

SEGREGATION – CAUSES AND CURES

IT'S SIGNIFICANCE AND MITIGATION IN AIRSIDE ASPHALT PAVEMENTS

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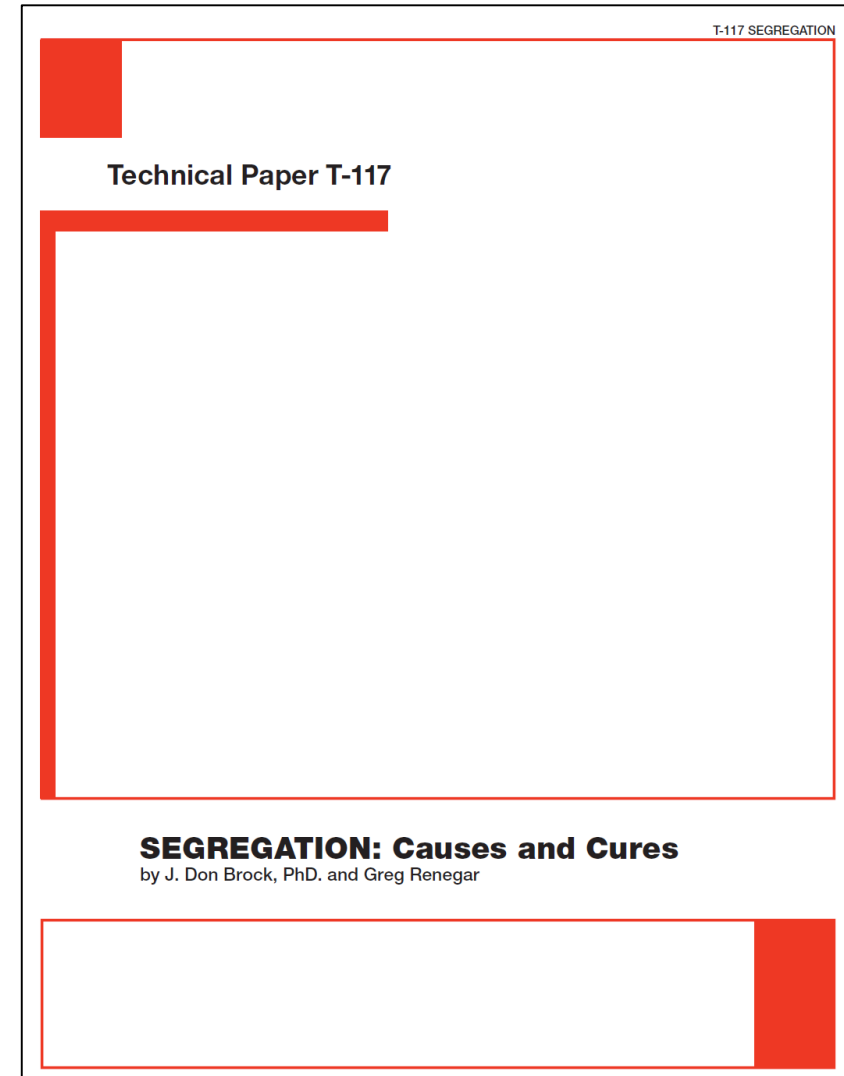
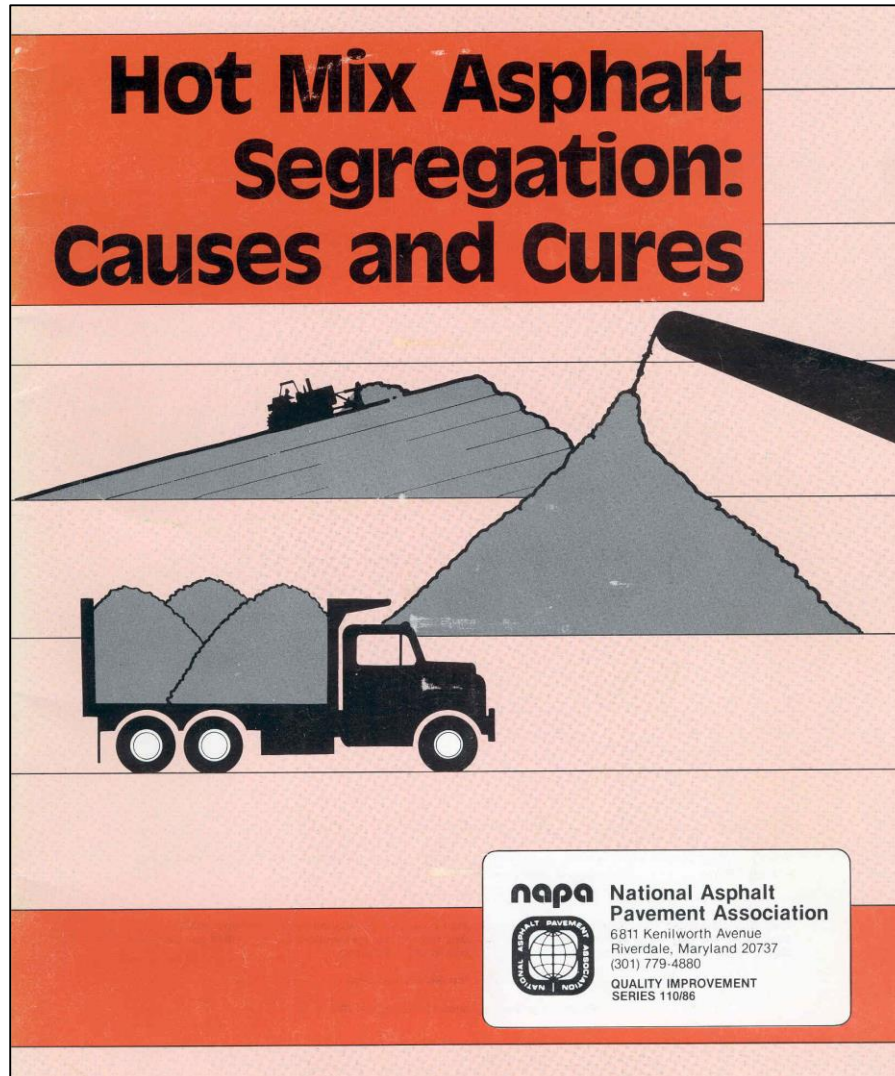




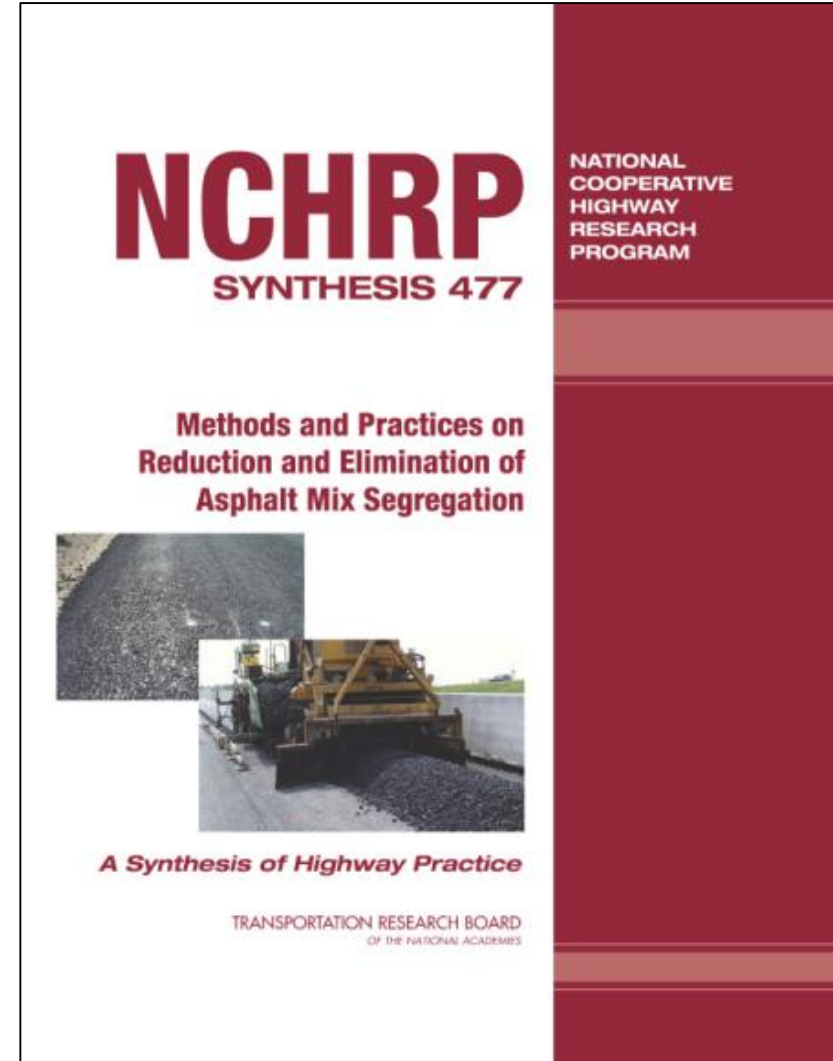
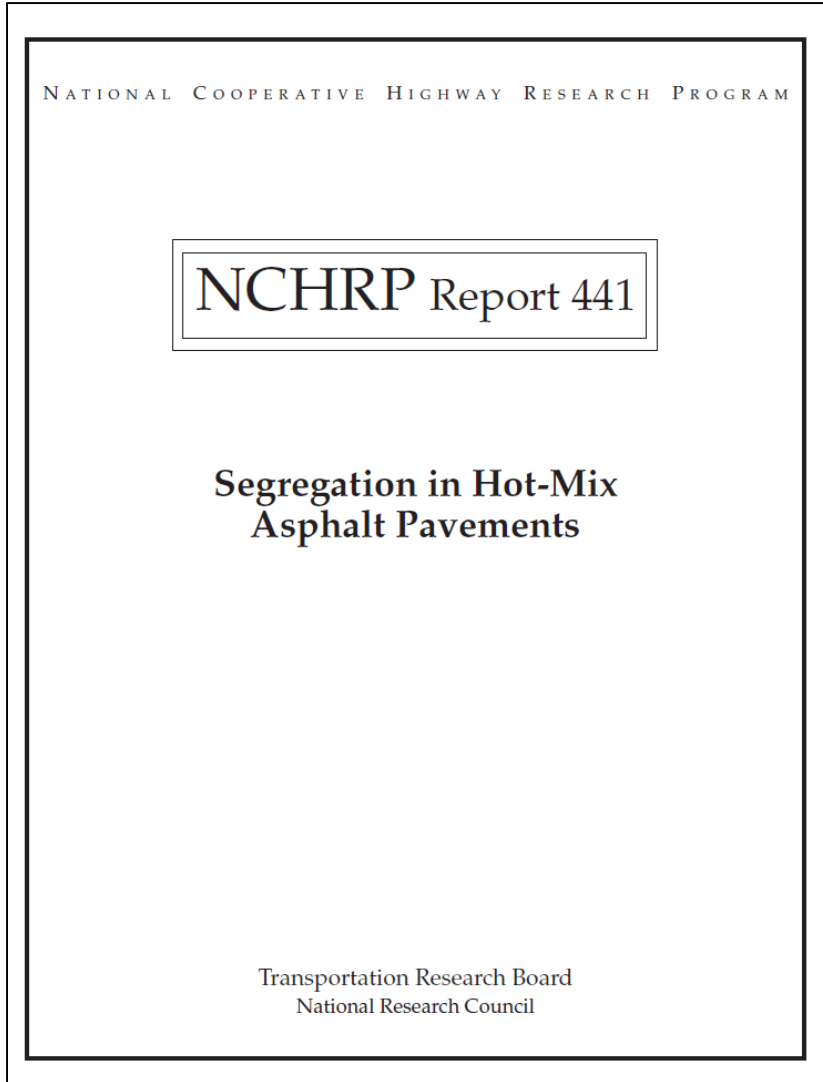
SEGREGATION AND AIRSIDE PAVEMENTS

