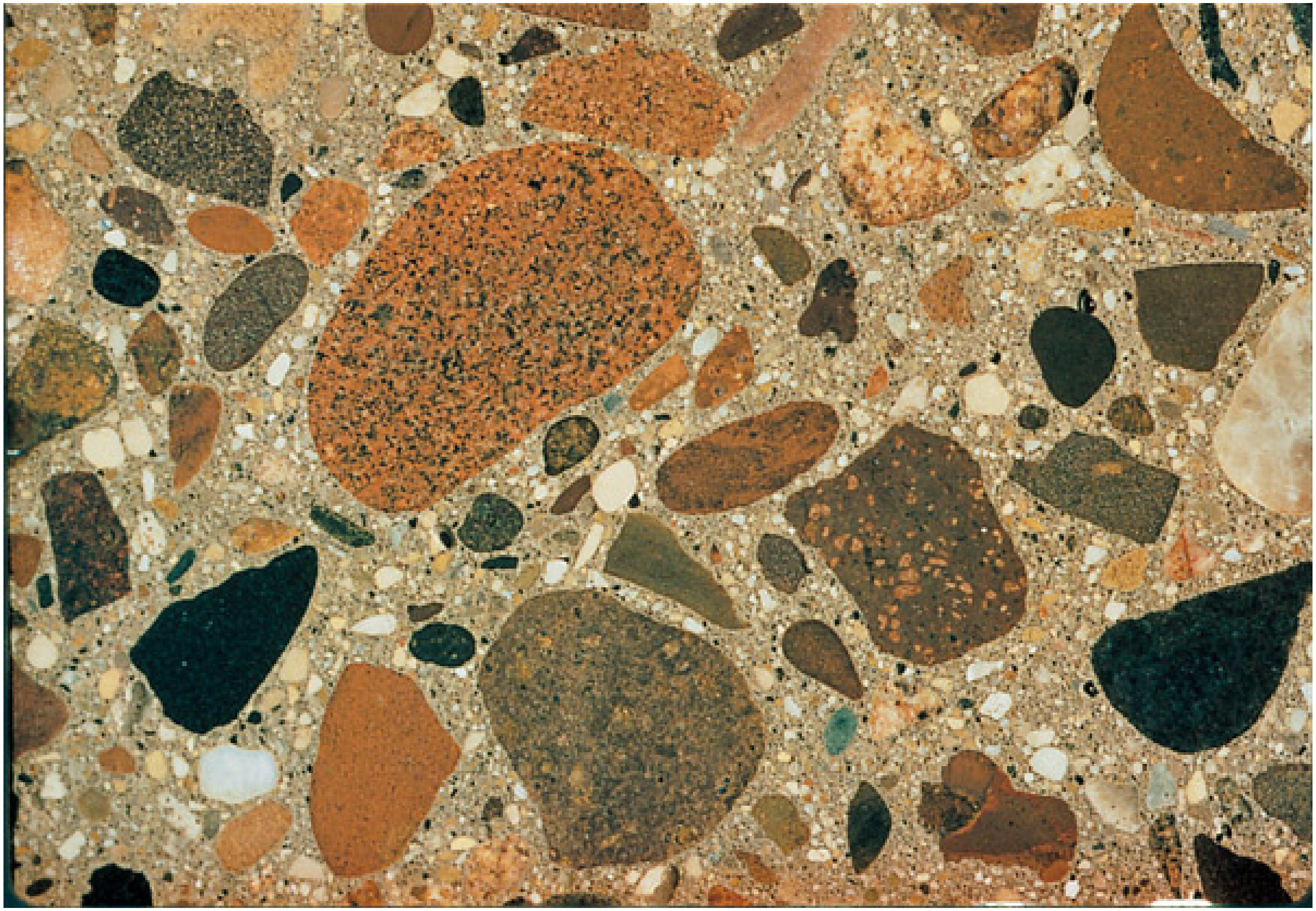
Aggregate Specifications and Performance in Concrete

Aggregates



Aggregate Characteristics

- Properties
  - Surface texture
  - Particle shape
  - Gradation
  - Absorption
  - Bulk unit weight
  - Specific gravity
  - Moisture content
- Performance
  - Abrasion resistance
  - Freeze-thaw resistance
  - Sulfate resistance
  - Alkali Resistance
  - Strength
  - Shrinkage

Aggregate Properties

Characteristic	Test
Definition of constituents	ASTM C 125, ASTM C 294
Aggregate constituents	ASTM C 40, ASTM C 87, ASTM C 117, ASTM C 123, ASTM C 142, ASTM C 295
Particle shape and surface texture	ASTM C 295, ASTM D 3398
Relative density	ASTM C 127 (fine), ASTM C 128 (coarse)
Absorption and surface moisture	ASTM C 70, ASTM C 127, ASTM C 128, ASTM C 566
Grading	ASTM C 117, ASTM C 136
Void content	ASTM C 1252
Bulk density	ASTM C 29

Aggregates – ASTM C33

- Physical properties
  - Gradation
  - Deleterious substances
- Chemical properties
  - Reactivity

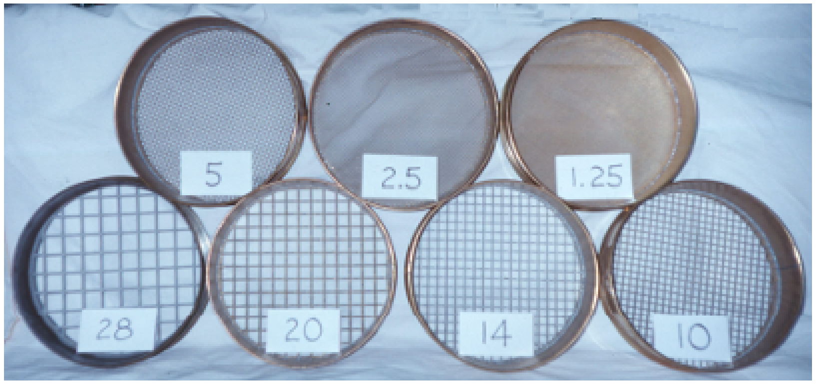
Aggregate Terms...defined

- Gradation (sieve analysis)
- Fineness modulus
- SSD (Moisture conditions)
- Absorption
- Unit Weight
- Specific gravity
- Porosity

Porosity

- Pore structure
  - Mix proportions – pore space affects bulk volume of aggregate
  - Permits increase and retention of water or aggressive solutions
- Greater porosity:
  - Aggregate strength decreases
  - Less abrasion resistance
  - Modulus less
  - Freeze-thaw (large pores)
  - Possibly greater shrinkage

Aggregate Grading

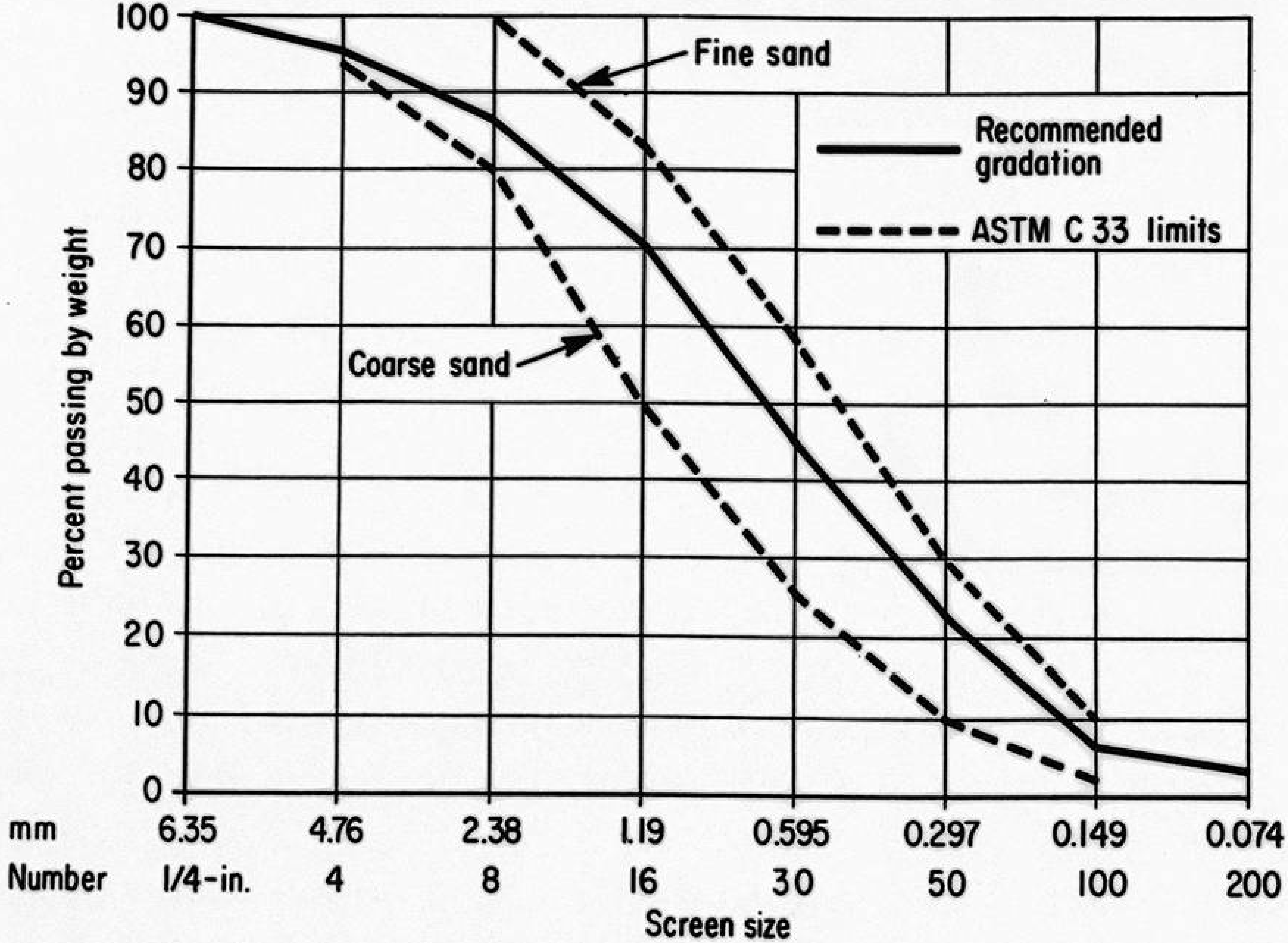


Fine Aggregate

Aggregate Grading

Standard sieve sizes for fine aggregate

ASTM & AASHTO		
Sieve #	Size (in.)	Size (metric)
3/8-in	0.375	9.5 mm
No. 4	0.187	4.75 mm
No. 8	0.0937	2.36 mm
No. 16	0.0469	1.18 mm
No. 30	0.0234	600 µm
No. 50	0.0117	300 µm
No. 100	0.0059	150 µm


