Final Report VTRC 08-R18

Virginia Transportation Research Council

research report

Network-Level Pavement Evaluation of Virginia's Interstate System Using the Falling Weight Deflectometer

http://www.virginiadot.org/vtrc/main/online_reports/pdf/08-r18.pdf

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Standard Title Page - Report on State Project

Report No.	Report Date	No. Pages	Type Report:	Project No.:
VTRC 08-R18	June 2008	123	Final Period Covered:	77209 Contract No.

Title:
Network-Level Pavement Evaluation of Virginia's Interstate System Using the Falling Weight Deflectometer

Key Words: Falling weight deflectometer, pavement, structural capacity, pavement design, pavement rehabilitation

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Supplementary Notes

Abstract

The Virginia Department of Transportation (VDOT) currently uses the results of automated surface distress surveys to assist in developing pavement maintenance strategies for its interstate and primary roadways. Totaling nearly 27,000 lane-miles, these roadways consist of flexible, rigid, and composite (flexible over rigid) pavements. These video-based surface distress data consist of quantities of distress that is visible in the pavement surface; however, no information regarding the actual structural capacity of the pavement system on a network level is currently available.

This study describes the processes and presents the results of a network-level survey conducted on Virginia's interstate system using the falling weight deflectometer (FWD). The data obtained from this study can be used by pavement engineers to determine the structural capacity of the interstate network and to develop condition forecasting tools to assist with determining future structural conditions. Similar network surveys have been performed by the Kansas, Texas, New Jersey, Indiana, and Oklahoma departments of transportation.

Although it is not yet possible to assign a monetary benefit to the results of this study as these data were not previously available, their benefits to VDOT's Asset Management Division are expected to be great. The use of these data can result in more cost-effective decisions regarding pavement rehabilitation. In a study comparing pavement rehabilitation designs based on visually observable distresses versus pavement rehabilitation designs based on structural capacity using the FWD for sections of interstate pavement in New Jersey, the authors estimated that only 27% of the designs based on visually observable distresses agreed with those based on structural data; 41% of the rehabilitation treatments were underdesigned, and 32% were overdesigned.

The current study recommends that VDOT continue network-level structural evaluation of the interstate system using the FWD and perform similar testing on the primary network.

FINAL REPORT

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Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

Charlottesville, Virginia

June 2008
VTRC 08-R18

DISCLAIMER

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FINAL REPORT

NETWORK-LEVEL STRUCTURAL EVALUATION OF VIRGINIA'S INTERSTATE SYSTEM USING THE FALLING WEIGHT DEFLECTOMETER

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INTRODUCTION

The Virginia Department of Transportation (VDOT) uses the results of automated video distress surveys to assist in developing maintenance priorities to manage the pavement on Virginia's interstate and primary roadways. Totaling nearly 27,000 lane-miles, these roadways consist of flexible, rigid, and composite (flexible over rigid) pavements. The video-based surface distress data consist of quantities of distress that is visually observable at the pavement surface; however, no information regarding the structural capacity of the pavement system on a network level is currently available. The distress quantities are transformed into a condition index. From the condition index values, typical maintenance treatments are determined and average costs are calculated. It is from this process that a performance-based budget is developed.

Previous research conducted at the Virginia Transportation Research Council developed a protocol to collect pavement structural capacity data using the falling weight deflectometer (FWD) on portions of Virginia's interstate system (Alam et al., 2007; Galal et al., 2007). The FWD has also been used by the Kansas, Texas, New Jersey, Indiana, and Oklahoma departments of transportation to develop structural data for their pavement networks (Hossain et al., 2000; Noureldin et al., 2003; Zaghloul et al., 1998; Zhang et al., 2003). Such data typically include the deflection, subgrade resilient modulus, effective structural number, deflection basin area, individual layer moduli, and the overall pavement moduli.

PURPOSE AND SCOPE

This study describes the processes and presents the results of a network-level FWD survey on Virginia's interstate system. The data obtained are intended to be used by VDOT pavement design and management engineers to determine the structural capacity of the interstate network and to develop condition forecasting tools to assist with determining future structural conditions. By knowing the pavement structural condition, these engineers can better program pavement maintenance and rehabilitation funding.

The scope of the FWD data collection encompassed Virginia's interstate network.

METHODS

FWD testing of the interstate system was conducted in two phases. In the first phase, the test protocol was developed and its effectiveness was evaluated (Alam et al., 2007; Galal et al., 2007). This phase was conducted on I-77 and the western portion of I-64 in Virginia. I-77 connects Virginia with North Carolina and West Virginia and runs through the southwestern portion of the state. The route is approximately 69 miles long and consists of rolling hills to mountainous terrain. I-64 runs east to west across the midsection of Virginia. The western portion of I-64 (that portion located west of I-81) consists of approximately 55 miles of interstate in mountainous terrain.

In the second phase of the study, the reminder of Virginia's interstate system was surveyed using the developed FWD test protocol. The test protocol used was developed following a statistical analysis of the results from the first phase (Alam et al., 2007). This protocol allowed for a reduced sampling frequency, which allowed a greater production rate and significantly reduced costs (in terms of operator hours, traffic control expenses, and lane closure time) without sacrificing data quality.

FWD Deflection Testing

Testing was performed using a Dynatest Model 8000 FWD in the travel (right-hand) lane of the roadway in both directions. The FWD load plate was located in the right wheel path during testing. The FWD was equipped with nine sensors at radial distances of 0, 8, 12, 18, 24, 36, 48, 60, and 72 in from the center of a load plate. Testing in the first phase was conducted at 0.1-mi intervals and at four load levels (6,000; 9,000; 12,000; and 16,000 lb). At each load level, two deflection basins were recorded. Testing in the second phase was conducted at 0.2-mi intervals and at three load levels (9,000; 12,000; and 16,000 lb). At each load level, two deflection basins were recorded. It has been shown elsewhere that testing as few as three points per mile can yield statistically meaningful results (Alam et al., 2007; Hossain et al., 2000). Table 1 shows the mileage for each interstate route in Virginia.

The output from the Dynatest FWD is provided as a text-delimited raw data file. In nearly all cases, a separate raw data file was created for each county of each direction of each interstate route. During the testing, each raw data file was collected either during one day or over several days depending on the length of the section, the allowable work time, the weather, and other local conditions. The date and time were reported in the raw data along with the infrared pavement temperature and ambient temperature at the time of testing. Where a single raw data file encompassed multiple pavement types or differing structural cross sections, the data for similar pavement structures and types were analyzed as a group following the procedures described in the next section.

Table 1. Virginia Interstate Mileage

Interstate	Distance (mi)				
	Northbound	Southbound	Eastbound	Westbound	Total
64			300.42	300.38	600.80
66			74.77	75.16	149.93
77	68.37	68.00			136.37
81	324.92	325.04			649.96
85	69.12	68.94			138.06
95	178.25	178.56			356.81
264			25.07	25.07	50.14
295			52.62	52.75	105.37
381	1.41	1.67			3.08
395	9.85	9.91			19.76
464	5.67	5.83			11.50
495	14.59	14.50			29.09
564	2.77	2.64			5.41
581	6.64	6.57			13.21
664			20.57	20.35	40.92
					2310.41

In addition to the measured deflection (sensors 1 through 9), the following data are reported or calculated from VDOT's interstate network FWD testing for each pavement type: plate load, plate pressure, air and surface temperature, test date, and time. The previous day average air temperature (average of high and low) was obtained for each test date from a nearby weather station from Weather Underground (www.wunderground.com). These data were used to calculate a temperature-corrected deflection under the load plate (D_0) for flexible pavement sections. In addition, the resilient modulus, pavement modulus, and effective structural number were calculated for flexible pavements. The deflection basin area and the static k-value were calculated for composite and rigid pavement sections. The raw data and all calculated quantities are available in a spreadsheet format from the author upon request. These data can be used to identify areas where more detailed study is needed and sections where no further study is warranted.

Data Analysis

The data analysis began by identifying continuous stretches of pavement having similar surface materials and structural cross sections such that they would be expected to act homogeneously with respect to traffic loading. Grouping structurally similar pavement sections is often performed in FWD analysis for ease of data analysis. The structural cross sections may consist of many varied layers, but for the purpose of analysis in this study, they were simplified and considered as an idealized three-layer system. For flexible and rigid pavements, the three-layer system consisted of bound layer(s), aggregate layer(s), and subgrade. For composite pavements, the three-layer system consisted of flexible layer(s), rigid layer(s), and subgrade. The pavement structure information (layer type and thickness) was obtained from VDOT's Highway Traffic Record Information System (HTRIS).

During the data analysis process, the pavement sections were identified in accordance with nomenclature standards previously established by VDOT's Asset Management Division as one of the following types: BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; BOC: a composite with flexible pavement over continuously reinforced concrete pavement; JPC: jointed plain concrete pavement; JRC: jointed reinforced concrete pavement; or CRC: continuously reinforced concrete pavement.

In general, adjacent test locations that were identified to be structurally similar (thickness and/or surface layer type) were grouped to form larger homogeneous sections to make the data analysis more computationally efficient. This grouping was performed where the bound layer thickness of adjacent sections differed by less than approximately 2.0 in. Any identified homogeneous section less than 0.5-mi in length was grouped with adjacent sections until the total length of the combined homogeneous section was greater than 0.5 mi. Where multiple sections were joined to create a larger homogeneous section, the thickness of each layer of the larger homogeneous section was calculated based on an average layer thickness weighted by the length of the smaller portions. In addition, homogeneous sections were started and terminated when the interstate route crossed a county boundary. Tables A.1 through A.30 in Appendix A list the thickness of the upper two layers used in the data analysis for each homogeneous section of each interstate route. An example of the homogeneous sectioning is provided in Table 2. The thickness of the bottommost layer (subgrade) is given by an analysis of the data to identify the depth to the hard-bottom or rigid layer; in most cases, this ranged from approximately 100 in to more than 300 in.

In some cases, the thickness and layer information obtained from HTRIS did not pass the "test of reasonableness" or appeared to be missing some portions of data. In these cases, the three-layer system thickness for the homogeneous section in question was estimated based on average data for adjacent homogeneous sections that appeared to be of similar structure. These sections are identified in Table 2 and in the tables in Appendix A where the thickness value is bold and shaded.

Table 2. Homogeneous Pavement Sections: I-66 Eastbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 Thickness (in)	Layer 2 Thickness (in)
93	1.00	6.78	BIT	9.0	18.0
93	7.00	10.60	BIT	7.2	13.5
93	10.80	11.80	BIT	12.3	18.0
30	0.00	6.20	BIT	10.7	18.0
30	6.40	14.00	BIT	**10.5**	**14.0**
30	14.20	21.92	BIT	10.5	18.0
76	0.00	6.60	BIT	10.8	12.0
76	6.80	12.35	BIT	**10.8**	**12.0**
29	0.00	3.60	BIT	10.0	12.0
29	3.80	9.80	JPC	14.0	12.0
29	10.00	15.60	JRC	15.0	12.0
29	15.80	18.94	BIT	9.5	12.0
0	0.00	2.00	BIT	9.5	12.0
0	2.20	6.40	BIT	9.5	12.0

BIT: flexible pavement (bituminous); JPC: jointed plain concrete pavement; JRC: jointed reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

FWD data were analyzed using ModTag, Version 4.1.4 (VDOT, 2007). Flexible pavements were analyzed by calculating the subgrade resilient modulus (M_R), the effective pavement modulus (E_p), and the effective structural number (SN_{eff}). Rigid and composite pavements were analyzed by calculating the area under the deflection basin and the static modulus of subgrade reaction (k-value). The analyses were conducted in accordance with the 1993 American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures* (AASHTO, 1993) and the 1998 *Supplement to the AASHTO Guide for Design of Pavement Structures: Part II, Rigid Pavement Design and Rigid Pavement Joint Design* (AASHTO, 1998). The step-by-step procedure used to process the data in ModTag is provided in Appendix B.

Flexible Pavements

Subgrade Resilient Modulus (M_R)

The subgrade resilient modulus (M_R) is a fundamental engineering material property that describes the subgrade strength and ability to resist deformation under repeated traffic loadings (Huang, 2004; National Cooperative Highway Research Program, 2004). The subgrade resilient modulus is computed from the following:

$$M_R = C\left(\frac{P*\left(1-\mu^2\right)}{\pi * r * d_r}\right) \quad \text{(Eq. 1)}$$

where

M_R = subgrade resilient modulus (psi)
P = applied load (lb)
μ = Poisson's ratio
r = radial distance at which the deflection is measured (in)
d_r = measured deflection at a radial distance, r (mils)
C = correction factor, 0.33.

Effective Pavement Modulus (E_p)

The effective pavement modulus (E_p) is the effective modulus of all combined pavement layers on top of the subgrade soil. The E_p is used to calculate the pavement effective structural number (SN_{eff}). The E_p was calculated using the following equation:

$$d_0 = 1.5 * p * a \left[\frac{1}{M_r \sqrt{1 + \left(\frac{D}{a} \sqrt[3]{\frac{E_p}{M_r}} \right)^2}} + \frac{\left(1 - \frac{1}{\sqrt{1 + \left(\frac{D}{a} \right)^2}} \right)}{E_p} \right] \quad \text{(Eq. 2)}$$

where

d_o = deflection at the center of the load plate (mils)
p = contact pressure (psi)
M_R = subgrade resilient modulus (psi)
D = total pavement thickness above the subgrade (in)
a = radius of load plate (in)
E_p = effective pavement modulus of all layers above the subgrade (psi).

Effective Structural Number (SN_{eff})

The pavement effective structural number (SN_{eff}) describes the structural capacity of a flexible pavement and is often calculated during the pavement design process as the sum of the individual layer thicknesses multiplied by their respective empirically based layer coefficient (in accordance with the AASHTO design methodology [AASHTO, 1993]). Based on FWD data, the effective structural number may be calculated from the following:

$$SN_{eff} = 0.0045 * D * \sqrt[3]{E_p} \quad \text{(Eq. 3)}$$

where

SN_{eff} = effective structural number
D = total pavement thickness above the subgrade (in)
E_p = effective pavement modulus of all layers above the subgrade (psi).

Rigid and Composite Pavements

Deflection Basin Area

The deflection basin area represents the deflected area resulting from the applied load. The deflection basin area for a nine-sensor FWD is calculated as follows:

$$Area = 4 + 6\left(\frac{d_8}{d_0}\right) + 5\left(\frac{d_{12}}{d_0}\right) + 6\left(\frac{d_{18}}{d_0}\right) + 9\left(\frac{d_{24}}{d_0}\right) + 18\left(\frac{d_{36}}{d_0}\right) + 12\left(\frac{d_{60}}{d_0}\right) \qquad \text{(Eq. 4)}$$

where

$Area$ = deflection basin area (in)
d_o = deflection at the center of the load plate (mils)
d_8 = deflection at 8 in from the center of the load plate (mils)
d_{12} = deflection at 12 in from the center of the load plate (mils)
d_{18} = deflection at 18 in from the center of the load plate (mils)
d_{24} = deflection at 24 in from the center of the load plate (mils)
d_{36} = deflection at 36 in from the center of the load plate (mils)
d_{60} = deflection at 60 in from the center of the load plate (mils).

Static Modulus of Subgrade Reaction (k_{static})

The static modulus of subgrade reaction (static k-value), a measure of the subgrade strength beneath rigid pavements, is calculated by first determining the radius of relative stiffness (*l*) and the dynamic modulus of subgrade reaction as follows:

$$l_{est} = \left[\frac{ln\left(\frac{60 - Area}{289.708}\right)}{-.698}\right]^{2.566} \qquad \text{(Eq. 5)}$$

where

l_{est} = estimated radius of relative stiffness (in)
$Area$ = deflection basin area (in).

Using Equation 6, the estimated dynamic (effective) modulus of subgrade reaction is calculated as follows:

$$k_{est} = \left(\frac{P \times d_0^{*}}{d_0 \times l_{est}^{2}}\right) \qquad \text{(Eq. 6)}$$

where

k_{est} = estimated dynamic (effective) modulus of subgrade reaction
P = applied load (lb)
d_o^* = coefficient of deflection at the center of the load plate
l_{est} = estimated radius of relative stiffness (in).

The coefficient of deflection at the center of the load plate is calculated as follows:

$$d_0^* = 0.1245e^{\left(-0.14707e^{\left(-0.07565\times l_{est}\right)}\right)} \quad \text{(Eq. 7)}$$

where

d_o^* = coefficient of deflection at the center of the load plate
l_{est} = estimated radius of relative stiffness (in).

Once the estimated dynamic modulus of subgrade reaction (k_{est}) is determined, it is corrected based on the dimensions of the concrete slab. A composite length (L) is determined from the slab width and length as follows:

$$S_l \le 2\times S_w \qquad L = \sqrt{S_l \times S_w} \quad \text{(Eq. 8a)}$$

$$S_l > 2\times S_w \qquad L = \sqrt{S_w} \times S_l \quad \text{(Eq. 8b)}$$

where

S_l = concrete slab length (in)
S_w = concrete slab width (in)
L = composite length factor.

The dynamic (effective) modulus of subgrade reaction (k) is calculated based on a series of adjustment factors to the slab length and deflection at the center of the load plate as follows:

$$k = \frac{k_{est}}{AF_l^{\,2} \times AF_{d_0}} \quad \text{(Eq. 9)}$$

where

k = dynamic (effective) modulus of subgrade reaction (pci)
k_{est} = estimated dynamic (effective) modulus of subgrade reaction
AF_l = adjustment factor for finite slab size
AF_{d0} = adjustment factor for deflection at the center of the load plate

The adjustment factors in Equation 10 are calculated as follows:

$$AF_{d_0} = 1 - 1.15085e^{-0.71878\left(\frac{L}{l_{est}}\right)^{0.80151}} \quad \text{(Eq. 10a)}$$

$$AF_l = 1 - 0.89434e^{-0.61663\left(\frac{L}{l_{est}}\right)^{1.04831}} \quad \text{(Eq. 10b)}$$

where

L = composite length factor
l_{est} = estimated radius of relative stiffness (in).

From the dynamic (effective) modulus of subgrade reaction (k), the static modulus of subgrade reaction (k_{static}) is calculated as follows:

$$k_{static} = \frac{k}{2} \tag{Eq. 11}$$

where

k_{static} = static modulus of subgrade reaction (pci)
k = dynamic (effective) modulus of subgrade reaction (pci).

RESULTS AND DISCUSSION

Figure 1 shows an example of the calculated effective structural number and the resilient modulus for a section of I-81 at a load level of approximately 9,000 lb. Similar figures are presented in Appendix C for all flexible pavements. Calculated using Equation 3, the effective structural number offers an empirical means for determining the structural capacity of a flexible pavement structure. A higher structural number indicates a higher capacity for carrying traffic. The computed value may be compared to an as-designed structural number (obtained using the original pavement design) or a required structural number (required for carrying future traffic) using the protocols given in the AASHTO pavement design guide (AASHTO, 1993) and the VDOT guidelines for using the AASHTO pavement design guide (VDOT, 2000). The subgrade resilient modulus, calculated using Equation 1, offers a means for evaluating the strength of the subgrade. A greater resilient modulus value indicates a stronger subgrade.