- **What** is it?
- **Why** is it a problem, and specifically, for airside pavements?
- **How/where** is it caused?
- **What** can we do to eliminate or mitigate?

KEY REFERENCES



KEY REFERENCES



ACKNOWLEDGMENTS

I also borrowed liberally from presentations and publications online, most notably the following whom I would like to most gratefully acknowledge:

- **Tim Murphy, Murphy Pavement Technology “*Segregation – The Cardiac Arrest of Hot Mix Asphalt Pavements*”**
- **Vince Aurilio, formerly of Ontario Asphalt Pavement Council, and Liakram Narsingh, Wirtgen “*Segregation – Causes and Cures*”**
- **Paul Schartz, Roadtec: “*Minimizing Segregation*”**

DEFINITION

Segregation is defined as a lack of surface uniformity where areas of pavement are either too coarse or too fine in relation to the surrounding acceptable pavement.

Segregation is visually classified as:

- **Slight** – area where the matrix is in place between the coarse aggregate, however there is slightly more coarse aggregate in comparison with the surrounding acceptable pavement
- **Medium** – area which has significantly more coarse aggregate than the surrounding acceptable pavement and usually exhibits some lack of matrix
- **Severe** – area which appears very coarse, with coarse aggregate against coarse aggregate and little or no matrix.

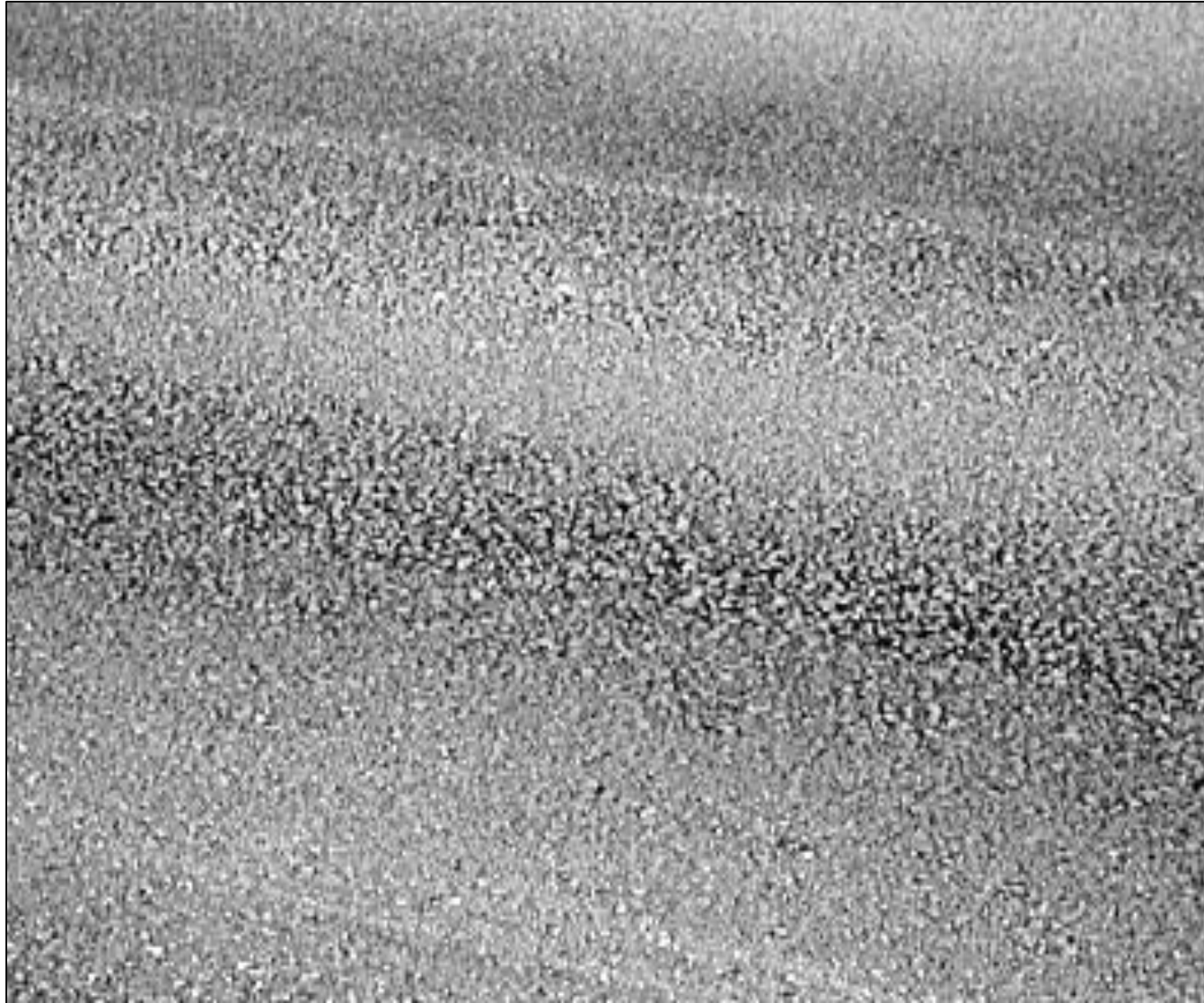
SLIGHT SEGREGATION



MEDIUM SEGREGATION



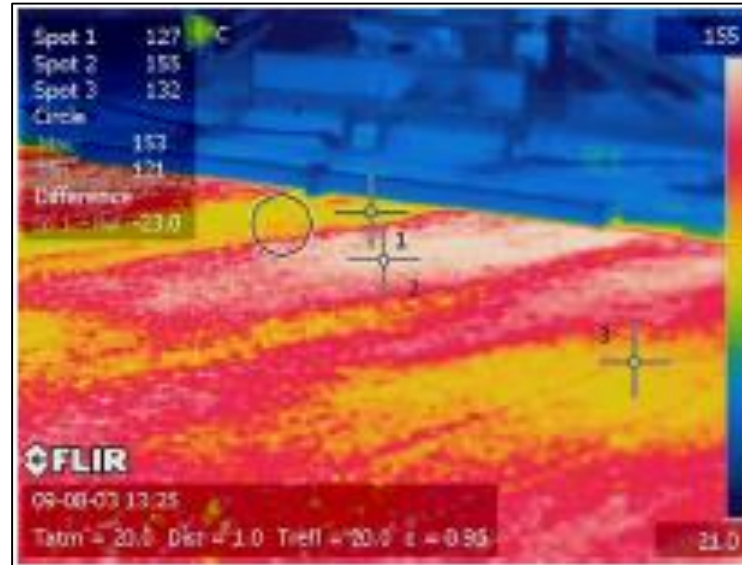
MEDIUM TO SEVERE SEGREGATION



SEVERE SEGREGATION



END OF LOAD SEGREGATION



At the beginning of each trailer and the end of each trailer are cold spots of asphalt mix. Stone rolls from the middle to the outside making segregation of the stone and the mix temperature.

This mix must be re-integrated into the mix or compaction will be uneven in density.

END OF LOAD SEGREGATION





WHAT IS IT?

