CONFERENCE OMAINTEC 2023 EXHIBITION

THE 20TH INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE IN THE ARAB COUNTRIES

The Role of Nano Size Additives in Enhancing the Sustainability of Asphalt Concrete

Prof. Saad Issa Sarsam
Sarsam and Associates Consult Bureau (SACB), Baghdad, Iraq.

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Problem statement

- Asphalt concrete pavement practices repeated flexural stresses caused by vehicular traffic throughout its service life.
- The resistance to such stresses could be enhanced by incorporation of Nano size additives for partial replacement of mineral filler.

Methodology

An attempt has been made to introduce fly ash and Silica fumes into asphalt concrete mixture as partial substitute of mineral filler.

Asphalt concrete slab samples were compacted in the laboratory at optimum binder content of 4.5 % using roller compaction.

The optimum percentages of fly ash and Silica fumes are (4 and 2) % by weight of binder respectively.

Beam specimens were extracted from the slab samples and subjected to dynamic flexural stresses with the aid of four points bending beam test under three constant microstrain levels of (250, 400, and 750).

The change in the resistance of the mixtures to repeated flexural stresses was monitored through the elapsed time required for initiation of micro cracks.

Materials and Methods

Physical properties of asphalt cement, AL-Nasiriya oil Refinery

Property	Testing condition	ASTM, 2016 Designation	Test result
Penetration (0.1 mm)	25 °C, 100 gm, 5 seconds	D-5	42
Softening point (°C)	Ring and ball	D-36	49
Specific gravity	25 °C	D-70	1.04
Ductility (Cm)	25 °C, 5 Cm/Minute	D-113	100+
Flash point (°C)	Cleveland open cup	D-92	275
After thin film oven test			
Penetration (0.1 mm)	25 °C, 100 gm, 5 seconds	D-5	33
Ductility (Cm)	25 °C, 5 Cm/Minute	D-113	83
Mass loss (%)	163°C, 50 gm, 5 Hours	D-1754	0.3

Physical properties of coarse aggregates, AL-Ukhaider quarry

Property	ASTM, (2016) Designation	Test value
Bulk specific gravity	C-127	2.542
Water absorption (%)	C-127	1.076
Los Angeles abrasion (%)	C-131	18
Soundness in sodium sulfate solution (%)	C-88	2.67
Flat and elongated particles (%)	D-4791	1.6

Physical properties of Fine aggregates

Property	ASTM, (2016) Designation	Test value
Bulk specific gravity	C-128	2.558
Water absorption (%)	C-128	1.83
Sand equivalent (%)	D-2419	51

Physical properties of mineral filler, Limestone dust, Karbala

Property	Test value
Passing sieve No. 200 (%)	94
Bulk specific gravity	2.150
Specific surface area (m^2/Kg)	412

Chemical composition of Fly Ash

Oxide	Percent	ASTM, 2016 requirement C618 %
SiO_2	61.95	---------
Fe_2O_3	2.67	---------
Al_2O_3	28.82	---------
SiO_2+ Fe_2O_3+ Al_2O_3	93.44	70.0 min.
Na_2O	0.26	1.5 max.
CaO	0.88	----------
MgO	0.34	5.0 max
SO_3	< 0.07	5.0 max
L.O.I	0.86	6.0 max

Physical properties of Fly Ash

Maximum Sieve size (mm)	% Passing	Specific gravity	Specific surface area (m^2/ kg)
0.075	98	2.016	600

Chemical composition of Silica Fumes

Chemicals	Percent
SiO_2	90%
Al_2O_3	3 %
CaO	1.2 %
Fe_2O_3	1.0 %
MgO	< 6%
Loss on Ignition	1%

Physical properties of Silica Fumes

Property	Test value
Bulk specific gravity	2.134
Specific surface area (m^2/ Kg)	200000

