# Optimized Aggregates



# Goal of Optimized Aggregates

- Reduce permeability
  - Reduce mortar
    - Less shrinking
    - Cost savings related to less cementitious
- Better for pumping and finishing
- Lower w-cm ratio
- Greater durability

# Improved Finishing

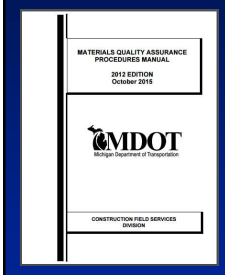
Less Handwork

Better Barrier Walls

# Workability

Harsh initial appearance, but very workable once vibrated.

# MQAP Section 4.13




- Does not specify MDOT gradation series for aggregates
  - CA – retained on ½ inch sieve or greater
  - IA – retained on No. 4 and passing ½ inch
  - FA – passing No. 4 sieve
- Physical Requirements for each aggregate are located in subsection 902.03.C of the 2012 Spec Book

# MQAP Section 4.13

- Stockpile Management Plan
  - Process controls for shipping, handling, and storage
- Two different max aggregate sizes
  - Pavements ≥ 6 inches = 2 inch max size
  - Pavements < 6 inches = 1½ inch max size
  - All other applications = 1½ inch max size

# The "Shilstone" Method

- Utilizes:
  - Fineness Modulus
  - Power 0.45 Charts
  - Percent Retained Charts
    - ~~5-15 or 8-18 Rule~~
  - Coarseness Factor
  - Workability Factor

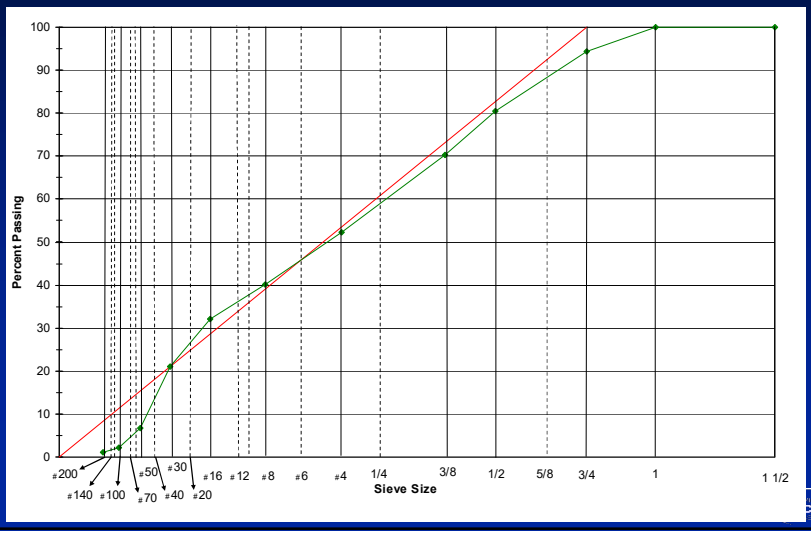
To determine "Optimized" Gradations

# Combined Gradation

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | 6AA | 26A | 2NS | | Combined | Percent |
| 9 | | % Blend ⇨ | 50.0% | 10.0% | 40.0% | 0% | 100% | Retained |
| 10 | | Sieve Size | | | Percent Passing | | | |
| 11 | 50 mm | 2 | 100.0 | 100.0 | 100.0 | 0.0 | 100.0 | 0.0 |
| 12 | 37.5 mm | 1 1/2 | 100.0 | 100.0 | 100.0 | 0.0 | 100.0 | 0.0 |
| 13 | 25 mm | 1 | 98.6 | 100.0 | 100.0 | 0.0 | 99.3 | 0.7 |
| 14 | 19 mm | 3/4 | 77.7 | 100.0 | 100.0 | 0.0 | 88.9 | 10.5 |
| 15 | 12.5 mm | 1/2 | 41.6 | 99.5 | 100.0 | 0.0 | 70.8 | 18.1 |
| 16 | 9.5 mm | 3/8 | 22.7 | 79.4 | 100.0 | 0.0 | 59.3 | 11.5 |
| 17 | 4.75 mm | #4 | 2.7 | 9.8 | 99.0 | 0.0 | 41.9 | 17.4 |
| 18 | 2.36 mm | #8 | 1.4 | 3.2 | 84.0 | 0.0 | 34.6 | 7.3 |
| 19 | 1.18 mm | #16 | 1.4 | 2.1 | 66.0 | 0.0 | 27.3 | 7.3 |
| 20 | 600 µm | #30 | 1.3 | 1.8 | 47.0 | 0.0 | 19.6 | 7.7 |
| 21 | 300 µm | #50 | 1.3 | 1.7 | 19.0 | 0.0 | 8.4 | 11.2 |
| 22 | 150 µm | #100 | 1.2 | 1.6 | 4.0 | 0.0 | 2.4 | 6.1 |
| 23 | 75 µm | #200 | 0.8 | 1.6 | 0.3 | 0.0 | 0.7 | 1.7 |
| 24 | | | | | | | | |
| 25 | | Coarseness Factor | | 62.3 | | | 34.6 | Workability |
| 26 | | | | | | | | |

