Increasing In Place Density by 1%

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SAKAI America Inc.
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ROADS MUST BE BUILT. WORLDS MUST BE CONNECTED.

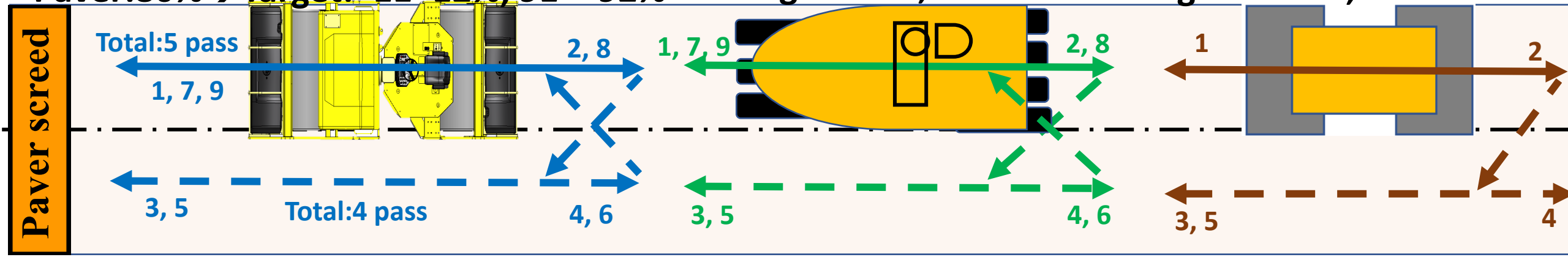
Conventional Rolling Pattern “RP” vs Density

Breakdown(BD):High vs Low Freq. Vibe, Intermediate(IM):PTR, Finish(FN): Static

BD: High Freq.(4,000vpm) Vibe roller,
Paver:80%→Target:+11~12%, 91～92%

IM: Pneumatic Tire roller,
Target: +1%, 92~93%

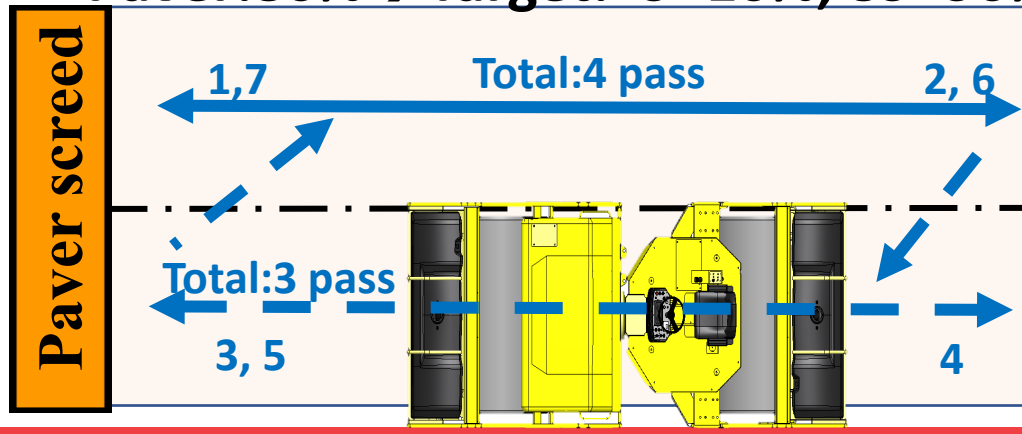
FN: Static roller
Target: +0.5%, 92.5~93.5%



BD: Low Freq.(3,000vpm) Vibe roller,
Paver:80%→Target:+9~10%, 89~90%

IM: Pneumatic Tire roller,
Target: +1%, 90~91%

FN: Static roller
Target: +0.5%, 90.5~91.5



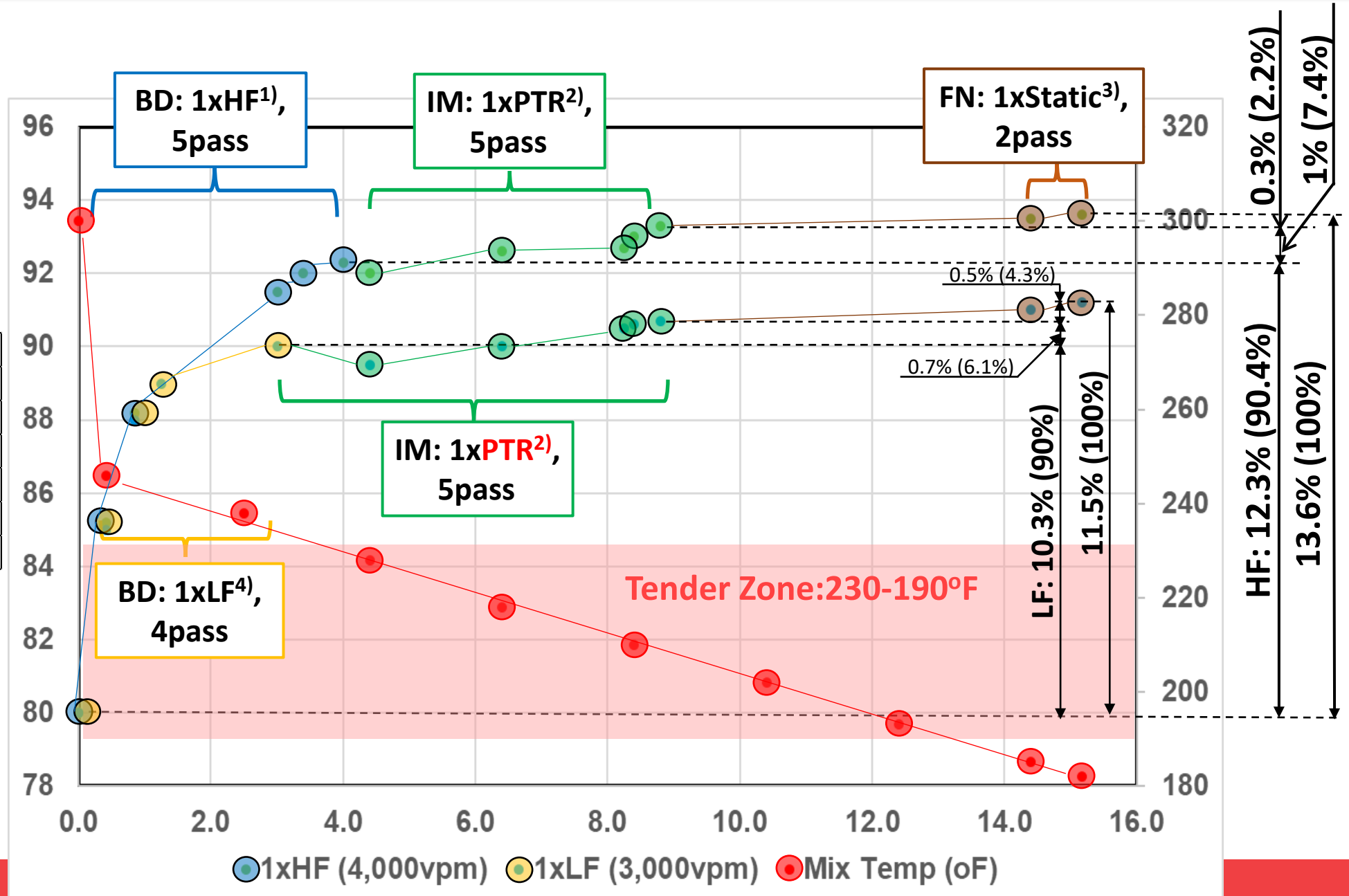
IM & FN: Rolling pattern & Density Increase (Target: +1% & +0.5%) are as same as above.

1) HF: High Freq. vibe roller, 2) PTR: Pneumatic Tire roller
3) Static: Steel Drum roller, 4) LF: Low Freq. vibe roller

Conventional RP vs Density & Temp.

1) HF: High Freq. vibe roller
2) PTR: Pneumatic Tire roller
3) Static: Steel Drum roller
4) LF: Low Freq. vibe roller

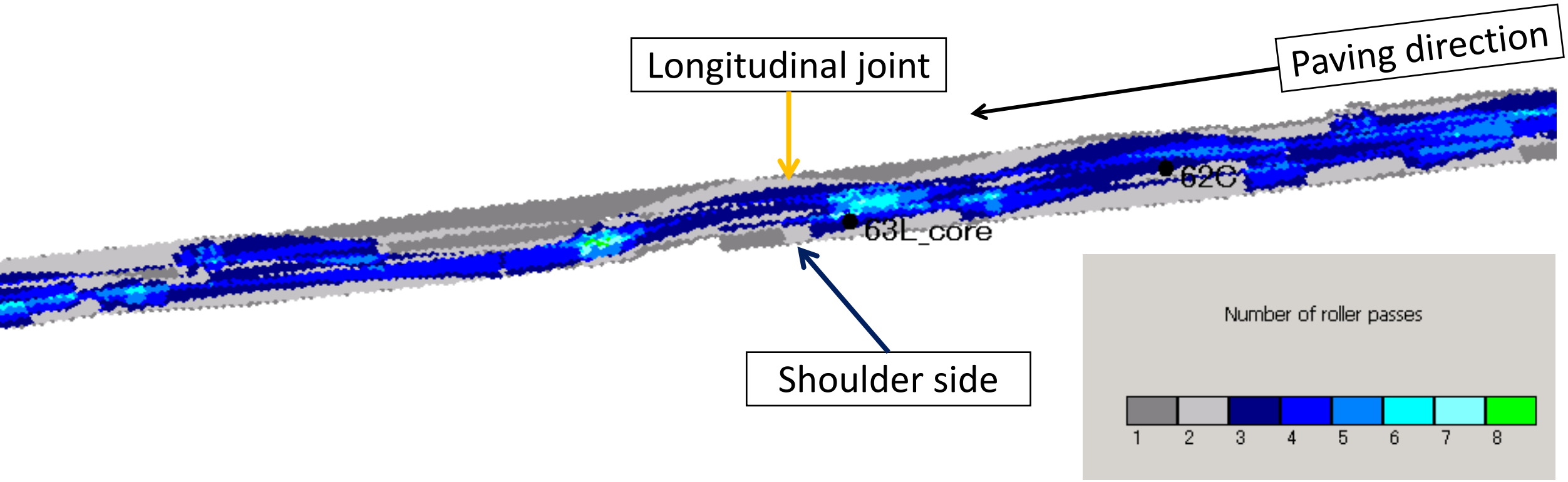
	BD Rolling Process	
	HF	LF
Speed	4.5mph	3mph
IPF	10	10
Roller Pass	9=4+(4+1)	7=3+(3+1)
Rolling Distance	135 ft	105 ft
Density Increase	12.3%	10%



Inconsistent Roller Pass by One BD Roller

Especially in Night Paving

- Even the best roller operator in a paving company made very inconsistent pass number over the mat.



"Intelligent Compaction, Does it IC exists?", J. Sherocman, S. Rakowski and K. Uchiyama, Canadian Technical Asphalt Association (CTAA), 2007.

