Acceptance Criteria for Unbonded Aggregate Road Surfacing Materials

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Problem

- Good sand clay gravel sources nearly depleted
- Crushed aggregates provide various levels of performance
- Need to update/improve UFGS 02731A, “Aggregate Surface Course”

Objective

- Update UFGS 02731A to allow the use of various types of unbound materials
  - Well-defined limits used to accept or reject proposed material sources
  - Differentiate between construction and maintenance situations

Current UFGS 02731A

- 4 grading options
  - Natural or crushed

USACE Grading Requirements for Surface Aggregate				
Sieve Size	**No. 1**	**No. 2**	**No. 3**	**No. 4**
1 in.	100	100	100	100
3/8 in.	50 – 85	60 – 100	---	---
No. 4	35 – 65	50 – 85	55 – 100	70 – 100
No. 10	25 – 50	40 – 70	40 – 100	55 – 100
No. 40	15 – 30	24 – 45	20 – 50	30 – 70
No. 200	8 – 15	8 – 15	8 – 15	8 – 15

- Coarse fraction
  - LA abrasion <= 50%
  - Flat/elongated <= 20%
- Fine fraction
  - LL <= 35%
  - PI = 4 to 9

MVD Specifications

- 3 material options
  - 1 grading each
- Coarse fraction
  - LA abrasion <= 40%
  - MgSO4 soundness < 15%

MVK Grading Requirements for Surface Aggregate			
Sieve Size	Sand Clay Gravel	Crushed Stone	Crushed Stone with Binder
2 in.	100	No data	No data
1-1/2 in.	95 – 100	100	100
1 in.	75 – 100	No data	No data
3/4 in.	No data	50 – 95	50 – 100
1/2 in.	45 – 90	42 – 85	42 – 85
No. 4	30 – 65	25 – 65	25 – 65
No. 10	20 – 50	No data	20 – 50
No. 40	10 – 30	10 – 32	10 – 32
No. 200	5 – 15	3 – 12	3 – 12

- Fine fraction
  - LL <= 30%
  - PI = 5 to 15%

- Fine fraction
  - LL <= 30%
  - PI = 4 to 9%

Compaction Requirements

- UFGS 02731A
  - 100% modified Proctor
- MVD
  - "… compacted as evenly and densely as practicable by the controlled movement of the hauling equipment over the entire area."
  - Dress with a motor grader

Review of Other Agencies

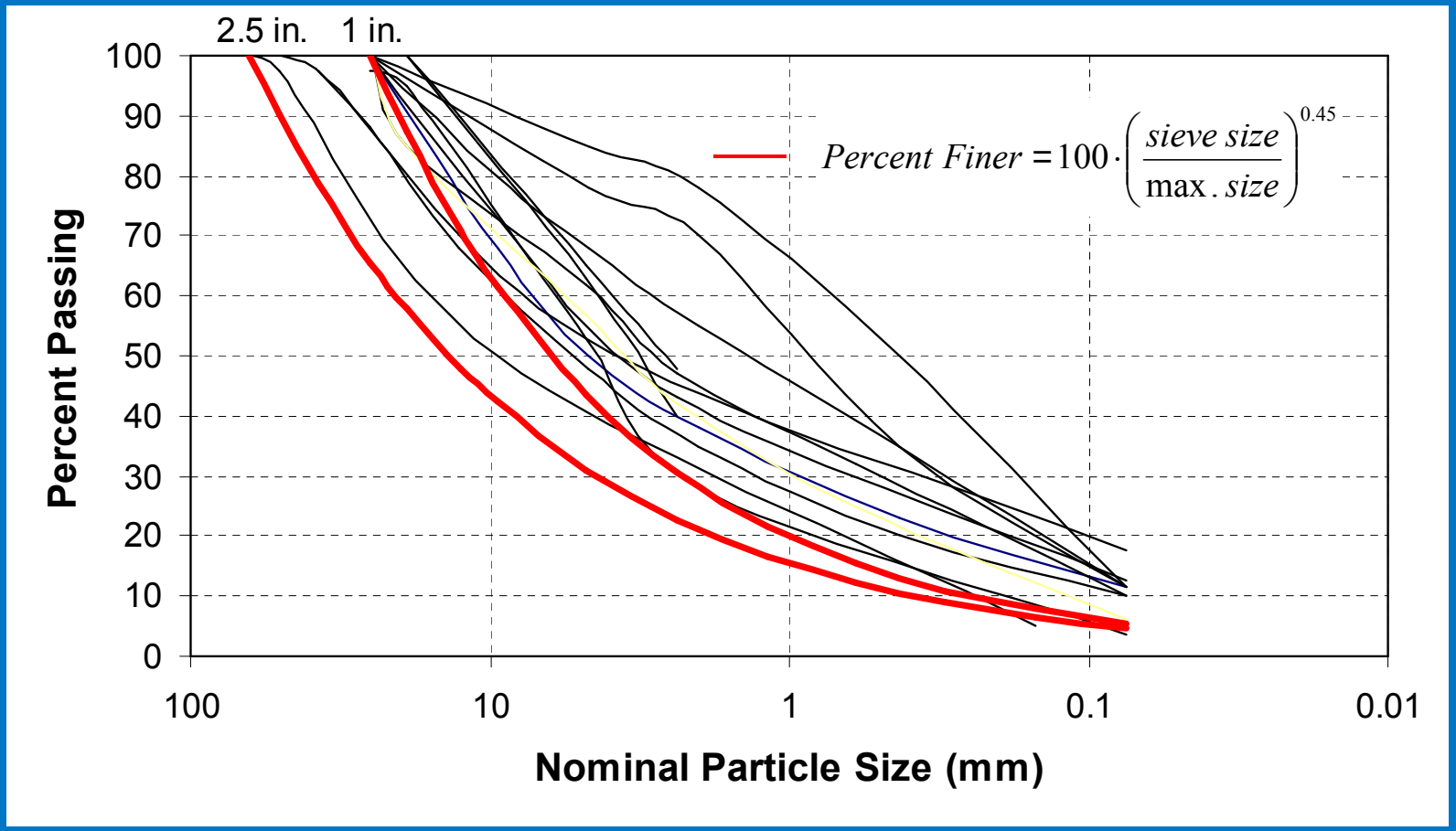
- 9 state DOTs
- US Forest Service
- FHWA
- South Africa, SRA and CSIR
- Popular specification tests:
  - gradation
  - LA abrasion
  - flat / elongated
  - fractured face counts
  - LL and/or PI
  - sulfate soundness
  - sand equivalent
  - % passing No. 200
  - No. 200 / No. 40

Popular Specification Tests

Test	Limit(s)	Note
Gradation	next slide	
LA Abrasion	35 to 50% max.	% loss
Flat / Elongated	10 to 20% max.	3 to 1 ratio
Fractured Face Counts	50 to 75% min.	at least one face
LL	25 to 40% max.	
PI	8 to 15% max. 0 to 5% min.	
Sulfate Soundness	12 to 15% max.	Na or Mg
Sand Equivalent	40 to 45% min.	
% Passing No. 200	10 to 20% max. 0 to 10% min.	
No. 200 / No. 40	67% max.	

