hz) (MPa)	E⁽³⁾ (θ_{Design},10Hz) (MPa)
EME2	1.0	130	16,940	14,000
GB3	1.3	90	11,880	9,000

(1) Calibration coeffient : from laboratory to onsite performance

(2) Test result from 2 Point Bending test; θ_{test} = 10°C; f_{test}=25Hz; a_2 = -1/b = 5

(3) θ_{Design} = 15°C

Fatigue Life "Gain" of Pavement Using EME2 Mix as Asphalt Base Course

- To calculate ($N_{f,\theta}^{Site}$), we refer to the Wholer law:

Coefficients — Lab Material Properties

$$N_{f,\theta}^{Site} = \beta_{risk} \cdot \beta_{a_1} \cdot N_{f1}(\theta_{test}, f_{test}) \cdot E(\theta_{test}, f_{test})^{a_3} \cdot E_{\theta}^{-a_3} \cdot \varepsilon_t^{-a_2}$$

In-site parameters

Alizé

$$N_{f,\theta}^{Site} = (k_r k_c k_s)^{-1/b} \cdot 10^6 \cdot \epsilon_6\,(\theta_{test}, f_{test})^{-1/b} \cdot E(\theta_{test}, f_{test})^{-1/2b} \cdot E_{\theta}^{1/2b} \cdot \varepsilon_t^{1/b}$$

- All calculation were done with OPECC tool (https://opecc.etsmtl.ca)

Fatigue Life "Gain" of Pavement Using EME2 Mix as Asphalt Base Course

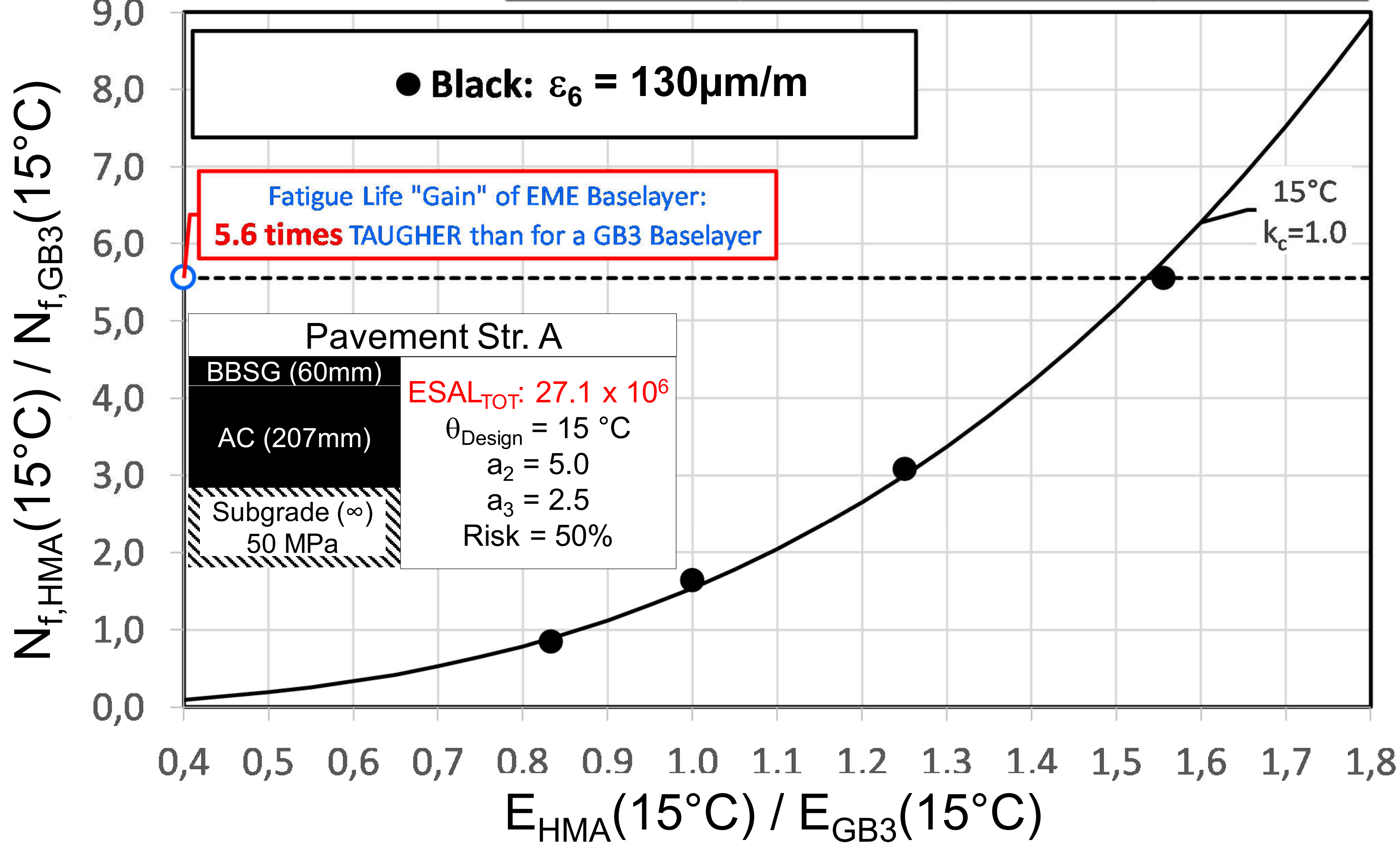
- For a given HMA base course thickness (e_{Base}), the fatigue duration life (N_f^{Site}) of pavements using either EME2 or GB3 were compared.

Pavement Str. A	
BBSG (60mm) / EME2 (207mm) / Subgrade (∞) 50 MPa	$ESAL_{TOT}$: 27.1 x 10^6 θ_{Design} = 15 °C a_2 = -1/b = 5.0 $a_3 = a_2/2$ = 2.5 Risk = 50%

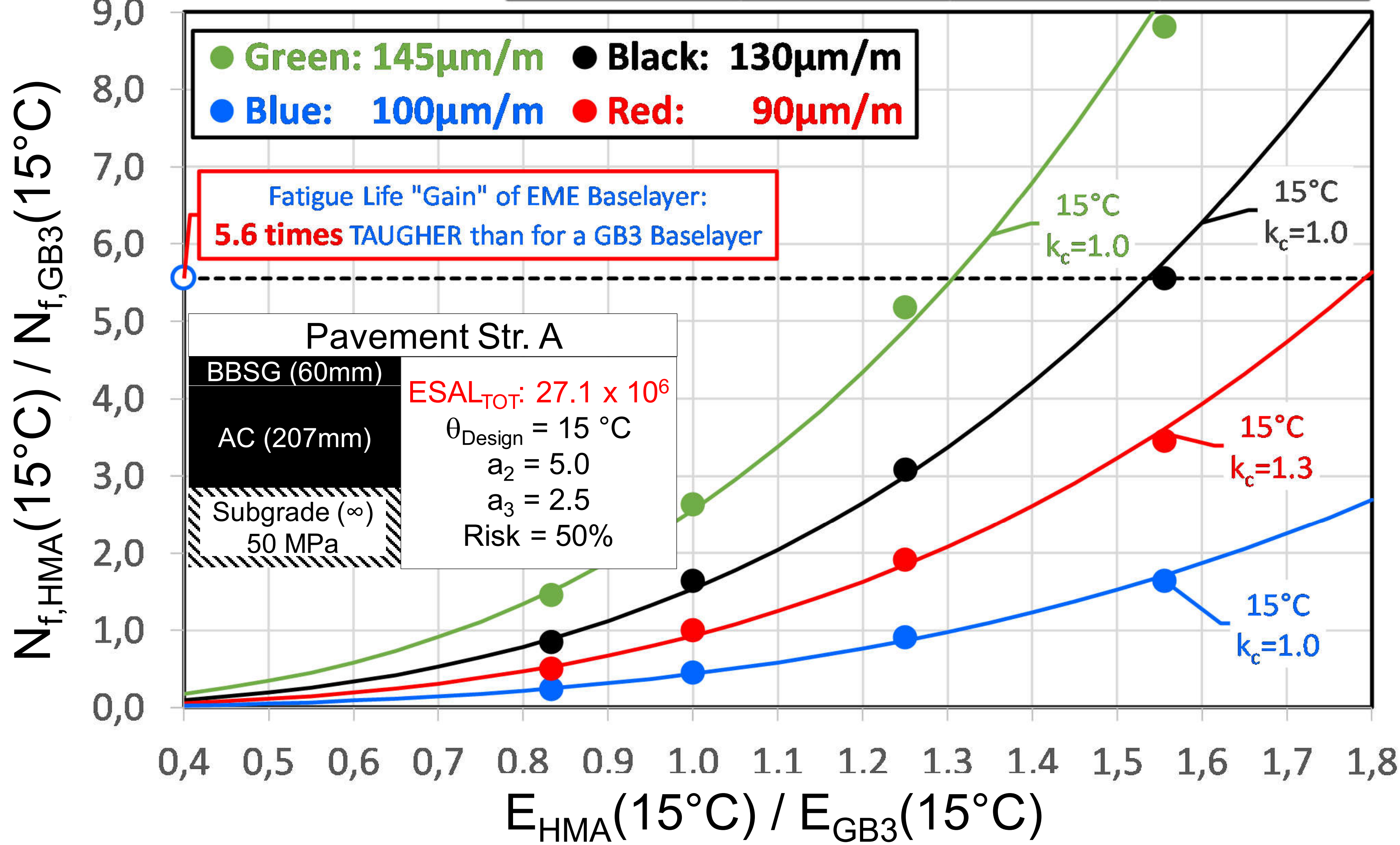
Pavement Str. A	
BBSG (60mm) / GB3 (207mm) / Subgrade (∞) 50 MPa	$ESAL_{TOT}$: 4.9 x 10^6 θ_{Design} = 15 °C a_2 = -1/b = 5.0 $a_3 = a_2/2$ = 2.5 Risk = 50%

$$\text{“ Fatigue Life Gain”} = \frac{N_{f,EME2}^{Site}}{N_{f,GB3}^{Site}} = 5.55$$