FHWA Report on High Density

U.S. Department of Transportation
Federal Highway Administration

Office of Preconstruction, Construction, and Pavements

FHWA-HIF-21-021

Date: December 2020

Roller Type/Position/Process	Number of Projects	Outcome
Breakdown in Echelon	10	9 of 10 projects had density ≥ 94% 5 of 10 project had density ≥ 95%
Pneumatic Intermediate in Echelon	2	Highly effective
Pneumatic	11	Inconsistent
Vibratory Pneumatic	2	1.8 to 2.5% density increase
Oscillatory	7	Comparison to vibratory not possible Fewer passes and greater density
Combination	1	2.0% density increase
Same in Tighter Rolling Pattern	2	Density standard deviation decreased 50%

Density Increase in Breakdown “BD” Critical for Success

- Breakdown “BD” rolling process is the most critical to increase the density.
- This is because the increase in density due to BD accounts for about 90% of the total increase in density in all rolling process of BD, intermediate "IM," and finishing "FN.
- Effective methods to achieve the high density:

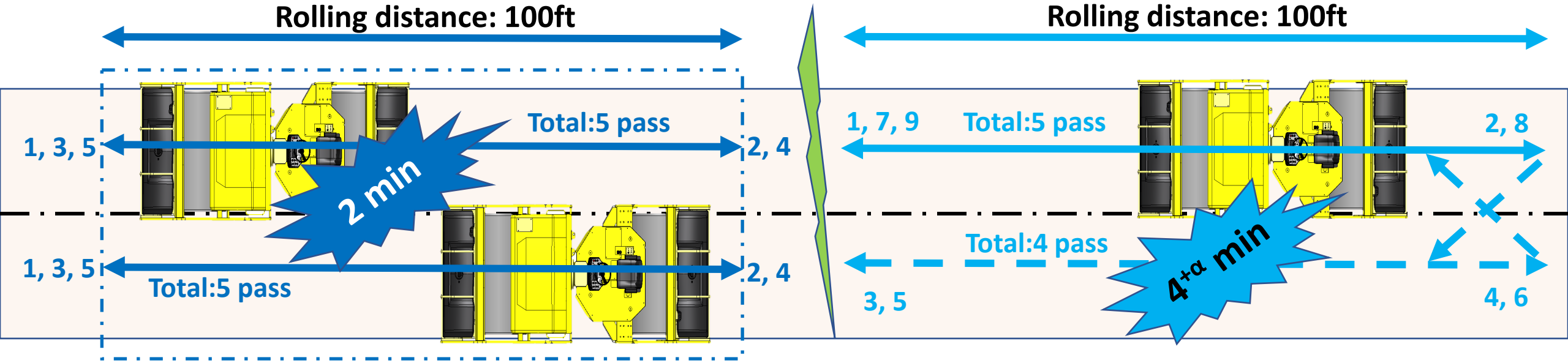
1) Rolling Patterns:
   (1) Echelon rolling: Two same rollers in side by side
   (2) Column rolling: Two different rollers arranged vertically
2) Rolling Position vs. Rollers:
   (1) BD, IM & FN: Double drum Oscillatory Roller
   (2) BD: High Frequency (4,000vpm) Vibratory Roller
   (3) BD (Base & Binder), IM & FN: Vibratory Pneumatic Tire “VPT” Roller

Benefits of Echelon Rolling in BD

Rolling Conditions: Distance:100ft, Pass #:4 or 5, Speed:3mph

Rolling Time: 2min, Consistent Pass #

Rolling Time: $4^{+\alpha}$ min Inconsistent Pass #

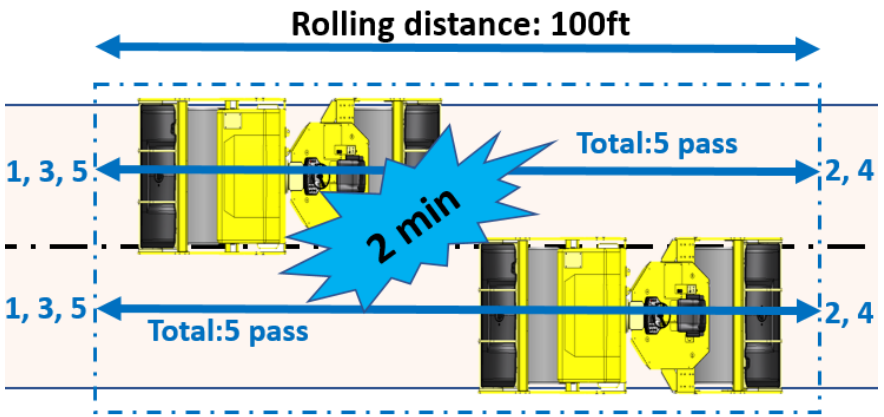


Two Rollers in Echelon (Side by Side)

One Roller to Cover 2 lanes

Density Increase

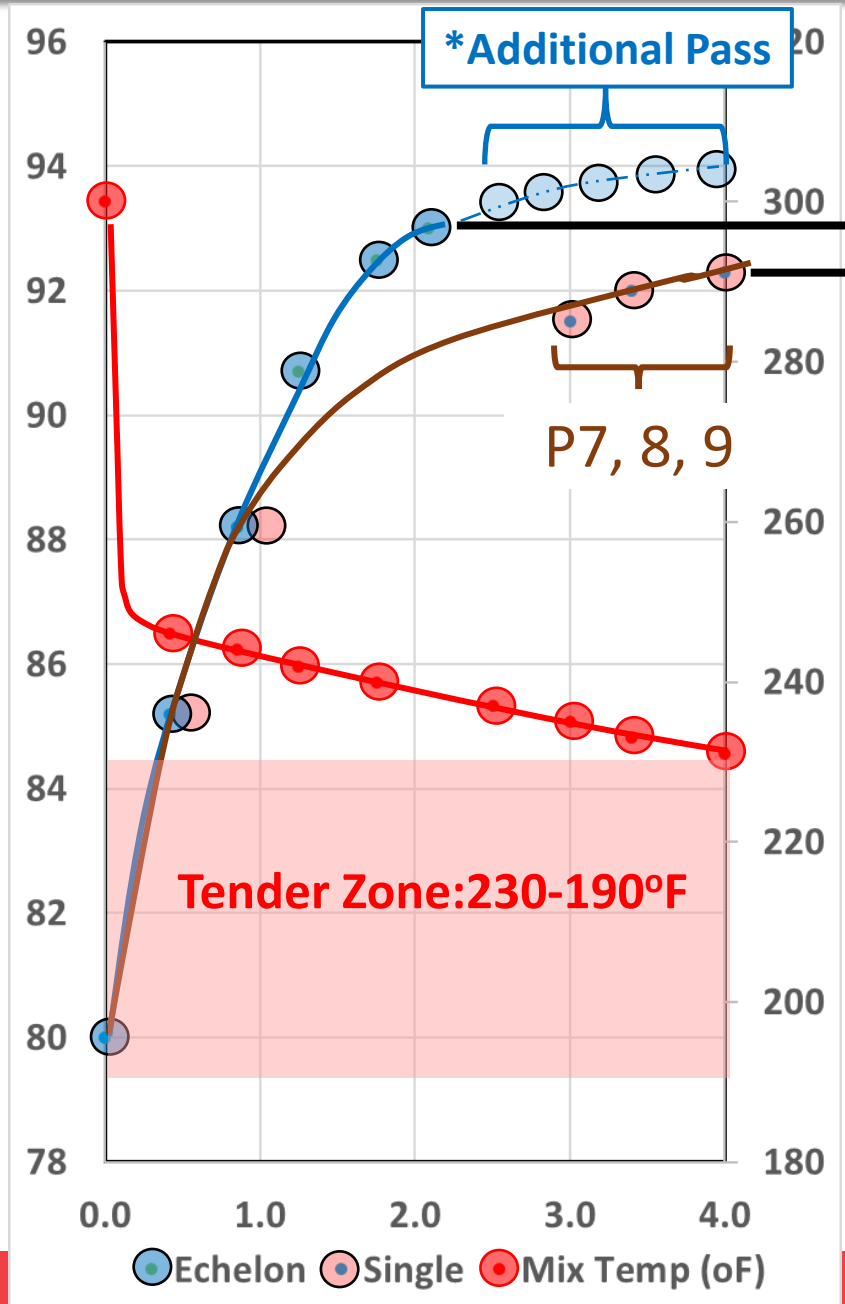
By Echelon BD Rolling



Two Rollers in Echelon (Side by Side)

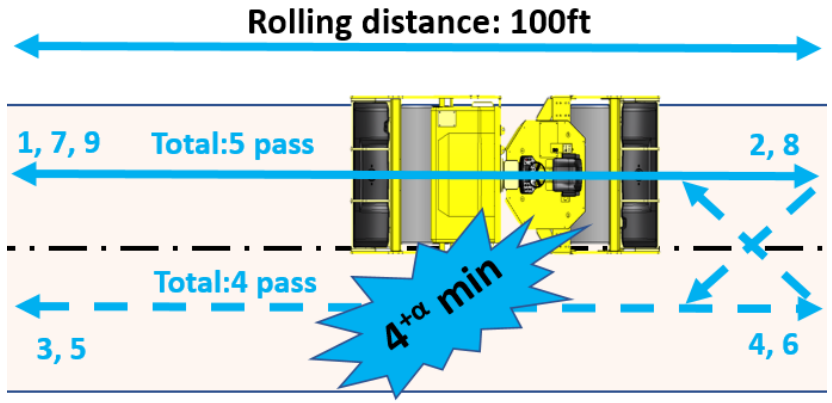
2 min for 5 passes

***By additional 5 passes the target density can be achieved.**



1%, after 5 passes

By Single BD Rolling



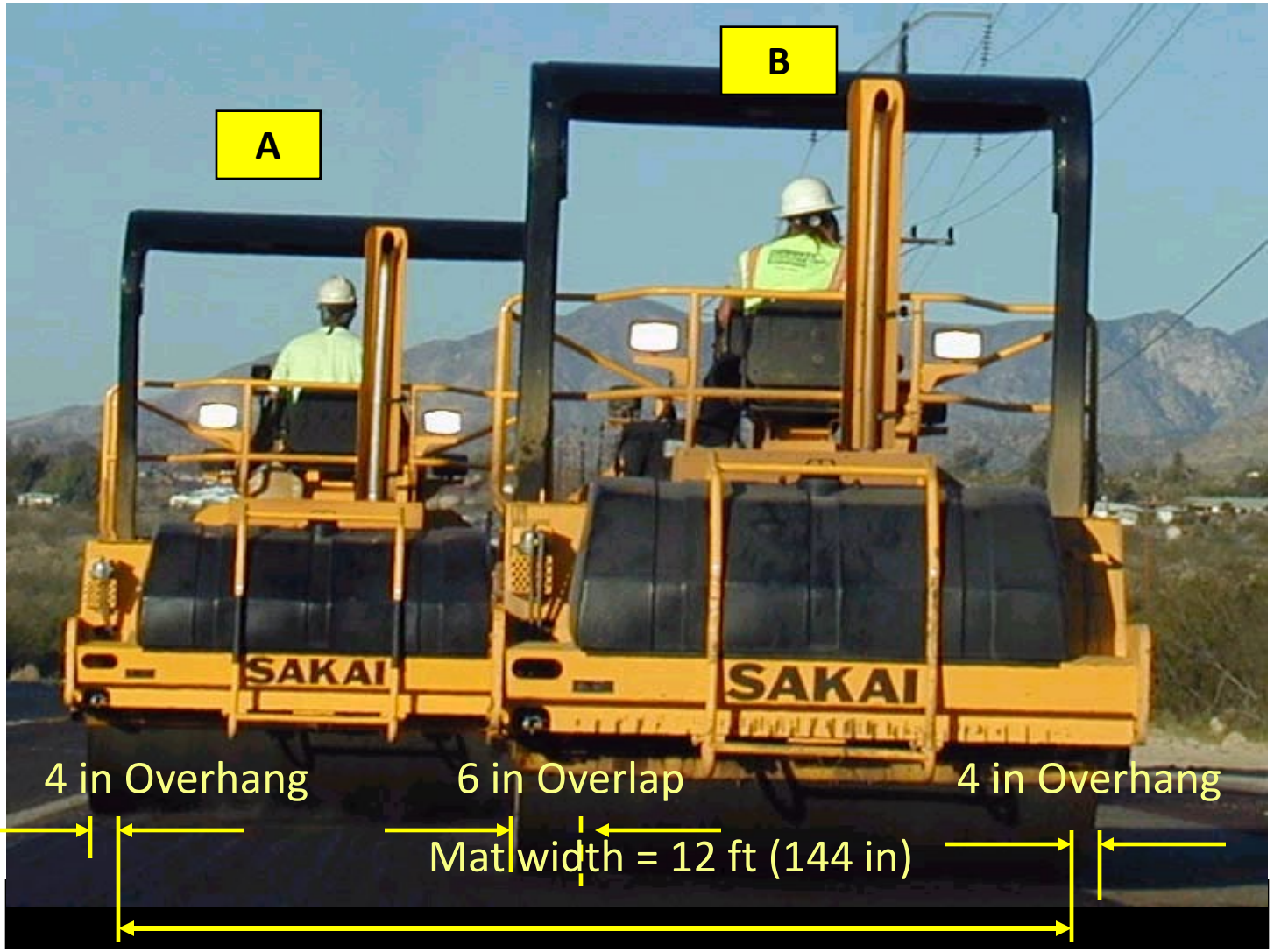
One Roller to Cover 2 lanes

$4^{+\alpha}$ min for 9 passes

Best Practice of Two Rollers in Echelon

1) Shorter Rolling Time = Easy to achieve the target density above Tender Zone “TZ”.
2) Consistent Pass # = Uniform density to meet PWL spec.
3) Double Drum Osc rollers are the best one, especially for thin layer less than 1-1/4” and jobsite where Vibe compaction is not allowed.
4) High Frequency (4,000vpm) Vibe rollers are also good option.

