

Rehabilitation of Low-Volume Roads Using FDR (Full Depth Reclamation)

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What is Full Depth Reclamation (FDR)

- FDR is a recycling technique that can improve the structural capacity of the full depth HMA pavement
- Full Depth HMA pavement is:
 - Generally surface milled (1.5" to 4")
 - Milling is not required
 - Uniformly pulverized pavement in-place to a homogeneous mix
 - Depth is determined in the design
 - Blended and mixed with stabilizing agents
 - Cement
 - Asphalt emulsion
 - Compacted and shaped to the desired profile grade (PG) and cross-slope
 - Overlaid with a surface as such HMA
 - Other surface material could be used
- Our specs limit FDR to treating a pavement thickness of 10" (originally 14")
- It can be combined with cold central plant recycling (CCPR) to treat thicker section
- CCPR is similar to FDR except the pulverized material is removed, treated at processing plant and returned to be place

What is Full Depth Reclamation (FDR) - 2

- FDR can correct:
 - Cracking of all types
 - Poor ride quality
 - Permanent deformation
 - Bond loss between layers
 - Stripping
 - Loss of surface
 - Edge drop-off
 - Inadequate structural capacity
 - Subgrade instability
- It can be used to widen narrow roads
 - Adding a 2' -3' shoulder provides a bound edge along the travel lane
 - This reduces or eliminates edge cracking of the pavement
- FDR requires a mix design for each project
 - Based on the composition of the existing HMA and subbase/subgrade material
 - Cement or asphalt emulsion is selected based on the subbase/subgrade material present
 - Cement when clays/silts is encountered
 - Asphalt emulsion when granular material is encountered
 - Mix design may be changed
 - If testing for mix design indicates a need for a change (asphalt emulsion vs cement)
 - Additional material is required

What is Full Depth Reclamation (FDR)

- Selection of FDR is based on existing pavement conditions
- Includes:
 - Full Depth HMA required
 - FWD results
 - Pavement cracking – both severity and extent
- FDR is not pavement replacement
 - It is equivalent to a structural overlay
- Look at the background of 4 FDR projects
 - Why they were selected as an FDR
 - Location and length of project
 - Number and width of lanes
 - Shoulder
 - AADT and AADT
 - Before and after condition
 - Falling weight deflectometer FWD
 - Cost - total and per lane mile

RS-38002 – SR 59 From SR 234 to S of Waveland CL

- First FDR for Crawfordsville District
- Let in April, 2015
- Rural 2-lane road in Montgomery & Parke Counties
- Length: 2.17 miles
- AADT: 800 vpd – AADTT: 152 vpd
- Selected due to:
 - Cracking
 - Distresses
 - General pavement condition
- Final cross section
 - 11' travel lanes
 - No shoulders added due to tight R/W
- Final pavement design
 - Cement used as stabilizer
 - 14" Stabilized subbase (old standard)
 - Minor structural overlay (1.5" surface on 2.5" intermediate HMA on stabilized subbase)
- Included a one year warranty
 - Warranted against delamination and rutting
- Cost:
 - Awarded: \$1,211,246
 - Final: \$1,040,352

RS-38002 – SR 59 SR 234 to S of Waveland CL

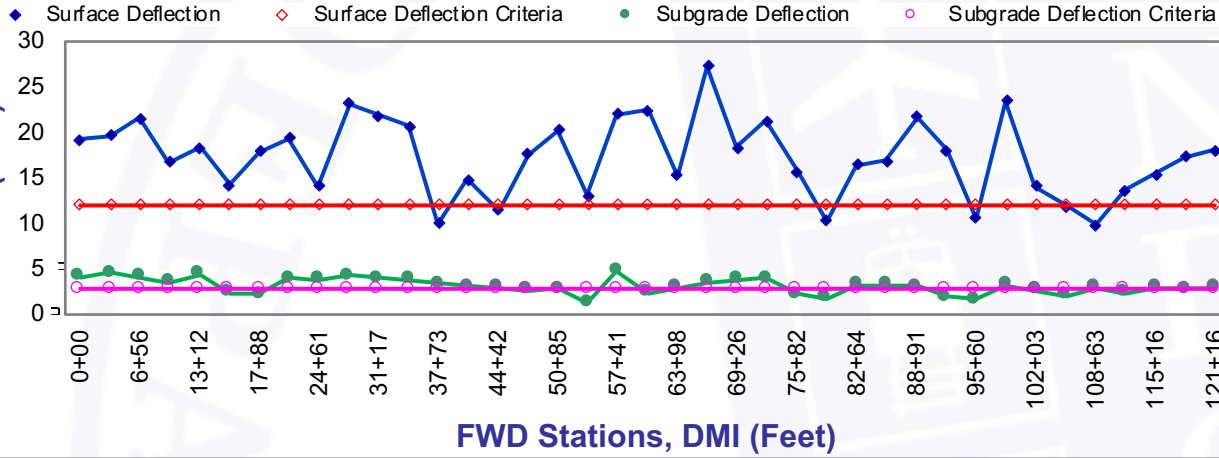


Before Project - 2015

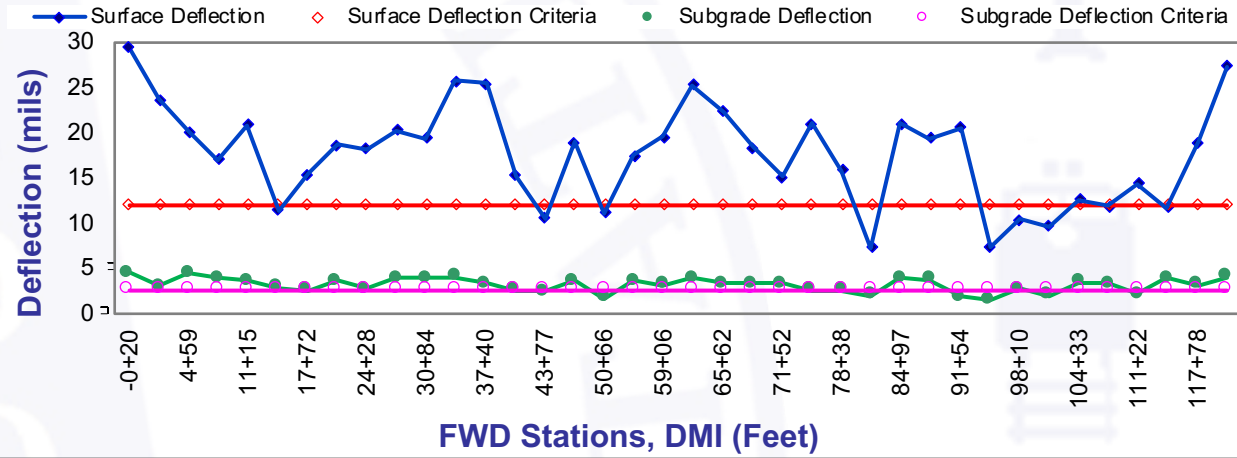
Completed Project - 2019

SR 59 FWD Before & After Results

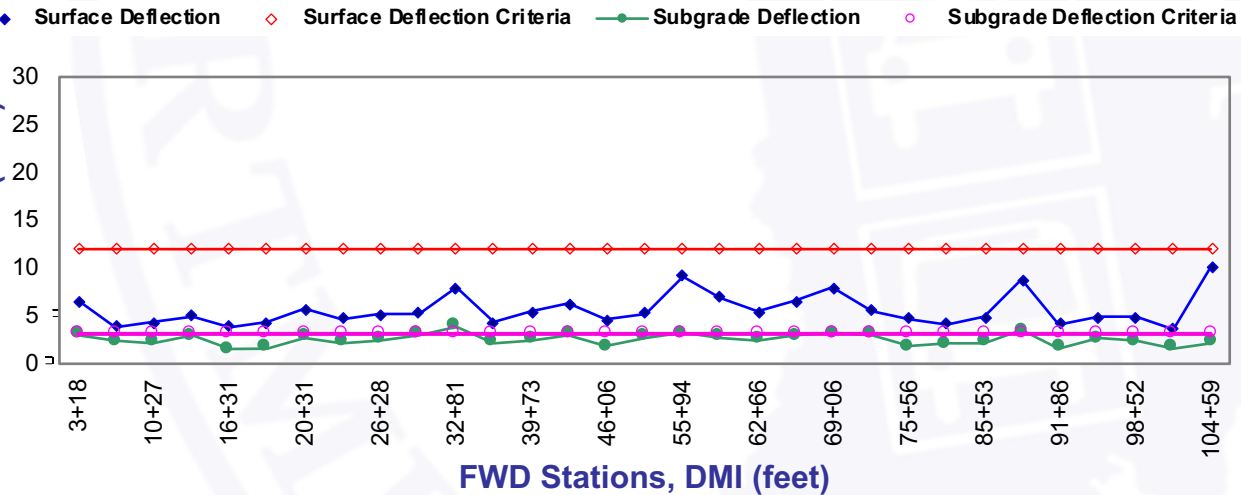
SR 59 NB Surface and Subgrade Deflection 2015