Percent passing by weight
100
90
80
70
60
50
40
30
20
10
0
Fine sand
Coarse sand
Recommended gradation
ASTM C 33 limits
mm
6.35
4.76
2.38
1.19
0.595
0.297
0.149
0.074
Number
1/4-in.
4
8
16
30
50
100
200
Screen size

Sieve Analysis and FM

Sieve size		Percentage of individual fraction retained, by mass	Percentage passing, by mass	Cumulative percentage retained, by mass
9.5 mm	(3/8 in.)	0	100	0
4.75 mm	(No. 4)	2	98	2
2.36 mm	(No. 8)	13	85	15
1.18 mm	(No. 16)	20	65	35
600 μm	(No. 30)	20	45	55
300 μm	(No. 50)	24	21	79
150 μm	(No. 100)	18	3	97
	Pan	3	0	—
Total		100		283

Fineness modulus = 283 ÷ 100 = 2.83

% Material <#200 (75 µm)

Fine Aggregate	ASTM C 33	
Source	Natural	Manufactured
Subject to Abrasion	3.0	5.0*
Not Subject to Abrasion	5.0	7.0*

* *Minus No. 200 Essentially Free of Clay or Shale*

Coarse Aggregate

Aggregate Grading

Standard sieve sizes for coarse aggregate

ASTM & AASHTO		
Sieve #	Size (in.)	Size (metric)
2 in	2.0	50 mm
1½ in	1.5	37.5 mm
1 in	1.0	25.0 mm
3/4 in	0.75	19.0 mm
1/2 in	0.50	12.5 mm
3/8 in	0.375	9.5 mm
No. 4	0.187	4.75 mm
No. 8	0.0937	2.36 mm
No. 16	0.0469	1.18 mm

Coarse Aggregate - #57

25-4.75 mm [28-5] (1 in.-No. 4)

Sieve Size		% Passing
37.5 mm	(1½ in.)	100
25.0 mm	(1 in.)	95 to 100
12.5 mm	(½ in.)	25 to 60
4.75 mm	(No. 4)	0 to 10
2.36	(No. 8)	0 to 5

Maximum vs. Nominal Maximum

- Maximum Size — smallest sieve that **all** of a particular aggregate must pass

100% Required to Pass

- Nominal Maximum Size — standard sieve immediately smaller than maximum size

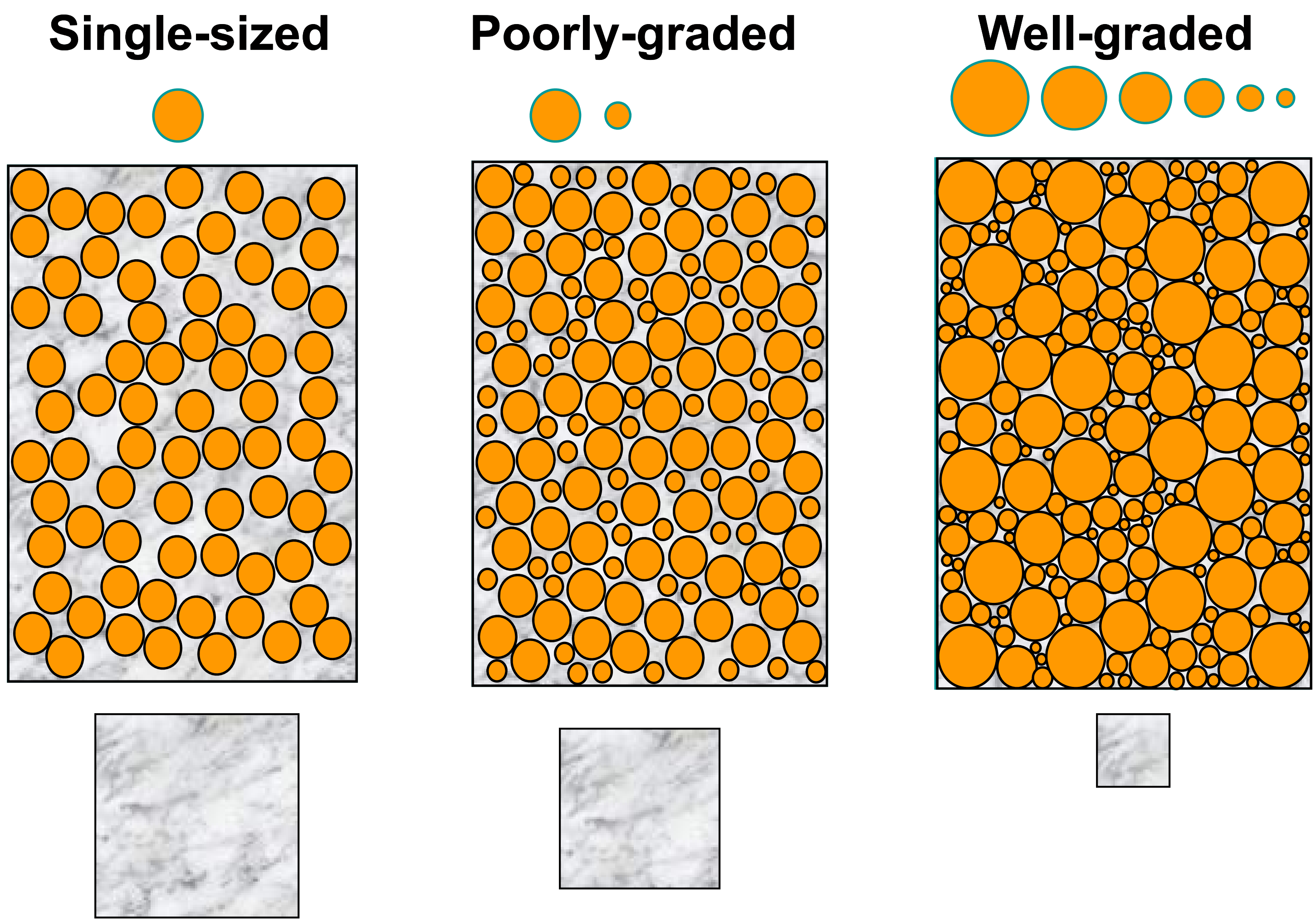
100% Permitted to Pass

- May retain 5% to 15%

Other Coarse Aggregate Limits

- <#200 Max 1.0% or 1.5% if free of clay or shale
- LA Abrasion, Loss – 50% Maximum
- Coal & Lignite Max 0.5% or 1.0% if not exposed to weather or traffic

Aggregate Grading



Volume of paste (cement + water) to fill voids

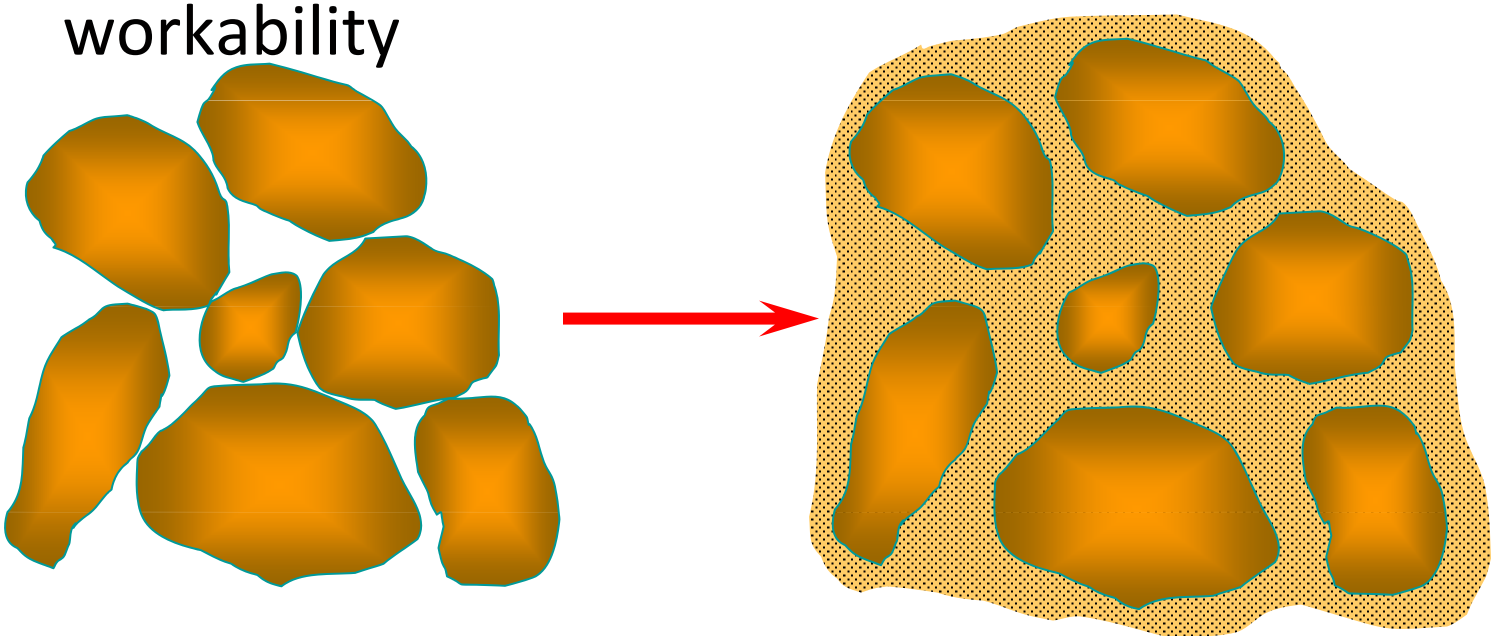
Aggregate Grading

Reducing the paste content of concrete leads to:

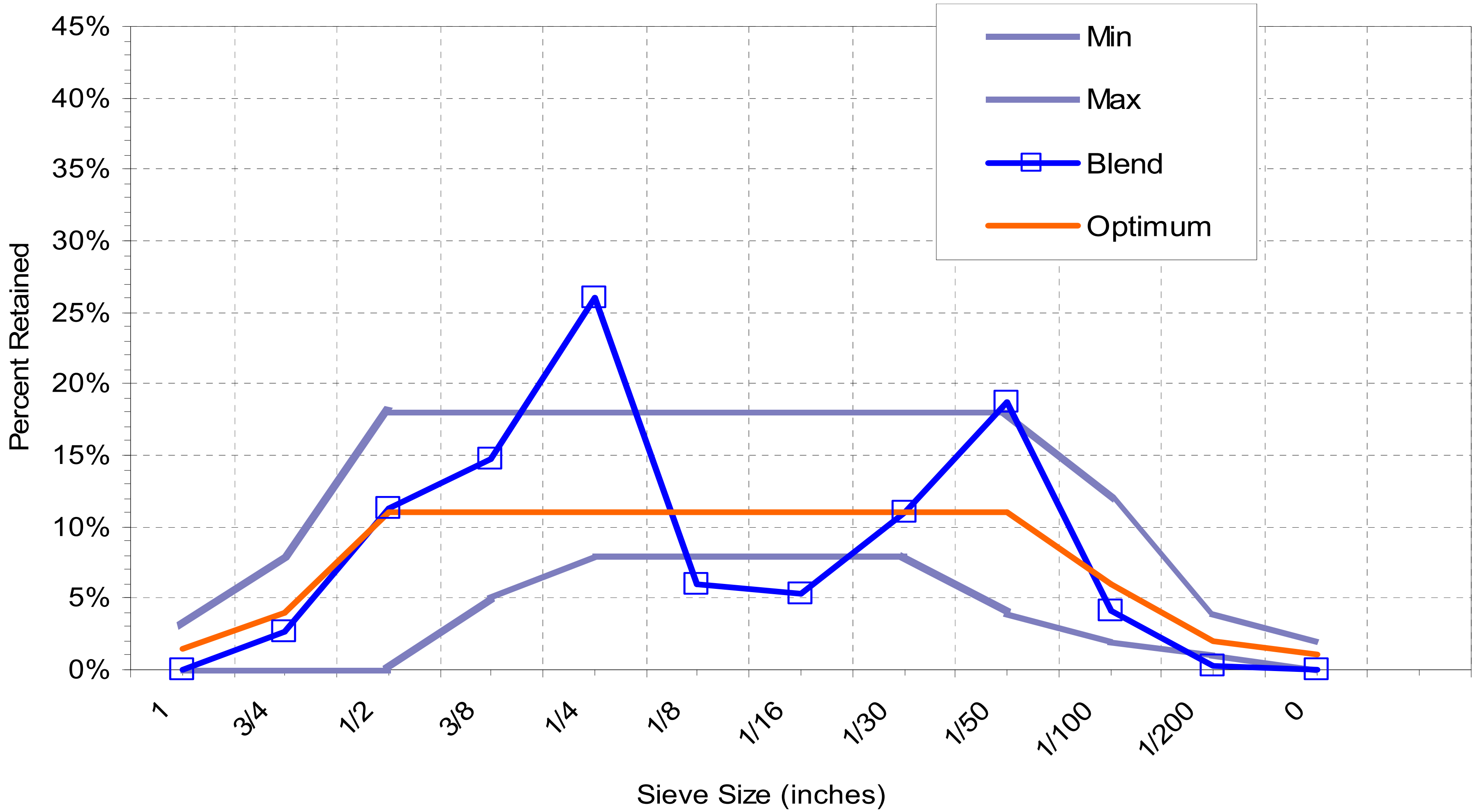
- Reduced cost
- Reduced temperature rise
- Reduced shrinkage
- Reduced permeability

Aggregate Grading

- Amount of paste required > volume of voids between aggregates
- Aggregates need to be coated by and become dispersed in the paste to provide workability



Aggregate Optimization

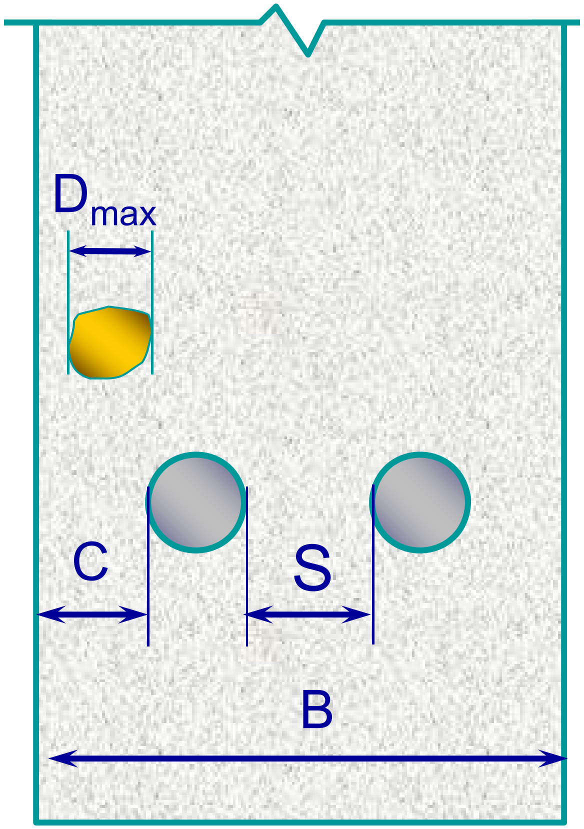


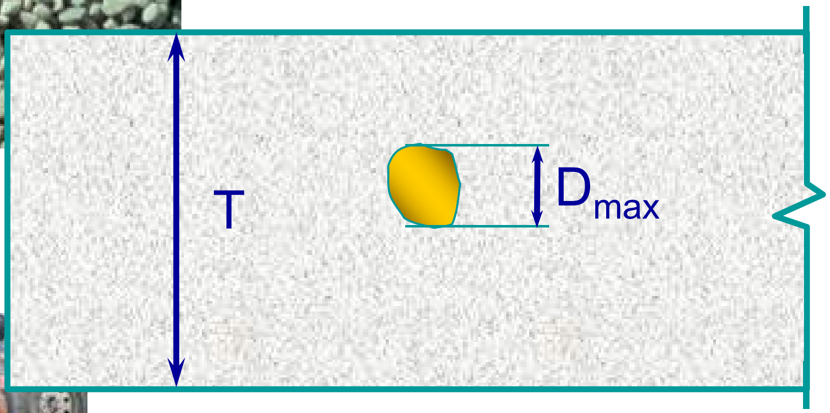
Minimum Cement Requirements for Flatwork

Maximum size of aggregate, in.	Cement, lb/yd^3
1½	470
1	520
¾	540
½	590
3/8	610

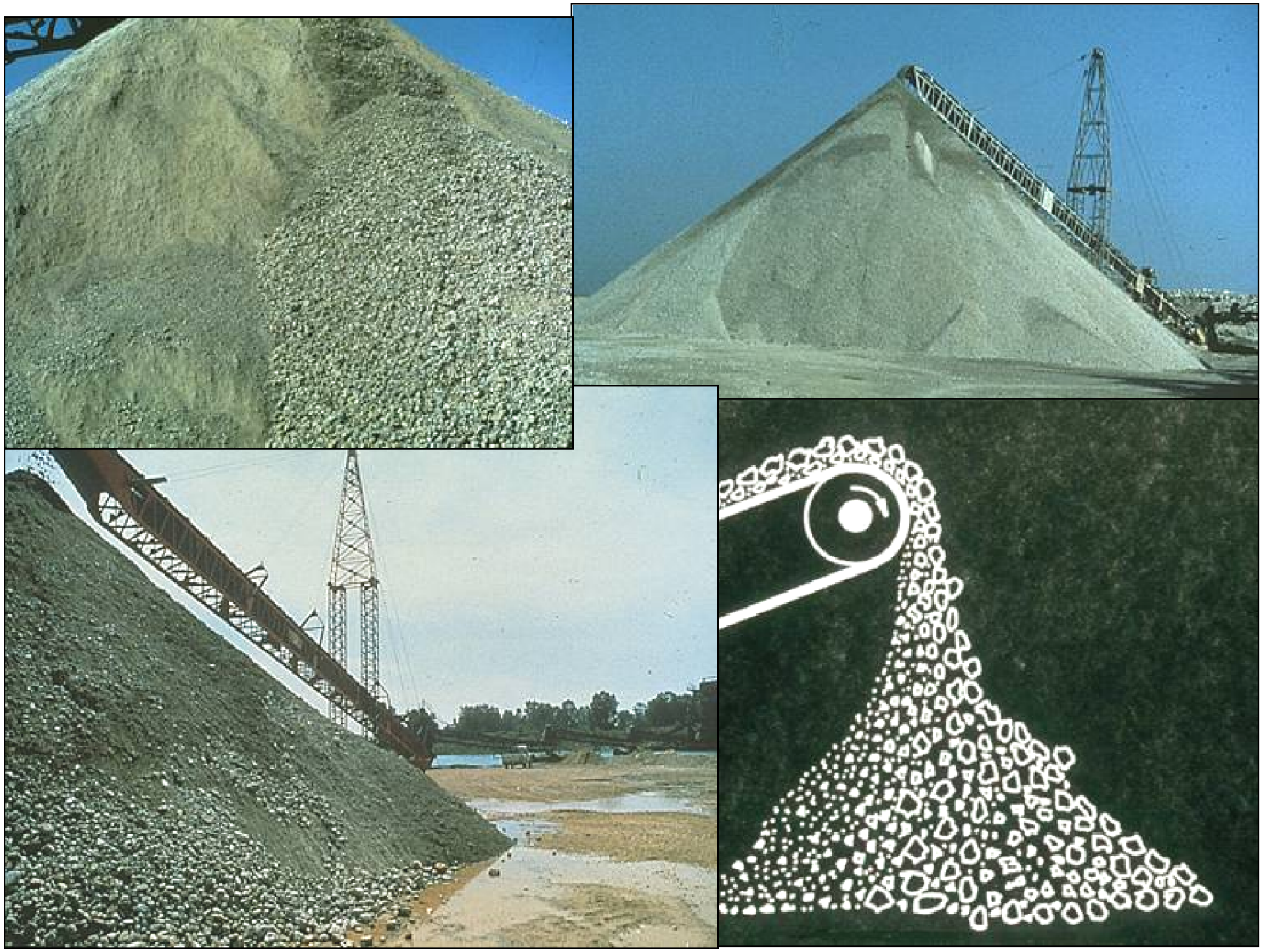
*Cement quantities may need to be greater for severe exposure.