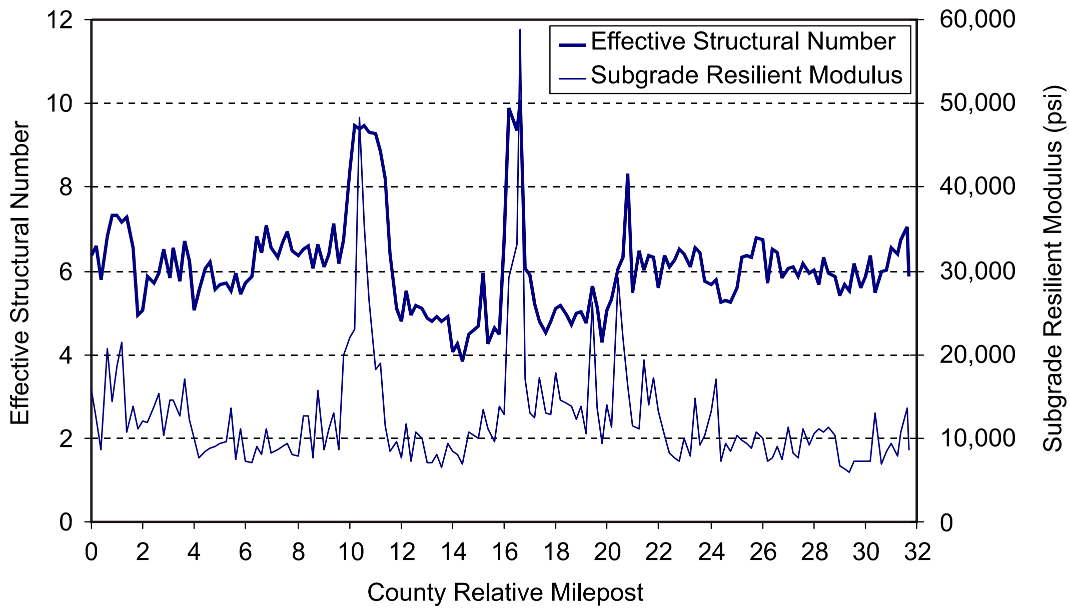

Figure 1. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Rockbridge County

Figures 2 and 3 show the cumulative distribution of the effective structural number and the corrected resilient modulus, respectively, for all flexible pavements tested in this study. Figure 2 indicates that the 50th percentile for the effective structural number is approximately 6.5. Thus, half the locations tested had an effective structural number less than 6.5, and half greater. As may been seen in Figure 1, the section of pavement approximately between mileposts 12 and 20 represents a weaker structure that warrants further project-level study as the average structural number is approximately 5, less than approximately the 10th percentile when compared to statewide values. Similarly, Figure 3 indicates that the 50th percentile of the subgrade resilient modulus is approximately 13,000 psi. From Figure 1 it can be seen that there are numerous locations where the subgrade resilient modulus ranges from approximately 8,000 to 10,000 psi, ranging from approximately the 15th to 30th percentile when compared to statewide values.

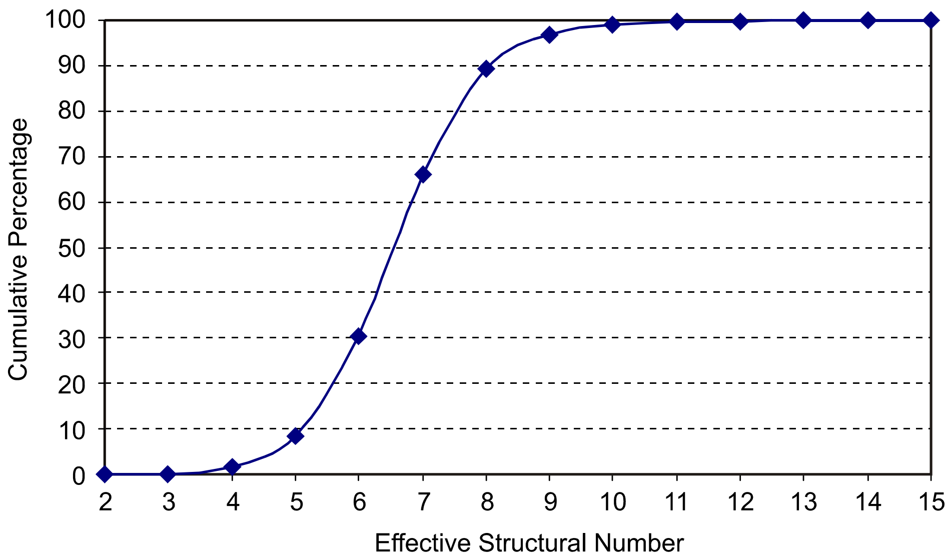

Figure 2. Cumulative Distribution of Effective Structural Number for All Flexible Pavements

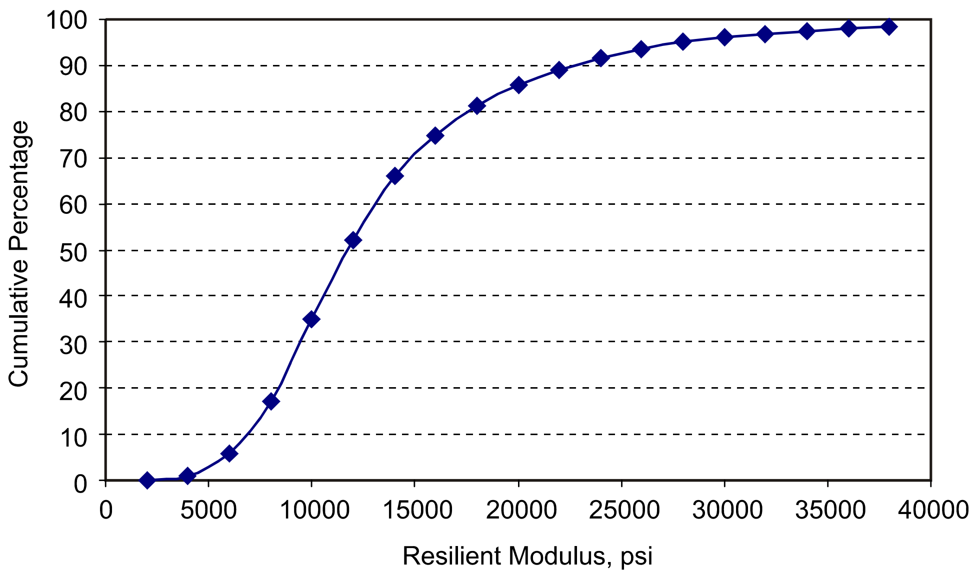

Figure 3. Cumulative Distribution of Subgrade Resilient Modulus for All Flexible Pavements

As another means to analyze the computed data from flexible pavements, Damnjanovic and Zhang (2006) suggested that parameters calculated from the FWD, such as effective structural number, can be compared to a needed structural number depending on actual traffic levels. The authors presented calculations of a structural condition index (SCI) as the ratio of effective to required structural number. A value greater than or equal to 1 indicates that the pavement structure is sufficient for future traffic conditions. A value less than 1 indicates that the pavement will require some type of structural rehabilitation. This type of calculation could be done for each interval where the traffic volume (especially percent trucks) is known. This type of analysis should be considered for future work but is beyond the scope of this study.

Figure 4 shows an example of the measured deflection under the load plate and the calculated deflection basin area for a section of I-64 at a load level of approximately 9,000 lb. Similar figures are presented in Appendix C for rigid and composite pavements. The deflection under the load plate is taken directly from the raw FWD data and is generally indicative of the stiffness of the pavement foundation. Thus, a greater deflection indicates a weaker pavement foundation. The deflection basin area comprises a means for assessing the overall structural condition of the rigid or composite pavement structure. Although termed an area, the quantity is given in inches as the value is normalized with respect to the deflection under the load plate, as shown by Equation 4. A greater deflection basin area value indicates a stronger pavement structure.

Figures 5 and 6 present the cumulative distributions of the deflection under the load plate and the deflection basin area for rigid and composite pavements, respectively. Figure 5 shows the similar cumulative distributions of the deflection under the load plate for the composite (BOC and BOJ) and rigid (CRC, JPC, and JRC) pavements. Figure 6 shows that the cumulative distributions for deflection basin area for the composite and rigid pavements form two distinct groupings. Figure 4 shows the average deflection under the load plate to be approximately 4 mils, with periodic peaks up to 12 mils at a load level of approximately 9,000 lb.

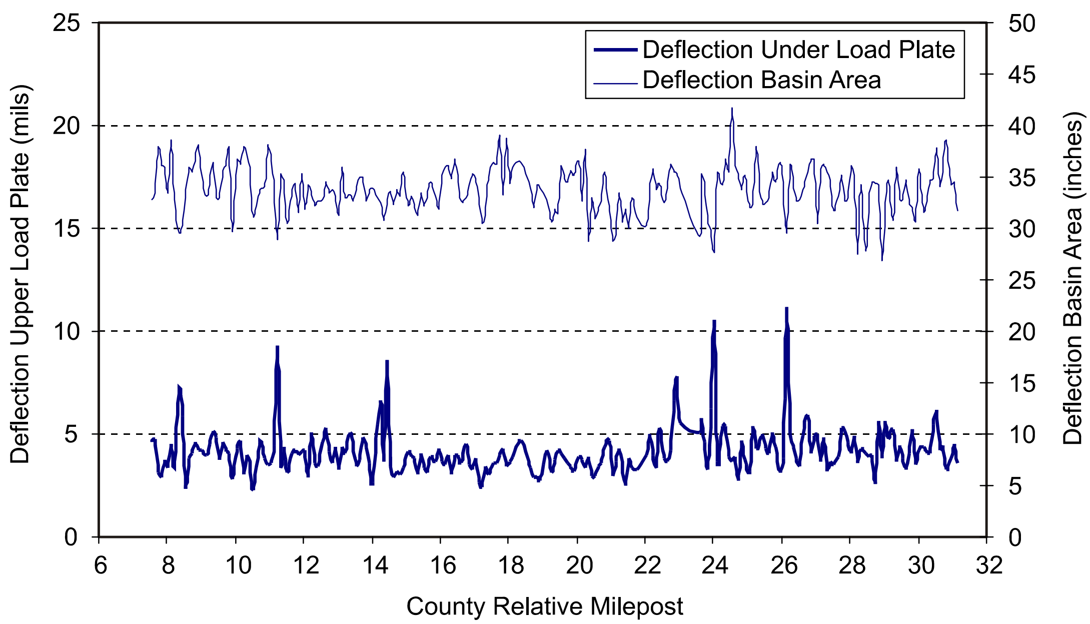

Figure 4. Deflection Under Load Plate and Deflection Basin Area: Eastbound I-64, Albemarle County

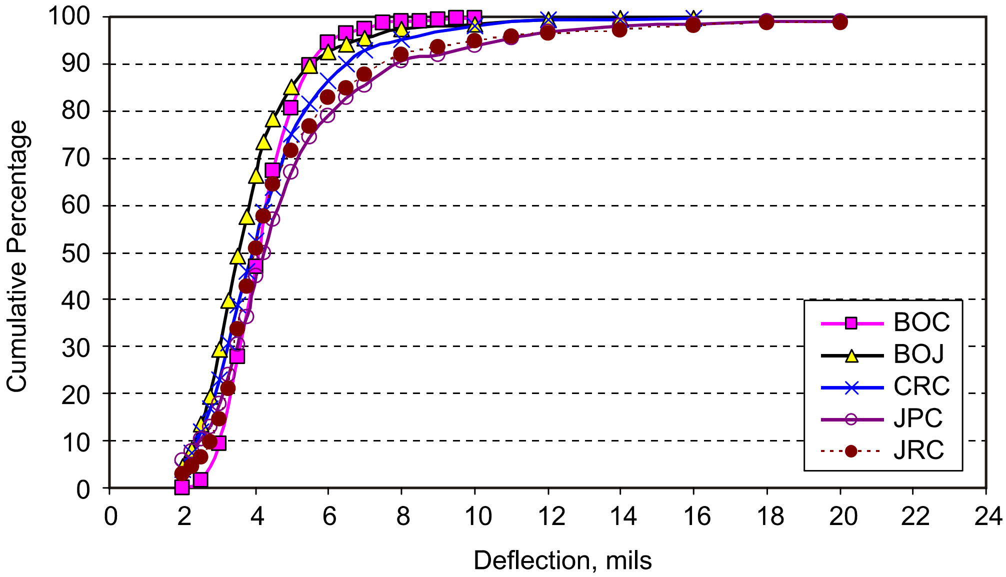

Figure 5. Cumulative Distribution of Deflection Under Load Plate for All Composite and Rigid Pavements. BOC = a composite with flexible pavement over continuously reinforced concrete pavement; BOJ = a composite with flexible pavement over jointed concrete pavement; CRC = continuously reinforced concrete pavement; JPC = jointed plain concrete pavement; JRC = jointed reinforced concrete pavement.

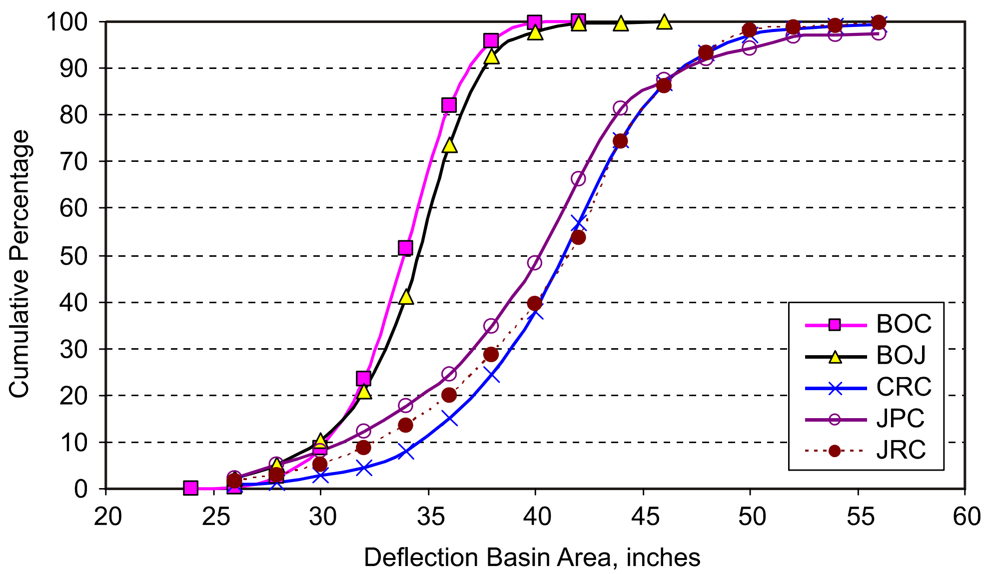

Figure 6. Cumulative Distribution of Deflection Basin Area for All Composite and Rigid Pavements. BOC = a composite with flexible pavement over continuously reinforced concrete pavement; BOJ = a composite with flexible pavement over jointed concrete pavement; CRC = continuously reinforced concrete pavement; JPC = jointed plain concrete pavement; JRC = jointed reinforced concrete pavement.

From Figure 5 it can be seen that this average deflection is approximately at the 50th percentile of values seen statewide. The peaks ranging from 8 to 12 mils are approximately within the 90th to 98th percentile when compared to statewide values. Thus, the average deflection compares well to values statewide but the peaks indicate areas within the pavement that warrant further project-level study. Figure 4 also shows the average deflection basin area to be approximately 34 in. As the pavement section shown in Figure 4 is a composite, this average deflection basin is approximately equal to the 50th percentile when compared to statewide values. Figure 4 also shows that locations exist where the deflection basin area ranges from approximately 27 to 30 in. From Figure 6, these basin area values fall approximately within the 5th to 10th percentile when compared to statewide values. These locations appear to possess relatively weaker pavement structures that warrant further project-level investigation.

Table 3 offers a means for qualitatively assessing the pavement condition using both the deflection under the load plate and the deflection basin area. From the data in Figure 4 and the descriptions in Table 3, the highest deflections at mileposts 24 and 26 (corresponding with local minimum deflection basin areas) indicate pavements having a relatively weaker structure and a weaker subgrade.

Table 3. Trends in Deflection Basin Area and Deflection Under Load Plate

FWD Parameter		Generalized Conclusions
Area	**Deflection Under Load Plate**	
Low	Low	Weak structure, strong subgrade
Low	High	Weak structure, weak subgrade
High	Low	Strong structure, strong subgrade
High	High	Strong structure, weak subgrade

Source: Washington State Department of Transportation, Environmental and Engineering Programs, Materials Laboratory, Pavements Division. (2000). *Everseries User's Guide: Pavement Analysis Computer Software and Case Studies.* Olympia.

CONCLUSION

- *FWD network level testing is a viable tool to classify existing network structural conditions.* The data obtained from this study can be used by pavement designers and pavement management engineers to address network needs in terms of rehabilitation strategies and fund management decisions based on the structural condition of the pavement.

RECOMMENDATIONS

1. *VDOT's Asset Management Division should use the results of the network-level FWD survey to complement the current video-based surface distress survey to develop pavement maintenance funding requests as part of the performance-based budget process.*

2. *VDOT's Asset Management Division should use the results of the network-level FWD survey to identify candidate sites where complete reconstruction is needed.* In these sections, application of typical preservation or maintenance treatments is not cost-effective if the structural capacity is such that the service life of these treatments will be significantly reduced.

3. *VDOT's Asset Management Division and Materials Division should conduct testing to determine the pavement structure on those homogeneous sections where the pavement structure was estimated during this project.* This testing would allow for a more accurate

determination of the structural capacity of these sections if the actual pavement cross section is known. This should be performed with a combination of ground-penetrating radar to identify sections having a similar cross section followed by core sampling within each identified section.

4. *VDOT's Materials Division should equip their existing FWD device with a GPS locator to provide coordinates for each collected data point. This requirement should also be extended to any additional FWD device purchased in the future and to any FWD work contracted to private consultants*. Having these data would allow for confirmation of the test location for each data point. In certain instances, this ability would have proven useful during this project.

5. *The Virginia Transportation Research Council and VDOT's Asset Management Division and Materials Division should consider developing required structural parameters for each pavement type based on current and future traffic levels*. Once these are established, a condition index can be determined for each test location to determine if the existing structural capacity is sufficient to meet future traffic demands. Similar work was performed by Damnjanovic and Zhang (2006).

6. *VDOT's Asset Management Division should consider conducting similar testing on the primary network.* These data would be extremely valuable as there is no pavement structural capacity data available for the primary network (except in those portions where project level testing has occurred). As VDOT's primary network is more than 4 times larger than its interstate network, such an operation would be difficult to do in a timely manner without either purchasing an additional FWD or contracting the work to a private consultant. In addition, rather than attempting to test the entire primary network at once, a systematic approach should be taken that tests the entire network over a 4- or 5-year timeframe.

COST AND BENEFITS ASSESSMENT

The benefits of using FWD to conduct a network-level structural survey are estimated to be very great to VDOT's Asset Management Division for use in developing pavement maintenance funding requests as part of the performance-based budget process. Previously, VDOT did not have access to this information and thus many pavement rehabilitation decisions were based on the results of surface distress surveys. Unfortunately, it is not always possible to determine the vertical extent of deterioration from surface observation. Incorporating structural information from the FWD can provide this missing evidence to determine if the proper repair should be made to the surface layers or deeper within the structure. As this information was not available previously, it is not yet possible to assign a dollar value benefit. However, it is certain that unnecessary spending can be avoided if the pavement rehabilitation treatments are applied according to both their functional and structural need.

In a previous study, Zaghloul and Kerr (1999) offered a means of estimating the possible benefits of this current work. They compared pavement rehabilitation designs based on visually observable distresses versus pavement rehabilitation designs based on structural capacity using FWD for sections of interstate pavement in New Jersey. They estimated that only 27% of the designs based on visual distress ratings agreed with those based on structural data; 41% of the rehabilitation treatments were underdesigned, and 32% were overdesigned. If this comparison holds true for other locations, a significant amount of money could be misspent by not performing sufficient maintenance, and thereby likely risking premature deterioration in the future, or by performing maintenance than is more than actually required.

ACKNOWLEDGMENTS

The author acknowledges the assistance of Tanveer Chowdhury and Raja Shekharan of VDOT's Asset Management Division; Affan Habib, Trenton Clark, Bipad Saha, William Duke, and David Thacker of VDOT's Materials Division; Michael Wells of VDOT's Richmond District; Thomas Tate of VDOT's Hampton Roads District; Khaled Galal, formerly of the Virginia Transportation Research Council (VTRC); and Javed Alam, graduate student at the University of Virginia. The author also thanks Bipad Saha and William Duke for assisting with the data processing and David Thacker for collecting the majority of the data for this study. Thanks also go to Jim Gillespie, VTRC, for his assistance with the cost and benefits analysis. The author acknowledges Randy Combs, Ed Deasy, and Linda Evans of VTRC for their assistance with the graphics and editorial process.

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APPENDIX A

HOMOGENEOUS PAVEMENT SECTIONS

The tables in this appendix document the thickness of the upper two layers used in the FWD data analysis.   In certain instances, the pavement structure was estimated; these locations are noted in bold and shaded.

