Well Graded Concrete

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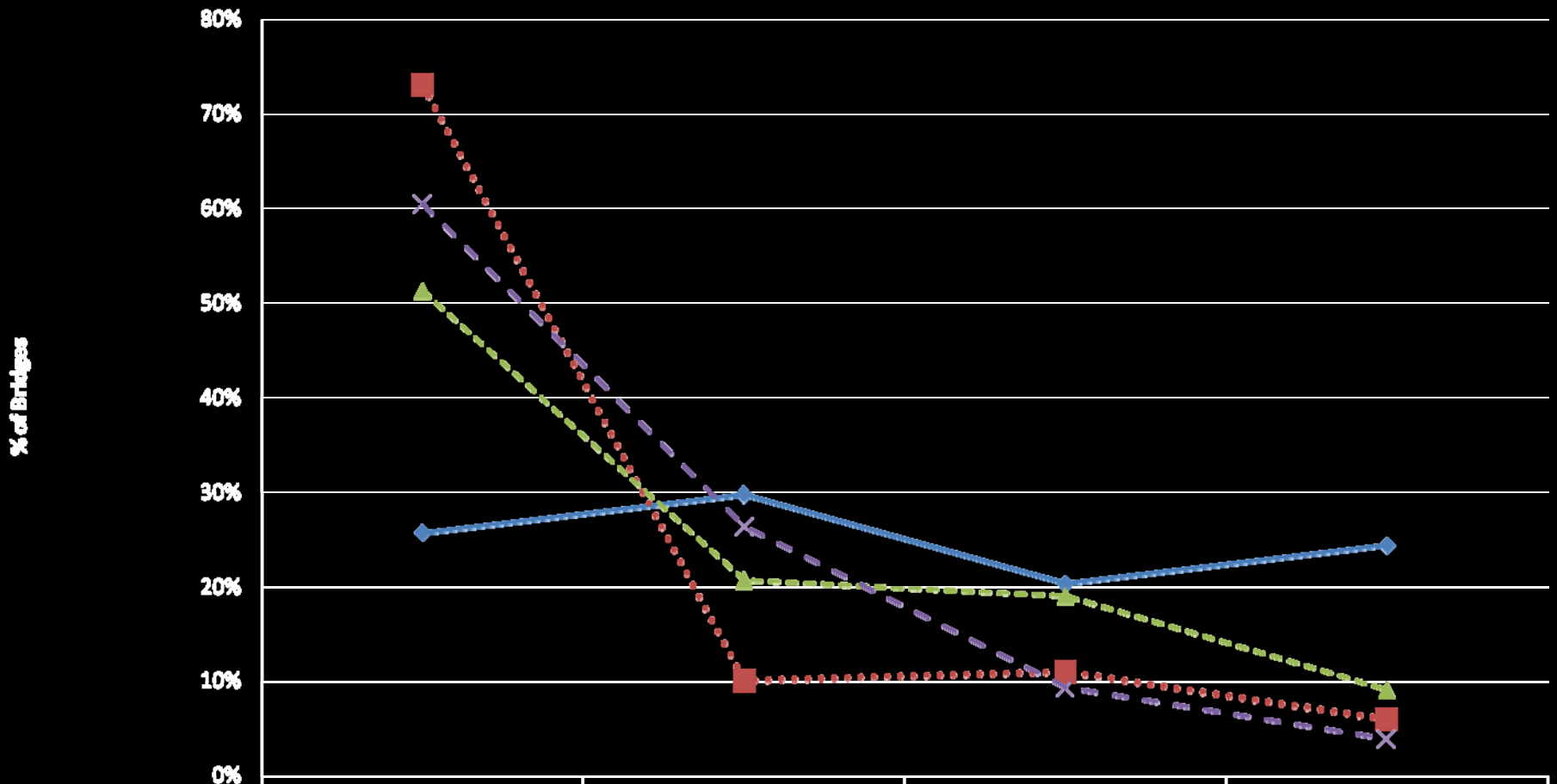
Agenda

- Why is ODOT Going to Well Graded Concrete?
- Role of Well Graded Aggregate in Concrete
- Challenges