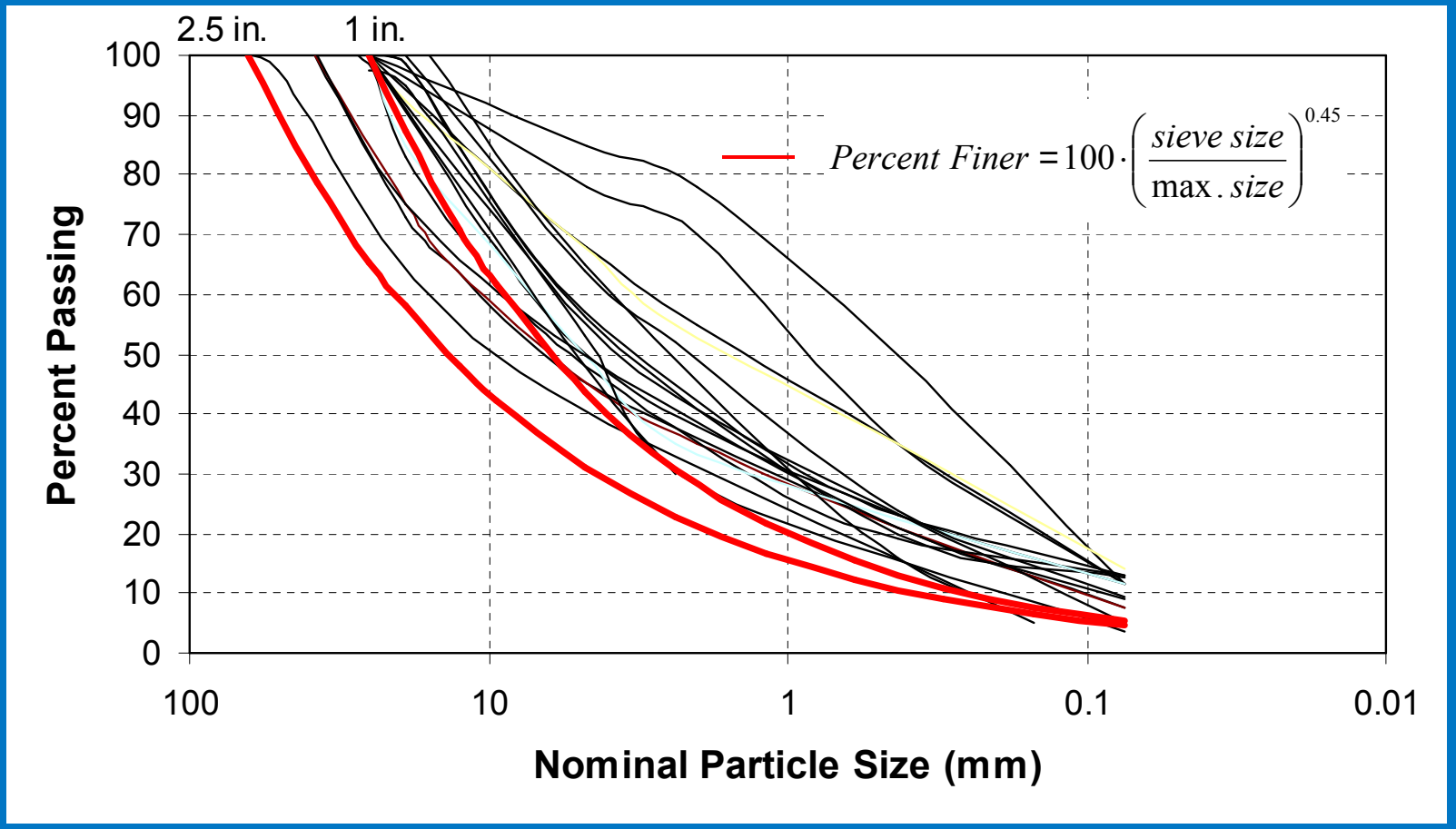
Target Gradations - Literature

Natural Aggregate



Target Gradations - Literature

Crushed Aggregate



This Study - 5 Aggregate Sources

1) Sand clay gravel, SCG

SC

Greenwood Hill Gravel in Greenwood, MS

5 Aggregate Sources

2) Crushed limestone, LS

GW-GM

Vulcan Materials Co., Reed Quarry, Gilbertsville, KY

5 Aggregate Sources