SW994 (84”) Echelon Over 12ft Wide Mat



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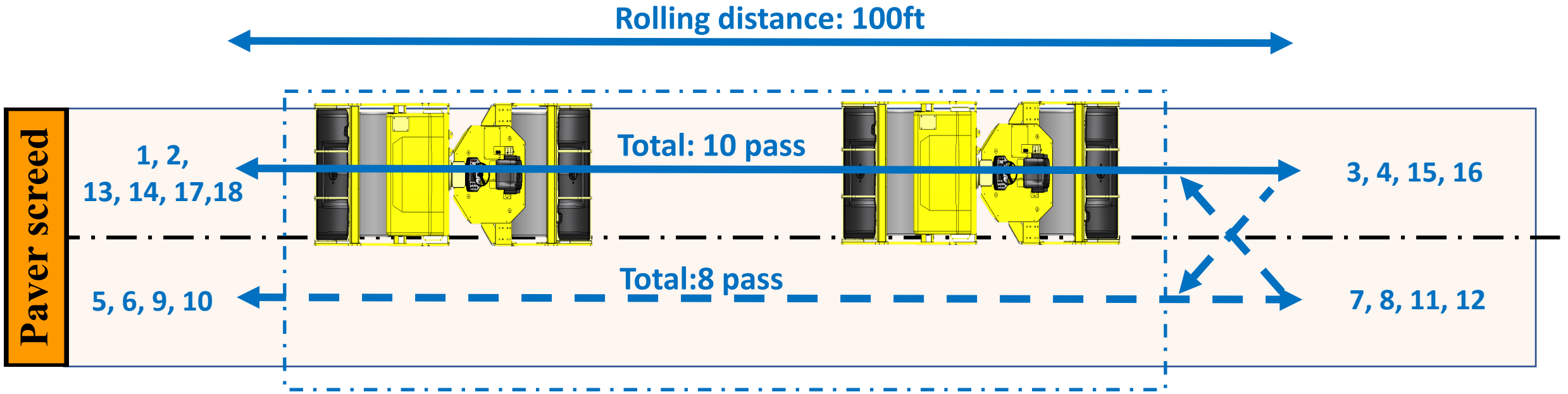
Rolling PatternSW884ND(79”) in Echelon for 12ft Mat

Benefits of Column Rolling

Rolling conditions: Distance:100ft, Pass #:8 or 10, Speed:3mph

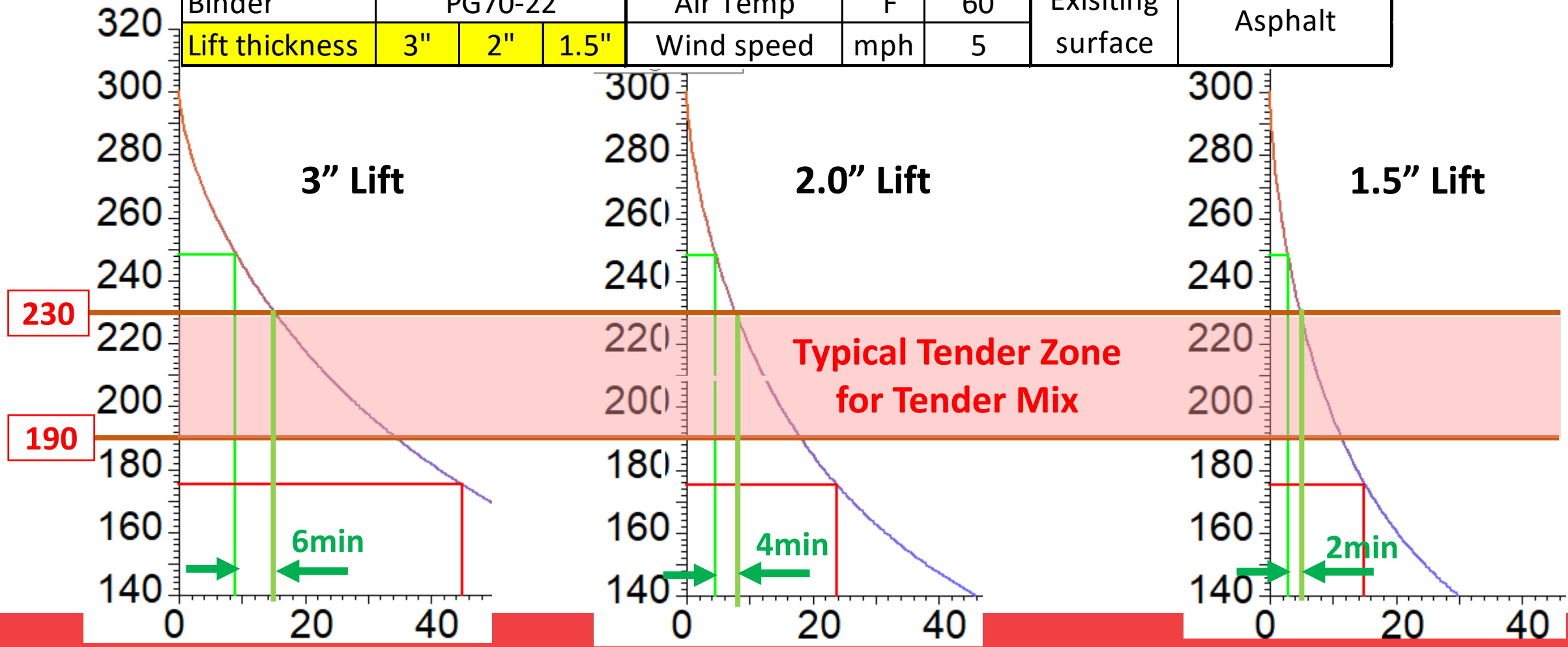
Two Different Rollers: 1) Consistent Pass #, 2) Uniform Compactive Efforts, 3) Both in BD & IM available, 4) No Finish roller may be needed.



Why Shorter Rolling Time, Better?

Time Available for Compaction is Short!

Mix type	Fine/dense			Delivery Temp	°F	300	Sky	Humid & Hazy
Binder	PG70-22			Air Temp	°F	60	Exisiting surface	Asphalt
Lift thickness	3"	2"	1.5"	Wind speed	mph	5		



Weapons for Better Density & Smoothness

- (Osc ⇔ Vibe) - Oscillatory Dbl Drum or High Frequency

  Density & Smoothness

- Vibratory Pneumatic: VPT or PTR

  Uniform Density in Depth

- (Static): Three Wheel for high PLI

  Smoothness

U.S. Department of Transportation
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Oscillation “Osc” vs. Vibration “Vibe”