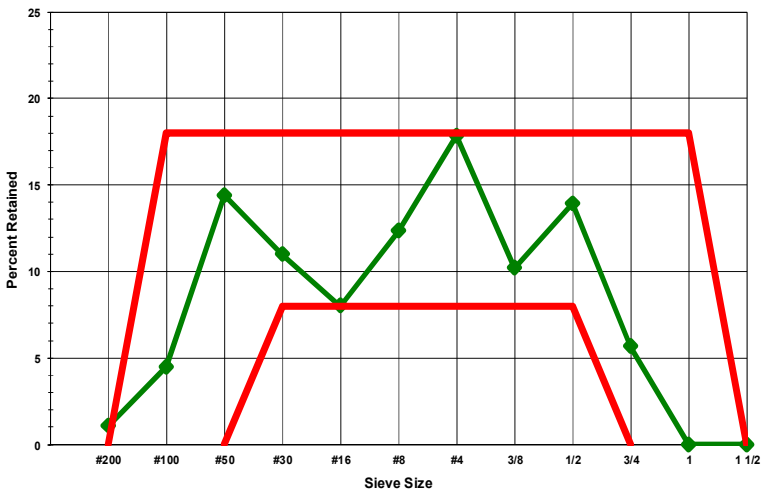
# Power 0.45 Chart

- Ideal gradation line representing the maximum aggregate density




# Percent Retained Charts

"Haystack" graph

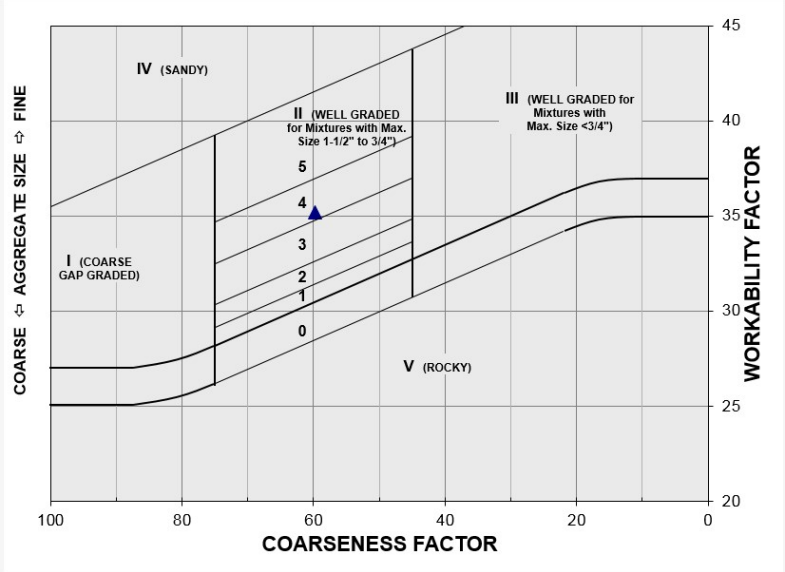


# Coarseness vs. Workability

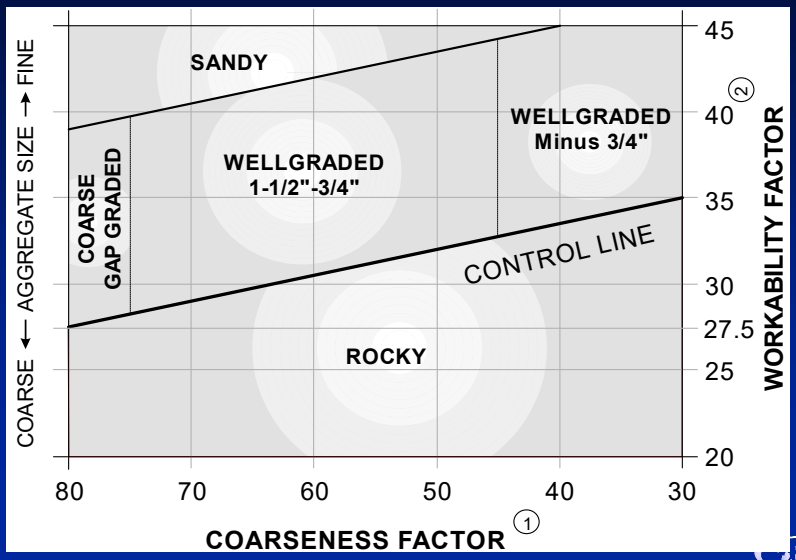
- CF = $\frac{\text{[combined \% retained above 3/8 inch sieve]}}{\text{[combined \% retained above No.8 sieve]}}$ X 100