	5°C	10°C	15°C
E_{GB3}(MPa)	15,090	11,880	9,000



	5°C	10°C	15°C
EGB3(MPa)	15,090	11,880	9,000



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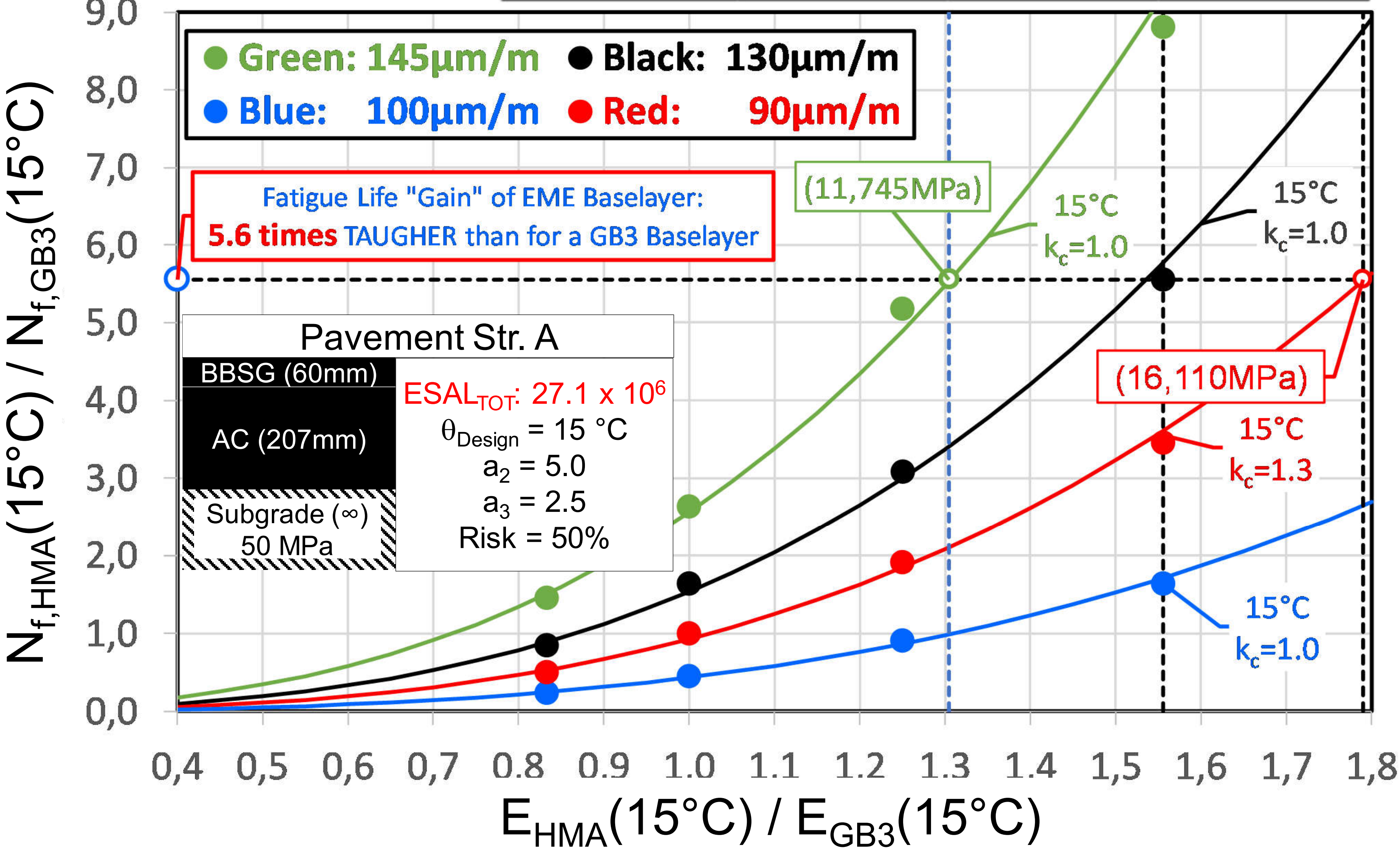
	5°C	10°C	15°C
EGB3(MPa)	15,090	11,880	9,000



Set of HMA twin properties as regard Stiffness/fatigue resistance (E, ε_6)

- For Pavement Str. A, we look for different “fictive” HMA mixes (E ; ε_6) that provide

  a constant pavement fatigue performance

  …always the same : **$ESAL_{TOT}$**

Pavement Str. A	
BBSG (60mm)	**$ESAL_{TOT}$: 27.1 x 10^6**
HMA (207mm)	θ_{Design} = 15 °C a_2 = 5.0 a_3 = 2.5 Risk = 50%
Subgrade (∞) 50 MPa	

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Set of HMA twin properties as regard Stiffness/fatigue resistance (E,ε_6)

- We choose four HMA mixes having a wide range of $\varepsilon_6(\theta_{test}, f_{test})$ values

30 times!

$\varepsilon_6(\theta_{test}, f_{test})$ (µm/m)	104	130	195	260
$N_{f1}(\theta_{test}, f_{test})$ x10^{14}	1.22	3.71	28.20	118.81
θ_{test} = 10°C and f_{test} = 25Hz				

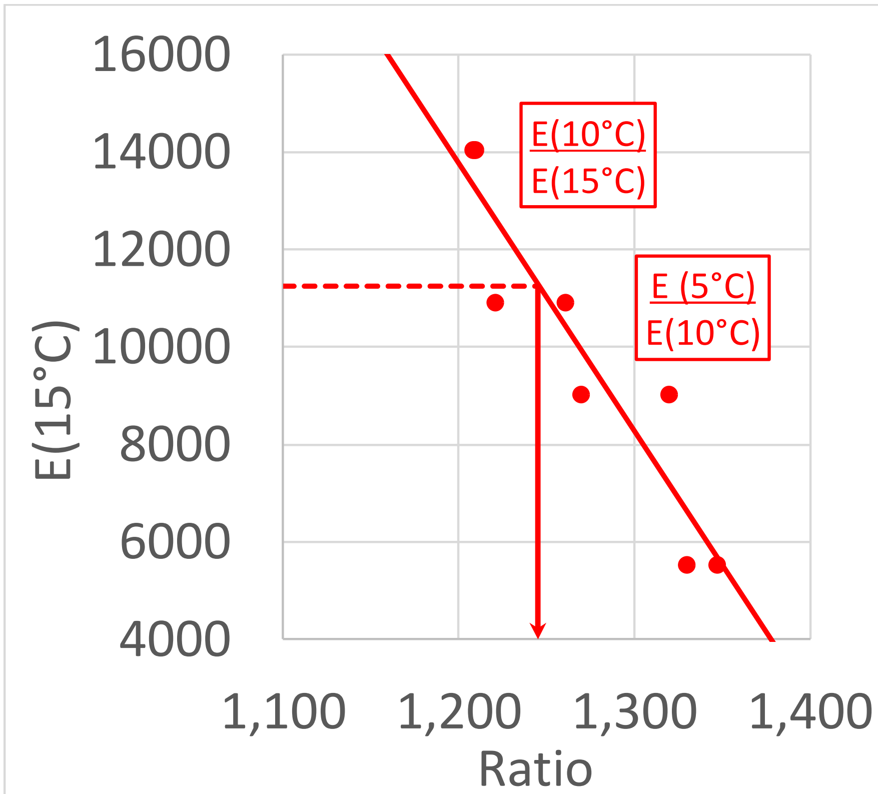
- Keeping constant de thickness of the HMA base course, we seek to identify the stiffness – $E(\theta_{Design})$ of the HMA mix to reach:

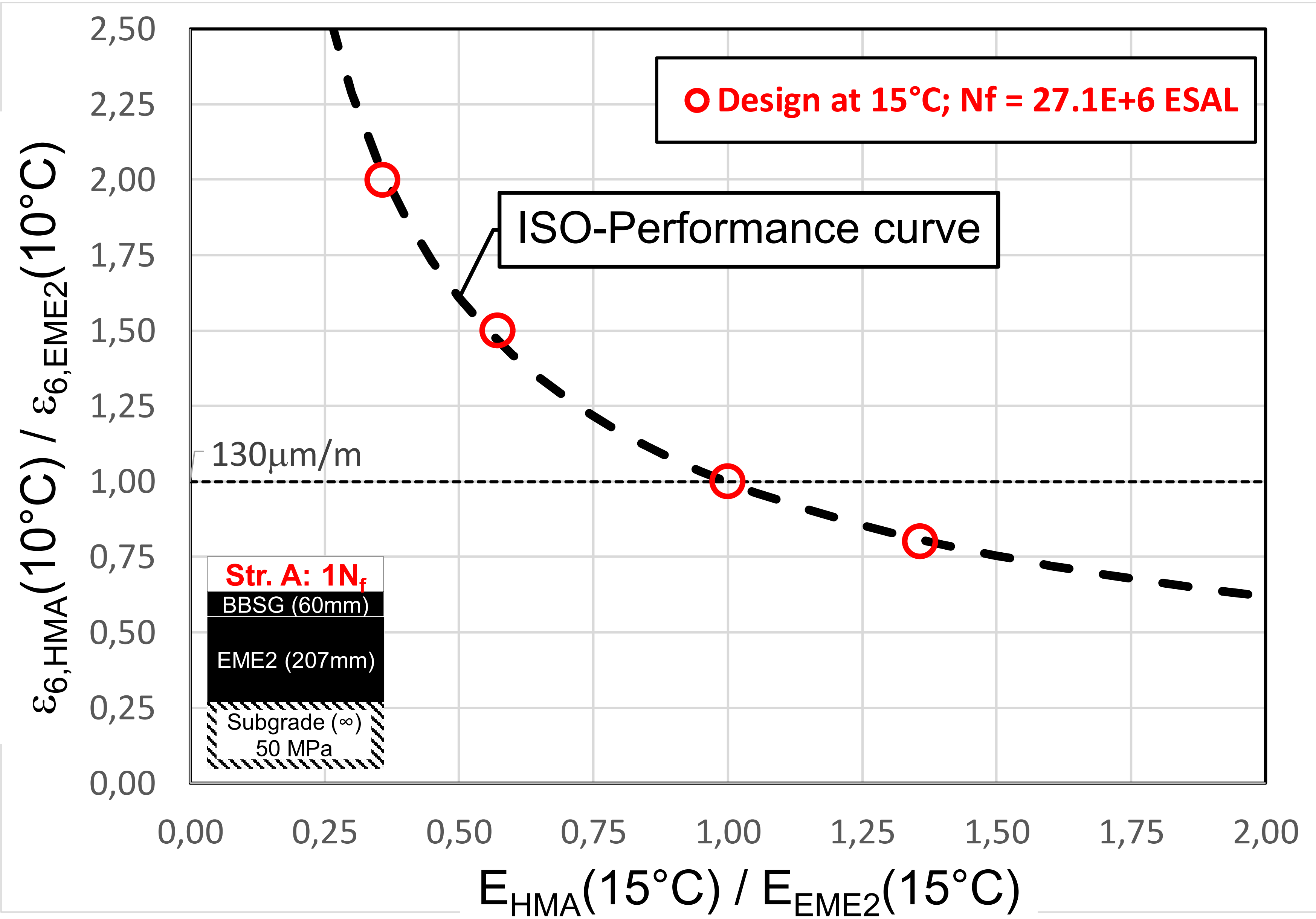
$ESAL_{TOT}$ fixed at **27.1 x 10^6**

Set of HMA twin properties as regard Stiffness/fatigue resistance (E,ε_6)

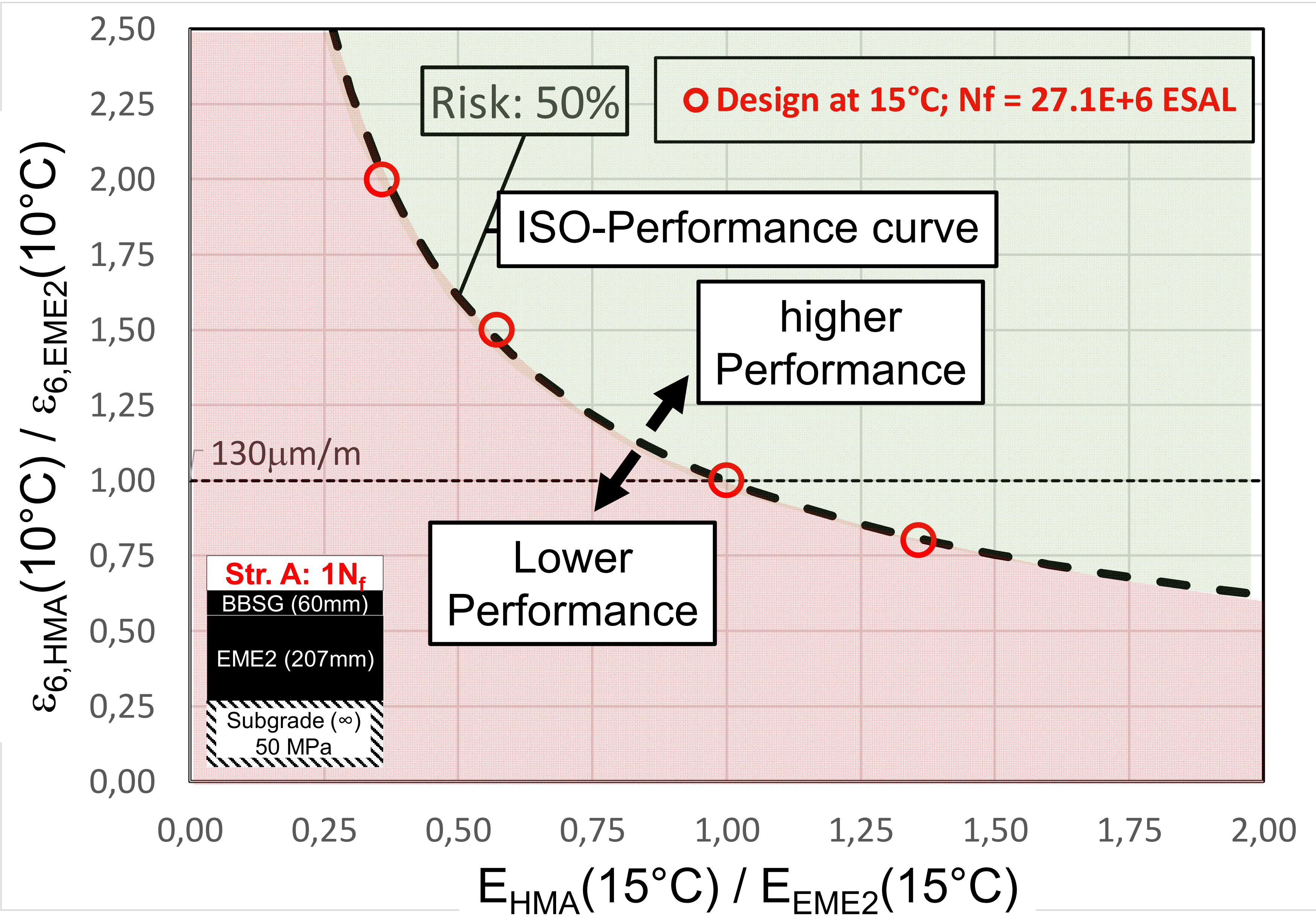
- To be consistency, E(θ_{test}) was adjusted in accordance to the selected E(θ_{Design}) value.

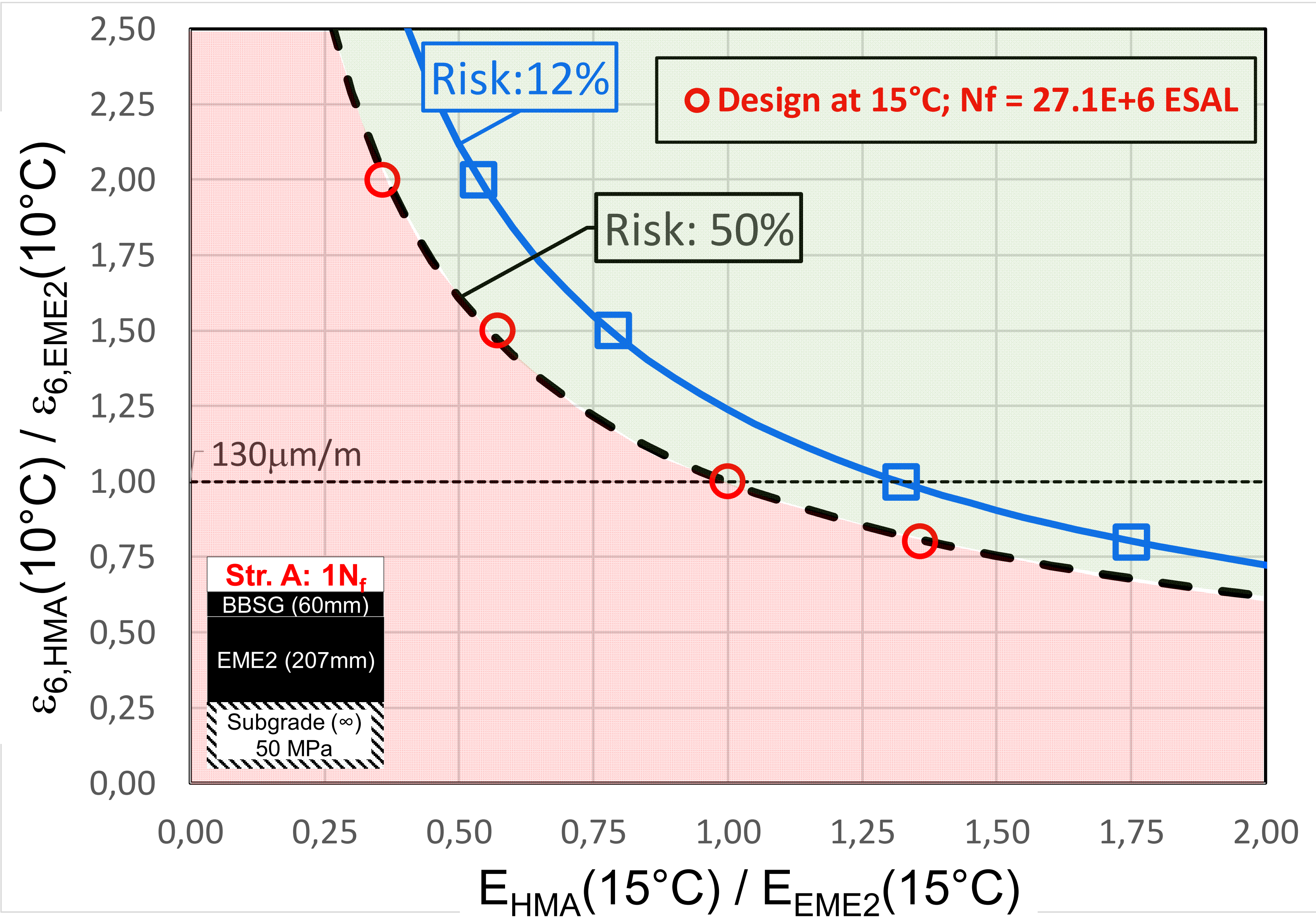
- The E(θ_{test}) was adjusted by considering typical ratio between E(θ_{Design}) and E(θ_{test}) for BBSG, GB3 and EME2 mixes