Selected Combined Gradation of Aggregates

Sieve size (mm)	19	12.5	9.5	4.75	2.36	0.3	0.075
Selected limit	100	95	83	59	43	13	7
SCRB, 2003 Specification	100	90-100	76-90	44-74	25-58	5-21	4-10


Fly Ash
Silica Fumes

Preparation of Modified Asphalt Cement

- Modified asphalt cement binder is prepared by using the wet process.
- Asphalt cement was heated to 150°C and then the fly ash or silica fumes were added in powder form using various percentages of each additive.
- The mixture was blended in a mixer at a blending speed of about 1300 rpm and the mixing temperatures of 160°C was maintained for 20 minutes to promote the chemical and physical bonding of the components.
- The optimum percentages of fly ash and Silica fumes are (4 and 2) % by weight of binder respectively.

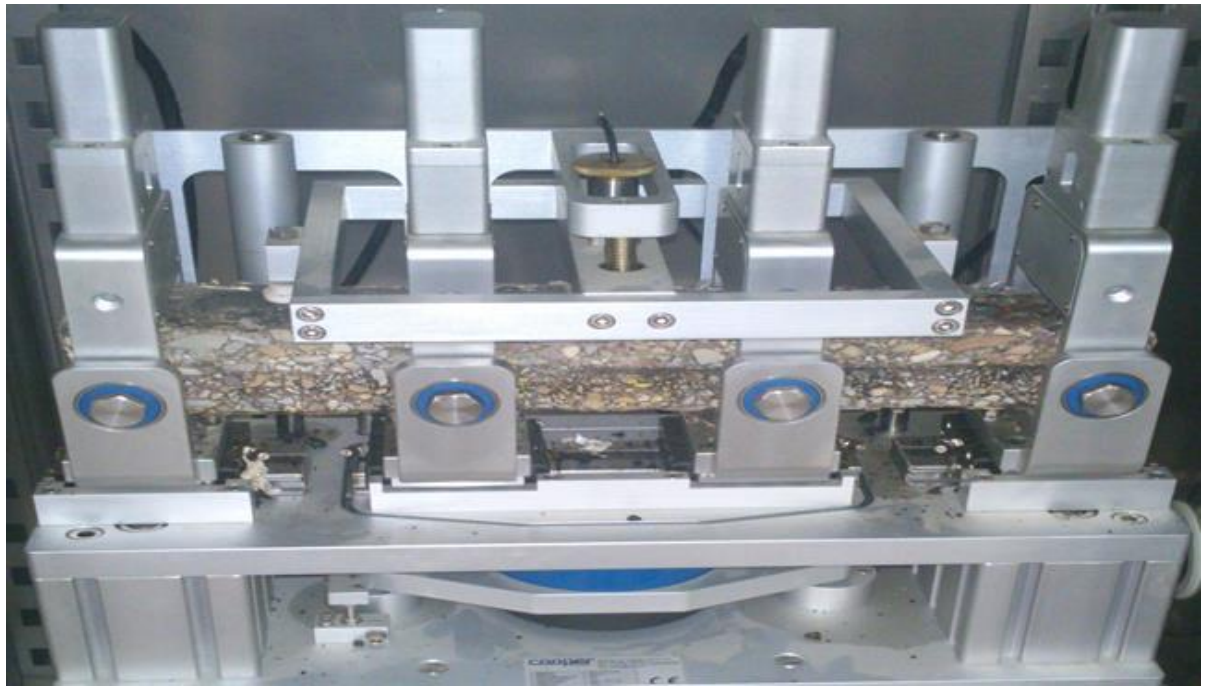
Preparation of Asphalt Concrete Mixture and Specimens

- The asphalt concrete mixtures were casted in a slab mold of (40 x 30 x 6) Cm and subjected to roller compaction to the target bulk density according to EN12697-33, (2007).
- The optimum asphalt content of 4.5% was implemented.
- Beam specimens of 50±2 mm high, 63±2 mm wide and 400 mm length were obtained from the compacted slab sample using the Diamond-saw.

