1ST INTERNATIONAL CONFERENCE ON
Stone Matrix Asphalt

Test method analysis for different types of fillers used in the SMA mix through semi-circular bending (SCB) fracture energy test

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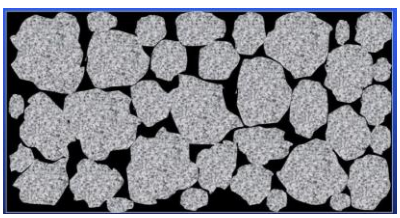
¿What is the SMA?

- Stone Matrix Asphalt



Discontinue gradation

Excellent Aggregates properties

High skeleton Aggregate

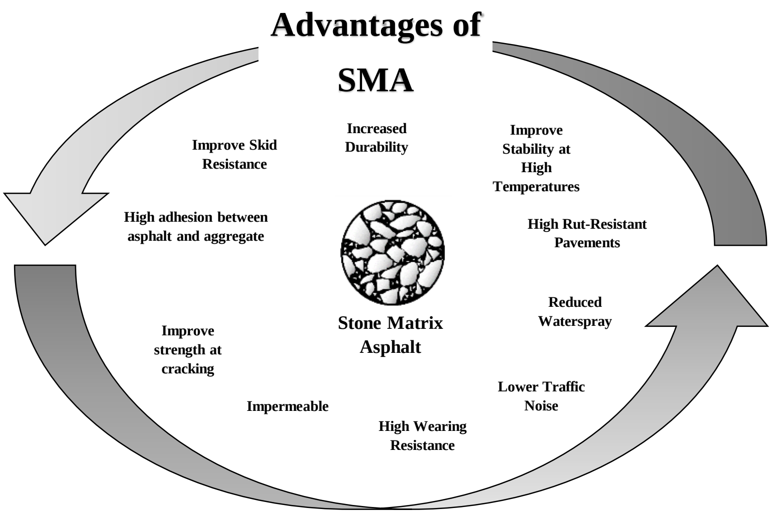
Low Sand

High Binder Content (6% minimum/total mix)

Passing #200 (8 – 12%/total aggregates)

Cellulose fiber (0.3% minimum/total mix)

SMA Benefits



SMA ISSUES

- Coarse aggregates quality
- Aggregates gradation
- Inadequate Design
- Old pavement surface
- Low passing #200
- Filler Quality
- Others

SCB TEST

The SCB test was presented by Kuruppu, Obara as a quick 3-point bending test. It evaluate fracture resistance at different temperatures and characteristics, such as: different aggregate, asphalt types, asphalt content and filler types.

The semicircular bending test determines the fracture energy necessary to cause an asphaltic mixture to crack by measuring various physical and/or chemical characteristics and external factors such as temperature or induced damage to the specimen.

Research Objectives

1) To Evaluate different fillers with methylene blue test and microscope

2) To Analyze results of different fillers in SMA mix through of semicircular bending test

3) To Evaluate graphical load-displacement of the SMA mix at different temperatures

4) To Contrast fracture energy and energy index results of different SMA mix using different filler types