Gradation or Mechanical Segregation:

- **most common type** and can occur as the result of aggregate stockpiling and handling, production, storage, truck loading practices, paving practices, and equipment adjustments

Temperature or Thermal Segregation:

- result of differential cooling of portions of the mix on the surface of the mix in the haul truck, along the sides of the truck box, and in the wings of the paver

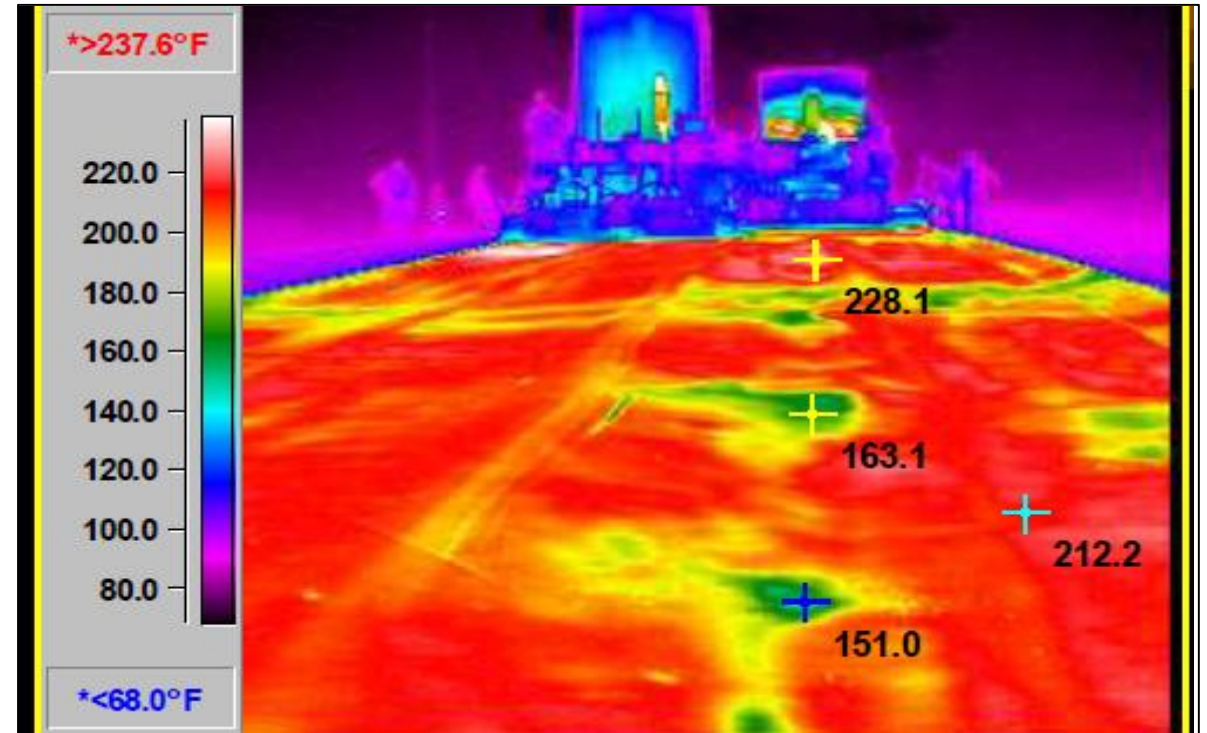
GRADATION SEGREGATION

Non-uniform distribution of coarse & fine aggregate:

- Large stones separating from smaller stones and fines
- Usually occurs on a pile (sloped surface) during handling
- Heat and asphalt cement binder separated with the fines
- Can also contribute to Thermal Segregation
- Less asphalt to hold large aggregate particles together
- Mostly visible on the pavement
- Minor tractor / screed adjustments could sometimes mask

THERMAL SEGREGATION

- Inconsistent or variable temperature of the asphalt mix due to method of hauling, loading/unloading, and distribution through the paver
- Can also be associated with Gradation Segregation





WHY IS SEGREGATION A PROBLEM?

- **Profound influence on pavement performance**
 - Increased ravelling
 - Reduced tensile strength
 - Reduced fatigue life
 - Increased moisture sensitivity
- **Relationship to air voids and density/compaction**



WHY IS IT A PROBLEM FOR AIRSIDE PAVEMENTS?

Potential Foreign Object Debris and Foreign Object Damage (FOD)

- For a roadway/highway pavement, the ‘impact’ of FOD particle might be a stone chip or broken windshield
- For an airfield pavement, ‘impact’ is potentially much more significant! Can cause damage to aircraft engines or tires.
- In DND 32 12 16 specification, areas of severe segregation in the binder course and medium or severe segregation in the surface course are considered to be defective areas, remove and replace.

LOCKHEED-MARTIN F35 LIGHTNING

- Canadian government considering purchase of 88 F-35 or equivalent aircraft to replace F-18
- Approximate unit cost: **US\$ 80 million**
- While FOD from a piece of asphalt pavement is unlikely to cause a crash, there is a substantial cost to repair FOD on any commercial or military aircraft.
- Purchase cost of P&W F135 engine: **\$US 16-18 million**
- Purchase cost of MD-80 engine: **US\$3-5 million**
- **MD-80 engine overhaul** to correct FOD damage: **\$250K – \$1.0 million**
MD-80 fan blades (per set*): **\$7K**
- Costs can easily exceeds **US\$ 250,000**, much more than a windshield!



HOW / WHERE IS SEGREGATION CAUSED?

Segregation is very much related to the mix design and the type or shape of the aggregates used in the design.

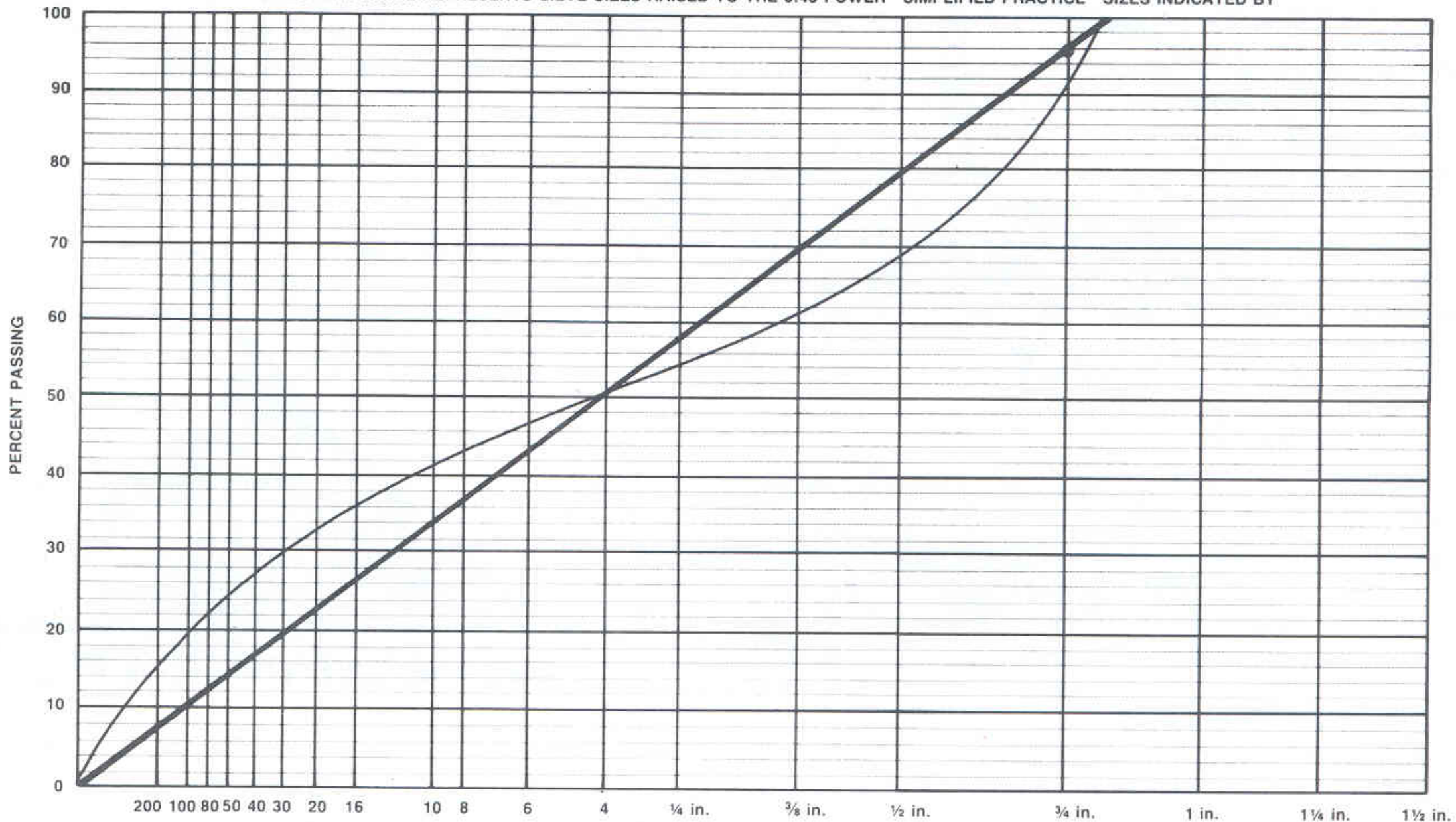
Segregation can originate at any point where the materials are handled or moved.