Table A.1. Homogeneous Pavement Sections: I-64 Eastbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
3	0.00	7.00	BIT	9.5	15.0
3	7.10	18.73	BIT	8.0	12.0
3	18.80	35.99	BIT	10.2	16.0
3	36.00	38.40	BIT	7.0	16.0
3	38.60	41.00	BIT	9.0	12.0
81	0.00	3.80	BIT	13.0	17.0
81	3.90	9.60	BIT	13.5	18.0
81	9.70	15.80	BIT	9.5	20.0
7	16.75	25.60	BIT	9.0	15.0
7	25.70	28.73	BIT	10.2	15.0
2	7.04	7.44	BIT	11.5	14.0
2	7.54	16.94	BOC	4.5	8.0
2	17.04	18.94	BOC	5.8	8.0
2	19.14	31.14	BOC	4.5	8.0
54	0.04	4.84	BOC	6.0	8.0
54	5.00	5.40	BOC	6.0	8.0
54	5.60	16.55	BIT	**10.5**	**15.0**
37	0.00	27.98	BIT	**10.5**	**15.0**
43	0.00	3.00	BIT	**10.5**	**15.0**
43	3.20	11.66	CRC	**8.0**	**6.0**
43	15.80	20.00	BOJ	4.0	8.0
43	20.20	28.89	JRC	**8.0**	**6.0**
63	0.00	1.20	JRC	**8.0**	**6.0**
63	1.40	10.20	BOJ	4.0	8.0
63	10.40	20.08	BOJ	5.5	8.0
47	0.00	6.40	BOJ	4.5	8.0
47	6.60	8.66	BIT	12.3	14.0
99	0.00	5.00	BIT	12.3	14.0
99	5.20	9.40	JRC	**8.0**	**6.0**
99	12.40	29.20	JRC	8.0	6.0
99	29.40	31.80	BOJ	5.5	8.0
99	32.00	32.80	BOJ	4.5	8.0
99	33.20	33.40	BOJ	4.5	8.0
99	34.60	35.20	BOJ	6.0	9.0
64	39.00	44.00	CRC	**9.0**	**6.0**
64	44.20	44.80	BIT	**24.0**	**6.0**
64	45.00	49.60	JRC	**9.0**	**6.0**
64	49.80	50.40	BOJ	6.0	9.0
64	50.80	51.60	JRC	**9.0**	**6.0**
64	51.80	52.20	BIT	13.5	6.0
64	52.60	55.20	JRC	**9.0**	**6.0**
64	55.40	57.40	JPC	11.0	6.0
64	57.80	59.80	JRC	**9.0**	**6.0**
64	60.00	67.02	CRC	8.0	6.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; BOC: a composite with flexible pavement over continuously reinforced concrete pavement; JPC: jointed plain concrete pavement; JRC: jointed reinforced concrete pavement; CRC: continuously reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.2. Homogeneous Pavement Sections: I-64 Westbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
3	0.00	17.13	BIT	9.0	13.0
3	17.20	20.20	BIT	**8.5**	**16.0**
3	20.40	23.86	BIT	9.0	16.0
3	23.90	36.00	BIT	10.5	16.0
3	36.10	41.00	BIT	8.5	12.0
81	0.00	5.97	BIT	13.0	18.0
81	6.10	9.67	BIT	15.0	18.0
81	9.70	15.80	BIT	10.0	20.0
7	16.22	28.82	BIT	10.0	15.0
2	7.09	7.39	BIT	10.0	15.0
2	7.49	29.99	BOC	6.0	8.0
2	30.09	31.19	CRC	8.0	10.0
54	0.08	4.88	CRC	8.0	10.0
37	0.00	27.84	BIT	**10.0**	**15.0**
43	-0.01	2.60	BIT	**10.0**	**15.0**
43	2.80	11.20	JPC	**8.0**	**6.0**
43	15.80	20.00	BOJ	3.5	8.0
43	20.20	26.40	JPC	**8.0**	**6.0**
63	1.80	4.60	BOJ	2.0	8.0
63	4.80	7.80	BOJ	8.5	8.0
63	8.00	11.00	BOJ	12.0	8.0
63	11.20	20.17	BOJ	5.5	8.0
47	0.00	6.40	BOJ	5.5	8.0
47	6.60	8.68	BIT	12.0	14.0
99	0.00	3.40	BIT	11.0	14.0
99	4.20	11.20	JPC	**9.0**	**6.0**
99	11.40	29.00	JPC	8.0	6.0
99	29.20	30.80	BOJ	5.5	8.0
99	31.00	33.60	BOJ	3.0	8.0
99	34.40	35.20	BOJ	5.0	9.0
64	40.60	43.00	JPC	8.0	6.0
64	43.20	44.60	JPC	8.0	6.0
64	44.80	49.60	JPC	**8.0**	**6.0**
64	49.80	50.50	BOJ	**8.0**	**6.0**
64	50.80	51.17	JPC	**8.0**	**6.0**
64	51.40	52.20	BIT	4.5	8.0
64	52.80	53.00	JPC	9.0	6.0
64	53.20	53.80	JPC	13.5	6.0
64	54.00	56.80	JPC	**9.0**	**6.0**
64	57.00	57.80	JPC	11.0	6.0
64	58.02	59.40	JPC	11.0	6.0
64	59.60	67.01	JPC	9.0	6.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; BOC: a composite with flexible pavement over continuously reinforced concrete pavement; JPC: jointed plain concrete pavement; JRC: jointed reinforced concrete pavement; CRC: continuously reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.3. Homogeneous Pavement Sections: I-66 Eastbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
93	1.00	6.78	BIT	9.0	18.0
93	7.00	10.60	BIT	7.2	13.5
93	10.80	11.80	BIT	12.3	18.0
30	0.00	6.20	BIT	10.7	18.0
30	6.40	14.00	BIT	**10.5**	**14.0**
30	14.20	21.92	BIT	10.5	18.0
76	0.00	6.60	BIT	10.8	12.0
76	6.80	12.35	BIT	**10.8**	**12.0**
29	0.00	3.60	BIT	10.0	12.0
29	3.80	9.80	JPC	14.0	12.0
29	10.00	15.60	JRC	15.0	12.0
29	15.80	18.94	BIT	9.5	12.0
0	0.00	2.00	BIT	9.5	12.0
0	2.20	6.40	BIT	9.5	12.0

BIT: flexible pavement (bituminous); JPC: jointed plain concrete pavement; JRC: jointed reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.4. Homogeneous Pavement Sections: I-66 Westbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
93	0.76	10.40	BIT	9.7	18.0
93	10.60	14.83	BIT	12.0	18.0
30	0.20	5.60	BIT	11.3	20.0
30	5.80	13.80	BIT	**10.0**	**14.0**
30	14.00	21.97	BIT	10.7	12.0
76	0.02	2.20	BIT	9.2	13.0
76	2.40	12.54	BIT	**10.0**	**14.0**
29	0.00	3.60	BIT	10.6	8.0
29	3.80	9.00	JPC	14.5	8.0
29	9.20	15.60	JRC	14.5	8.0
29	15.81	18.97	BIT	9.5	12.0
0	0.00	6.25	BIT	9.5	12.0

BIT: flexible pavement (bituminous); JPC: jointed plain concrete pavement; JRC: jointed reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.5. Homogeneous Pavement Sections: I-77 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
17	0.00	6.90	BIT	12.0	14.0
17	7.00	11.50	BIT	**13.0**	**14.0**
17	11.60	22.07	BIT	12.0	14.0
17	22.10	22.63	BIT	15.0	6.0
17	22.70	24.29	BIT	12.0	14.0
98	0.00	8.50	BIT	11.5	14.0
98	17.00	22.37	BIT	**12.0**	**14.0**
10	0.00	1.20	BIT	**12.0**	**14.0**
10	1.30	2.10	BOJ (tunnel)	2.5	10.0
10	2.20	20.50	BIT	**15.0**	**12.0**
10	20.59	21.69	BOJ (tunnel)	3.0	10.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement.
Bold and shaded values indicate the pavement structure was estimated.

Table A.6. Homogeneous Pavement Sections: I-77 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
17	0.01	2.52	BIT	11.5	13.5
17	2.60	6.80	BIT	**11.0**	**14.0**
17	6.89	8.91	BIT	10.5	14.5
17	9.00	24.29	BIT	12.5	14.0
98	0.10	7.20	BIT	12.5	14.0
98	16.40	22.02	BIT	**12.5**	**14.0**
10	0.01	1.20	BIT	**12.5**	**14.0**
10	1.30	2.10	BOJ (tunnel)	2.5	10.0
10	2.80	20.61	BIT	**12.5**	**14.0**
10	20.70	21.69	BOJ (tunnel)	3.0	8.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement.
Bold and shaded values indicate the pavement structure was estimated.

Table A.7. Homogeneous Pavement Sections: I-81 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
95	0.10	34.30	BIT	**11.0**	**20.0**
86	0.00	23.38	BIT	**11.0**	**20.0**
98	0.00	17.40	BIT	**11.0**	**20.0**
98	17.60	21.40	BIT	10.0	20.0
98	21.60	23.80	BIT	10.0	20.0
98	24.60	26.20	BIT	10.0	20.0
98	26.40	29.77	BIT	**11.5**	**20.0**
77	0.00	6.20	BIT	12.5	14.0
77	6.40	15.40	BIT	12.5	14.0
77	15.60	17.53	BIT	13.0	15.0
60	0.00	2.40	BIT	13.5	15.0
60	2.60	9.40	BIT	11.5	15.0
60	9.60	13.60	BIT	13.5	15.0
60	13.80	20.20	BIT	11.5	15.0
60	20.40	25.60	BIT	12.0	15.0
80	0.00	5.00	BIT	11.5	15.0
80	5.20	7.20	BIT	14.0	15.0
80	7.40	10.40	BIT	12.0	15.0
80	10.60	14.00	BIT	13.5	14.0
80	14.20	16.80	BIT	12.0	20.0
11	0.00	14.40	BOJ	3.5	9.0
11	14.60	16.20	BIT	13.5	15.0
11	16.40	17.00	BIT	**13.5**	**15.0**
11	17.20	19.40	BIT	13.5	15.0
11	19.60	24.40	BIT	10.0	15.0
11	24.60	26.80	BIT	13.0	15.0
81	0.00	21.25	BIT	10.0	16.0
81	21.40	31.70	BIT	9.0	15.0
7	0.00	3.40	BIT	12.0	14.0
7	3.60	12.20	BIT	11.0	14.0
7	12.40	31.49	BIT	12.0	15.0
82	0.00	10.40	BIT	10.5	18.0
82	10.80	14.11	BIT	11.5	18.0
82	14.29	27.09	BIT	11.5	18.0
85	0.09	2.09	BIT	12.5	16.5
85	2.19	18.39	BIT	11.5	18.0
85	19.21	31.00	BIT	11.5	18.0
85	31.20	34.68	BIT	12.5	18.0
34	0.00	25.60	BIT	11.0	18.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement.
Bold and shaded values indicate the pavement structure was estimated.

Table A.8. Homogeneous Pavement Sections: I-81 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
95	0.35	3.80	BIT	**11.5**	**14.0**
95	4.00	5.20	BIT	**11.5**	**14.0**
95	5.40	34.67	BIT	**11.0**	**20.0**
86	0.00	23.23	BIT	**11.0**	**20.0**
98	-0.01	15.20	BIT	**11.0**	**20.0**
98	16.80	18.00	BIT	**9.5**	**20.0**
98	18.20	21.40	BIT	11.0	20.0
98	21.60	26.40	BIT	**10.5**	**20.0**
98	26.60	29.85	BIT	**11.5**	**20.0**
77	0.00	6.40	BIT	12.0	15.0
77	6.60	7.20	BIT	9.0	15.0
77	7.40	13.80	BIT	12.5	15.0
77	14.00	17.80	BIT	11.0	15.0
60	0.29	2.40	BIT	14.0	15.0
60	2.60	12.80	BIT	13.0	15.0
60	13.00	14.60	BIT	14.0	15.0
60	14.80	21.80	BIT	11.5	15.0
60	22.00	25.49	BIT	14.0	15.0
80	0.00	6.60	BIT	11.0	15.0
80	7.00	13.60	BIT	13.5	15.0
80	13.80	16.82	BIT	11.5	20.0
11	0.03	14.40	BOJ	3.5	9.0
11	14.60	16.20	BIT	12.5	15.0
11	16.40	23.00	BIT	10.0	15.0
11	23.20	26.74	BIT	13.0	15.0
81	0.00	4.00	BIT	12.0	15.0
81	4.20	6.60	BIT	14.0	15.0
81	6.80	16.00	BIT	10.0	15.0
81	16.20	21.17	BIT	9.5	18.0
81	21.40	30.40	BIT	10.5	15.0
81	30.60	31.73	BIT	12.0	15.0
7	0.00	1.80	BIT	10.0	14.0
7	2.00	8.60	BIT	13.0	14.0
7	8.80	12.20	BIT	**8.0**	**14.0**
7	12.40	31.47	BIT	12.0	15.0
82	0.01	8.40	BIT	12.5	18.0
82	8.60	14.19	BIT	10.5	18.0
82	14.30	27.00	BIT	11.0	18.0
85	0.02	18.12	BIT	11.5	18.0
85	19.10	25.00	BIT	12.2	18.0
85	25.20	34.68	BIT	10.5	18.0
34	0.00	11.20	BIT	12.0	18.0
34	11.40	25.48	BIT	11.5	18.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement.
Bold and shaded values indicate the pavement structure was estimated.

Table A.9. Homogeneous Pavement Sections: I-85 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
58	0.00	19.52	BIT	**10.0**	**12.0**
12	0.00	19.40	BIT	**10.0**	**12.0**
12	19.60	20.75	CRC	**8.0**	**6.0**
26	0.00	5.60	CRC	**8.0**	**6.0**
26	5.80	7.00	BOC	6.0	8.0
26	7.20	21.20	CRC	**8.0**	**6.0**
26	21.45	23.80	JRC	**8.0**	**6.0**
26	24.00	28.72	BIT	**10.0**	**12.0**

BIT: flexible pavement (bituminous); BOC: a composite with flexible pavement over continuously reinforced concrete pavement; JRC: jointed reinforced concrete pavement; CRC: continuously reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.10. Homogeneous Pavement Sections: I-85 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
58	0.01	19.52	BIT	**10.0**	**12.0**
12	6.60	19.40	BIT	**10.0**	**12.0**
12	19.60	20.77	CRC	**8.0**	**6.0**
26	0.08	21.20	CRC	**8.0**	**6.0**
26	21.40	23.80	JRC	**8.0**	**6.0**
26	24.00	27.00	BIT	**10.0**	**12.0**

BIT: flexible pavement (bituminous); JRC: jointed reinforced concrete pavement; CRC: continuously reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.11. Homogeneous Pavement Sections: I-95 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
40	0.00	13.20	BOJ	14.0	9.0
40	13.40	17.14	BOC	6.5	8.0
91	0.00	5.00	BOC	6.5	8.0
91	5.20	17.60	BIT	10.0	14.0
74	0.00	8.60	BIT	15.0	14.0
74	8.80	16.74	BIT	**15.0**	**14.0**
26	0.00	1.47	BIT	10.5	12.0
20	0.00	5.20	BIT	12.5	10.0
20	5.40	6.80	BIT	**13.5**	**10.0**
20	7.00	20.57	BIT	11.5	12.0
43	1.71	2.60	BIT	9.5	12.0
43	2.80	6.00	BIT	9.5	12.0
43	6.40	7.60	BIT	**9.5**	**12.0**
43	7.80	11.40	BOJ	7.0	8.0
43	11.60	11.80	JPC	8.0	8.0
43	12.00	12.77	BIT	10.5	12.0
42	0.00	5.60	BOJ	7.0	8.0
42	5.80	14.68	BIT	19.5	12.0
16	0.00	6.80	BIT	10.0	12.0
16	7.00	15.54	BOJ	4.5	9.0
88	0.00	3.40	BOJ	3.5	9.0
88	3.60	15.57	BOJ	7.0	9.0
89	0.00	1.20	BOJ	4.5	9.0
89	1.40	1.80	BOJ	10.0	9.0
89	2.00	4.40	BOJ	4.0	9.0
89	4.80	6.40	BOJ	3.0	9.0
89	6.60	13.00	BOJ	7.0	9.0
89	13.20	15.58	BOJ	5.5	9.0
76	0.00	7.40	BOJ	3.5	9.0
76	7.80	9.20	BIT	**10.0**	**12.0**
76	9.40	13.00	BOJ	5.0	9.0
29	0.20	6.20	BOJ	5.0	9.0
29	9.80	14.40	BOJ	4.5	9.0
29	14.60	16.58	BIT	17.0	12.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; BOC: a composite with flexible pavement over continuously reinforced concrete pavement; JPC: jointed plain concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.12. Homogeneous Pavement Sections: I-95 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
40	-0.01	7.20	BOJ	15.0	9.0
40	7.40	13.20	BOJ	11.5	9.0
40	13.40	17.14	BOC	6.5	8.0
91	0.00	4.80	BOC	6.5	8.0
91	5.00	17.60	BIT	10.5	14.0
74	0.01	3.40	BIT	15.5	14.0
74	3.60	6.00	BIT	15.5	14.0
74	6.20	16.75	BIT	**15.5**	**14.0**
26	0.00	1.55	BIT	10.5	12.0
20	0.05	1.20	BIT	12.5	12.0
20	1.41	20.69	BIT	10.0	11.0
43	1.20	7.40	BIT	9.5	11.0
43	7.81	11.80	BOJ	7.0	8.0
43	12.20	12.40	BIT	7.0	8.0
43	12.40	12.74	BOJ	7.0	8.0
42	-0.01	5.80	BOJ	7.0	8.0
42	6.00	14.76	BIT	**18.0**	**12.0**
16	1.00	5.80	BIT	10.0	12.0
16	6.00	7.00	BIT	14.5	13.0
16	7.20	15.74	BOJ	4.0	9.0
88	0.00	4.20	BOJ	4.5	9.0
88	4.40	14.20	BOJ	6.5	9.0
88	14.40	15.61	BOJ	3.5	9.0
89	0.00	3.80	BOJ	4.5	9.0
89	4.00	9.80	BOJ	8.0	9.0
89	10.00	12.80	BOJ	10.0	9.0
89	13.00	15.54	BOJ	8.0	9.0
76	0.00	9.00	BOJ	4.5	9.0
76	9.20	9.40	BOJ	7.0	9.0
76	10.00	13.18	BOJ	4.0	9.0
29	0.14	1.90	BOJ	4.0	9.0
29	2.10	6.30	BOJ	7.0	9.0
29	10.00	14.80	BOJ	4.0	9.0
29	15.00	16.54	BIT	**17.0**	**12.0**

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; BOC: a composite with flexible pavement over continuously reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.13. Homogeneous Pavement Sections: I-264 Eastbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
64	0.00	1.00	BIT	12.5	12.5
64	1.20	6.05	BIT	11.0	12.0
64	8.60	11.00	JRC	**9.0**	**6.0**
64	11.40	12.80	BIT	**11.0**	**12.0**
75	13.00	14.78	BOJ	5.0	9.0
75	15.00	25.00	JRC	9.0	6.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; JRC: jointed reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.14. Homogeneous Pavement Sections: I-264 Westbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
64	0.00	1.00	BIT	13.0	12.0
64	1.20	2.20	BIT	11.0	12.0
64	2.40	6.20	BIT	12.5	12.0
64	9.00	11.00	JRC	**9.0**	**6.0**
64	11.60	13.00	BIT	**12.0**	**12.0**
75	13.20	14.20	BOJ	4.0	9.0
75	14.40	14.99	BOJ	6.0	9.0
75	15.20	25.21	JRC	9.0	6.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; JRC: jointed reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.15. Homogeneous Pavement Sections: I-295 Eastbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
43	1.35	4.00	CRC	8.0	8.0
43	4.20	6.60	BOC	3.5	8.0
43	6.80	10.20	CRC	8.0	6.0
43	10.40	12.80	BOC	3.5	8.0
43	13.00	16.20	CRC	8.0	6.0
43	16.40	20.80	BOC	3.5	8.0
42	0.00	1.00	BOC	3.5	8.0
42	1.20	2.00	BOC	1.5	8.0
42	2.20	13.70	CRC	8.0	6.0
20	0.60	9.00	CRC	9.0	8.0
20	9.20	17.20	CRC	8.0	6.0

BOC: a composite with flexible pavement over continuously reinforced concrete pavement; CRC: continuously reinforced concrete pavement.

Table A.16. Homogeneous Pavement Sections: I-295 Westbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
43	1.00	16.40	CRC	8.0	6.0
43	16.60	20.83	BOC	3.5	8.0
42	0.30	3.00	BOC	3.5	8.0
42	3.20	4.00	CRC	8.0	6.0
42	4.20	13.84	CRC	9.0	8.0
20	0.60	3.00	CRC	9.0	8.0
20	3.20	4.60	BOC	3.5	9.0
20	5.20	10.40	CRC	9.0	8.0
20	10.60	17.18	CRC	8.0	6.0

BOC: a composite with flexible pavement over continuously reinforced concrete pavement; CRC: continuously reinforced concrete pavement.

Table A.17. Homogeneous Pavement Sections: I-381 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
95	0.00	1.10	BIT	10.5	10.0

BIT: flexible pavement (bituminous).

