Designing at Higher Air Voids

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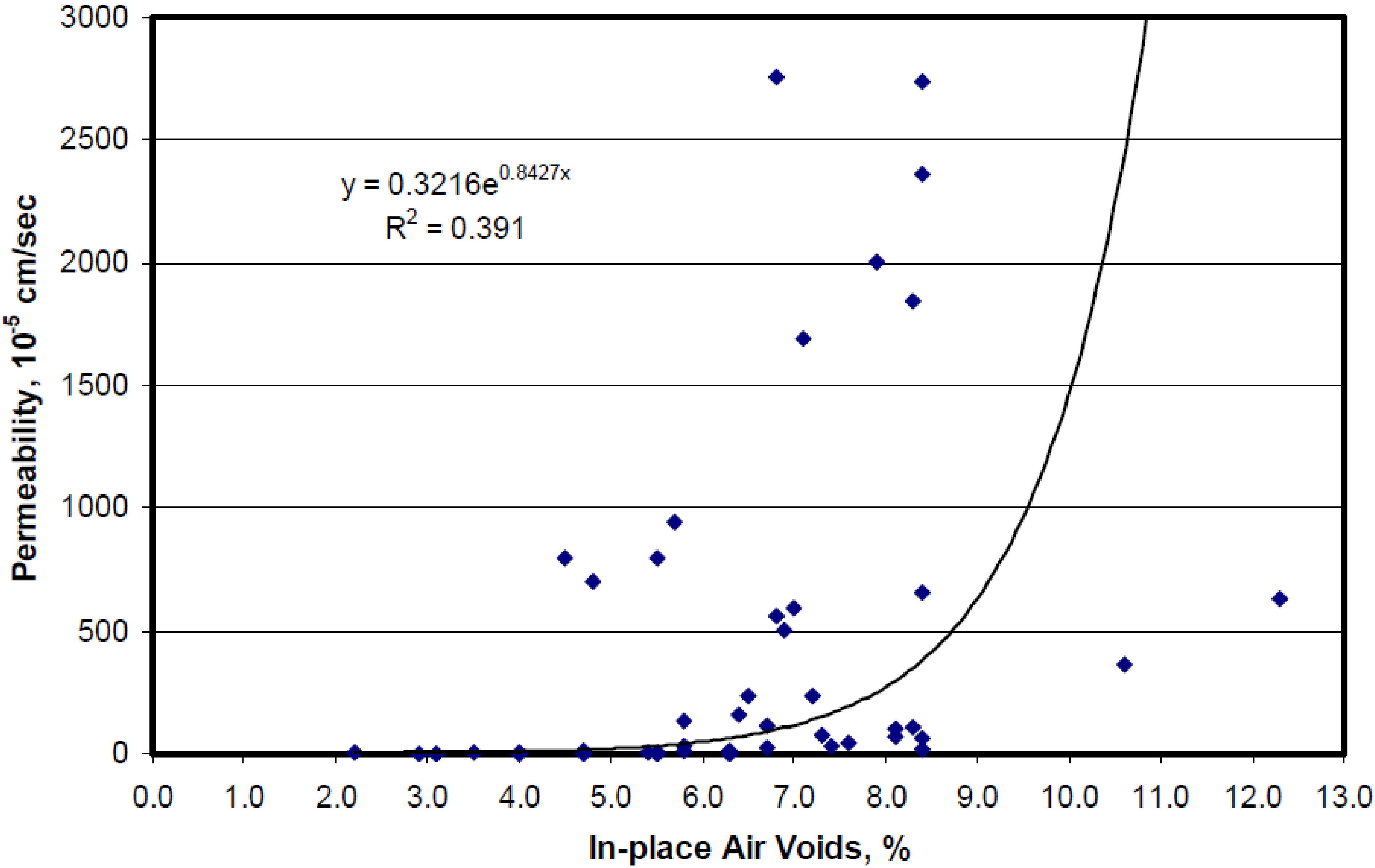
BACKGROUND

- Indiana pavements generally reach end of service because of durability issues after 15-20 years
  - Typically cracking caused in part by oxidized binder
  - Rutting has been significantly reduced
- Reducing permeability (to air) decreases rate of binder aging
- Mixes designed at 4% air voids can be placed in the field at lower densities, in some cases with air voids > 9%
- Above 8% air voids, permeability increases dramatically

NCAT STUDY (Report 03-02, Mallick et al.)