Reinforced Concrete

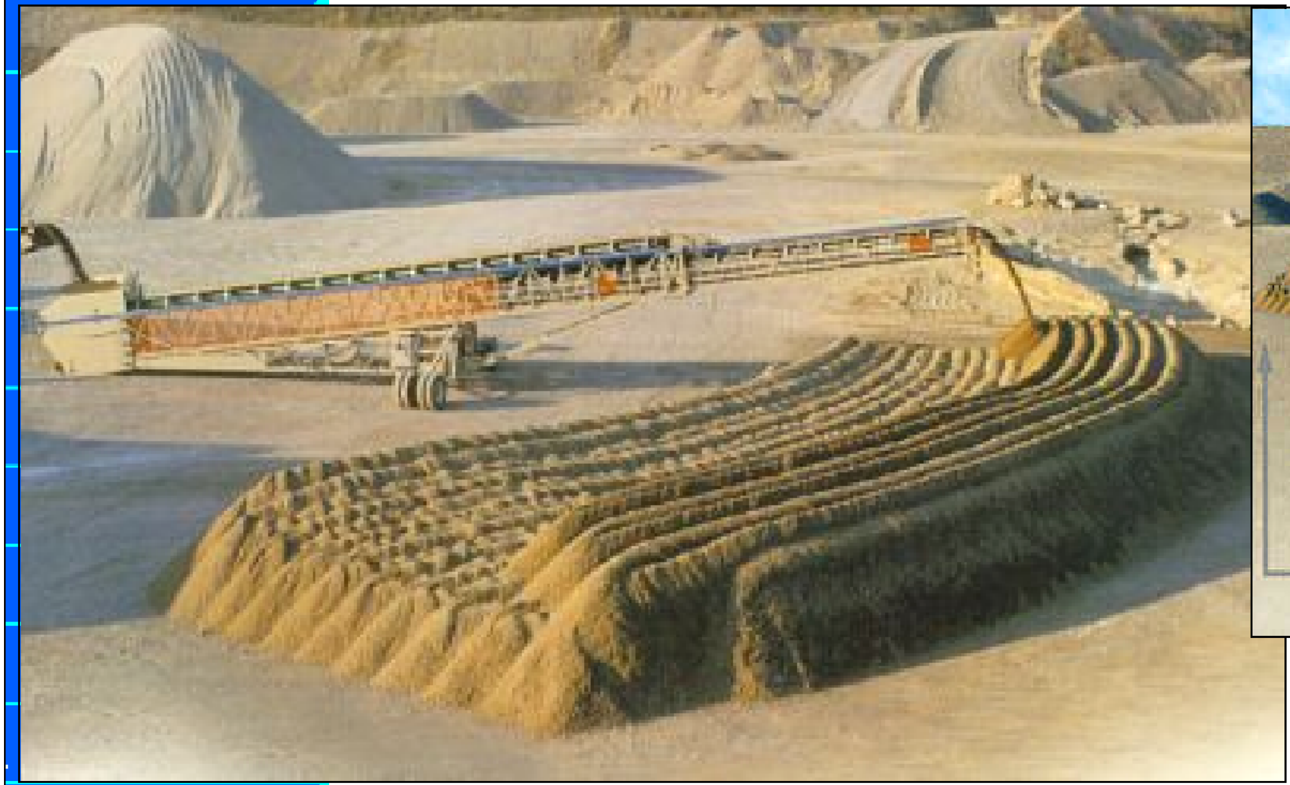


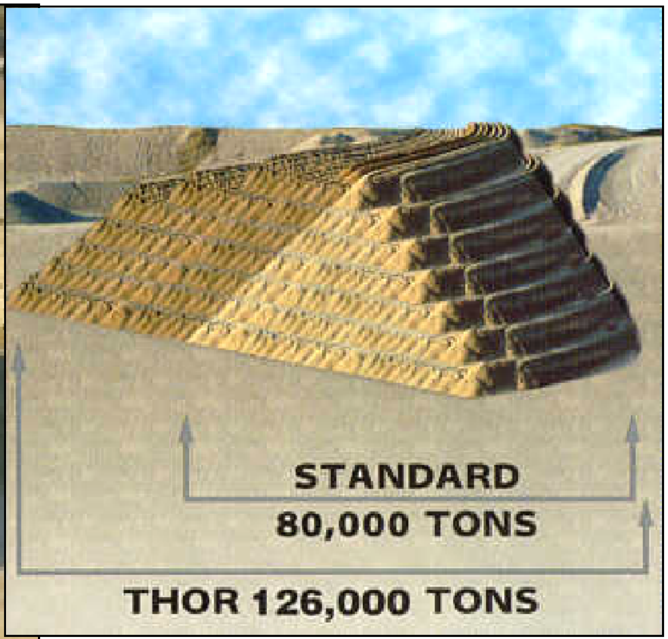

T
D_{max}

Coarse Aggregate Stockpiles – Segregation in Cone-Shaped Piles



Telescoping Conveyors





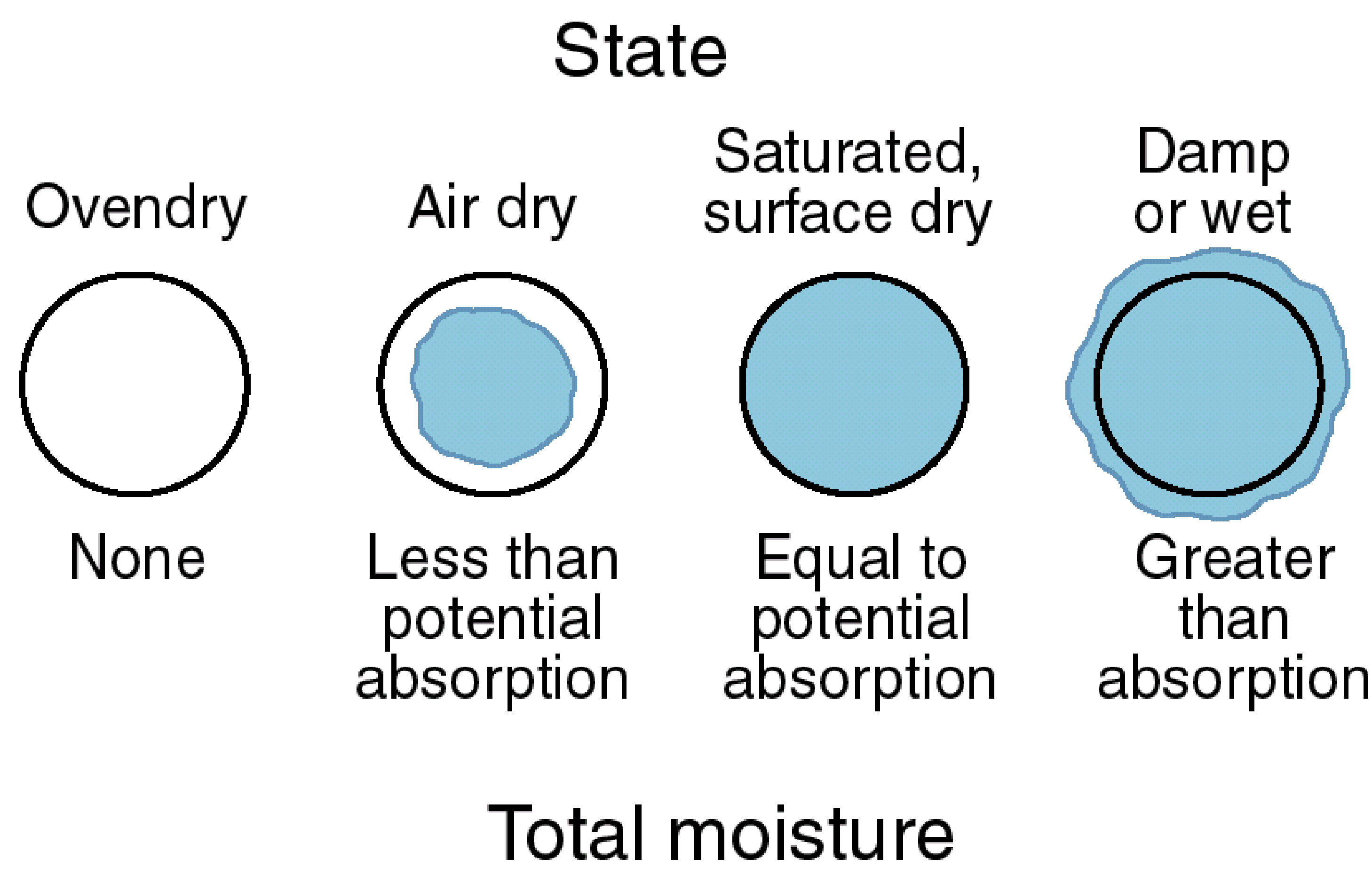
Variation in Grading of a Coarse Aggregate

Std. Dev. %	Batch to Batch	Sampling	Inherent &Testing
Process Stream	3%	1%	1%
Belt to Bin	5%	1%	1%
Bin Discharge	<u>8%</u>	3%	1%
Barge	<u>10%</u>	<u>7.5%</u>	1%
Stockpile	<u>8%</u>	<u>4.5%</u>	1%
Truck	<u>8.5%</u>	3.5%	1%

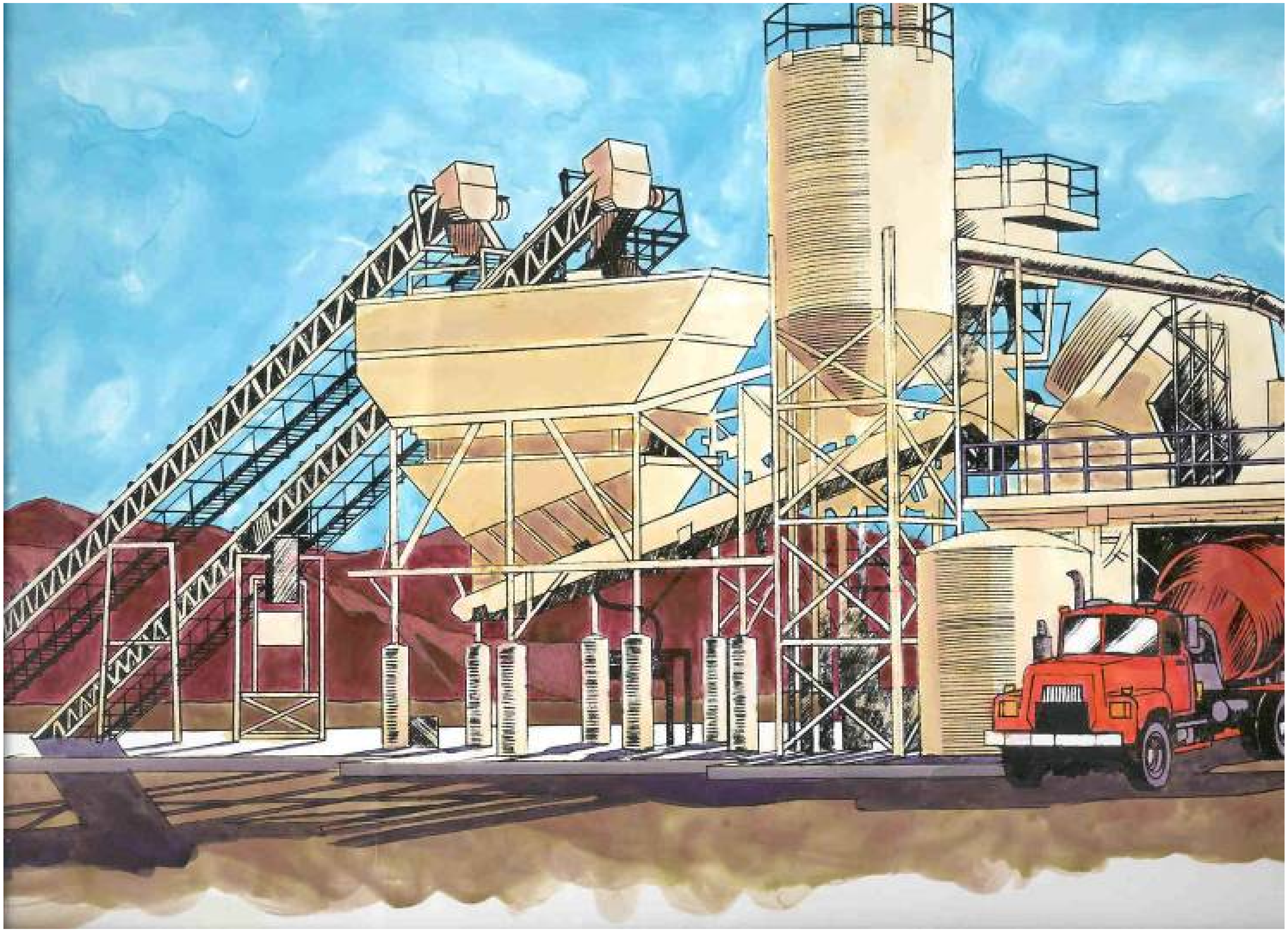
Aggregate Grading – Summary

- Practically Any Sound Aggregate Distribution Can Be Combined to Produce a Given Concrete Strength
- But Poorly Graded Mixes Cause Construction and Performance Problems
- Find the Optimum Gradation that Best Meets Your Needs In the Field