5) To compare SCB results versus Indirect tensile fatigue

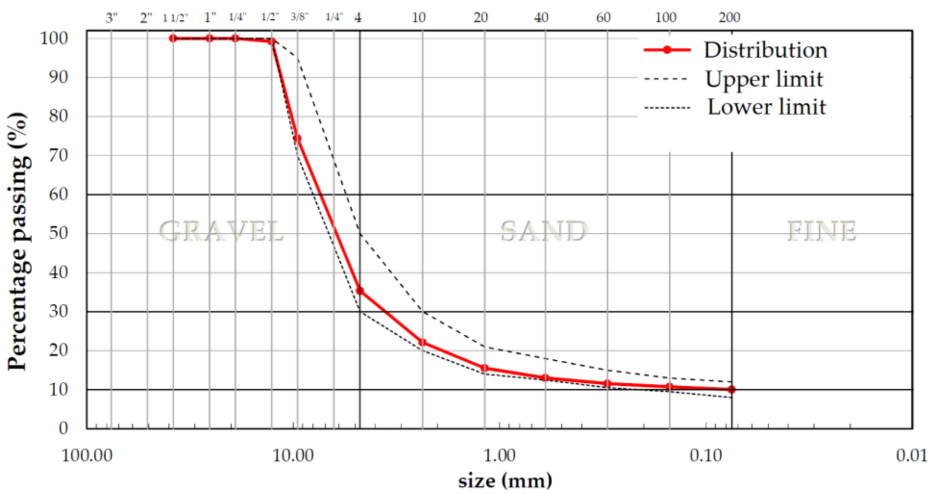
Research Results

Aggregate Type	Test	Results
Coarse	L. A. abrasion, (%)	13
	accelerated Weathering, (%)	5
	Crushed particles (%)	100
	Elongated particles (%)	24
	Flat particles (%)	16
	Density (T/m^3)	2,72
	Absorption (%)	0,75
Fine	Sand equivalent (%)	61
	Methylene blue (mg/g)	10
	Density (T/m3)	2,55

Binder analysis	Test	Results
Original binder	Penetration to 25 °C 100gr 5 sec (1/10 mm)	69
	Elastic recovery by torsion to 25°C (%)	5
	Softening point 5°c/min. (°C)	49
	Performance grade PG	70
	Cleveland Flashpoint	>260
	Brookfield Viscosity to 135°c sc4-27 12 rpm (cP)	530
	Fail temperature [G*/senδ=1.0 kPa] (°C)	71.1
	Module DSR to PG [G*/senδ] (kPa)	1.21
	Phase angle (δ) to PG (°)	82.36
Aged binder RTFO	Loss mass to 163 °C (%)	0.57
	Performance grade PG	70
	Fail temperature [G*/senδ=2.2 kPa] (°C)	70.1
	Module DSR to PG [G*/senδ] (kPa)	2.23
	Phase angle (δ) to PG (°)	81.11
Aged binder PAV	Module DSR to 34 °C [G*senδ] (kPa)	2102
	slope (m) BBR test to -6 °C	0.312
	module stiffness BBR test to -6 °C (MPa)	287

Research Results

The design aggregate gradation has been made according to AASHTO MP-8 standard, in which a gradation adjusted to the limits for a nominal maximal size of 12.5 mm



Research Results

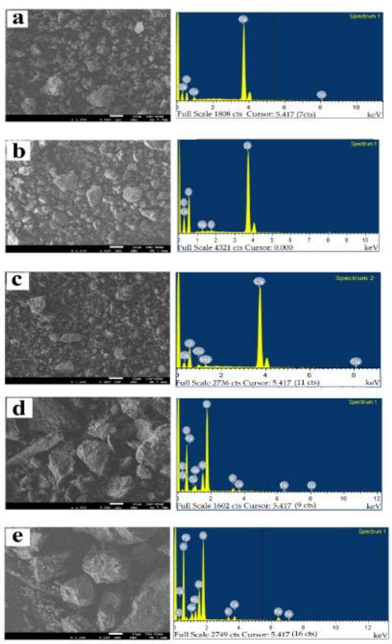
Filler properties

FILLER	Blue methylene value (mg/gr)
Lime	-------
$Ca(OH)_3$	-------
Filler #1	4
Filler #2	17
Filler #3	32

FILLER	Plasticity index (%)
Lime	-------
$Ca(OH)_3$	-------
Filler #1	Not Plastic
Filler #2	5,2
Filler #3	9,4