STATIC	OSCILLATION	VIBRATION
HMA Mixes	HMA Mixes	HMA Mixes & Agg. Base

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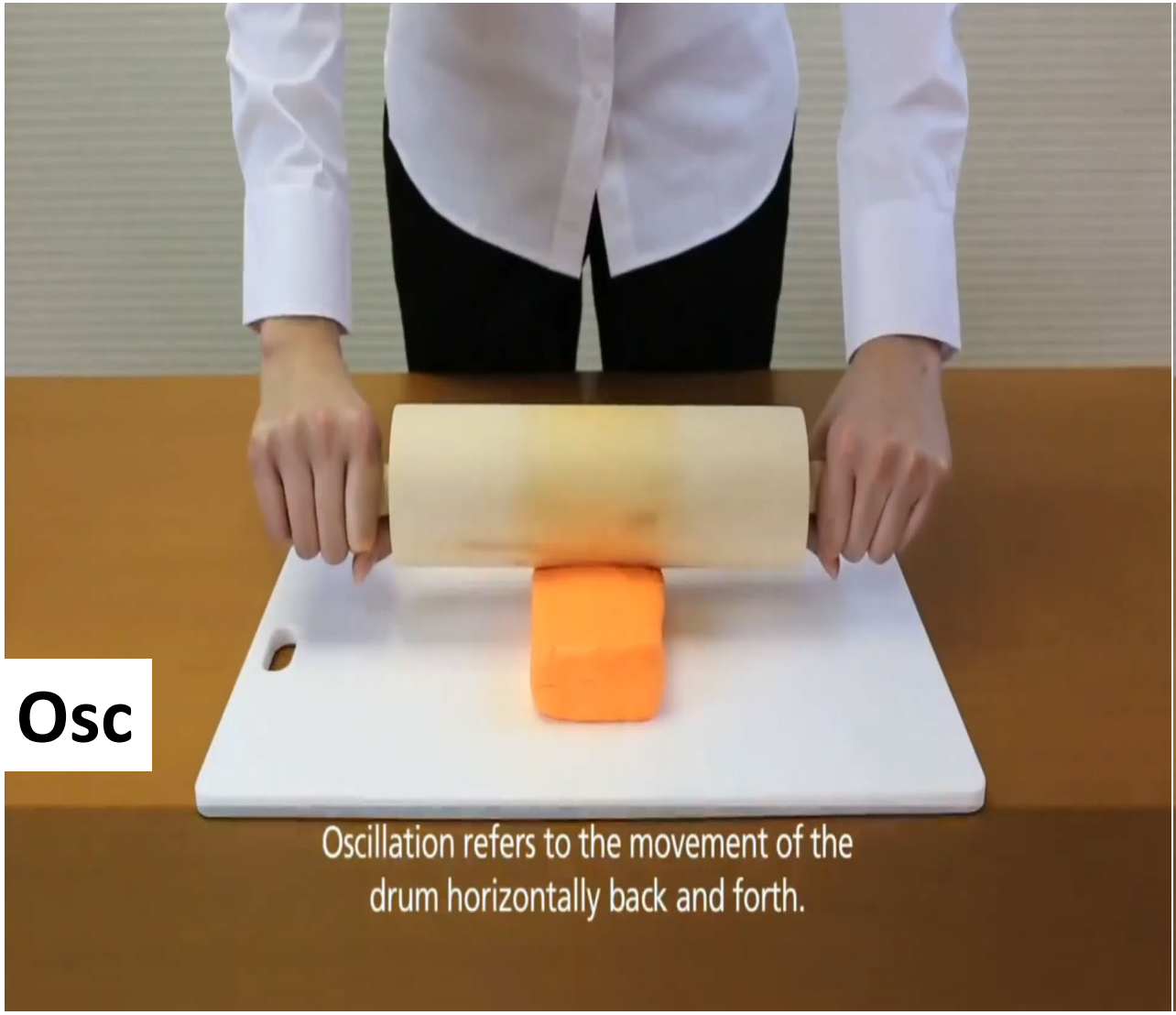
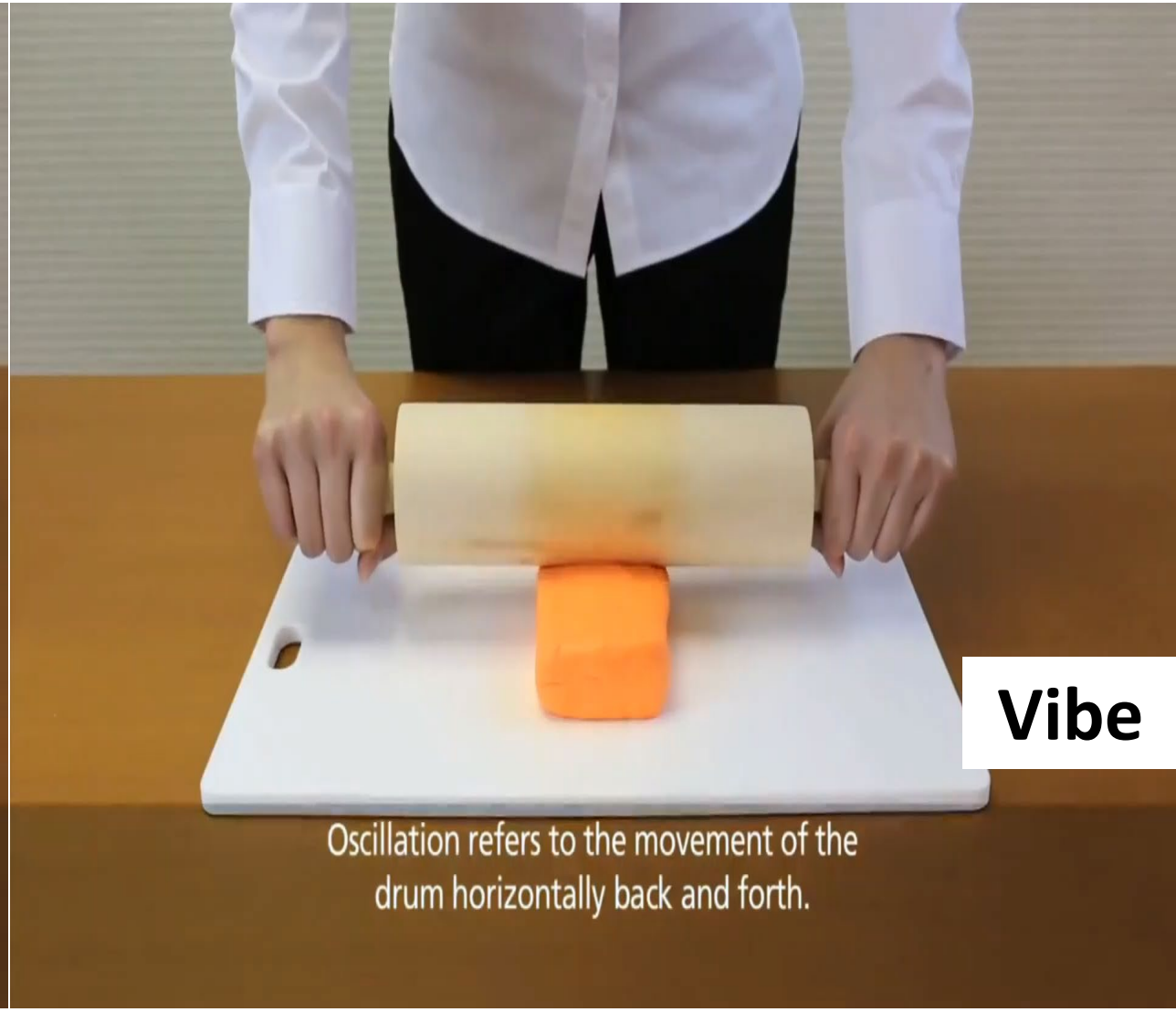
Use of Rolling Pin is the Same as Osc & Vibe





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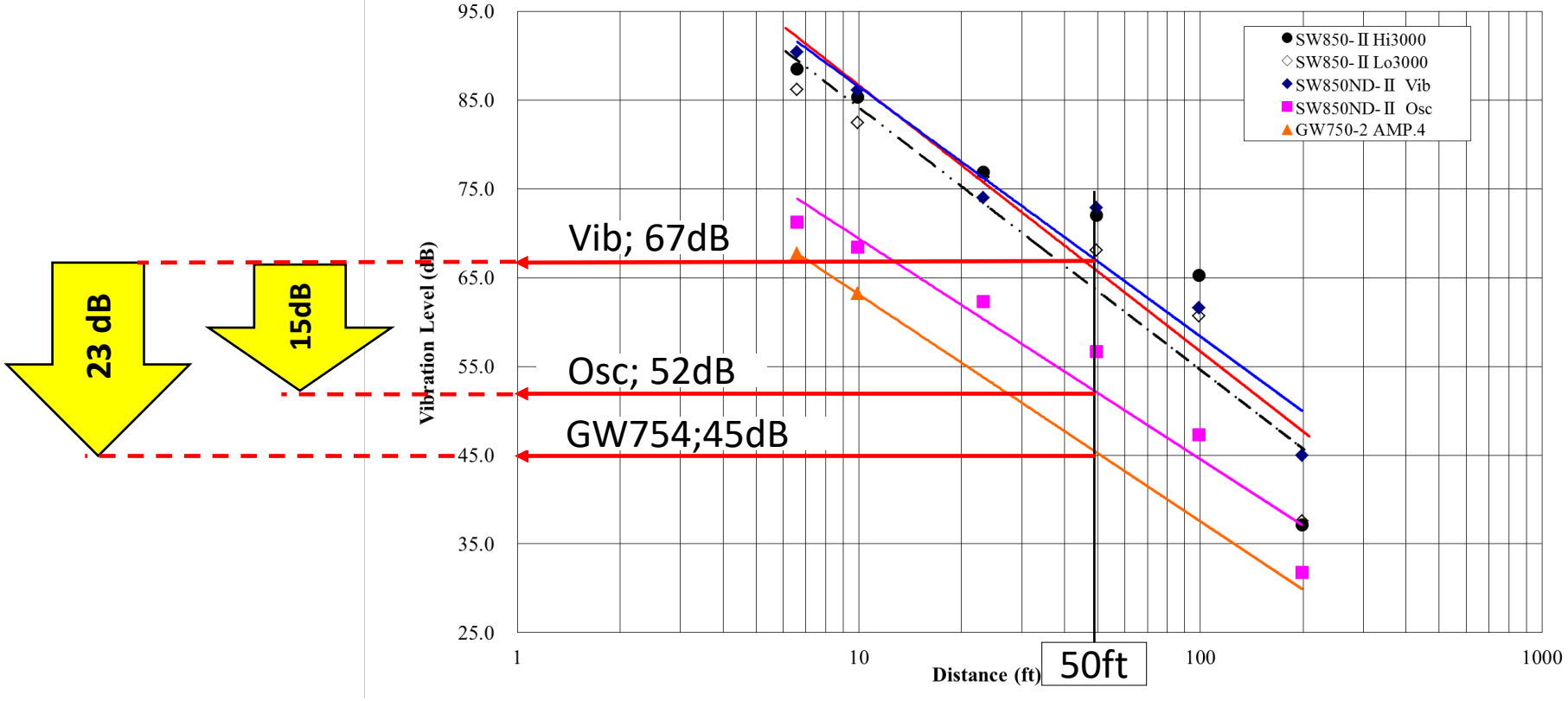
Drum Motion for Osc vs Vibe

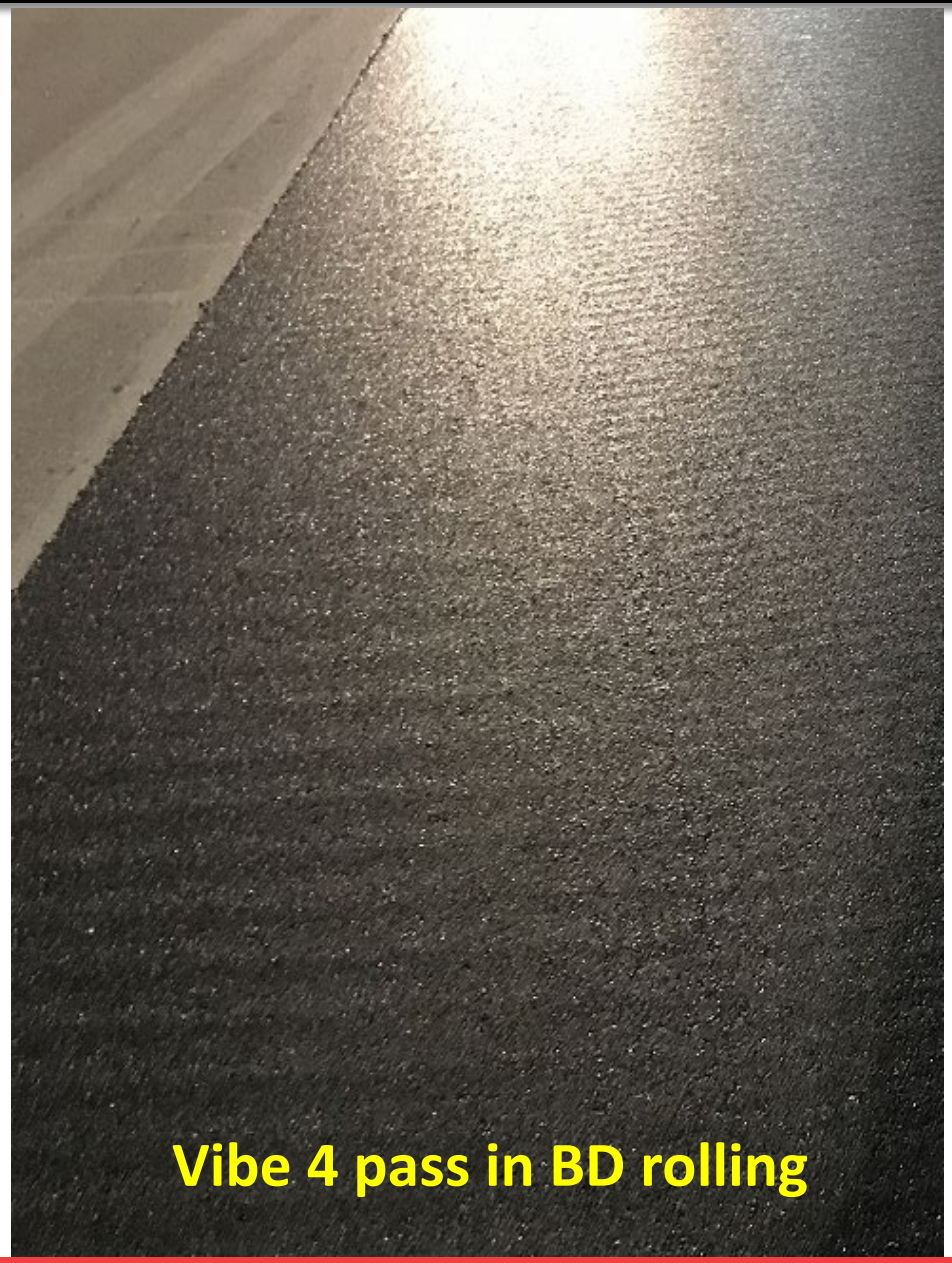
Why is Osc so GOOD in Residential Areas?