Repeated Flexural Bending Beam Test

- The four-point repeated flexural bending beam test according to AASHTO T321, 2010 was implemented to identify the influence of additives on the fatigue life of asphalt concrete beam specimens at intermediate pavement operating temperature of 20°C and under three types of constant strain level, (250, 400, and 750) microstrain.

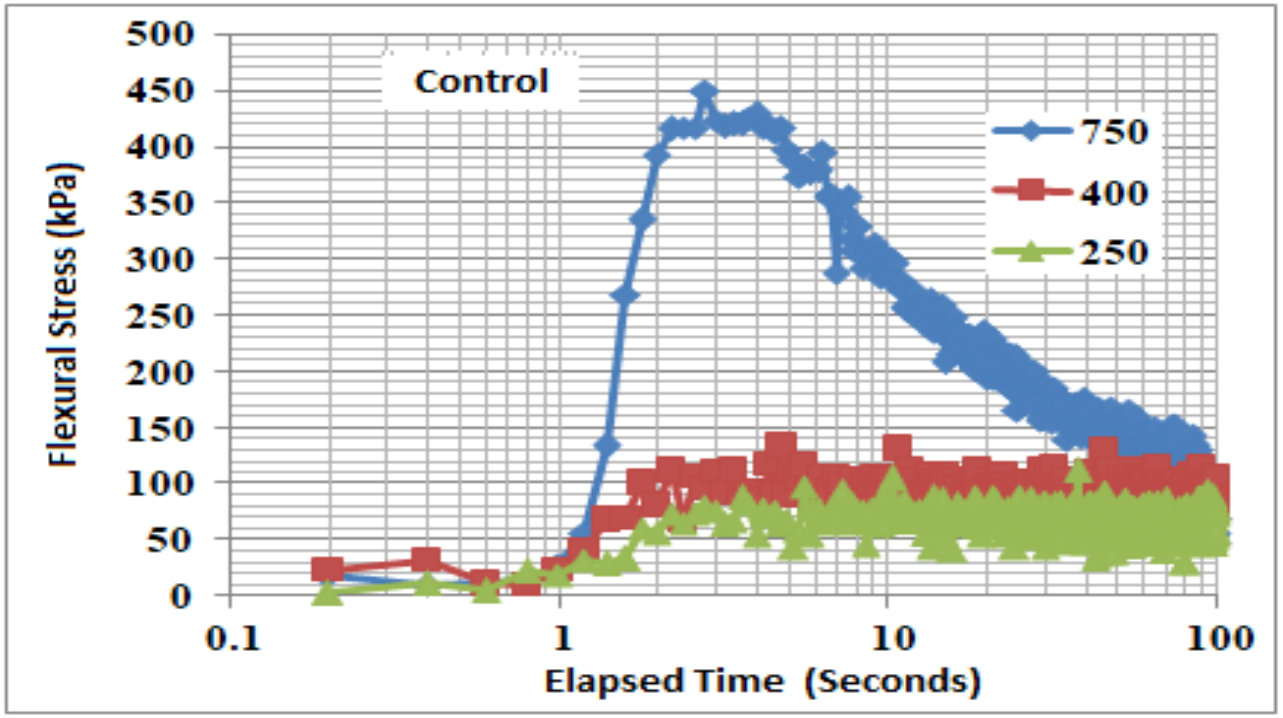
Four points flexural bending test



Influence of Microstrain Level on the Flexural Strength:

The resistance of the mixture to the applied stresses increases sharply after one second and reaches its peak values, then decline as the loading proceeds.