Research Results

Filler properties



a

Element	Weight, %	Atomic, %
O K	72.43	86.81
Ca K	27.57	13.19

b

Element	Weight, %	Atomic, %
O K	45.59	67.88
Mg K	0.61	0.6
Ca K	51.72	30.74
Cu L	2.07	0.78

c

Element	Weight, %	Atomic, %
C K	14.82	22.1
O K	59.01	66.08
Mg K	0.28	0.2
Si K	0.19	0.12
Ca K	25.71	11.49

d

Element	Weight, %	Atomic, %
O K	51.18	65.96
Na K	2.68	2.4
Al K	6.03	4.6
Si K	32.61	23.94
K K	2.21	1.16
Ca K	0.7	0.36
Fe K	1.62	0.6
Cu L	2.97	0.96

e

Element	Weight, %	Atomic, %
O K	55.29	69.75
Na K	2.1	1.84
Mg K	2.32	1.93
Al K	7.53	5.64
Si K	23.8	17.1
K K	1.28	0.66
Ca K	2.12	1.07
Fe K	5.55	2.01

Research Results

Volumetric properties

Optimal asphalt content was calculated by using gyratory compactor at 100 gyres, and an internal angle of 1.16° and pressure of 600 KPa.

ID	AC (%)	Gmm (Kg/m³)	Gmb (Kg/m³)	Air voids (%)	VMA (%)	VFA (%)
Lime	6.5	2,394	2,298	4.0	18.2	78.0
$Ca(OH)_3$	6.5	2.394	2,298	4.0	18.2	78.0
Filler #1	6.5	2,393	2,299	3.9	18.3	78.6
Filler #2	6.5	2,394	2,300	3.9	18.3	78.6
Filler #3	6.5	2,393	2,299	3.9	18.3	78.6

Research Results

SCB TEST

The specimens were made with the same proportions of asphalt content, gradation, and type of stone aggregate and have different types of filler. The SCB tests were performed in specimens of 4’’ diameter at 1 cm notch depth (CMOD), a loading speed of 1 mm/min and at four different temperatures (-10, 5, 15 and 25°C). The SCB tests taken in the present study correspond to the average of four specimens.

Research Results

SCB TEST

Tensile strength (R_T) calculation:

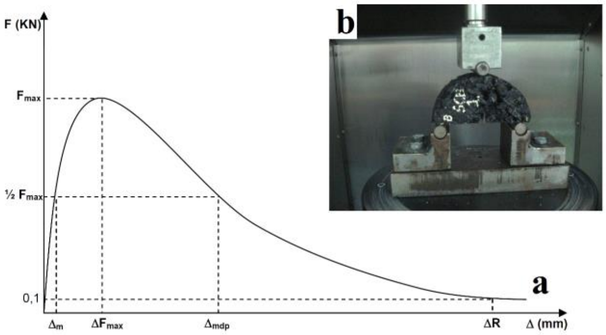
$$R_T = \frac{1000 \cdot F_{max}}{h \cdot l}$$

Tensile stiffness index I_{RT} calculation:

$$I_{RT} = \frac{\frac{1}{2} \cdot F_{max}}{\Delta_m}$$

Dissipated energy during cracking (G_D) calculation:

$$G_D = \frac{W_D}{h \cdot l}$$



Research Results

SCB TEST

Calculation cracking process (W_D) :

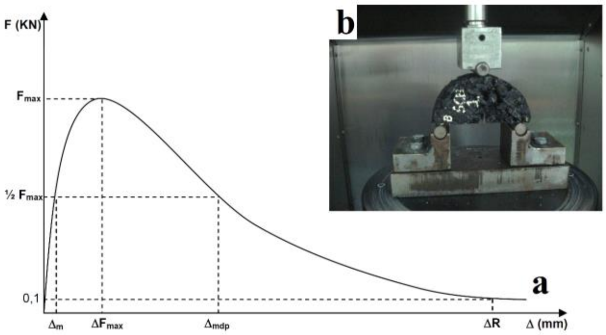
$$W_D = \sum_{i=1}^{n} (x_{i+1} - x_i) y_i + 0.5(x_{i+1} - x_i)(y_{i+1} - y_i)$$

Tenacity index (I_T) calculation:

$$I_T = \frac{W_D - W_{Fmax}}{h \cdot l} \left(\Delta_{mdp} - \Delta_{Fmax}\right)$$

