Washington State Asphalt IC Demonstration Report

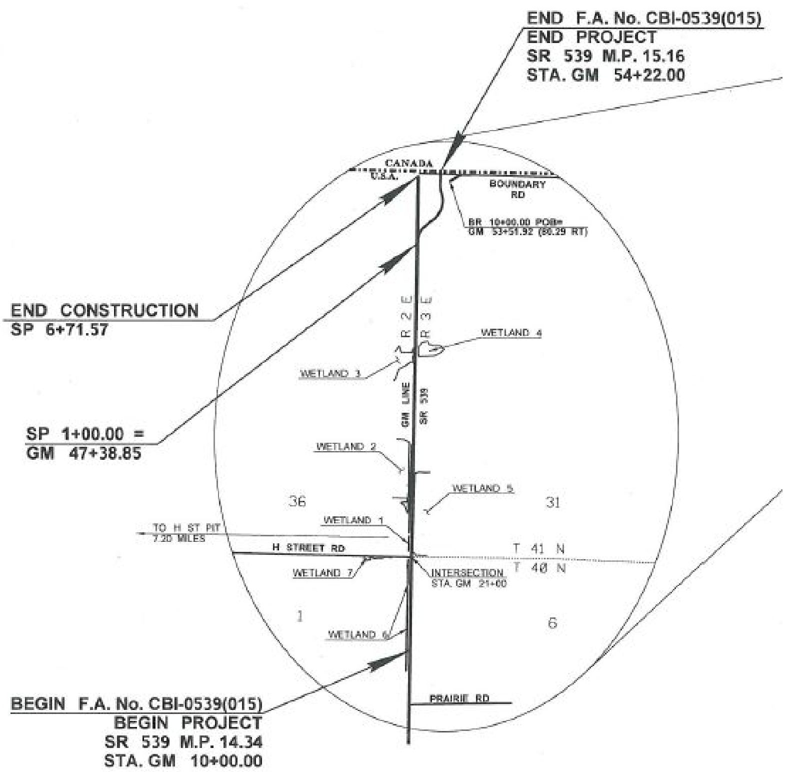




Contents

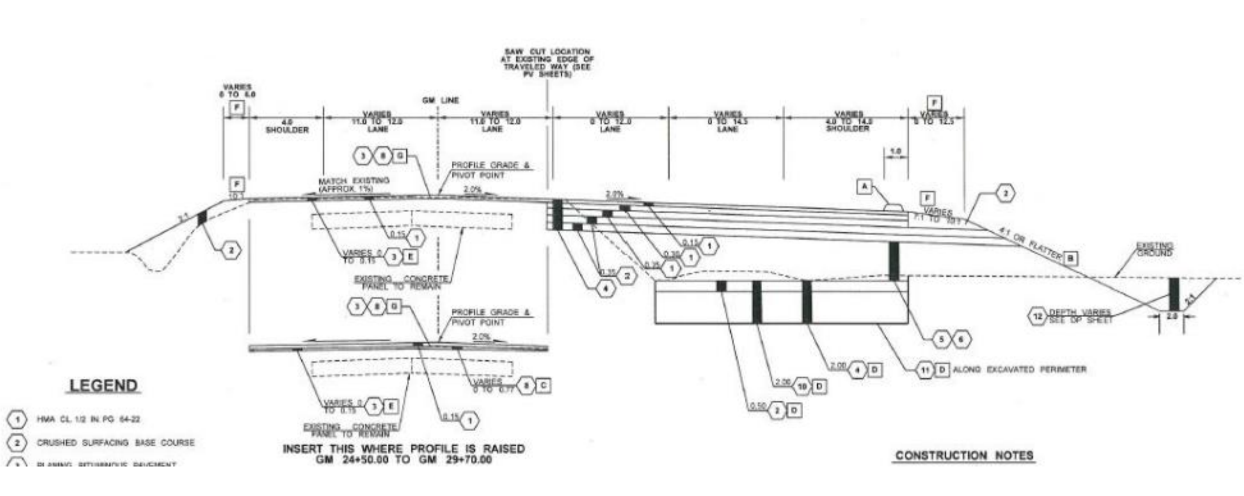
Project Site

SR 539, Lynden-Aldergrove Port of Entry Improvements, WA (August 25-28, 2014)



The target layer construction for this FHWA IC study was on the base course of asphalt layers.

A typical section design is as follows:



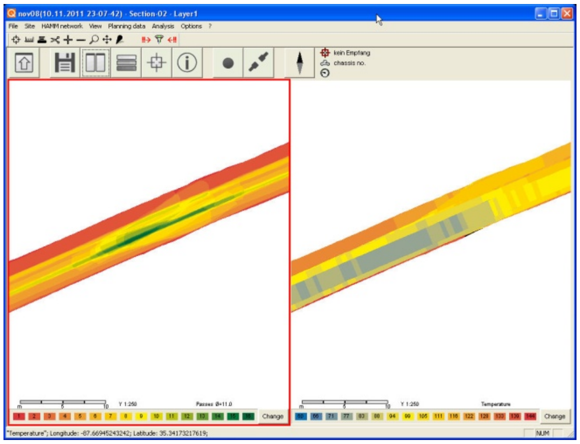
Project Test Beds

The total length of this project was 2,500 ft with three lanes of construction. The lane widths ranges from 13 to 14 ft. The paving direction was from the north to the south.

TB	Description	Date	Machine
1A	NB right lane - 4.25" base course	8/25	Hamm (breakdown)
1B	NB right lane - 4.25" base course	8/25	CAT (intermediate)
2A	NB left lane - 4.25" base course	8/26	Hamm (breakdown)
2B	NB left lane - 4.25" base course	8/26	CAT (intermediate)
2C	NB middle lane - 4.25" base course	8/26	Hamm (breakdown)
2D	NB middle lane - 4.25" base course	8/26	CAT (intermediate)
3A	NB right lane - 4.25" intermediate course	8/27	Hamm (breakdown)
3B	NB right lane - 4.25" intermediate course	8/27	CAT (intermediate)
3C	NB middle lane - 4.25" intermediate course	8/27	Hamm (breakdown) CAT(intermediate)
3D	NB middle lane - 4.25" intermediate course	8/27	CAT (breakdown) Hamm(intermediate)
3E	NB left lane - 4.25" intermediate course	8/27	CA (breakdown)
3F	NB left lane - 4.25" intermediate course	8/27	Hamm (intermediate)

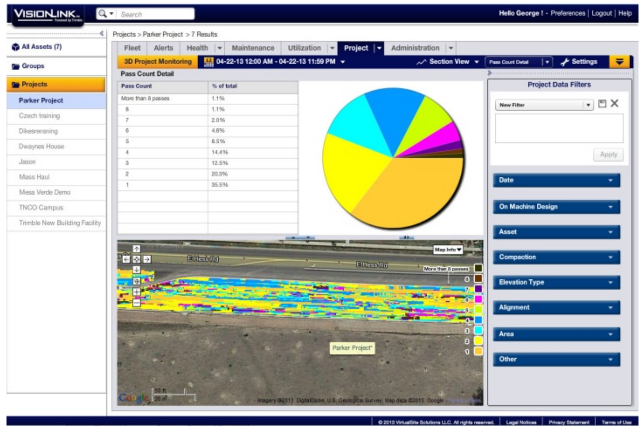
IC Rollers

HAMM Double-Drum IC Roller



Manufacturer/ Vendor	HAMM/Wirtgen
Model Name	HCQ (Hamm Compaction Quality)
Model Number	HD+ 140
Drum Width	84”
Machine Weight	Operating wt. 28,929 lbs. w/max of 31,509 lbs.
Amplitude Settings	High/Low - .03/.01 in.
Frequency Settings	Variable from 2700 - 4020 vpm
Auto-Feedback	NA
Measurement System	HAMM Compaction Quality (HCQ)
Measurement Value	HMV, density estimator, temperature, passes
Measurement Unit	[unitless, % compaction, °C, color coded]
GPS Capability	Yes
Documentation System	HCQ with ability to export to Veda
Contact	Tim Kowalski (615) 594-4604 tkowalski@Wirtgenamerica.com