- Aggregate production: processing, stockpiling, load-out and transport
- Hot-mix plant: stockpiling, cold feed, batching, load-out and transport
- Paving site: Discharge from haul trucks to paver, paver operation, and placement and compaction

MIX DESIGN CONSIDERATIONS

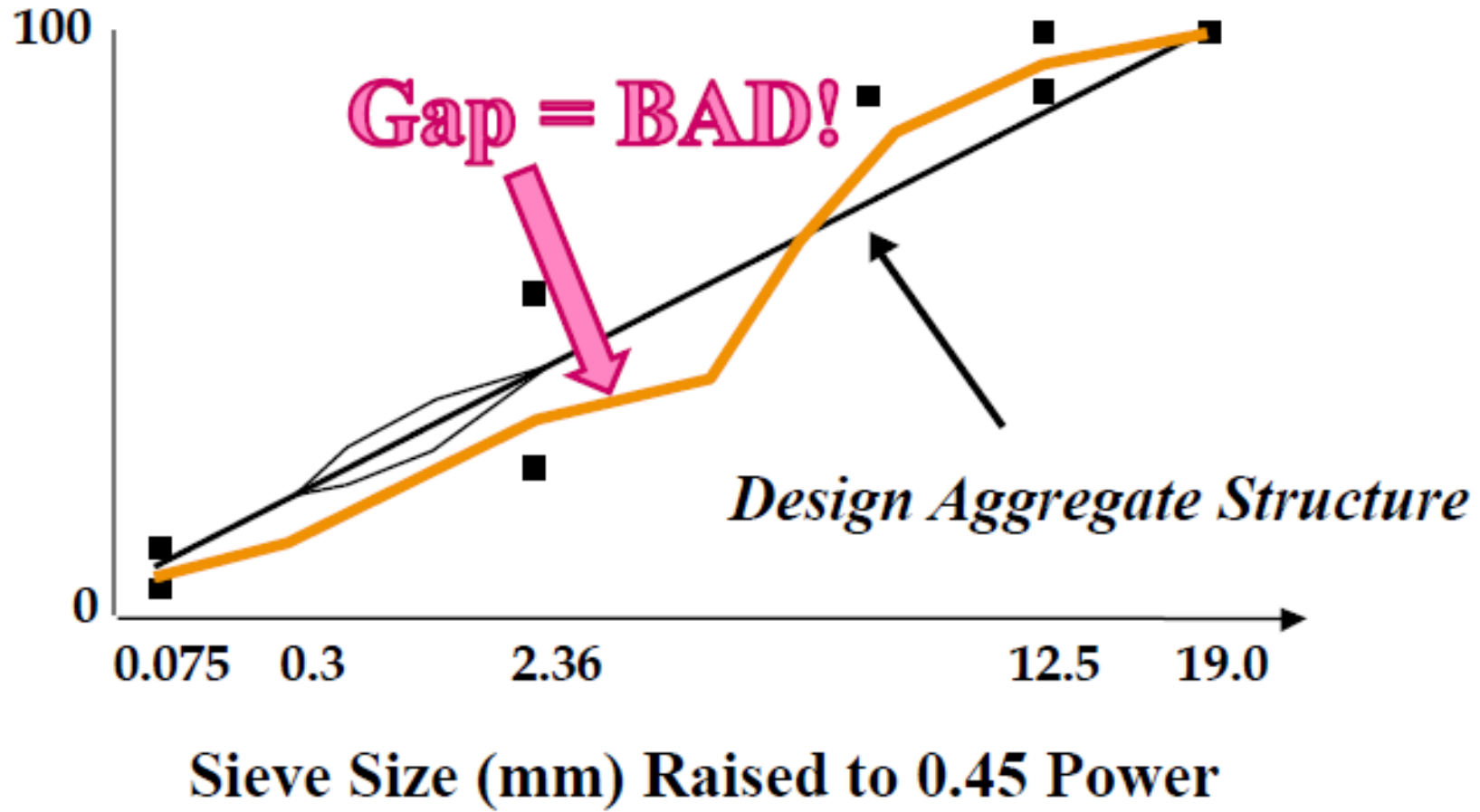
- Important to design mixes that are not prone to segregation
 - The mix type and its design should reflect where and how the mix is to be used
 - Machine placed versus areas of hand work?
 - Job Mix Formula that is well graded through the entire gradation through to the fines
- Avoid “gap-graded” mixes having a steep grading curve that tend to be unforgiving, especially if the asphalt cement content is even slightly low.
- Particularly a challenge for large stone mix types
- When reviewing mix designs, don’t just look at whether or not the mix meets gradation specifications – look at whether it is suitable for the intended purpose!

HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER "SIMPLIFIED PRACTICE" SIZES INDICATED BY



FHWA Chart Showing Aggregate Gradation of Hot Mix Asphalt That May Tend to Segregate

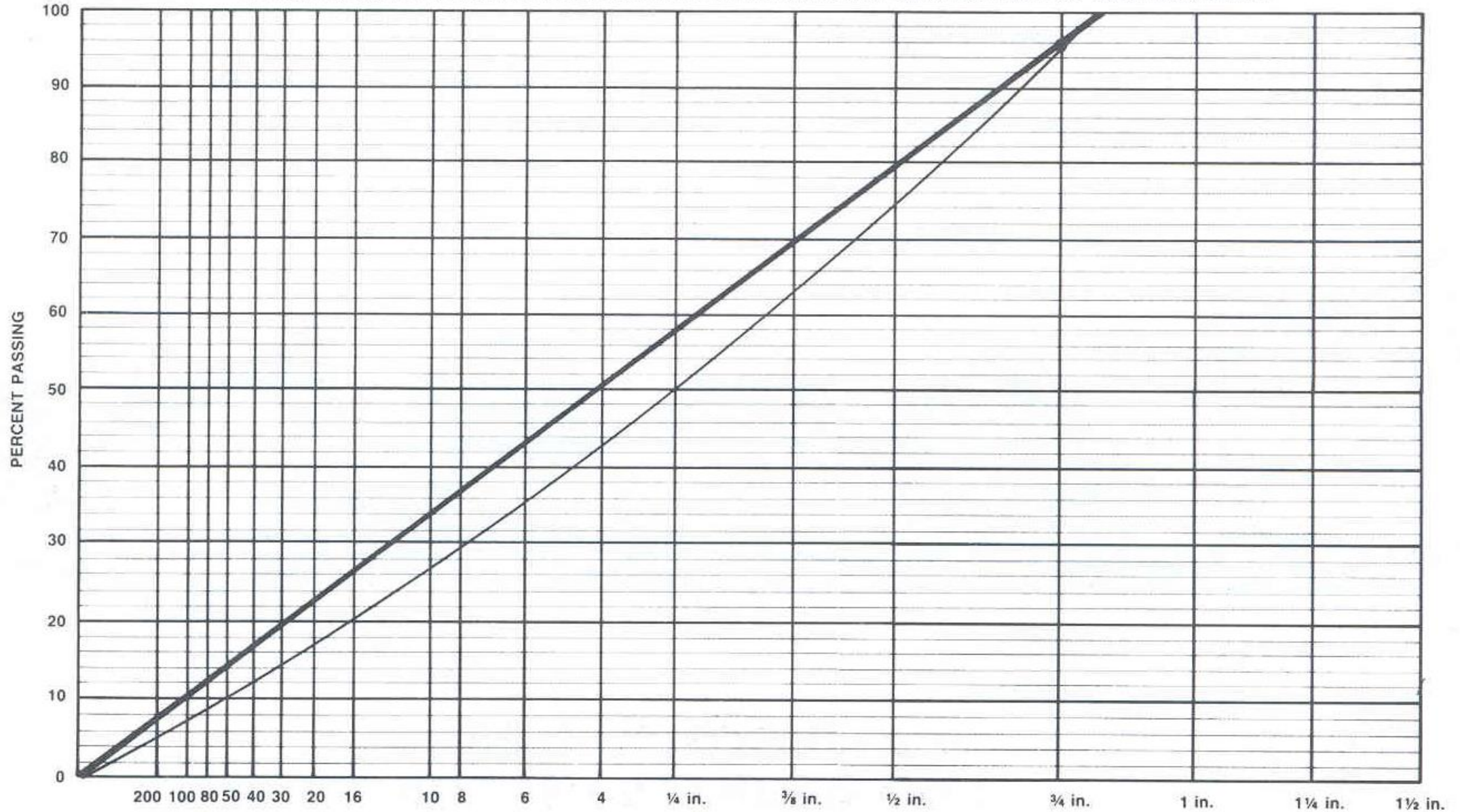
Percent Passing



LARGE TOP-SIZE + GAP GRADING = TROUBLE



HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER "SIMPLIFIED PRACTICE" SIZES INDICATED BY

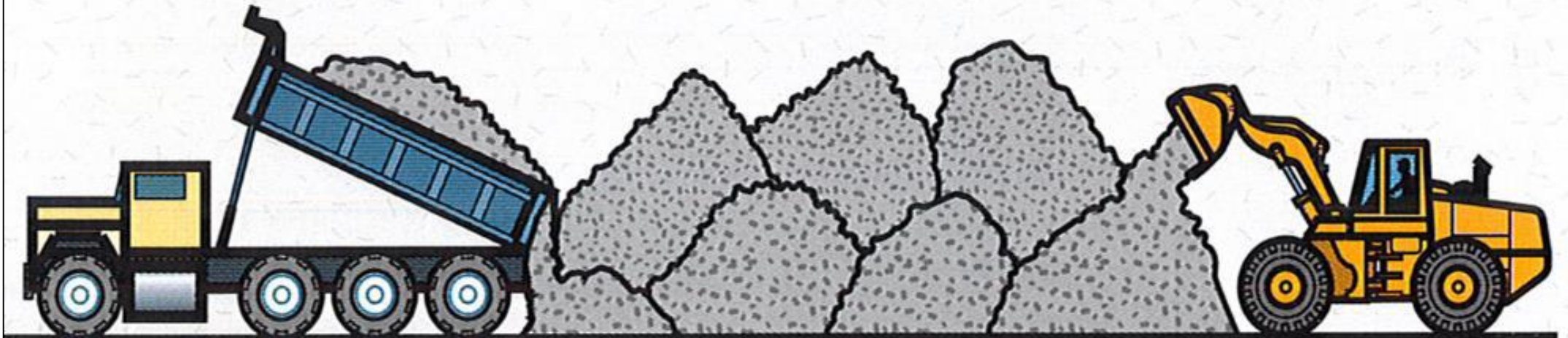


FHWA Chart Showing Aggregate Gradation of a Typical Good Performance Hot Mix Asphalt

