Performance Testing --- Update

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Regional Effort

- Look at lab performance of typical mixes from the region (|E*| and flow number)
- Compare with SST results (FS and RS)
  - Seven conventional Superpave mixes (one with 15% RAP)
  - One Marshall mix
  - Three SMA mixes

Mixes Tested

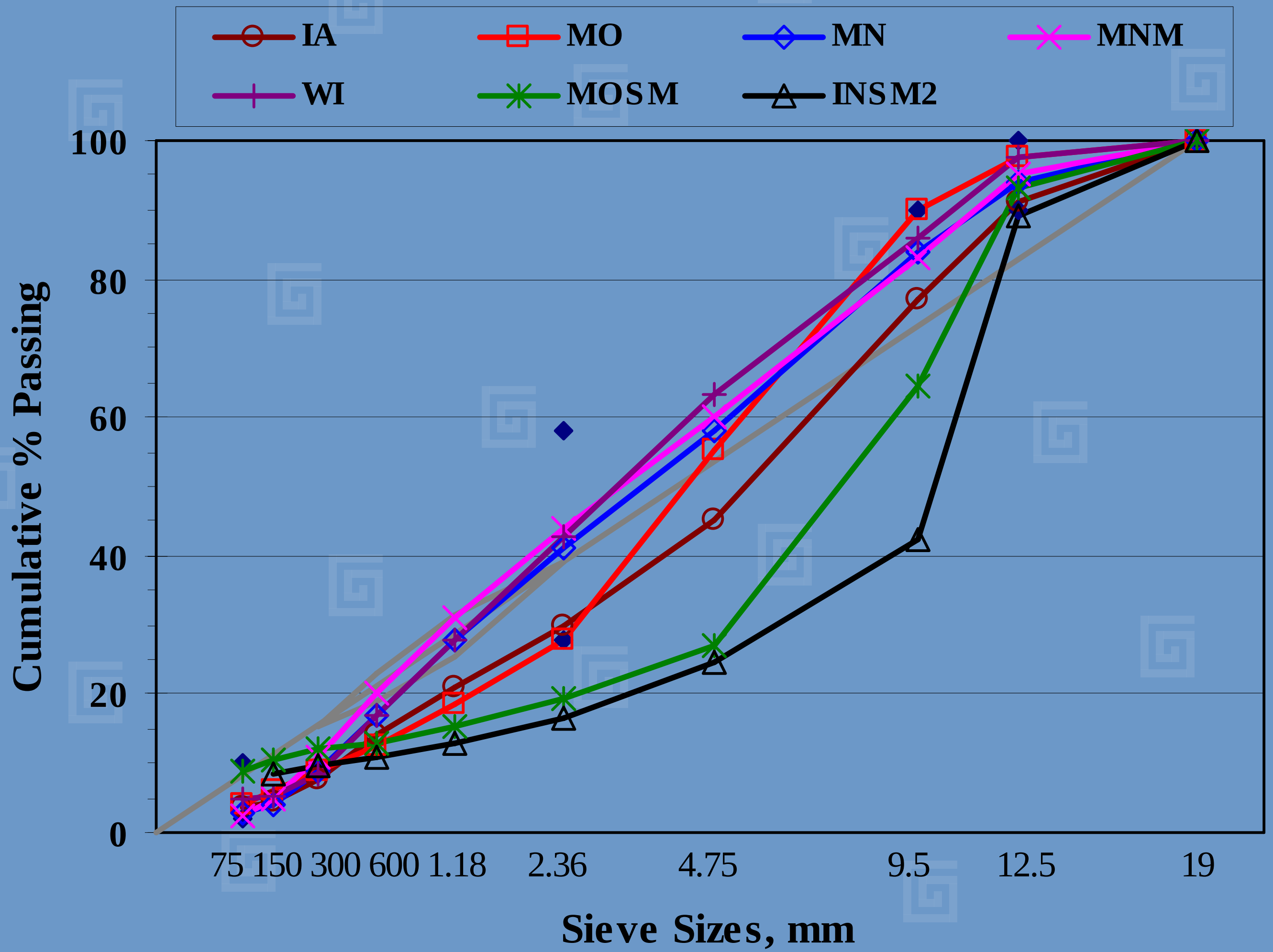
Mix ID	Binder	N_{des}	NMAS	T_{eff} °C
IA	PG64-22	109	12.5 mm	39.1
KS	PG64-22	75	9.5 mm	40.4
MO	PG70-22	125	12.5 mm (c)	41.8
MI	PG58-28	76	9.5 mm (f)	34.2
MN	PG64-22	100	12.5 mm (f)	36.9
MN-M	PG64-28	75 blows	Minus 3/4"	36.9
WI1	PG70-28	100	12.5 mm	34.0
WI2	PG58-28	100	12.5 mm	34.0

Mixes Tested -- SMA

Mix ID	Binder	N_{des}	NMAS	T_{eff} °C
IN1	PG76-22	100	9.5 mm	38.4
IN2	PG70-28	100	12.5 mm	39.6
MOSM	PG70-22	100	12.5 mm	41.1