- WF = Combined % Passing No.8 Sieve

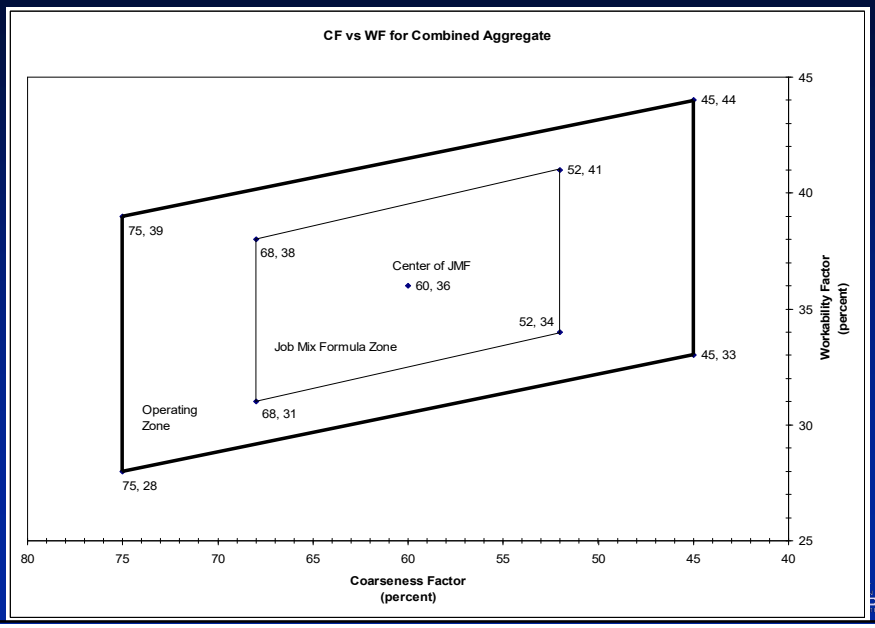
# Coarseness vs. Workability Chart



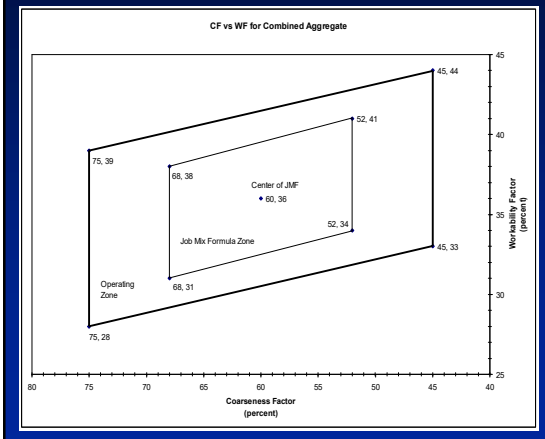
# Coarseness vs. Workability Chart




# MDOT Chart



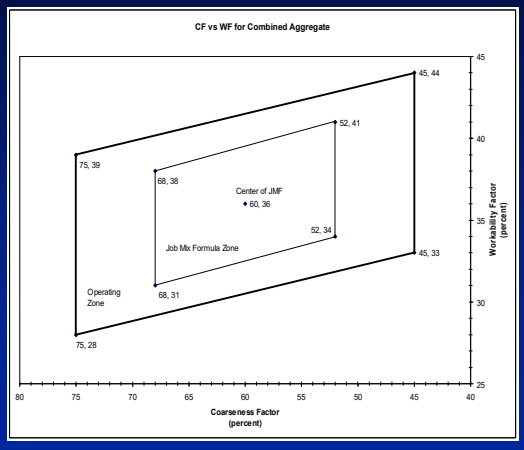