Caterpillar Double-Drum IC Roller

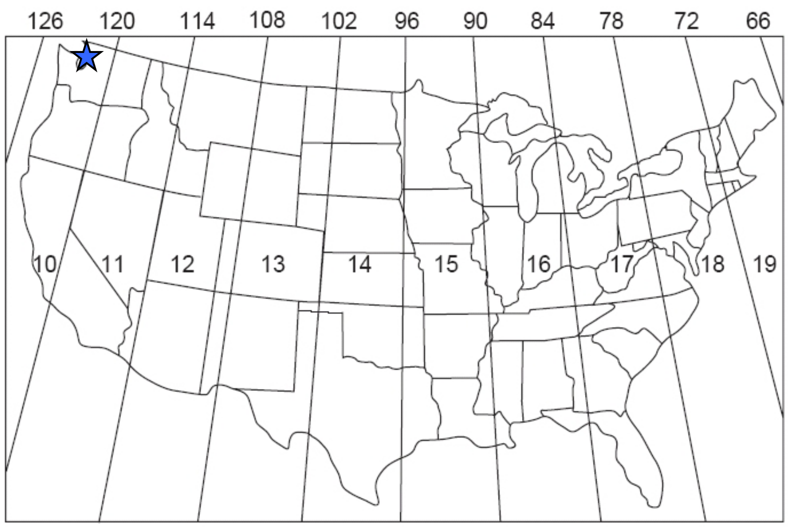


Manufacturer/ Vendor	Caterpillar
Model Name	Tandem vibratory rollers
Model Number	CB54XW
Drum Width	79"
Machine Weight	Operating wt. 26,230 lbs.
Amplitude Settings	0.034 – 0.012”
Frequency Settings	2,520 and 3,800 vpm
Auto-Feedback	NA
Measurement System	Compaction Meter Value (CMV)
Measurement Value	CMV
Measurement Unit	[unitless]
GPS Capability	Yes
Documentation System	VisionLink
Contact	Todd Mansell, 763-447-5695, Mansell_Todd_W@cat.com Dave King, 763-412-5553, King_David_A@cat.com

Global Positioning System (GPS)

Grid Reference

UTM-10N is the preferred coordinate reference for all devices.



Trimble GPS

- A Trimble GPS receiver and a radio were mounted on the Caterpillar IC roller.
- A Trimble GPS base station was setup to provide RTK correction signals.
- A hand-held Trimble GPS rover was used for in-situ point measurements.

OmniSTAR GPS

- A GPS receiver with OmniSTAR subscription will be mounted on the HAMM IC roller.

Test Plan

On-site Activities

Schedule	Activities
Day 0 Sunday (Aug 24)	• Conduct IC rollers/GPS setup and trial runs (equipment vendors and FHWA IC team only) at the staging area. (2PM-4PM) • Conduct project briefing at the staging area and IC training for roller operators (4PM-5PM).
Day 1 Monday (Aug 25)	• Conduct project and safety briefing at the staging area (5:30AM). • Set up the GPS base station and IC roller/GPS system (6AM). • Start paving with one IC roller at breakdown and another IC roller at intermediate position. • Select a 500-ft section as a test strip to establish the rolling pattern. Conduct NG/GPS/LWD-a testing immediately behind the paver and at selected locations after each breakdown and intermediate roller pass within the test strip. • Perform production compaction using the rolling pattern. • Conduct NG/GPS/LWD-a at selected locations after the finishing rolling
Day 2 Tuesday (Aug 26)	• Set up the GPS base station and IC roller/GPS system (by 6AM). • Start paving with one IC roller at breakdown and another IC roller at intermediate position. • Conduct NG/GPS/LWD-a testing immediately behind the paver and at selected locations after each breakdown roller pass within the 1500-ft section. • Conduct NG/GPS/LWD-a testing at selected locations after each intermediate roller pass within the 1500-ft section. • After the finishing rolling, mark 60 locations within the 1500-ft paved section. Conduct NG/GPS tests at marked locations. Conduct FWD, GPS and LWD-a tests at designated locations. Conduct GPR scanning. Conduct coring at the marked locations.
Day 3 Wednesday (Aug 27)	• Set up the GPS base station and IC roller/GPS system (by 6AM). • Start paving with one IC roller at breakdown and another IC roller at intermediate position. • Select a 500-ft section. Conduct NG/GPS/LWD-a testing immediately behind the paver and at selected locations after each breakdown and intermediate roller pass within the test strip. • Perform production compaction using the rolling pattern. • Conduct NG/GPS/LWD-a at selected locations after the finishing rolling.
Days 4 Thursday (Aug 28)	• Conduct the Open House event including presentation and equipment demonstration.

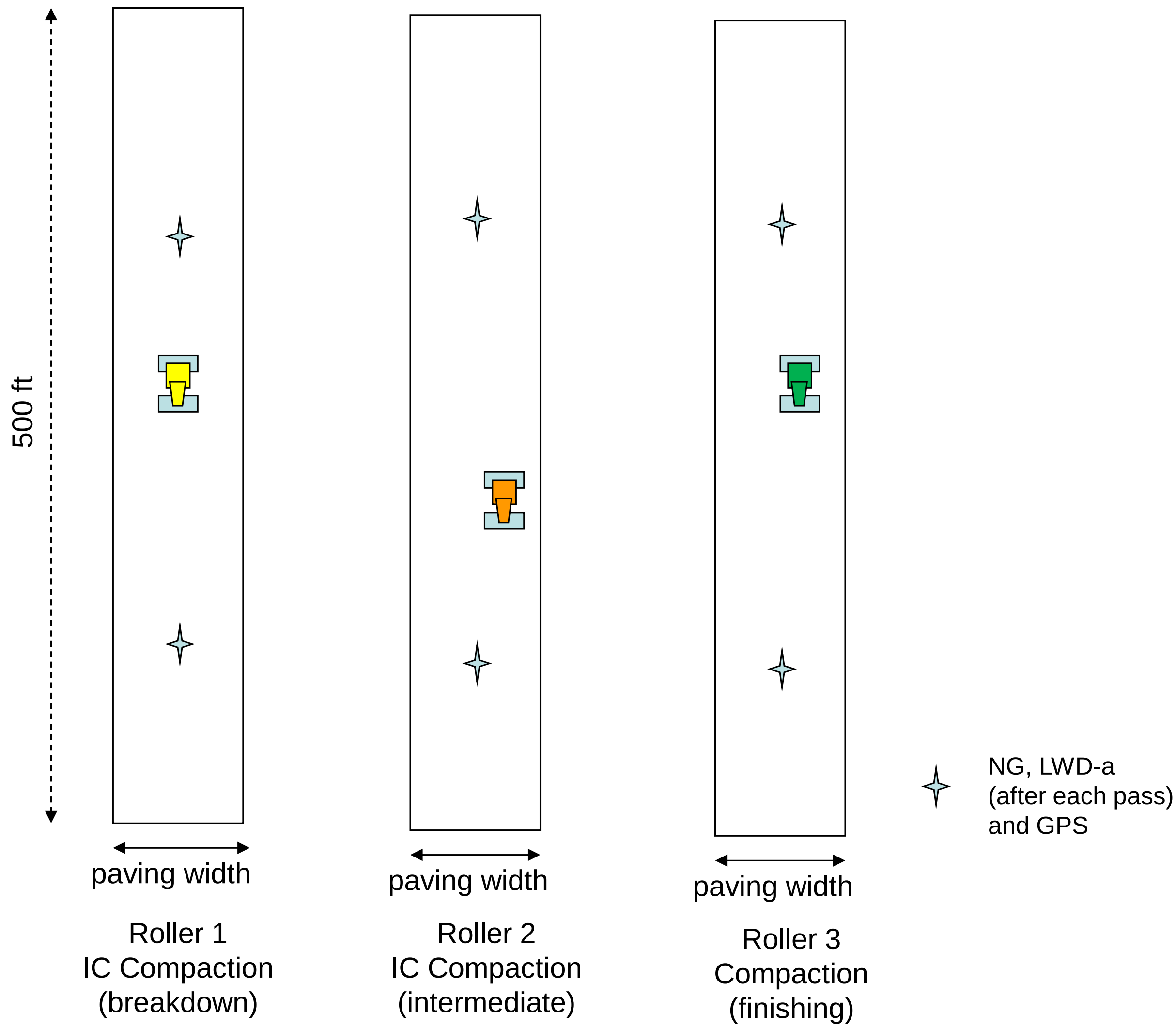
- GPS: Hand-held GPS rover and a base station was provided by SITECH-NW.
- NG: Nuclear density gauge and an operator was provided by the contractor and DOT.
- LWD-a: Lightweight deflectometer for asphalt tests were provided by Kessler.
- FWD: Falling weight deflectometer and an operator was provided by DOT.

- GPR: Ground Penetration RADAR and an operator were provided by Infrasense.
- Coring: 60 X 4” cores were taken with two coring rigs by DOT.