The Results

CHART 1: Overall Rating of Bridge Decks for Cracks



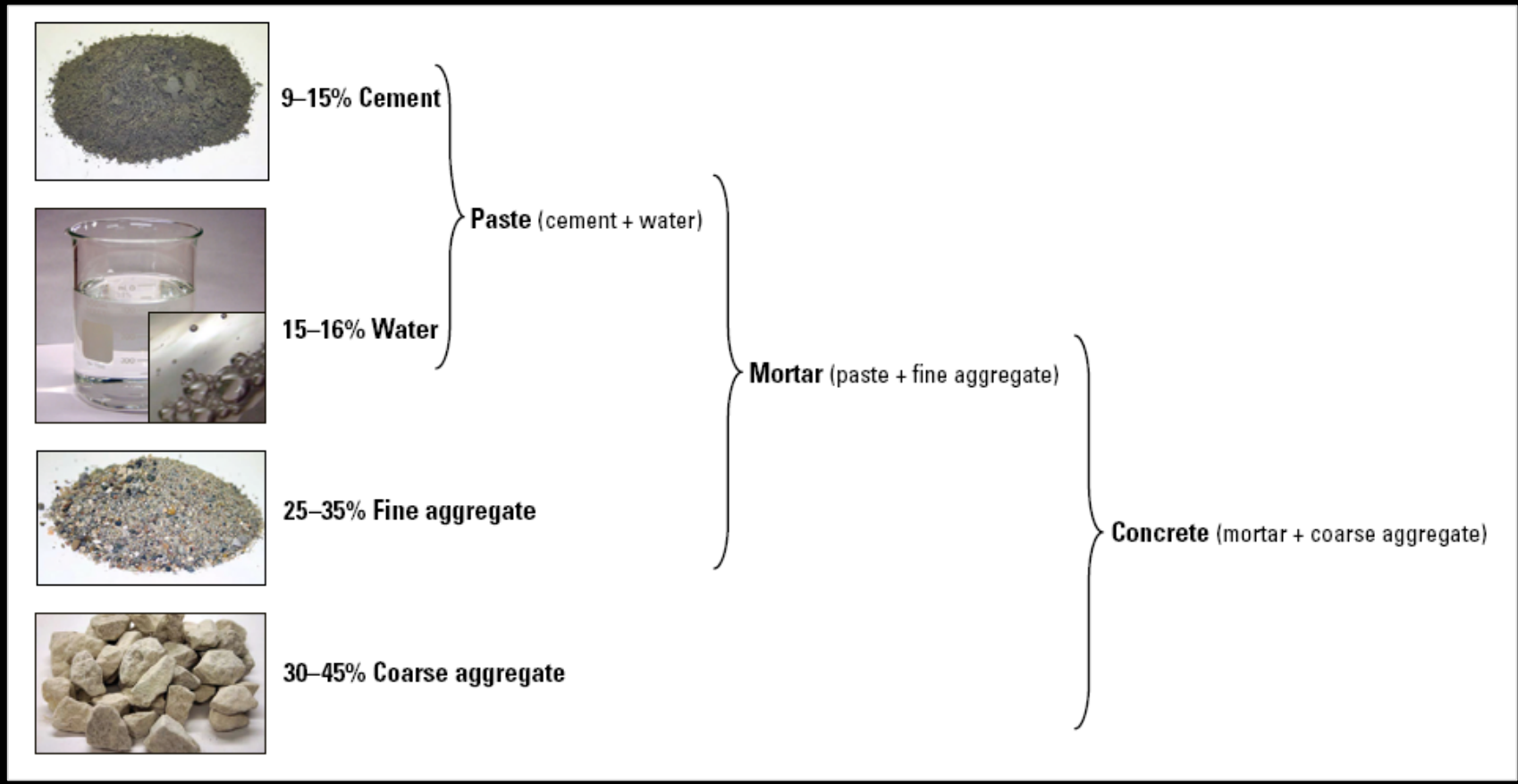
	A	B	C	D
Class S + Options	26%	30%	20%	24%
Special Mix	73%	10%	11%	6%
High Performance	51%	21%	19%	9%
QC/QA	60%	26%	9%	4%

Findings from Inspection

- Gap Graded Concrete (Class S) performed poorly
  - Only 26% of decks reviewed received a rating of A
- Well Graded Concrete ('Special' Mix) performed well
  - 73% of decks reviewed received a rating of A
- Findings led ODOT to pursue Well Graded Concrete

What is Concrete?

From, "**Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual**"



Concrete Aggregate

Variables that effect Concrete

- Structural and Functional Design
  - Must carry the designed loads without failing
- Quality (and Variability) of Materials
  - Aggregate, Admixtures, Cements, and Supplementary Cementitious Materials
- Construction Factors
  - Weather, equipment, personnel

The Role of Aggregate

From, "**Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual**"