# Zones in MDOT Chart

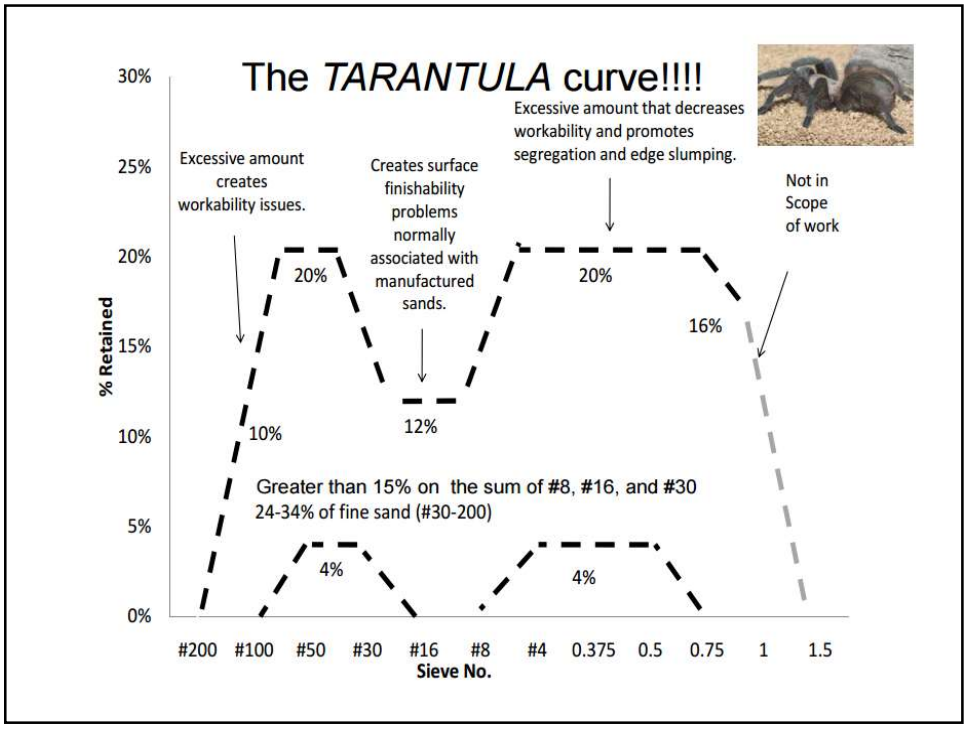


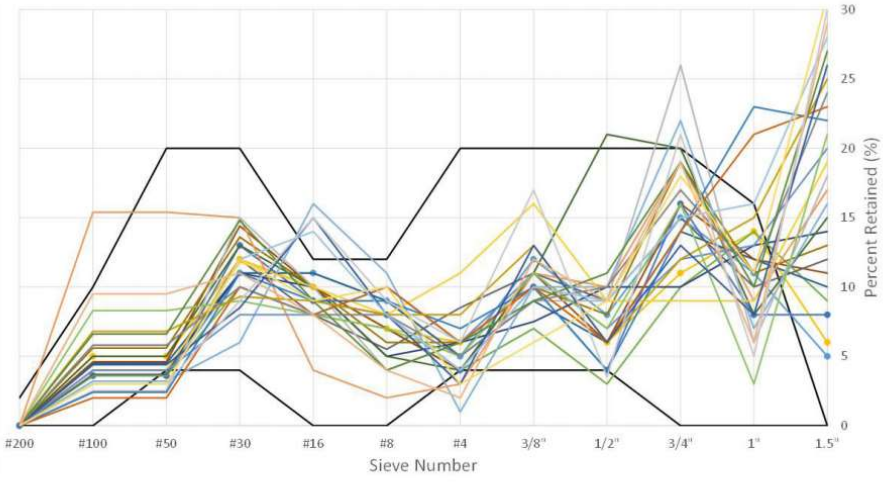

- Job Mix Formula (JMF) Zone
  - Contractors proposed optimized gradation for production, as submitted to the Engineer in the Initial Mix Design, must plot within this zone