3) Sandstone, SS

GP-GM

Pine Bluff Sand and Gravel, River Mountain Quarry, Delaware, AR

5 Aggregate Sources

4) Igneous, IGN

GP

McGeorge Corp., Granite Mountain Quarries, Little Rock, AR

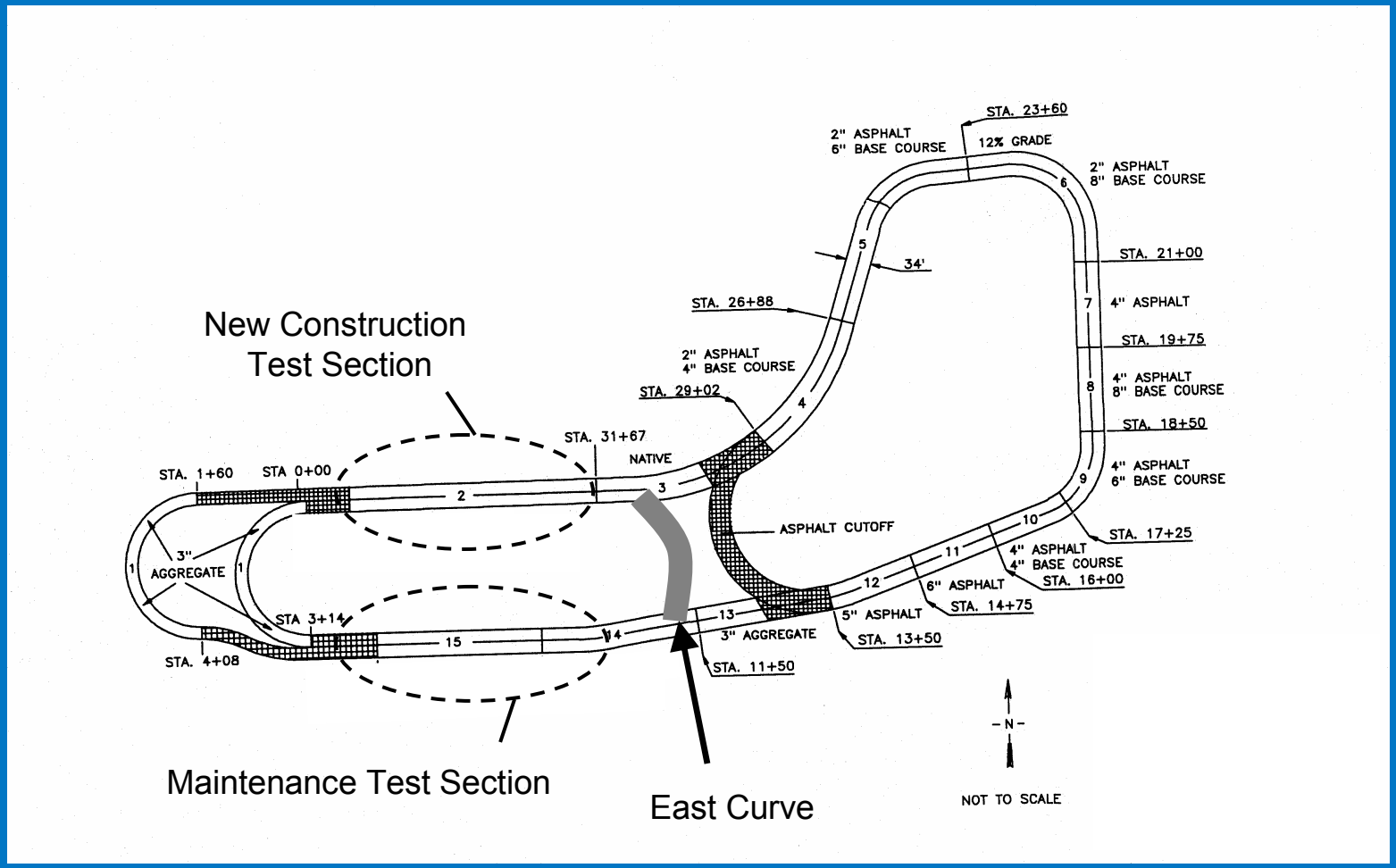
5 Aggregate Sources

5) Sandstone with binder, SSB

GC

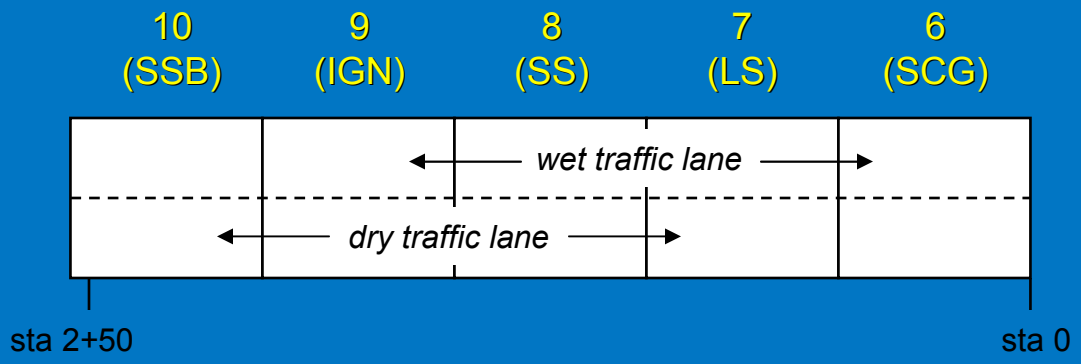
Martin Marietta Aggregates, Sawyer Quarry, Sawyer, OK