Moisture Conditions



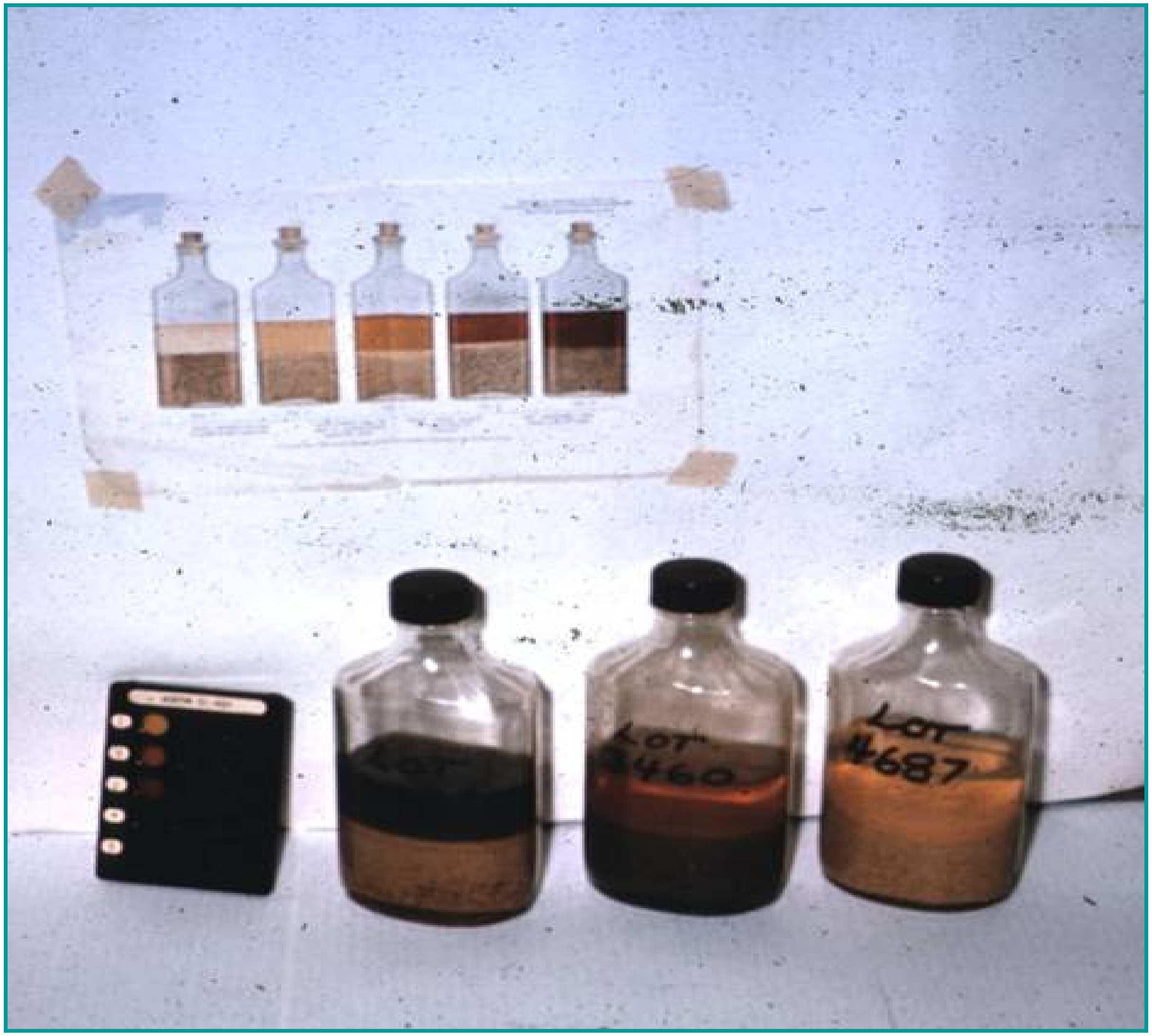
Concrete Production



Deleterious Substances

Item	Weight Percent of Total Sample, max
Clay lumps and friable particles	3.0
Material finer than No. 200 (75µm) sieve:	
Concrete subject to abrasion	3.0
All other Concrete	5.0
Coal and lignite:	
Where surface appearance of concrete is of importance	0.5
All other concrete	1.0

Organic Impurities

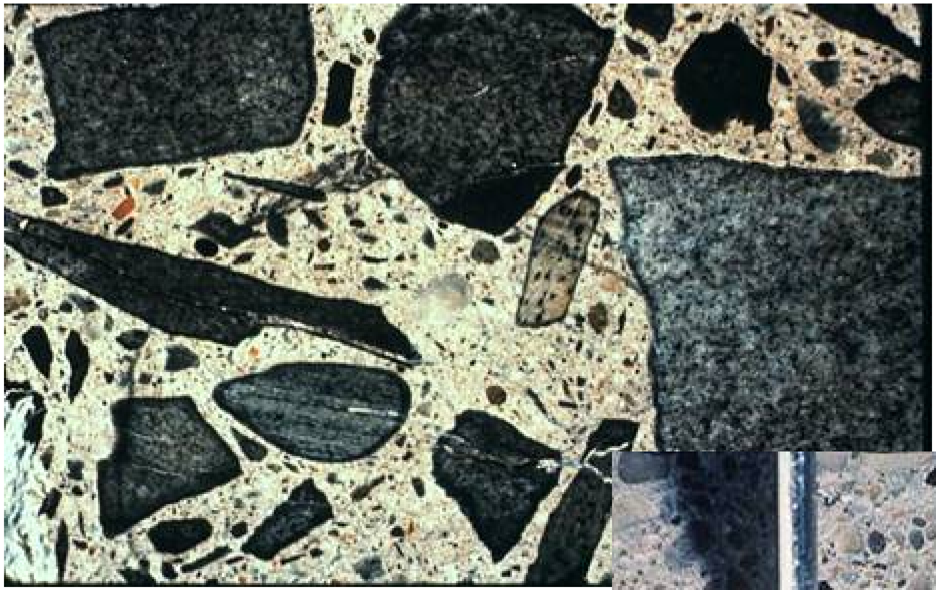


Deleterious Contributions

- Lack of Cleanliness
- Soft and/or friable
- Absorbed chemicals
- Fine coatings (hydration and bond)
- Porous
- Cherts and Shale
- AAR & D-cracking

SERVICE RECORD →

Summary of Aggregate Properties

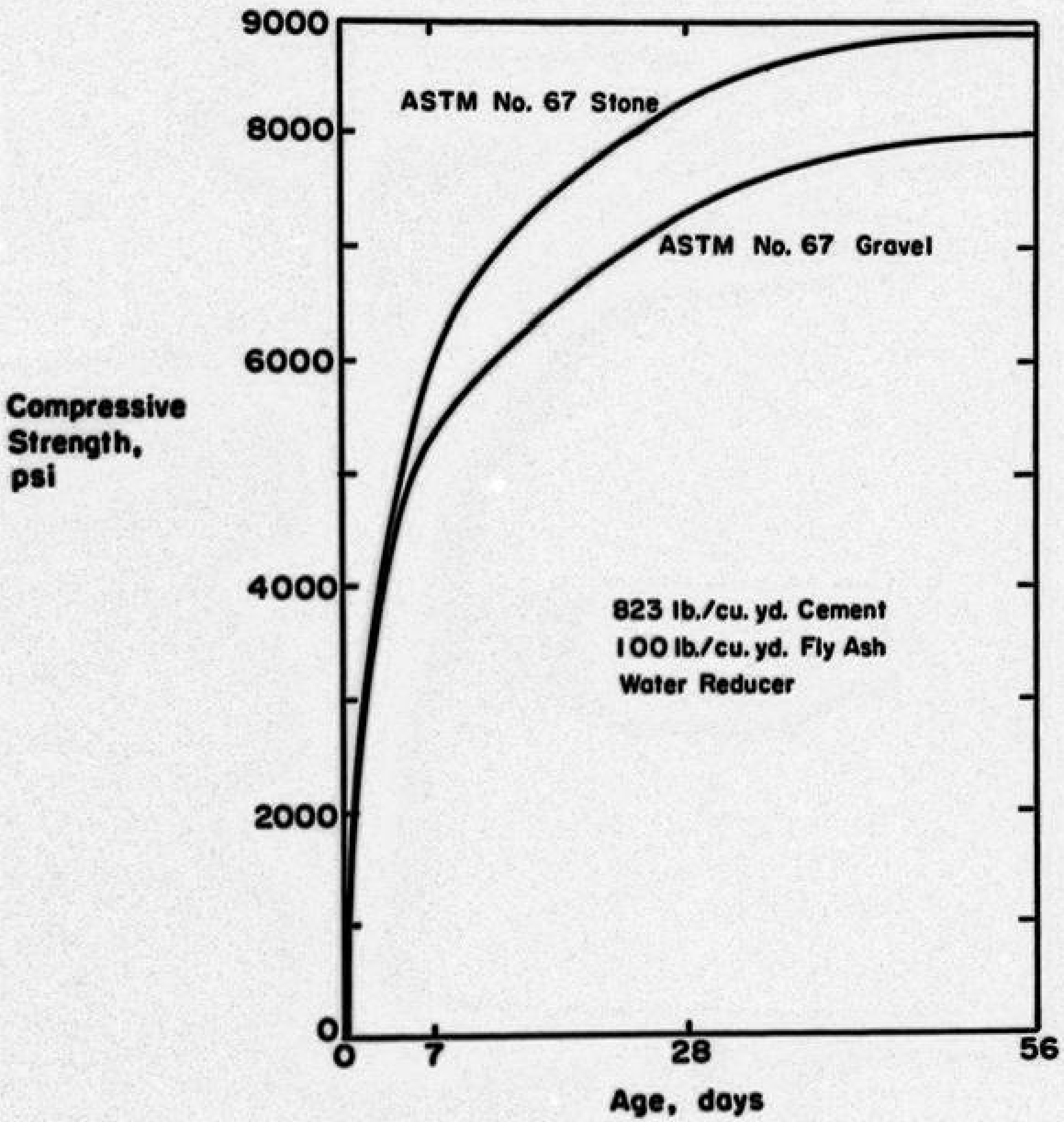


Aggregate Performance

Characteristic	**Test**
Abrasion resistance	ASTM C 131, ASTM C 535, ASTM C 779
Freeze-thaw resistance	ASTM C 666, ASTM C 682
Sulfate resistance	ASTM C 88
Concrete Strength	ASTM C 39, ASTM C 78
Fine aggregate degradation	ASTM C 1137
Alkali Resistance	ASTM C 227, ASTM C 289, ASTM C 295, ASTM C 342, ASTM C 586, ASTM C 1260, ASTM C 1293