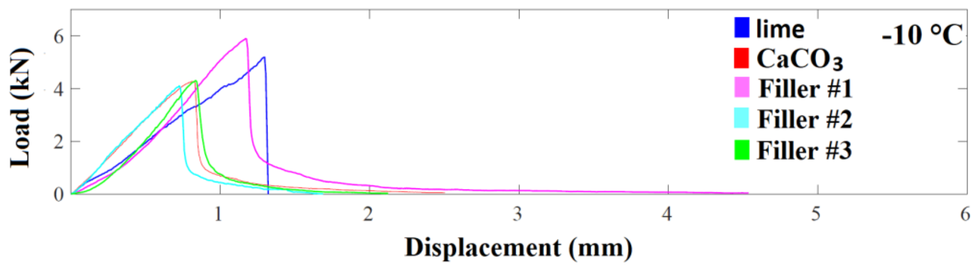
Energy index (U) calculation:

$$U = \frac{W_S}{h \cdot l} \left(\frac{W_S}{W_D}\right)$$



Research Results

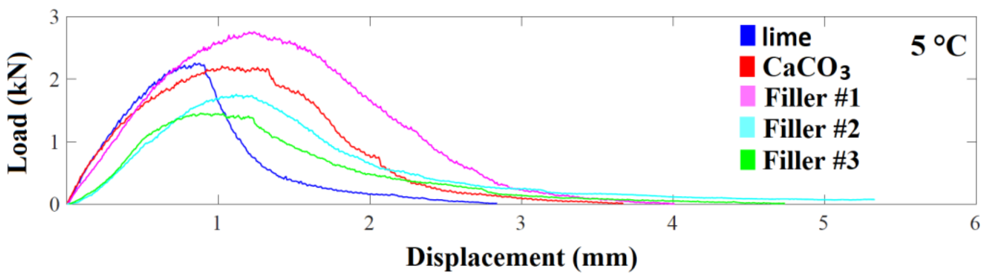
SCB TEST



FILLER ID	Fmax	ΔFmax	R	IRT	U	GD	IT
Lime	4,72	0,95	0,95	5,59	1146	1176	n.a.
$Ca(CO)_3$	4,27	0,69	1,35	7,13	753	914	n.a.
Filler #1	4,91	0,99	2,46	5,70	1215	1540	n.a.
Filler #2	4,44	0,74	0,94	6,13	738	855	n.a.
Filler #3	4,63	0,85	0,78	5,97	847	949	n.a.

Research Results

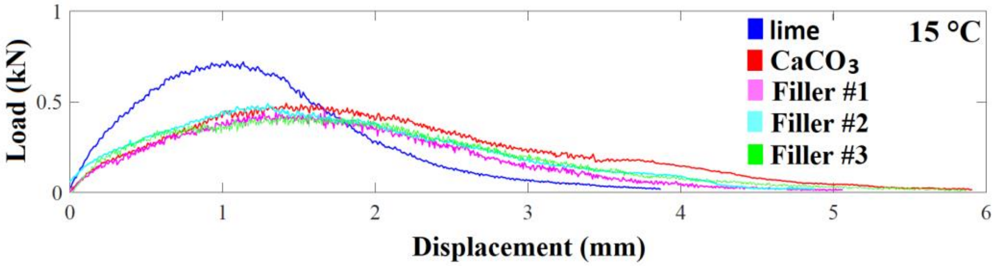
SCB TEST



FILLER ID	Fmax	ΔFmax	ΔR	IRT	U	GD	IT
Lime	2,30	0,83	2,17	3,93	588	1109	190
$Ca(CO)_3$	2,28	1,14	2,89	3,11	860	1699	487
Filler #1	2,85	1,28	3,46	2,95	1099	2379	979
Filler #2	2,39	1,06	2,66	3,20	782	1559	344
Filler #3	1,83	1,04	2,61	3,06	605	1249	403