Experimental Approach

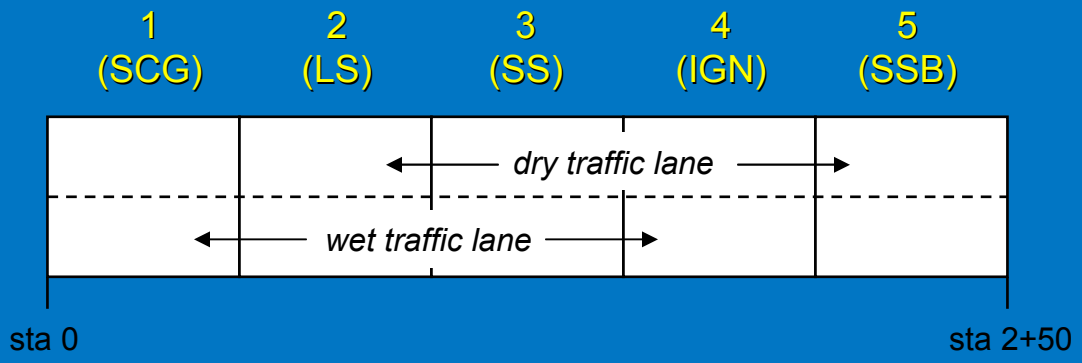


Experimental Approach

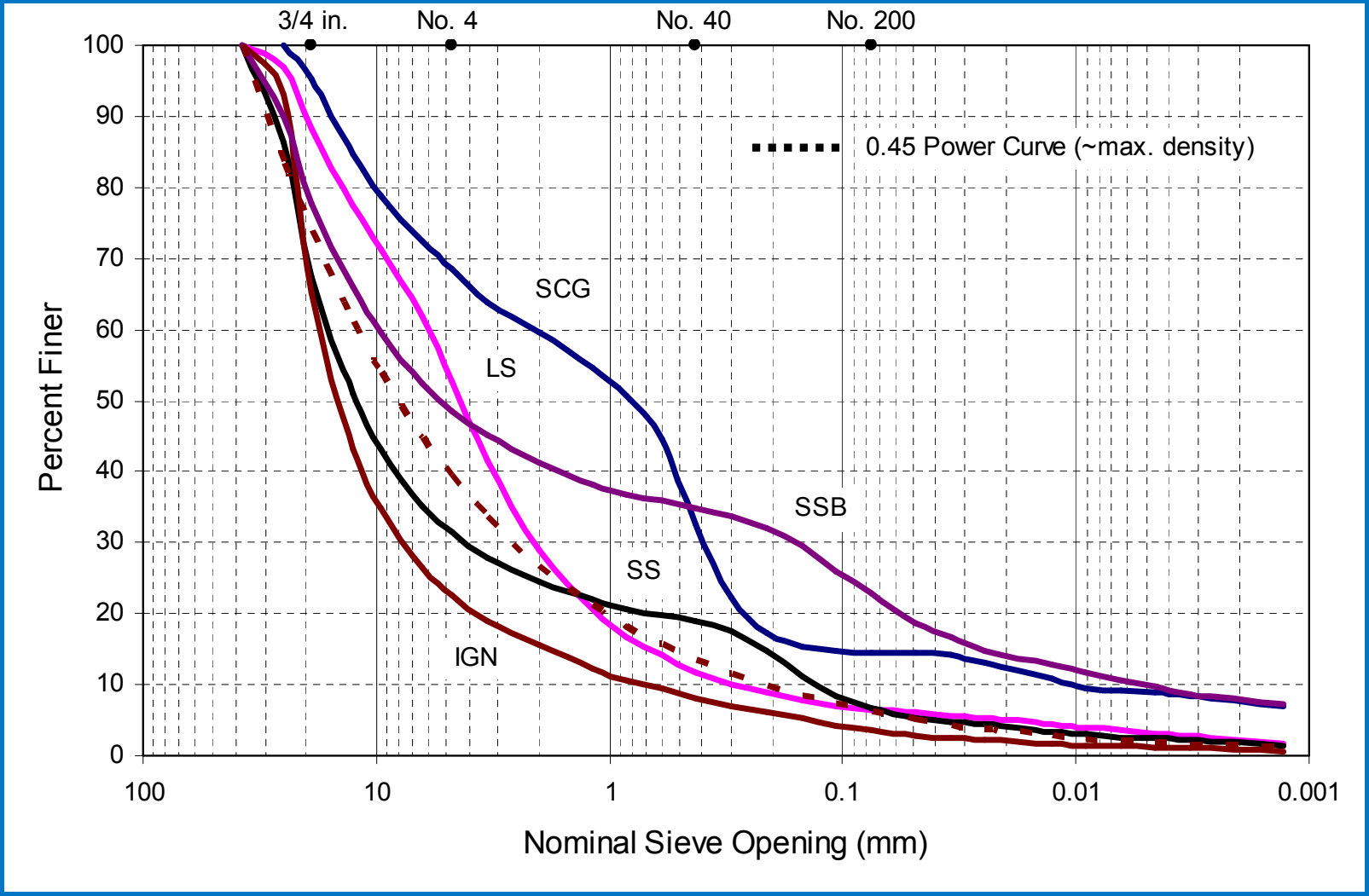
New Construction



Maintenance

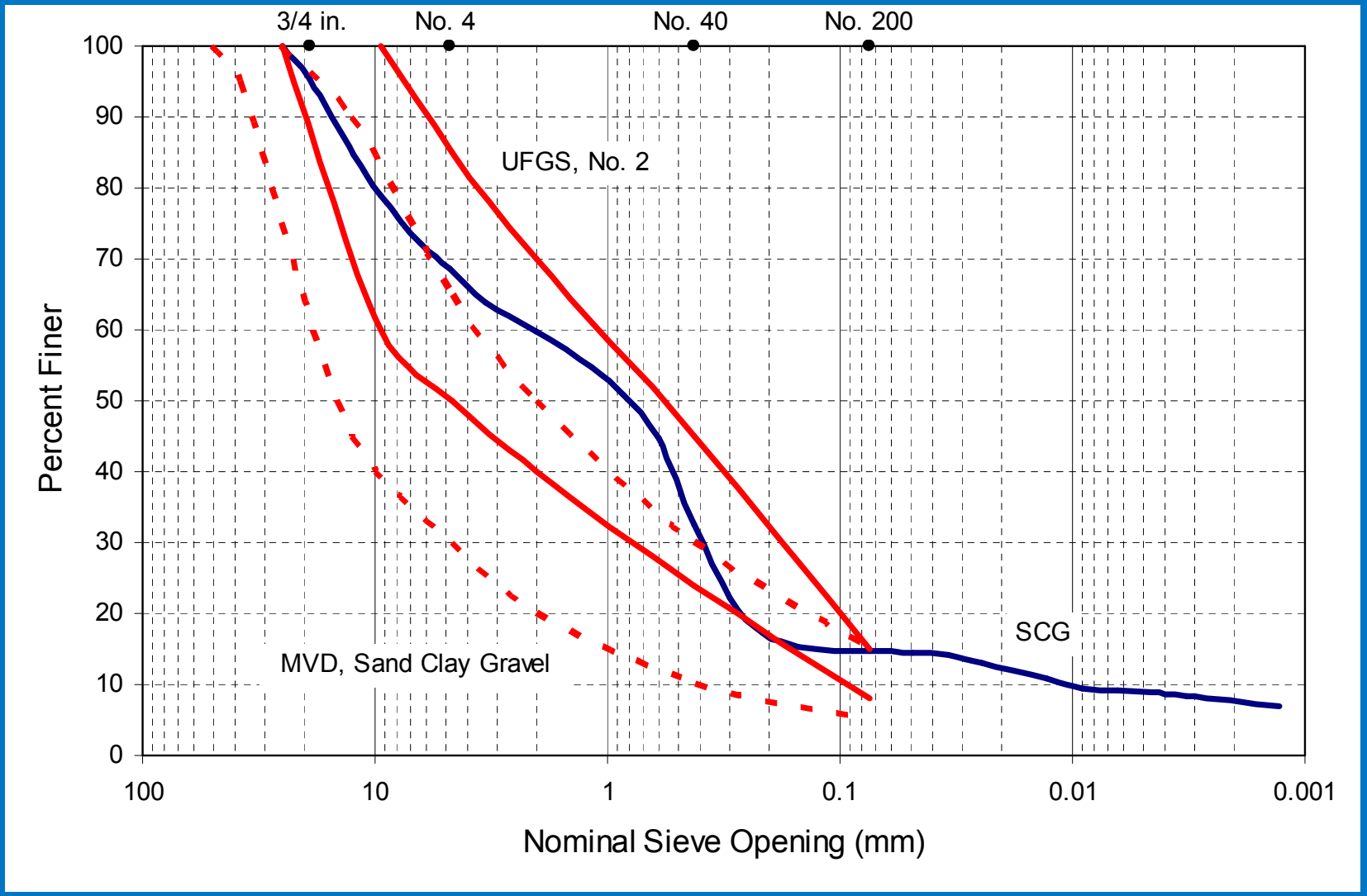


Particle Size Distribution



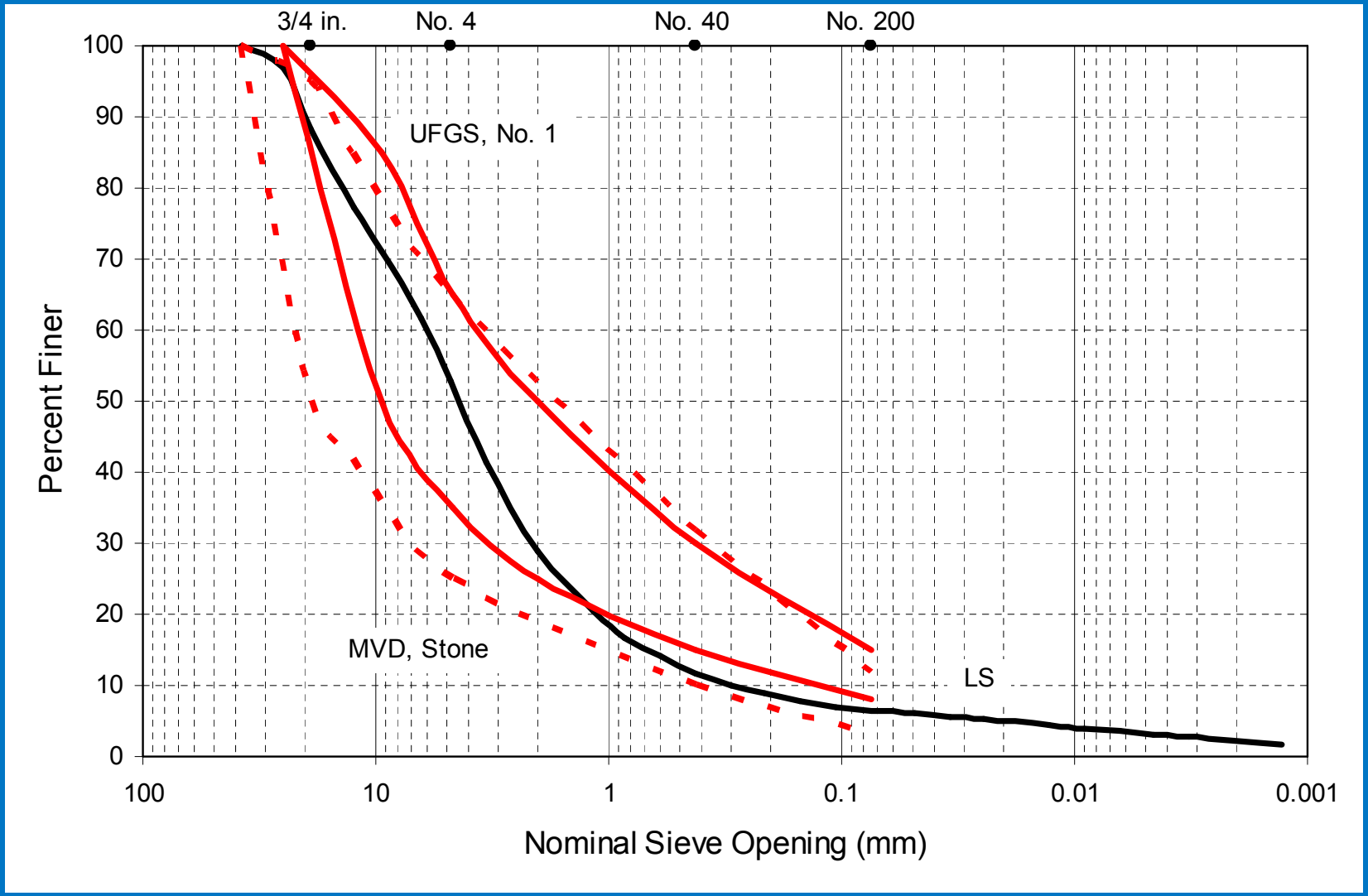
Particle Size Distribution

sand clay gravel



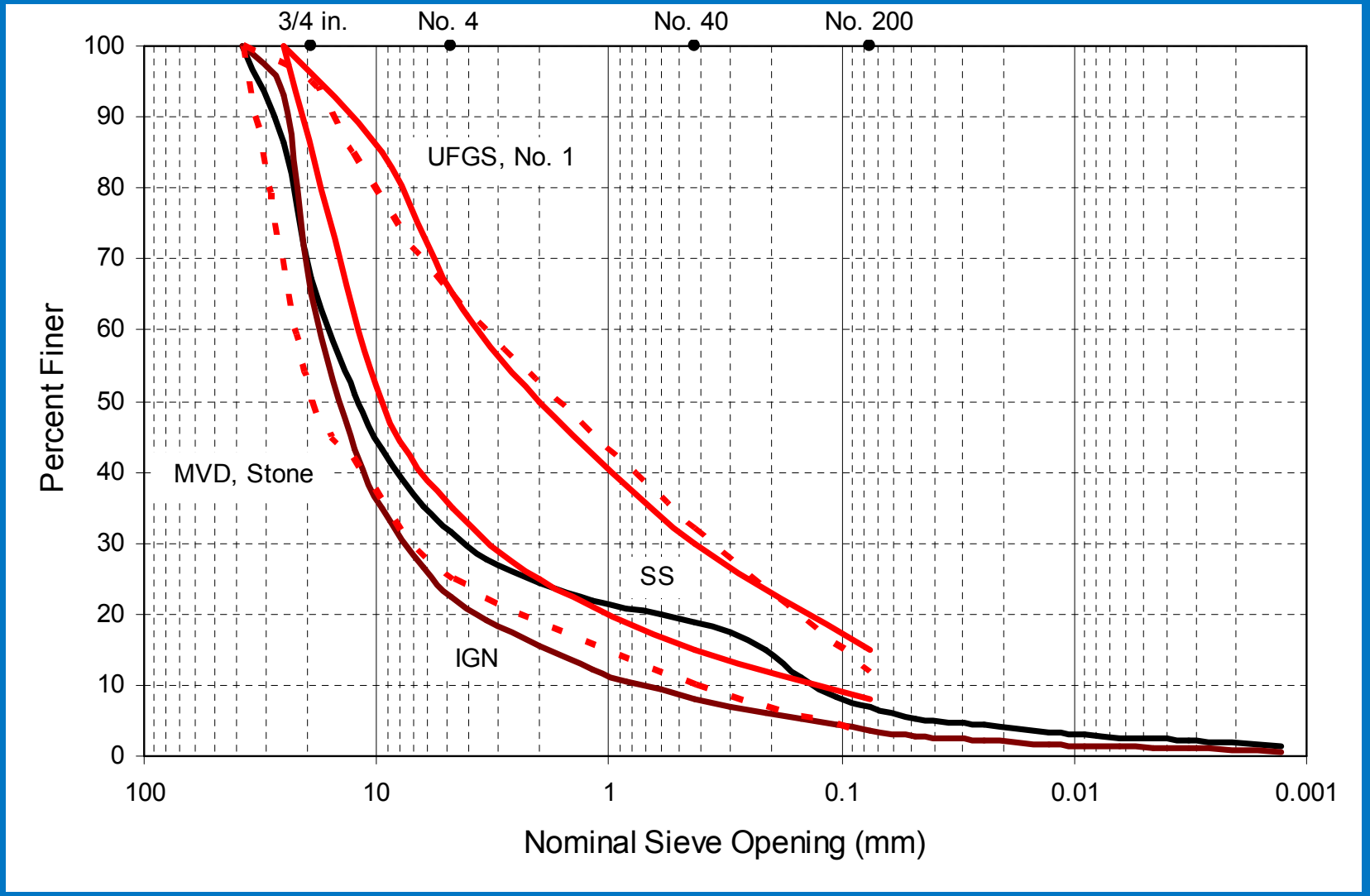
Particle Size Distribution

limestone



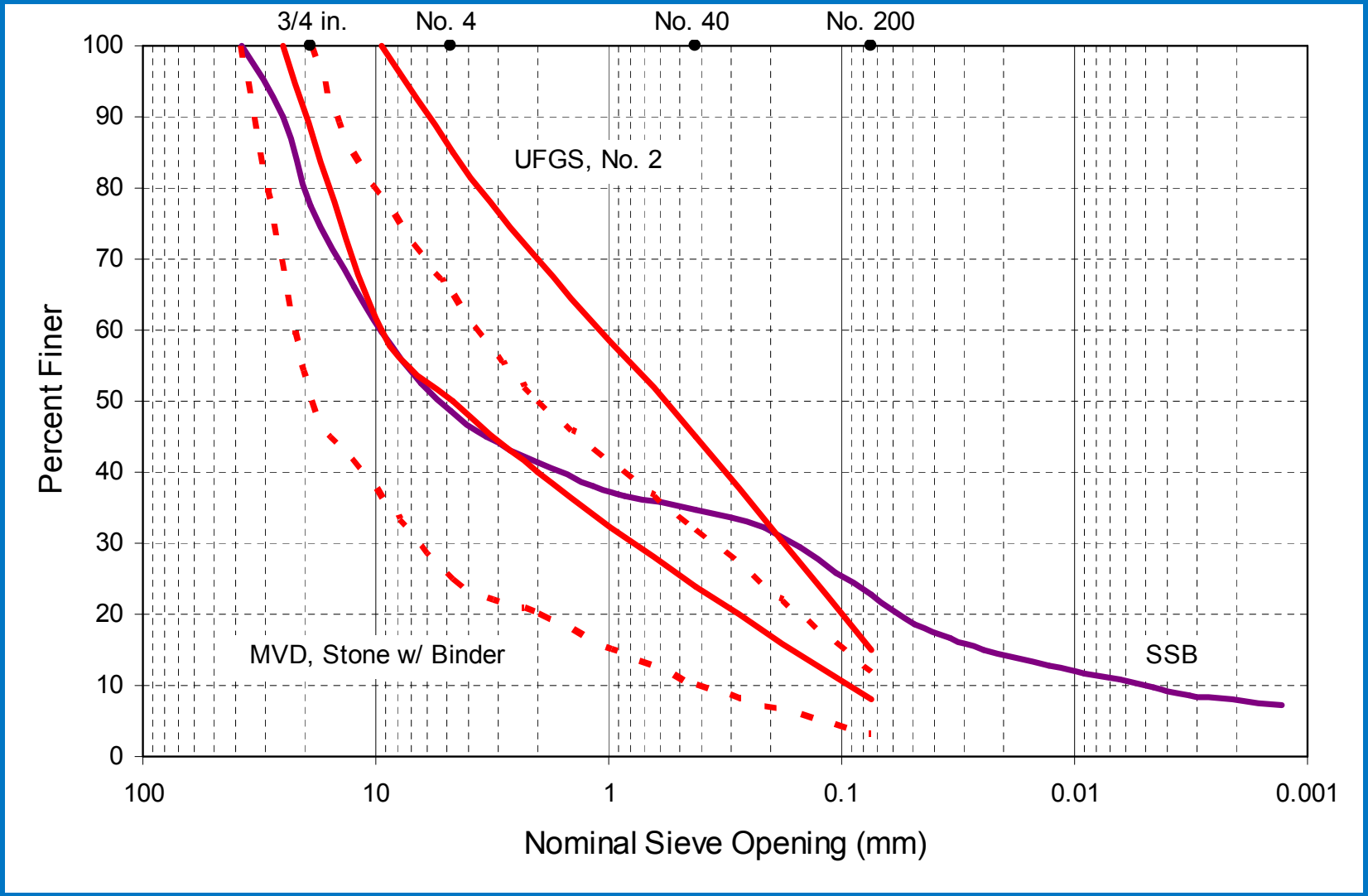
Particle Size Distribution