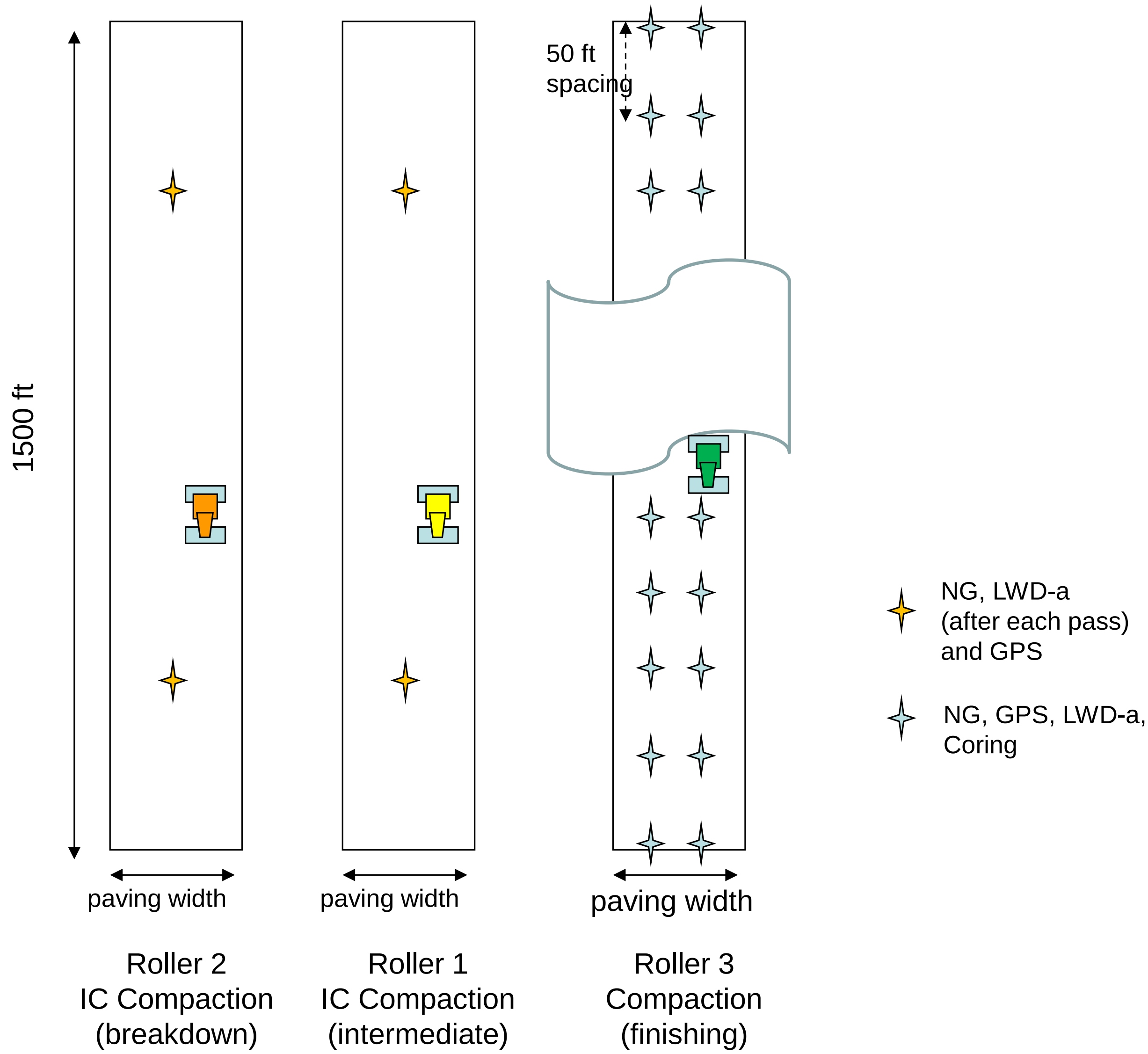
Machines Settings

Date	TB	Machine	Setting	Spot Tests	Notes/Comments
Day 1	1A	IC 1	0.3mm at 4000 vpm	NG, GPS, LWD-a	Breakdown compaction for asphalt base course. 1. Compact with normal roller passes. 2. NG/GPS/LWD-a tests after each roller pass at selected locations within the test section.
	1B	IC 2	Low amp at 4000 vpm	NG, GPS, LWD-a	Intermediate compaction for asphalt base course. 1. Compact with normal roller passes. 2. NG/GPS/LWD-a tests after each roller pass at selected locations within the test section.
	1C	Conventional Roller	Static	NA	Finishing rolling 1. Compact with normal roller passes.
Day 2	2A	IC 2	Low amp at 4000 vpm	NG, GPS, LWD-a	Breakdown compaction for asphalt base course. 1. Compact with normal roller passes. 2. NG/GPS LWD-a tests after each roller pass at selected locations within the test section.
	2B	IC 1	0.3mm at 4000 vpm	NG, GPS, LWD-a	Intermediate compaction for asphalt base course. 1. Compact with normal roller passes. 2. NG/GPS LWD-a tests after each roller pass at selected locations within the test section.
	2C	Conventional Roller	Static	NG, GPS, LWD-a, FWD Coring	Finishing rolling 1. Compact with normal roller passes. 2. NG/GPS/LWD-a/FWD/Coring tests after the finishing rolling at marked locations within the test section.
Day 3	3A	IC 1	0.3mm at 4000 vpm	NG, GPS, LWD-a	Breakdown compaction for asphalt base course. 1. Compact with normal roller passes. 2. NG/GPS LWD-a tests after each roller pass at selected locations within the test section.
	3B	IC 2	Low amp at 4000 vpm	NG, GPS, LWD-a	Intermediate compaction for asphalt base course. 1. Compact with normal roller passes. 2. NG/GPS LWD-a tests after each roller pass at selected locations within the test section.
	3C	Conventional Roller	Static	NA	Finishing rolling 1. Compact with normal roller passes.

Day 1 & 3 – Test Plan



Day 2 – Test Plan



Analysis Results

IC Data Analysis

Pre-Mapping

The IC maps and statistics for the Hamm and Caterpillar IC pre-mapping data on the existing granular base are presented in Figure 1. The HMV map (5 mm, 3,800 vpm) indicates stiffer values on the eastern edge as compared with the western edge that is confined by the existing southbound asphalt pavements. The CMV map indicates a similar trend. HMV and CMV are based on frequency analysis methods.

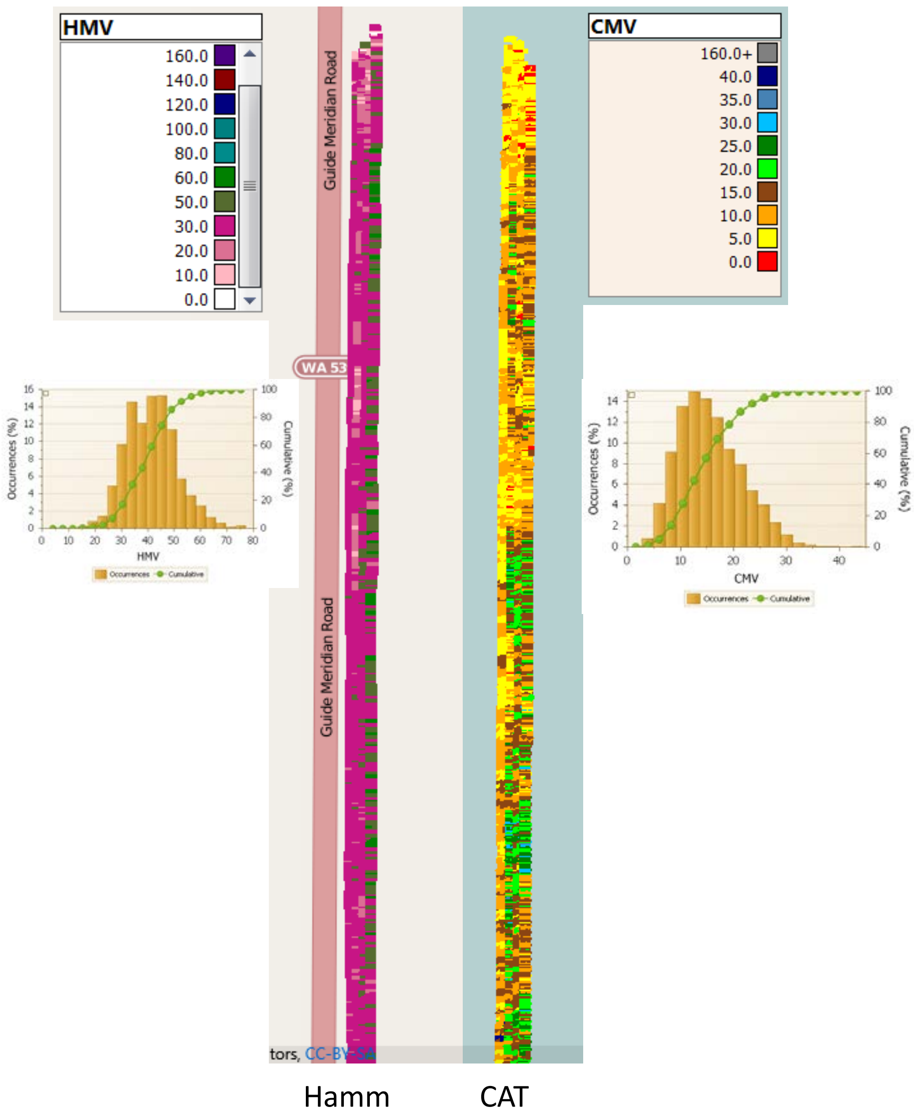


Figure 1. Hamm HMV map and Caterpillar CMV map for pre-mapping existing granular base, northern half, WA site.