Importance of Compaction

Each 1% increase in air voids (over 7%) reduces pavement life by about 1 year!

CONCEPT

- Lower air voids in the field would improve durability by decreasing binder aging.
- Requires changing the mix design.
- With higher voids in mix design, mix will be somewhat easier to compact in lab and field.
- Important to keep effective binder content (volume) the same for durability.
- Design at 5% and compact to 5% – then keep the voids at that level (reduce traffic densification).

Objective

- Optimize HMA lab mix design compaction as it relates to field compaction in order to increase in-place durability without sacrificing rutting resistance.
  - Design at 5% air voids and compact in field to 5% air voids.

- Additional compaction equipment should not be needed in the field but roller patterns (speed, frequency and number of passes) may vary.

PRECEDENT

- Laboratoire Central des Ponts et Chaussées (LCPC)
  - Developed in 1960s-1970s
  - Design and construct to ultimate density; no post construction densification
  - Design compaction selected to match construction densities under pneumatic tired roller
  - Gyratory compaction similar to Superpave gyratory
  - Design effective binder content fixed for each mix type; select aggregate structure to provide desired air voids (range 4-8%)
  - Field density requirement = 95% (generally thicker lifts)
  - Little to no additional compaction under traffic

Precedent

- Ministère de Transports de Québec (MTQ)
  - Wanted to implement LCPC method but compactors were hard to get and $$$
  - Merged LCPC with Superpave gyratory
  - Effective binder volume fixed, as in LCPC
  - Design air voids between 4 and 7%
  - Field density requirement = 92% (similar lift thicknesses to US)

Changing Gyration Levels

- With same aggregate stockpiles
  - Same crushed faces, FAA and hardness
- Decreasing gyrations→
  - Change in gradation
  - Lower mix stiffness
  - Easier compaction

APPROACH

- Start with 3 current mix designs
  - 9.5 and 19 mm
  - 100 gyration mixes
  - 3-10 and 10-30 million ESAL designs (~50% of INDOT work)
  - Dolomite, limestone and blast furnace slag with PG 64-22
- Adjust gradation to achieve 5% voids at different gyrations
  - 70, 50 and 30 gyrations
  - Maintain VMA and effective binder content in 5% void mixes
  - Bailey method used to guide adjustments

EXPERIMENTAL MATRIX

Traffic Level	No of Gyrations	Mixture Type	
		9.5 mm	19.0 mm
3 – 10 million	30	X	
	50	X	
	70	X	
	100	X	
10 – 30 million	30	X	X
	50	X	X
	70	X	X
	100	X	X

Approach (continued)