# Zones in MDOT Chart

- Operating Zone
  - Contractor must ensure that the optimized gradation for production plots within this zone

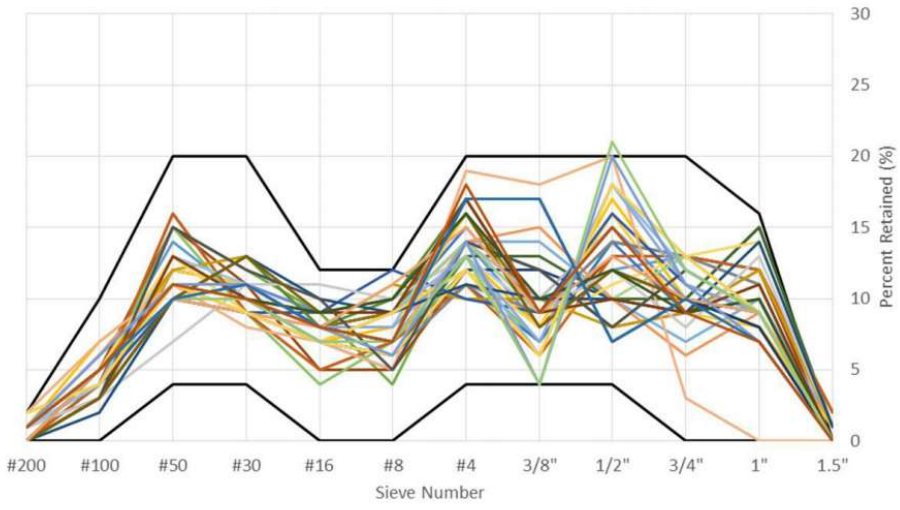





Ley et al. 2014 with data from Maria Masten

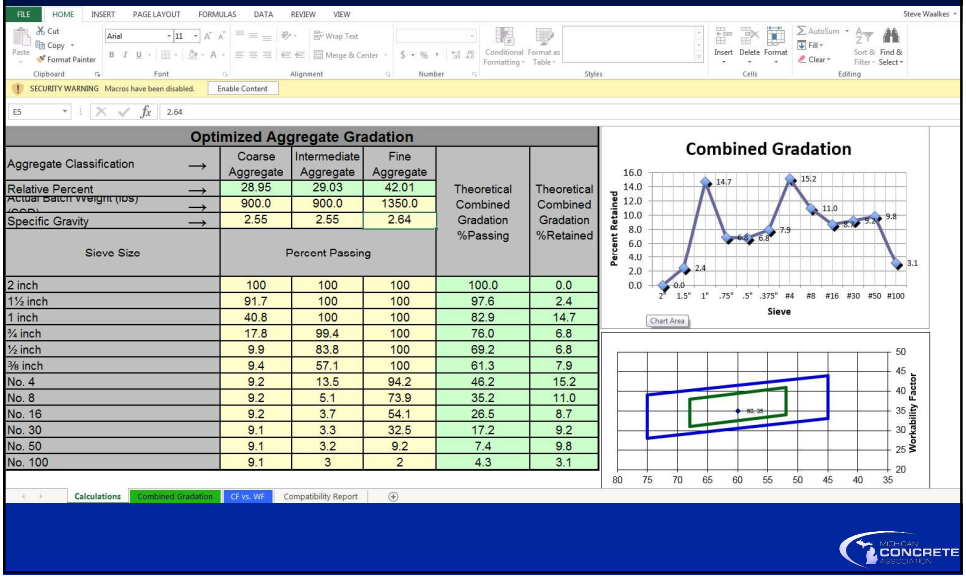
***Figure 5. MnDOT 1996 – 1998 combined gradation with data showing poor correlation to Tarantula curve***