TB02 IC Data

The IC maps and statistics for the Hamm IC data (breakdown position) for TB02 are presented in Figure 2 and Figure 3.

Comments on Hamm Data:

- ICMV: The mean HMV value is 56.2 with standard deviation of 16.22.
- Temperature: The mean surface temperature is 218°F with standard deviation of 41.36°F.
- Pass Counts: The recorded mean roller passes is 6, but the distribution is erratic.
- Frequency: The mean frequency is 3,943 vpm. Note that the amplitude was set to low.
- Compaction curve: The curve grows and tapers off after 5 passes.

The IC maps and statistics for the Caterpillar IC data (intermediate position) for TB02 are presented in Figure 4 and Figure 5.

Comments on Caterpillar Data:

- ICMV: The mean CMV value is 6.96 with standard deviation of 2.68. The value is relative low compared with the CMV values from the other field sites (e.g., KY) with the same roller. It is suspected that the differences may be due to the changes of the mounting of the accelerometer.
- Temperature: The mean surface temperature is 193°F with standard deviation of 19.4°F. The mat temperatures stay at elevated temperatures except for several discrete areas.
- Pass Counts: The recorded mean roller passes is 13. It is higher than the 5 passes recorded manually during pass-by-pass NG measurements. Further investigation is warranted regarding the gridding and pass counting procedure in VisionLink.
- Frequency: The mean frequency is 3,824 vpm.
- Compaction curve: The curve appeared to be in an unusual shape without an apparent plateau that indicate optimal passes. Further investigation is warranted.

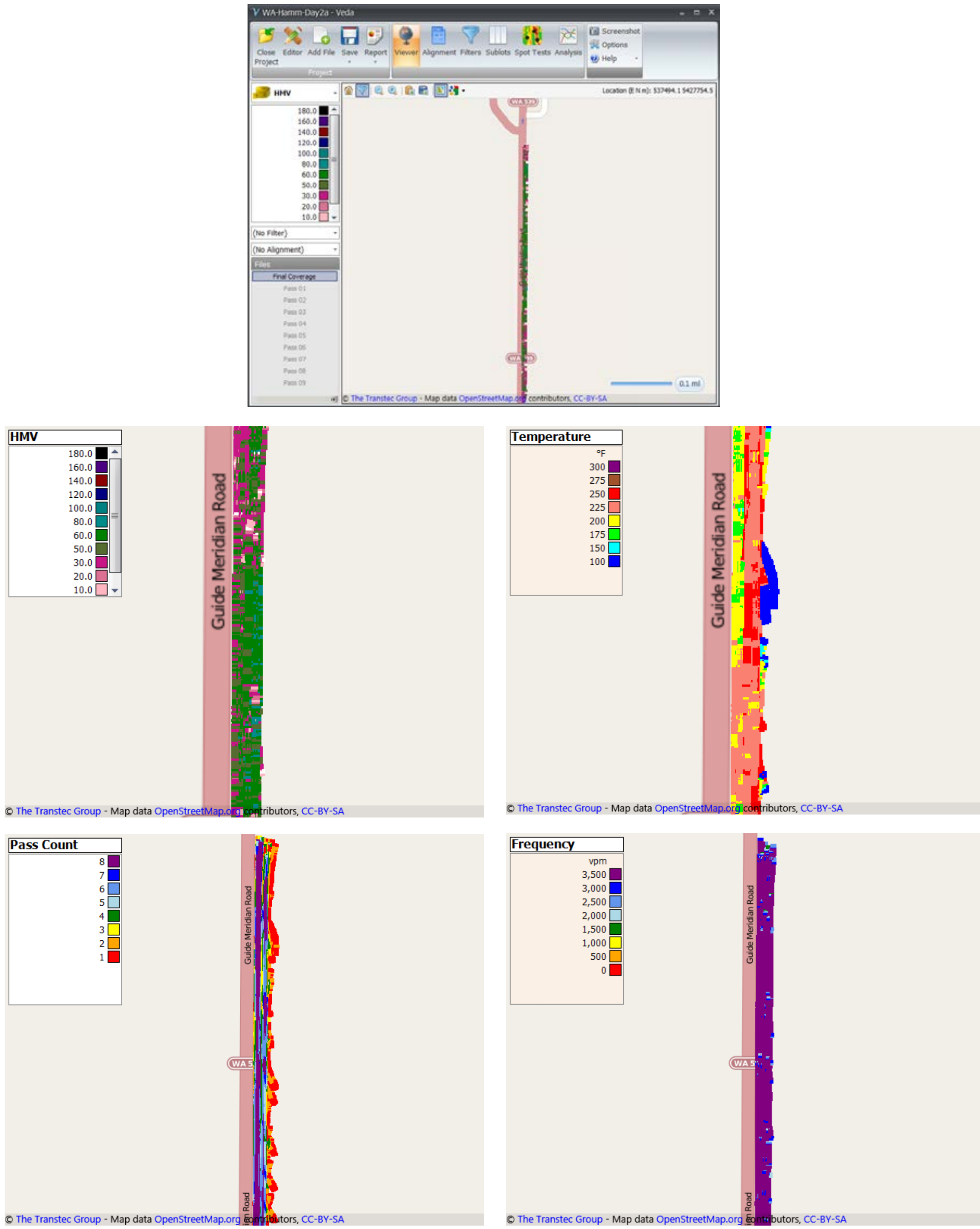


Figure 2. Hamm IC maps (breakdown), TB02A and TB02B, WA site.

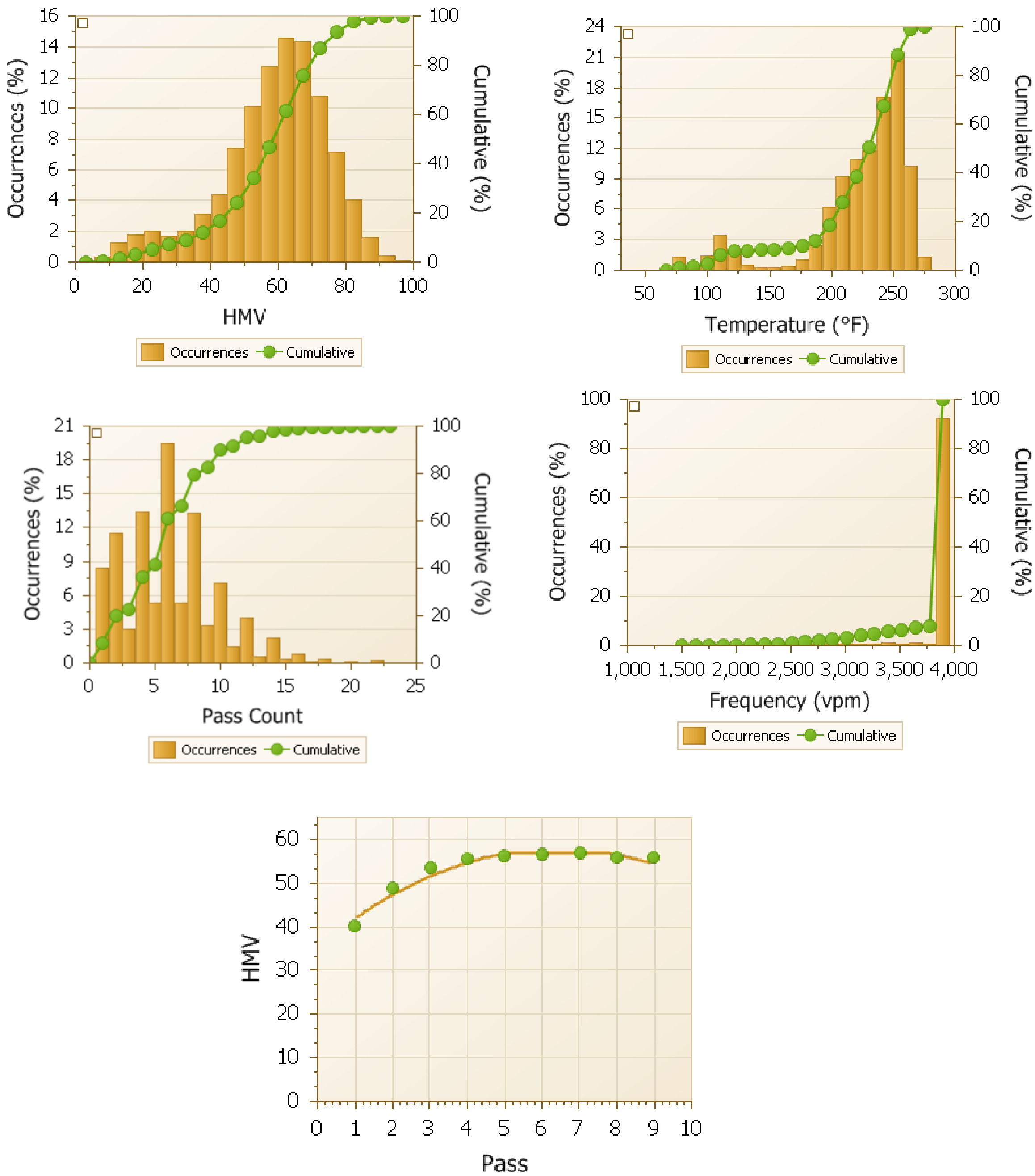


Figure 3. Hamm IC statistics (breakdown), TB02A and TB02B, WA site.