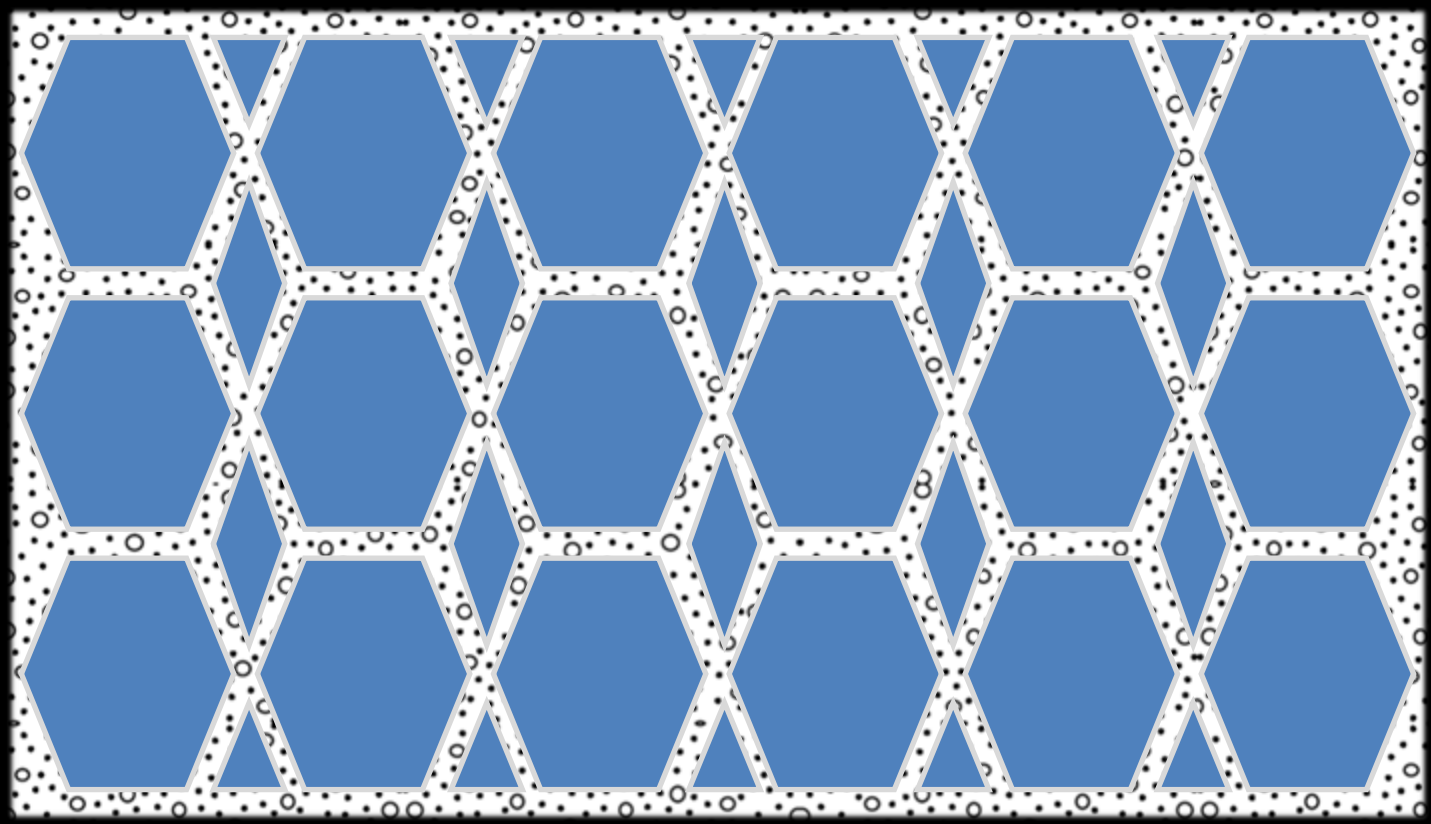
- Accounts for 60 to 75 percent of concrete by volume.
- Acts as the filler held together by the cement
- Compared to cement paste, aggregates are generally more chemically stable and less prone to moisture-related volume changes.
- Therefore, in concrete mixtures it is desirable to maximize the volume of aggregate and reduce the volume of cement while maintaining desired concrete properties.
- How do we minimize the volume of cement while maintaining our desired concrete properties?

Well Graded Aggregate

From, "**Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual**"

- Add an intermediate aggregate
  - Smaller particles (like No. 4 mesh found in ODOT 8s) reduce the volume of void space in a traditional 57 sand concrete mix.
- Use less sand
  - To maximize the mix you only want to have enough cement to coat each aggregate. The fine portion of the sand has the particles with the highest surface to volume ratios. Using a well graded mix minimizes the sand, thus minimizes the fine portion of the concrete mix.
- Reduction of cement /voids and increase in coarse aggregate generally yields concrete with
  - Lower Permeability
  - Lower Shrinkage