Ley et al. 2014 with data from Maria Masten

***Figure 6. MnDOT 2010 combined gradation with 98% of mixtures meeting Tarantula curve***

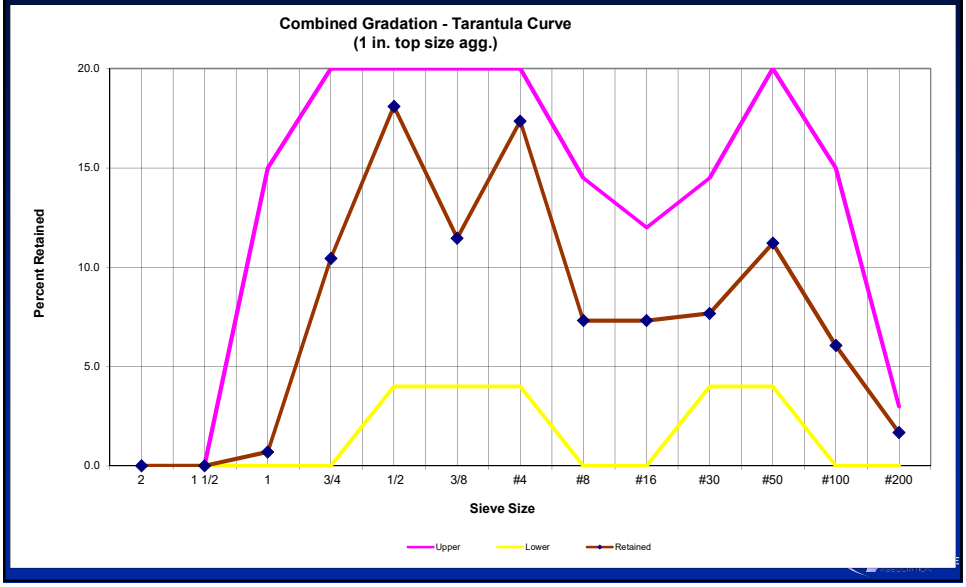
# MDOT Spreadsheet



**Optimized Aggregate Gradation**

| Aggregate Classification → | Coarse Aggregate | Intermediate Aggregate | Fine Aggregate | Theoretical Combined Gradation %Passing | Theoretical Combined Gradation %Retained |
|---|---|---|---|---|---|
| Relative Percent → | 28.95 | 29.03 | 42.01 | | |
| Actual Batch Weight (lbs) → | 900.0 | 900.0 | 1350.0 | | |
| Specific Gravity → | 2.55 | 2.55 | 2.64 | | |
| Sieve Size | Percent Passing | | | | |
| 2 inch | 100 | 100 | 100 | 100.0 | 0.0 |
| 1½ inch | 91.7 | 100 | 100 | 97.6 | 2.4 |
| 1 inch | 40.8 | 100 | 100 | 82.9 | 14.7 |
| ¾ inch | 17.8 | 99.4 | 100 | 76.0 | 6.8 |
| ½ inch | 9.9 | 83.8 | 100 | 69.2 | 6.8 |
| ⅜ inch | 9.4 | 57.1 | 100 | 61.3 | 7.9 |
| No. 4 | 9.2 | 13.5 | 94.2 | 46.2 | 15.2 |
| No. 8 | 9.2 | 5.1 | 73.9 | 35.2 | 11.0 |
| No. 16 | 9.2 | 3.7 | 54.1 | 26.5 | 8.7 |
| No. 30 | 9.1 | 3.3 | 32.5 | 17.2 | 9.2 |
| No. 50 | 9.1 | 3.2 | 9.2 | 7.4 | 9.8 |
| No. 100 | 9.1 | 3 | 2 | 4.3 | 3.1 |

# Tarantula Example




# What Does It Take To Implement Optimized Mixtures?

- Possibly extra or dedicated bin
- "Coarse" limestone, 6AAA quality, crushed to "custom" size/gradation
- "Intermediate" limestone, crushed to "custom" size/gradation
  - Particles >½ inch must meet quality specs for coarse aggregate (F-T dilation); anything >½ inch that doesn't meet F-T limited to less than 5% of total aggregate
- Extra testing… How much?

# Questions?