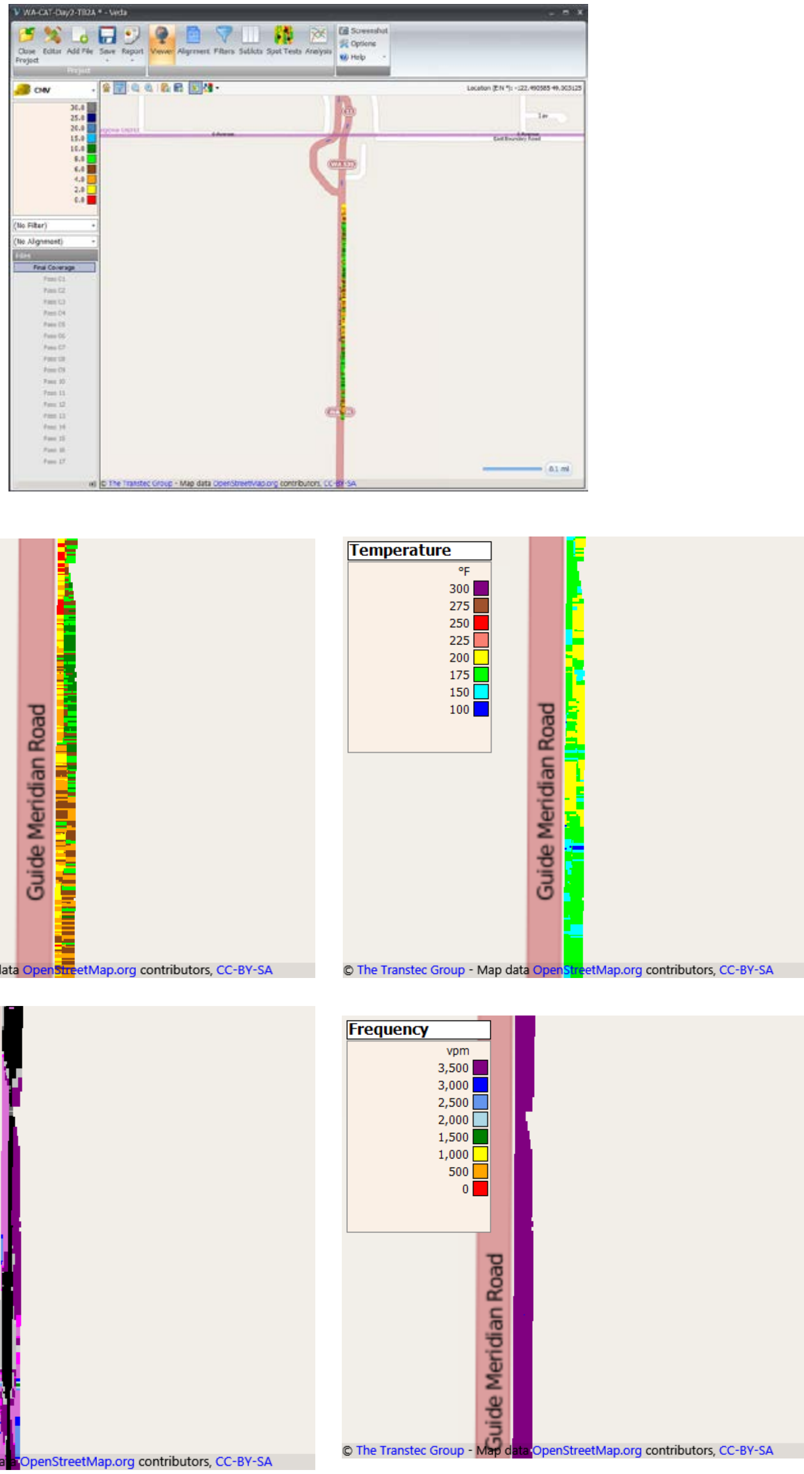


Figure 4. Caterpillar IC maps (intermediate), TB02A, KY site.

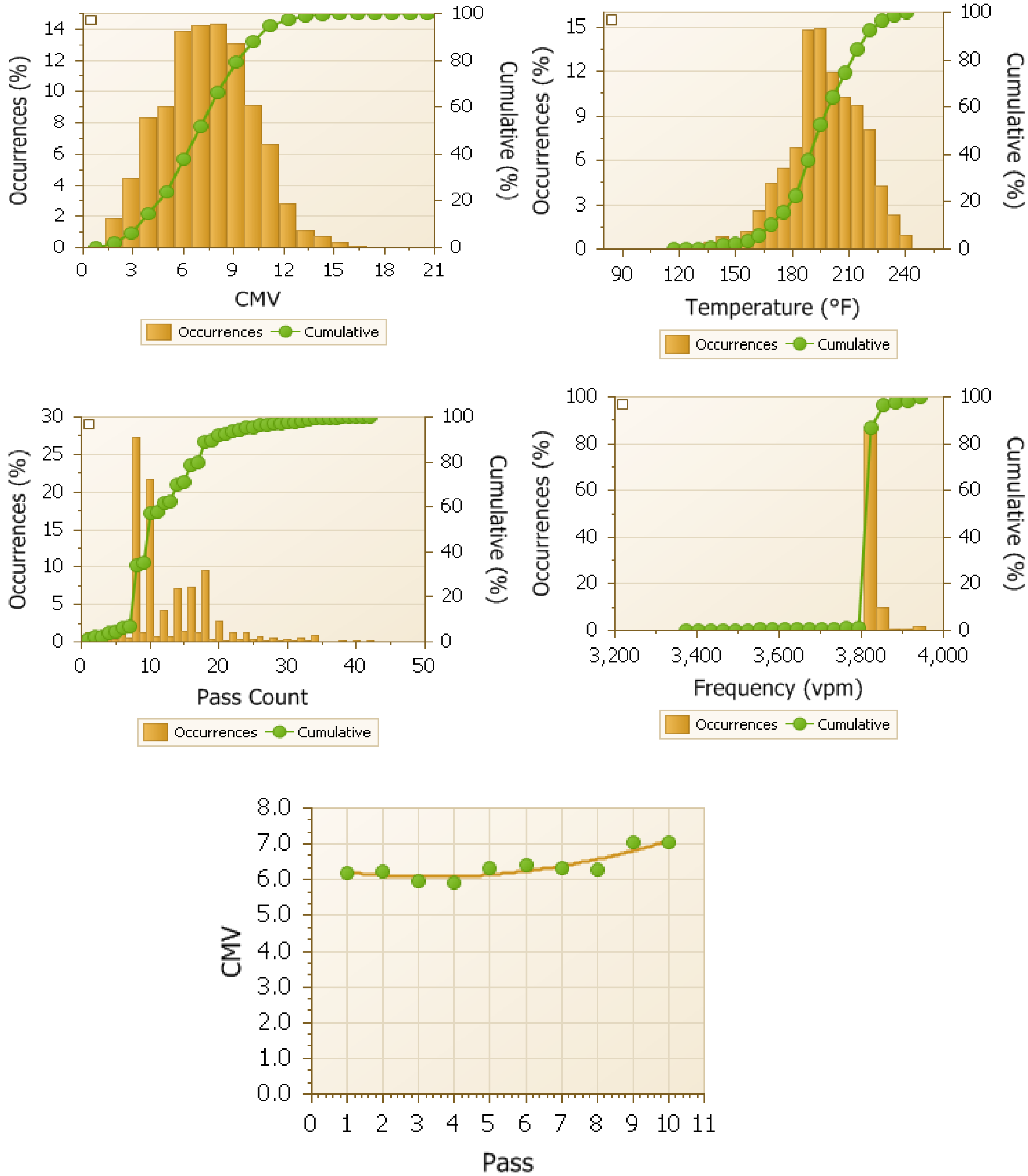


Figure 5. Caterpillar IC statistics (intermediate), TB02A, WA site.

Correlation Analysis

The correlation analysis results are presented as follows.

Correlation between Core Densities and Nuclear Density Gauge Measurements

The correlation between core densities and NG measurements (TB02A, WA site) is presented in Figure 6. The R^2 of the linear regression is 0.64 without significant bias. The goodness of correlation is considered medium to good, as compared with all other 8 field results from this study.