Design at 15°C; Nf = 27.1E+6 ESAL
ISO-Performance curve
130µm/m
Str. A: 1Nf
BBSG (60mm)
EME2 (207mm)
Subgrade (∞)
50 MPa
2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
ε6,HMA(10°C) / ε6,EME2(10°C)
EHMA(15°C) / EEME2(15°C)


2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
ε6,HMA(10°C) / ε6,EME2(10°C)
Risk: 50%
O Design at 15°C; Nf = 27.1E+6 ESAL
ISO-Performance curve
higher Performance
130µm/m
Lower Performance
Str. A: 1Nf
BBSG (60mm)
EME2 (207mm)
Subgrade (∞) 50 MPa
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
EHMA(15°C) / EEME2(15°C)

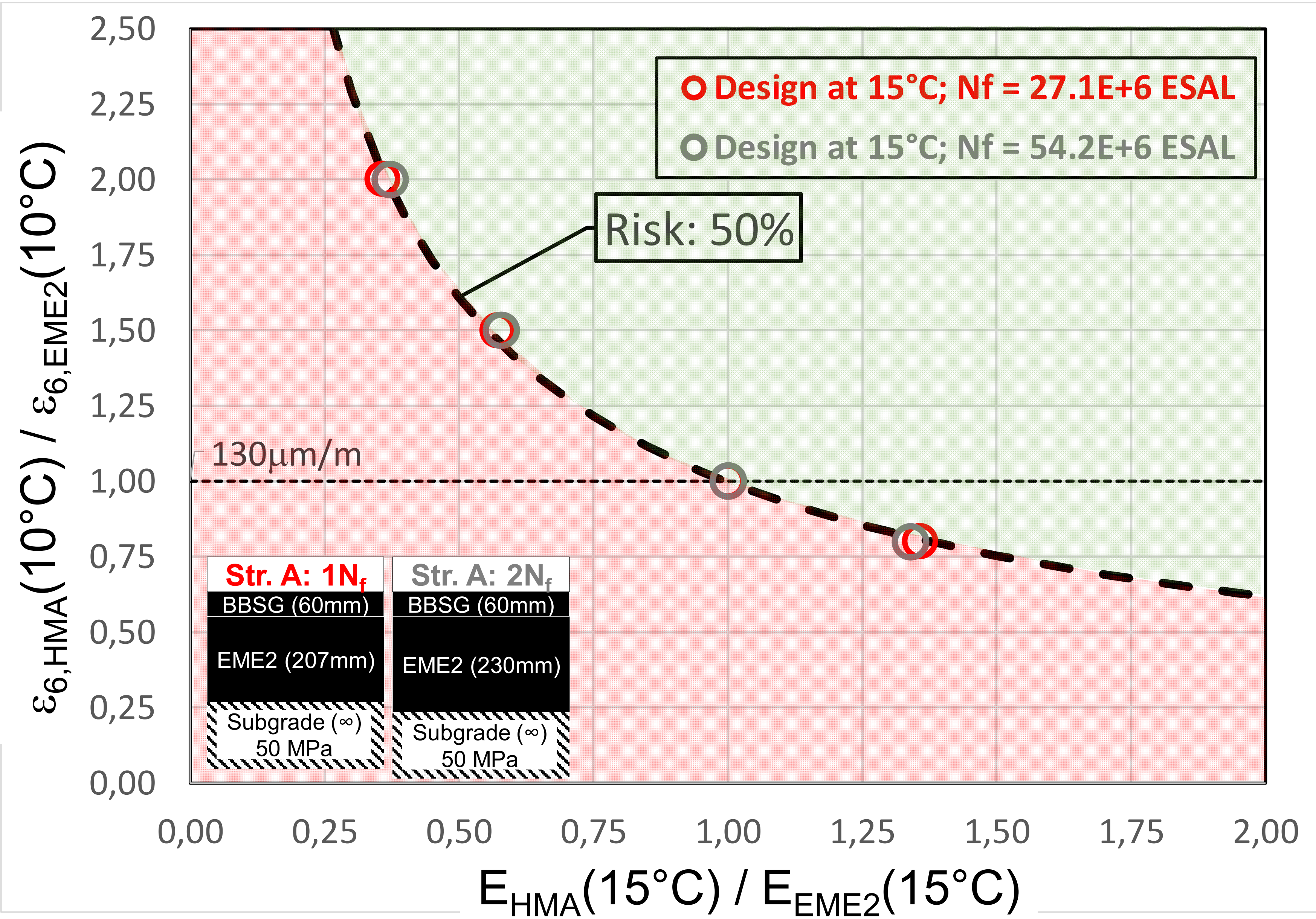


Risk:12%
Design at 15°C; Nf = 27.1E+6 ESAL
Risk: 50%
130µm/m
Str. A: 1Nf
BBSG (60mm)
EME2 (207mm)
Subgrade (∞)
50 MPa
2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
ε6,HMA(10°C) / ε6,EME2(10°C)
EHMA(15°C) / EEME2(15°C)

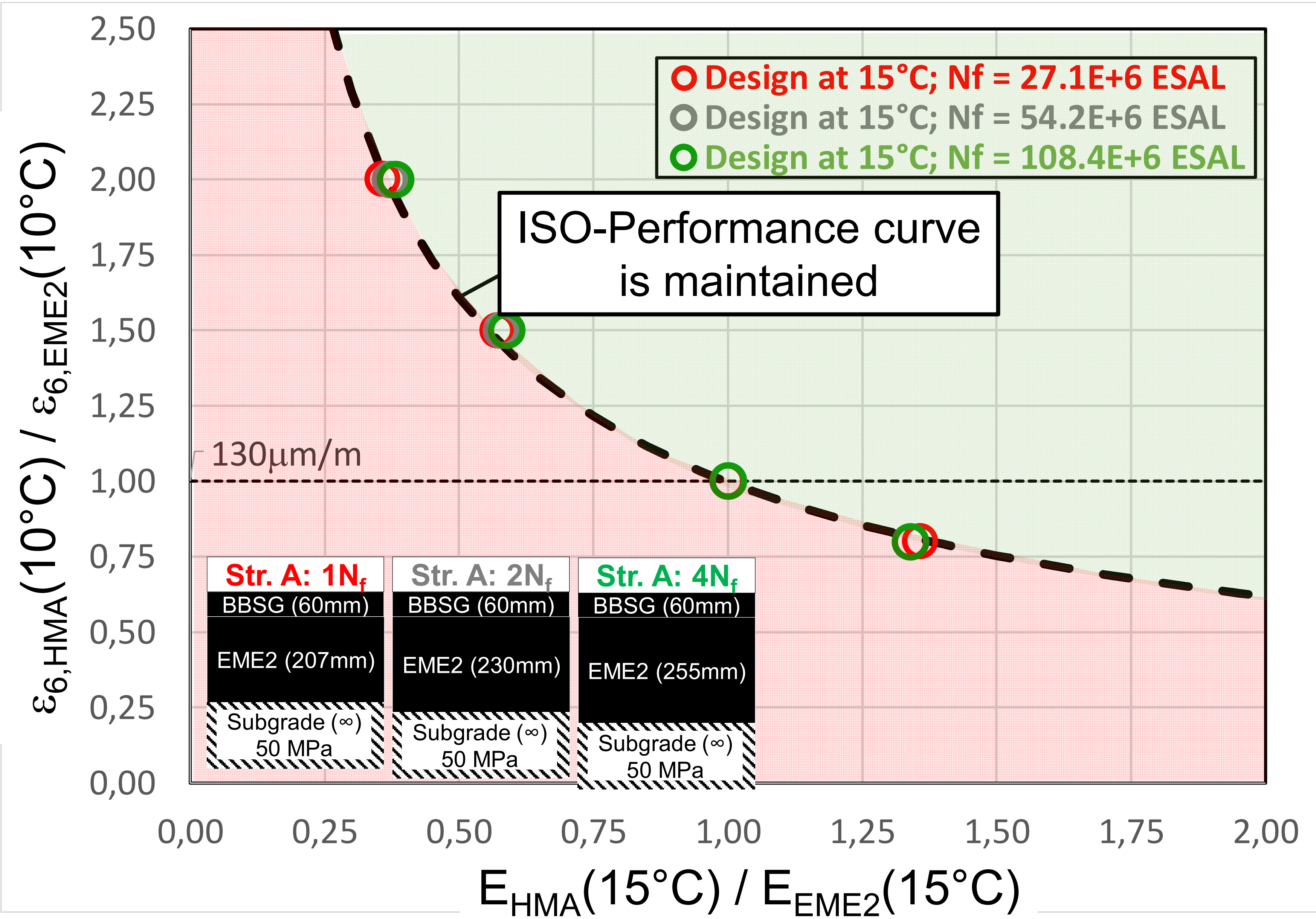
Set of HMA twin properties as regard Stiffness/fatigue resistance (E,ε_6)

- What's going on if the traffic level is more significant?
- Are the ISO-Performance curve is unique?
- HMA set values of (E,ε_6) were determined for:

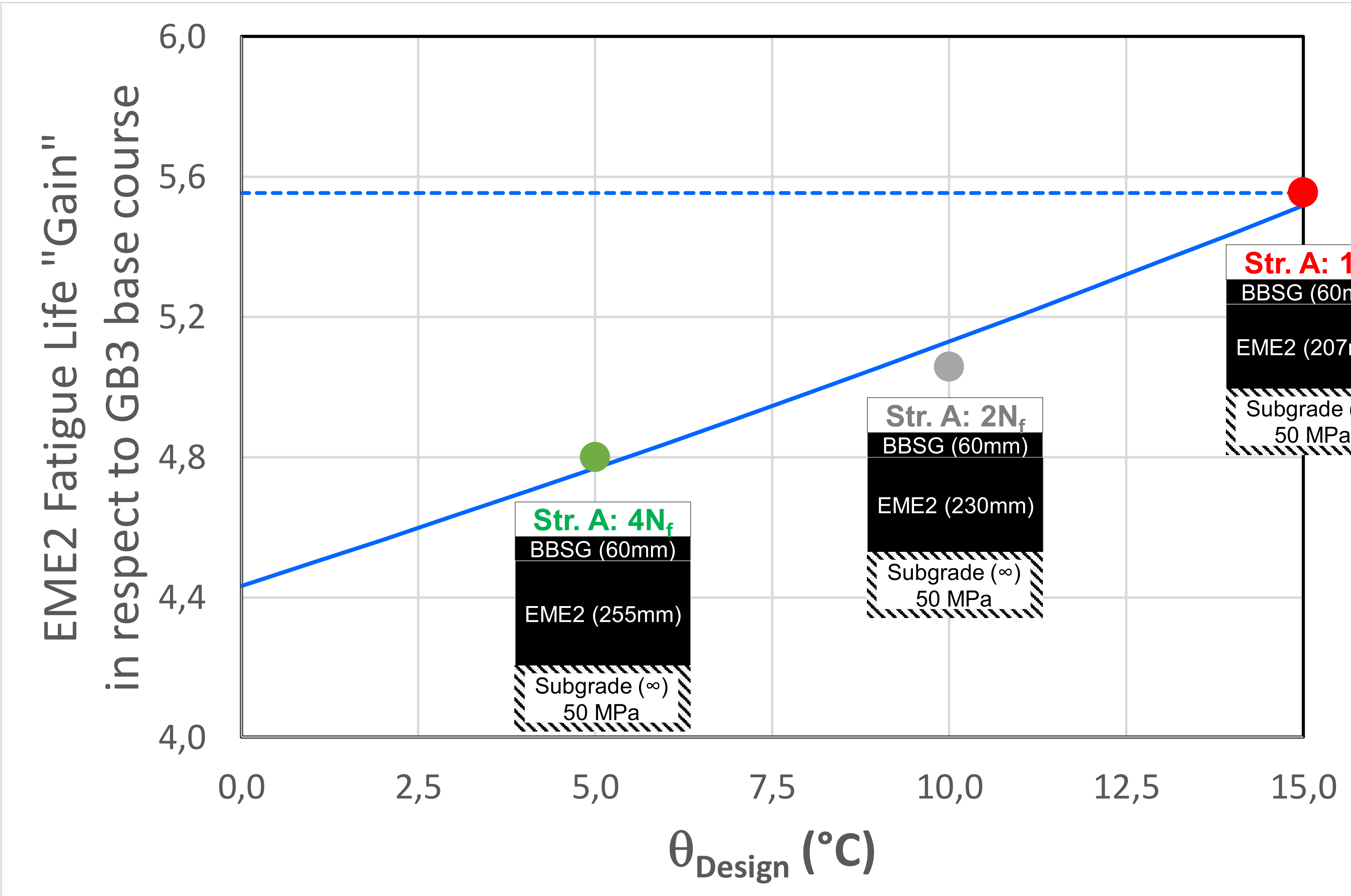
$1N_f = 27.1 \times 10^6$ ESAL
$2N_f = 54.2 \times 10^6$ ESAL
$4N_f = 108.4 \times 10^6$ ESAL



2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
Design at 15°C; Nf = 27.1E+6 ESAL
Design at 15°C; Nf = 54.2E+6 ESAL
Risk: 50%
130µm/m
Str. A: 1Nf
BBSG (60mm)
EME2 (207mm)
Subgrade (∞)
50 MPa
Str. A: 2Nf
BBSG (60mm)
EME2 (230mm)
Subgrade (∞)
50 MPa
ε6,HMA(10°C) / ε6,EME2(10°C)
EHMA(15°C) / EEME2(15°C)



Design at 15°C; Nf = 27.1E+6 ESAL
Design at 15°C; Nf = 54.2E+6 ESAL
Design at 15°C; Nf = 108.4E+6 ESAL
ISO-Performance curve is maintained
130µm/m
Str. A: 1Nf
BBSG (60mm)
EME2 (207mm)
Subgrade (∞) 50 MPa
Str. A: 2Nf
BBSG (60mm)
EME2 (230mm)
Subgrade (∞) 50 MPa
Str. A: 4Nf
BBSG (60mm)
EME2 (255mm)
Subgrade (∞) 50 MPa
2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
ε6,HMA(10°C) / ε6,EME2(10°C)
EHMA(15°C) / EEME2(15°C)



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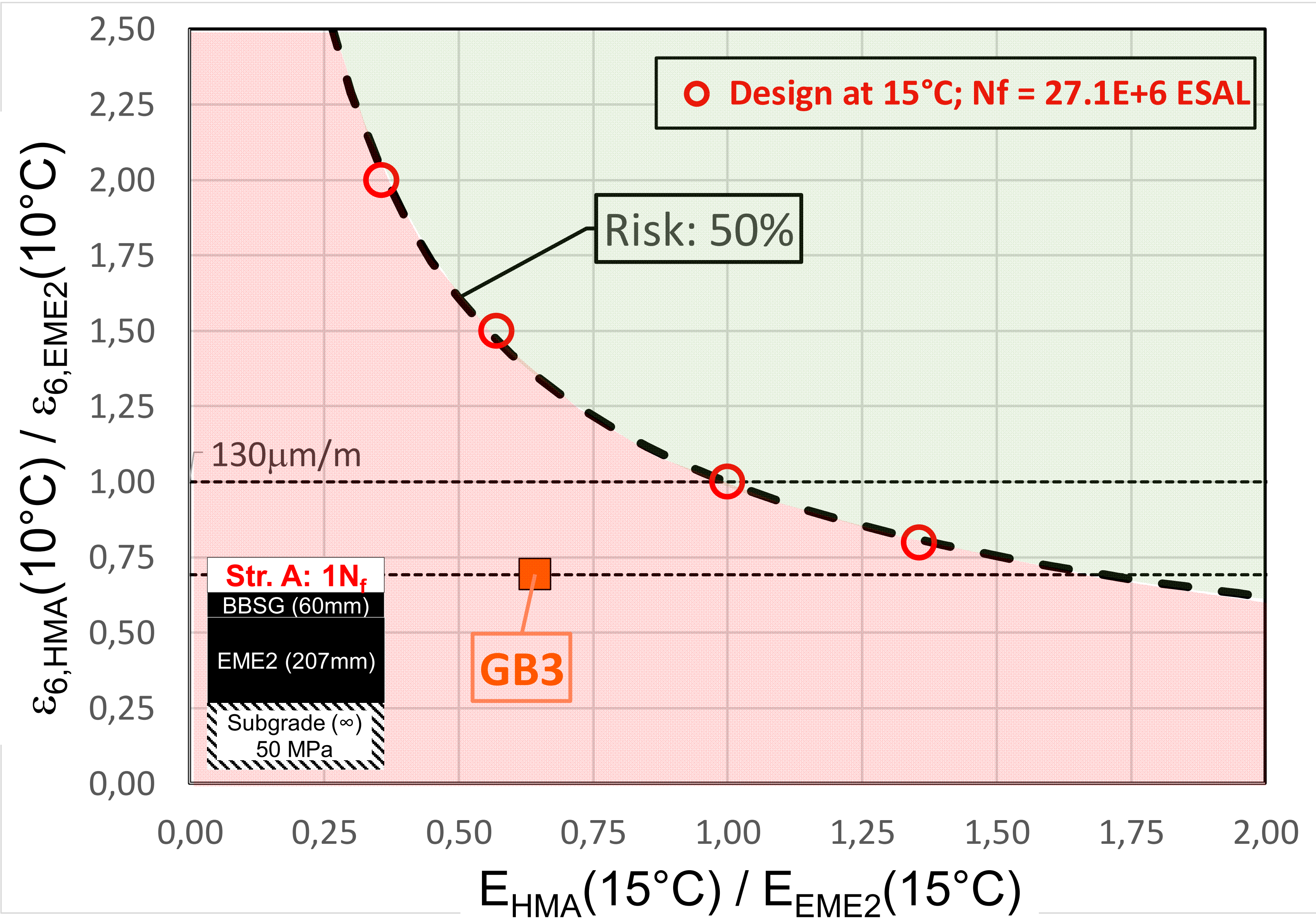
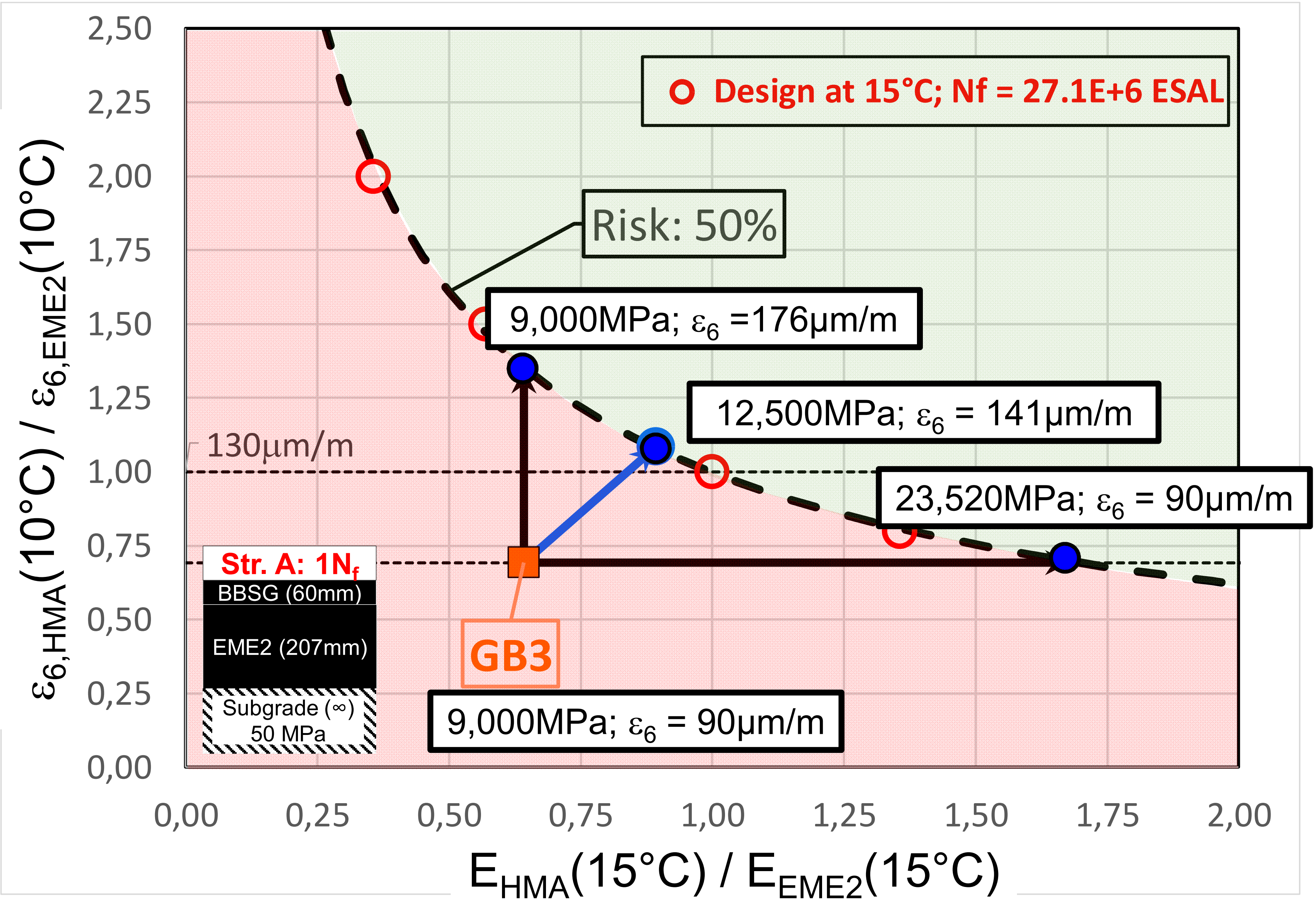