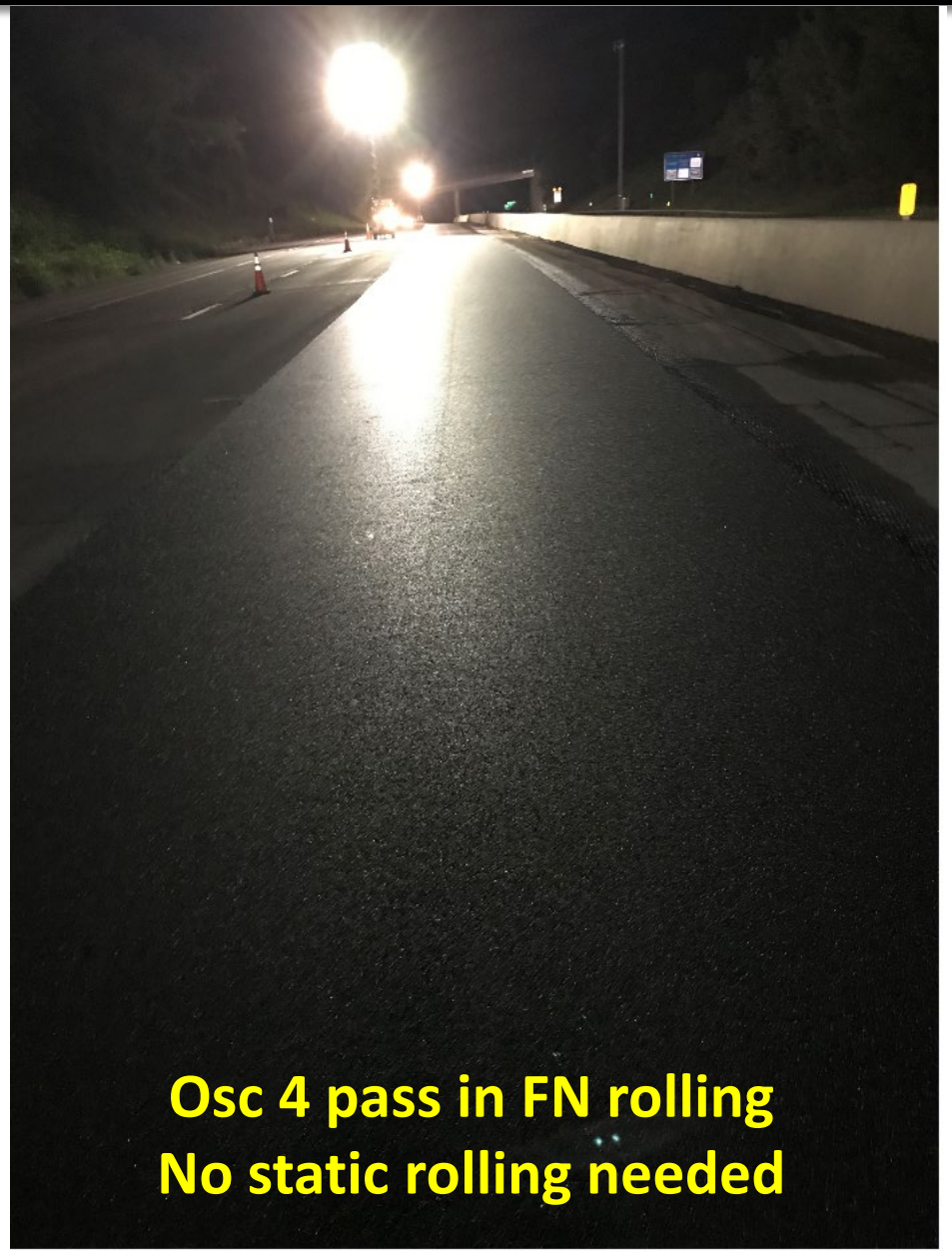
- Vibe levels measured at 50ft are 52dB (Osc) vs. 67dB (Vibe).
- This gap may remain constant, although the absolute values may fluctuate according to the type of soil and pavement, geometrical conditions, trench, ponds, etc.
- Less dB vibration measured equals less force being put through sub-structures or surrounding buildings.



- Osc is best applied when incentives (bonus or penalty) are given for pavement smoothness and density, i.e., it 's a bounty hunter roller.
- Especially for thin HMA pavement surface layers less than 1.5 inches, such as SMA, Open Graded Friction Course (OGFC), and HMA mixes with higher percentages of (RAP < 20%)
- Paving jobsites where vibratory compaction is NOT allowed.
  1) Residential area, hospital, school, etc.
  2) Bridge deck pavement.
  3) Soft aggregates and sand in HMA mixes.
- Improve the quality of the pavement
  1. Better Smoothness to No Washboarding
  2. In finish rolling process, increase density and smoothness
  3. Negative textures achieve high friction
     low noise and rolling resistance
  4. Longitudinal joint without crushing aggregates

Smoothed Thin Pavement in NY





1) Less Material limits compaction methods.
2) Over compaction/ White capping risk higher
3) Cooling occurs rapidly so compacting time reduced.
4) Oscillation best method to compact due to kneading effect.

Osc's Density is More than Equal to Vibe

- Target & Results:
  1) Smoothness (IRI)≦60 ⇒ Osc: 52 vs. Vibe: 80
  2) Density (%) 92~96 ⇒ Both: 93.0%
- Both made 4 Osc & 4 Vibe pass & 1 static pass.

	Statioin #	Osc	Vibe
Smoothness (IRI)	1	61.10	89.27
	2	52.25	82.10
	3	45.21	74.88
	4	46.49	69.65
	5	57.63	82.68
	6	48.96	71.53
	7	49.80	87.54
	Avg.	51.63	79.66
	Max.	61.10	89.27
	Min.	45.21	69.65
	Stdv.	5.83	7.73
Density, % of TMD		93.0	93.0

*FHWA Report says, "Comparison to vibratory not possible Fewer passes and greater density." May be the result of using other (single drum) vibratory rollers.

Category	MIRI (in/mi)	Pay Adjustment $ per 0.1 mi
Type A (Three or more HMA Lifts)	<30.0	$580
	30.0- less than 35.0	$480
	35.0- less than 40.0	$380
	40.0- less than 45.0	$280
	45.0- less than 50.0	$180
	50.0- less than 55.0	$80
	55.0- less than 60.0	$0
	> 60.0	Corrective Work
Type B (Two HMA Lifts)	<35.0	$420
	35.0- less than 40.0	$360
	40.0- less than 45.0	$300
	45.0- less than 50.0	$240
	50.0- less than 55.0	$180
	55.0- less than 60.0	$120
	60.0 less than 65.0	$60
	65.0 less than 70.0	$0
	> 70.0	Corrective Work
Type C (One HMA Lift)	<40.0	$280
	40.0- less than 45.0	$240
	45.0- less than 50.0	$200
	50.0- less than 55.0	$160
	55.0- less than 60.0	$120
	60.0- less than 65.0	$80
	65.0- less than 70.0	$40
	70.0- less than 75.0	$0
	> 75.0	Corrective Work

There are three (3) categories of acceptable MRI values:

Category	Description	MRI
Type A	Three or more HMA Lifts	Shall not exceed 60 in/mi
Type B	Two HMA Lifts	Shall not exceed 70 in/mi
Type C	One HMA Lift	Shall not exceed 75 in/mi

For example, IRI for Osc and Vibe measured in AR corresponds to $160/0.1ml as 50-55 and $0 as above 75.0 in Type C.

Statioin #	Osc	Vibe
1	61.10	89.27
2	52.25	82.10
3	45.21	74.88
4	46.49	69.65
5	57.63	82.68
6	48.96	71.53
7	49.80	87.54
Avg.	51.63	79.66

- The following example are not applicable to a competitor's Osc roller that combines a single Viber and Osc drum on the front and rear axles, respectively.
- FAQ: Why can't Vibe and Osc be used at the same time?

  Answer: It is more efficient and effective to equip two drums with the necessary functions, i.e., Osc or Vibe than one drum.

	Max Speed	Weather	Roller Position Used			Type of HMA Mixes					Layer Thickness		Type of Jobsite	
	(mph)	Cold & Windy	Break-down BD	Inter-mediate IM	Finish FN	Open Graded Friction Course	Superpave			SMA	<1.25"	>1.25"	Residential area	Bridge deck
							Tender	Stiff	RAP*[2] >20%					
ND Osc	4.0	✔	✔	✔	✔	✔	N/R	✔	✔	✔	✔	✔	✔	✔
HF Vibe	4.5	✔	✔	✔	N/R*	✔	✔*[1]	✔	✔	✔	✔	✔	N/R	N/R

*N/R: Not recommended

*[1]: Above Tender Zone

*[2] RAP: Reclaimed Asphalt Pavement

Tender Zone “T.Z.”

What is T.Z.?

Temperature zone in which mix is very tender.

Why?

Excess of fluids with too much binder or moisture.

Symptom?

Mat moves easily and difficult compact.

Result?

Shoving and cracking

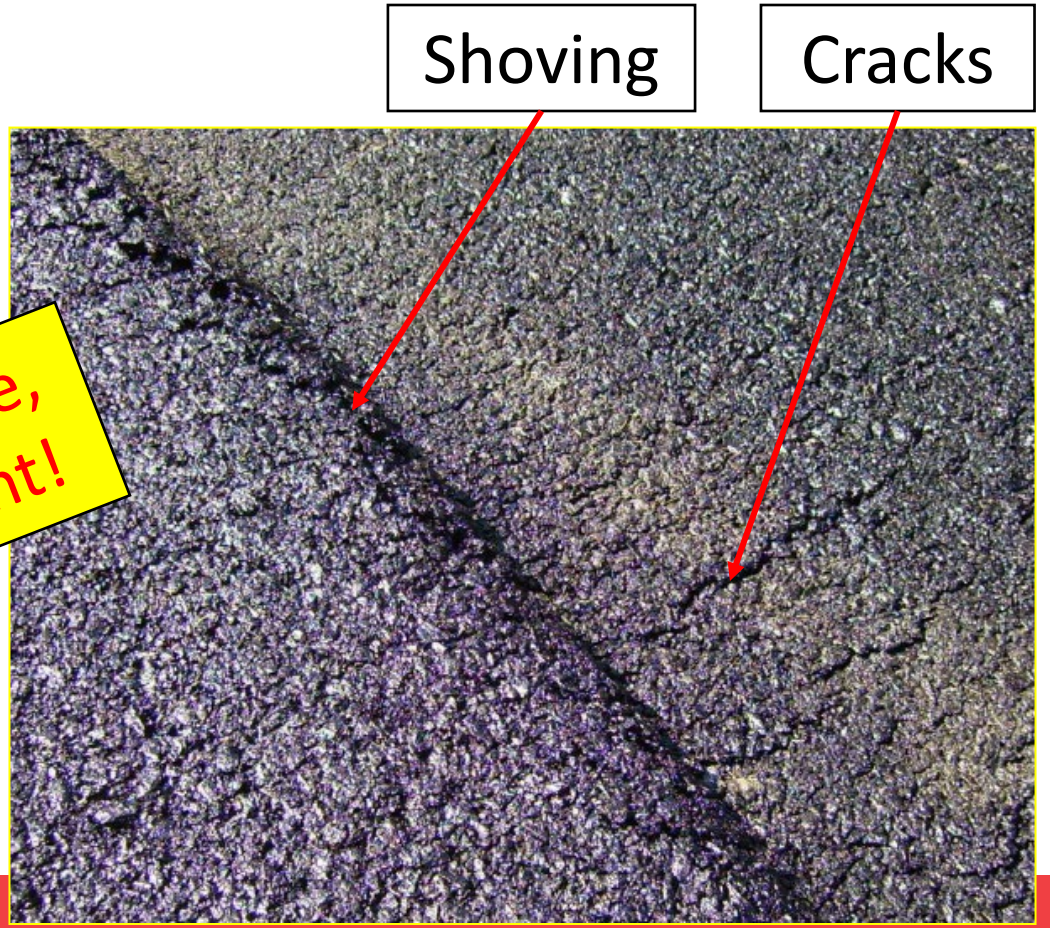
How to Compact Tender Mix in Tender Zone, “TZ”

1. Use Static Pneumatic Tire Roller, “PTR” or

Use Vibratory Pneumatic Tire Roller, “VPT”

2. Stop rolling by (Vibe) steel drum roller.
3. Wait for HMA mix cooling down below Tender Zone “TZ”.

2 & 3: Not acceptable, as it’s very Inefficient!