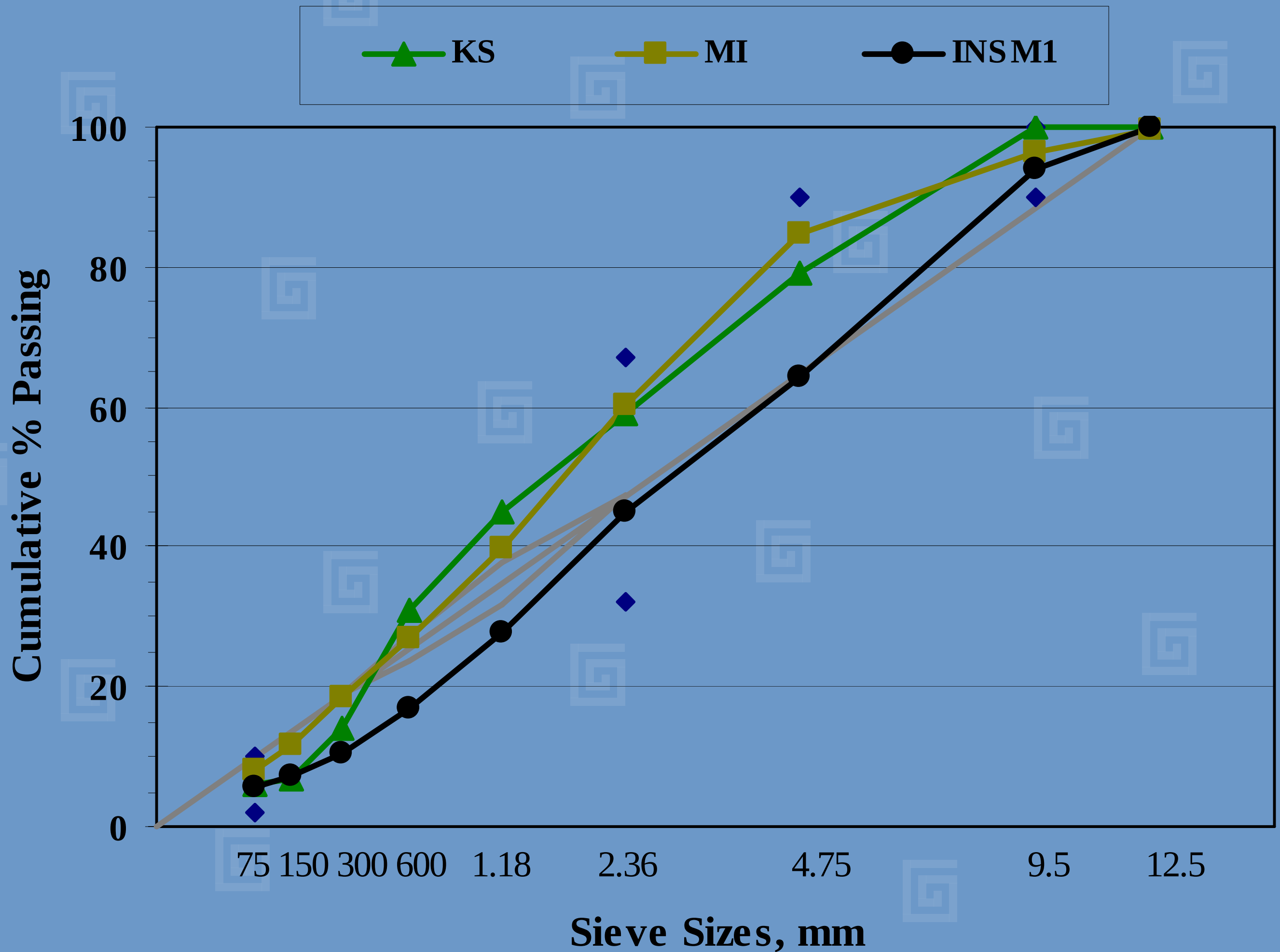
- WI1 and WI2 also tested in confined mode

12.5 mm NMAS



IA
MO
MN
MNM
WI
MOSM
INSM2
Cumulative % Passing
100
80
60
40
20
0
75 150 300 600 1.18 2.36 4.75 9.5 12.5 19
Sieve Sizes, mm

9.5 mm NMAS



KS
MI
INSM1
100
80
60
40
20
0
Cumulative % Passing
75 150 300 600 1.18 2.36 4.75 9.5 12.5
Sieve Sizes, mm

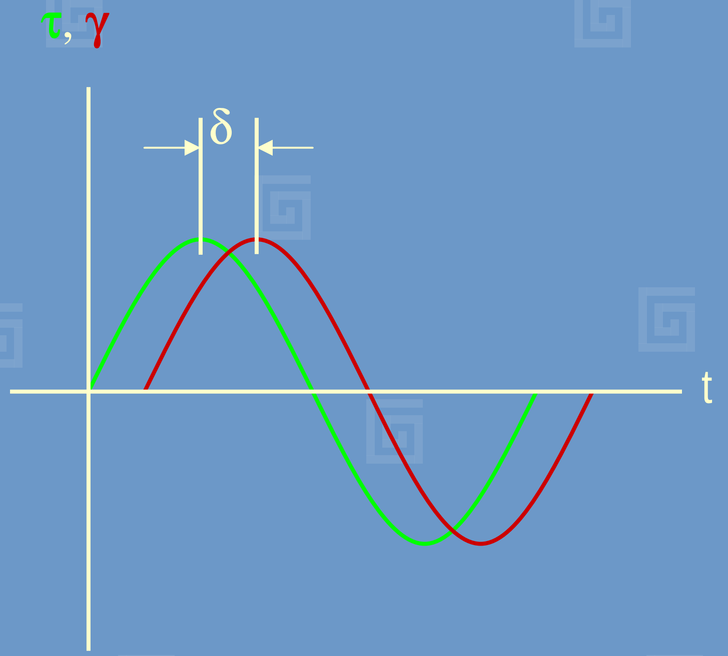
Tests Conducted

Test Method	T °C	
Frequency Sweep	T_{eff}	54.4
Repeated Shear	---	58.0
Dynamic Modulus	T_{eff}	54.4
Dynamic Creep	T_{eff}	---

Superpave Shear Tests

Frequency sweep (10 Hz - 0.01 Hz)