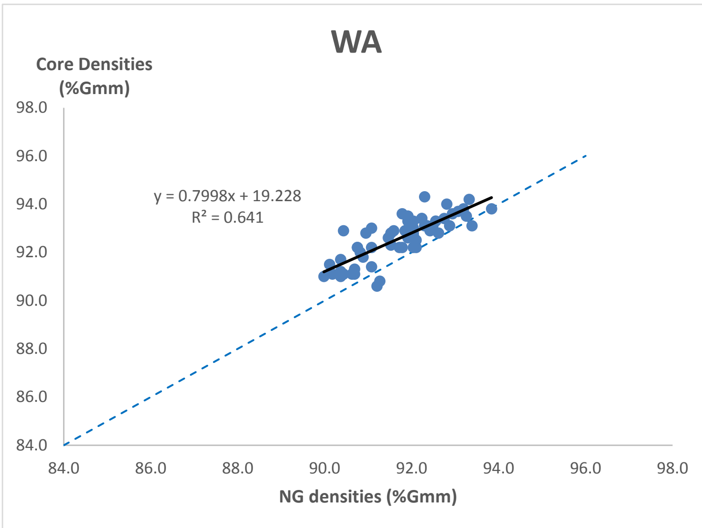


Figure 6. Correlation between core densities and NG measurements, TB02A, WA site.

The distribution of core densities indicate a pattern with those closer to the western edges lower those closer to the eastern edges of TB02A. As seen in Figure 7, the E-sides core density is about 1% more than the W-sides. Also, this trend is similar as that in the Caterpillar CMV maps. The possible explanation is that it is more difficult to compact the W-sides due to the confinement of the adjacent, existing pavement to prevent rollers from properly compacting both the base and asphalt.

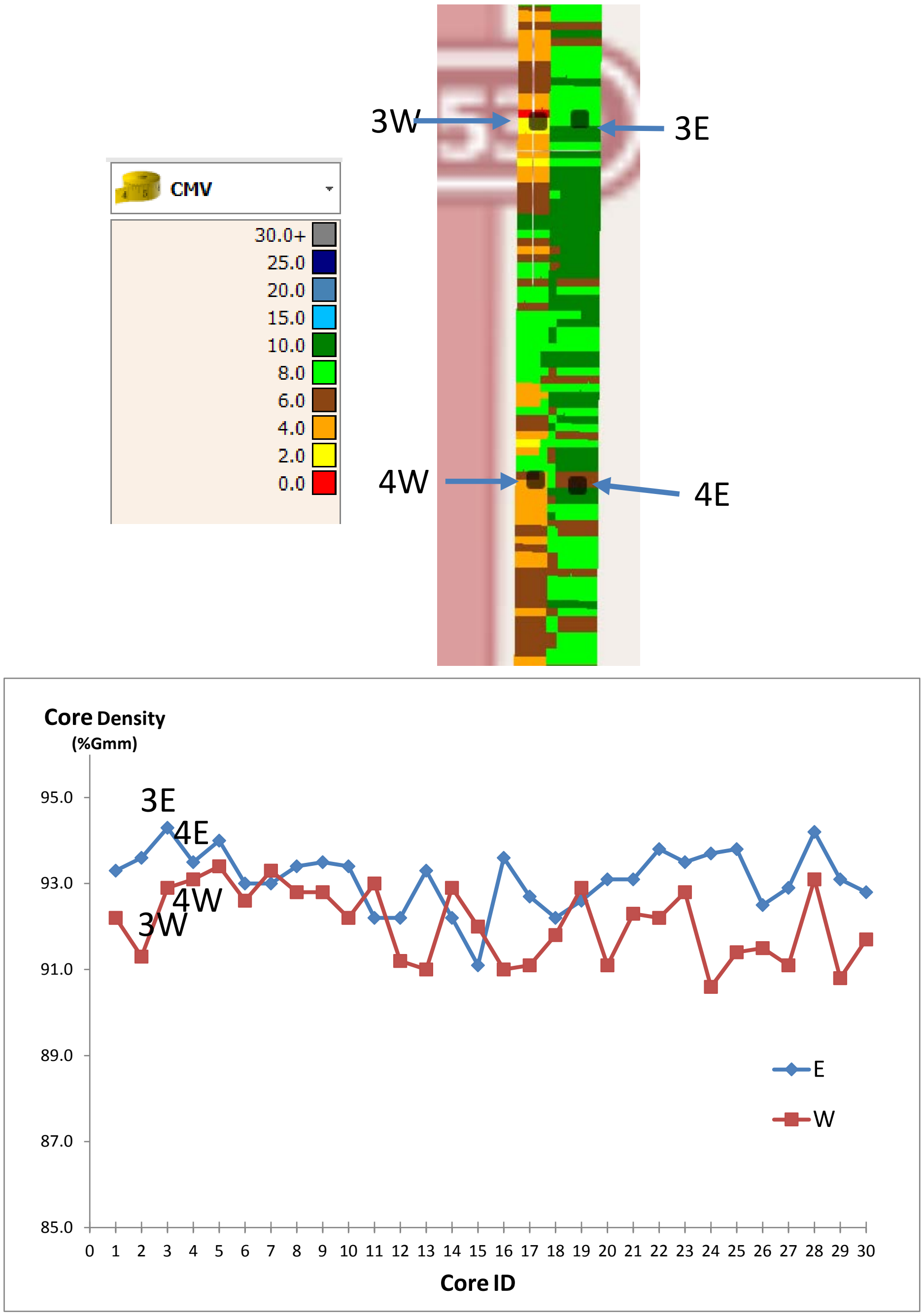


Figure 7. Visual and numerical comparison of core densities and Caterpillar CMV, TB02A, WA site.

Correlation between Core Densities and Backcalcualted Asphalt Layer Moduli from FWD

There is no correlation between the core densities and the layer moduli backcalculated from the LWD measurement. Density and modulus simply two different properties.

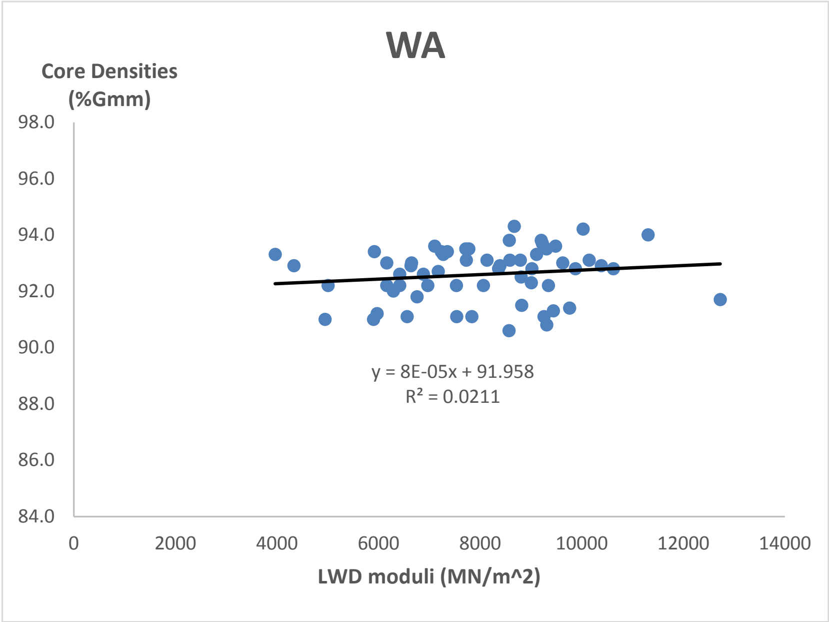


Figure 8. Correlation between core densities and LWD backcalculated moduli, TB02A, WA site.

Pass-by-Pass IC Data Analysis and Correlation Study

The pass-by-pass measurements include NG density growth, temperature drops, and ICMV from the breakdown and intermediate rollers. Six (6) test points were conducted; T1, T2 and T3 in TB01; T4 in TB02A; T5 and T6 in TB03A and TB03B. The analysis includes only the NG measurements with the DOT device that is calibrated with core densities at T2, T4, T5, and T6.

All test points indicate similar trends for density growth and temperature drops. The ICMV from the breakdown rollers correlate well with the NG density values, with R^2 of linear correlation ranges from 0.5 to 0.9. On the other hand, the ICMV from the intermediate rollers do not correlate well with the NG density values. The probably causes may include lower mix temperature, and narrower range of values.