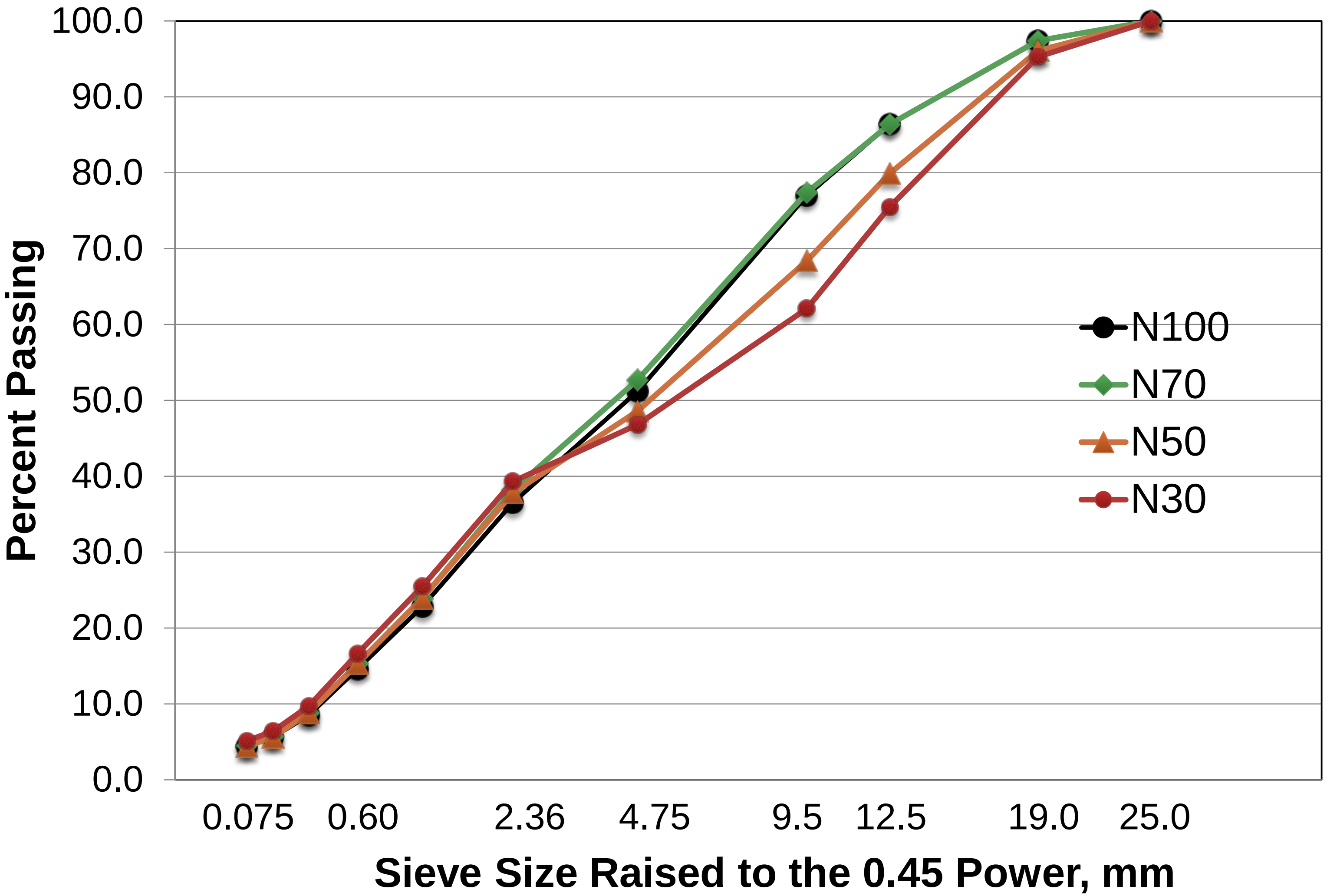
- Test mechanical properties of the mixes
  - Want same (or better) mechanical properties in the higher air void mixes as the original mix provided
  - Do not sacrifice rutting resistance for higher density
  - Test 100 gyration mix at 7% and others at 5% air voids
  - Determine number of gyrations to achieve 5% air voids and similar (or better) mechanical properties
- Field Validation
  - Can we achieve higher densities with revised mix design?

19.0 mm Mix Volumetrics

	Redesign			
Gyrations	100	70	50	30
P_b, % *	4.7	4.7	5.1	5.1
V_a, %	4.0	4.9	4.9	4.9
VMA, %	13.6	14.5	14.4	14.9
VFA, %	70.7	66.2	65.9	67.2

* P_{be} relatively constant.

19.0 mm Mixture Gradations



Gradation Changes in 19.0 mm Mixes

Sieve	N100	N70	N50	N30
19.0 mm (¾ in)	97.4	97.4	96.1	95.3
12.5 mm (½ in)	86.4	86.4	79.9	75.5
9.5 mm (⅜ in)	77.0	77.4	68.4	62.1
4.75 mm (#4)	51.2	52.7	48.6	46.8
0.600 (#30)	14.6	15.3	15.3	16.6
0.075 (#200)	4.4	4.5	4.4	5.1

Mixes getting finer on fine sieves.
PCS = 4.75. Fine if > 47%

Gradation Changes in 9.5 mm Mixes

Sieve	N100	N70	N50	N30
9.5 mm (⅜ in)	97.4	97.3	95.6	
4.75 mm (#4)	65.4	65.8	60.1	
2.36 mm (#8)	33.0	34.7	38.1	
0.600 (#30)	12.4	12.9	16.1	
0.300 (#50)	7.8	7.7	9.5	
0.075 (#200)	4.0	3.4	4.0	