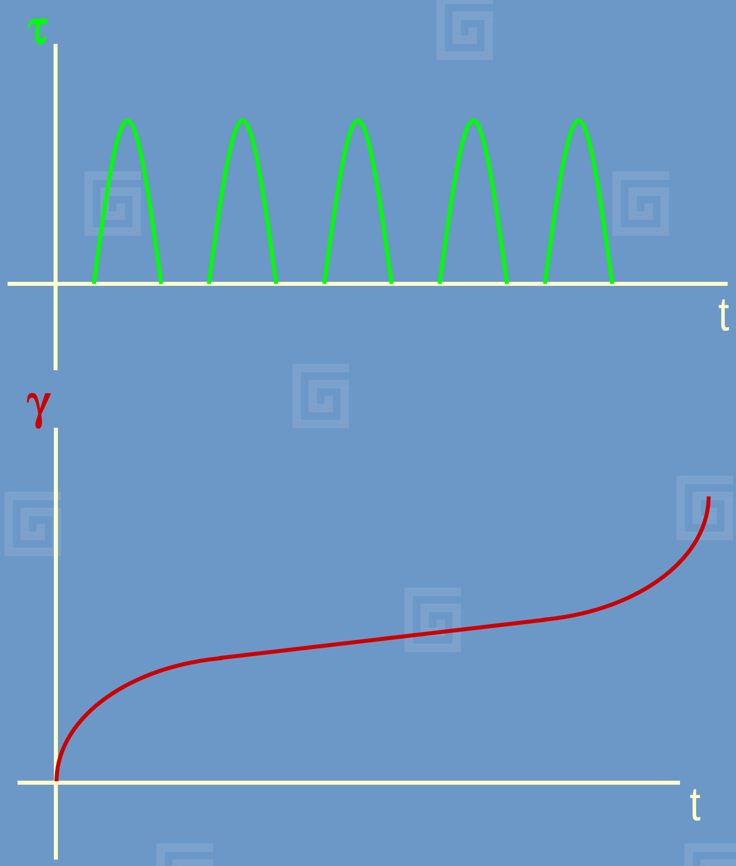
- Apply sinusoidal shear strain (0.01%)
- Measure axial and shear load and deformations
- Determine |G*| and δ



Superpave Shear Tests

Repeated shear

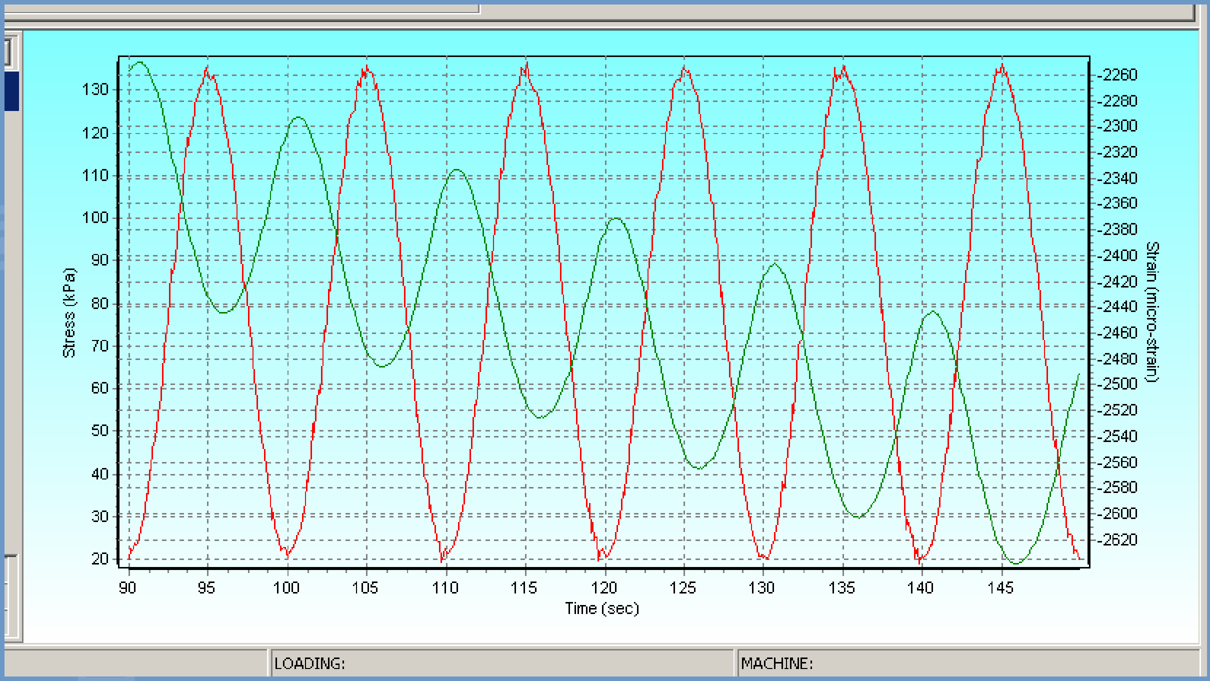
- Apply shear stress (69 kPa for 0.1 s with 0.6 s rest period)
- Measure cumulative shear deformation
- 5000 cycles or 5% strain