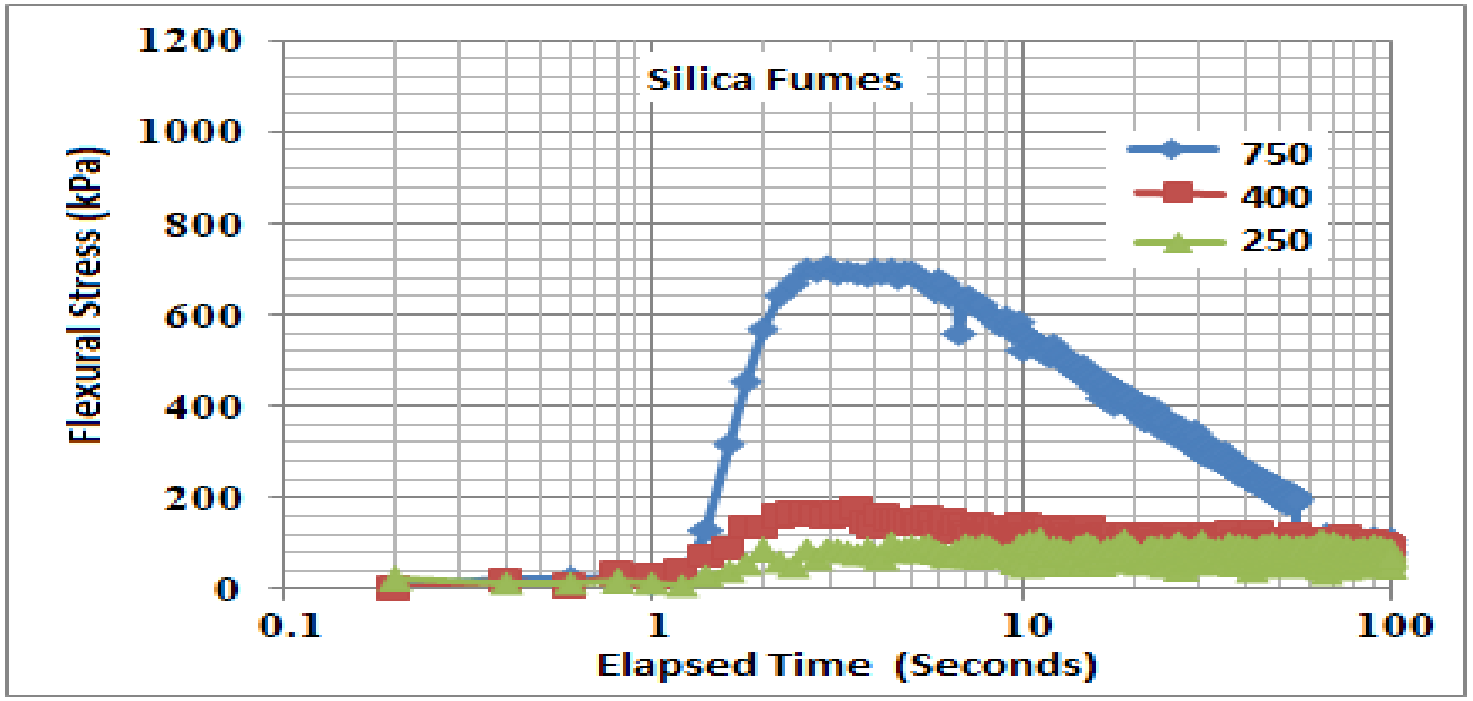
Variation of flexural strength under various microstrain levels of control mixture



Influence of Silica Fumes on Flexural Strength

The implication of silica fumes additive exhibit higher flexural strength of asphalt concrete as compared with the control mixture.