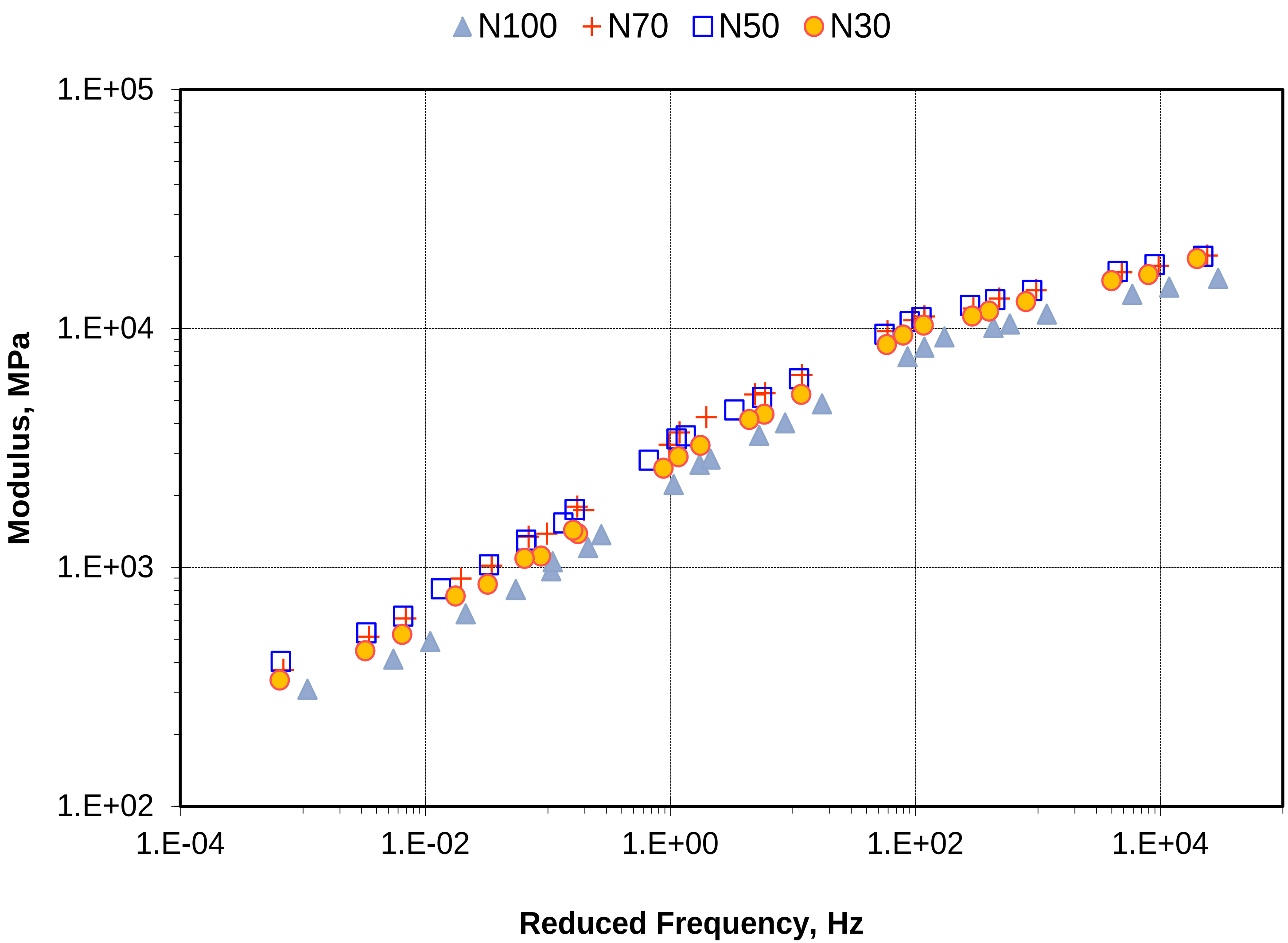
Mixes getting finer on fine sieves.
PCS = 2.36 mm. Fine if > 47%

Testing

- Dynamic Modulus Test
  - Stiffness
  - Rutting
  - Fatigue Cracking
- Flow Number Test
  - Rutting
- Cantabro Test
  - Durability

- 100 gyration mix tested at 7% air, redesigned mixes at 5% air (field compaction level)