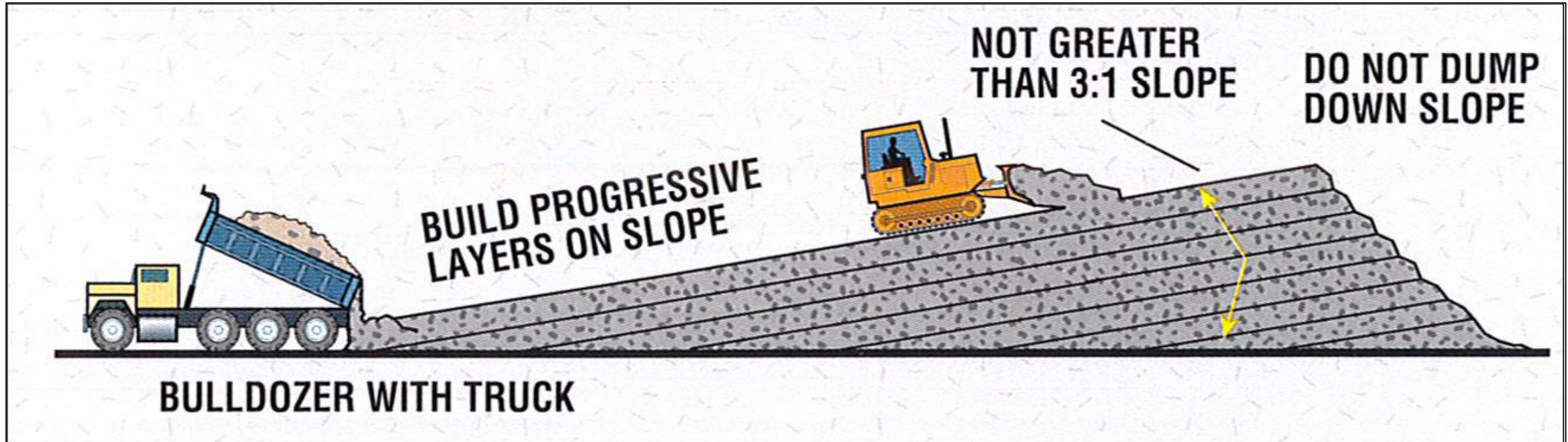
AGGREGATE PROCESSING AND STOCKPILING

**DUMP AGGREGATES
IN PILES NOT LARGER
THAN A TRUCKLOAD**

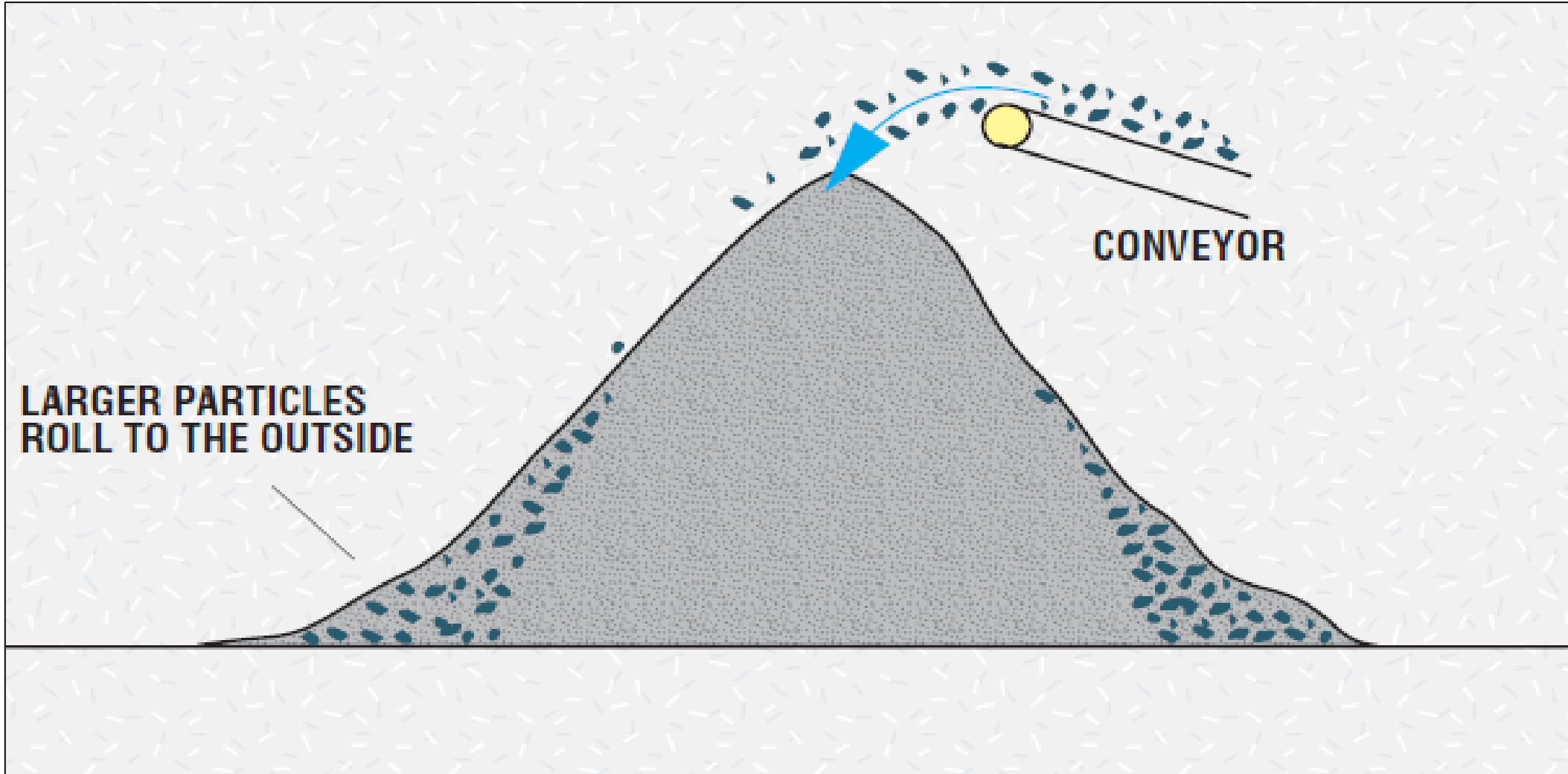
**MAKE PILES SO THEY STAY
IN PLACE AND DO NOT ROLL
DOWN SLOPES**



AGGREGATE PROCESSING AND STOCKPILING



AGGREGATE PROCESSING AND STOCKPILING







AGGREGATE PROCESSING AND STOCKPILING

- During load-out, it's important that the loader operator enter from different locations around the stockpile, not the same location
- The trucks should be loaded in different locations in the truck box, not all at the centre.
- Trucks should be tarped to prevent loss of fines (particularly when hauling fine aggregates)
- When the aggregates arrive at the plant, stockpiles for each aggregate should be developed the same as during aggregate processing
- The importance of process control during aggregate production cannot be overemphasized!

SEGREGATION DURING MIX PRODUCTION AND PLACEMENT



At the Plant?



During Haul?

Where do we cause segregation to happen?

Paver?

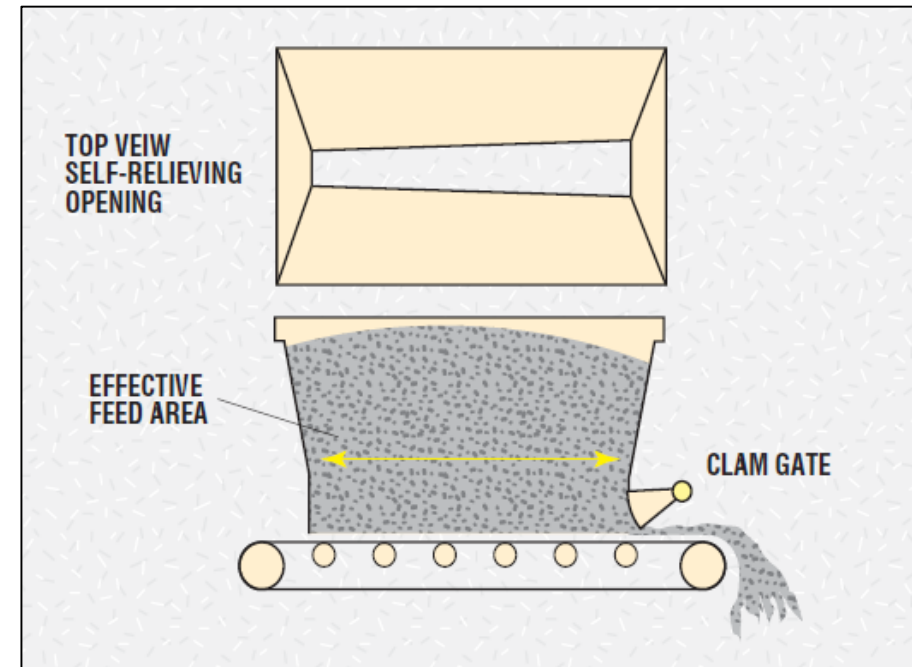
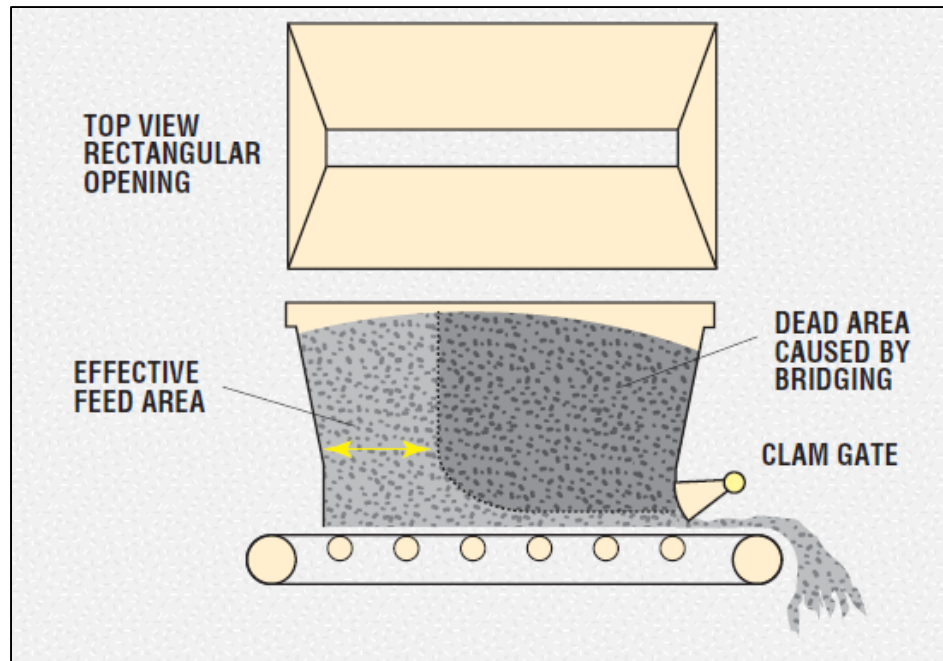