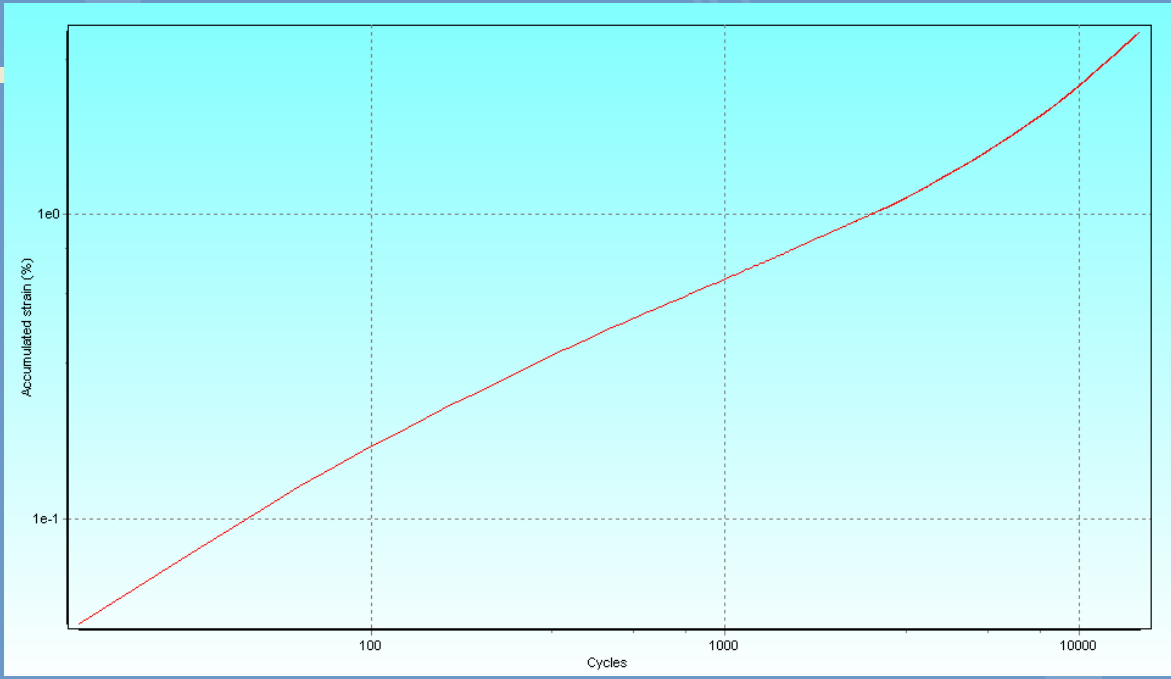
Superpave Performance Tests

Dynamic modulus (25 Hz to 0.1 Hz)

- Apply cyclic haversine loading
- Axial strains limited to 50 - 150 με
- Determine |E*| and δ



Superpave Performance Tests



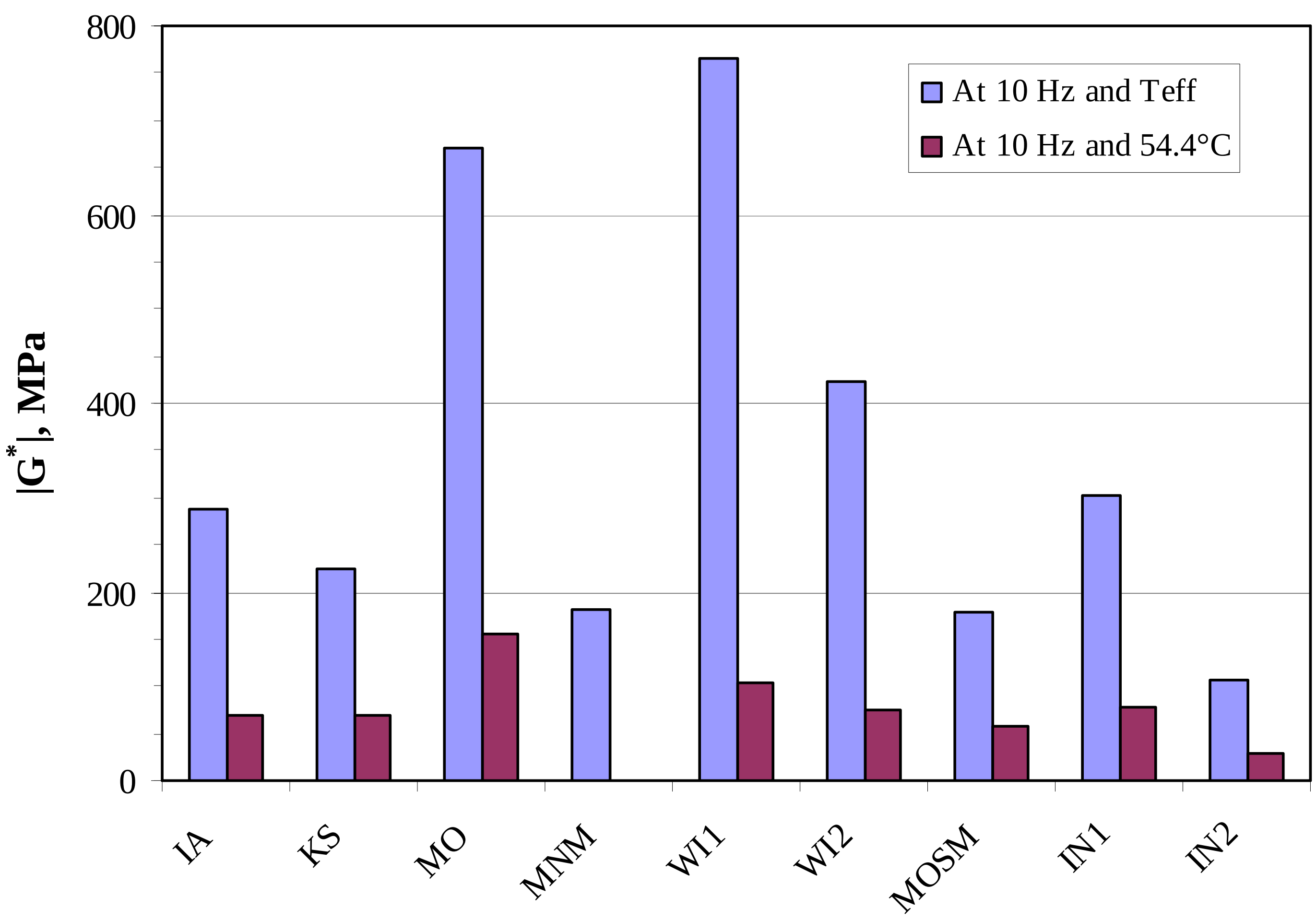
Dynamic creep

- Apply cyclic pulses;100 ms pulse width with 900 ms rest period
- 5% axial strain or 15000 cycles
- Determine flow number