Table A.18. Homogeneous Pavement Sections: I-381 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
95	0.03	1.67	BIT	**10.5**	**10.0**

BIT: flexible pavement (bituminous). Bold and shaded values indicate the pavement structure was estimated.

Table A.19. Homogeneous Pavement Sections: I-395 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
29	0.00	5.54	BOJ	4.2	8.0
0	0.00	4.40	BOJ	3.5	8.0

BOJ: a composite with flexible pavement over jointed concrete pavement.

Table A.20. Homogeneous Pavement Sections: I-395 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
29	0.00	5.50	BOJ	4.6	8.0
0	0.00	4.40	BOJ	3.9	8.0

BOJ: a composite with flexible pavement over jointed concrete pavement.

Table A.21. Homogeneous Pavement Sections: I-464 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
64	0.00	0.80	JRC	**8.0**	**6.0**
64	0.98	5.60	BIT	9.5	12.0

BIT: flexible pavement (bituminous); JRC: jointed reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.22. Homogeneous Pavement Sections: I-464 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
64	0.03	0.80	JRC	**8.0**	**6.0**
64	1.00	5.83	BIT	9.5	12.0

BIT: flexible pavement (bituminous); JRC: jointed reinforced concrete pavement. Bold and shaded values indicate the pavement structure was estimated.

Table A.23. Homogeneous Pavement Sections: I-495 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
29	0.00	4.60	BOJ	5.6	9.0
29	4.80	13.60	BOJ	4.0	9.0

BOJ: a composite with flexible pavement over jointed concrete pavement.

Table A.24. Homogeneous Pavement Sections: I-495 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
29	0.00	4.52	BOJ	5.6	9.0
29	4.72	11.52	BOJ	4.0	9.0
29	11.72	14.32	BOJ	5.4	9.0

BOJ: a composite with flexible pavement over jointed concrete pavement.

Table A.25. Homogeneous Pavement Sections: I-564 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
64	0.00	1.20	BOJ	3.0	8.0
64	1.40	2.79	CRC	9.0	6.0

BOJ: a composite with flexible pavement over jointed concrete pavement; CRC: continuously reinforced concrete pavement.

Table A.26. Homogeneous Pavement Sections: I-564 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
64	-0.20	0.40	BOJ	3.5	8.0
64	0.60	2.64	CRC	9.0	6.0

BOJ: a composite with flexible pavement over jointed concrete pavement; CRC: continuously reinforced concrete pavement.

Table A.27. Homogeneous Pavement Sections: I-581 Northbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
80	0.00	6.34	BIT	**11.5**	**15.0**

BIT: flexible pavement (bituminous). Bold and shaded values indicate the pavement structure was estimated.

Table A.28. Homogeneous Pavement Sections: I-581 Southbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
80	0.00	6.28	BIT	**11.5**	**15**

BIT: flexible pavement (bituminous). Bold and shaded values indicate the pavement structure was estimated.

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Table A.29. Homogeneous Pavement Sections: I-664 Eastbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
99	0.57	0.80	BOJ	6.0	9.0
99	1.00	3.80	CRC	9.0	6.0
99	4.10	5.00	BIT	11.0	12.0
61	10.80	14.20	CRC	9.0	6.0
64	14.40	18.00	CRC	9.0	6.0
64	18.20	19.64	BIT	10.0	12.0
64	19.80	20.57	BIT	8.0	12.0

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; CRC: continuously reinforced concrete pavement.

Table A.30. Homogeneous Pavement Sections: I-664 Westbound

Jurisdiction	Begin County Milepost	End County Milepost	Pavement Type	Layer 1 thickness, in	Layer 2 thickness, in
99	0.60	1.00	BOJ	3.5	9.0
99	1.20	4.36	CRC	8.5	6.0
99	4.60	5.30	BIT	10.5	12.0
61	11.01	14.20	CRC	9.0	6.0
64	14.40	18.20	CRC	9.0	6.0
64	18.40	19.00	BIT	10.5	12

BIT: flexible pavement (bituminous); BOJ: a composite with flexible pavement over jointed concrete pavement; CRC: continuously reinforced concrete pavement.

APPENDIX B

ModTag ANALYSIS PROCEDURE

Click on the “New Project” icon.

1. Enter the “New Database” name as the following:
   a. I66EB3 = Interstate 66, Eastbound direction, 3rd county
   b. Click on “Create Database.”
2. Click on the “Import” icon.
   a. Locate the directory with the appropriate f25 file (verify that the correct file is selected).
   b. Give the same project name as used for the database name (e.g., I66EB3).
   c. Click the “Process” button.
   d. Verify the load settings:
      i. Each FWD test should have 6 drops (2 each at 9, 12, and 16,000 lb).
   e. Click the “Process” button.
   f. Click the “Exit” button after viewing the error messages and “OK”ing them.
3. Click on the “Edit” dropdown menu and select “FWD Deflection Data.”
   a. Click on “Export to Excel.”
   b. Save file in Excel using the following as an example for the filename
      i. “I66EB3 defl” = deflection file for Interstate 66, Eastbound direction, 3rd county
   c. Close the FWD Data window in ModTag.
4. Click on the “Edit” dropdown menu again and select “Project Group Info.”
   a. If the f25 file has multiple homogeneous segments, continue; if not, go to step 5b.
      i. Click on “Segment Project.”
      ii. Choose the “start” and “end” locations for each segment and label each segment beginning with the letter “B” and continue for each segment, selecting the “Create Segment” after each one. Be sure that the end of one segment and the start of the next segment have adjacent milepost values and not the same milepost value. When finished, select “Exit.”
      iii. Select “Segment Map” to verify that the desired number of segments have been created.
   b. Enter the pavement layer information for each homogeneous segment. Enter the structure as a generic three-layer system composed of the following:
      i. For “Flexible” pavements:
         1. Choose the “Surface” layer as “Asphalt Concrete.”
         2. Choose the “Base” layer as “Graded Aggregate Base” or “Cement Treated Aggregate” (if CTA is present in the Excel Segmentation File).
         3. The “Sub Grd3” layer is filled in as “Unbound Layer” automatically
      ii. For “Composite” pavements
         1. The “Surf”ace layer and “Base” layer are filled in automatically.
         2. The “Sub Grd3” layer is filled in as “Unbound Layer” automatically.
         3. Enter the slab width as 12.0 feet and the slab length as 6.0 feet for CRC pavements or 15.0 feet for jointed concrete pavements.
      iii. For “Jointed/CRC” pavements:
         1. The “Surface” layer is filled in automatically.
         2. Choose the “Base” layer as “Graded Aggregate Base” or “Cement Treated Aggregate” (if CTA is present in the Excel Segmentation File).
         3. The “Sub Grd3” layer is filled in as “Unbound Layer” automatically.
         4. Enter the slab width as 12.0 feet and the slab length as 6.0 feet for CRC pavements or 15.0 feet for jointed concrete pavements.

c. Enter the "thickness" for the upper two layers (from the Excel Segmentation file) leaving the other information as the default values.
d. Select the "Compute HB Depth" button, and then press the button labeled "Exit." This will enter the thickness of the subgrade layer.
e. Select the "Close" button.

5. Click on the "Analysis" dropdown menu:
    a. For "Flexible" pavements, select "Effective Structural Number." Continue to step 6b for other pavement types.
        i. Select the "Project File" for analysis. If multiple homogeneous segments were created in step 5a, the following will have to be performed for each segment:
            1. Choose drop number "1."
            2. Select the "Yes" radio button for "Temperature Corrected AC."
            3. Select the "No" radio button for each "ESALs to Term Serv," "ESALs to Failure," and "Determine Remaining Life."
            4. Press the "Calculate" button.
            5. Select the "BELLS3 Prediction" radio button.
            6. Enter the Previous Day Average Temperature, found in the Excel Segmentation file.
            7. Choose the "Base/Subbase Type" as either "Granular" or "Cement Treated" if given as "CTA" in the Excel Segmentation file.
            8. Click on the "Calculate" button.
            9. Click on the "OK" button.
            10. Click on the "View Results" button.
            11. Click on the "Export to Excel" button and save the Excel file as the following:
                a. "I66EB3 SN" for structural number for Interstate 66, Eastbound direction, 3rd county
                b. If multiple homogeneous segments exist, save each to a separate worksheet.
    b. For "Composite" or "Jointed/CRC" pavements, select "Basin Area / K Calculation." and choose "composite" or "jointed/CRC."
        i. Select the "Project Name." If multiple homogeneous segments were created in step 5a, the following will have to be performed for each segment:
            1. Select "1" for the Drop Number for Analysis.
            2. Leave the default Poisson's Ratio as "0.15."
            3. Select the "Calculate" button.
            4. Press the "OK" button and then select the "Exit" button.
            5. Click on the "Reports" dropdown menu and then select "Composite Area – PCC k" for composite pavements or "Jointed/CRC Area – PCC k" for jointed/CRC pavements.
            6. Select either "Area graph" or "Epcc / K graph."
                a. Select the Project Name and Drop "1" and then click on the "Data" button.
                b. Click on the "Export to Excel" button and save the Excel file as the following:
                    i. "I66EB3 EPCC" for concrete data for Interstate 66, Eastbound direction, 3rd county
                    ii. If multiple homogeneous segments exist, save each to a separate worksheet.

6. Create an Excel output file of analyzed data for each route (a naming example is “I66 Network FWD Output”) showing the following (most are obtained from the saved Excel output files created in steps 4 and 6, the remainder can be calculated from these data):
   a. District
   b. Jurisdiction
   c. Route Type
   d. Route Number
   e. Direction
   f. Lane #
   g. Pavement Type
   h. Test MP
   i. Section
   j. Segment
   k. Measured Deflection
      i. D1 through D9
   l. Plate Load
   m. Plate Pressure
   n. Plate Radius
      i. Default value is “5.91”
   o. Air Temperature
   p. Surface Temperature
   q. Test Date
   r. Test Time
   s. FWD Device
      i. Default value is “VDOT1”
   t. Previous Day Average Air Temp
   u. Reference Temp
      i. Default value is “68”
   v. Temperature Corrected Deflection (D0)
   w. Resilient Modulus
   x. Design Resilient Modulus
      i. Equal to resilient modulus divided by 3
   y. Pavement Modulus, Ep
   z. Effective Structural Number
   aa. Area
   bb. Static k-value
   cc. Estimated Layer Thickness, Layer 1
   dd. Estimated Layer Thickness, Layer 2

APPENDIX C

RESULTS OF FWD NETWORK TESTING

This appendix presents figures showing the effective structural number and subgrade resilient modulus for all tested flexible pavements and deflection under the load plate and deflection basin area for all tested rigid and composite pavements.

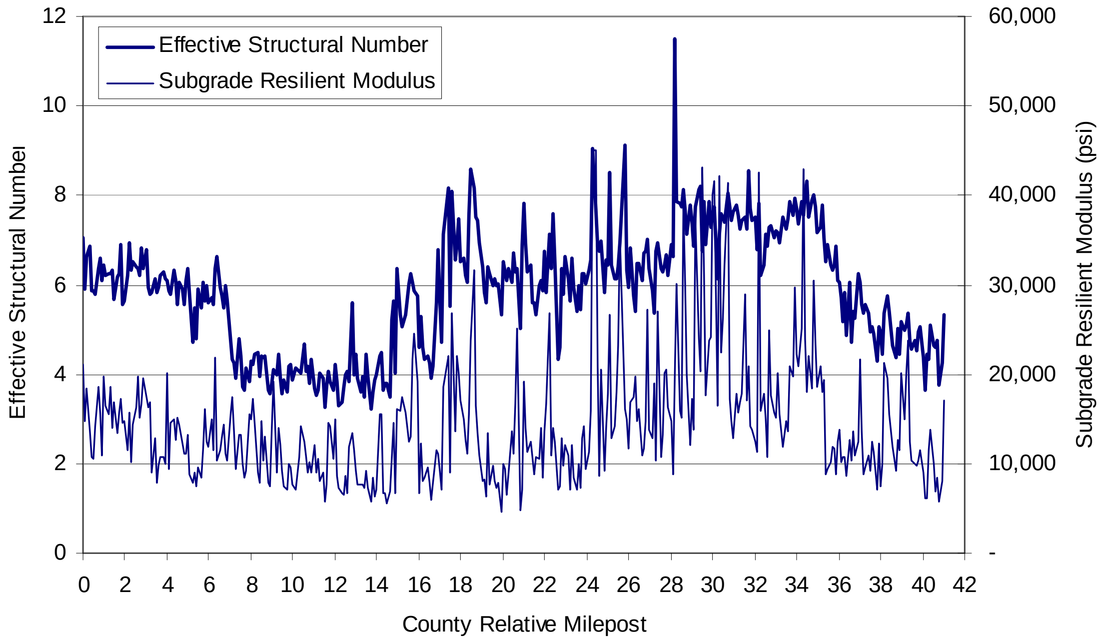

Figure C.1. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, Alleghany County (Maintenance Jurisdiction 003)

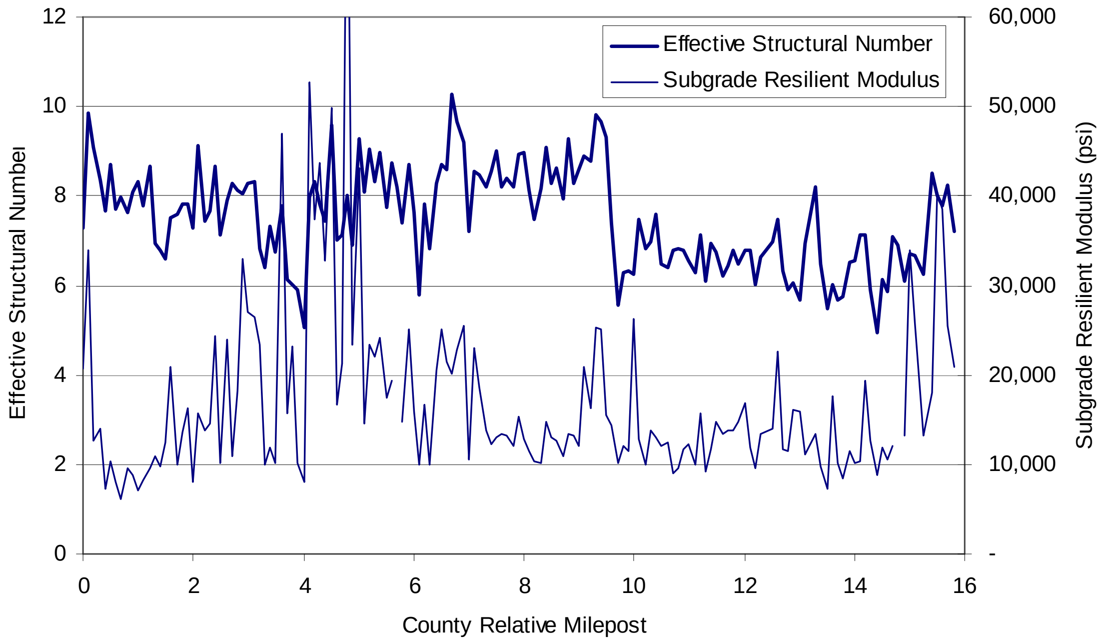

Figure C.2. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, Rockbridge County (Maintenance Jurisdiction 081)

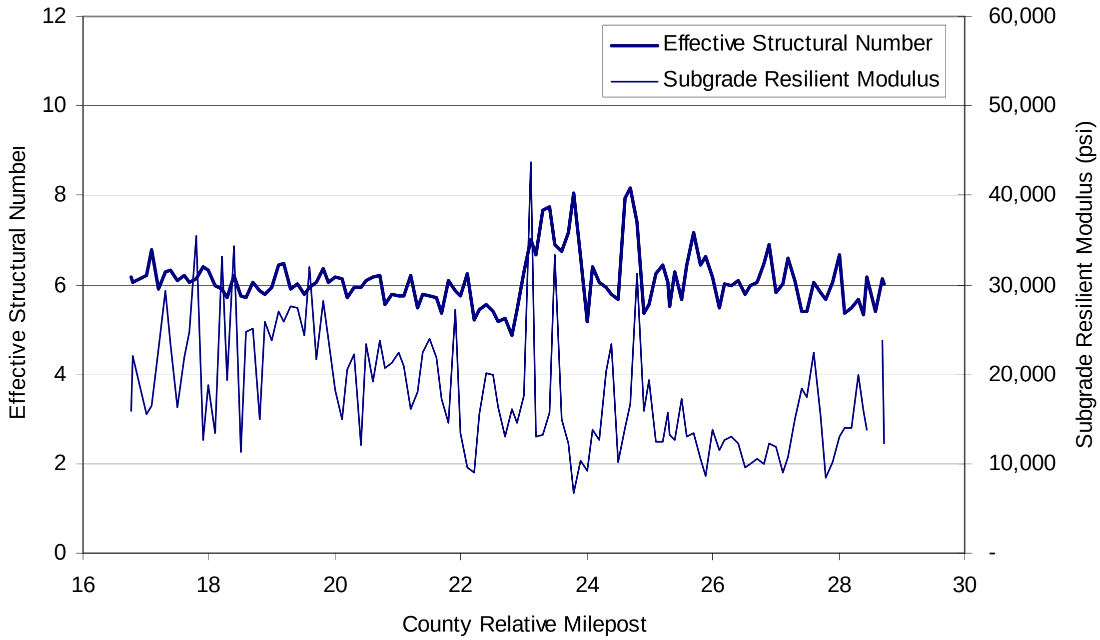

Figure C.3. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, Augusta County (Maintenance Jurisdiction 007)

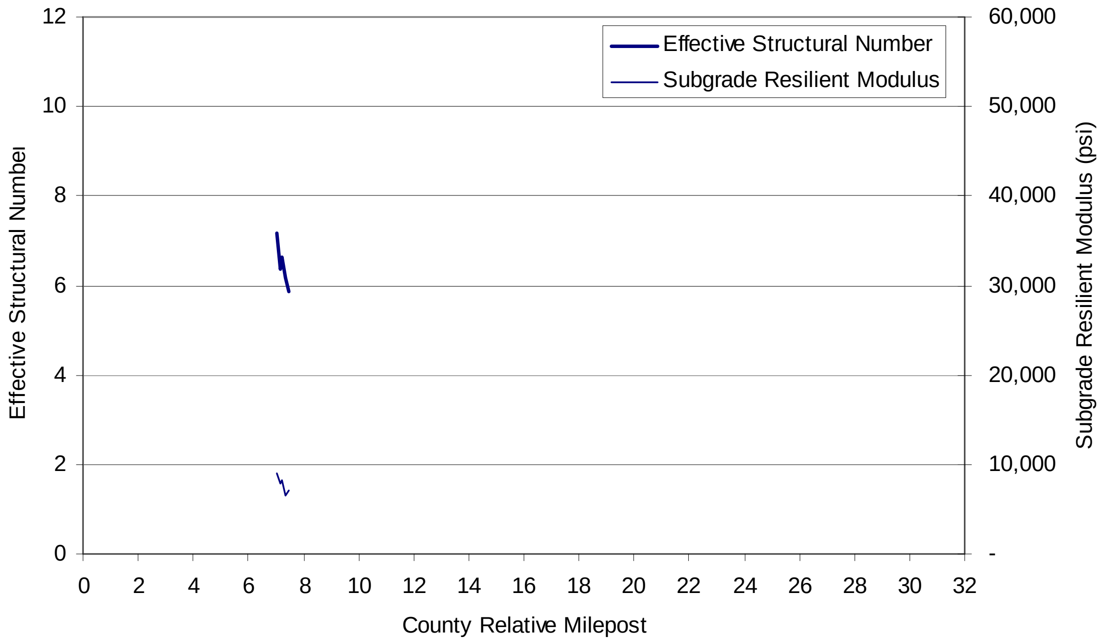

Figure C.4. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, Albemarle County (Maintenance Jurisdiction 002)