On the Mat?



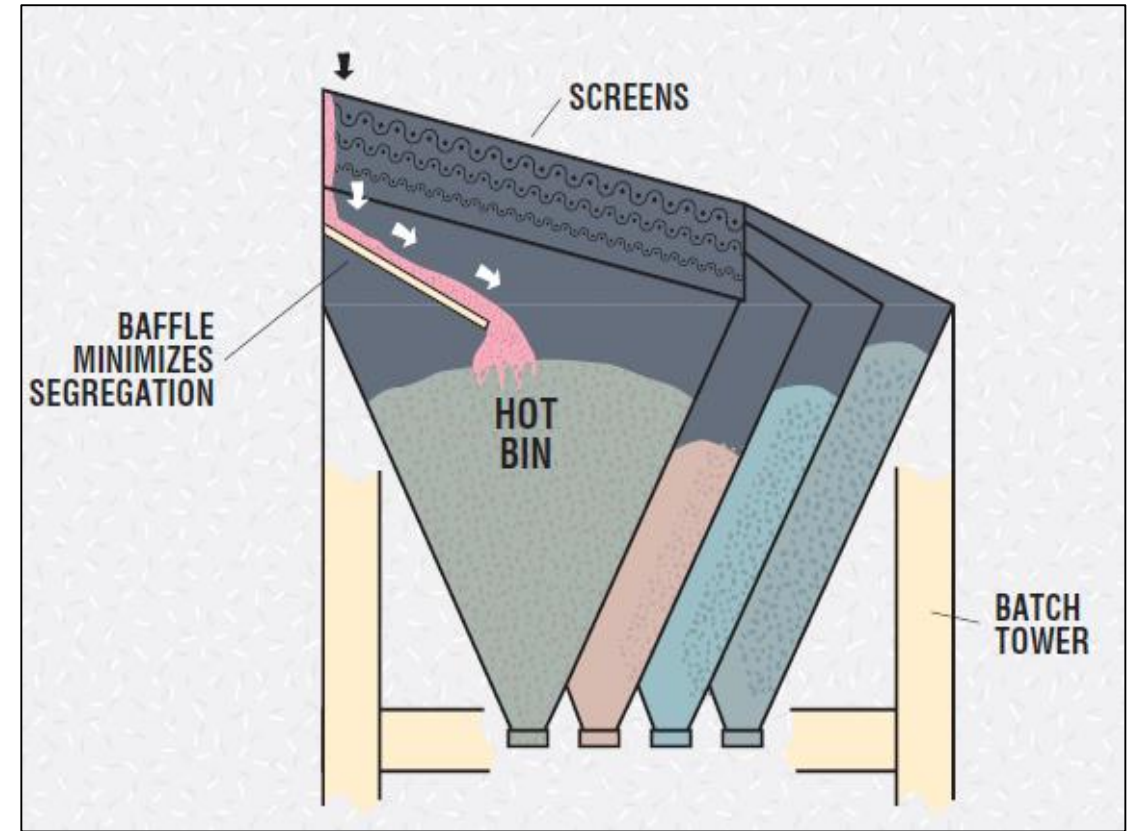
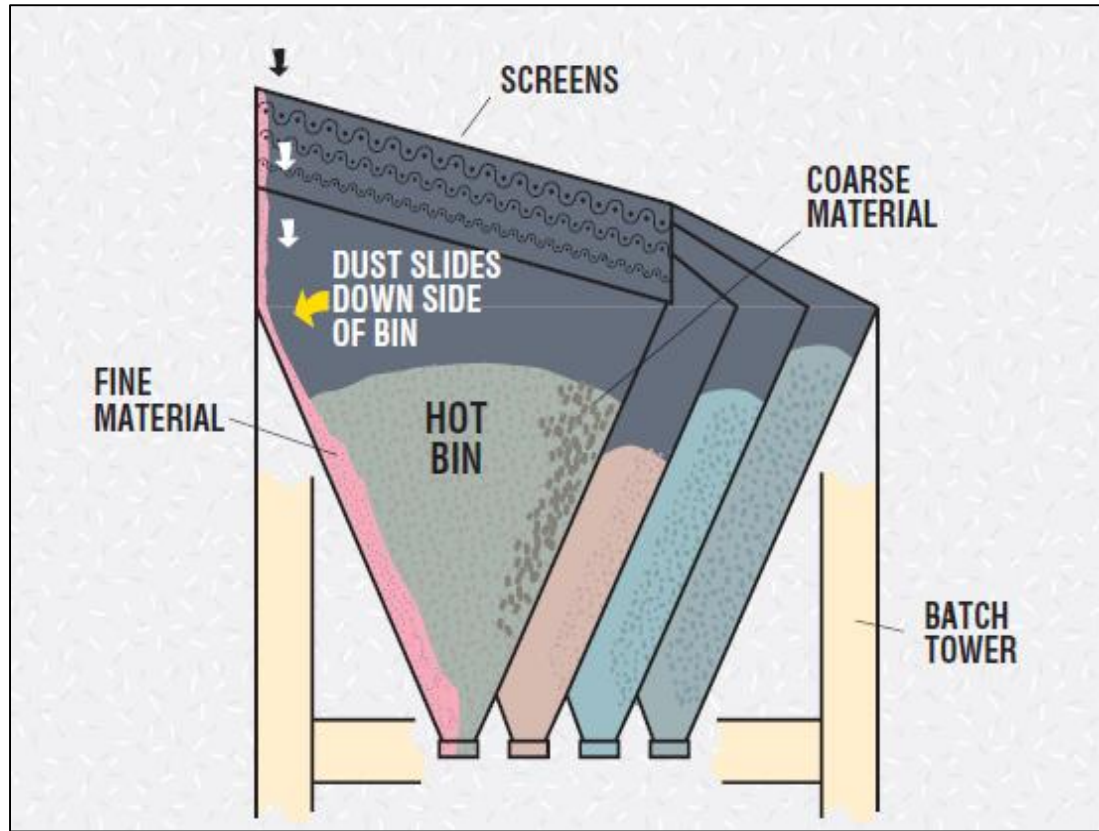
HOT-MIX ASPHALT PRODUCTION

- Segregation can occur at a number of locations during hot-mix asphalt production
- Varies somewhat with plant type: batch, drum, counter-flow drum, etc.
- Batch Plants: cold feed bins and hot bins



HOT-MIX ASPHALT PRODUCTION

- Hot bins



HOT-MIX ASPHALT PRODUCTION

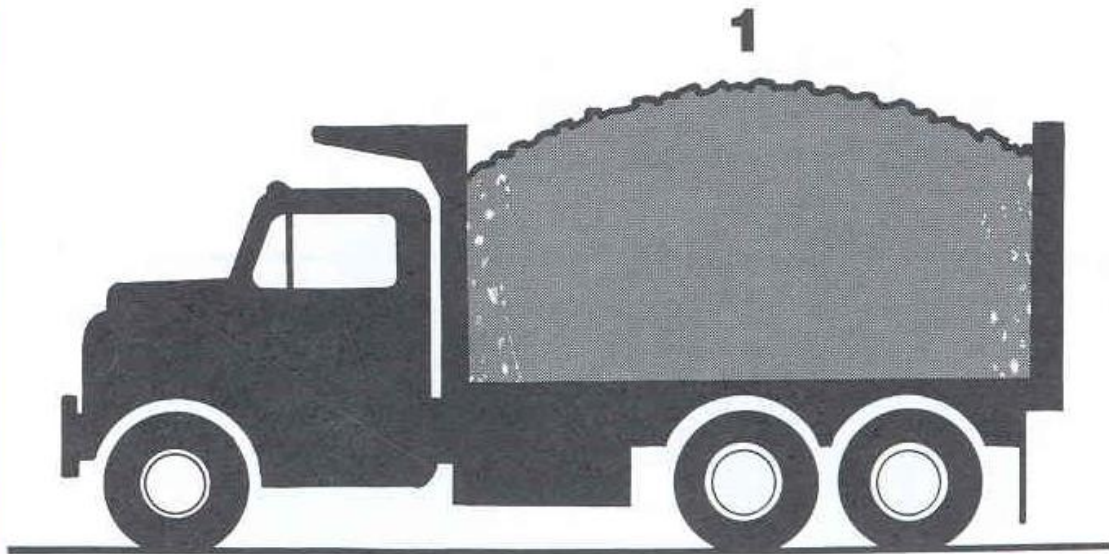
Drum Plants: surge bins and storage bins

- Larger particles flow through the drum faster than fines during start-up and shutdown
- Gap-graded mixes a potential problem as the coarser particles are more difficult to coat uniformly – non-existent to thin – and tend to segregate
- Segregation can occur in a number of locations including the drum, discharge point, drag conveyors, etc.
 - Moisture also a factor – retention time in the drum must be sufficient that the aggregates thoroughly dry; any moisture still present when AC is added will turn to steam and suck the AC into pores and crevices reducing film thickness and contributing to segregation
 - Coarser particles take much longer to dry!