Performance Testing --- Update

RESULTS

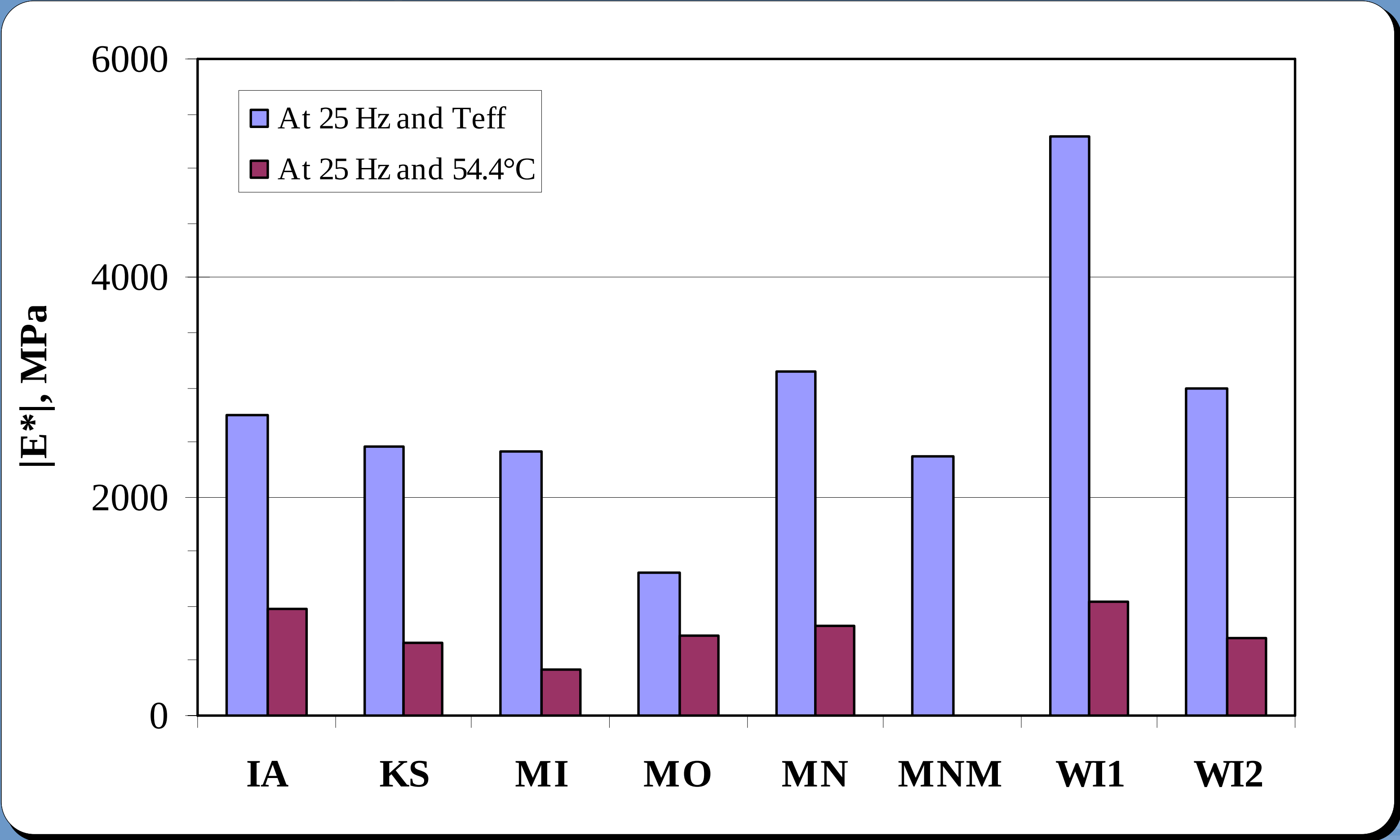
Frequency Sweep Data



Frequency Sweep Data

- Mixes significantly different
- Minnesota Marshall mix was too soft to be tested at 54.4°C
- At T_{eff}, WI1 and MO were statistically similar
- At 54.4°C, mixes showed overlapping groups
- At T_{eff}, all three SMA mixes were statistically different; but not at 54.4°C