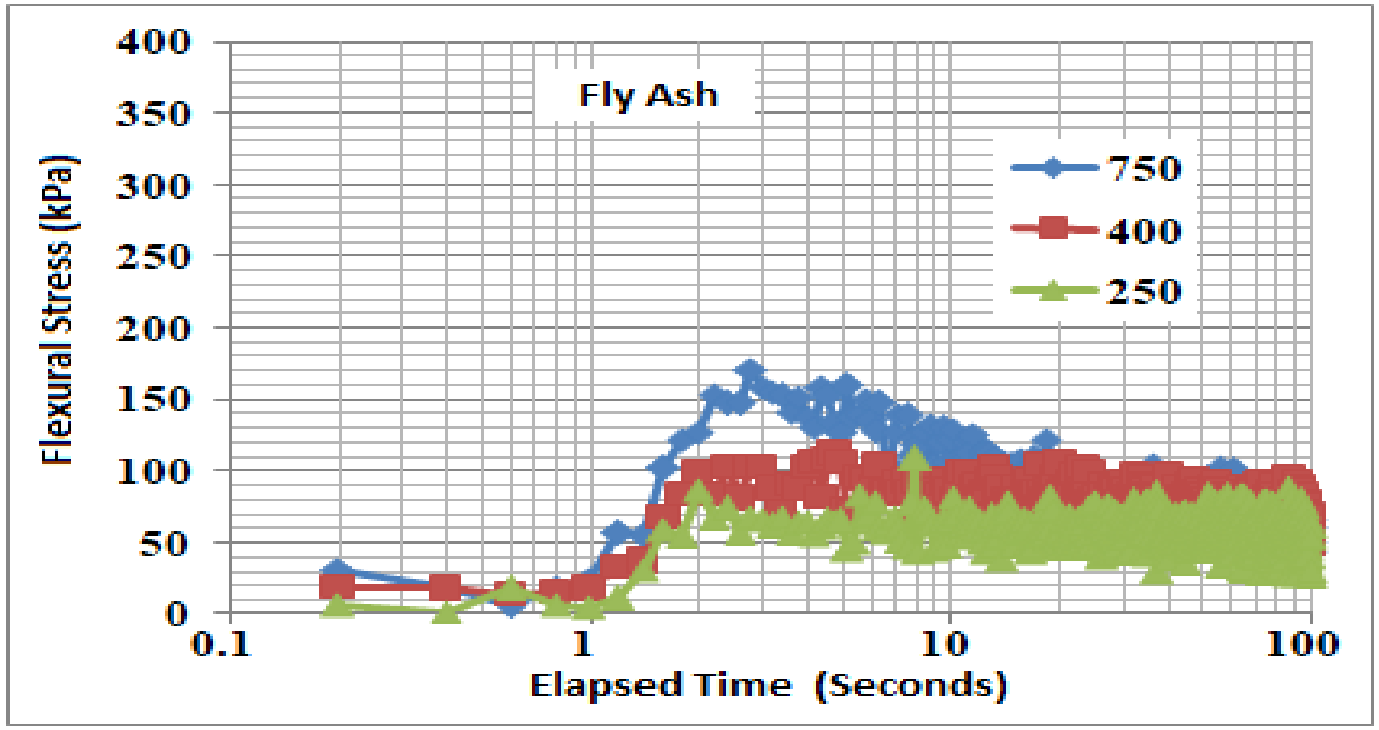
Influence of Silica Fumes on Flexural Strength



Influence of Fly Ash on Flexural Strength

After 3 seconds of repeated loading, the flexural strength of asphalt concrete mixture was (180, 110, and 75) kPa under (750, 400, and 250) microstrain levels respectively.

Influence of Fly Ash on Flexural Strength



Conclusions

1- For control mixture, the flexural strength of asphalt concrete mixture was (450, 150, and 80) kPa under (750, 400, and 250) microstrain levels respectively after 3 seconds of repeated loading. On the other hand, after 100 seconds of load repetitions, the flexural strength declines to (140, 100, and 70) kPa under (750, 400, and 250) microstrain levels respectively.

2- Implication of silica fumes into the asphalt concrete mixture as partial substitute of the filler had improved the flexural strength by (60, 33.3, and 12.5) % under (750, 400, and 250) microstrain levels respectively.

3- Implication of Fly Ash into the asphalt concrete mixture as partial substitute of the filler causes decline of the flexural strength by (60, 26.6, and 6.2) % under (750, 400, and 250) microstrain levels respectively.

Recommendations

Implication of Nano size additive as partial substitute of mineral filler is recommended to enhance the sustainability of asphalt concrete.

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