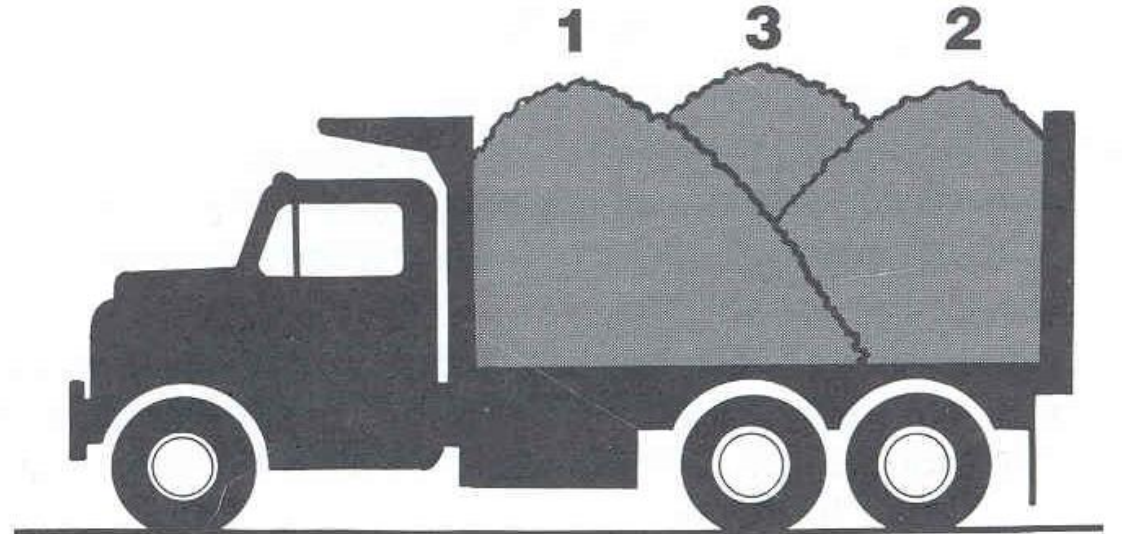
STORAGE SILOS

- Silos should be kept 25% to 75% full, not more not less, to minimize segregation
- If over filled, the mix segregates with coarser particles collecting around the outside of the silo
- If underfilled, the mix segregates when new mix is added to the silo

TRUCK LOADING

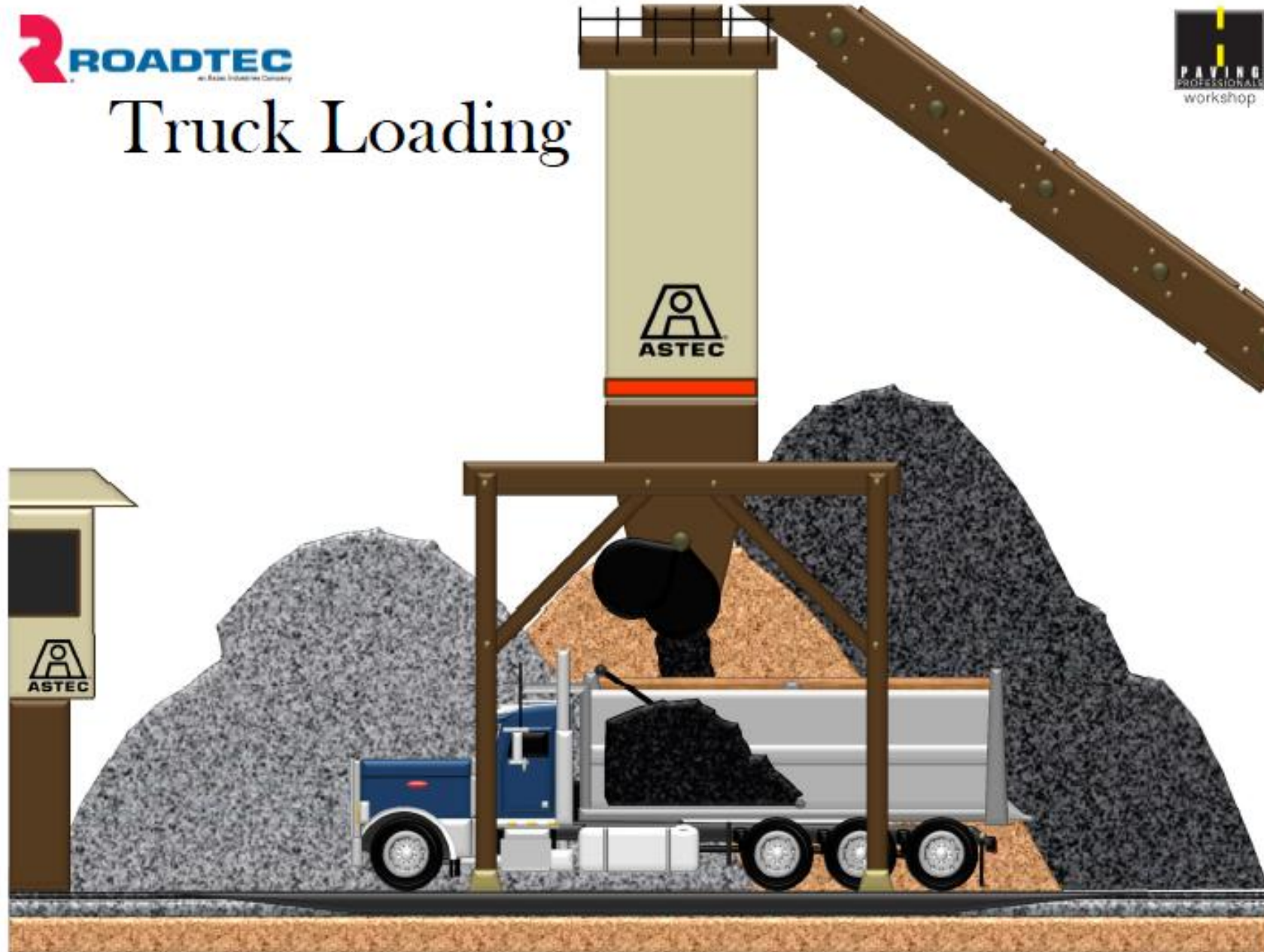


POOR TRUCK LOADING



PROPER TRUCK LOADING

Truck Loading





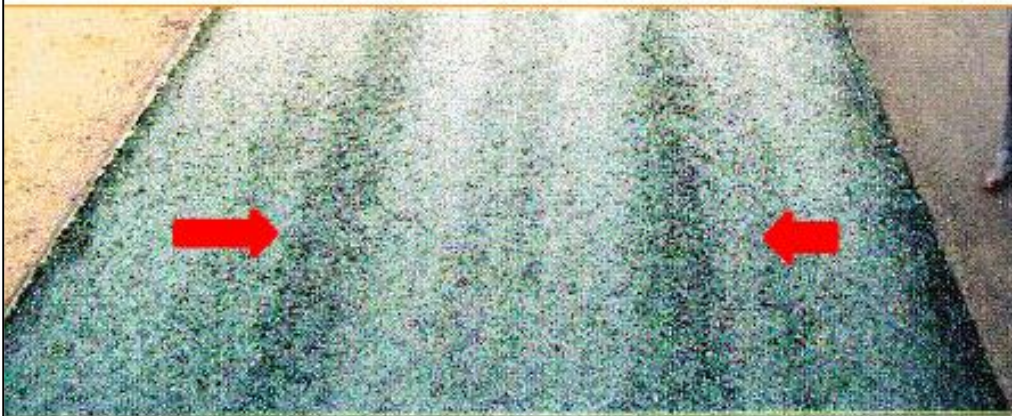
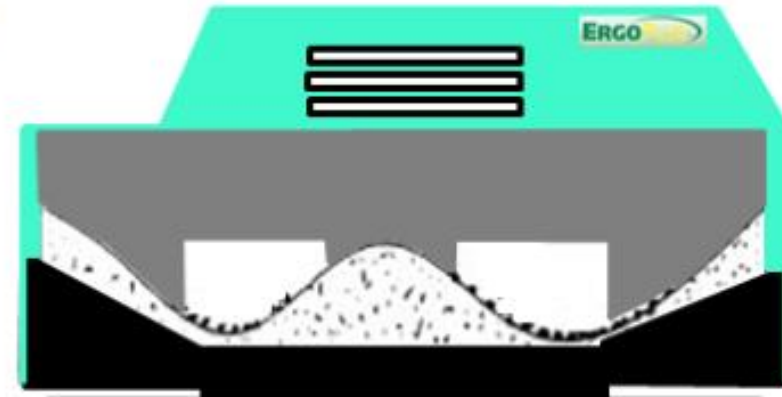
Truck Loading