The Principle of Void Reduction

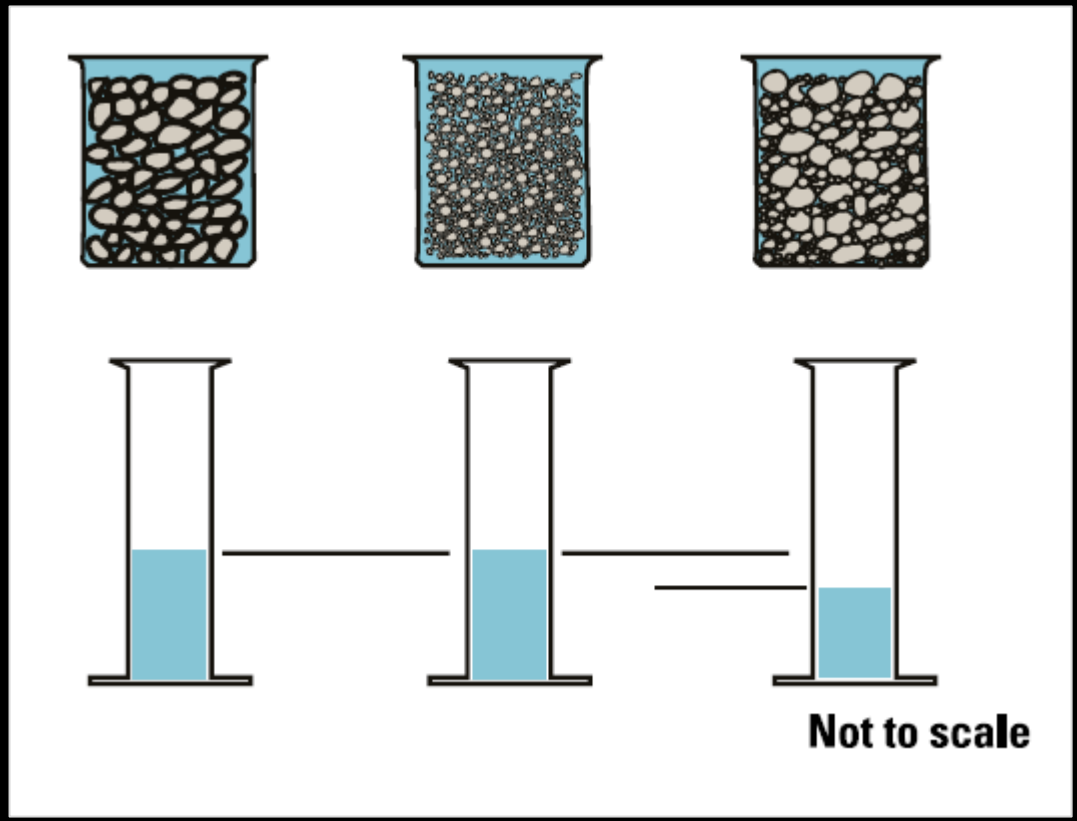


Particle Shape!

More Cement to Coat

Well Graded Aggregate

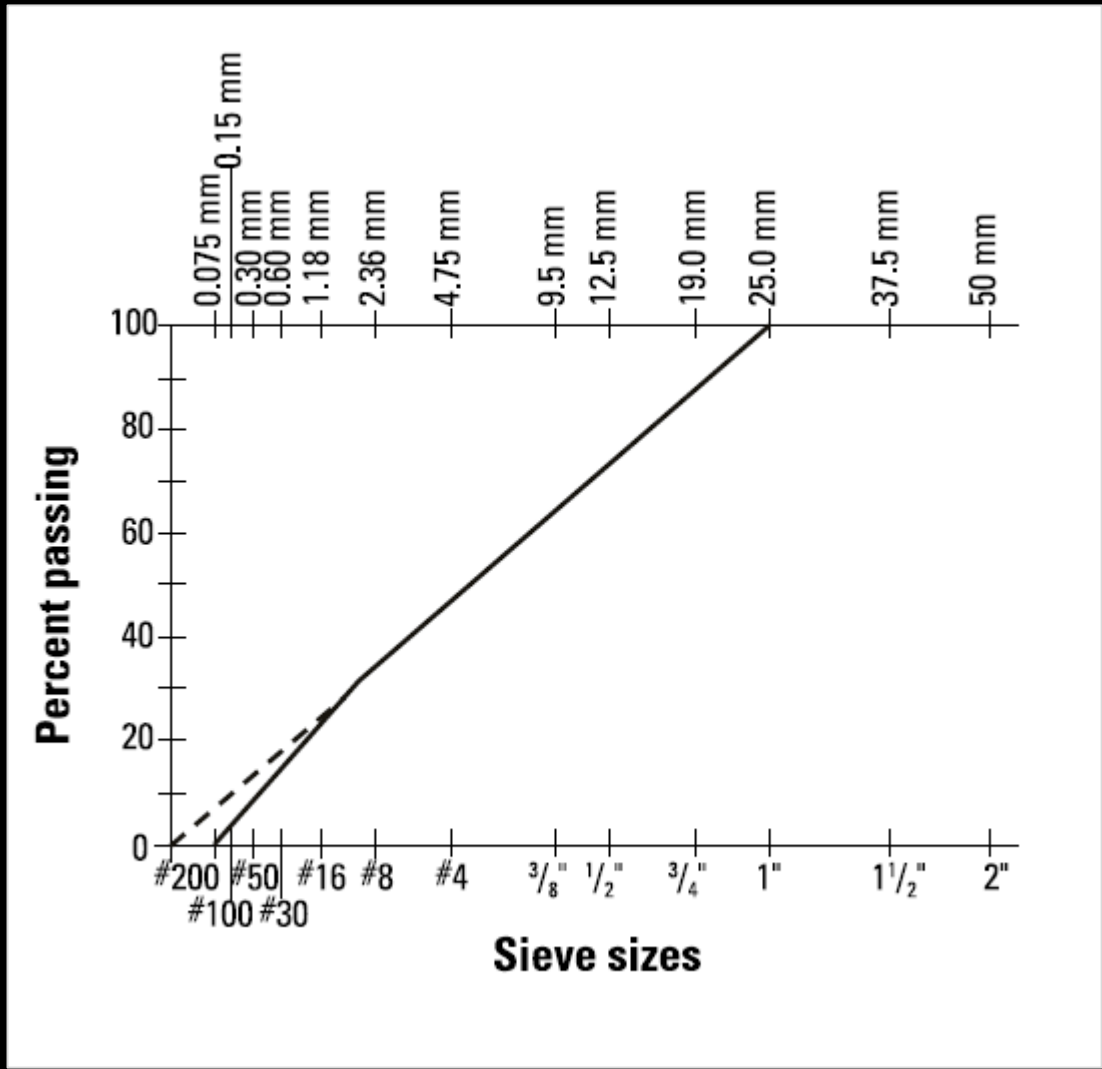
From, "**Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual**"