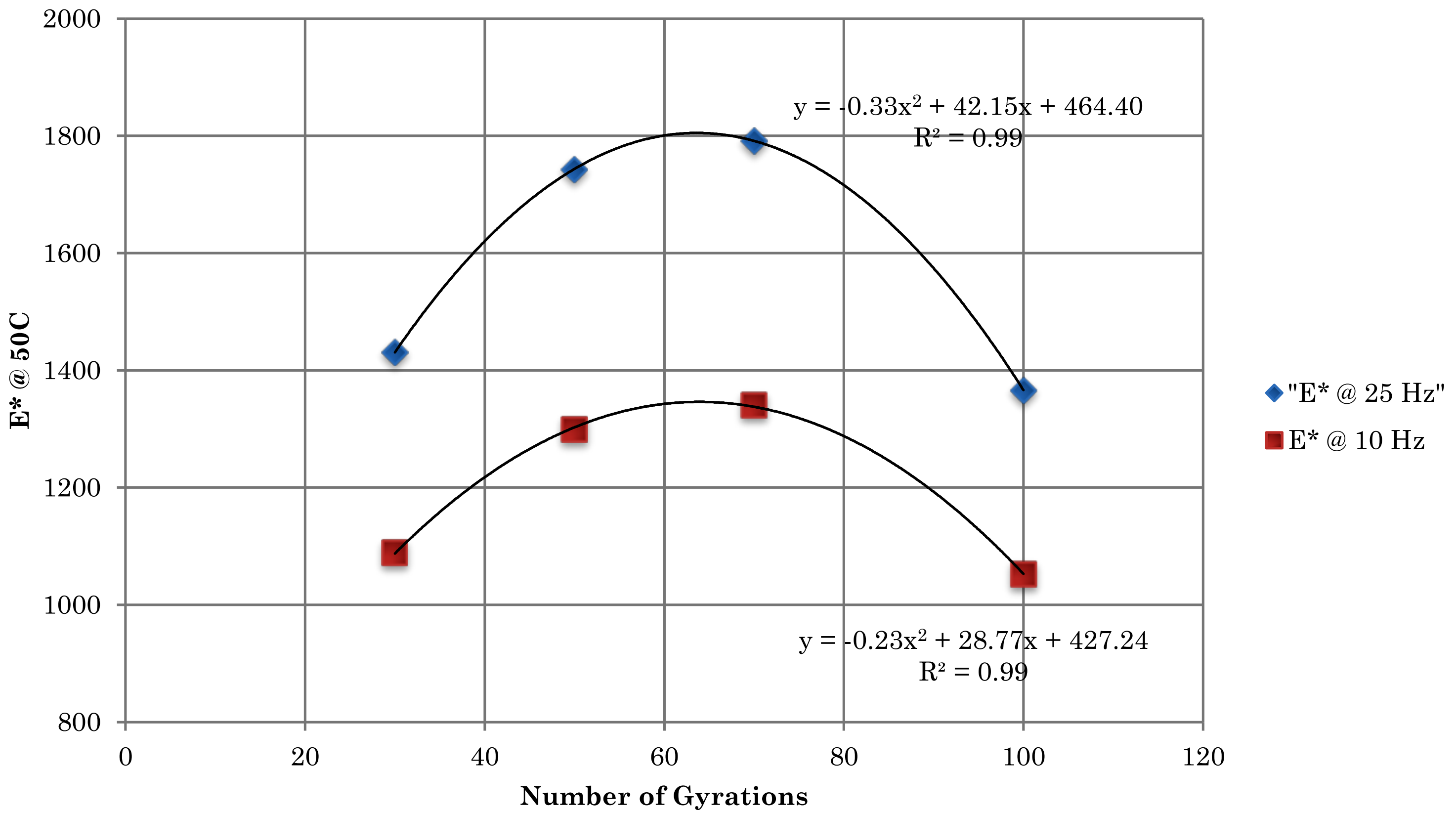
Dynamic Modulus Results – 19.0 mm Mixes



Flow Number Results – 19.0 mm Mixes

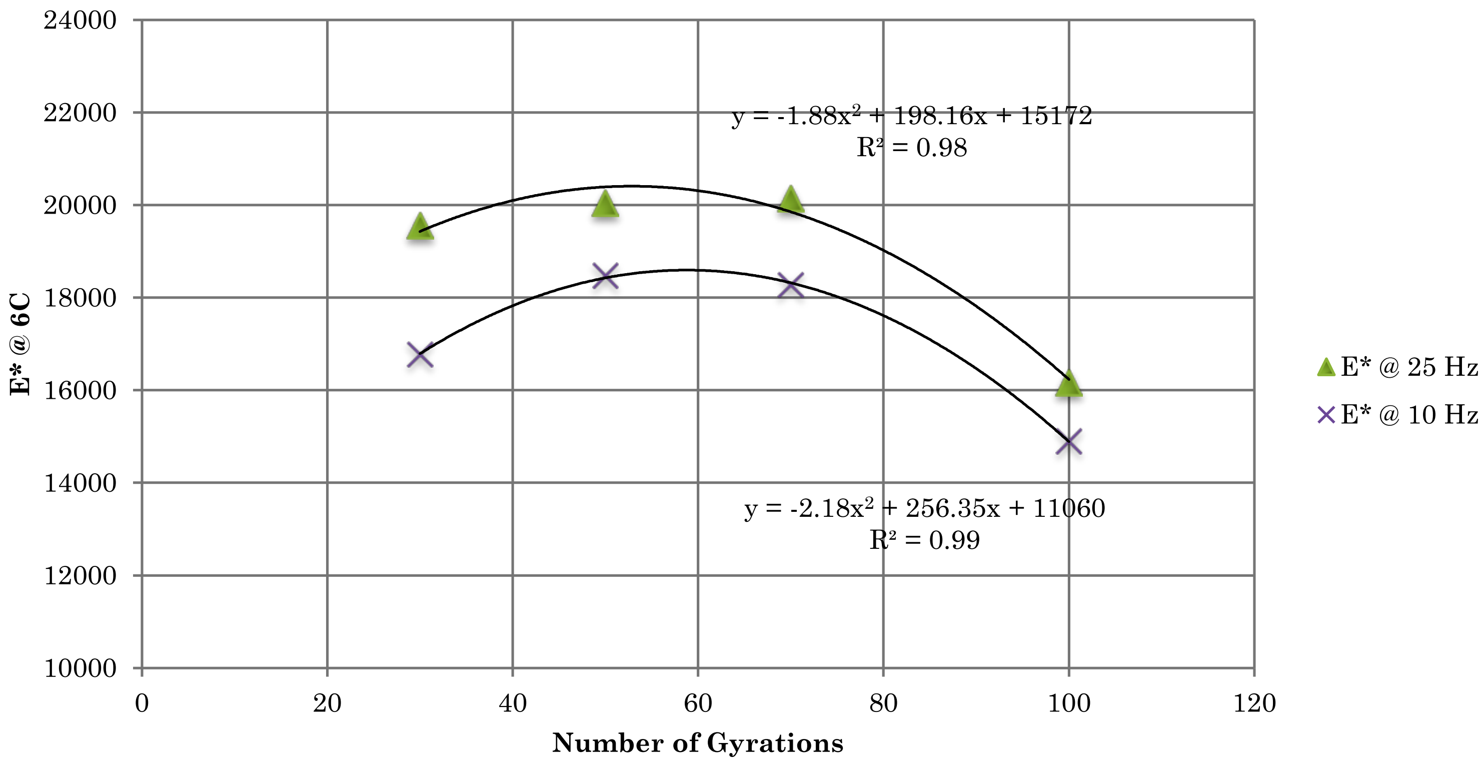
Gyrations	Average Flow Number	Average Strain at FN (µm)
100	162	23983
70	386	18269
50	348	19882
30	185	22090

CHANGE IN DYNAMIC MODULUS (19.0 mm)