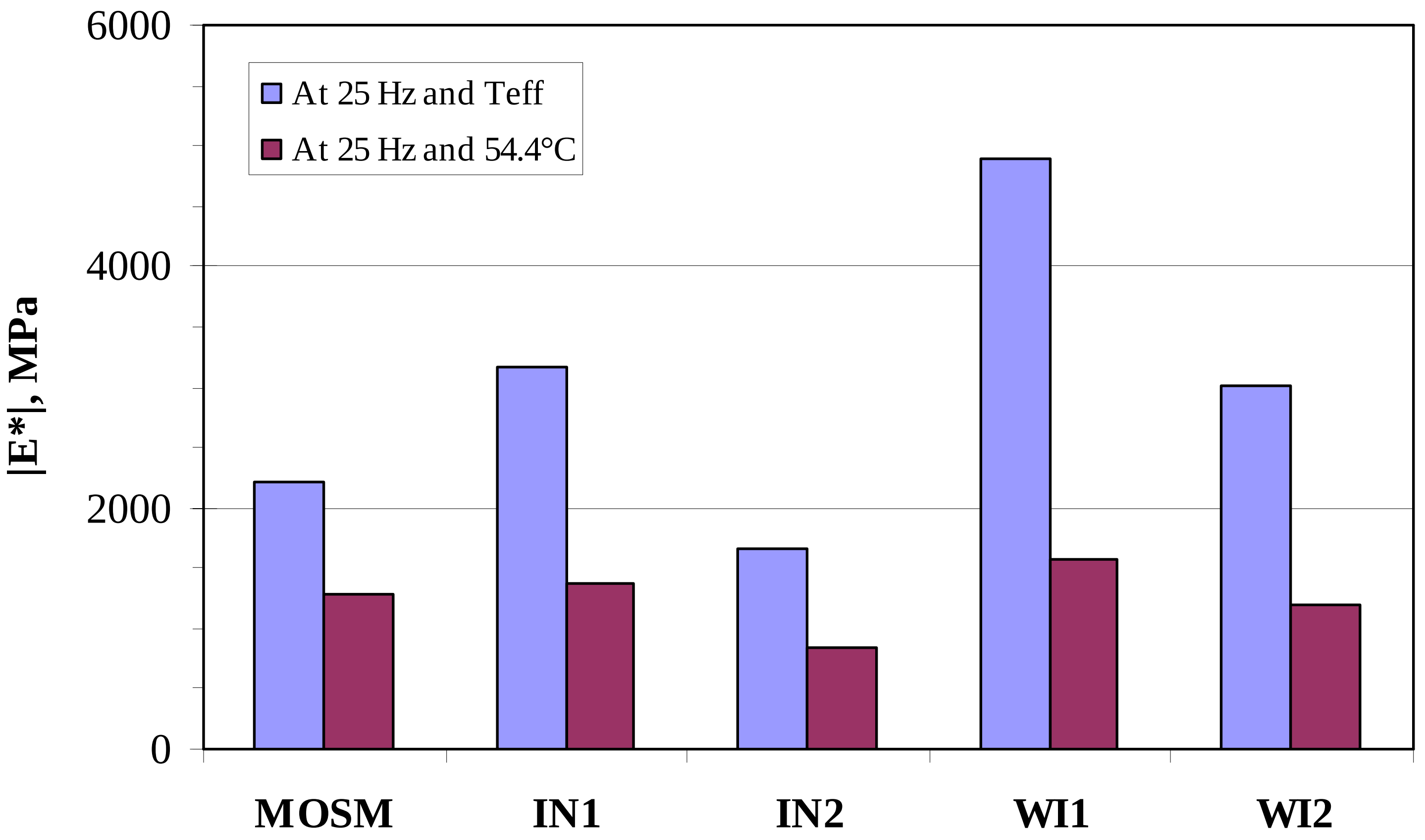
Dynamic Modulus Data



Dynamic Modulus Data

- Mixes significantly different
- Mixes with similar gradation, but different binder grades
  - MI and KS --- mix with softer binder showed lower modulus at higher test temperature
  - WI1, WI2, MN and MNM --- mix with stiffest binder (WI1) had highest modulus
  - WI2 with softest binder (PG58-28) performed better than Marshall mix with PG64-28
  - MO mix ranked low in DM; unlike that observed in FS