Influence of Aggregates

- STRENGTH
  - Aggregate shape
  - Aggregate size
  - Aggregate surface texture



Compressive Strength of Various Sizes and Type of Coarse Aggregate for 7500 psi Concrete

Influence of Aggregates

- SHRINKAGE

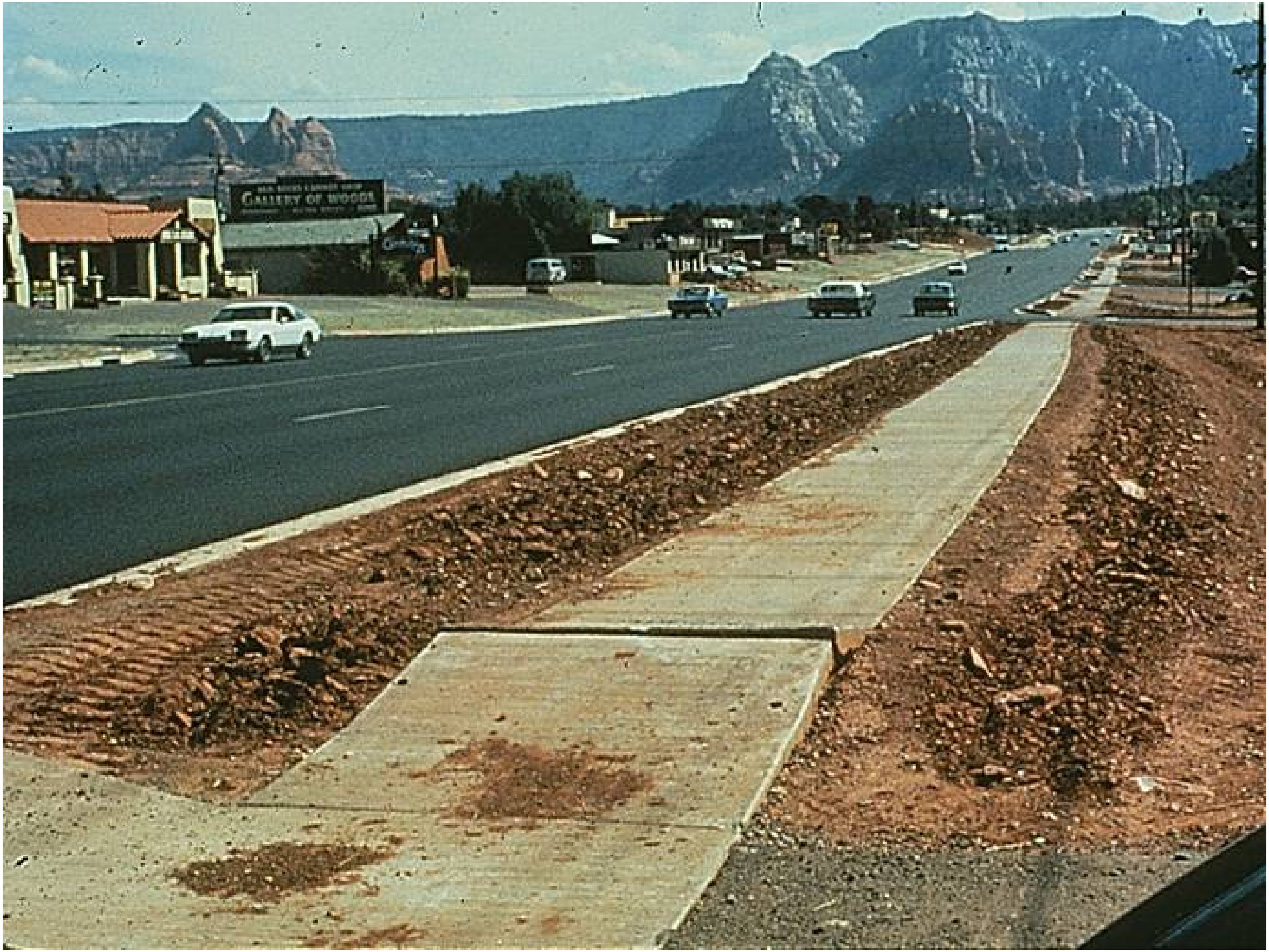
Drying Shrinkage & Thermal Dilation

- After Curing --
- Concrete Dries
- Shrinks as it Dries
- Up to 1 in. / 100 ft.
- Goes on up to 1 Yr
- If it is Rewetted
- Some Expansion
- Not Back to Original

- Concrete --
- Expands Upon Heating
- Contracts Upon Cooling
- Up to 3/4 in. / 100 ft.
- For a 100F Temp Range
- Cycles with Temp.
- Day / Night
- Summer / Winter

Volume Change of Concrete

- Thermal Dilation
  - Aggregate Minerals – Types & Quantity
  - AASHTO TP 60 Coefficient of Thermal Expansion
- Drying Shrinkage
  - Coarse Aggregate – Stiffness, Maximum Size
  - Cement Paste – Amount & Composition
  - Coarse Aggregate – Volume Change for some aggregate (recycled concrete)
  - ASTM C 157 (AASHTO T 160) Length Change
  - ASTM C 1581 (AASHTO PP 34-99)
Restrained Ring Shrinkage Cracking Tendency


GALLERY OF WOODS

Thermal Coefficient, Millionths/ F

	Aggregate	Concrete
Quartzite	6.5	7.5
Quartz	6.2	6.7
Sandstone	6.2	6.6
Granite, Gneiss	4.2	5.5
Basalt	3.8	4.4
Limestone	3.0	4.2

Concrete Drying Shrinkage (6 mo)

	Millionths (in./in.)	% Length Change
Quartz	530	0.053
Granite	640	0.064
Limestone	640	0.064
Sandstone	700	0.070
Gneiss	750	0.075
Sandstone	740	0.074
Greywacke	900	0.090

Drying Shrinkage

- Low (28 d) .03% = .0003 x 100 ft. x 12 = 0.36 in.
- High (6 mo) .09%= .0009 x 100 ft. x 12 = 1.08 in.

	7 Day	28 Day	6 Month
Quartz	.018%	.031%	.053%
Granite	.022	.038	.064
Limestone	.023	.042	.064
Sandstone	.024	.042	.070
Gneiss	.024	.042	.075
Sandstone	.023	.044	.074
Greywacke	.030	.055	.090