Results

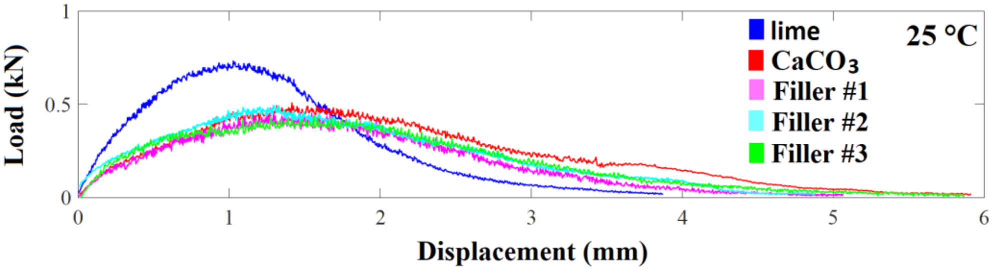
SCB TEST



FILLER ID	Fmax	ΔFmax	ΔR	IRT	U	GD	IT
Lime	0,74	0,58	1,18	2,33	146	286	56
Ca(CO)$_3$	0,31	0,78	1,49	1,55	81	170	58
Filler #1	0,66	1,05	2,37	1,65	241	494	182
Filler #2	0,62	0,71	1,76	2,16	153	363	130
Filler #3	0,58	0,85	1,69	1,63	170	328	87

Results

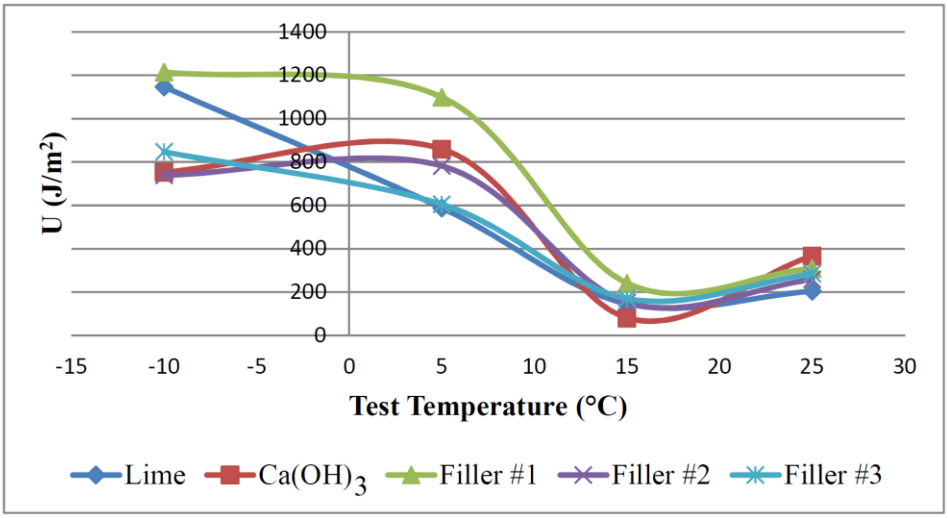
SCB TEST



FILLER ID	Fmax	ΔFmax	ΔR	IRT	U	GD	IT
Lime	0,76	0,87	2,40	1,43	204	526	159
Ca(CO)$_3$	0,62	1,80	4,37	0,48	367	832	305
Filler #1	0,60	1,63	3,91	0,64	309	762	484
Filler #2	0,60	1,25	3,17	0,74	258	650	287
Filler #3	0,60	1,67	3,81	0,60	285	668	323