Design at 15°C; Nf = 27.1E+6 ESAL
Risk: 50%
130µm/m
Str. A: 1Nf
BBSG (60mm)
EME2 (207mm)
Subgrade (∞)
50 MPa
GB3
2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
ε6,HMA(10°C) / ε6,EME2(10°C)
EHMA(15°C) / EEME2(15°C)



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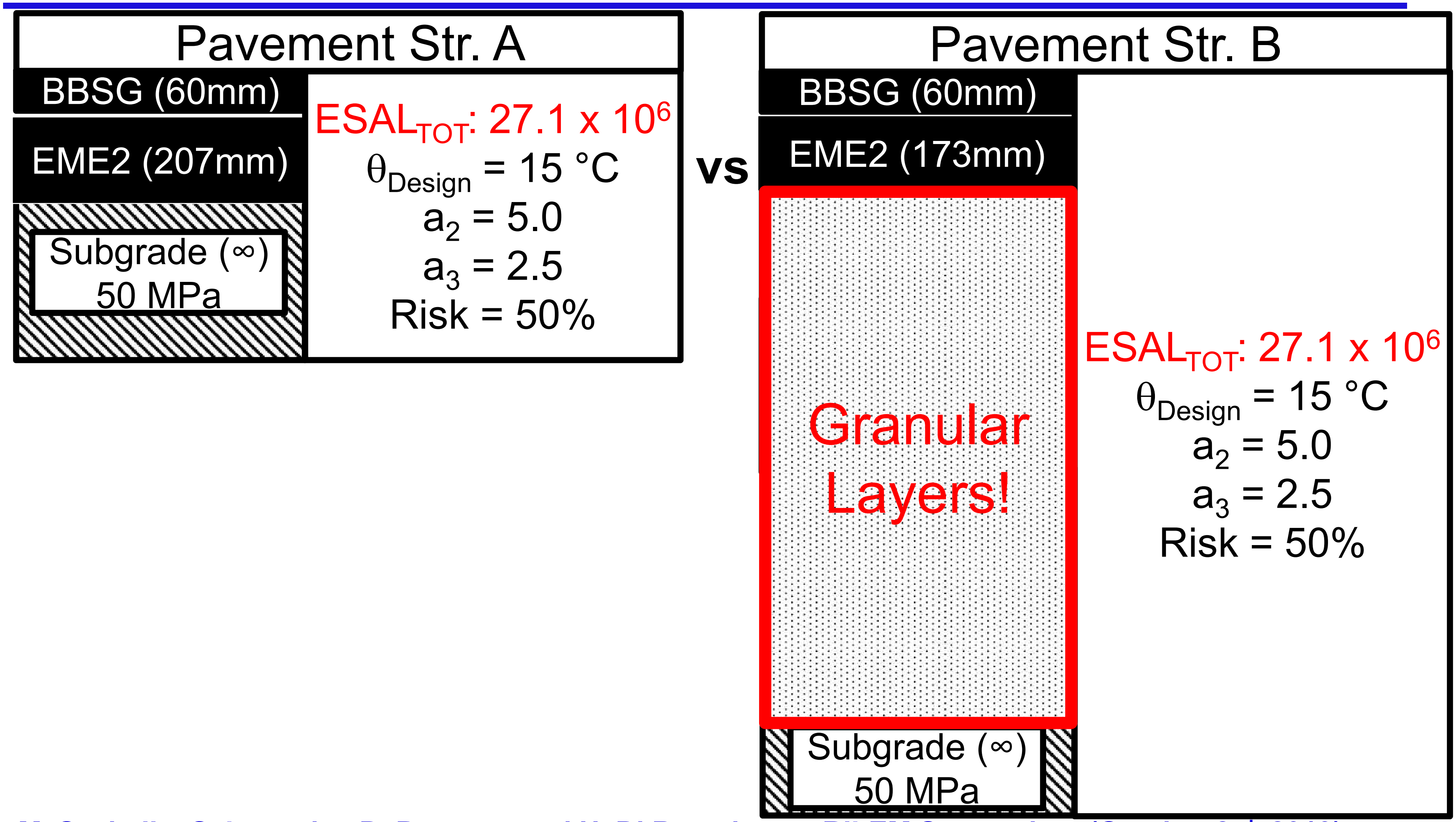
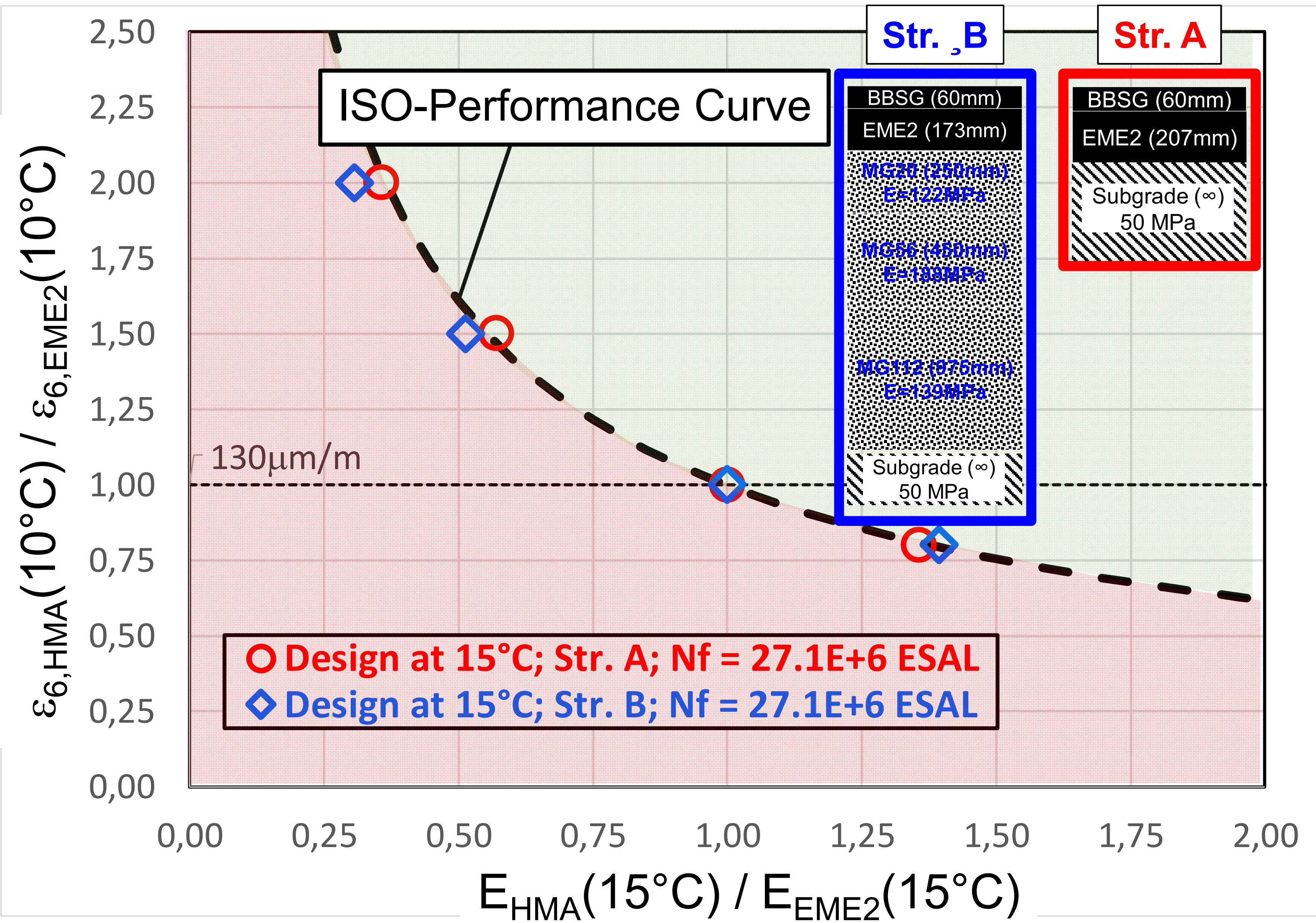
Set of AC twin properties as regard Stiffness/fatigue resistance (E, ε_6)

- What's going for a different type of Pavement Structure?
- In Canada, the bituminous layers are always placed over granular layers
- Could we expect that the ISO-Performance Curve will be unchanged following the pavement structure type?