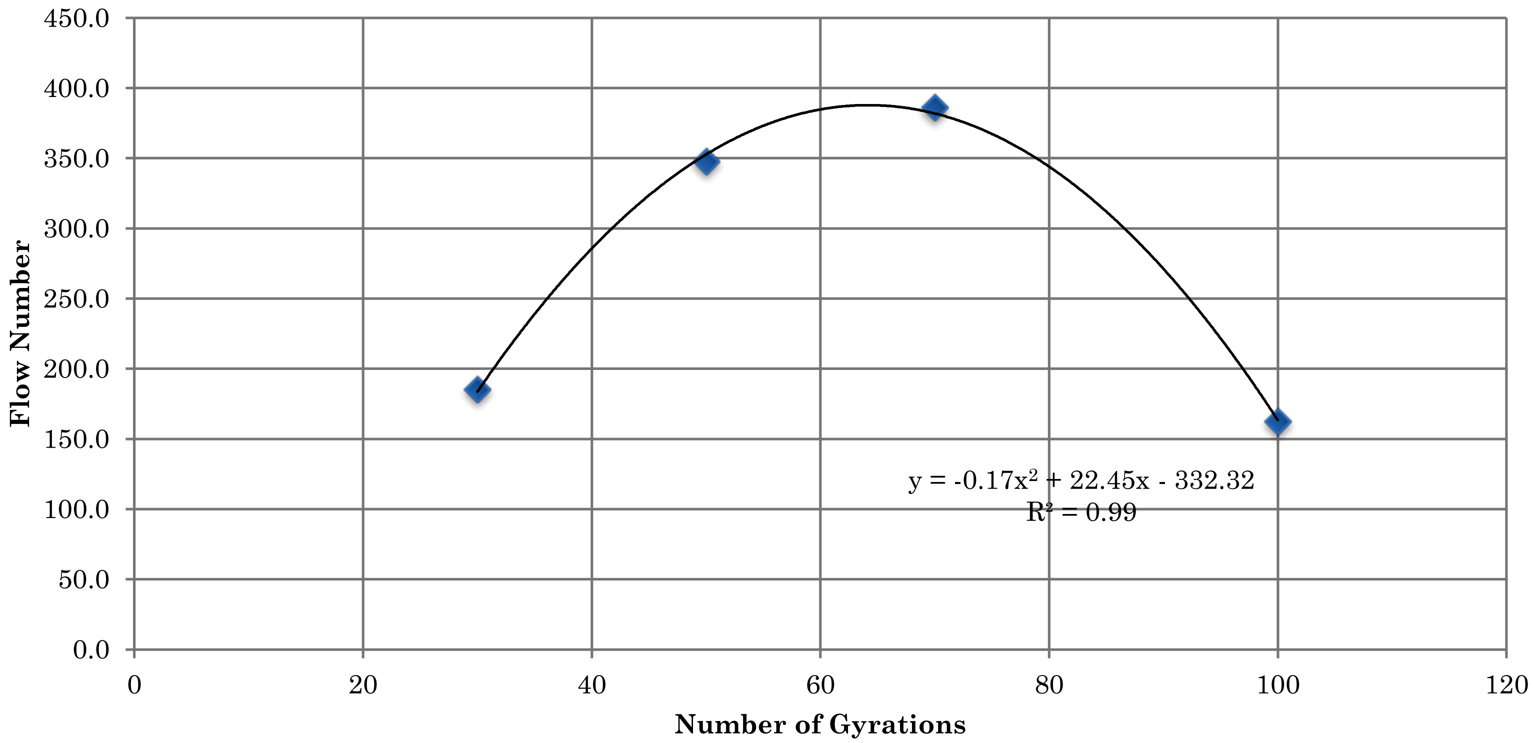
Peaks at 63-64 gyrations.

Change in Dynamic Modulus (19.0 mm)