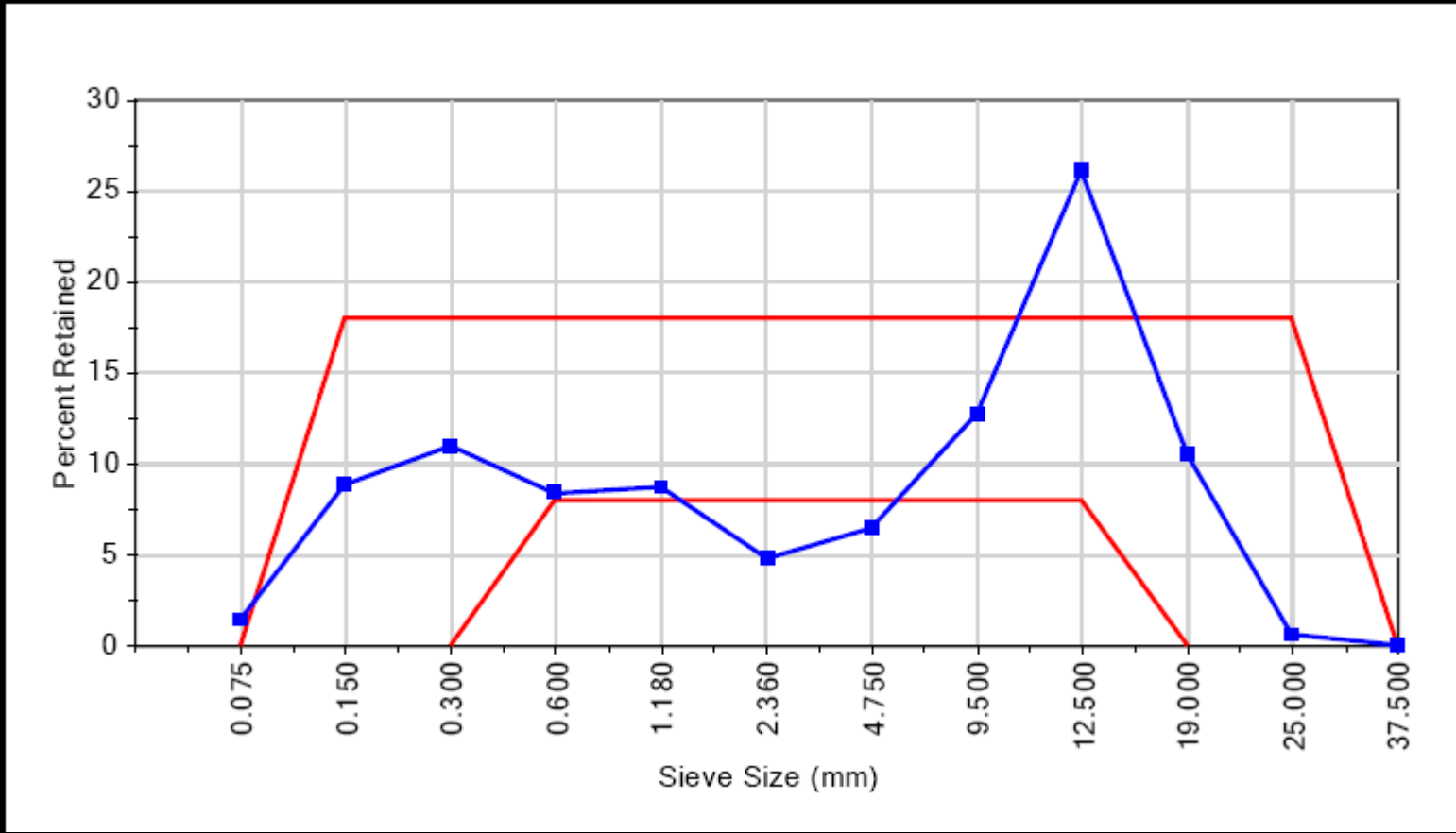
How to Determine a Well Graded Aggregate for Concrete

- Three tools to help in the process of optimizing the combined aggregate grading (Shilstone):
- The 0.45 Power Chart:
    - shows trends.
- The Percent of Aggregate Retained on Each Sieve (PARS):
    - shows details.
- The Coarseness Factor Chart (CFC):
    - provides overview of the mixture.