Vibratory Pneumatic Tire "VPT" Roller or Pneumatic Tire Roller

Conventional Pneumatic Tire Roller

- Make sure tire pressure set to application to ensure proper contact.
- Adjust ballast weight as needed from either blocks or different materials.
- Large concern for all pneumatic tires is pickup of material.

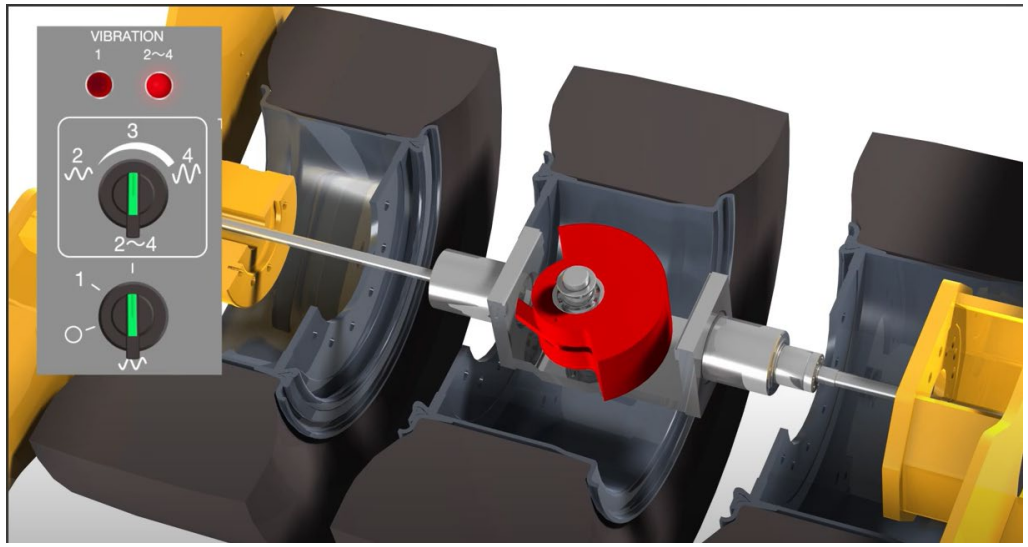
Ground Contact Pressures

Weight per Wheel

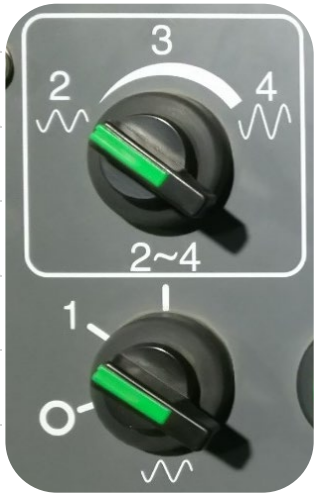
Average Wheel Load	Tire Pressure	300 kpa 44 psi	400 kpa 58 psi	500 kpa 73 psi	600 kpa 87 psi	700 kpa 102 psi	800 kpa 116 psi	850 kpa 123 psi	900 kpa 131 psi
	1500 kg 3,307 lb	242 kPa 35 psi	309 kPa 45 psi	406 kPa 59 psi	612 kPa 89 psi	680 kPa 99 psi_i	1038 kpa 151 psi	1265 kpa 184 psi_i	1587 kpa 230 psi
	2000 kg 4,410 lb	260 kPa 38 psi	299 kPa 43 psi	357 kPa 52 psi	462 kPa 67 psi	498 kPa 72 psi_i	628 kpa 91 psi	691 kpa 100 psi_i	764 kpa 111 psi
	2500 kg 5,512 lb	308 kPa 45 psi	322 kPa 47 psi	360 kPa 52 psi	429 kPa 62 psi	458 kPa 66 psi_i	539 kpa 78 psi	577 kpa 84 psi	618 kpa 90 psi
	3000 kg 6,614 lb	397 kPa 58 psi	369 kPa 54 psi	386 kPa 56 psi	433 kPa 63 psi	457 kPa 66 psi_i	516 kpa 75 psi	543 kpa 79 psi	573 kpa 83 psi
	3375 kg 7,441 lb	518 kPa 75 psi	423 kPa 61 psi	418 kPa 61 psi	448 kPa 65 psi	469 kPa 68 psi	517 kpa 75 psi	539 kpa 78 psi	564 kpa 82 psi

Vibratory Pneumatic Tire Roller

- Also Changes Centrifugal Force Settings for more fine tuning to application.
- No Ballast Required as vibration force = to static weight.



			EG Throttle Switch		
		Positon	Full		Middle (ECO)
		Engine	2,400rpm		1,900rpm
Vibe	Amplitude		Centrifugal force		
	Switch #	in	lbs		lbs
Front Axle	1	0.004	1,345		900
	2	0.012	4,270		2,695
	3	0.021	7,195		4,495
	4	0.029	10,115		6,295
Rear Axle	1	0.004	1,800		1,125
	2	0.012	5,620		3,370
	3	0.021	9,440		5,845
	4	0.029	13,040		8,315



VPT / PTR for Tender & Thin Lift Layer

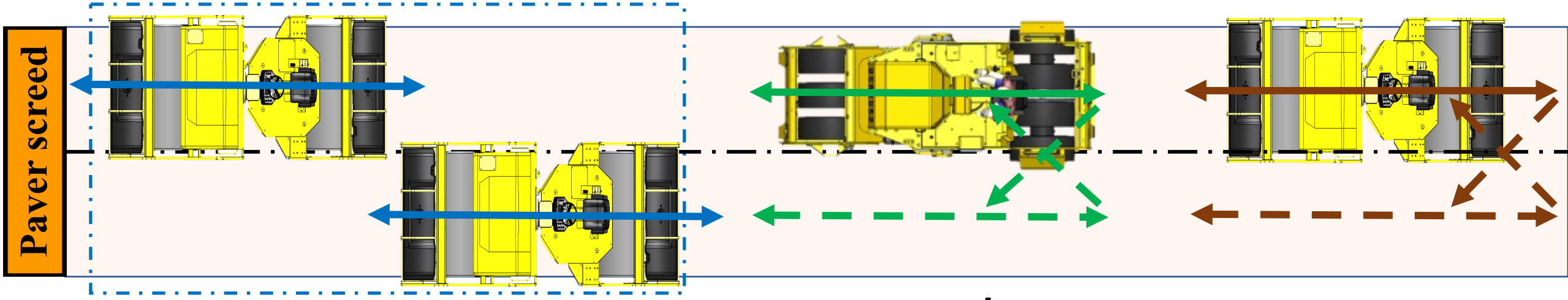
BD: Two Osc or HF Vibe roller in Echelon

After screed:80%→Target:

+12~13%, 92~93%

FN: Double Drum Osc roller

Target: +1~2%, 95~96%

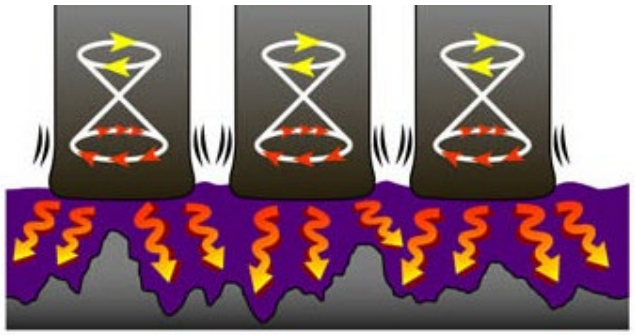


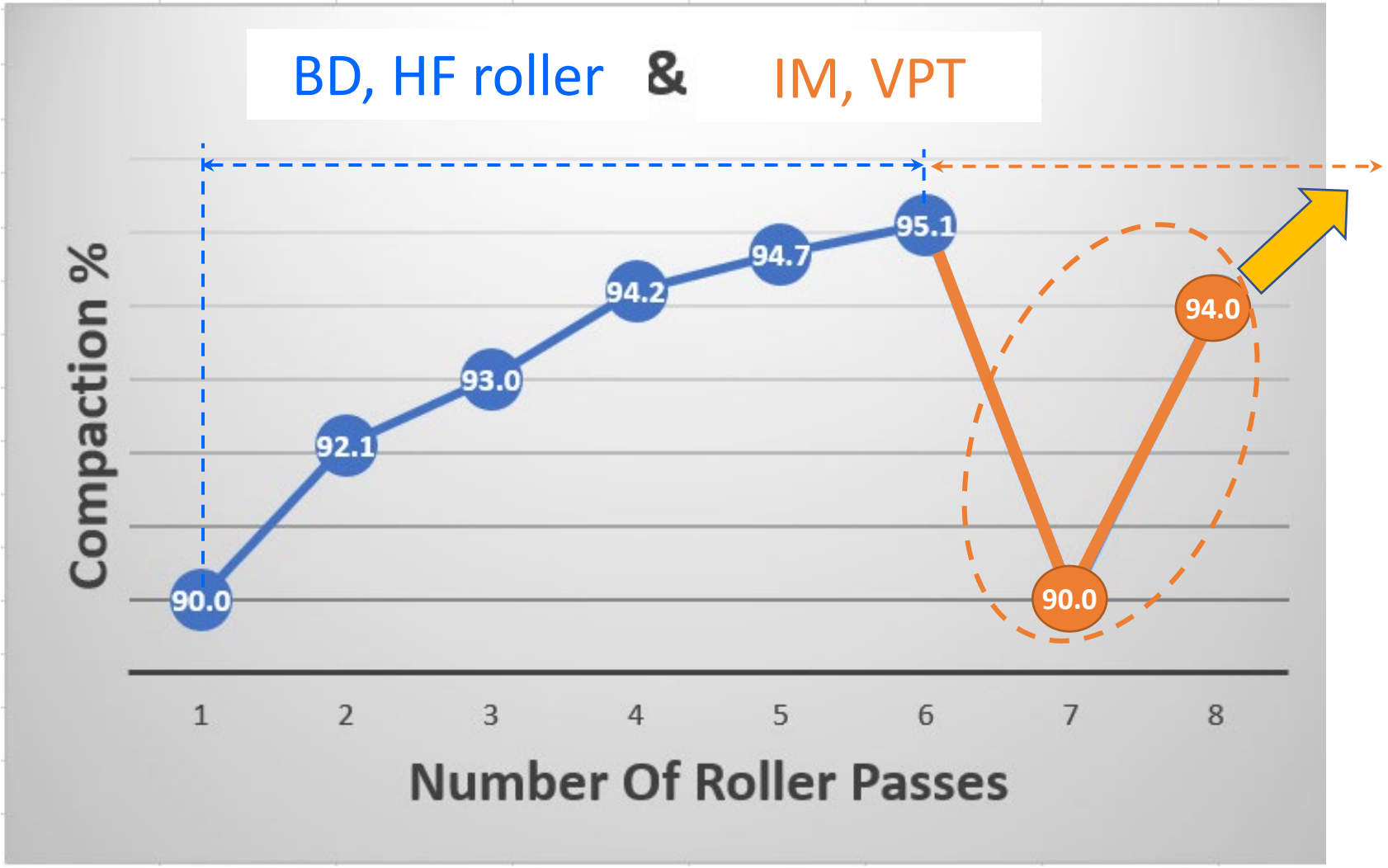
IM: VPT/PTR,

Target: +1~2%,

93～94%

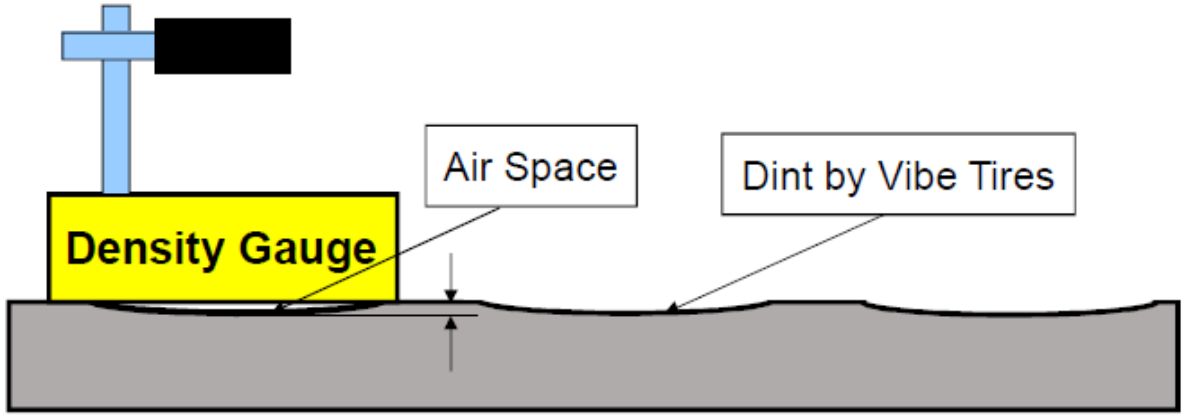
To improve bonding



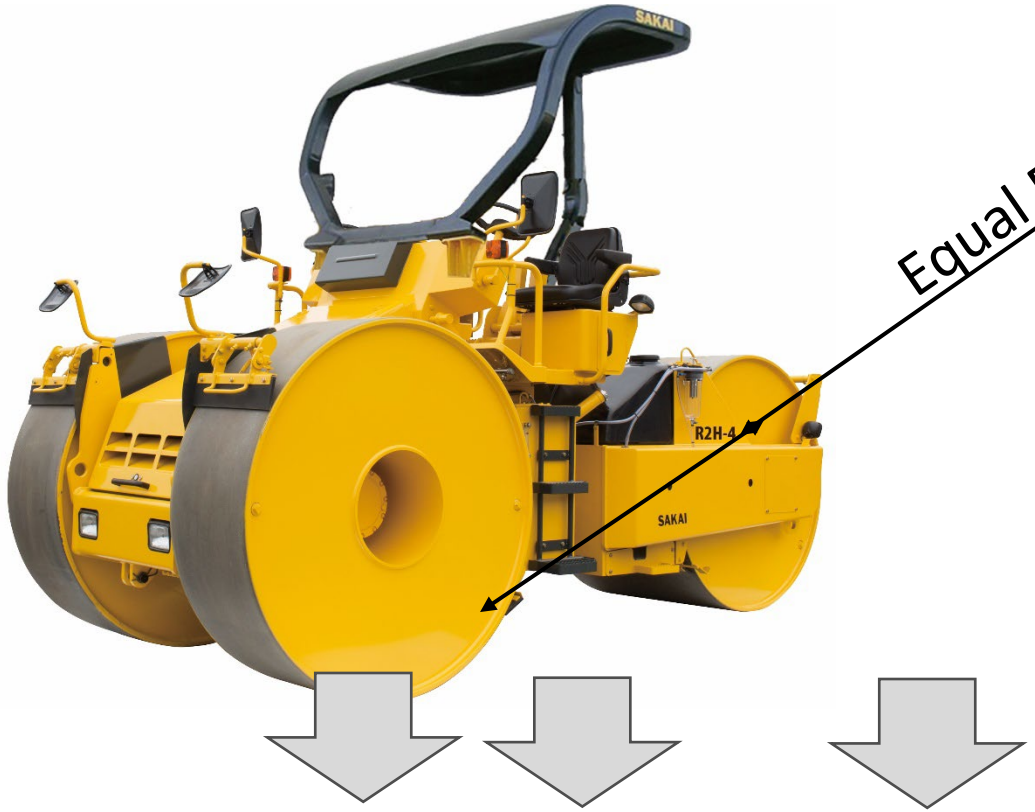

BD, HF roller & IM, VPT
Compaction %
90.0
92.1
93.0
94.2
94.7
95.1
90.0
94.0
1
2
3
4
5
6
7
8
Number Of Roller Passes

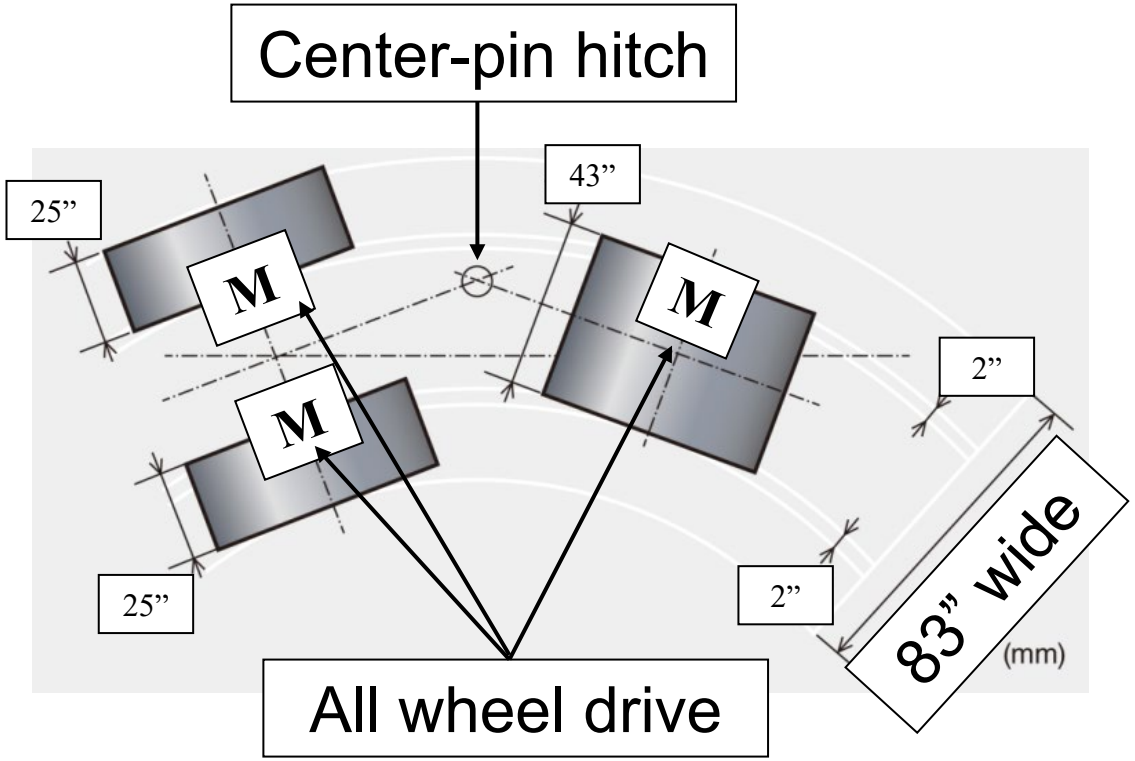
Pneumatic Tire Density Readings

- Dent left on mat surface compacted by VPT/PTR made slight air space under the bottom of gauge.
- The gauge reading includes the zero % density in air space.
- Gauge reading comes back after the surface is smoothed out by following passes.
- This indicates that VPT or PTR is still capable of densifying the mat, even though after BD rolling.



Dedicated Static Roller for Smoothness

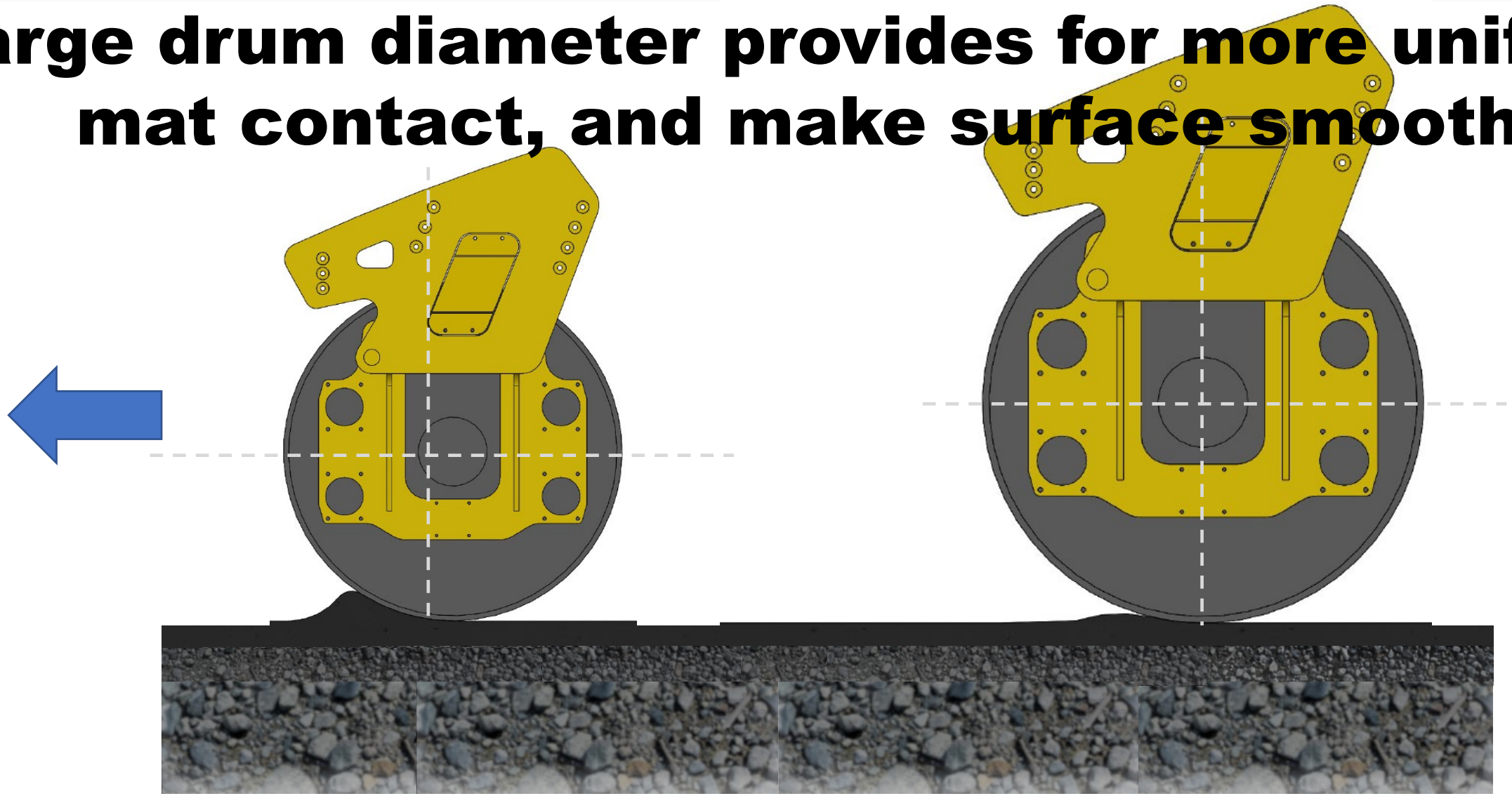




Uniform PLI* of 365,
Max weight; 31,625lb
*PLI: Pounds linear inch

- Application; Thin layer, soft aggregates base, bridge decks, & job sites where vibe operation is prohibited.