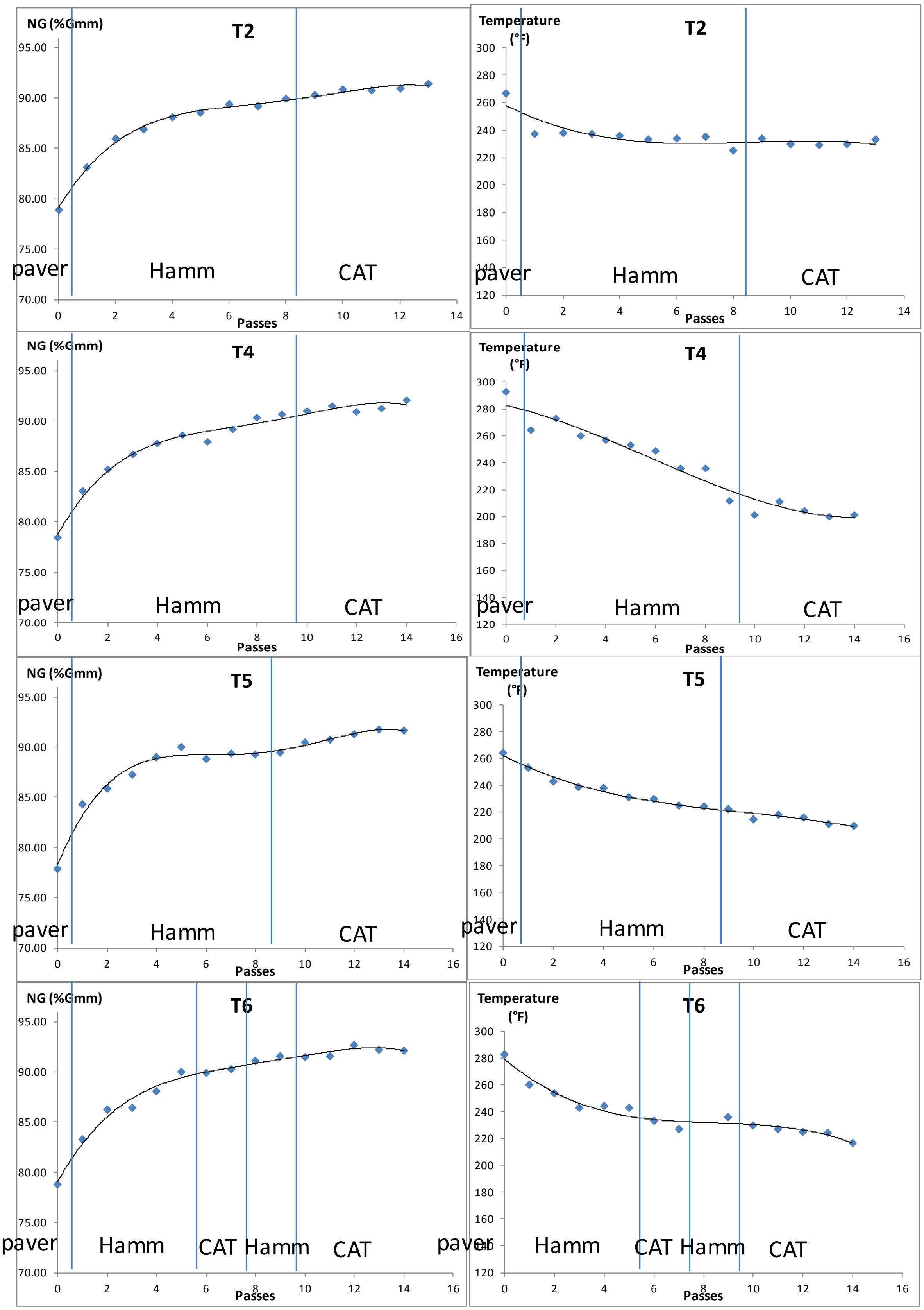


Figure 9. Pass-by-pass NG densities and temperatures, WA site.

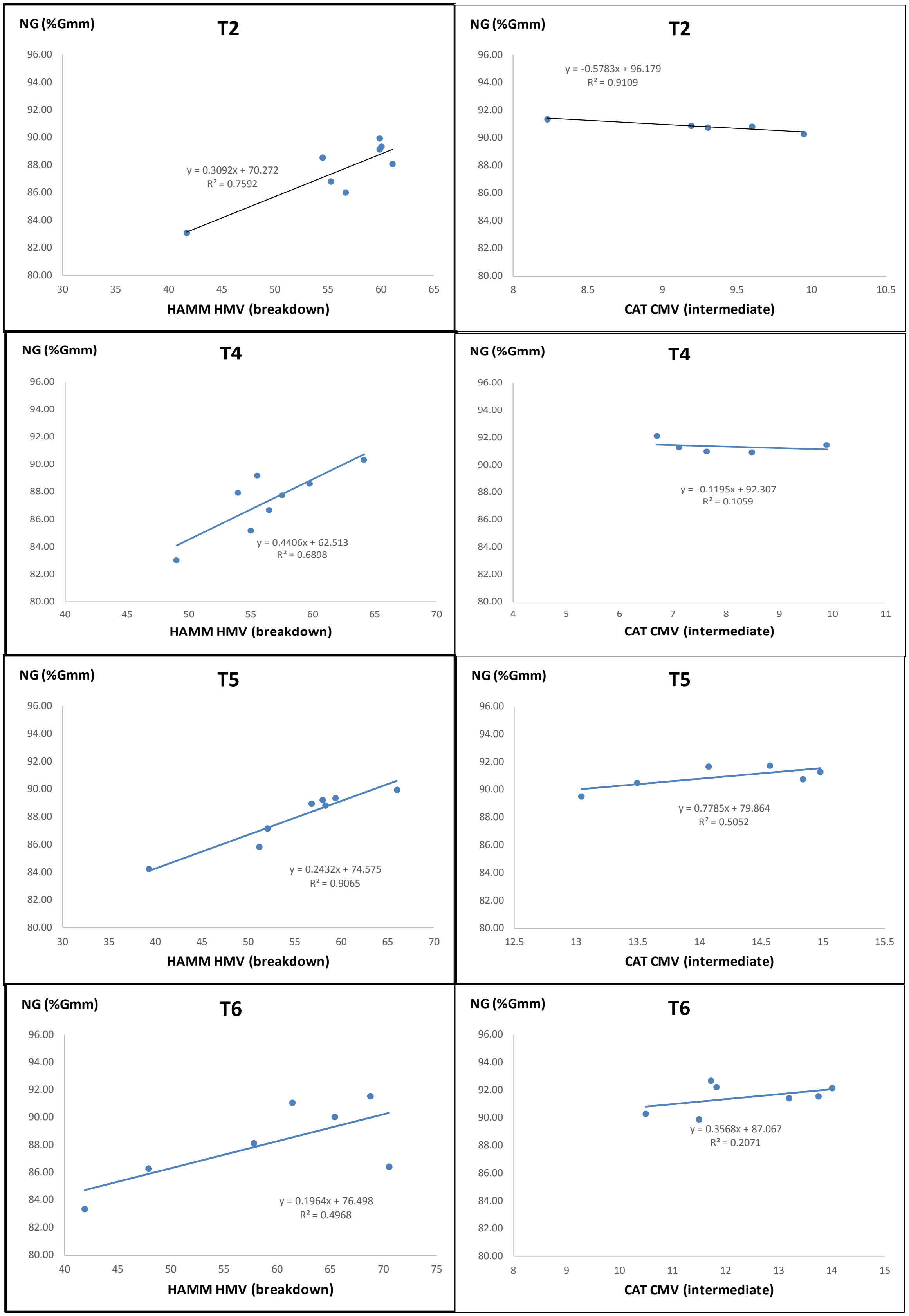


Figure 10. Pass-by-pass NG densities vs. ICMV, WA site.

Correlation between Core Densities and Pre-mapping Data

The linear correlation between core densities and Hamm IC pre-mapping the existing granular base is presented in Figure 12. The level of linear correlation is poor. The causes may be due to slight GPS data shifts between the two testing days and complex relationship between core densities and all affecting factors in additional to the support condition.

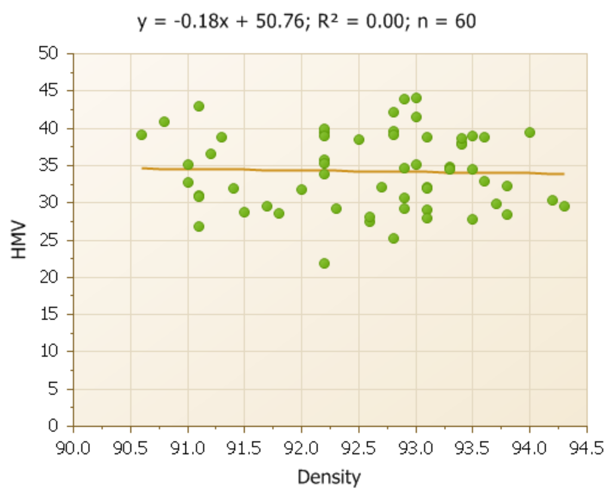


Figure 11. Correlation between core densities and Hamm IC pre-mapping data, WA site.