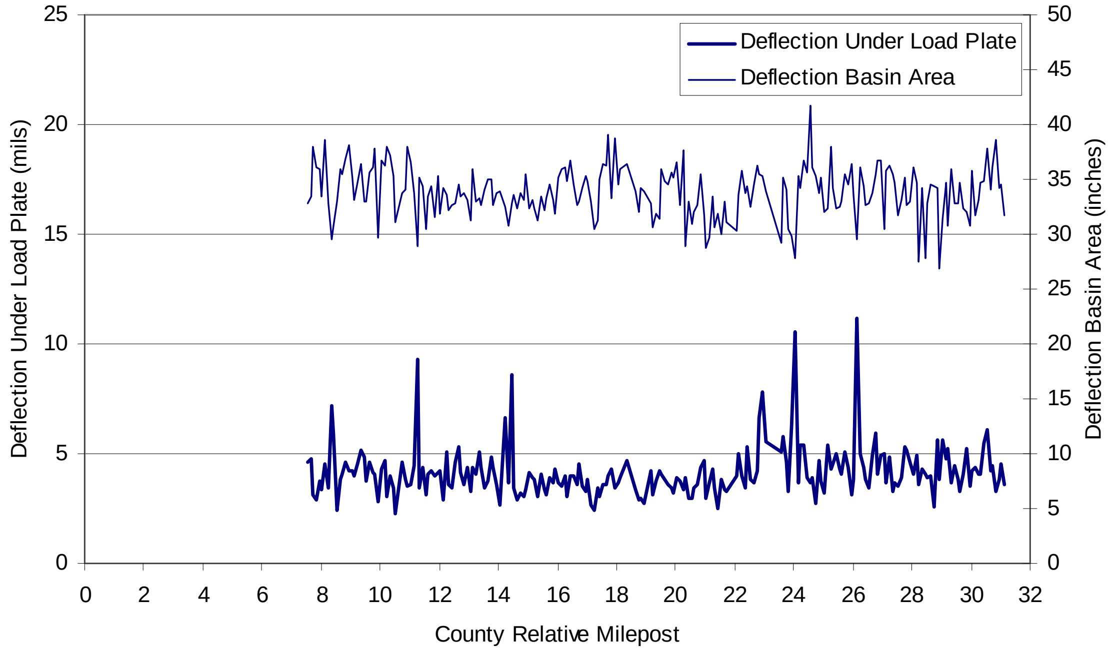

Figure C.5. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-64, Albemarle County (Maintenance Jurisdiction 002)

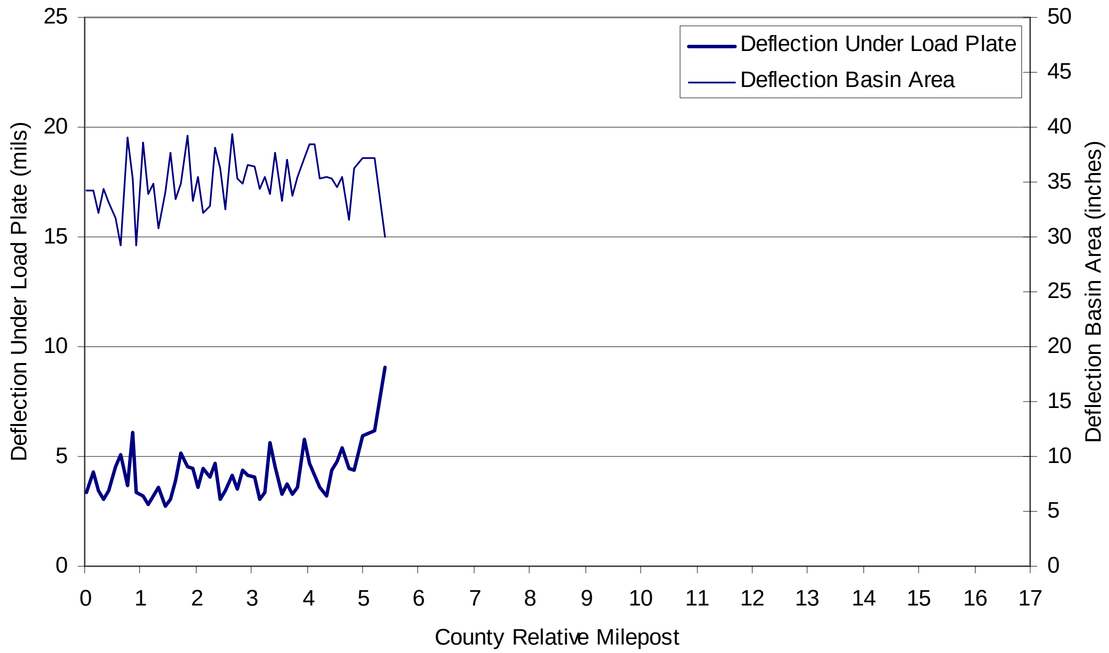

Figure C.6. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-64, Louisa County (Maintenance Jurisdiction 054)

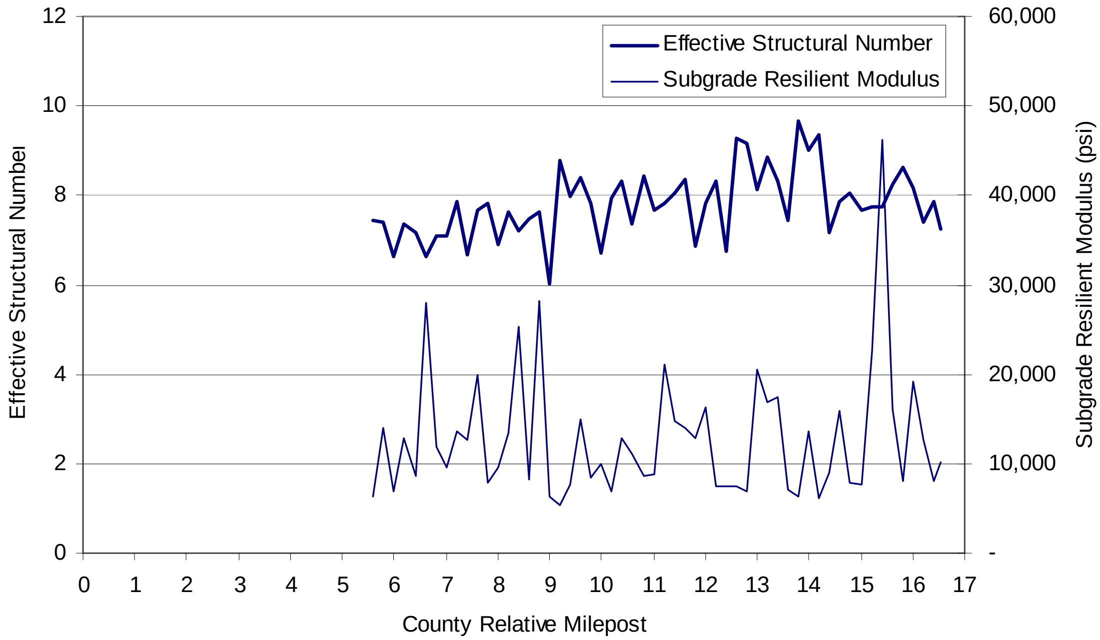

Figure C.7. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, Louisa County (Maintenance Jurisdiction 054)

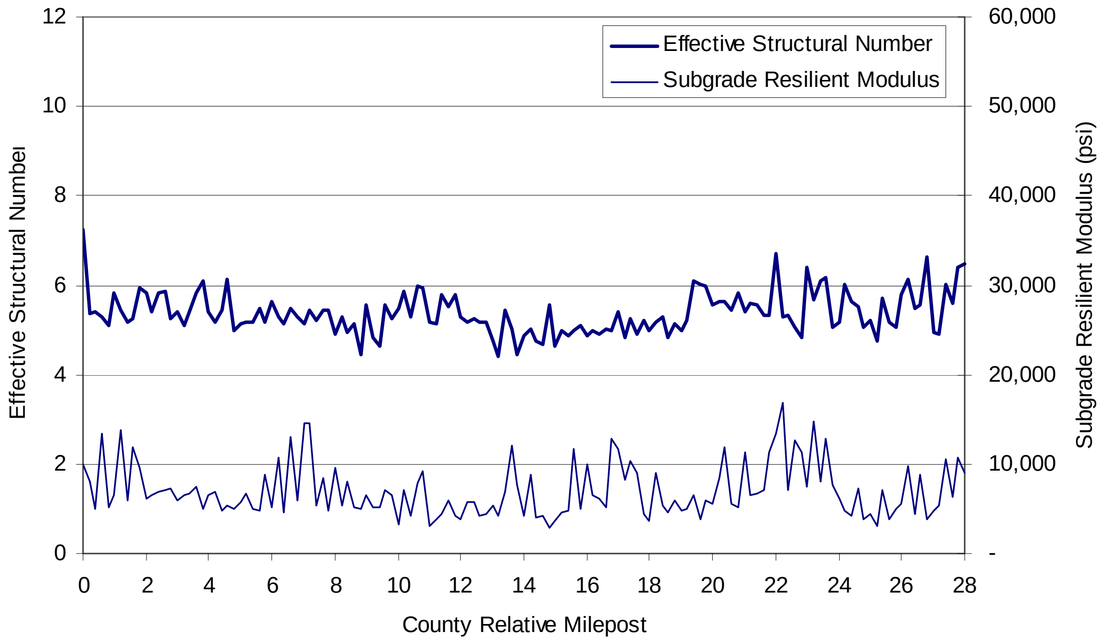

Figure C.8. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, Goochland County (Maintenance Jurisdiction 037)

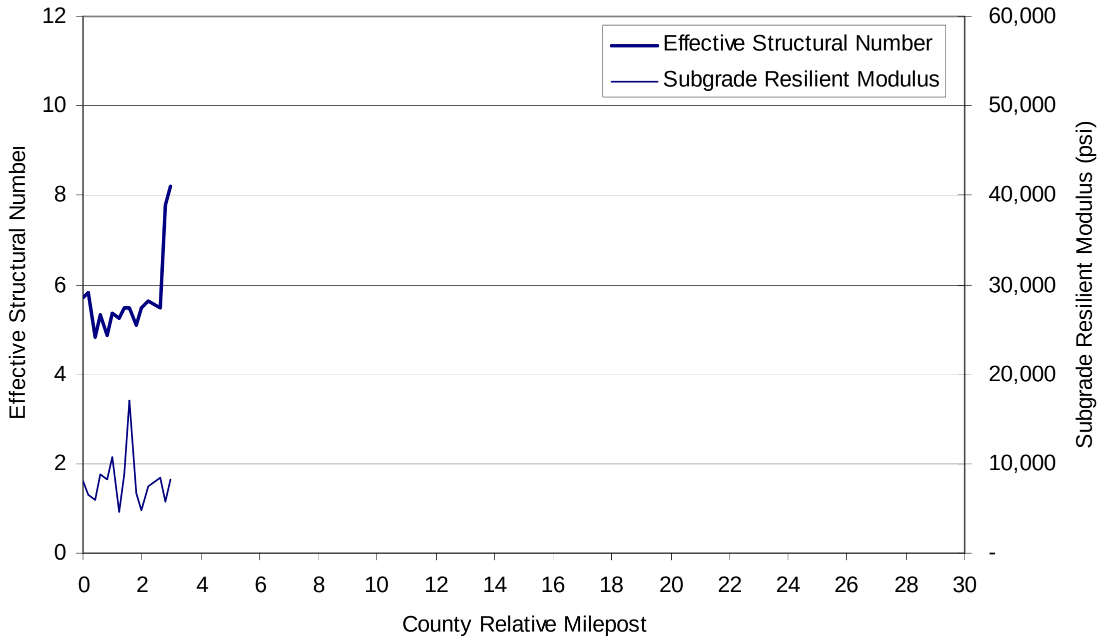

Figure C.9. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, Henrico County (Maintenance Jurisdiction 043)

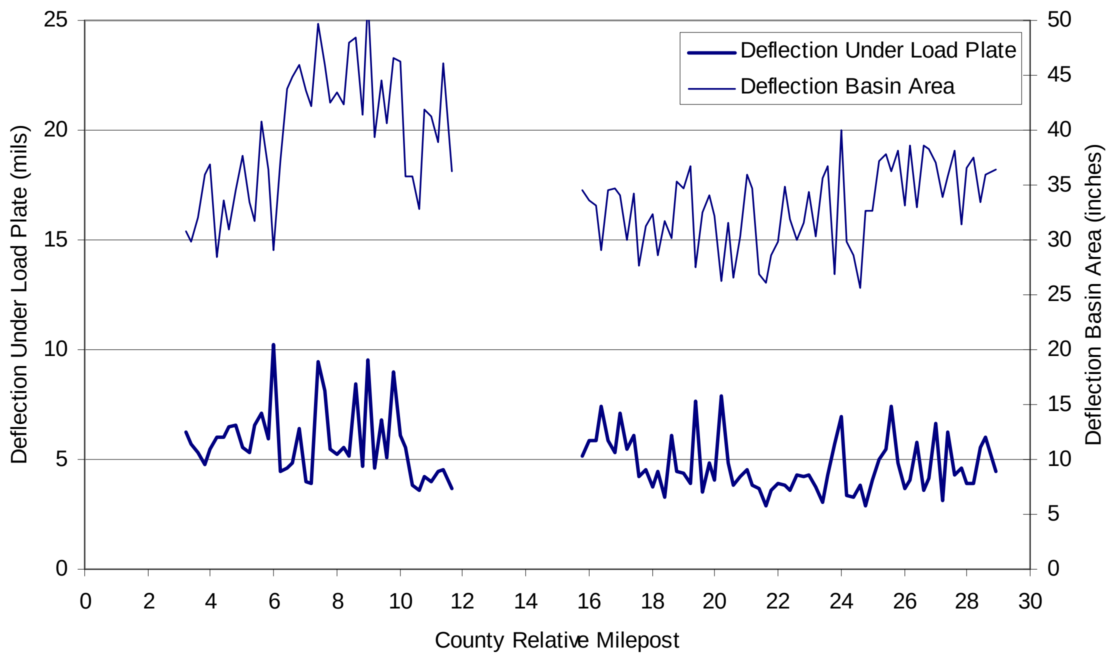

Figure C.10. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-64, Henrico County (Maintenance Jurisdiction 043)

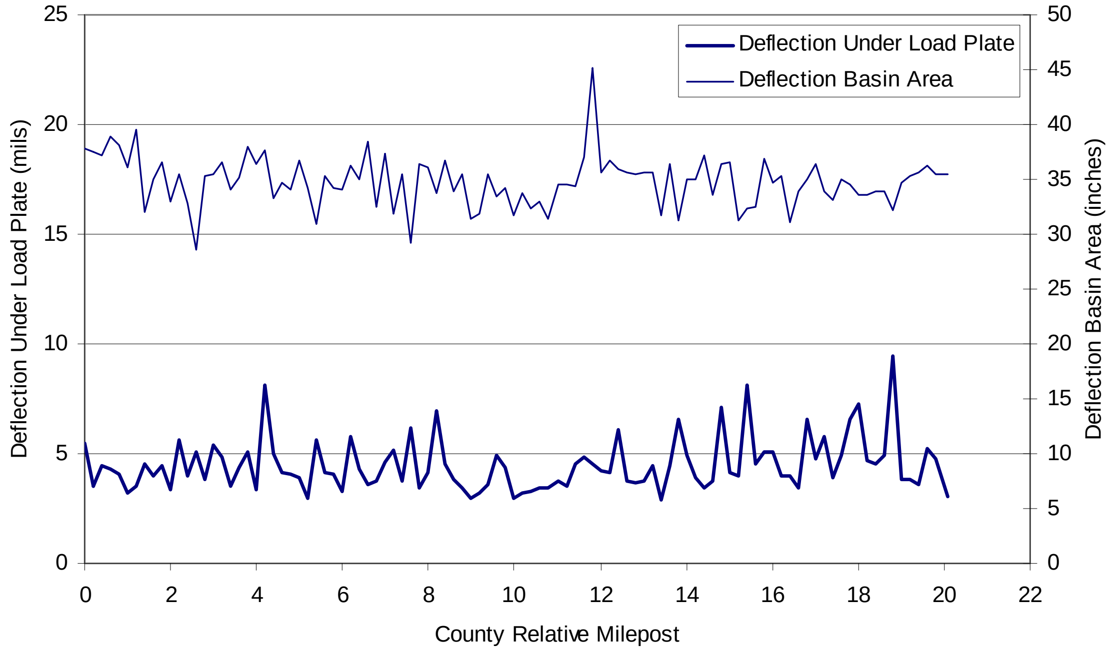

Figure C.11. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-64, New Kent County (Maintenance Jurisdiction 063)

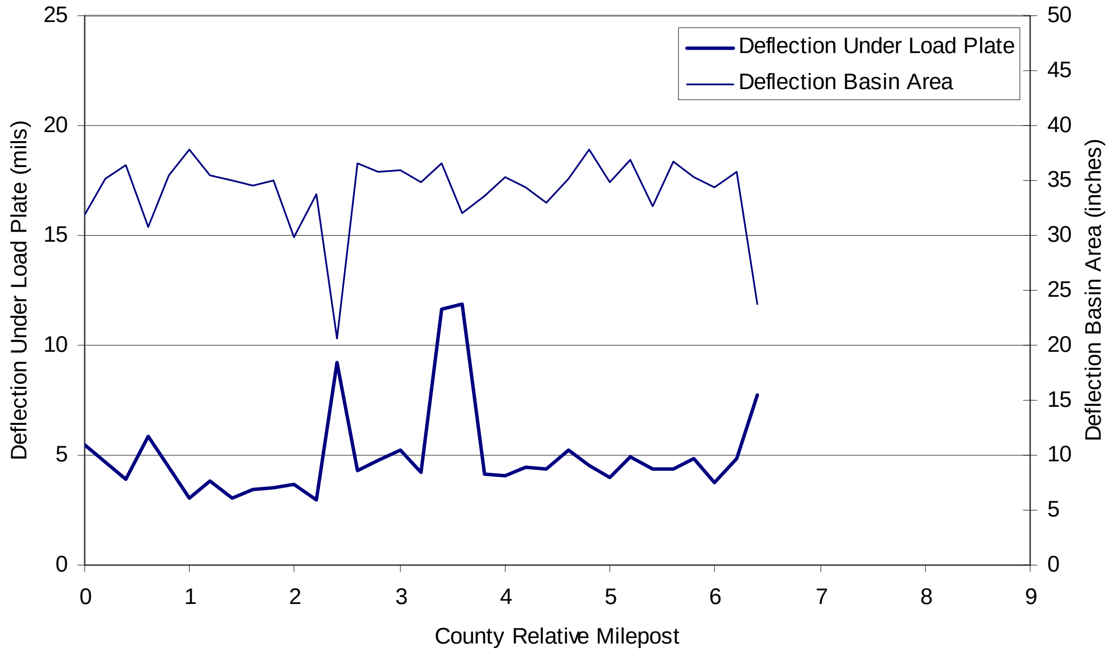

Figure C.12. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-64, James City County (Maintenance Jurisdiction 047)

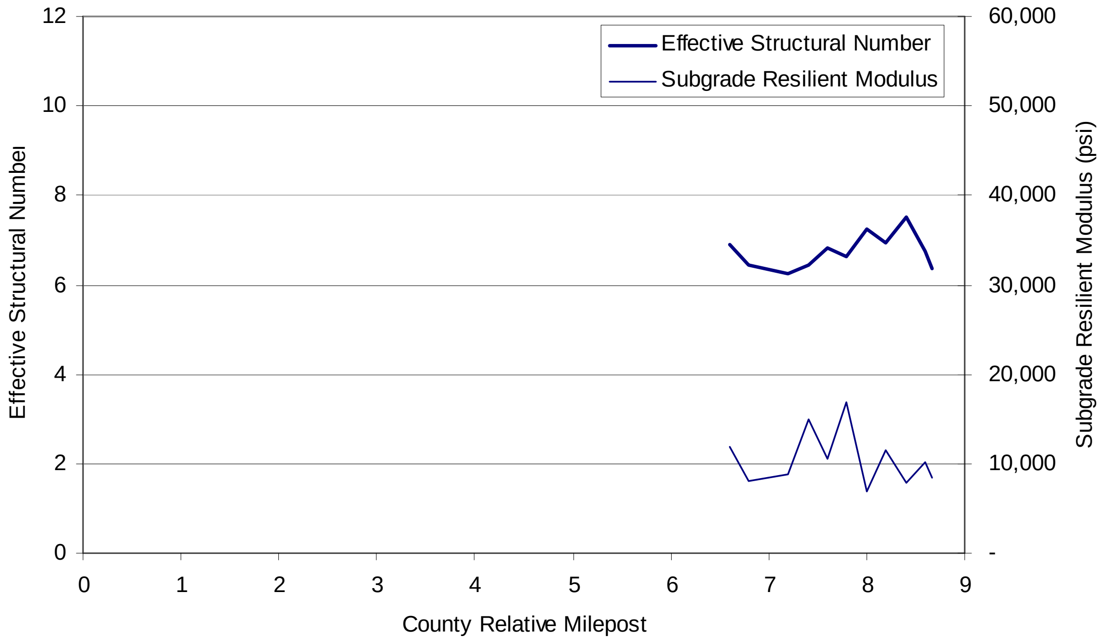

Figure C.13. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, James City County (Maintenance Jurisdiction 047)