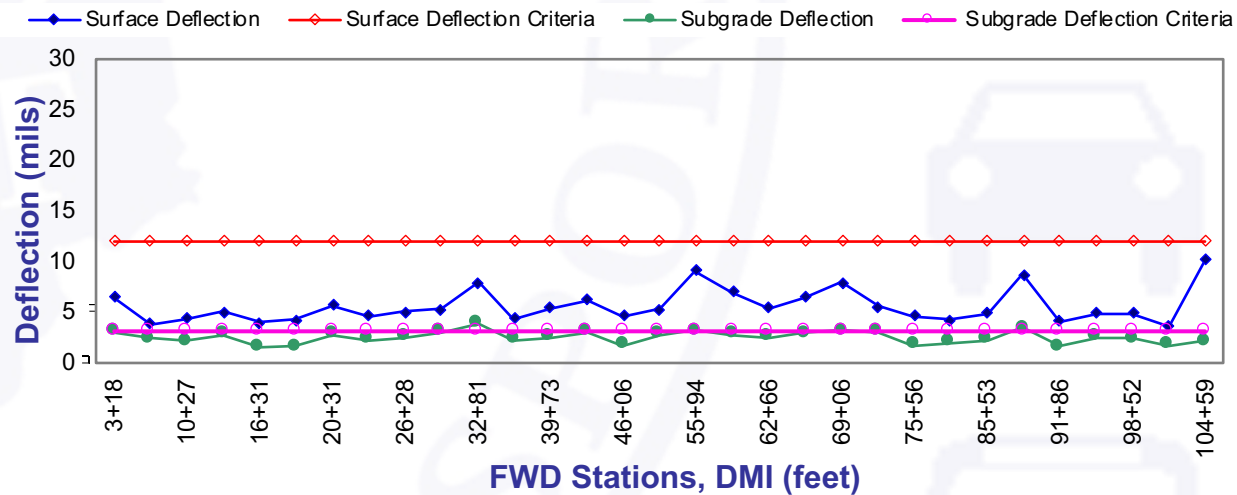
SR 59 SB Surface and Subgrade Deflection 2015



SR 59 NB Surface and Subgrade Deflection 2019



SR 59 SB Surface and Subgrade Deflection 2019



SR 59 FWD Before & After Results - 2

SR 59 From SR 234 to South CL of Waveland	2019 NB Surface Deflection	2015 NB Surface Deflection	2019 SB Surface Deflection	2015 SB Surface Deflection
Total Count	31	34	29	33
Count of Bad	0	29	0	26
Percent Bad	0%	85%	0%	79%
Average Difference	-6.37	5.64	-6.99	5.74
Average Deflection	5.63	17.64	5.01	17.74
Standard Dev	1.65	4.26	1.00	5.46
Average of Bad	0.00	18.81	0.00	19.89

SR 59 From SR 234 to South CL of Waveland	2019 NB Subgrade Deflection	2015 NB Subgrade Deflection	2019 SB Subgrade Deflection	2015 SB Subgrade Deflection
Total Count	31	34	29	33
Count of Bad	4	16	5	26
Percent Bad	13%	47%	17%	79%
Average Difference	-0.60	-0.13	-0.53	0.59
Average Deflection	2.54	3.18	2.31	3.17
Standard Dev	0.58	0.90	0.52	0.80
Average of Bad	3.43	1.91	3.09	3.48

SR 59 From SR 234 to South CL of Waveland	2015 to 2019			
	NB Surf Def Improvement	NB Surf Def Improvement	NB Surf Def % Improvement	NB Subgrade % Improvement
Average of > 0	9.98	3.11	33%	19%
Average	9.98	3.11	33%	13%
Max	12.94	4.51	38%	27%
Min	5.43	1.28	26%	-20%
Standard Dev	1.74	0.91	5%	5%
Count Imp Diff	26	5		
Count Not Imp	0	1		
Total Count	26	6		
% Improved Locations	100%	83%		

SR 59 From SR 234 to South CL of Waveland	2015 to 2019			
	SB Surf Def Improvement	SB Surf Def Improvement	SB Surf Def % Improvement	SB Subgrade % Improvement
Average of > 0	18.51	3.25	59%	18%
Average	18.51	3.25	59%	18%
Max	25.81	4.52	67%	28%
Min	7.39	1.66	48%	5%
Standard Dev	4.39	0.75	6%	7%
Count Imp Diff	8	8		
Count Not Imp	0	0		
Total Count	8	8		
% Improved Locations	100%	100%		

R-39636 – SR 101 From US 24 to Allen CL

- First FDR for Fort Wayne District
- Selected to add paved shoulders to the road
- Let in March, 2018
- Rural 2-lane road in Allen County
- Bundled Contract which included
 - FDR/CCPR
 - Intersection Improvement
 - ADA Ramp Work
- Length:
 - 8.62 miles FDR
 - 0.48 mile For intersection work
 - 0.18 mile ADA sidewalk work
- AADT: 1970 vpd AADTT: 350 vpd
- Selected due to:
 - Cracking
 - Distresses
 - No shoulders
- Final cross section
 - 11' travel lanes
 - 2' paved shoulder added to each side
- Final pavement design
 - Both FDR and CCPR were used
 - 6" of HMA was removed and stockpiled
 - 10" of cement FDR was used on the remaining pavement
 - The stockpiled material was stabilized with asphalt emulsion and paved on the FDR surface
 - This was done to treat the full depth of the existing HMA pavement
 - Overlaid with 2" HMA Surface
- Cost:
 - Awarded: \$6,044,169
 - FDR: \$4,970,715
 - Other Work: \$1,073,454
 - Final: \$6,030,257