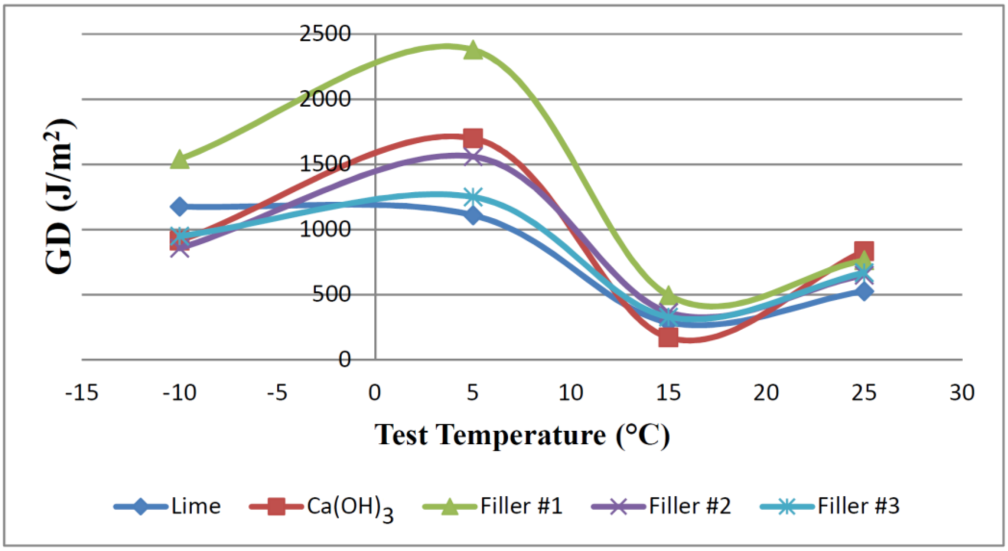
Results

SCB TEST



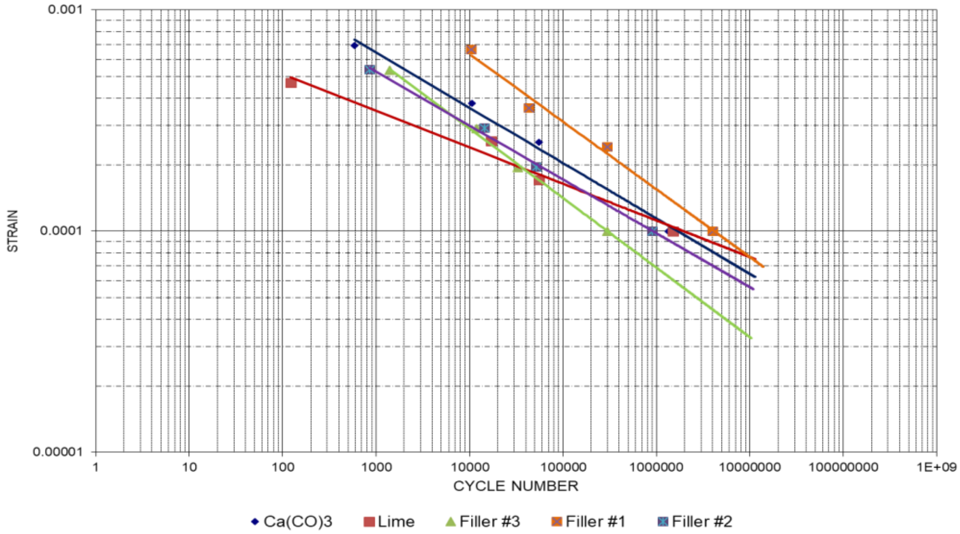
Results

SCB TEST



Results

FATIGUE TEST (INDIRECT TENSILE, UNE-EN 12697-24 ANEX E)



Conclusions

a) Filler quality is essential for SMA mixture performance.

b) It is important to note that the use of industrial materials such as $Ca(CO)_3$ and lime do not guarantee the best performance of the SMA mixtures in cracking processes, as it has been shown in the case of the fillers evaluated in this study through the SCB test.

Conclusions

c) The MF (Mineral Filler) results tested by SCB that show best performance are those with lower proportion of aluminum and silicon, therefore that require more facture energy.

d) Test Fatigue results have a similar tendency compare to SCB test results. Therefore SMA mix with filler # 1 (lower aluminum and silicon) has the best behavior.

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THANK YOU!!!!

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