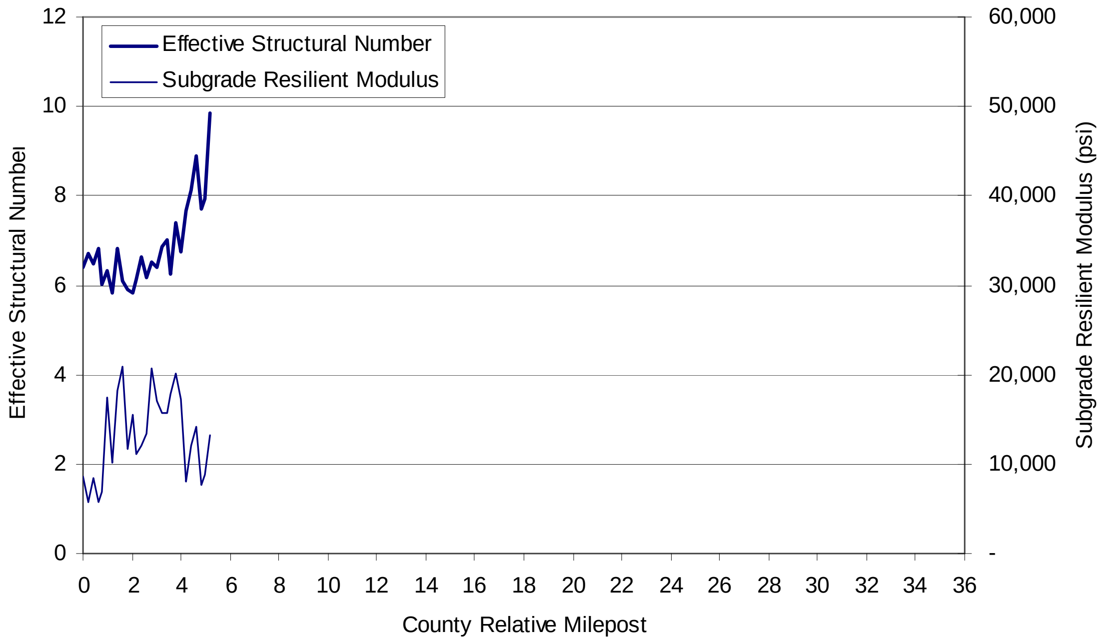

Figure C.14. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, York County (Maintenance Jurisdiction 099)

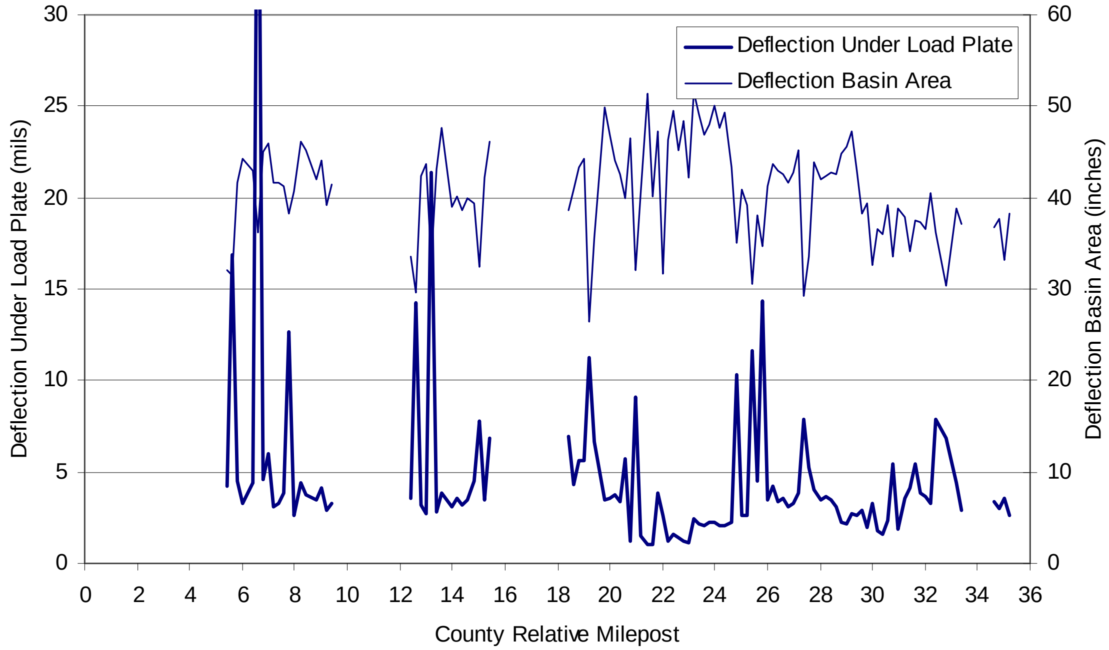

Figure C.15. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-64, York County (Maintenance Jurisdiction 099)

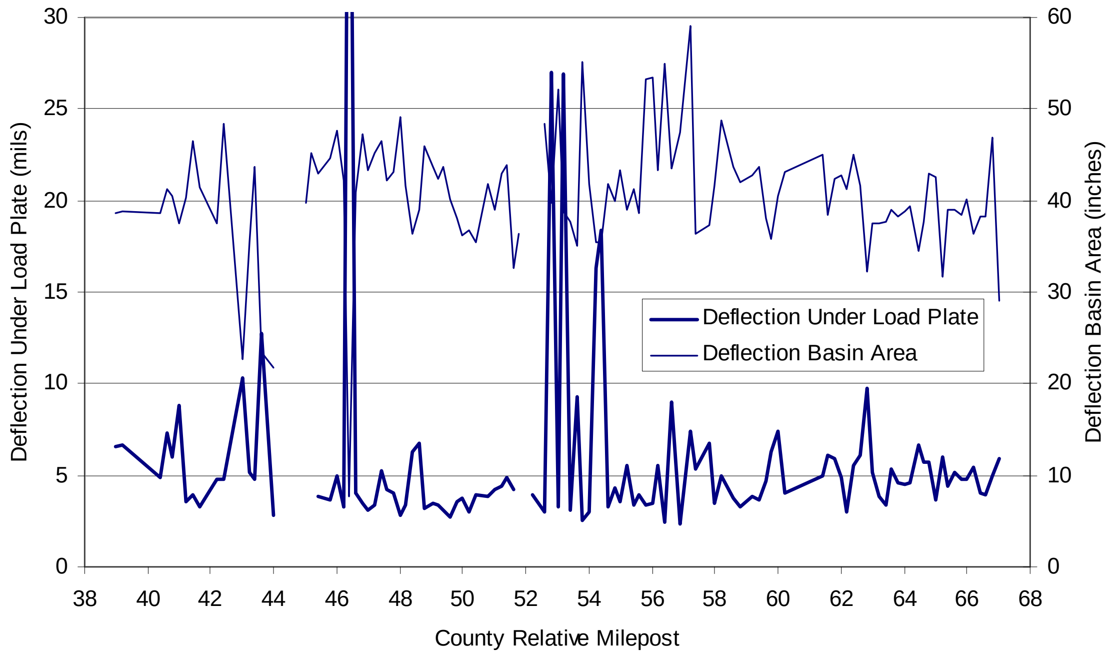

Figure C.16. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-64, City of Portsmouth (Maintenance Jurisdiction 064)

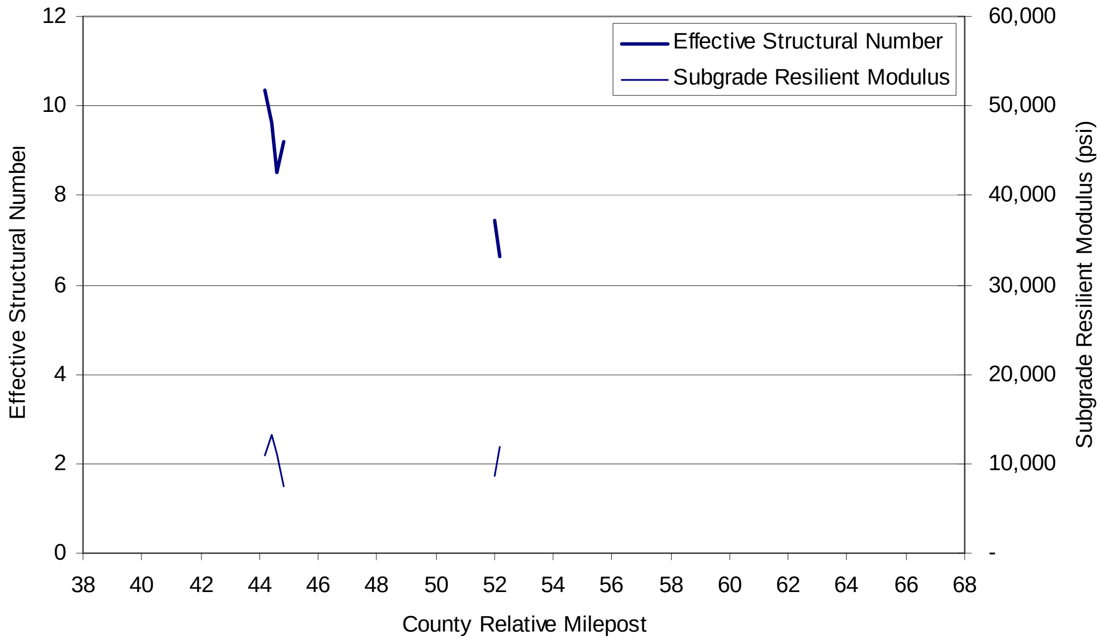

Figure C.17. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-64, City of Portsmouth (Maintenance Jurisdiction 064)

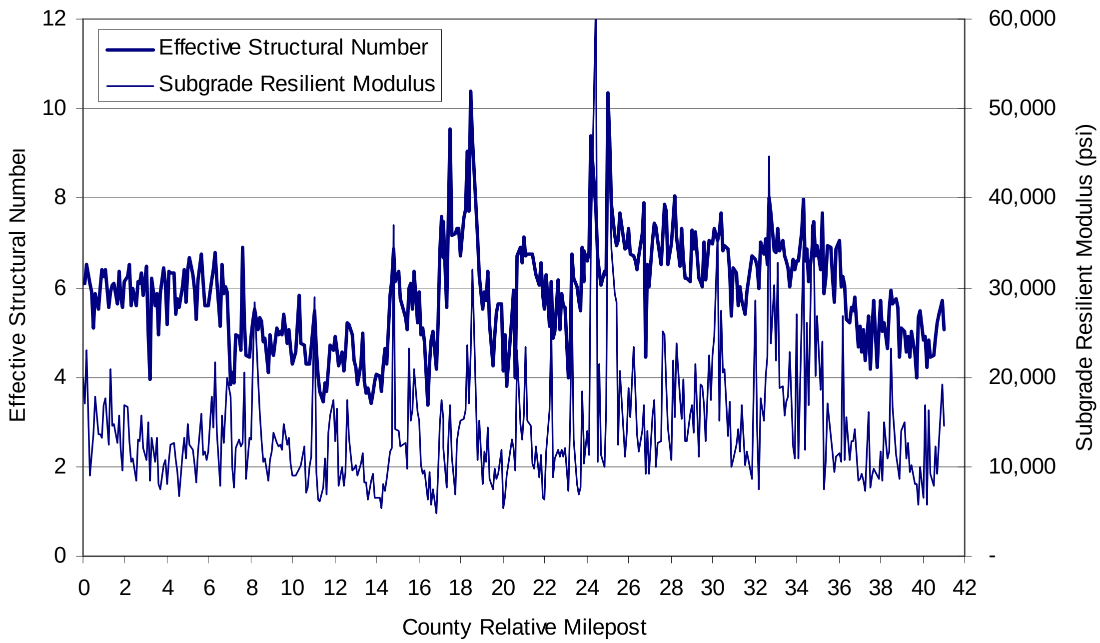

Figure C.18. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, Alleghany County (Maintenance Jurisdiction 003)

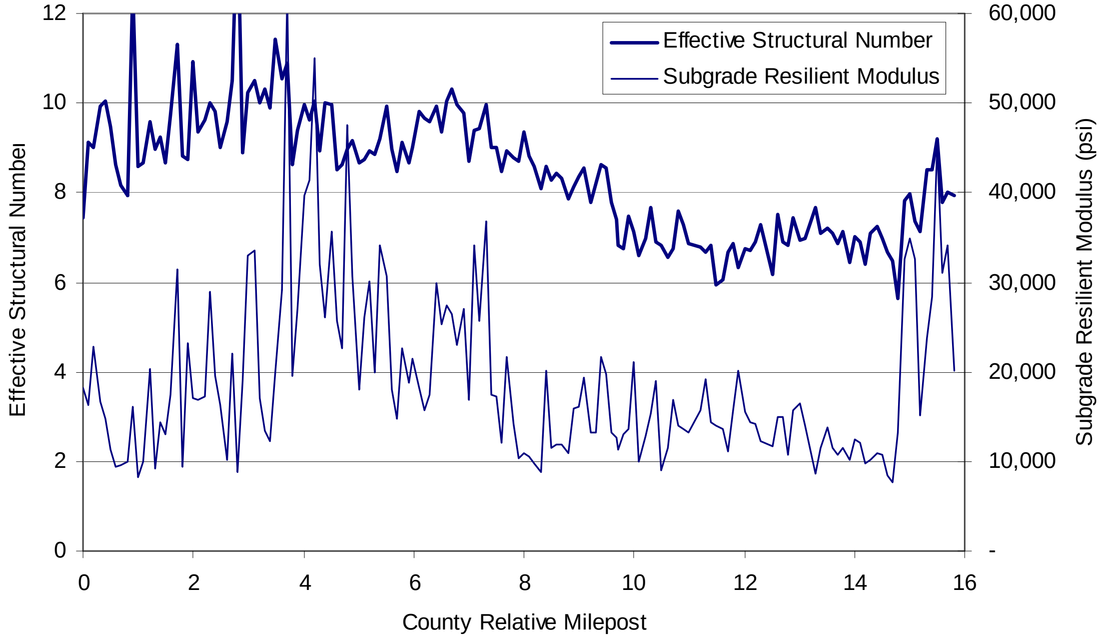

Figure C.19. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, Rockbridge County (Maintenance Jurisdiction 081)

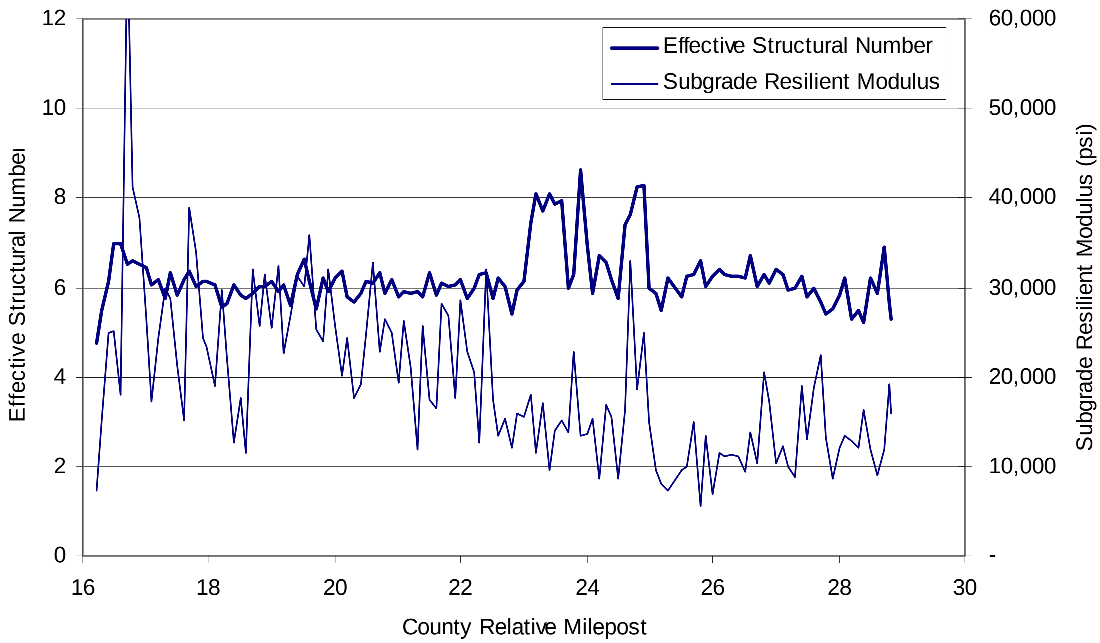

Figure C.20. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, Augusta County (Maintenance Jurisdiction 007)

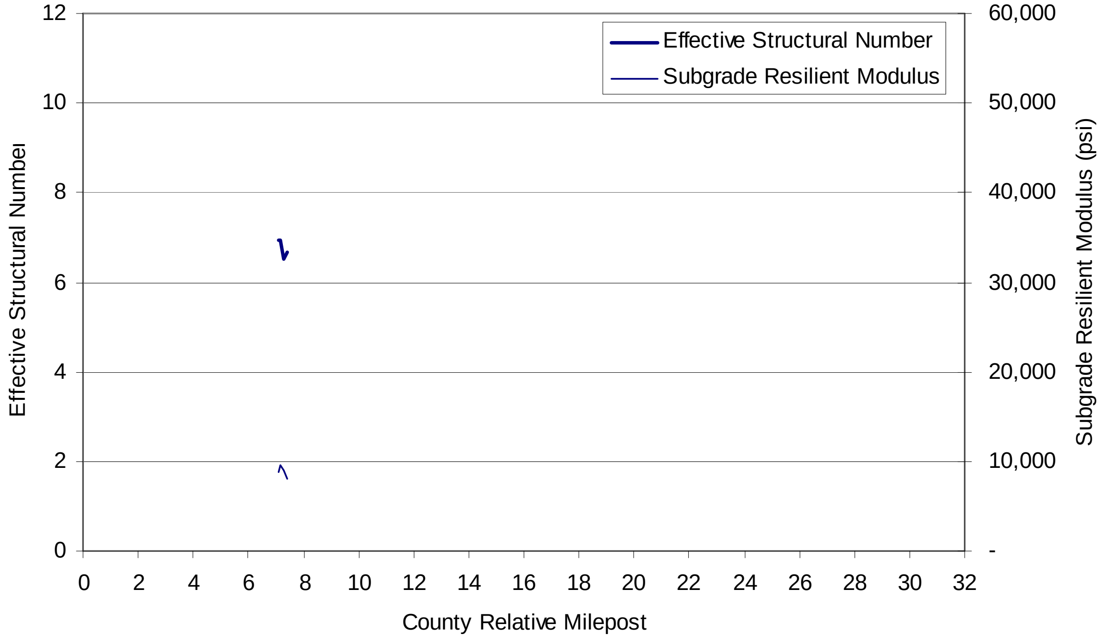

Figure C.21. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, Albemarle County (Maintenance Jurisdiction 002)

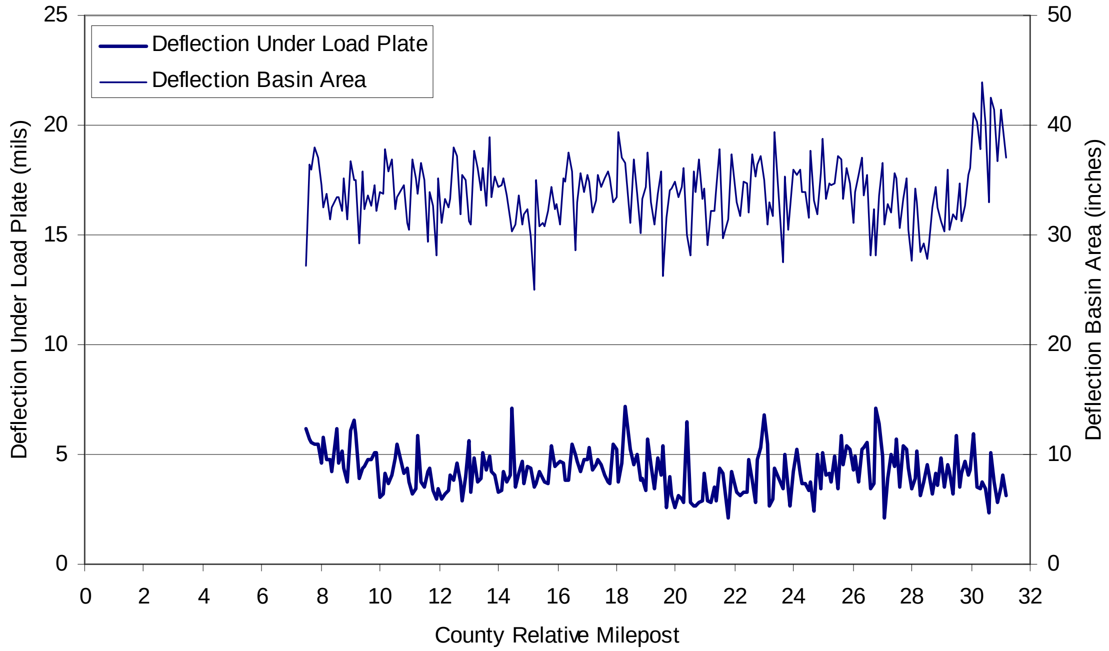

Figure C.22. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-64, Albemarle County (Maintenance Jurisdiction 002)