R-39636 – SR 101 From US 24 to Allen CL - 2

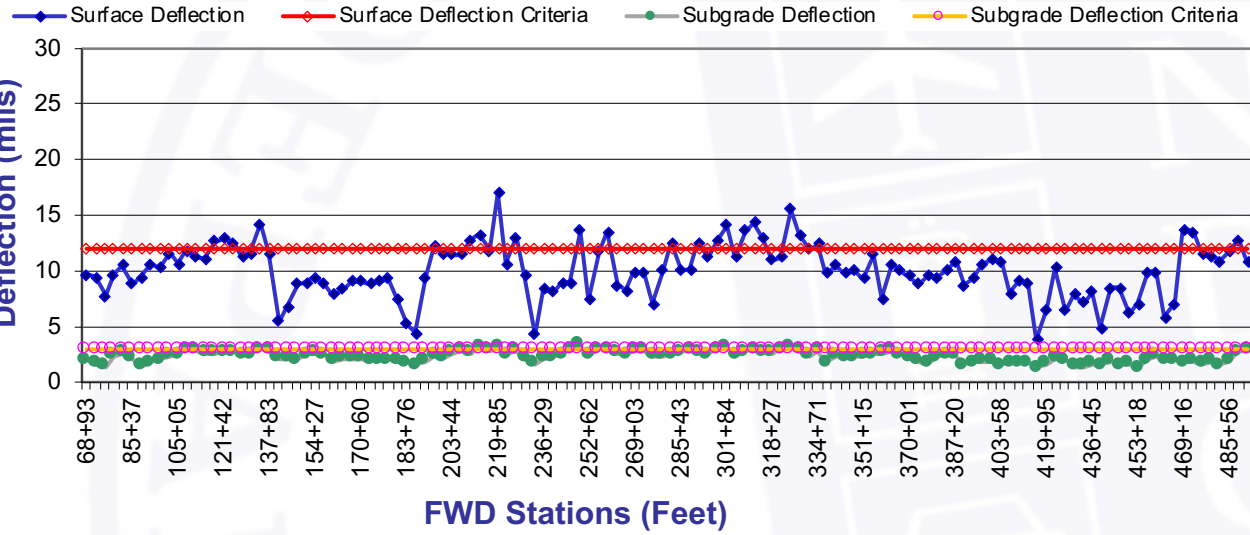


Before Project - 2018

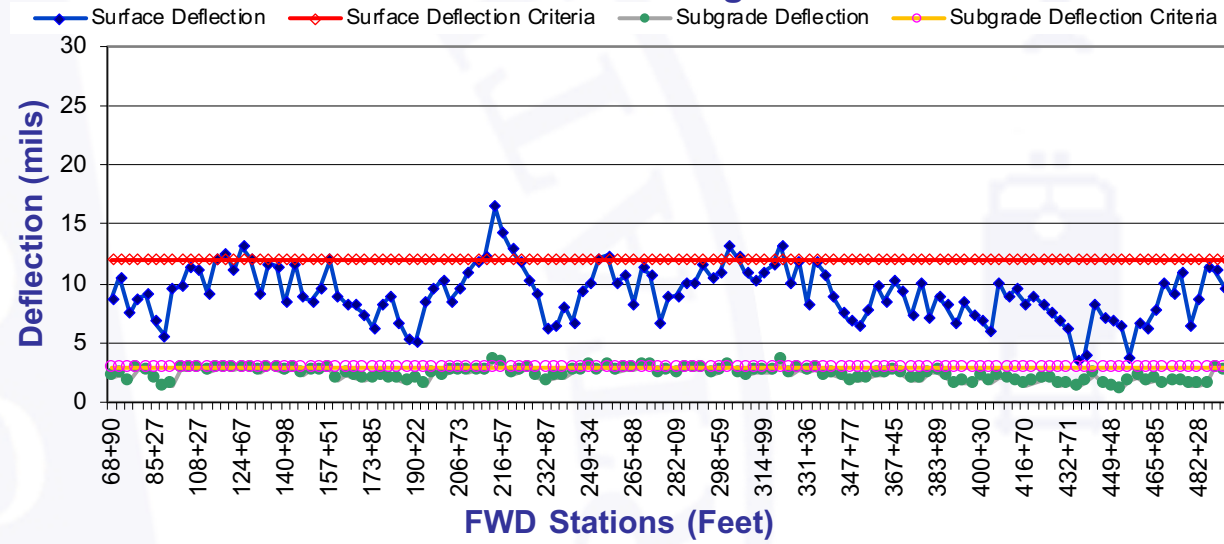
Completed Project - 2020

SR 101 FWD Before & After Results

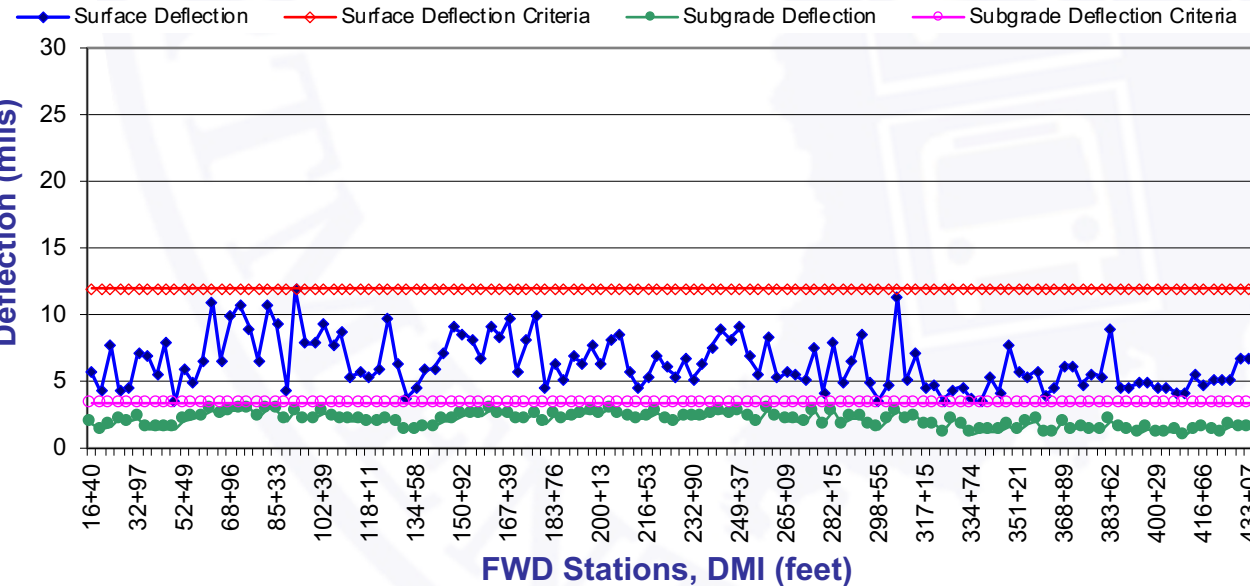
SR 101 NB Surface and Subgrade Deflection 2013



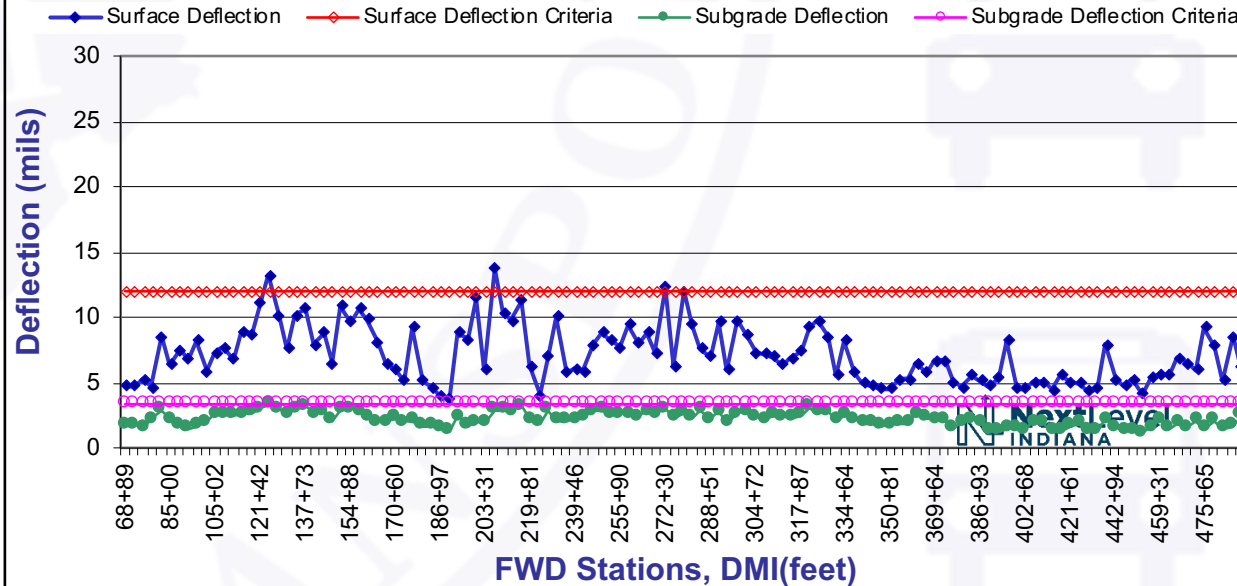
SR 101 SB Surface and Subgrade Deflection 2013



SR 101 NB Surface and Subgrade Deflection 2019



SR 101 SB Surface and Subgrade Deflection 2019



SR 101 FWD Before & After Results - 2

SR 101 From North of US 24 to Allen CL	2019 NB Surface Deflection	2018 NB Surface Deflection	2013 NB Surface Deflection	2019 SB Surface Deflection	2018 SB Surface Deflection	2013 SB Surface Deflection
Total Count	127	127	128	125	125	129
Count of Bad	0	2	25	12	2	12
Percent Bad	0%	2%	20%	10%	2%	9%
Average Diff	-5.62	-5.42	-1.93	-2.70	-4.53	-2.76
Average Defl	6.38	6.58	10.07	9.30	7.47	9.24
Standard Dev	1.90	1.75	2.38	2.26	1.86	2.26
Average of Bad	0.00	12.86	13.35	13.06	12.63	13.06

SR 101 From North of US 24 to Allen CL	2019 NB Subgrade Deflection	2018 NB Subgrade Deflection	2013 NB Subgrade Deflection	2019 SB Subgrade Deflection	2018 SB Subgrade Deflection	2013 SB Subgrade Deflection
Total Count	127	127	128	125	125	129
Count of Bad	0	0	6	2	0	12
Percent Bad	0%	0%	5%	2%	0%	9%
Average Diff	-1.36	-1.56	-0.69	-1.01	-1.49	-0.63
Average Defl	2.02	1.83	2.28	2.35	1.86	2.29
Standard Dev	0.52	0.44	0.49	0.51	0.43	0.52
Average of Bad	0.00	0.00	3.13	3.54	0.00	3.10

SR 101 From North of US 24 to Allen CL	2013 to 2019			
	NB Surf Def Improvement	NB Subgrade Improvement	NB Surf Def % Improvement	NB Subgrade % Improvement
Average of > 0	4.23	0.36	26%	9%
Average	3.90	0.26	24%	6%
Max	10.53	1.26	51%	36%
Min	-5.09	-0.66	-27%	-14%
Standard Dev	2.39	0.34	14%	8%
Count Imp Diff	92	80		
Count Not Imp	6	15		
Total Count	98	98		
% Improved Locations	94%	82%		