Influence of Aggregates

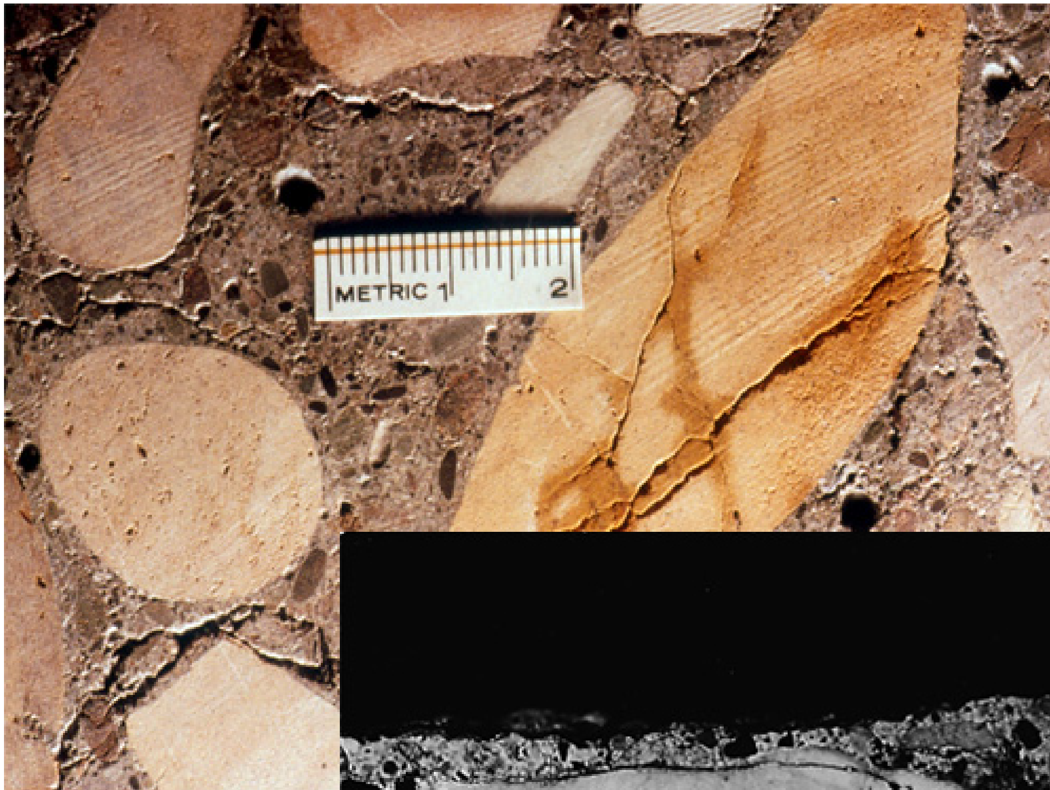
- WATER DEMAND

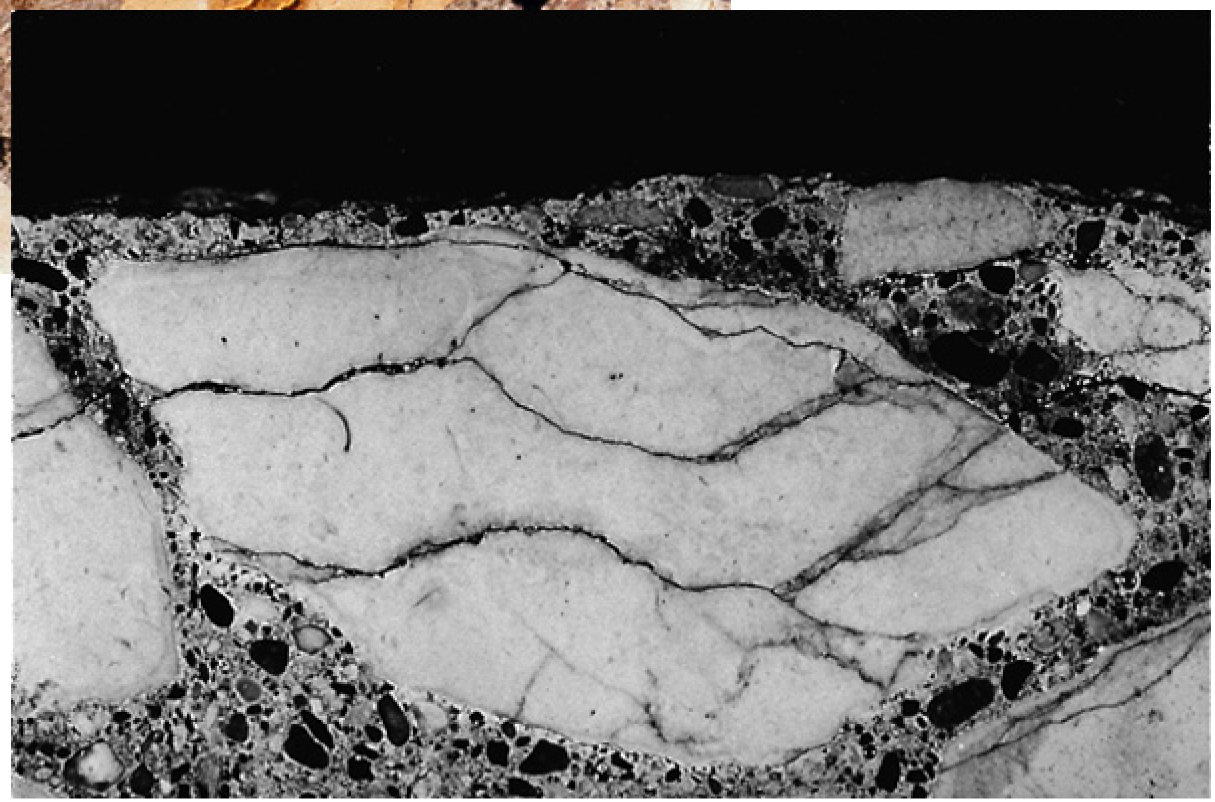
Influence of Aggregates

- AIR CONTENT
  - Maximum size
  - Gradation
  - Coarse to fine ratio
  - Testing procedures

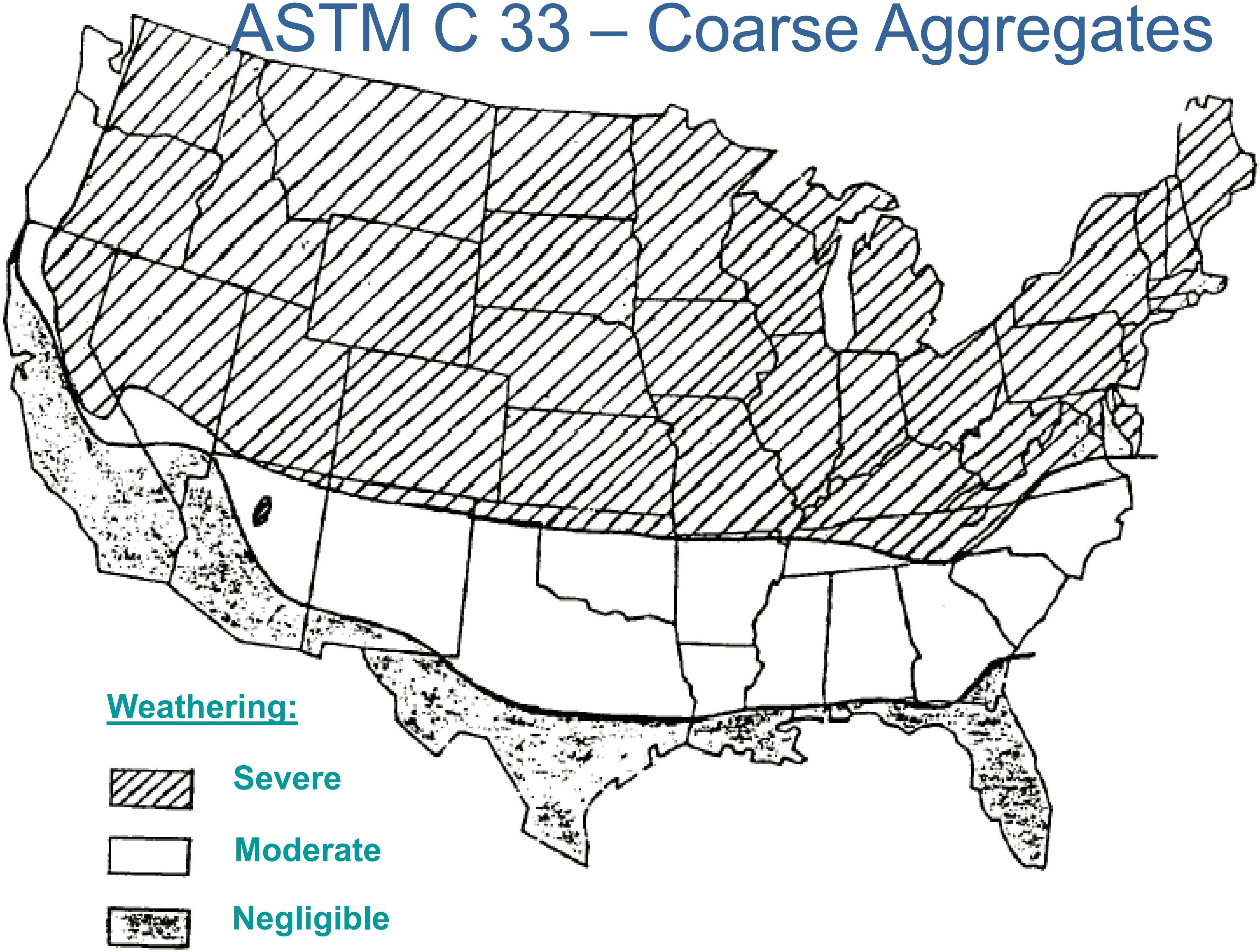
Influence of Aggregates

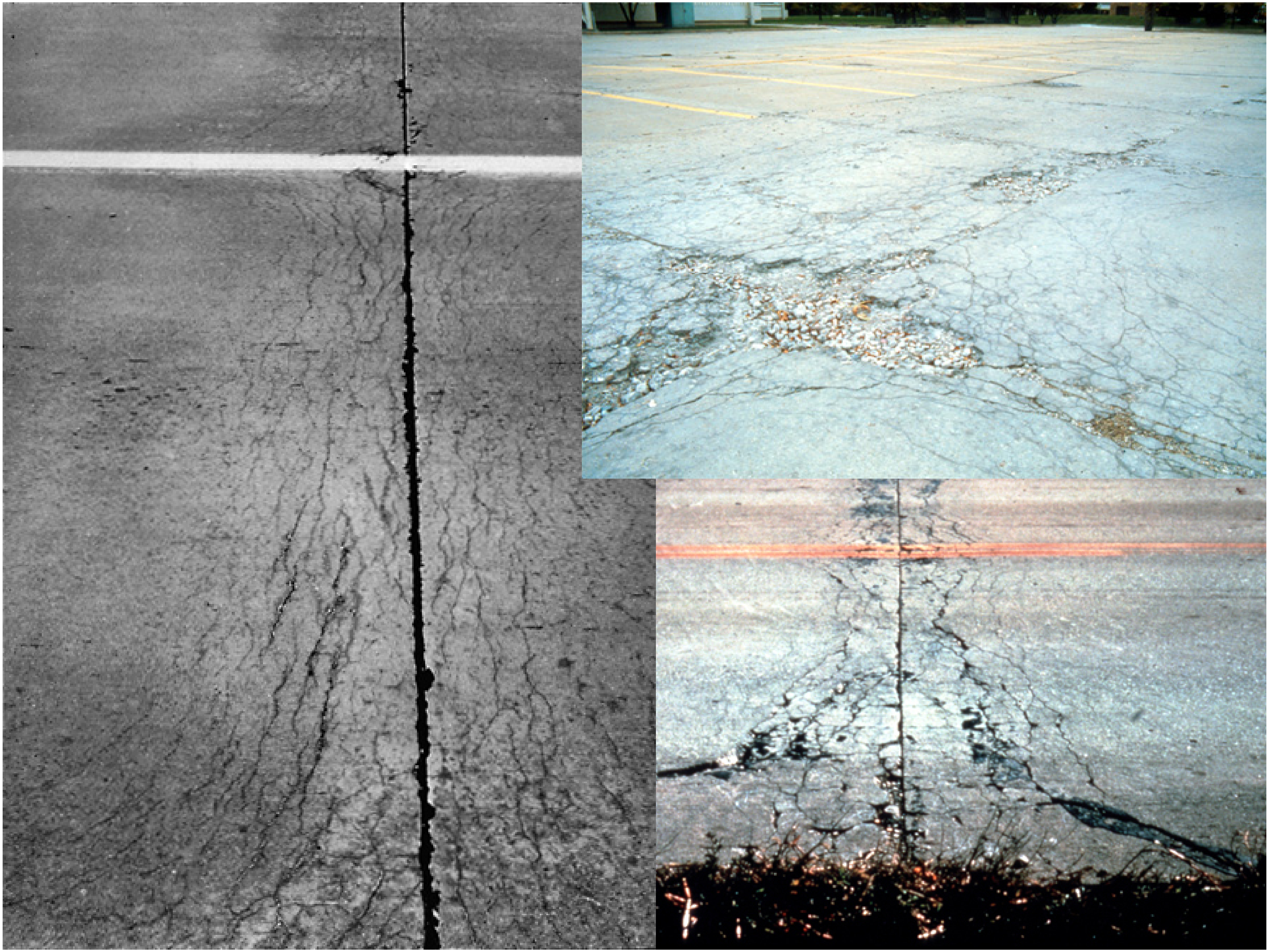
- DURABILITY
  - Weathering
  - Impurities
  - Hardness


METRIC 1
2



ASTM C 33 – Coarse Aggregates





Alternate Wetting and Drying

- Weathering
- Expansion and contraction – temperature and moisture
- Strain develops
- Permanent volume increase in concrete
  - Clay lumps
  - Friable particles
  - Shale
  - Cracking
  - Popouts – moisture swelling

Abrasion and Skid Resistance

- ASTM C131 or C535
- Test concrete for abrasion
- Skid resistance
- Want at least 25% siliceous content