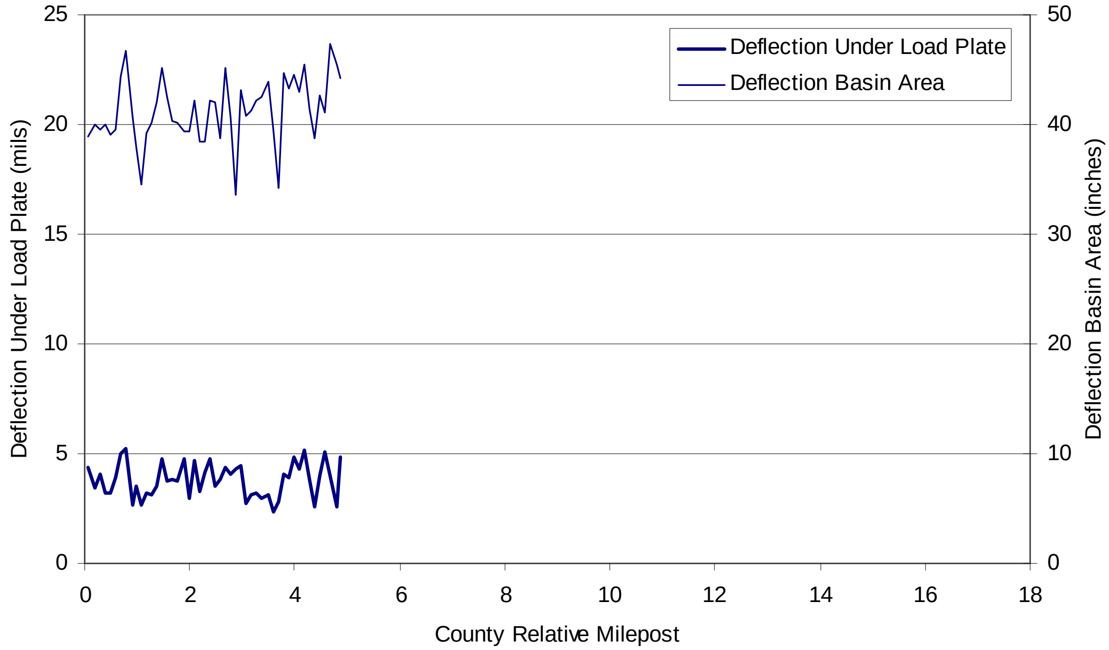

Figure C.23. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-64, Louisa County (Maintenance Jurisdiction 054)

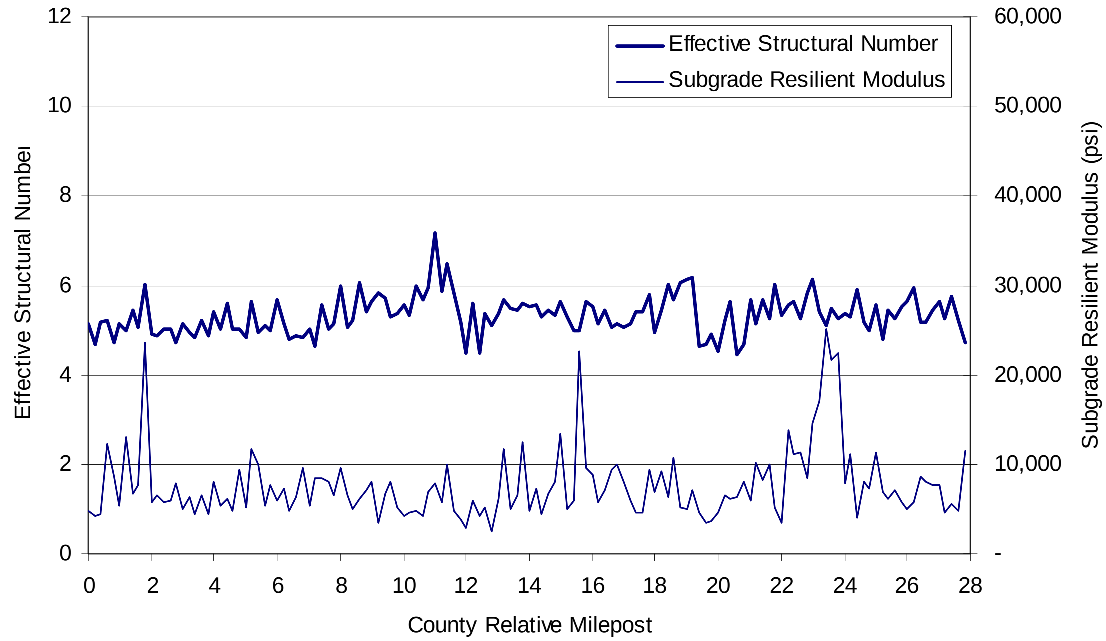

Figure C.24. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, Goochland County (Maintenance Jurisdiction 037)

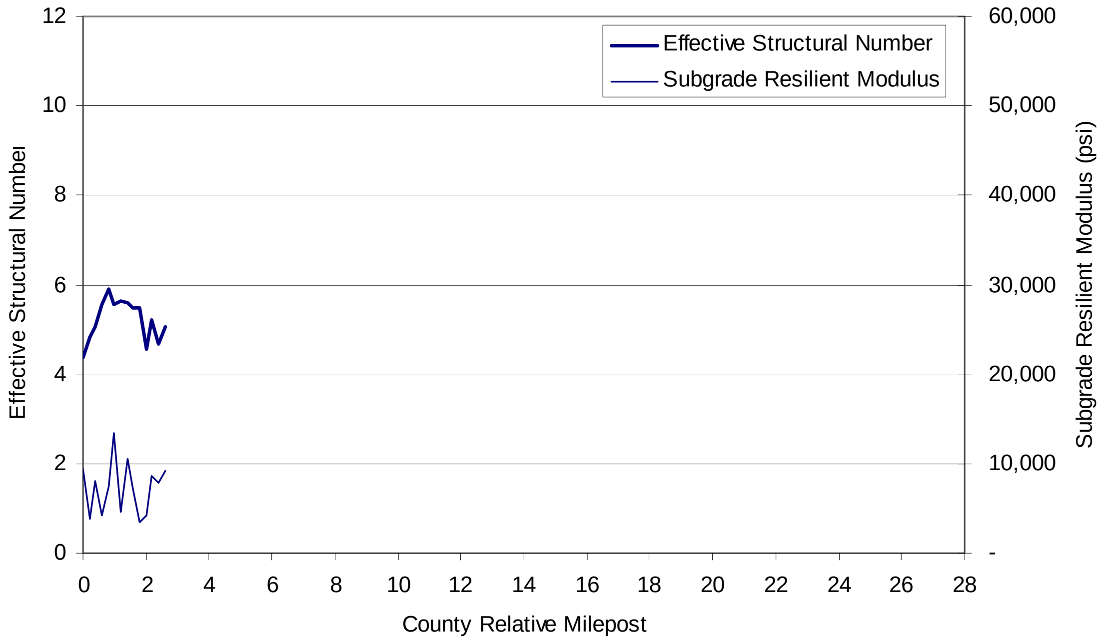

Figure C.25. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, Henrico County (Maintenance Jurisdiction 043)

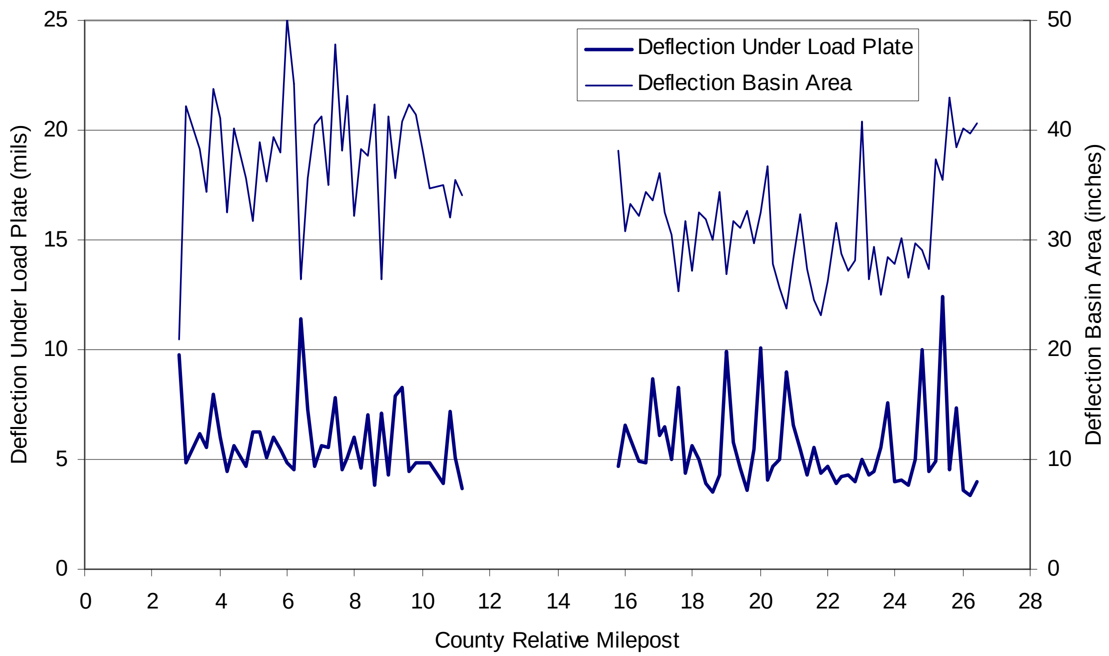

Figure C.26. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-64, Henrico County (Maintenance Jurisdiction 043)

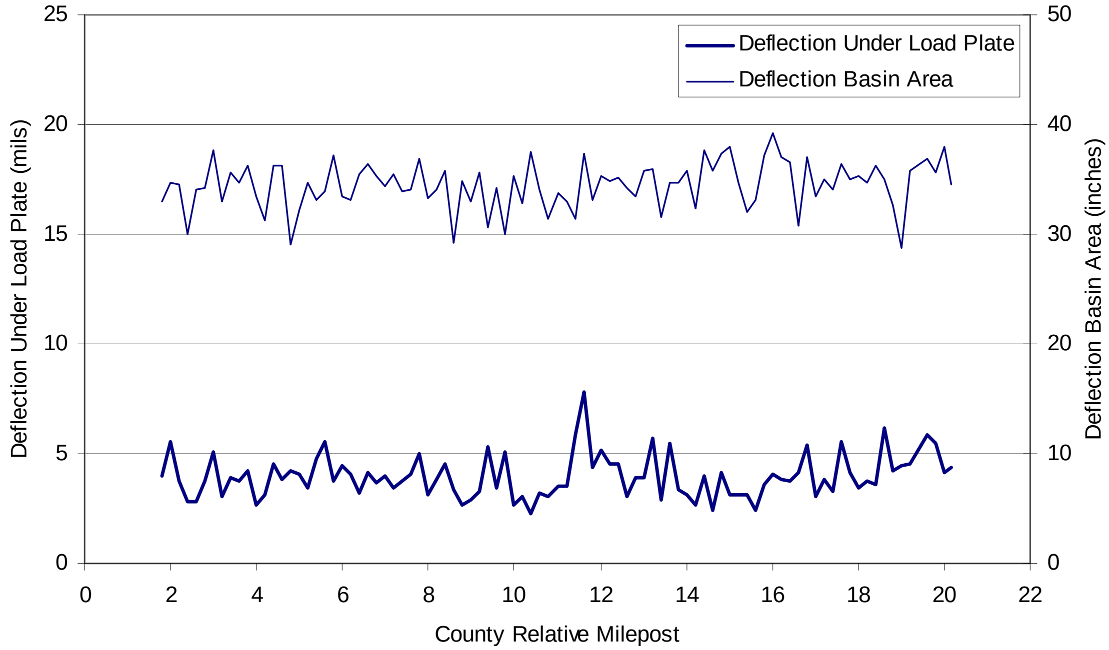

Figure C.27. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-64, New Kent County (Maintenance Jurisdiction 063)

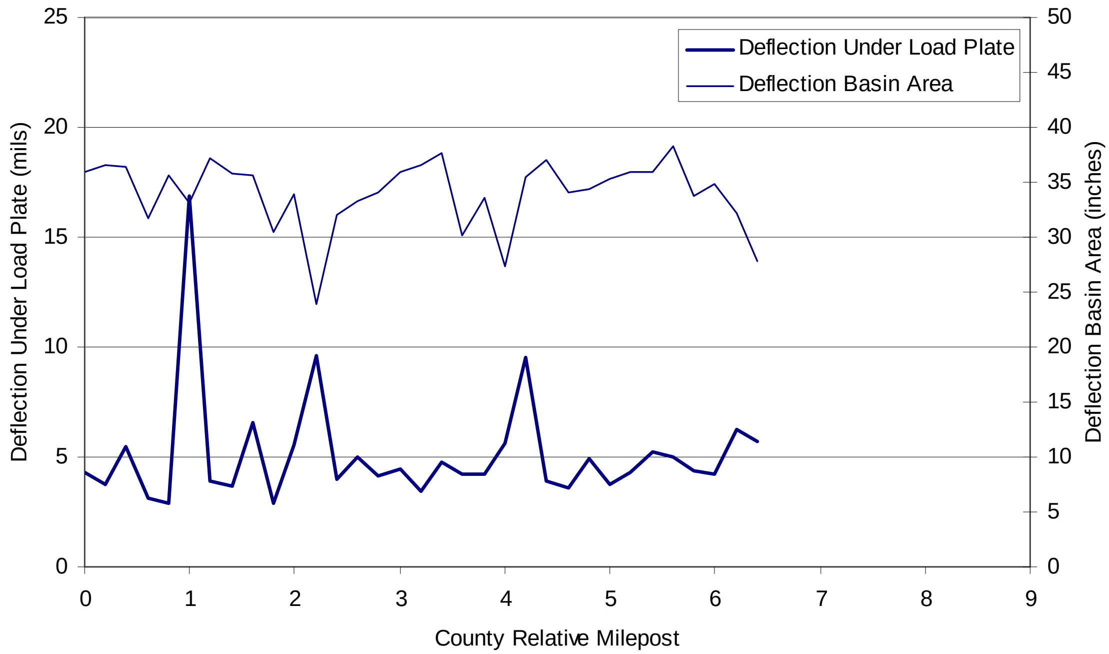

Figure C.28. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-64, James City County (Maintenance Jurisdiction 047)

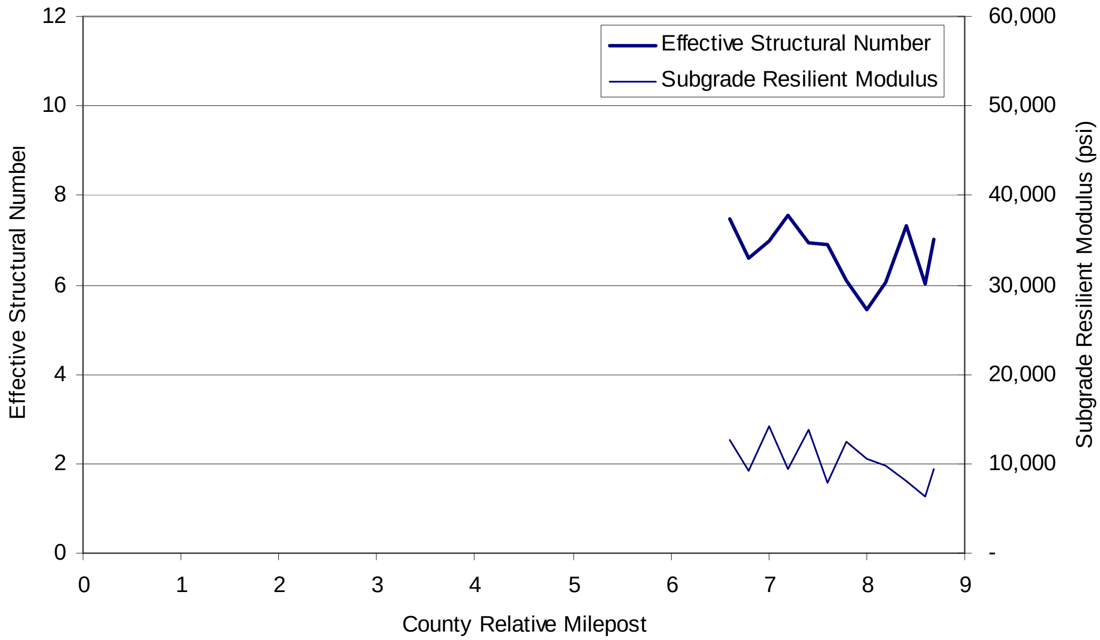

Figure C.29. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, James City County (Maintenance Jurisdiction 047)

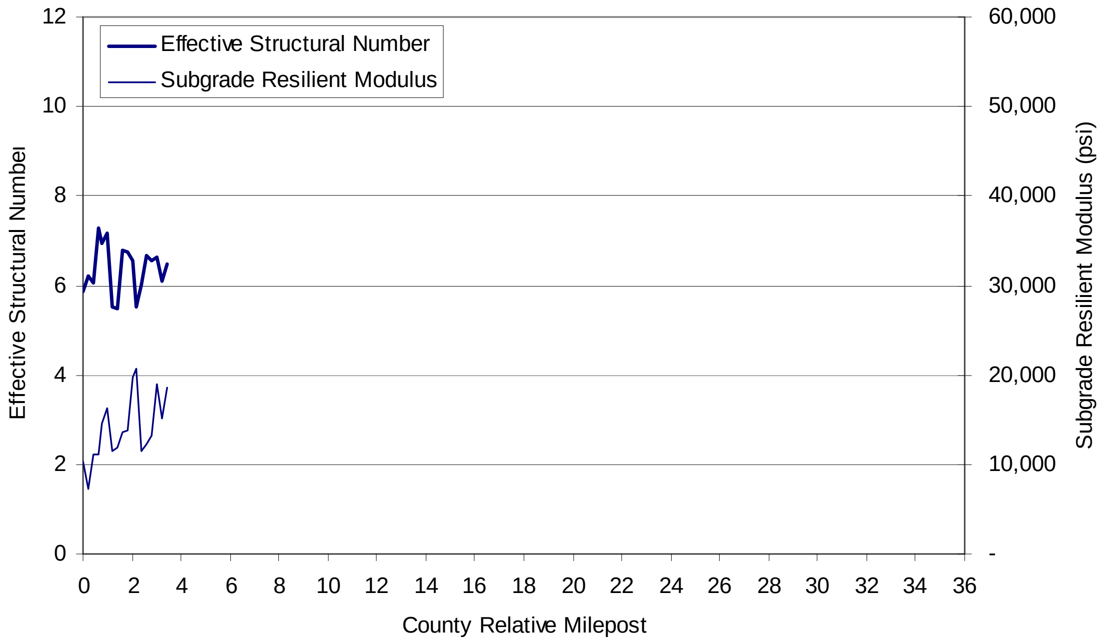

Figure C.30. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, York County (Maintenance Jurisdiction 099)