SR 101 From North of US 24 to Allen CL	2013 to 2019			
	SB Surf Def Improvement	SB Subgrade Improvement	NB Surf Def % Improvement	SB Subgrade % Improvement
Average of > 0	2.59	0.22	17%	6%
Average	1.82	0.08	12%	2%
Max	7.84	0.80	49%	24%
Min	-4.07	-0.95	-34%	-25%
Standard Dev	2.24	0.30	14%	8%
Count Imp Diff	60	51		
Count Not Imp	13	20		
Total Count	73	73		
% Improved Locations	82%	70%		

R-35100 – SR 327 FDR From SR 4 to US 20

- Second FDR for Fort Wayne District
- Selected to improve pavement structure and add paved shoulders
- Let in January, 2019
- Rural 2-lane road in Allen County
- Bundled Contract which included
 - PM Overlay
 - FDR
 - Small Structure Replacement
- Length:
 - 8.23 miles PM overlay (SR 327 north of US 20)
 - 8.5 miles FDR (SR 327 south of US 20)
- AADT: 2290 vpd – AADTT: 18 vpd
- Selected due to:
 - Cracking
 - Distresses
 - 10' travel lanes
 - No shoulders
- Final cross section
 - 11' travel lanes
 - 2' paved shoulder added to each side
- Final pavement design
 - 10" Cement stabilized subbase
 - Minor structural overlay
 - 1.5" surface
 - 2.5" Intermediate HMA
- Cost:
 - Awarded: \$8,818,151
 - FDR: \$5,959,990
 - Other: \$2,858,160
 - Final: \$8,679,797
 - FDR: \$5,820,481
 - Other: \$2,859,315
- Designed using asphalt emulsion stabilizer
- Changed to cement stabilizer after additional on-site testing of the pavement

R-35100 – SR 327 FDR From SR 4 to US 20 - 2



Spring - 2019



Winter - 2012



After Stabilization - 2019

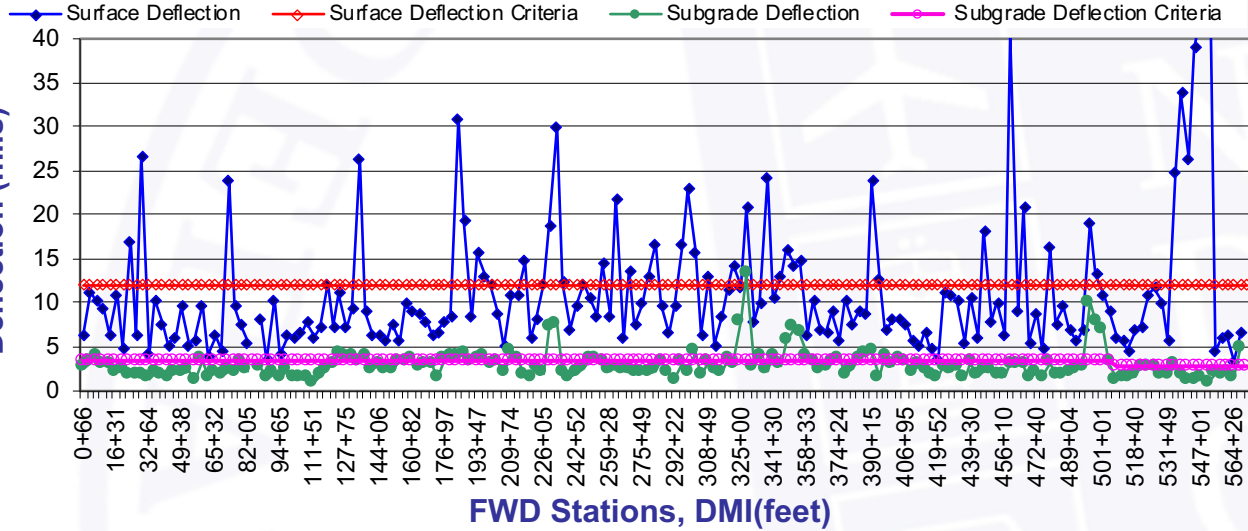


Completed Project - 2019

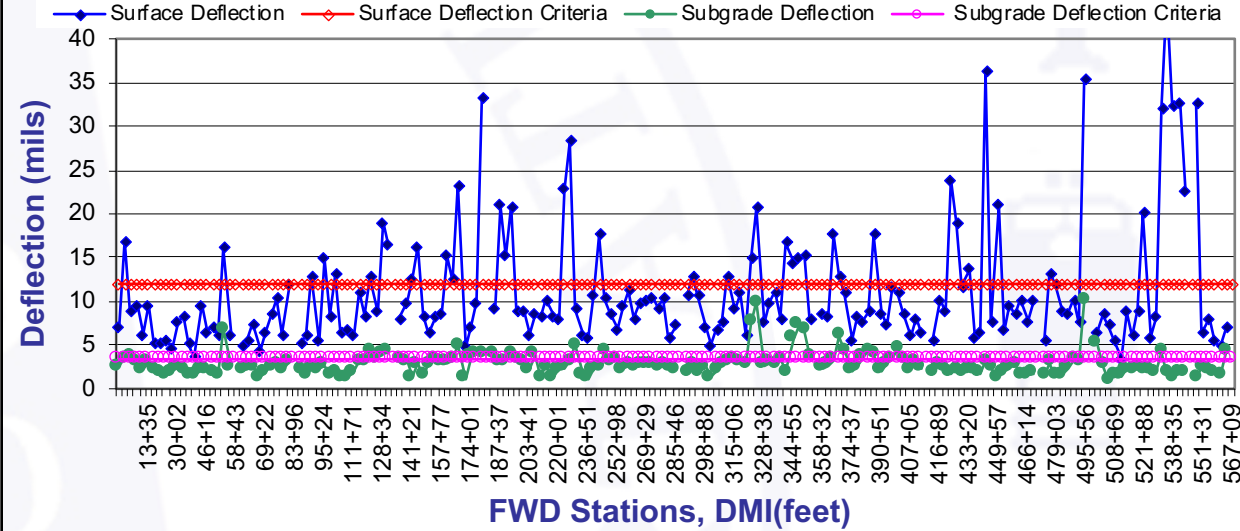
Before Project

SR 327 FWD Before & After Stabilization Results

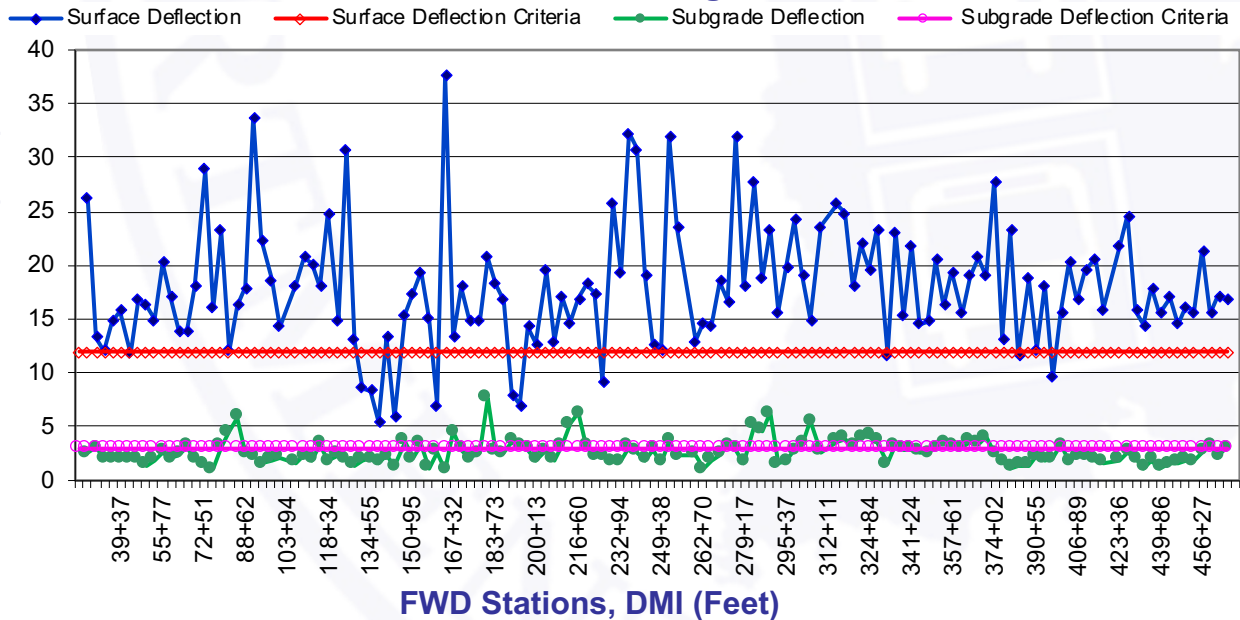
SR 327 NB Surface and Subgrade Deflection 2019 Before Surface