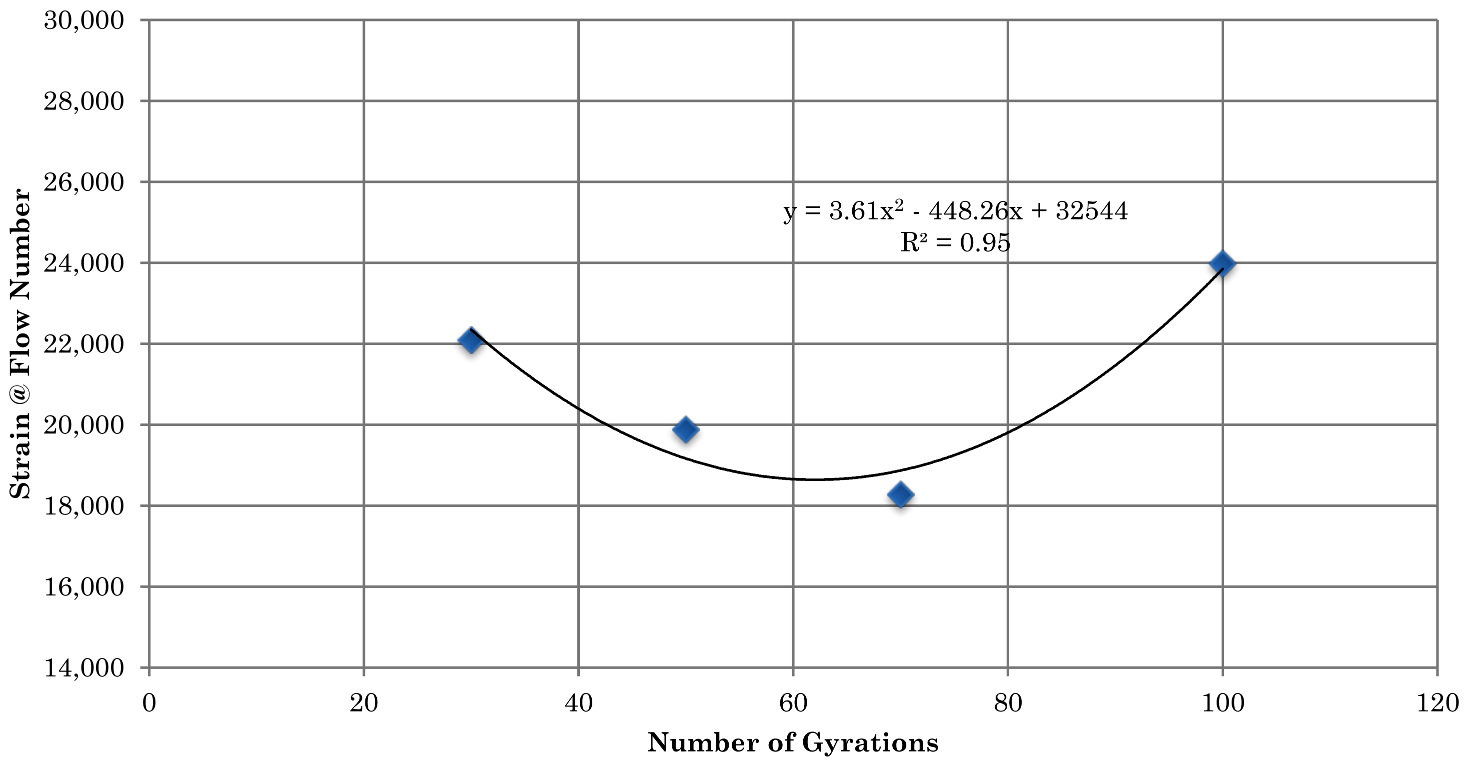
Peaks at 53 and 59 gyrations.

Change in Flow Number (19.0 mm)



Peaks at 66 gyrations.

CHANGE IN STRAIN AT FLOW NUMBER (19.0 mm)



Minimum at 62 gyrations.

Preliminary Findings

- Based on testing only one mix.
- With changes in gradation, mixes can be designed at 5% air voids in the lab.
- Redesigned mixes at 5% air can have higher stiffnesses and higher rut resistance than mixes designed at 4% air and compacted to 7% air.
- Concept looks promising at this point.

What Remains to be Seen

- Does this hold for other mixes?
  - Smaller NMAS
  - Lower traffic
- Can these mixes be compacted to 5% air voids in the field?
- Can they stay at 5% air voids under traffic?

Deliverables

- Revised lab compaction and mix design procedure
- Field validation plan (for 2013 pilot)
- Draft revised test methods
- Draft special provisions
- Training (for implementation phase)

Anticipated Implementation

- Implementation first on several trial projects
- If favorable, wider implementation possible
- No new equipment or increases in testing/design time
- Minimal training needed
- Minimal costs for implementation

Anticipated Benefits

- Potential 2-3 years of increased service life
- Potential savings of $20-30 million a year
  - Based on $300 million HMA rehab budget and that 50% of the HMA pavements reaching end of life do so because of durability problems

QUESTIONS?

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