Large drum diameter provides for more uniform mat contact, and make surface smooth



The effects are more visible on thick asphalt layer

R2H: Echelon Rolling on 12’ wide mat, IL

The smoothness of existing pavement can be also improved by “COLD ROLLING” as long as the mat temp. is above 120°F

SMA mix including crumb rubber

For Special Projects

Barber Motor Sports Park, AL
By Granite Construction

Target IRI: 20 in. / mile

R2H + SW850ND (Osc) + SW774 (Static)

You can see the movie
https://www.youtube.com/watch?v=S_LQtcsPdEs

Proposed RP (1) for Improved Density

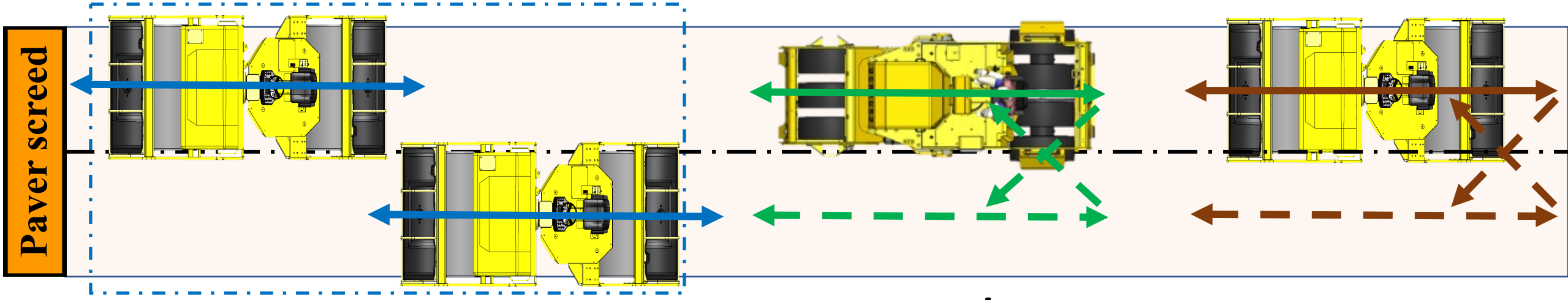
BD: Two Osc or HF Vibe roller in Echelon

After screed:80%→Target:

+12~13%, 92~93%

FN: Double Drum Osc roller

Target: +1~2%, 95~96%



IM: VPT/PTR,

Target: +1~2%,

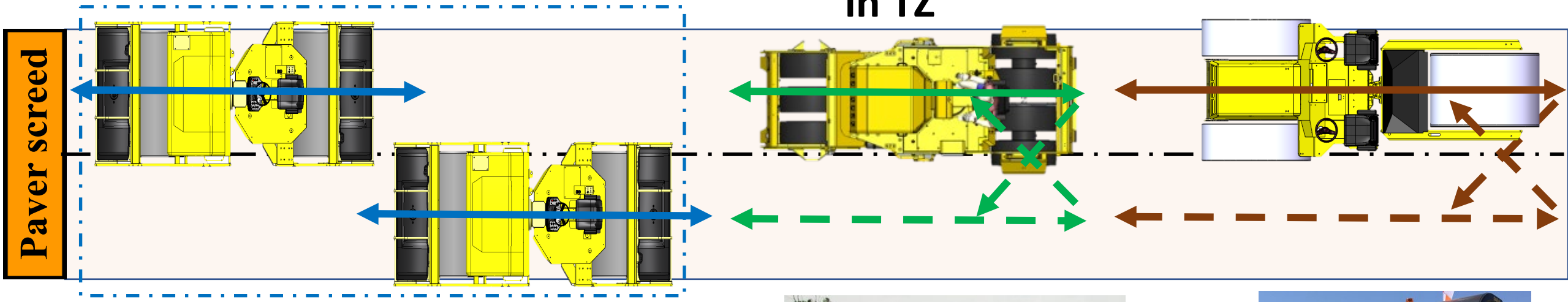
93～94%

Proposed RP (2) for Improved Density

BD: Two Osc or HF Vibe rollers in Echelon

IM: PTR or VPT in TZ

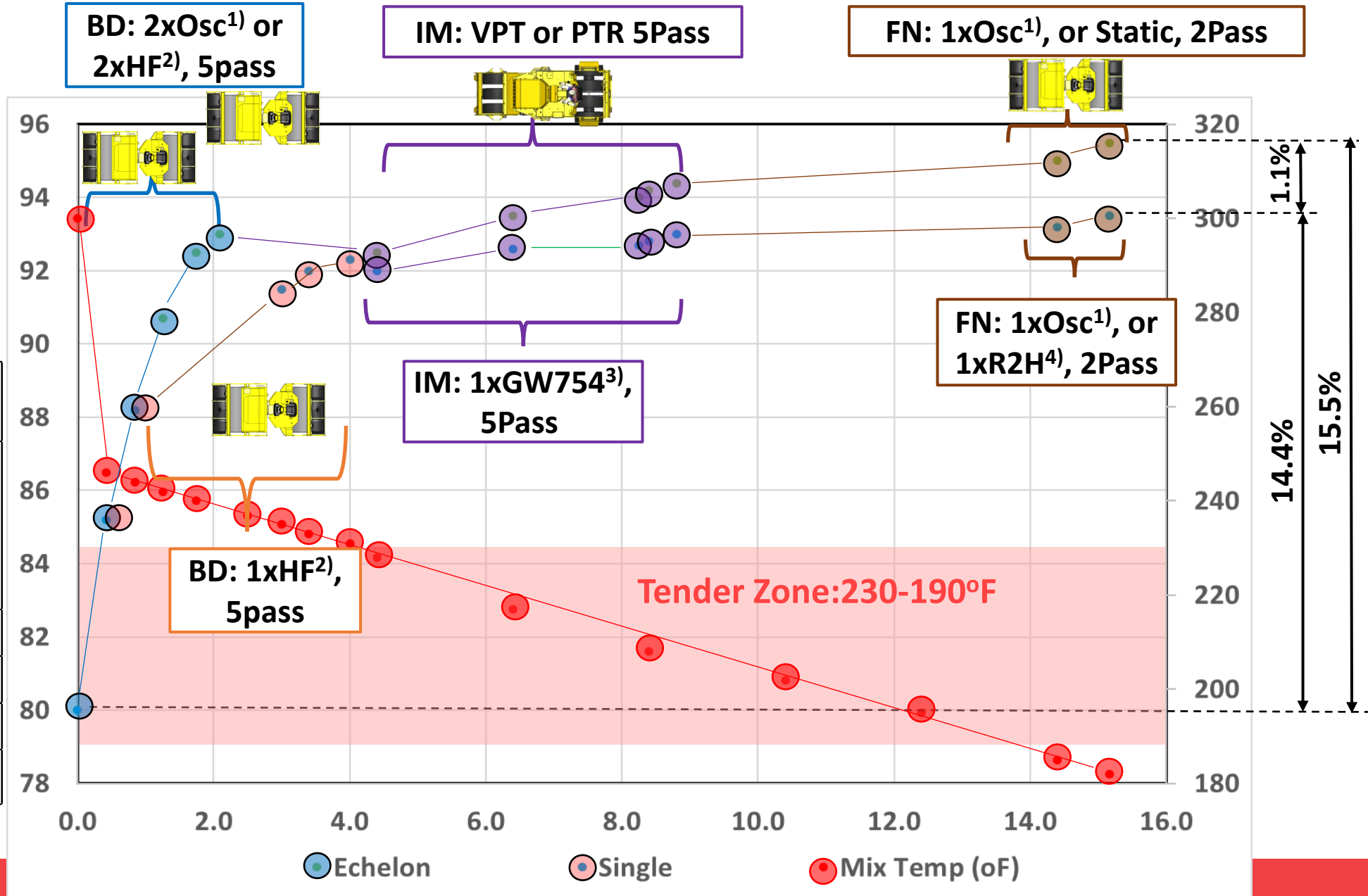
FN: Three Wheeler R2H



SAKAI
MASTERS OF COMPACTION

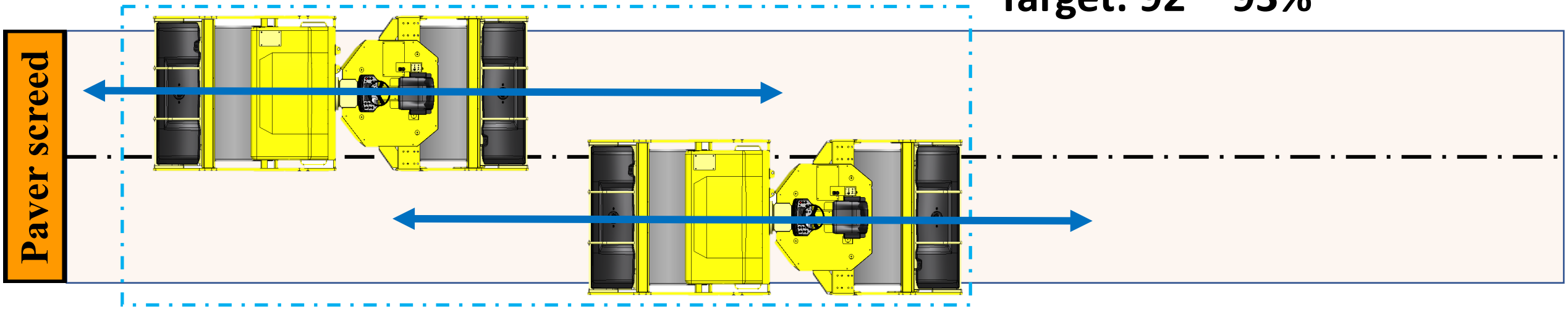
1) Osc: Oscillatory roller
2) HF: High Freq. vibe roller
3) Static Tire or Vibe pneumatic tire roller
4) Static Three Wheeler
5) PTR: Pneumatic Tire roller
6) Static: Steel Drum roller

	Density Increase in Each Rolling Position		
	2xOsc or 2xHF in BD	1xHF in BD	Gap
BD	13	12.2	0.8
IM/GW	1.4	1.1	0.3
FN/Osc	1.1	1.1	0.0
Total	15.5	14.4	1.1

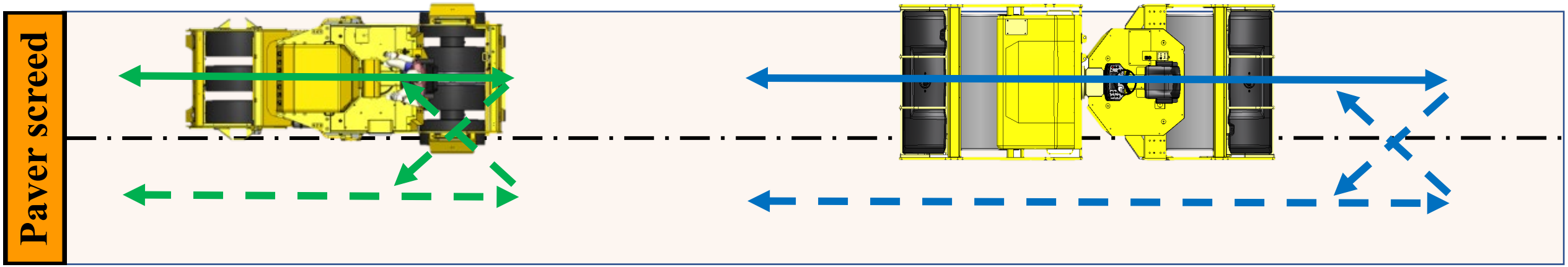


Proposed RP (3) Achieve Target Density & Smoothness by Minimum Rollers to Cut Cost

Target: 92～93%



Two Osc or HF Vibe rollers in Echelon (Side by Side)



BD: VPT or PTR

FN: Double Drum Osc


Questions?

Thank You

SAKAI

MASTERS OF COMPACTION

ROADS MUST BE BUILT. WORLDS MUST BE CONNECTED.