Set of AC twin properties as regard Stiffness/fatigue resistance (E, ε_6)

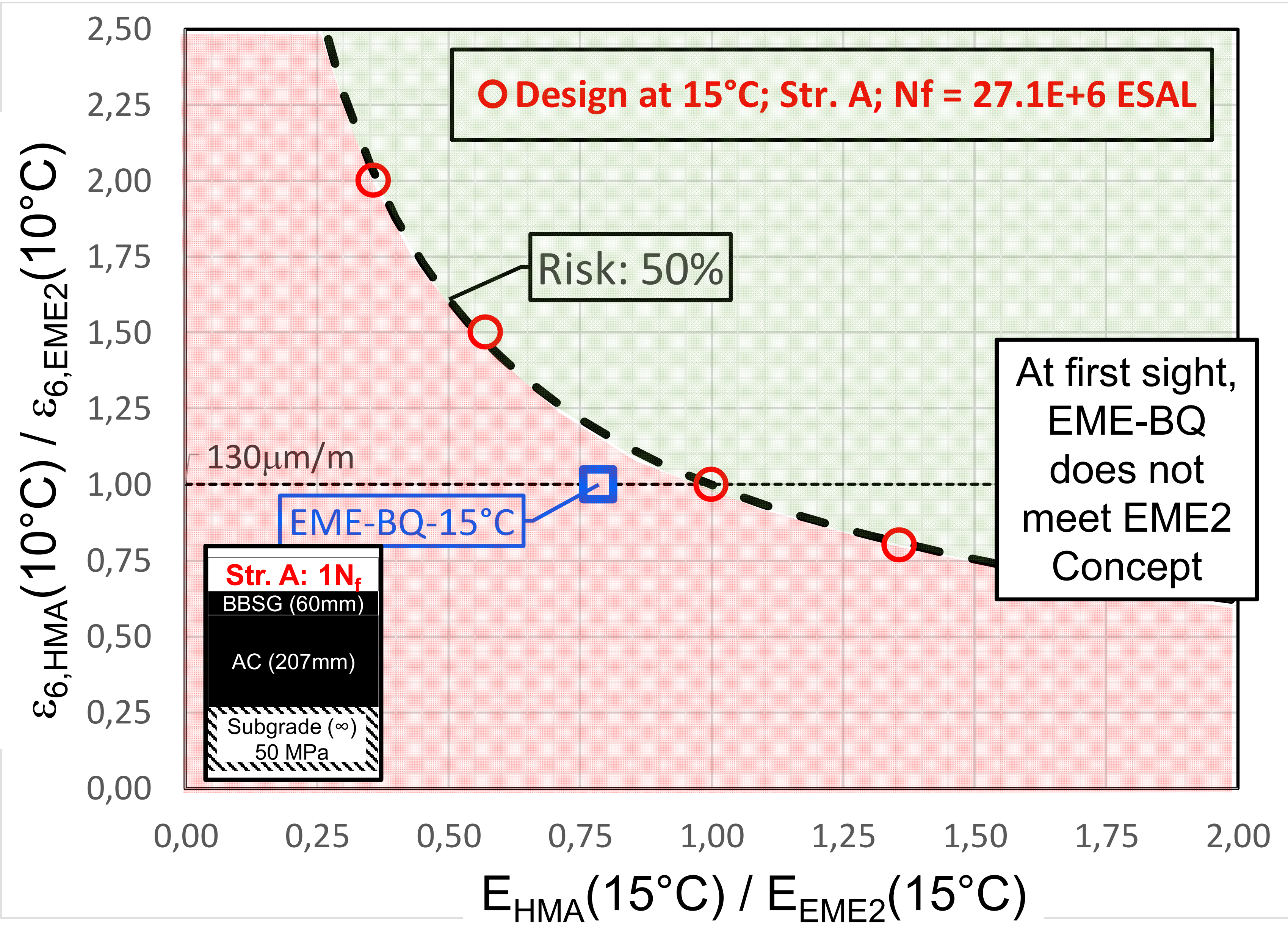




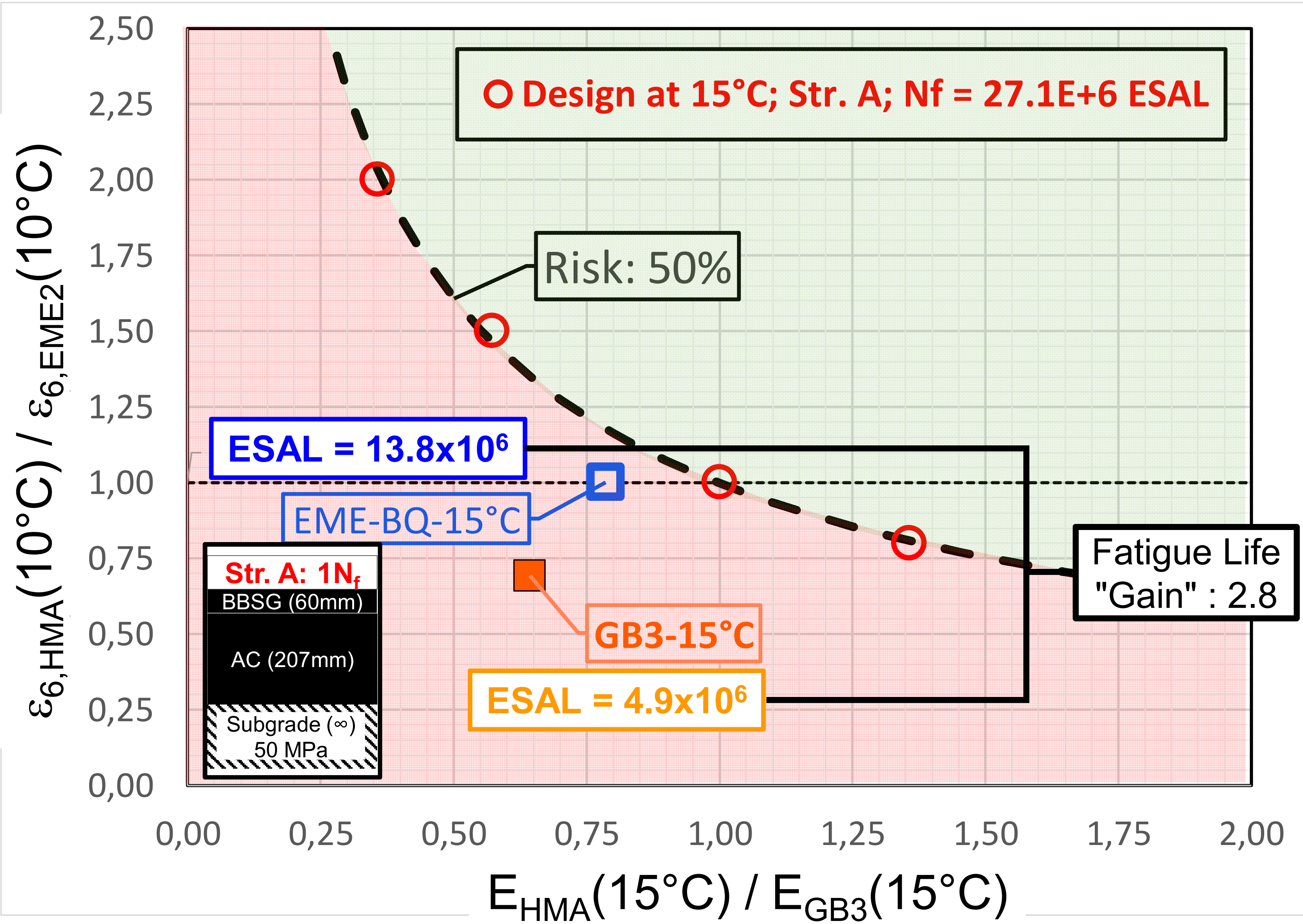
ISO-Performance Curve
Str. ¸B
Str. A
BBSG (60mm)
EME2 (173mm)
MG20 (250mm)
E=122MPa
MG56 (450mm)
E=188MPa
MG112 (975mm)
E=139MPa
Subgrade (∞)
50 MPa
BBSG (60mm)
EME2 (207mm)
Subgrade (∞)
50 MPa
130µm/m
Design at 15°C; Str. A; Nf = 27.1E+6 ESAL
Design at 15°C; Str. B; Nf = 27.1E+6 ESAL
2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
ε6,HMA(10°C) / ε6,EME2(10°C)
EHMA(15°C) / EEME2(15°C)

Set of AC twin properties as regard Stiffness/fatigue resistance (E, ε_6)

- How is the EME-BQ mix in reference to the ISO-Performance curve?