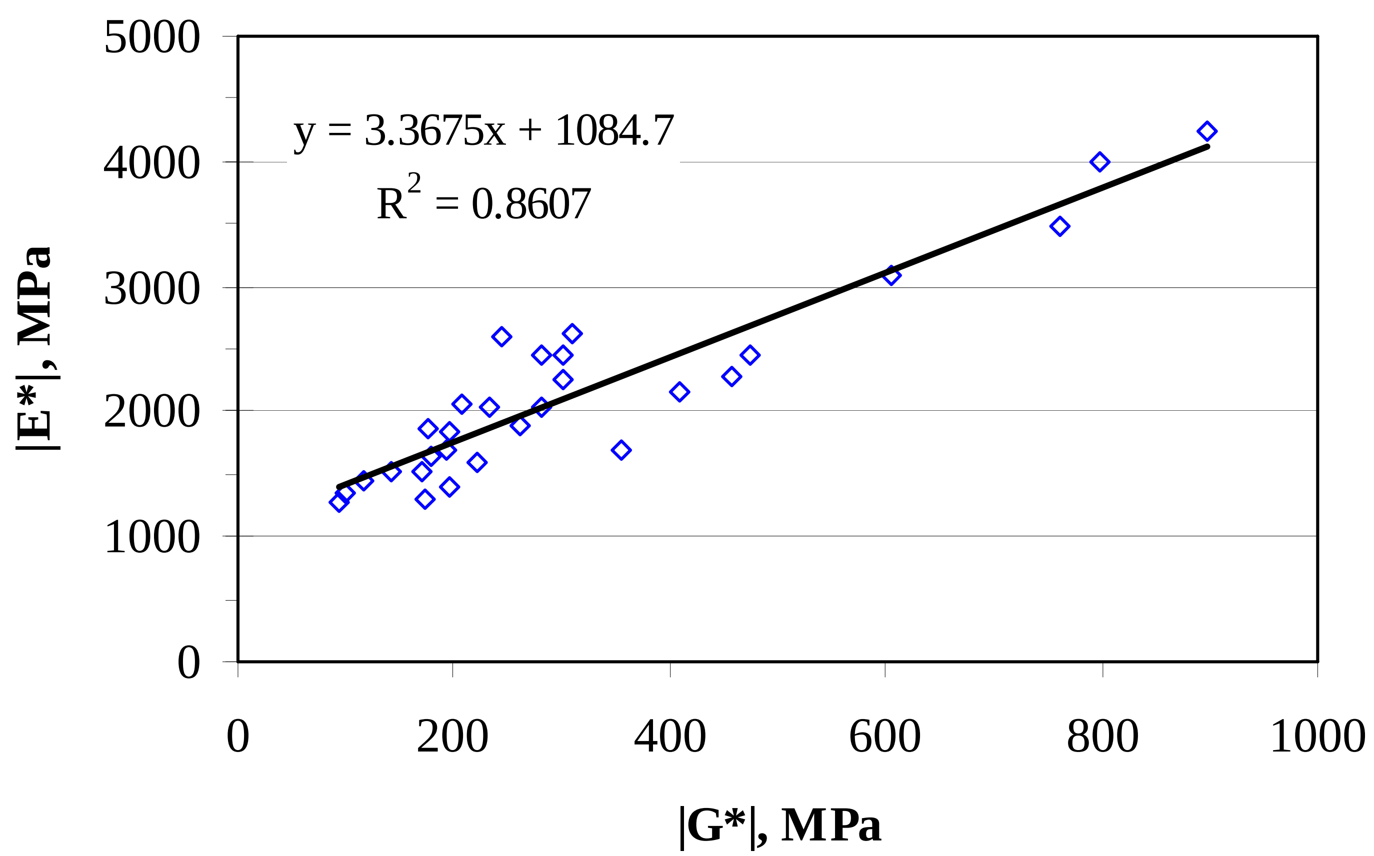
Dynamic Modulus Data



Dynamic Modulus Data

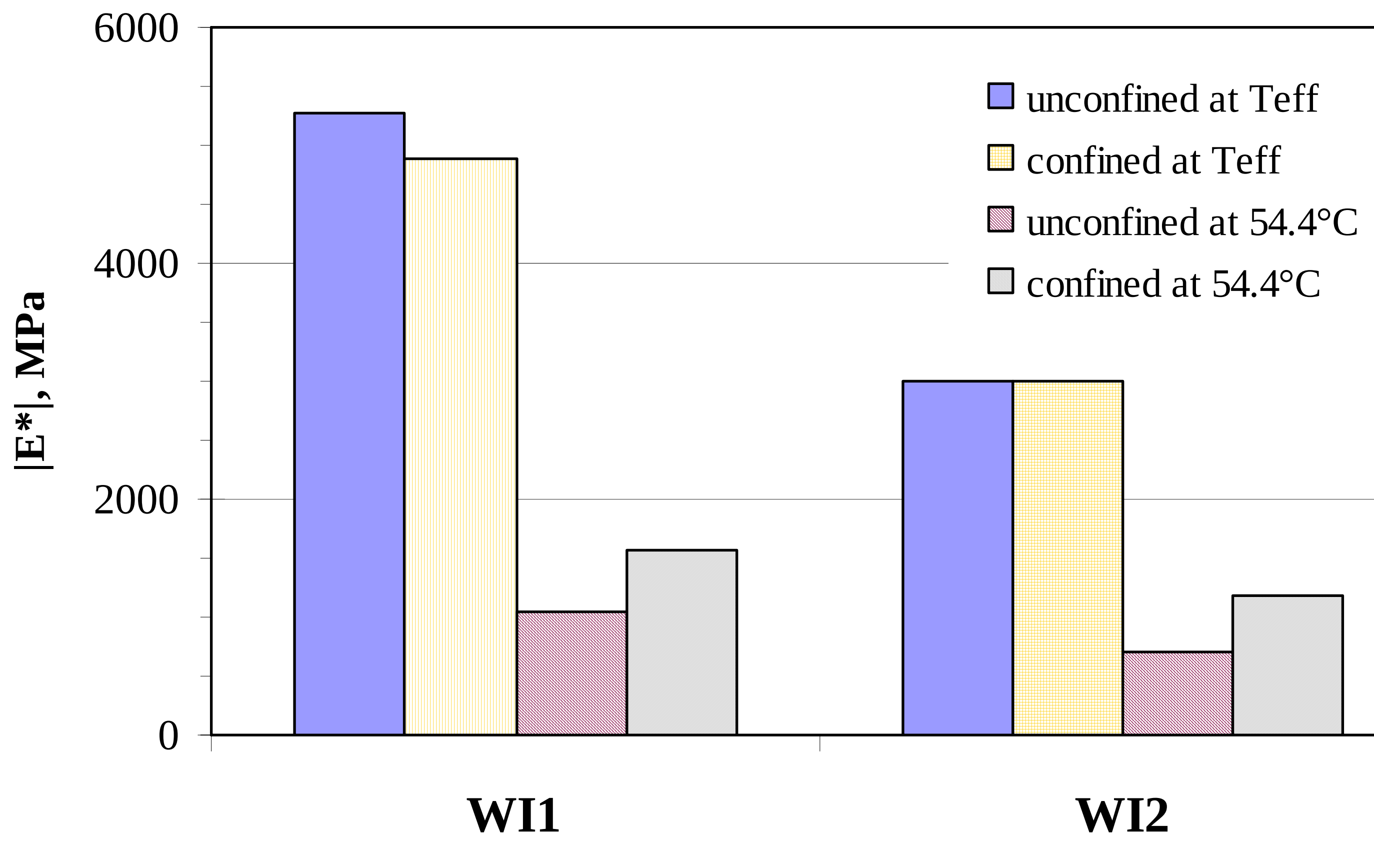
- Mixes significantly different
- IN2 with PG76-22 has the lowest stiffness under confined test conditions at both temperatures
- Modulus of conventional mixes was higher than (or was comparable to) that of SMA mixes
- Modulus of WI2 with PG58-28 binder was comparable to SMA mixes (MOSM, IN1) with stiffer binder grades (PG70-22 and PG70-28, respectively)

Mix |E*| vs. |G*|



5000
4000
3000
2000
1000
0
y = 3.3675x + 1084.7
R2 = 0.8607
|E*|, MPa
0
200
400
600
800
1000
|G*|, MPa