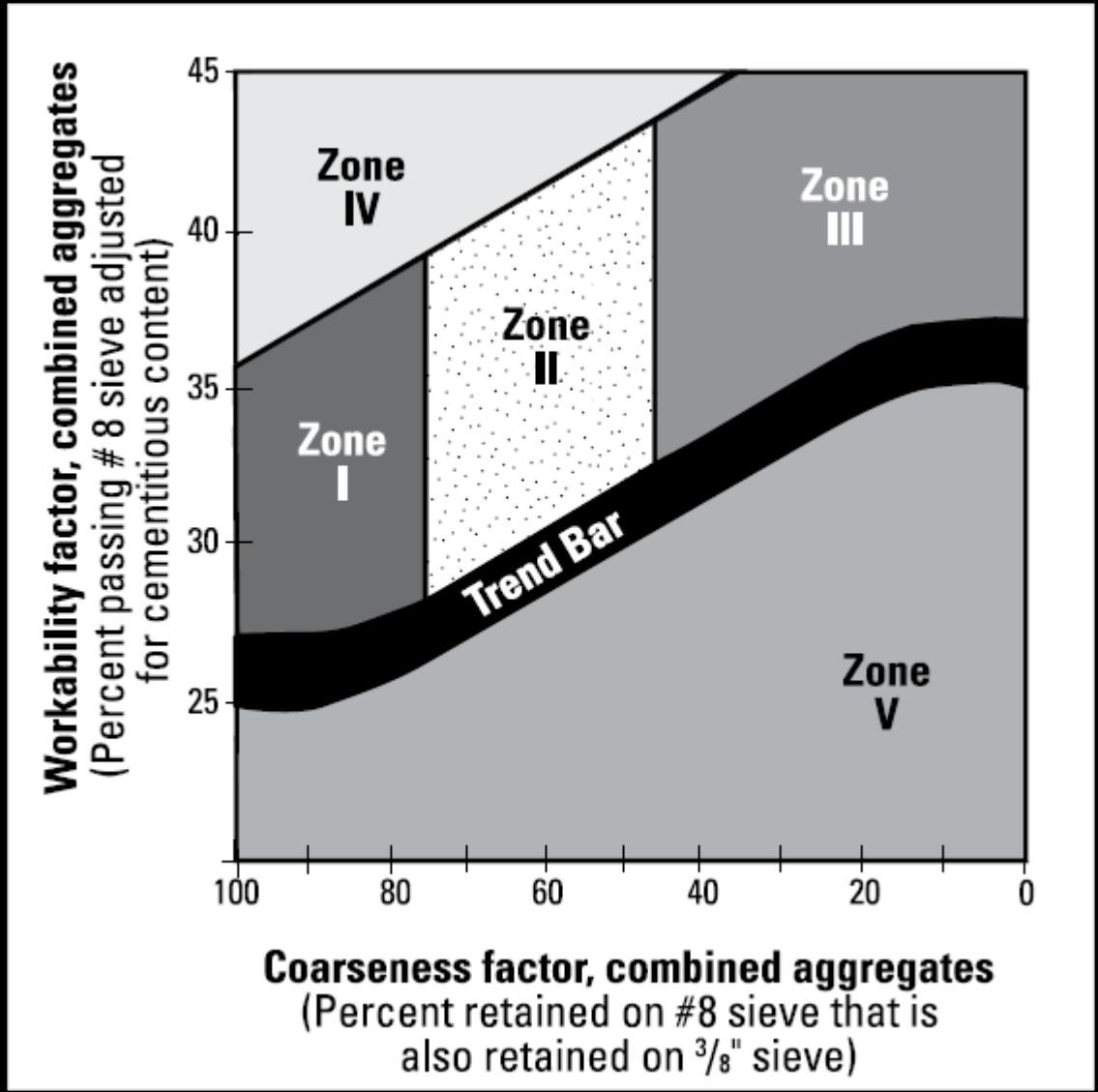
Power 45 Chart



Percent Retained Chart



CF/WF Chart


Workability factor, combined aggregates
(Percent passing # 8 sieve adjusted for cementitious content)
45
40
35
30
25
Zone IV
Zone III
Zone II
Zone I
Trend Bar
Zone V
100
80
60
40
20
0
Coarseness factor, combined aggregates
(Percent retained on #8 sieve that is also retained on 3/8" sieve)

The Coarseness Factor Chart (CFC):

- Mathematically separates aggregate into three groups
- Coarse particles are those retained on the 9.5-mm (3/8-in.) sieve.
  - They provide the primary body of the mixture.
- Intermediate particles pass the 9.5-mm (3/8-in.) sieve and are retained on the 1.18-mm (#8)
  - These particles fill major voids between the coarse particles.
- Fine particles pass the 1.18-mm (#8) sieve.