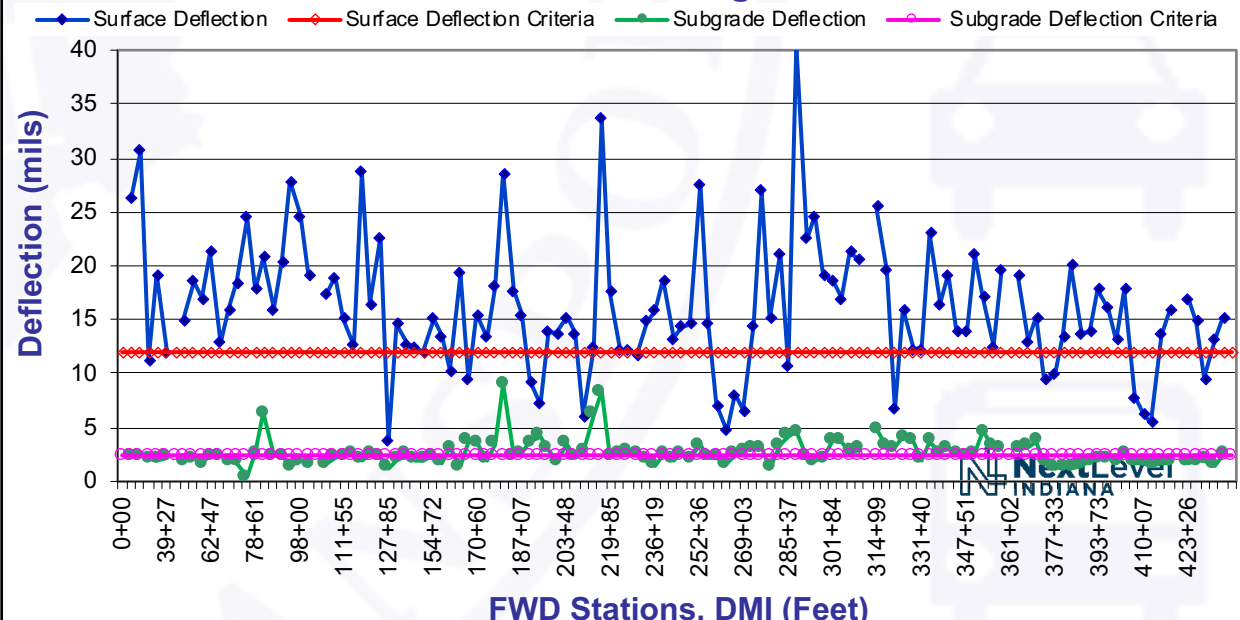
SR327 SB Surface and Subgrade Deflection 2019 Before Surface