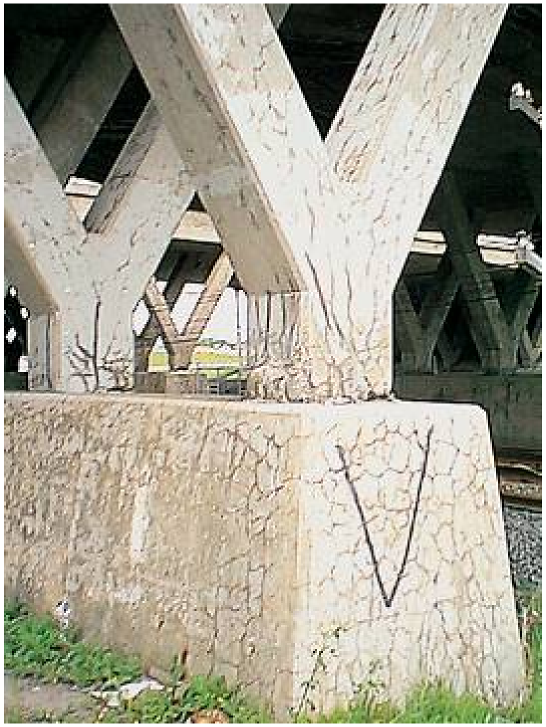
Resistance to Acids

- Acids will not attack siliceous aggregates
- Acids will attack calcareous aggregates
- Calcareous aggregates can be sacrificial and even attack wear

Fire Resistance

Alkali-Aggregate Reactivity

- ASR – Alkali Silica Reaction
- ACR – Alkali Carbonate Reaction



Alkali-Aggregate Reaction

Alkali-Silica Reactive Rocks & Minerals

<u>Rocks</u>
Shale
Sandstone
Limestone
Chert
Flint
Quartzite
Quartz-arenite
Gneiss
Argillite
Granite
Greywacke
Siltstone
Arenite
Arkose
Hornfels

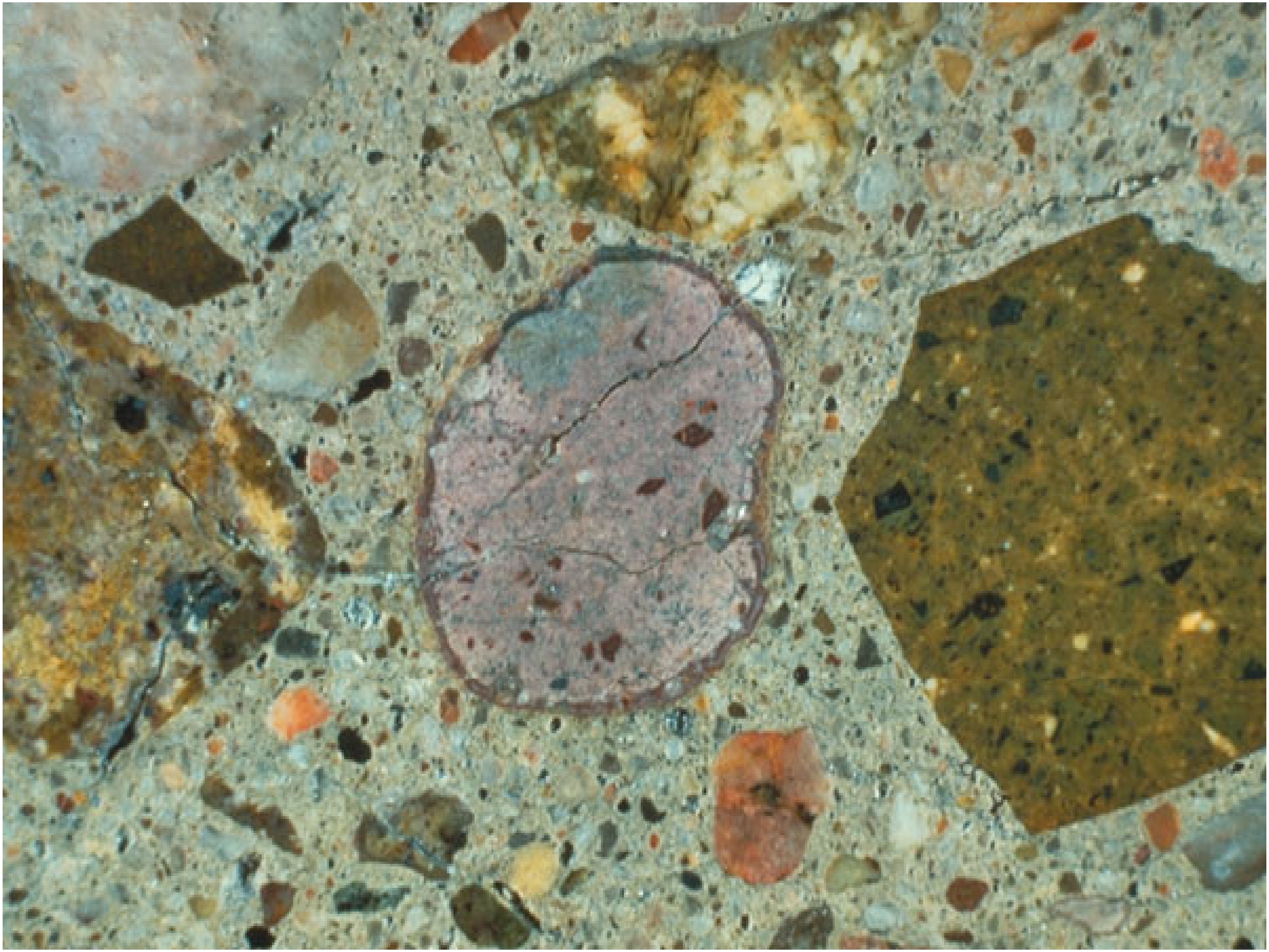
<u>Reactive Minerals</u>
Opal
Tridymite
Cristobalite
Volcanic glass
Cryptocrystalline (or microcrystalline) quartz
Strained quartz

Alkali-Carbonate Reactive Rocks

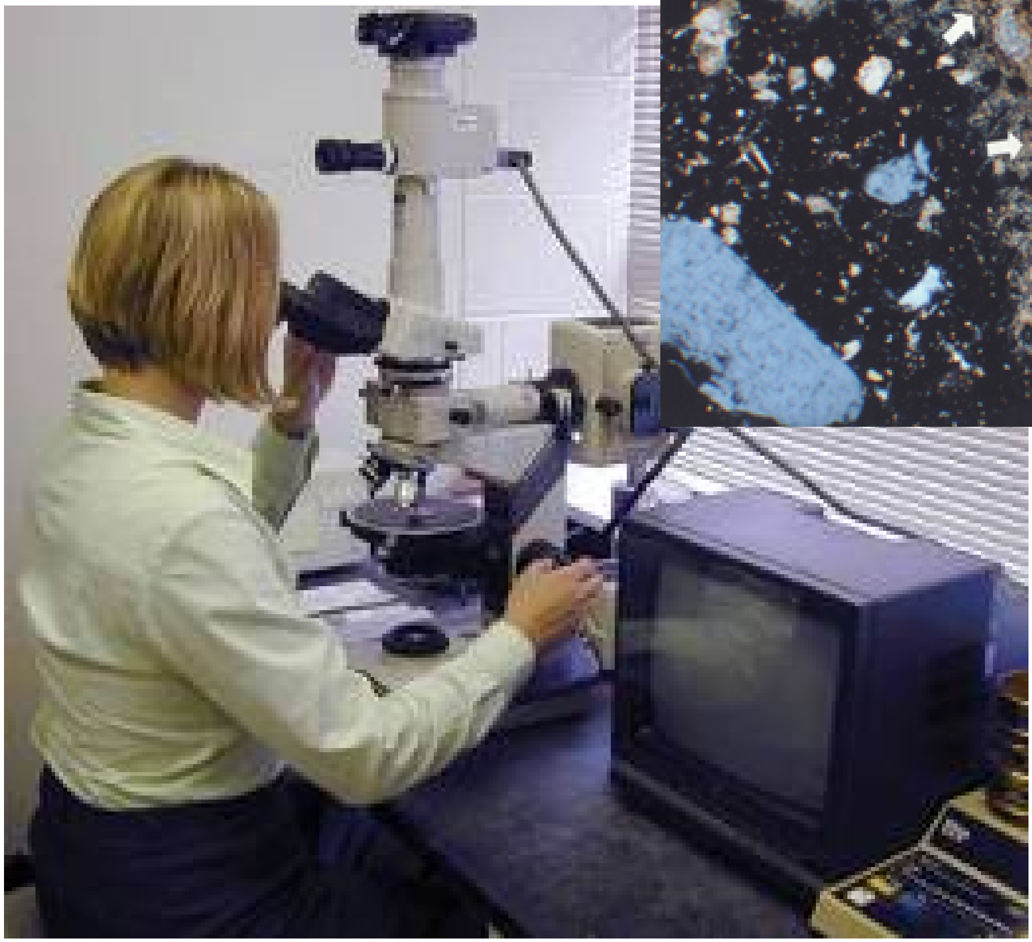
Calcitic dolomites
Dolomitic limestones
Fine-grained dolomites

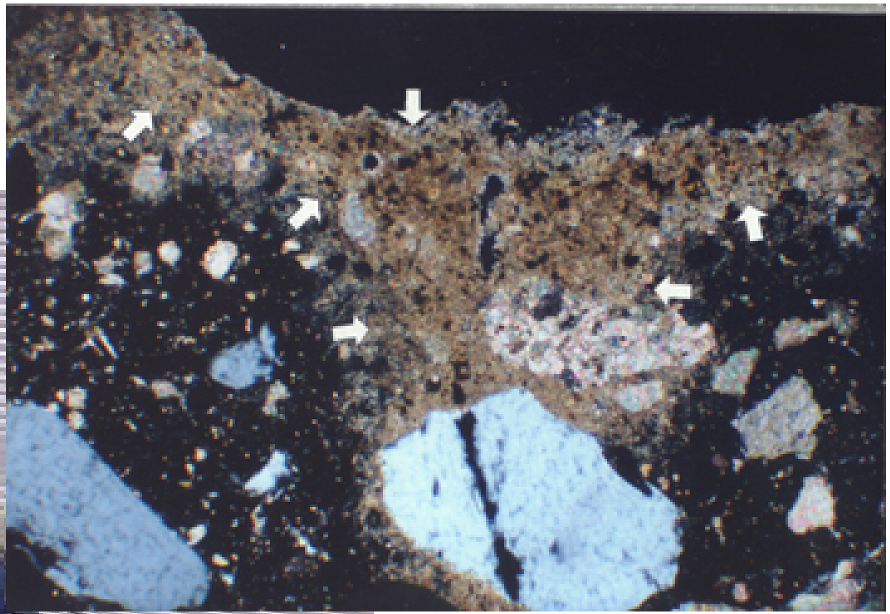
ASR

FHWA Report, 2002



Petrographic Examination





In Summary

- Aggregate properties
- Aggregate performance

Questions?