$$\text{Coarseness Factor} = \frac{\%\ \text{Coarse Aggregate}}{\%\ \text{Coarse Aggregate} + \%\ \text{Intermediate Aggregate}} \cdot 100$$

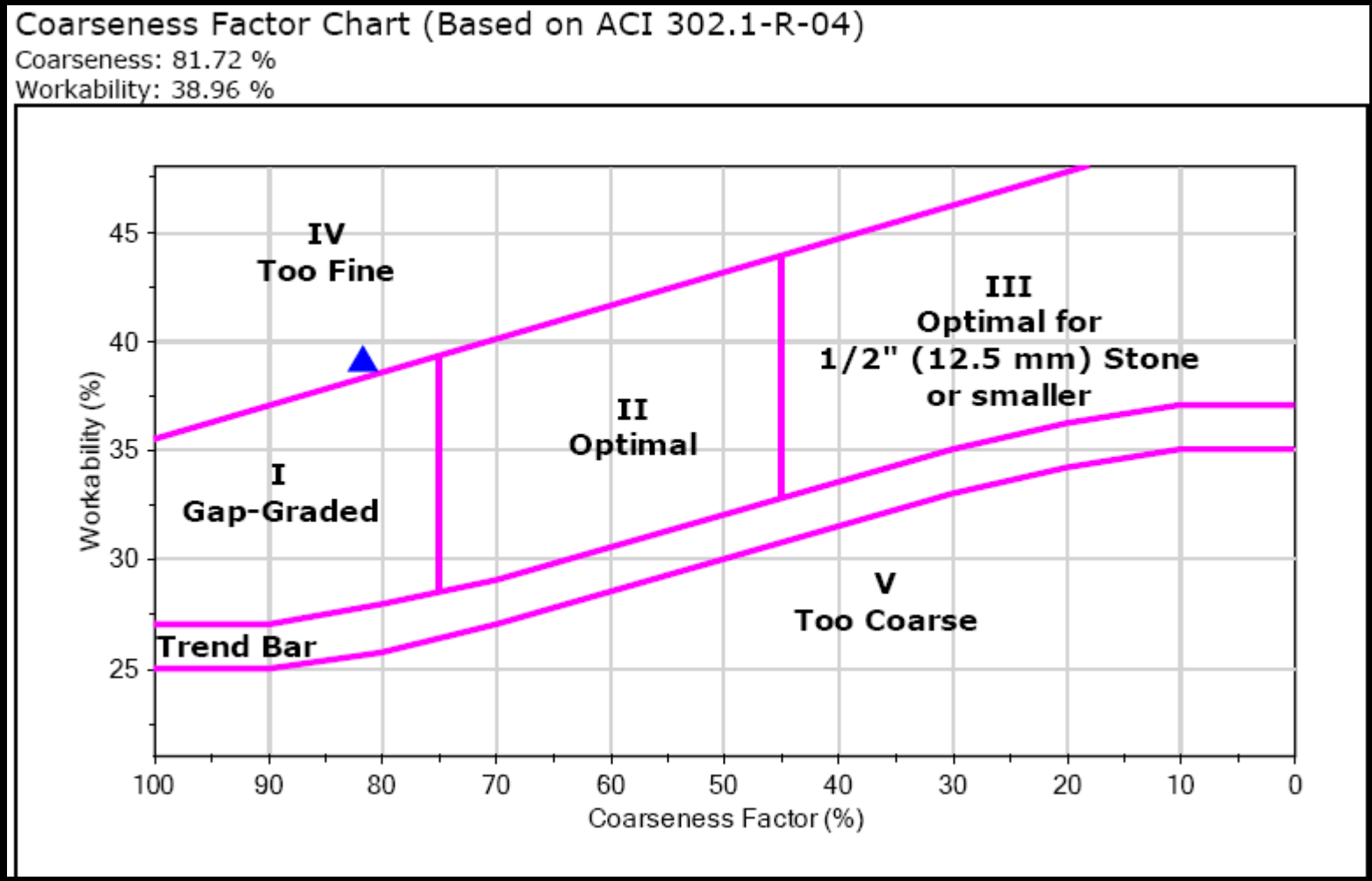
- 100 = No intermediate Aggregate (gap graded)
- 0 = No coarse aggregate (+3/8”)

Workability Factor

- The workability factor is the percent of the combined aggregate that passes the 2.36-mm (# 8) sieve plus an adjustment for the amount of cementitious material in a mixture.
- The base cementitious materials content for the chart is 335 kg/m3 (564 lb/yd3).
- The workability factor is increased 2.5 points for each 56 kg/m3 (94 lb/yd3) variation from the original cementitious materials content.