Final Coverage IC Data Analysis and Correlation Study

The linear correlation between core densities and the Hamm final coverage IC measurements (as the breakdown roller at TB02A), WA site, is presented in Figure 12. The level of linear correlation is poor.

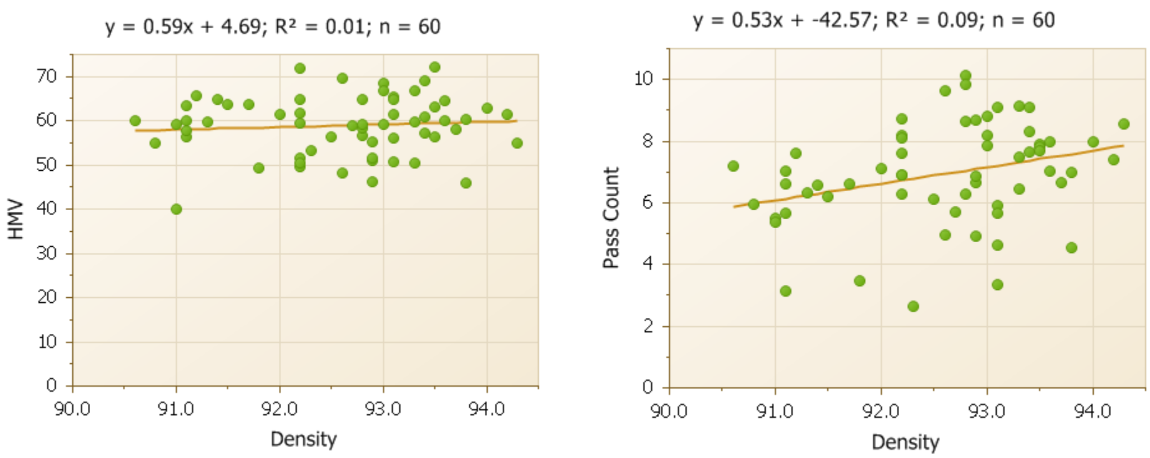


Figure 12. Correlation between core densities and Hamm final coverage IC measurements (breakdown roller), TB02A, WA site.

The linear correlation between core densities and Caterpillar IC measurements (as the breakdown roller at TB02A), WA site, is presented in Figure 12. The level of linear correlation is also poor.

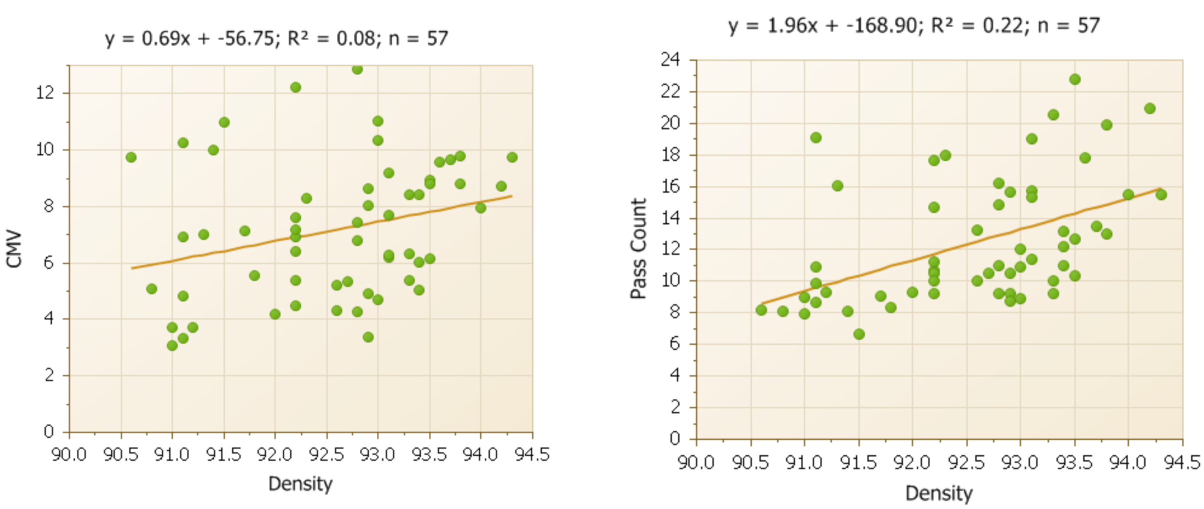
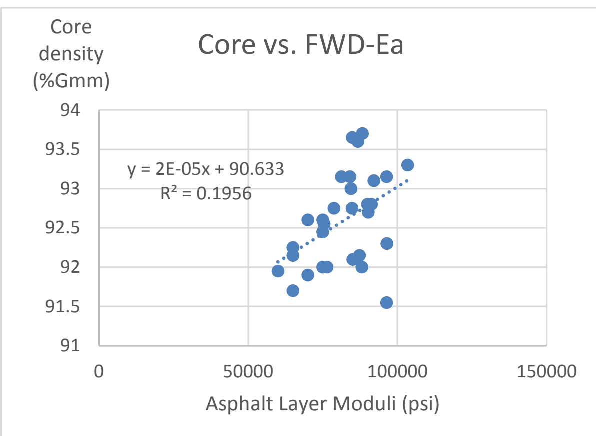


Figure 13. Correlation between core densities and Caterpillar IC measurements (intermediate roller), TB02A, WA site.

The low correlation between the core densities and the final coverage ICMV are due to:

- The measurement mechanism and properties of core density and ICMV are fundamentally different.
- There are many factors affecting core densities while the final coverage ICMV is simply one of the many and appears not to be one of the significant factors.
- The influence depth of ICMV is deeper than the asphalt layer. The footprint of ICMV is greater than that of a core. The influence depths and the ICMV measured based on the rebound behavior of the roller drums may vary after roller each pass due to the complex vehicle-surface interactions.
- The ICMV were measured during the breakdown and intermediate. In this case, the gains/losses of in-place densities by the finishing rollers (Sakai and Ingersoll Rand) in combination of vibration and static modes while the mat temperatures stay at relatively high temperature.
- The narrow range of core densities that makes the R^2 very sensitive to small changes under the influence of the item 2.

The core densities do not correlate well with the asphalt moduli backcalculated from FWD and LWD data. It is another evidence that the properties of densities and moduli are different in nature. The FWD and LWD backcalculated layer moduli do not correlate well either. The probable cause may be the different load level and backcalculation algorithms.



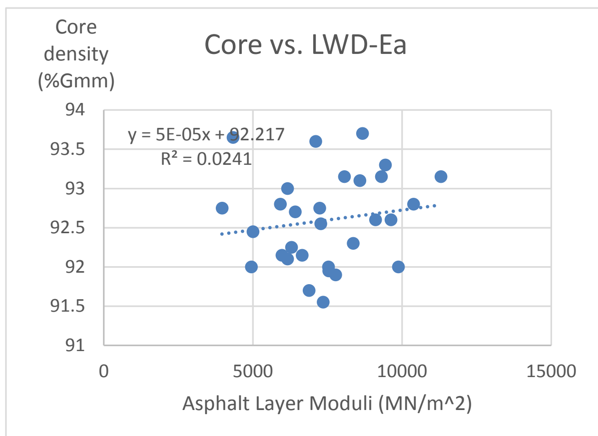


Figure 14. Correlation between core densities and asphalt layer moduli backcalcuated from FWD and LWD data, TB02A, WA site.

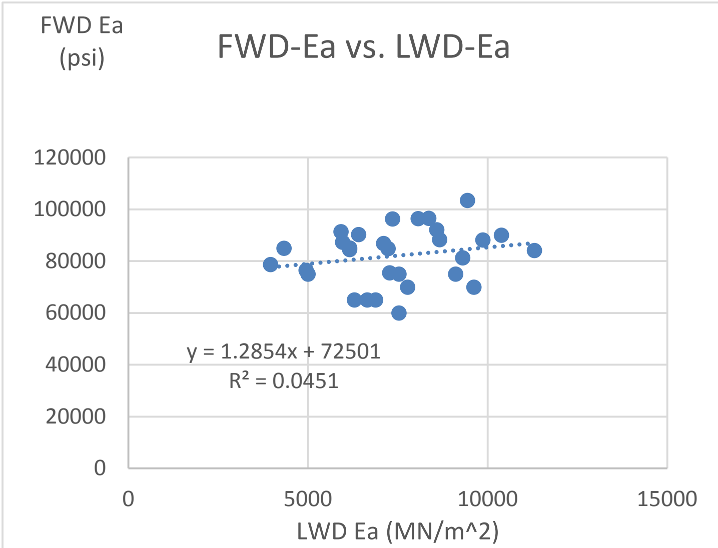


Figure 15. Correlation between asphalt layer moduli backcalcuated from FWD and LWD data, TB02A, WA site.

For further analyses, data interpretation, conclusions and recommendation, please refer to the FHWA IC and In-Place HMA density final report.