SR 327 NB Surface and Subgrade Deflection 2014

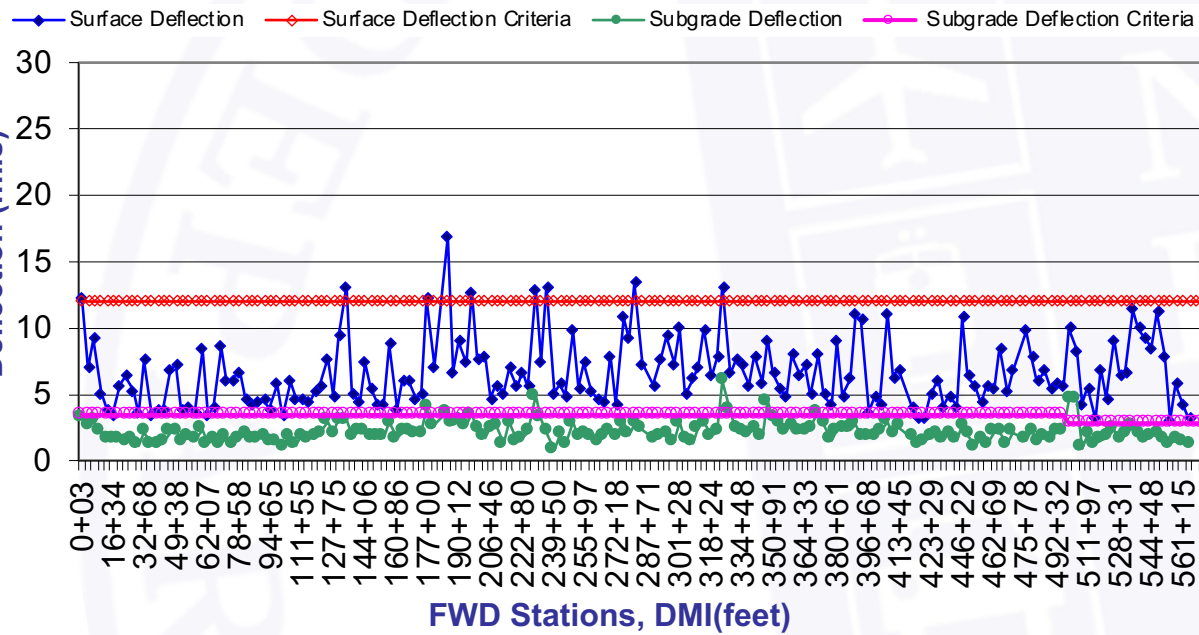


SR 327 SB Surface and Subgrade Deflection 2014

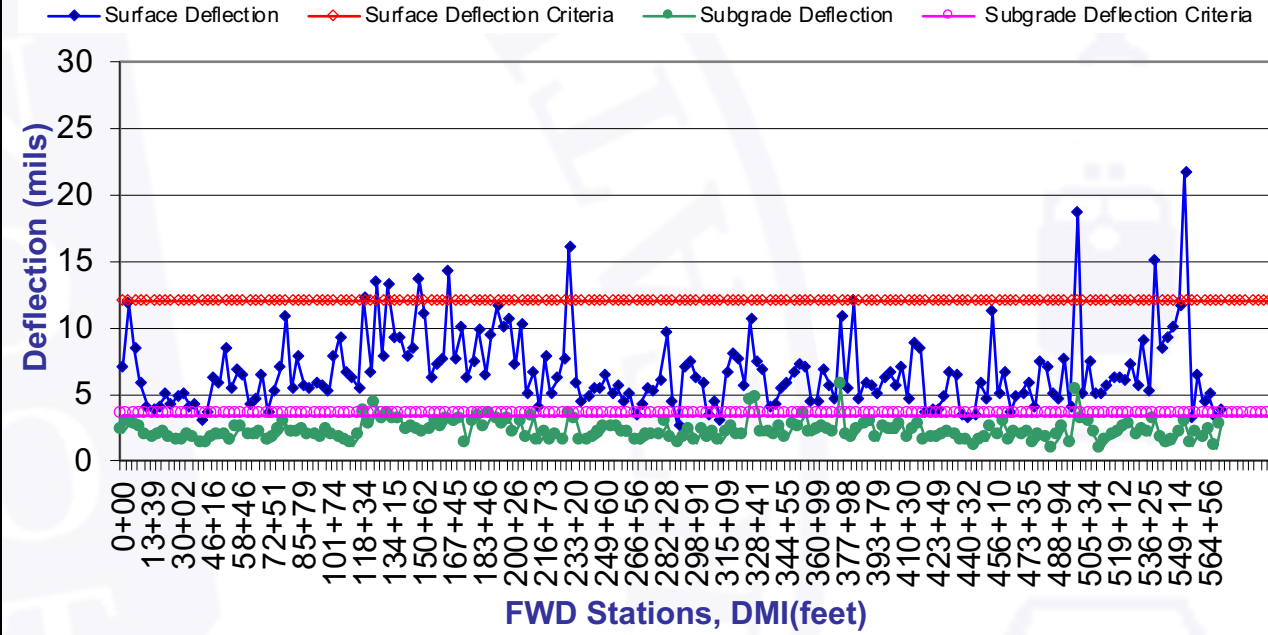


SR 327 FWD Before & After Final Surface Results

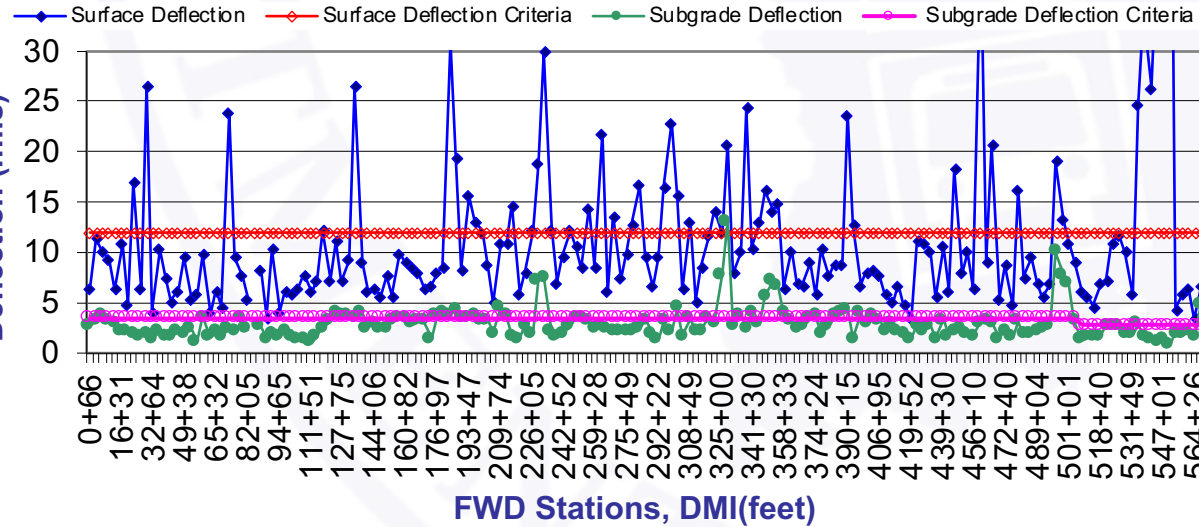
SR 327 NB Surface and Subgrade Deflection 2019 - After Surface



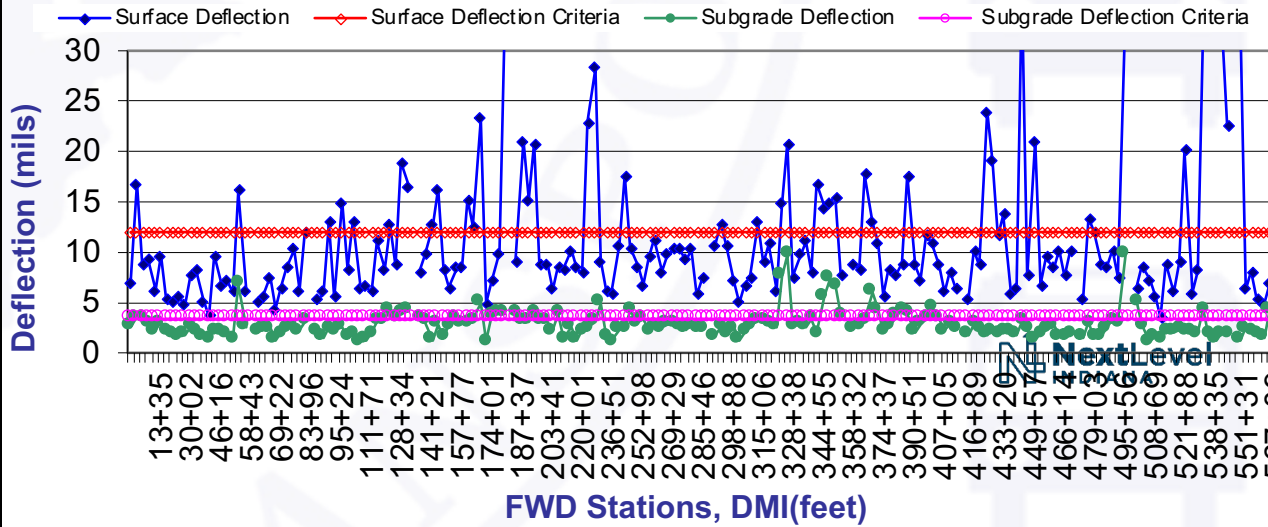
SR327 SB Surface and Subgrade Deflection 2019 - After Surface



SR 327 NB Surface and Subgrade Deflection 2019 Before Surface



SR327 SB Surface and Subgrade Deflection 2019 Before Surface



NextLevel

SR 327 FWD Before & After Results

SR 327 From SR 4 to US 20	2019 NB Surface Deflection	2019 NB Stabilized Surface Deflection	2014 NB Surface Deflection	2019 SB Surface Deflection	2019 SB Stabilized Surface Deflection	2014 SB Surface Deflection
Total Count	172	175	134	183	180	127
Count of Bad	9	46	122	9	46	104
Percent Bad	5%	26%	91%	5%	26%	82%
Average Difference	-5.37	-0.85	5.93	-5.33	-1.03	4.10
Average Deflection	6.63	11.15	17.93	6.67	10.97	16.10
Standard Dev	2.53	8.19	5.70	2.90	6.87	6.00
Average of Bad	13.31	20.94	18.84	15.34	20.07	17.79

SR 327 From SR 4 to US 20	2019 NB Subgrade Deflection	2019 NB Stabilized Surface Subgrade Deflection	2014 NB Subgrade Deflection	2019 SB Subgrade Deflection	2019 SB Stabilized Surface Subgrade Deflection	2014 SB Subgrade Deflection
Total Count	172	175	134	183	180	127
Count of Bad	9	40	41	9	35	59
Percent Bad	5%	23%	31%	5%	19%	46%
Average Difference	-1.34	-0.58	-0.67	-1.27	-0.66	0.16
Average Deflection	2.12	2.87	2.64	2.06	2.79	2.60
Standard Dev	0.77	1.59	1.14	0.77	1.36	1.20
Average of Bad	4.38	4.90	3.94	4.19	4.84	3.43

SR 327 From SR 4 to US 20	Stabilized Surface to Final Surface			
	NB Surf Def Improvement	NB Subgrade Improvement	NB Surf Def % Improvement	NB Subgrade % Improvement
Average of > 0	5.51	1.01	37%	29%
Average	4.61	0.75	28%	18%
Max	60.56	9.43	88%	72%
Min	-5.12	-1.12	-109%	-97%
Standard Dev	7.70	1.17	31%	28%
Count Imp Diff	141	131		
Count Not Imp	20	29		
Total Count	161	161		
% Improved Locations	88%	81%		

SR 327 From SR 4 to US 20	Stabilized Surface to Final Surface			
	SB Surf Def Improvement	SB Subgrade Improvement	SB Surf Def % Improvement	SB Subgrade % Improvement
Average of > 0	4.62	0.89	36%	27%
Average	3.88	0.66	29%	18%
Max	30.43	5.21	84%	66%
Min	-3.62	-1.22	-60%	-90%
Standard Dev	5.04	0.95	26%	25%
Count Imp Diff	139	130		
Count Not Imp	21	30		
Total Count	160	160		
% Improved Locations	87%	81%		

R-41287 - SR 1 From SR 18 to SR 218

- Let in February, 2019
- Rural 2-lane road in Jay & Wells Counties
- Length: 7.25 mi
- AADT: 2610 vpd – AADTT: 530 vpd
- Selected due to:
 - Cracking
 - Distresses
 - Structural problems in the top layers
 - Subbase/subgrade in fair condition
- Original pavement design
 - Asphalt used as stabilizer
 - 2" surface mill
 - 8" Stabilized subbase
 - Minor structural overlay
 - 1.5" surface
 - 2.5" intermediate HMA
- Road cross section (existing and final)
 - 11' Travel lanes
 - 2' Minimum shoulder
- Final pavement design
 - 2" surface mill
 - Asphalt used as stabilizer
 - 6" Stabilized subbase
 - Minor structural overlay
 - 1.5" surface
 - 2.5" intermediate HMA
- Cost:
 - Awarded: \$3,434,523
 - Final: \$3,620,438
- Change from 8" to 6" stabilized subbase caused by discovery of large aggregate macadam layer
 - Concern about processing the large aggregate in the FDR process