PCJMF: C110759

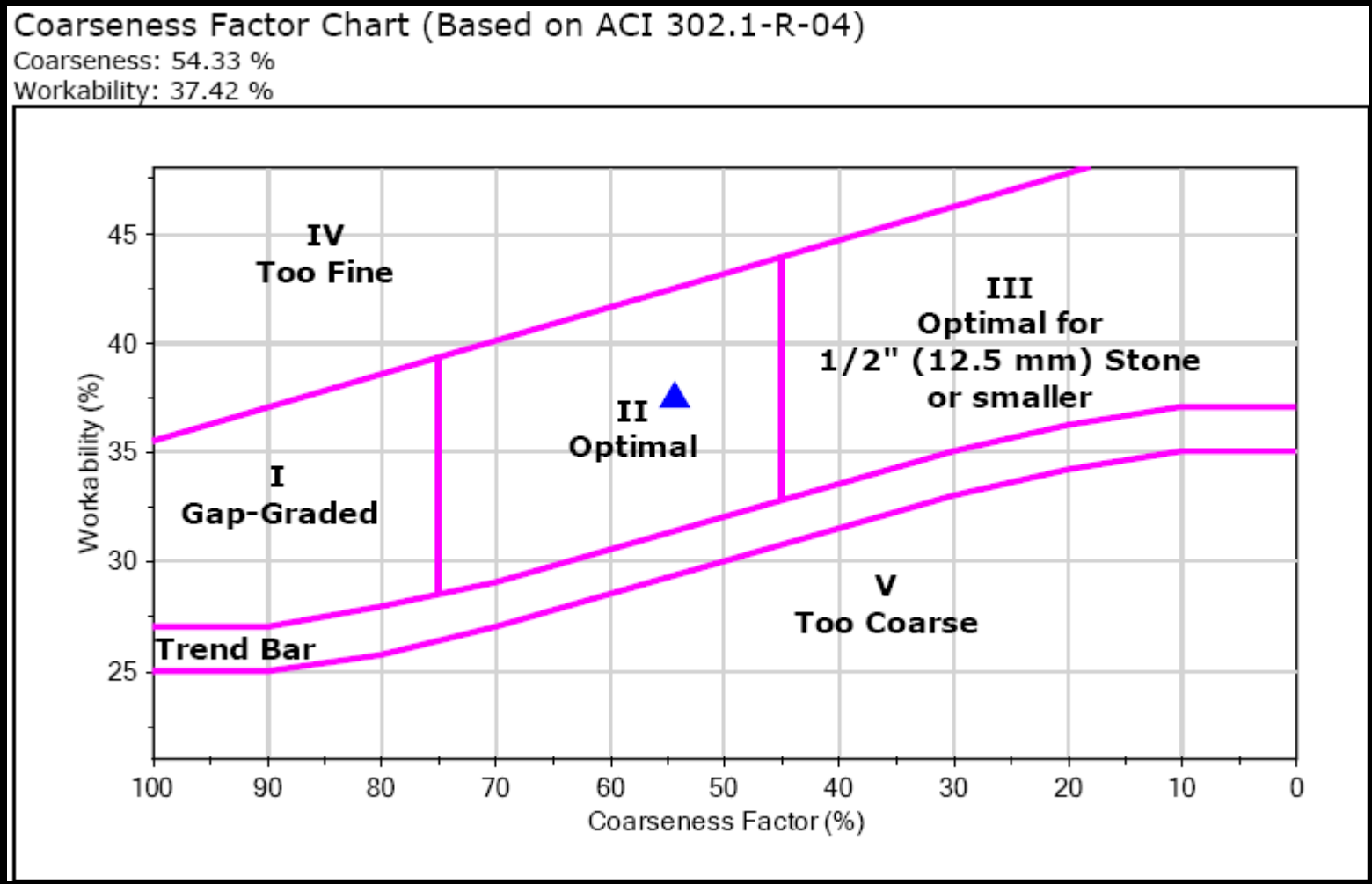
58% 57s – 1550 lbs/cu. yard
42% Sand – 1125 lbs/ cu. yard



1,125 lbs per cubic yard of natural sand and 1,550 lbs per cubic yard of 57s

38% 57s - 1,016 lbs/ cu. yard
22% 8s – 588 lbs/cu. yard
40% Sand - 1,070 lbs/cu. yard

JMF Adjusted



Proposed ODOT Control Measures

- Does my gradation change?
  - No (unless desired)
- Additional testing?
  - No
- Readi-Mixer develops aggregate size blend and gets approval (JMF). Based on average gradation
- Readi-Mixer obtains last gradation results on delivery of aggregate and compares to approved JMF
  - Tolerance is +/- 6% for each sieve of an aggregate size
- If outside of 6% tolerance, then Readi-Mixer needs to either adjust mix or get material back within tolerance
- Test runs (State wide) for bridge work will start next year

Challenges

- Could put additional demand on an already limited size of aggregate
  - ODOT 8s may be limited
- By ODOT going to a well graded concrete blend, other's may follow suit.
- Use of 4s in concrete pavement
  - Reduce the demand on 8s
- Allowance of producer defined gradations for concrete items

Aggregate Producer

Readi-Mix Producer

THANK YOU

Concrete Pavement

Structural Concrete