igneous and sandstone



Particle Size Distribution

sandstone with binder



Material Characteristics

Test		SCG	LS	SS	IGN	SSB
LA Abrasion	35 to 50% max.	18.2	18.8	33.5	27.3	27.8
Flat / Elongated	10 to 20% max.	4.2	5.8	5.5	5.8	10.8
LL	25 to 40% max.	31	NP	NP	NP	28
PI	8 to 15% max. 0 to 5% min.	18	NP	NP	NP	14
Sulfate Soundness	12 to 15% max.	1.0	0.3	4.2	0.4	6.4
Sand Equivalent	40 to 45% min.	20	73	23	61	10
Linear Shrinkage	So. Africa	6.1	1.1	0.2	0.5	6.4
% Passing No. 200	10 to 20% max. 0 to 10% min.	14.4	6.3	6.8	3.6	22.8
No. 200 / No. 40	67% max.	44	53	36	28	66

Construction

- Targets
  - Subgrade CBR = 5 to 10%
  - Surface to receive maintenance layer to have dry unit weight = 130 pcf
  - Compaction of surface layers to be similar to field

New Construction Test Section

Initial buildup
CBR = 4 to 25%

After reworking top 6 in.
Moisture = 13 to 19%
CBR = 5 to 15%

Maintenance Test Section

3 to 5 in. clay-limestone mix remains
CBR = 50 to 100% over
CBR ~ 10% at 10 in.