R-41287 - SR 1 From SR 18 to SR 218 - 2



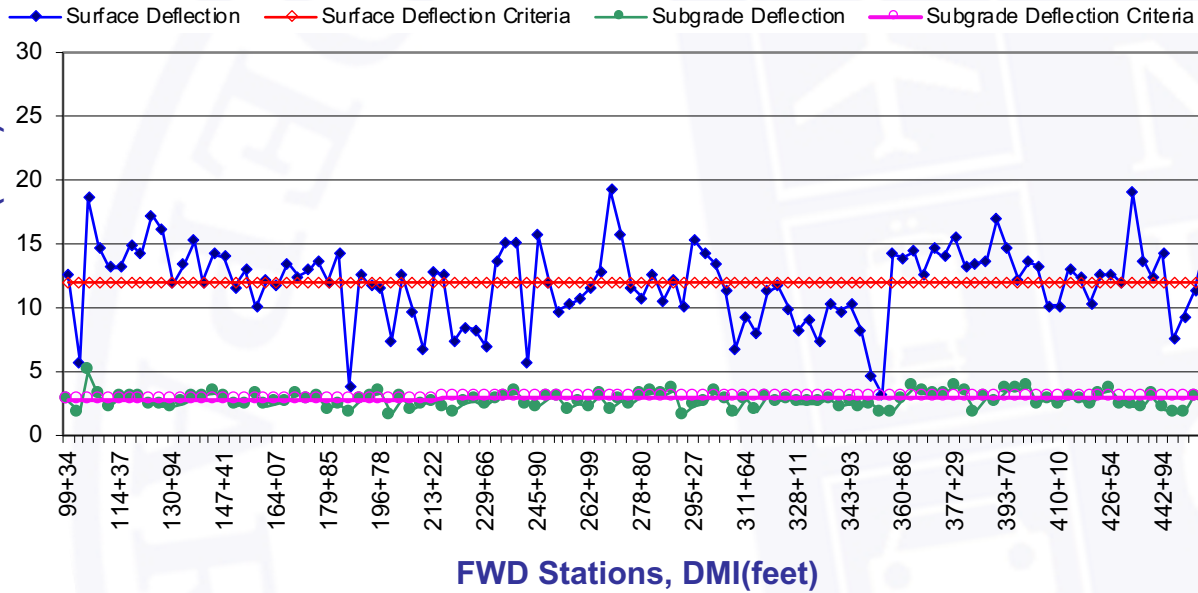
Before Project – 2017

2019 - Patching location showing macadam layer with large aggregate

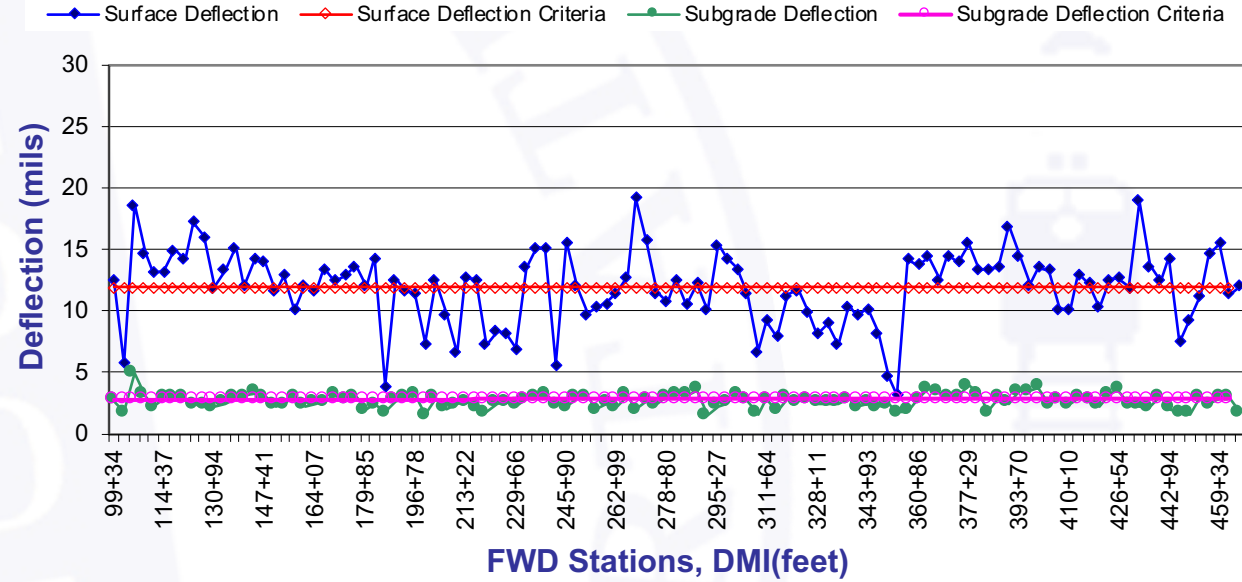
Completed Project - 2020

SR 1 FWD Before & After Results

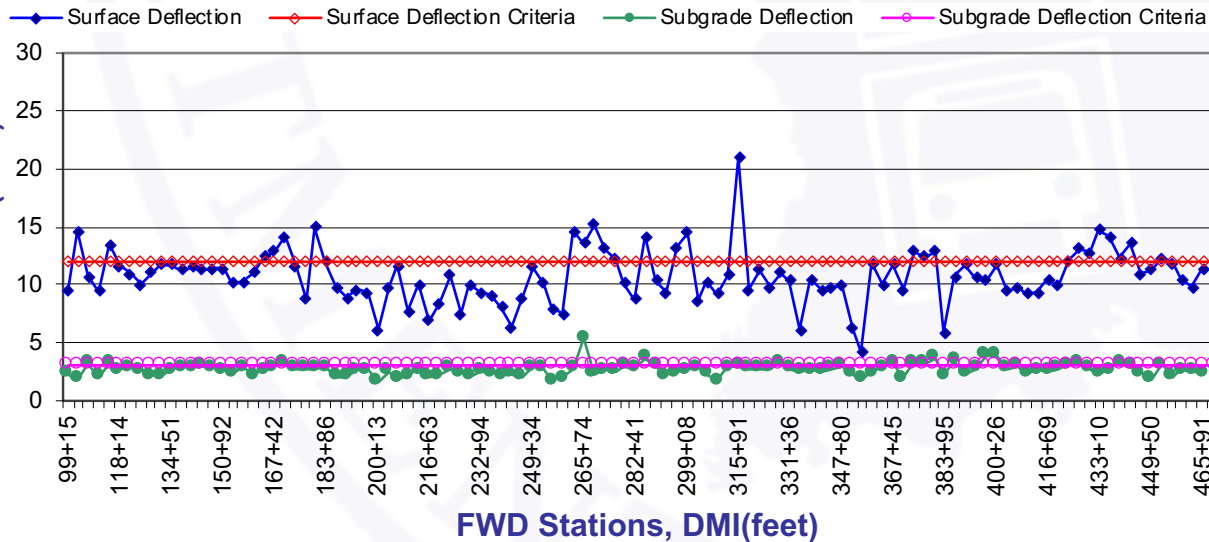
SR 1 SB Surface and Subgrade Deflection 2017



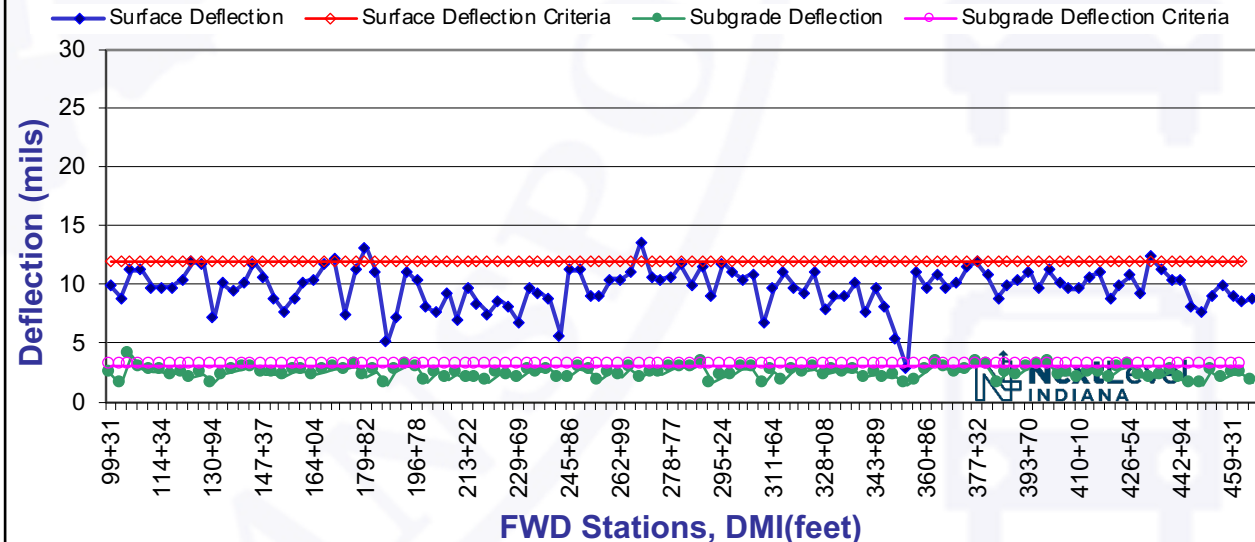
SR 1 SB Surface and Subgrade Deflection 2017