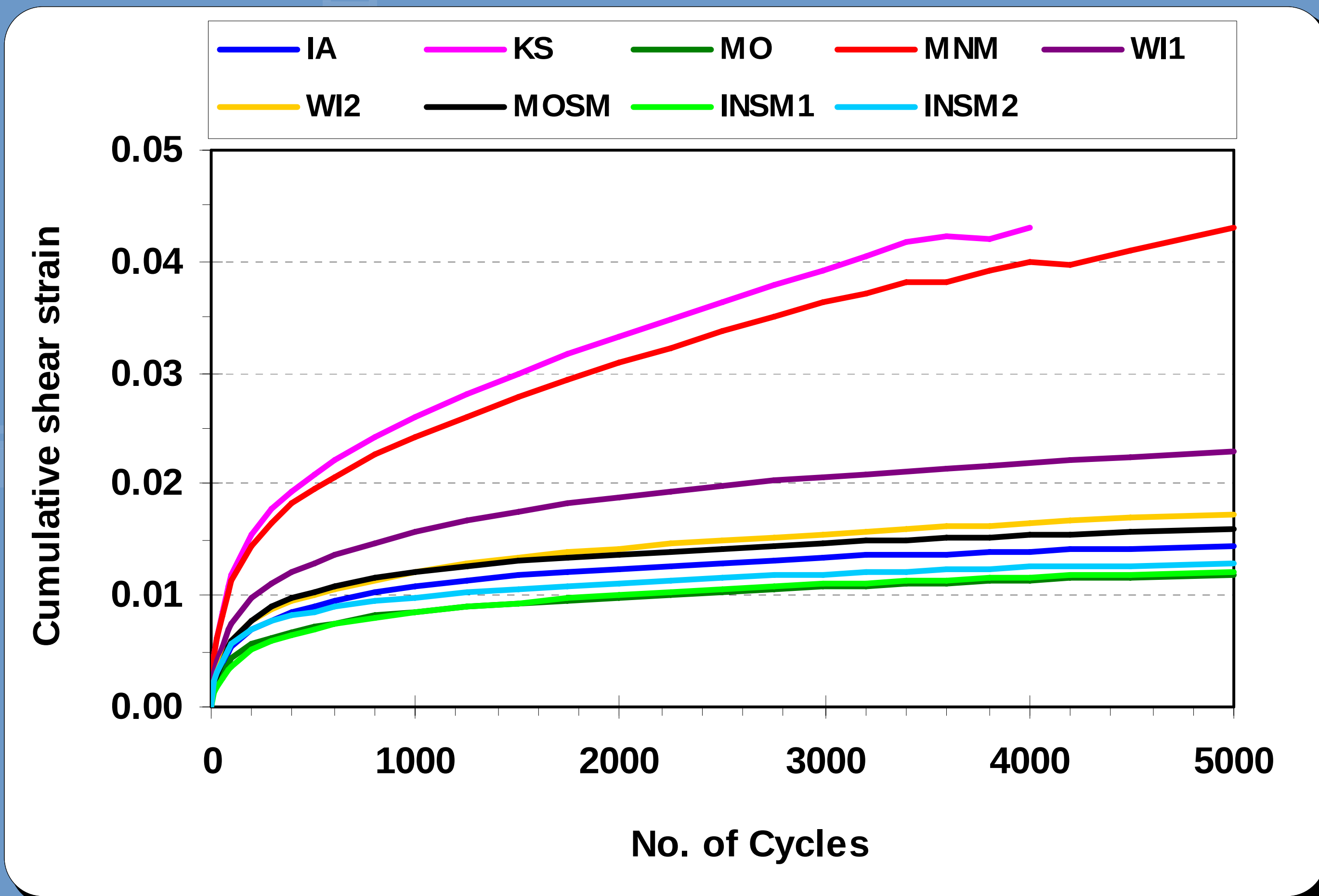
Confined vs. Unconfined



Confined vs. Unconfined

- WI1 and WI2 -- Different binder grades
  - Modulus of WI1 versus WI2 (confined)
    - Significant diff. in mean modulus at both test temperatures
  - Modulus of WI1 versus WI2 (unconfined)
    - Significant diff. in mean modulus at both test temperatures
  - Modulus of confined versus unconfined samples
    - For both WI1 and WI2 mixes
      - No significant differences at T_{eff}
      - Significant differences at 54.4°C

Repeated Shear Data



Repeated Shear Data

- All tested at 54.4°C
- Minnesota Marshall mix and Kansas mix exhibited poor rut resistance (4.3% strain)
- Indiana SMA mixes showed the lowest amount of cumulative strain overall
- Curiously, WI1 (PG70-28) showed higher cumulative strain than WI2 (PG58-28)
- WI2 mix outperformed KS and MNM mixes -- *aggregate structure contribution to rut resistance more dominant*

Dynamic Creep Data

Mix ID	Binder	T_{eff} °C	Flow #
IA	PG64-22	39.1	14767
KS	PG64-22	40.4	13044
MO	PG70-22	41.8	10484
MI	PG58-28	34.2	2183
MN	PG64-22	36.9	9898
MN-M	PG64-28	36.9	9795
WI1	PG70-28	34.0	11423
WI2	PG58-28	34.0	13307
MOSM	PG70-22	38.4	4458
IN1	PG76-22	39.6	14783
IN2	PG70-22	41.1	8381

Dynamic Creep Data

- Flow number -- No. of cycles at start of flow
- As in the case of repeated shear testing, WI2 showed better performance than WI1 under repeated load conditions
- In general, conventional mixes performed better than SMA mixes
- IA and IN1 ranked the highest; followed by KS and WI2 (but at diff. test temperatures)
- IA and IN1 also performed well in RS testing; but KS was ranked lowest in RS testing

Dynamic Creep Data

- Minnesota Marshall and Superpave mixes showed similar flow numbers
- MI and MOSM mixes ranked the lowest
- Overall, no good correlation between repeated shear test results and dynamic creep test results

Conclusions

- Good comparison b/w FS and DM test results.
- Poor correlation b/w RS and DC test results
- In general, conventional mixes had higher modulus than SMA mixes
- WI1 performed well in all four tests.
- MO mix designed for higher traffic volume showed high modulus in shear modulus testing, but not in dynamic modulus testing
- Influence of confinement on dynamic modulus more evident at higher temperatures