1. Controlling Segregation – Truck Dumping In Paver Hopper

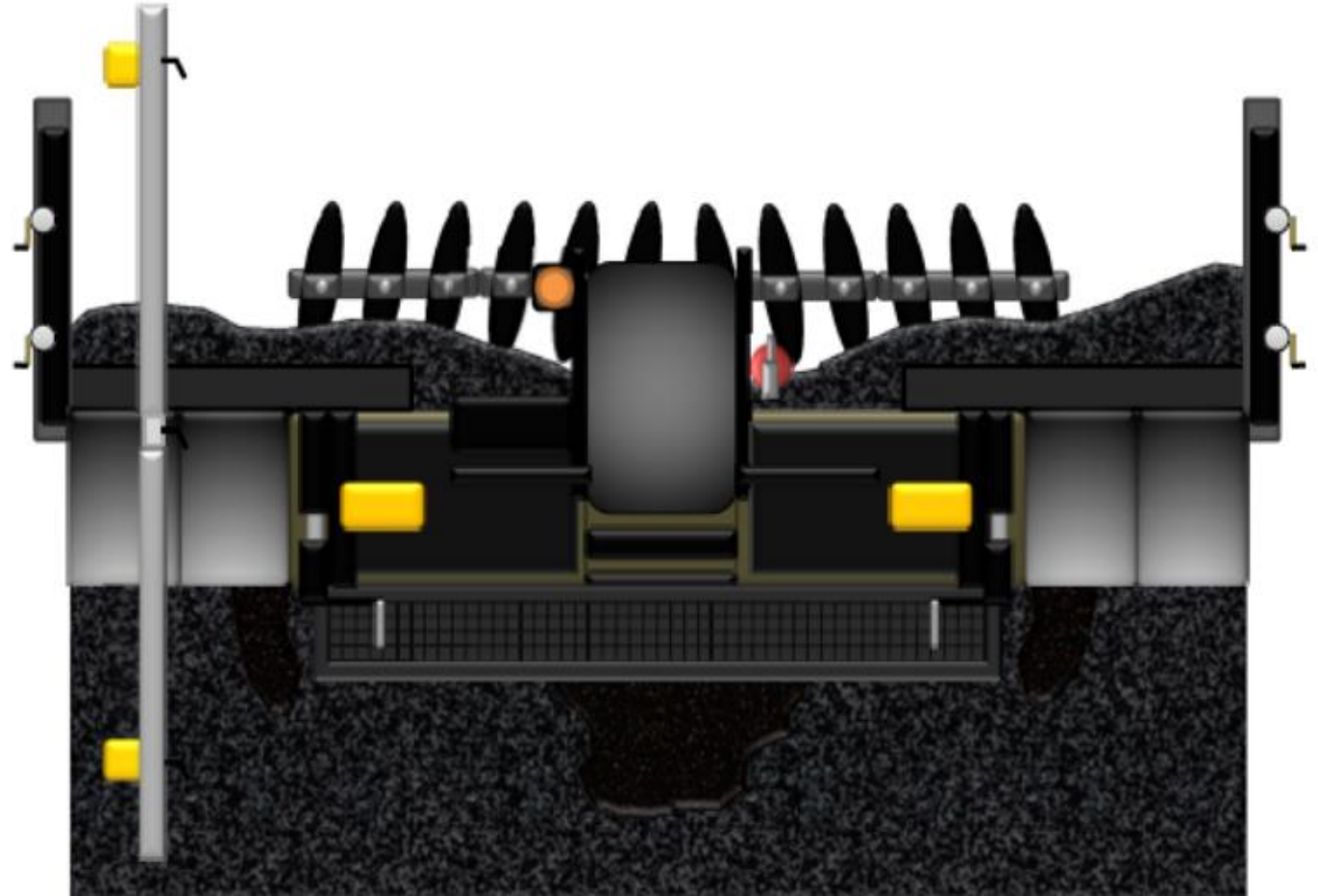
a. Running The Hopper too low

- Creates two valleys at the middle of flight Chain
- Two streaks appears in middle of the tunnel
- Would appear only when hopper is too low



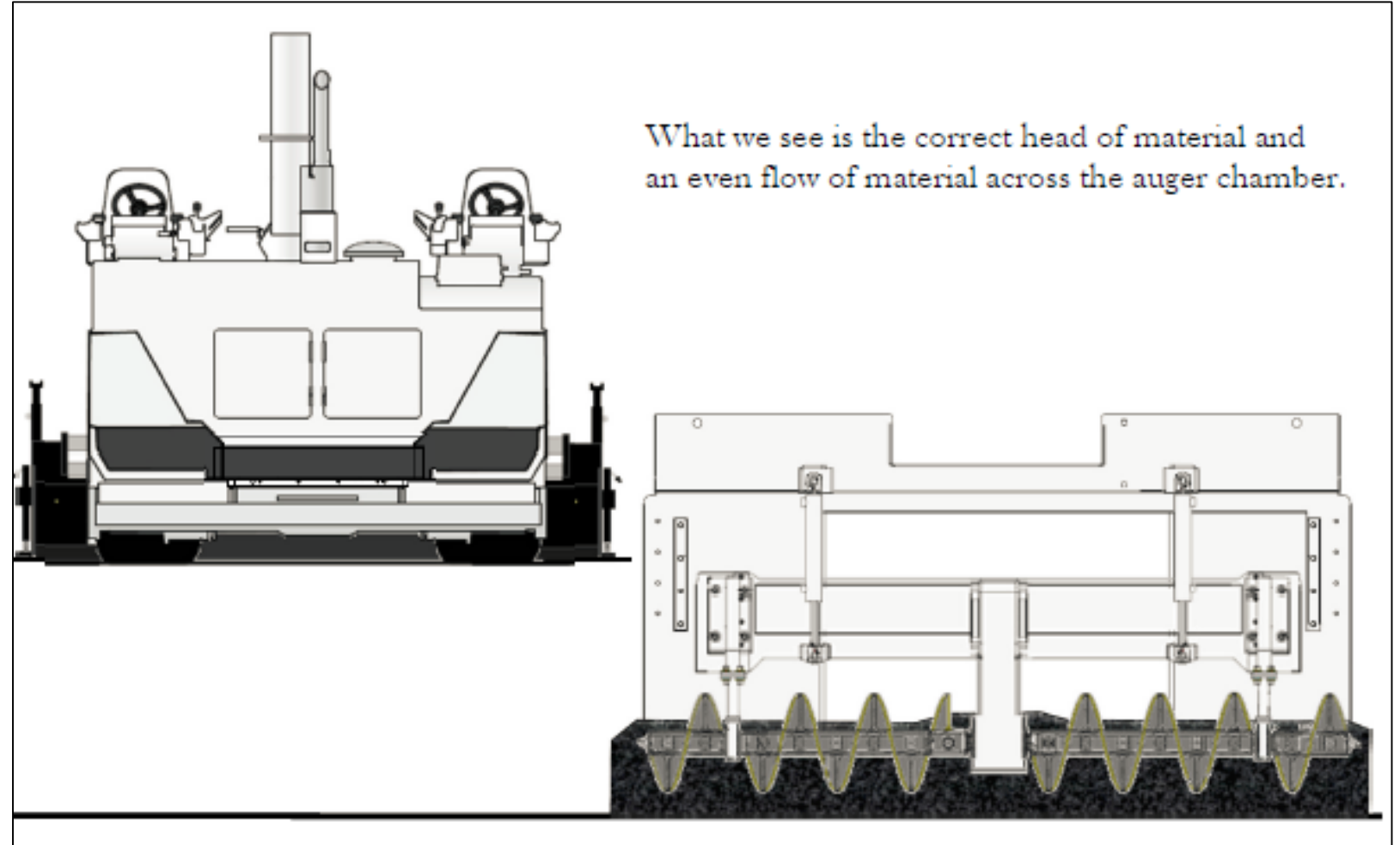
PAVER AND PLACEMENT

- Irregular head of material, imperfections in the mat
- Amount of material in the augers varies, with the centre of the mat under the auger box 'starved' for material



PAVER AND PLACEMENT

- This is the proper head that should be maintained at all times
- There is an even amount of material in the augers and the augers are running full time, not stopping and starting



MATERIAL TRANSFER VEHICLE (SHUTTLE BUGGY)

- ~30 t of mix in the MTV hopper
- Allows the paver to move continuously, without stops and starts
- Remixes the material and eliminates temperature variation from transport
- Faster turnaround on haul trucks



Material Flow



Make sure that the C2 has at least 1/3rd to 2/3rd capacity at all times.

Never deviate from the suggested amount of storage.



TPIA RUNWAY 05-23 (2017)

- Paving in Echelon
- 6 pavers fed from two different plants
- 9000 t per day
- 3 MTVs, each feeding two pavers continuously
- *Everything previously described had to be duplicated for each aggregate, at each plant and at each paver to minimize segregation!*



MACROTEXTURE TEST (ASTM E 965-87)

General:

Known volume of glass beads is spread over the pavement surface by moving “hockey puck” in a circular fashion. The average depth of the spread out “circle of beads” is called the average macrotexture depth.

$$Md = \frac{4 \times V}{(\pi \times D^2)}$$

where:

Md = the average macrotexture depth

V = Volume of graded glass beads

D = Average diameter of “circle of beads”







MACROTEXTURE RATIO = M_s/M_c

Where:

M_s = average macrotexture depth for 2 to 4 segregated locations

M_c = average macrotexture depth for 4 control (i.e. unsegregated areas)



MACROTEXTURE RATIOS

Mix type	Macro texture Ratio, M_s/M_c Degree of Segregation		
	Slight	Medium	Severe
HL Mixes (except HL1*), RHM, MDBC	< 1.9	1.9 to 2.5	> 2.5
HDBC	< 1.8	1.8 to 2.6	> 2.6
DFC/HL 1*	< 1.6	1.6 to 2.2	> 2.2

** Note: Modified HL 3 (>80% crushed stone) use DFC/HL 1 ratio*

Questions?

Thank you for your attention!



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