Placed 6 in. of SCG at
6 to 8% moisture
Dry unit wt. = 128 to 130 pcf

Placing Surface Materials

Spread with John Deere 550G track dozer

Add 16 coverages with dozer

Smooth with static steel drum

Placing Surface Materials

Maintenance Test Section

New Construction Test Section

Trafficking

15 to 20 mph

pickup w/ 500 lb

small empty dump truck

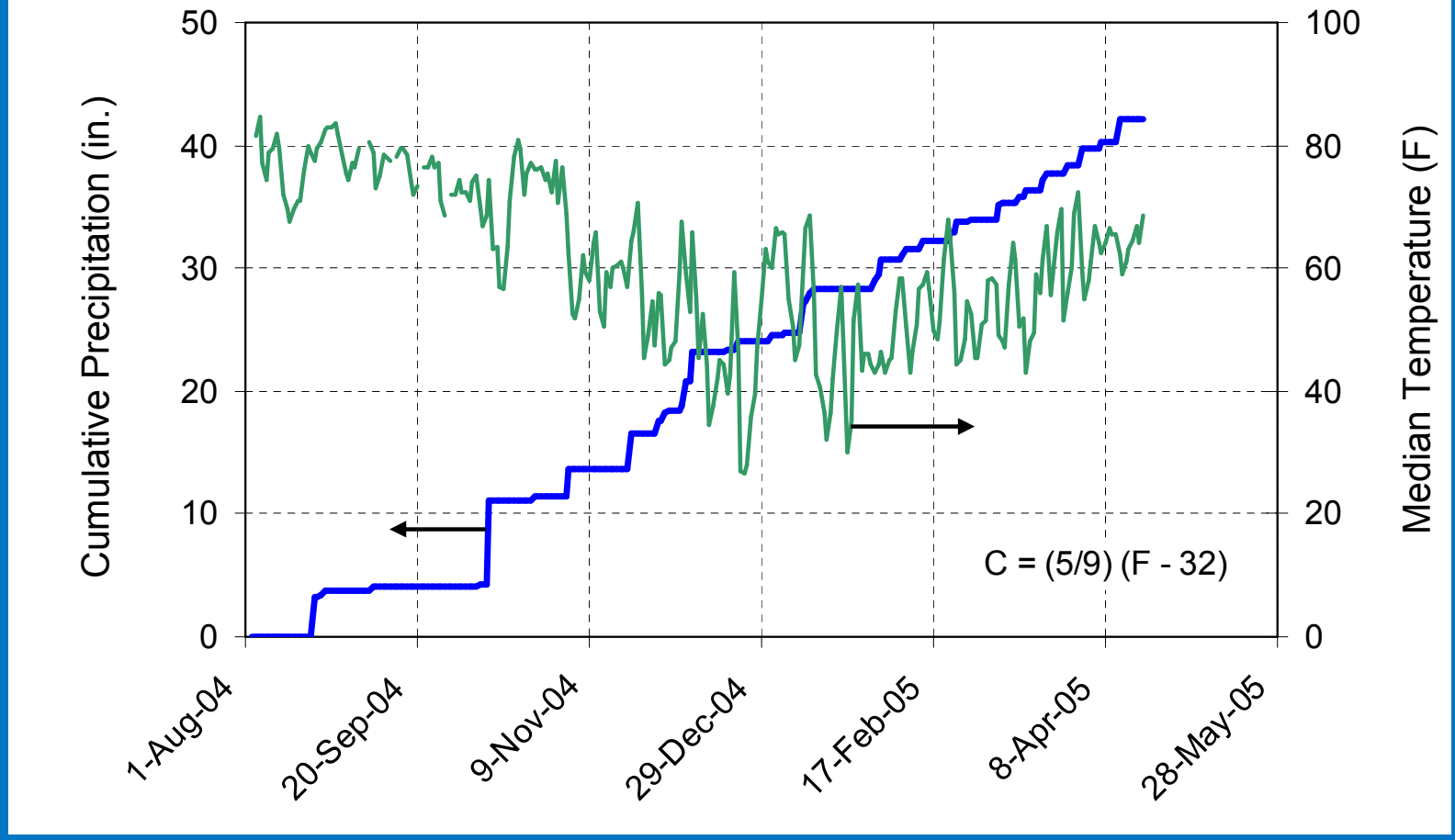
flatbed w/ 2000 lb

emulsion truck w/ 750 gal

Trafficking

Vehicle	Front Axle, lb	Rear Axle, lb	Inflation Pressure, psi
Pickup Truck	2600	2400	40
Dump Truck	6800	7500	110
Flatbed	5500	11000	80
Emulsion	5700	21800	80

Climate


Cumulative Precipitation (in.)
Median Temperature (F)
50
40
30
20
10
0
100
80
60
40
20
0
1-Aug-04
20-Sep-04
9-Nov-04
29-Dec-04
17-Feb-05
8-Apr-05
28-May-05
C = (5/9) (F - 32)

August 2004
Pickup Truck
150 passes

dry conditions

SCG

LS

SSB

October 2004
Pickup Truck
2500 passes

dry conditions

SS

IGN

After Rainy Oct./Nov. (> 10 in.)

17 November 2004
Dump Truck, 10 passes
dry surface – wet subgrade

Only LS on New Construction Rutted:
- 4 to 6 in.
- both wheelpaths

All other items had no distress.