SR 1 NB Surface and Subgrade Deflection 2019



SR 1 SB Surface and Subgrade Deflection 2019



SR 1 FWD Before & After Results - 2

SR 1 From SR18 to SR 218	2019 NB Surface Deflection	2017 NB Surface Deflection	2019 NB Subgrade Deflection	2017 NB Subgrade Deflection
Total Count	111	113	111	113
Count of Bad	27	65	17	53
Percent Bad	24%	58%	15%	47%
Avg Difference	-1.23	0.05	-0.40	-0.10
Avg Deflection	10.77	11.99	2.68	2.68
Standard Dev	2.33	3.01	0.53	0.58
Avg of Bad	13.70	13.71	3.54	3.05

SR 1 From SR18 to SR 218	2019 SB Surface Deflection	2017 SB Surface Deflection	2019 SB Subgrade Deflection	2017 SB Subgrade Deflection
Total Count	113	113	113	113
Count of Bad	4	65	17	28
Percent Bad	4%	58%	15%	25%
Avg Difference	-2.22	-0.01	-0.44	-0.31
Avg Deflection	9.78	11.99	2.63	2.47
Standard Dev	1.70	3.01	0.64	0.47
Avg of Bad	12.89	13.98	3.54	3.05

SR 1 From SR18 to SR 218	2017 to 2019			
SR 1 From SR18 to SR 218	NB Surf Def Improvement	NB Subgrade Improvement	NB Surf Def % Improvement	NB Subgrade % Improvement
Average of > 0	2.31	0.30	17%	10%
Average	0.76	-0.08	0%	-6%
Max	7.26	1.11	45%	36%
Min	-13.01	-2.26	-169%	-137%
StDev	3.25	0.50	39%	24%
Count Imp Diff	49	33		
Count Not Imp	22	37		
Total Count	71	71		
% Improved Locations	69%	46%		

SR 1 From SR18 to SR 218	SB Surf Def % Improvement	SB Subgrade % Improvement	SB Surf Def % Improvement	SB SubGrade % Improvement
Average of > 0	2.68	0.28	20%	10%
Average	2.21	0.21	15%	7%
Max	7.40	0.96	43%	25%
Min	-3.17	-0.42	-55%	-19%
StDev	2.16	0.23	17%	8%
Count Imp Diff	99	93		
Count Not Imp	0	0		
Total Count	113	113		
% Improved Locations	88%	82%		

Surface Deflection Improvement

Bad defined as deflection going over the threshold

- SR 59 – Surface Deflection % Bad
 - NB - 85% in 2015 0% in 2019
 - SB - 79% in 2015 0% in 2019
- SR 101 – Surface Deflection % Bad
 - NB - 20% in 2013 0% in 2018 0% in 2019
 - SB - 9% in 2013 2% in 2018 10% in 2019
- SR 327 – Surface Deflection % Bad
 - NB - 91% in 2014 5% in 2019
 - SB - 82% in 2014 5% in 2019
- SR 1 – Surface Deflection % Bad
 - NB - 58% in 2014 24% in 2019
 - SB - 58% in 2014 4% in 2019

Subgrade Deflection Improvement

Bad defined as deflection going over the threshold

- SR 59 – Subgrade Deflection % Bad
 - NB - 47% in 2015 13% in 2019
 - SB - 79% in 2015 17% in 2019
- SR 101 – Subgrade Deflection % Bad
 - NB - 5% in 2013 0% in 2018 0% in 2019
 - SB - 9% in 2013 0% in 2018 2% in 2019
- SR 327 – Subgrade Deflection % Bad
 - NB - 31% in 2014 5% in 2019
 - SB - 46% in 2014 5% in 2019
- SR 1 – Subgrade Deflection % Bad
 - NB - 47% in 2014 15% bad in 2019
 - SB- 25% in 2014 9% in 2019

Comparison of Deflection Locations - Pre-Project vs Post-Project

- Improvement of deflection at individual test locations
 - Locations of test spots were compared if the locations were within 20' of each other on each project
- SR 59 – 2015 to 2019 FWD Testing
 - NB – 6 locations compared, out of 31 tested
 - Surface – 100% improved
 - Subgrade – 100% improved
 - SB – 8 locations compared, out of 34 tested
 - Surface – 100% improved
 - Subgrade – 100% improved
- SR 101 – 2013 to 2019 FWD Testing
 - NB – 98 locations compared, out of 127 tested
 - Surface – 94% improved
 - Subgrade – 82% improved
 - SB – 73 locations compared, out of 125 tested
 - Surface – 82% improved
 - Subgrade – 70% improved
- SR 327 – FWD Stabilized to Final Surf Testing
 - NB – 161 locations compared, out of 175 tested
 - Surface – 88% improved
 - Subgrade – 81% improved
 - SB – 160 locations compared, out of 183 tested
 - Surface – 87% improved
 - Subgrade – 81% improved
- SR 1 – 2017 to 2019 FWD Testing
 - NB – 71 locations compared, out of 111 tested
 - Surface – 69% improved
 - Subgrade – 46% improved
 - SB – 113 locations compared, out of 13 tested
 - Surface – 88% improved
 - Subgrade – 82% improved

Cost Comparison – FDR vs Pavement Replacement

- SR 59 – 2.17 mi*2 lanes = 4.34 miles
 - FDR Cost:
 - \$1,211,246 (Awarded) - \$279,089/lane mile
 - Pavement Replacement
 - \$2,593,873 (estimated) - \$597,667/lane mile
 - Percent Difference: 53%
- SR 101 – 8.62 mi*2 lanes = 17.24 lane miles
 - FDR/CCPR Cost:
 - \$4,970,715 (Awarded) - \$288,325/lane mile
 - Pavement Replacement
 - \$11,939,980 (estimated) - \$692,574/lane mile
 - Percent Difference: 58%
- SR 327 – 8.5 mil*2 lanes = 17 lane miles
 - FDR Cost:
 - \$5,959,990 (Awarded) - \$350,588/lane mile
 - Pavement Replacement
 - \$10,160,331 (estimated) - \$597,666.53/lane mile
 - Percent Difference: 41%
- SR 1 – 7.25 miles*2 lanes = 14.5 lane miles
 - FDR Cost:
 - \$3,434,523 (Awarded) - \$236,863.66/lane mile
 - Pavement Replacement
 - \$11,626,120 (estimated) - \$896,195/lane mile
 - Percent Difference: 70%

Comparison – FDR vs Pavement Replacement

- FDR
 - Improves the structural capacity of the pavement
 - It can treat part of the pavement
 - It can treat all the pavement
 - A narrow pavement:
 - Can be widen
 - Add shoulders, if desired
 - Can be left at same width (replace in kind)
 - It is not considered a rehab/reconst:
 - Profile grade cannot be raised more than 3"
 - Features can remain the same i.e. lane width, shoulders
 - R/W may not be required
- Pavement Replacement
 - Improves the structural capacity of the pavement
 - Widens a narrow pavement
 - To at least minimum standards
 - Minimum shoulders are required
 - It is a reconstruction
 - All features are improved to minimum standards
 - A design exception may be needed
 - R/W is generally required

Full Depth Reclamation - 2

- It is only for Full Depth HMA pavements
- It is another tool in the toolbox
 - It is a promising way to improve low AADT road in a cost-effective way
 - It is not right technique for every low-volume road
- FDR can:
 - Improve structural capacity of the pavement
 - Full depth HMA pavement including subgrade
 - If thicker than 10" after surface milling, combine with CCPR
 - Top part of pavement up to 10" deep
 - If underlying structure is still good
 - Widen narrow travel lanes/add shoulders
 - Must cut trenches to required width along outside edge pavement
 - Fill with millings and/or supplement material
 - May need R/W
 - Eliminate HMA stripping/loss of layer bond
 - Set FDR depth to level of problem
 - Replace pavement in kind
 - As long as the profile grade is not more than raised 3", it is not considered a rehab/reconstruction
 - This good in areas of narrow R/W
- This is a relatively new technique for INDOT
 - Approximately 20 FDR's have been completed
 - At present only low AADT road are considered for FDR
 - AADT 5000 vph?
 - Many of these roads are approaching 80 to 100 years of structural life
 - Need to review effectiveness of FDR
 - Does it improve structural capacity over the long term
- Improvements
 - Selection of projects
 - What is the correct criteria
 - Project design
 - Selection of stabilizing agent
 - Pre-project testing requirements
 - Construction/inspection of project
 - Since it is a fairly process for INDOT, do we know how to build and inspect the projects

Full Depth Reclamation - 3

Questions