2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
ε6,HMA(10°C) / ε6,EME2(10°C)
Design at 15°C; Str. A; Nf = 27.1E+6 ESAL
Risk: 50%
130µm/m
EME-BQ-15°C
At first sight, EME-BQ does not meet EME2 Concept
Str. A: 1Nf
BBSG (60mm)
AC (207mm)
Subgrade (∞)
50 MPa
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
EHMA(15°C) / EEME2(15°C)

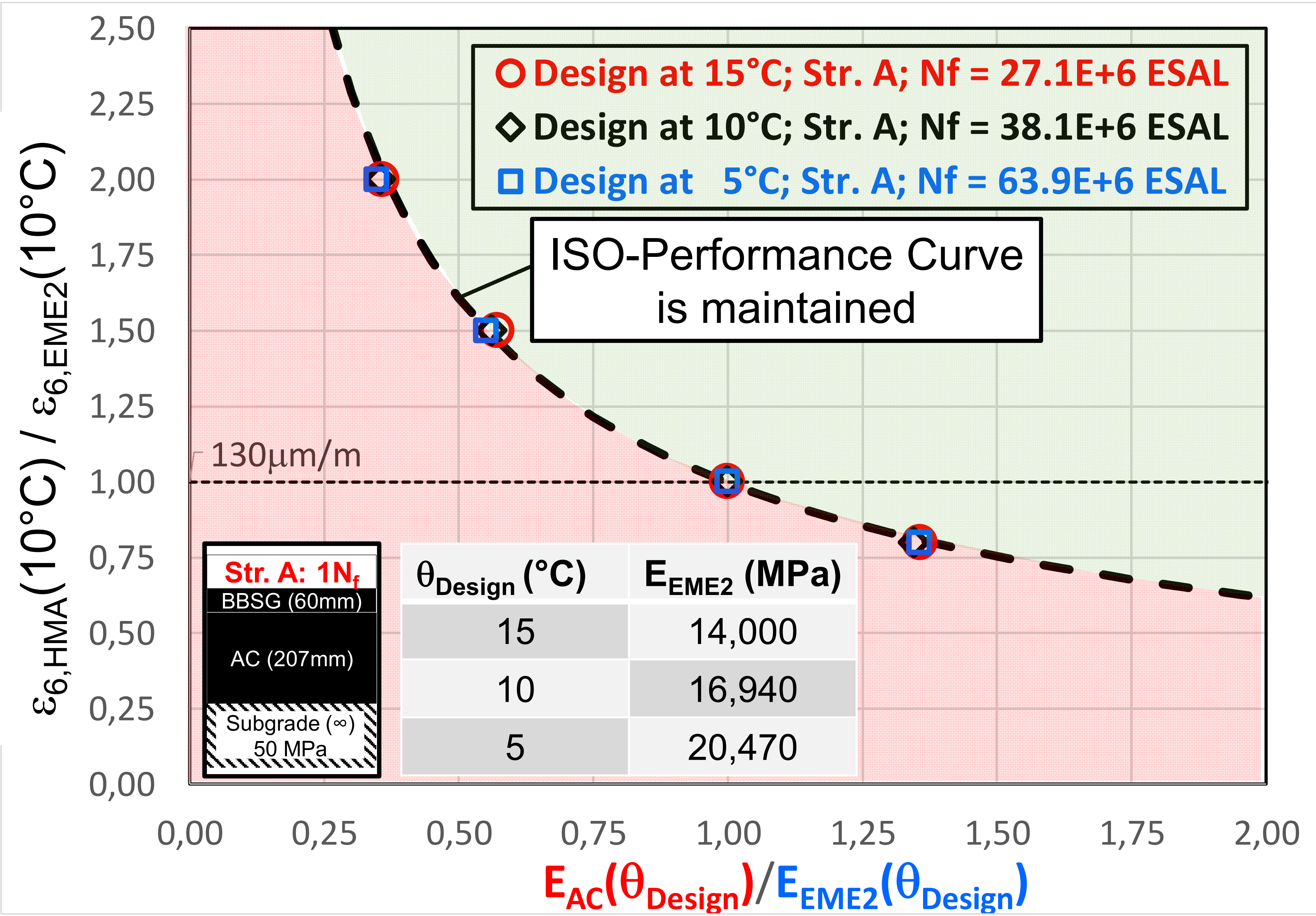


2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
$\varepsilon_{6,HMA}(10°C) / \varepsilon_{6,EME2}(10°C)$
$E_{HMA}(15°C) / E_{GB3}(15°C)$
O Design at 15°C; Str. A; Nf = 27.1E+6 ESAL
Risk: 50%
ESAL = 13.8x10^6
EME-BQ-15°C
Str. A: 1N_f
BBSG (60mm)
AC (207mm)
Subgrade (∞)
50 MPa
GB3-15°C
ESAL = 4.9x10^6
Fatigue Life
"Gain" : 2.8

Set of AC twin properties as regard Stiffness/fatigue resistance (E, ε_6)

- It's important to note that in Québec, the pavement temperature design (θ_{Design}) is closer to 10°C.
- How does the ISO-Performance Curve evolve in respect to θ_{Design}?
- For Pavement Str. A, we look for different set of twin values of (E ; ε_6) with changing θ_{Design}

θ_{Design} (°C)
15
10
5



θ_{Design} (°C)	E_{EME2} (MPa)
15	14,000
10	16,940
5	20,470

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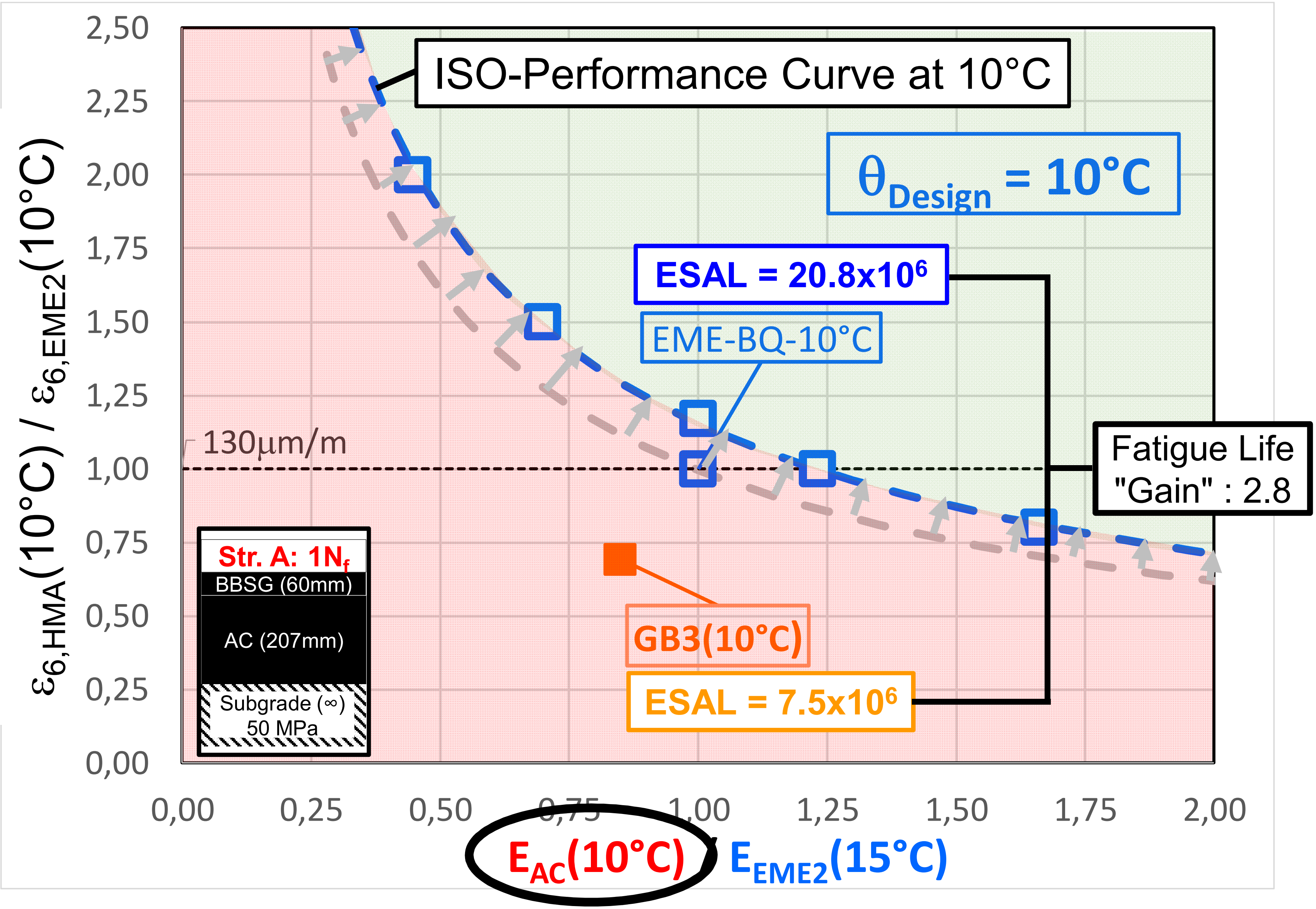

ISO-Performance Curve at 10°C
θDesign = 10°C
ESAL = 20.8x10⁶
EME-BQ-10°C
130µm/m
Fatigue Life "Gain" : 2.8
Str. A: 1Nf
BBSG (60mm)
AC (207mm)
Subgrade (∞) 50 MPa
GB3(10°C)
ESAL = 7.5x10⁶
ε6,HMA(10°C) / ε6,EME2(10°C)
EAC(10°C) / EEME2(15°C)
2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0,00
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00

Conclusions

- Pavement structure using EME2 base course provide a "fatigue life Gain" of 5.6 compared to a pavement structure using GB3 base course;
- Different set of twin values of (E,ε_6) could be used to get ISO performance of EME2 asphalt pavement structure;
- Material specifications as proposed by BQ for EME mix (**EME-BQ**) are not severe enough to meet "Fatigue Life Gain" of EME2 mix.

….But, fatigue specifications are based on the TC test! (…more severe than 2PB and 4PB)

Conclusions

- In any cases, for cold region, the “EME” Asphalt mix shall conform to local needs as regard low temperature requirement :

“EME” mix ⇨ “HPAC” mix (E;ε_6; rutting; durability…and low T°!)

- We will continue our reflection

Thank you
for your kind attention