05 April 2005
Emulsion Truck
200 passes

relatively dry conditions
maintenance section

SCG

LS

16 Feb 2005
Dump Truck
200 passes

SSB

very wet conditions
maintenance section

SS

IGN

SCG

LS

SSB

08 Mar 2005
Pickup Truck
150 passes

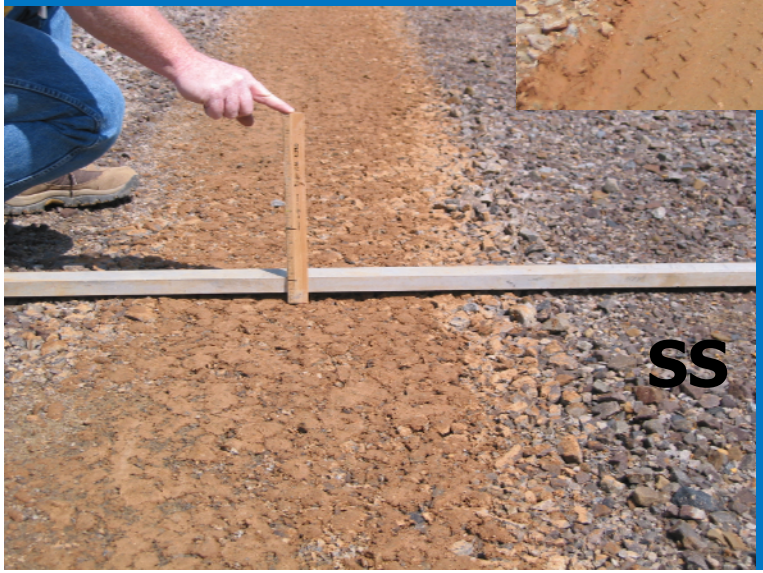
very wet surface
1.25 in. rain event
maintenance section

SS

IGN

01 April 2005
Flatbed Truck
50 passes

wet conditions
maintenance section



15 April 2005
Flatbed Truck
25 passes

wet subgrade
new construction section

least subgrade rutting

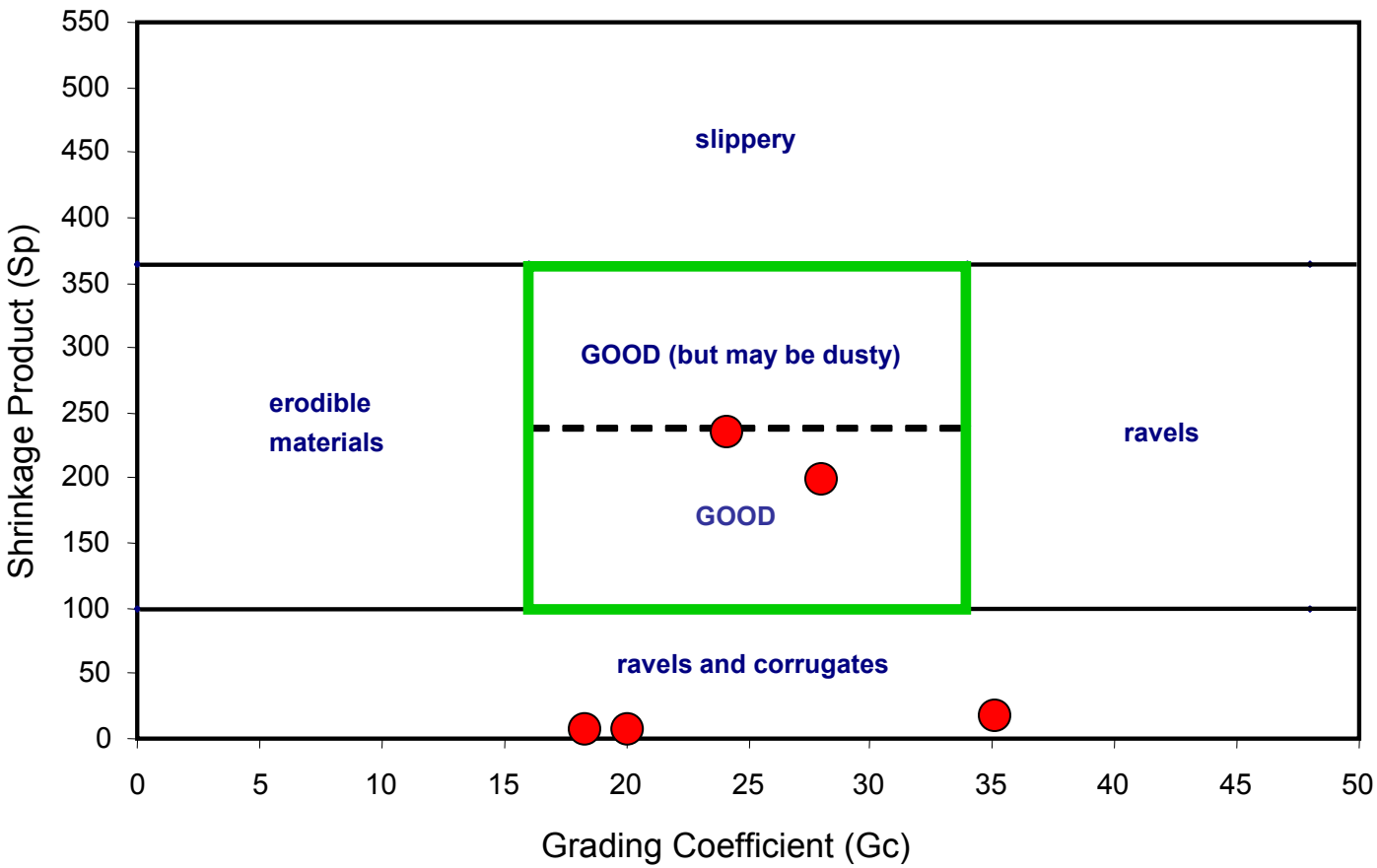
Summary

- New Construction (no subbase)
  - All materials could support light traffic adequately in dry conditions
  - SCG had surface rutting when wet, even under light traffic
  - Aggregates with high fines and plasticity partially protected subgrade from rain, thus prolonging life of road
  - SSB performed best under heavy traffic
  - If heavy traffic is possible, road should include a subbase

Summary

- Maintenance (SCG subbase)
  - All materials, except SCG, could support light traffic adequately in dry or wet conditions
  - SCG had surface rutting when wet, even under light traffic
  - SS and IGN performed best under medium and heavy traffic in wet conditions

South African Approach



Sp = linear shrinkage (%) x No. 40

$$Gc = \frac{(1\text{ in.} - \text{No. } 10)\cdot \text{No. } 4}{100}$$

Conclusions

- Subbase layer is recommended if heavy traffic is possible
  - If no subbase, criteria for surface aggregate will be different than for the case of aggregate on top of subbase
- Key components of new specification:
  - overall gradation
  - minus No. 200
  - No. 200 / No. 40
  - plasticity of fines
  - linear shrinkage?
- Apply concept similar to South Africans' but adjust for higher precipitation

Thanks