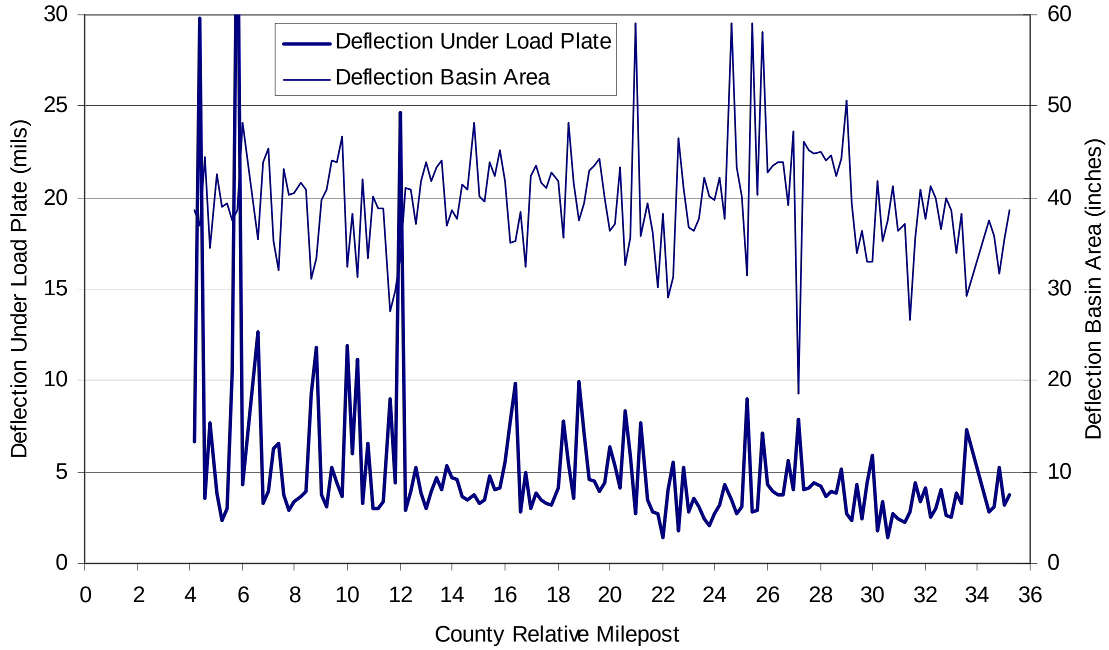

Figure C.31. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-64, York County (Maintenance Jurisdiction 099)

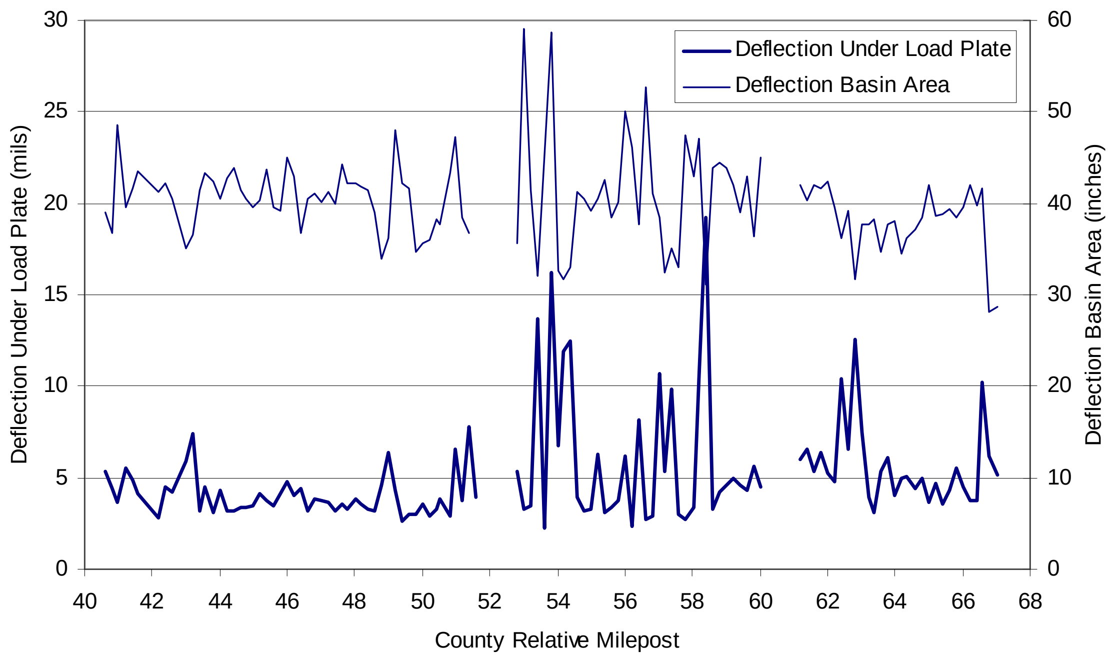

Figure C.32. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-64, City of Portsmouth (Maintenance Jurisdiction 064)

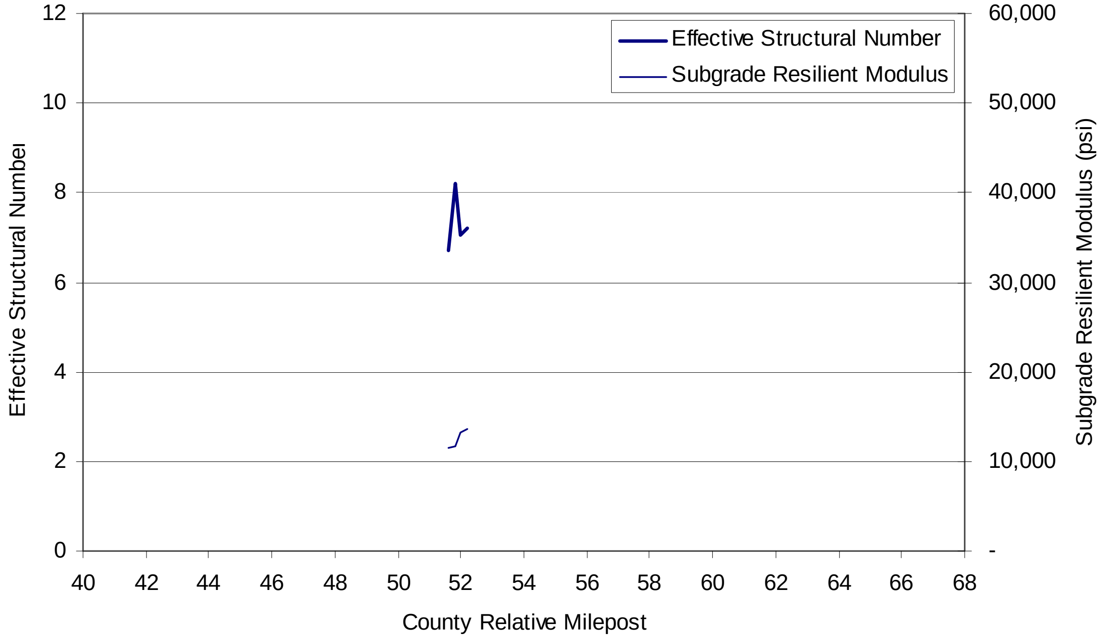

Figure C.33. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-64, City of Portsmouth (Maintenance Jurisdiction 064)

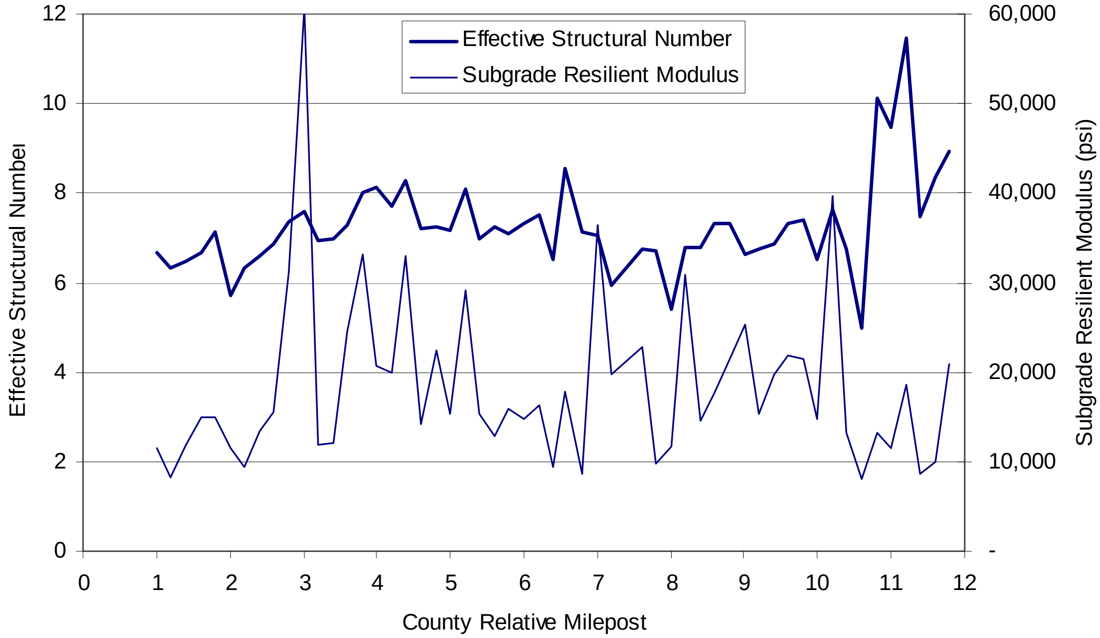

Figure C.34. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-66, Warren County (Maintenance Jurisdiction 093)

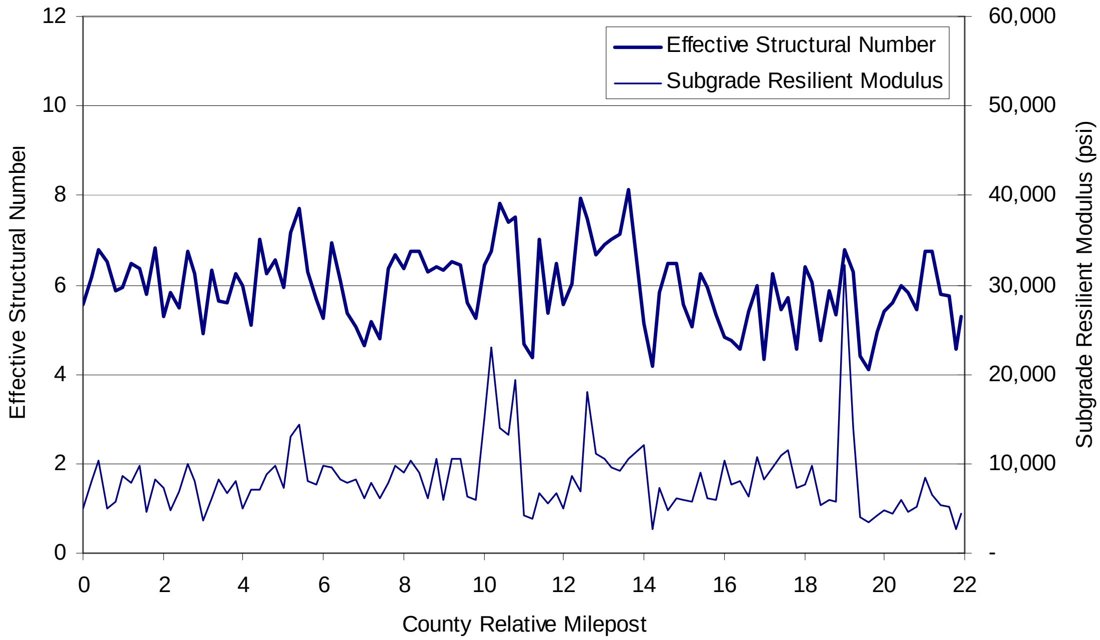

Figure C.35. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-66, Fauquier County (Maintenance Jurisdiction 030)

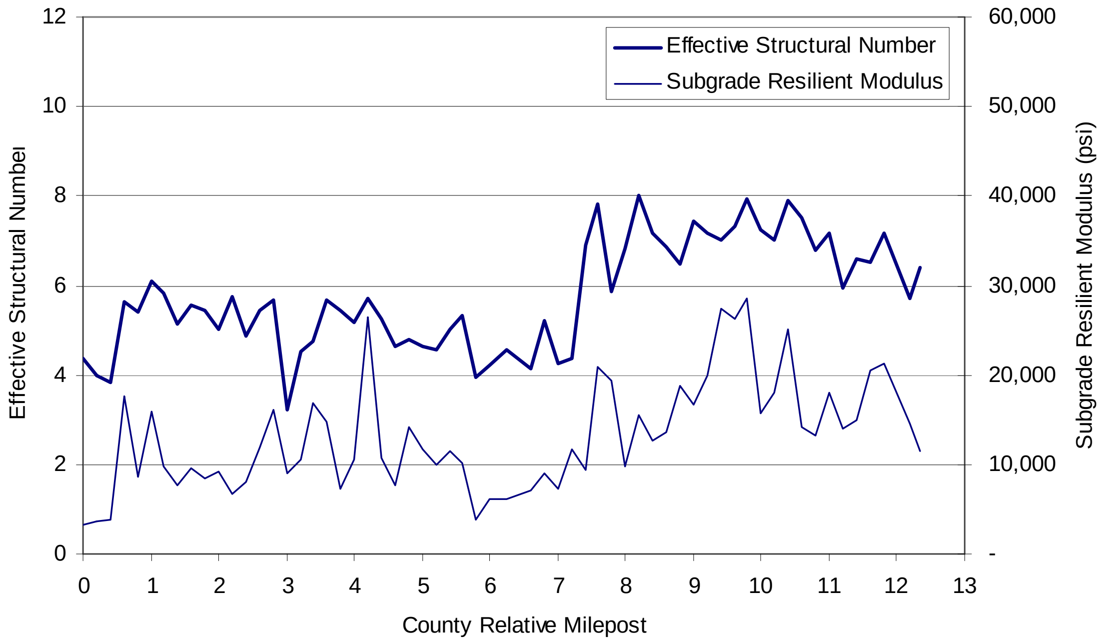

Figure C.36. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-66, Prince William County (Maintenance Jurisdiction 076)

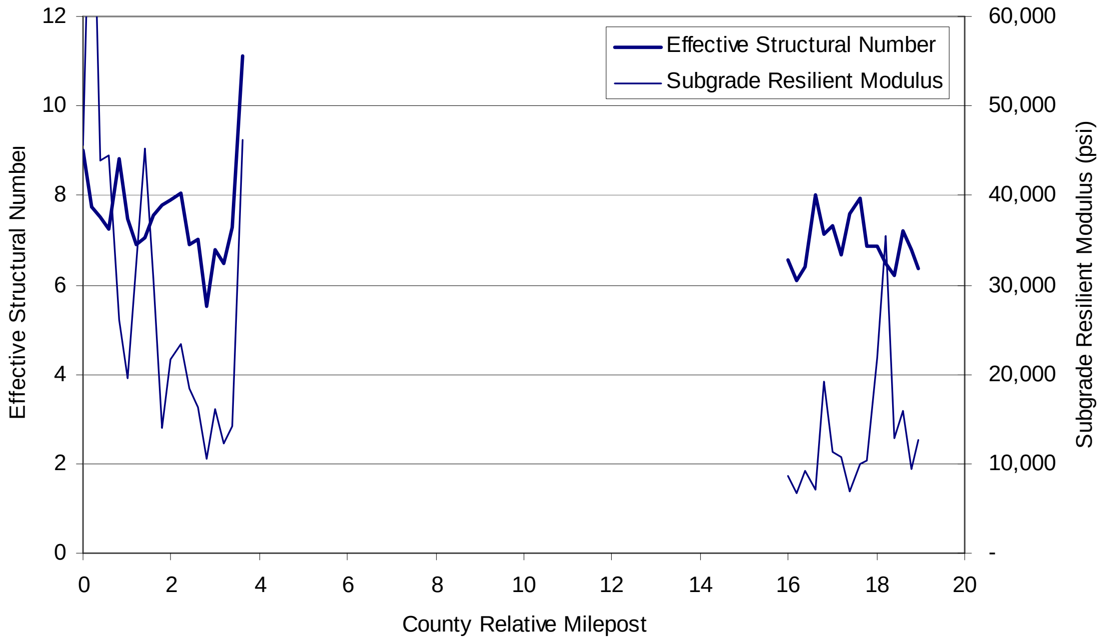

Figure C.37. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-66, Fairfax County (Maintenance Jurisdiction 029)

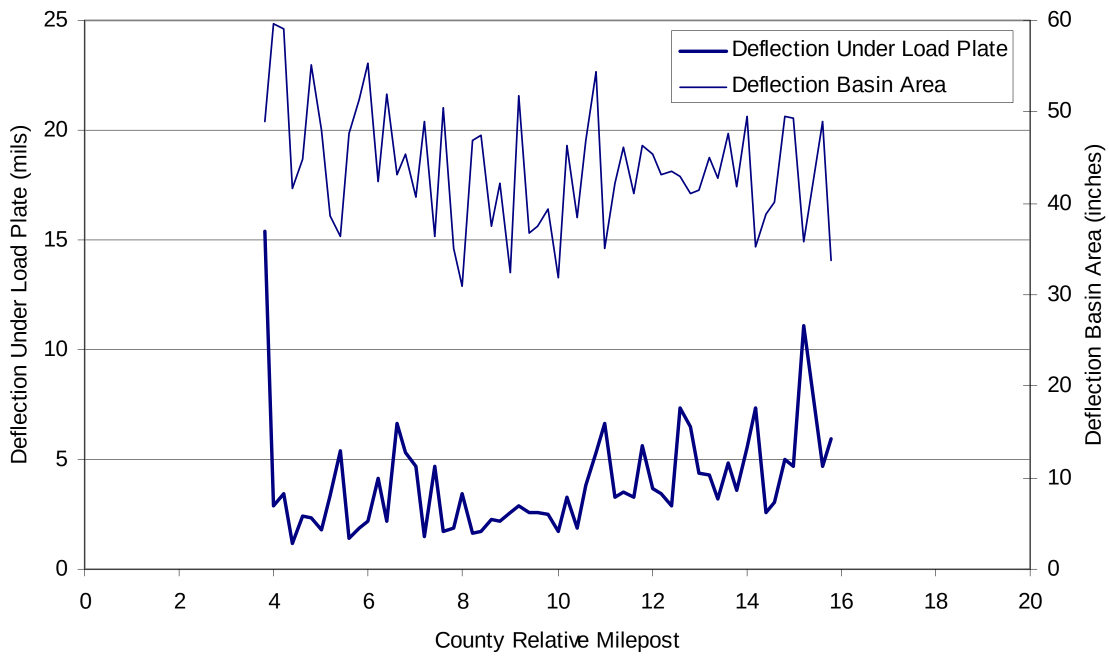

Figure C.38. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-66, Fairfax County (Maintenance Jurisdiction 029)

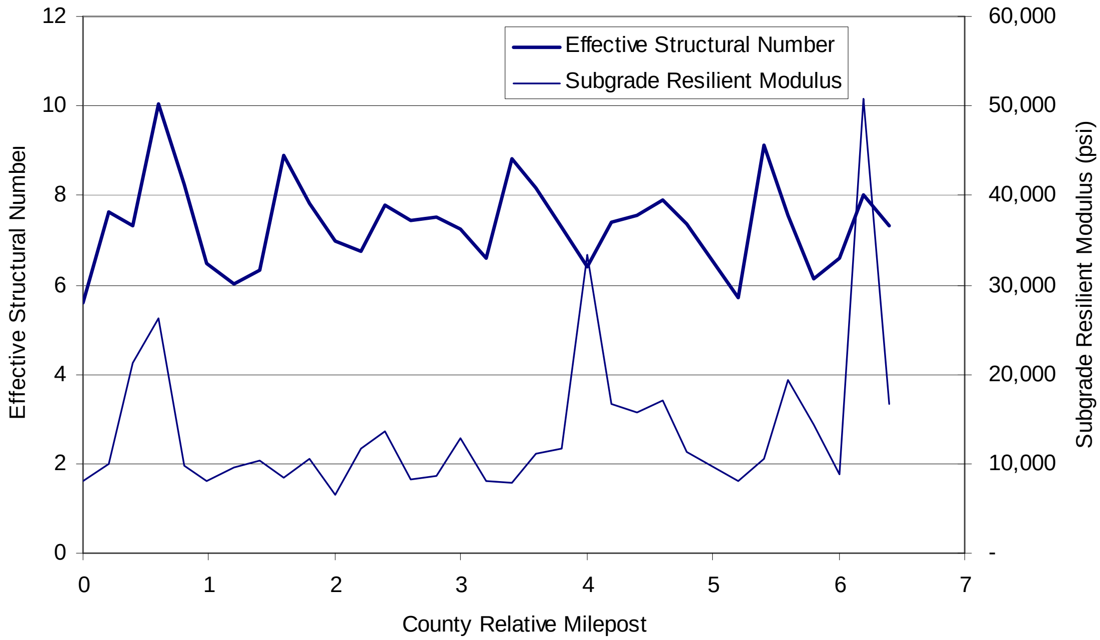

Figure C.39. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-66, Arlington County (Maintenance Jurisdiction 000)

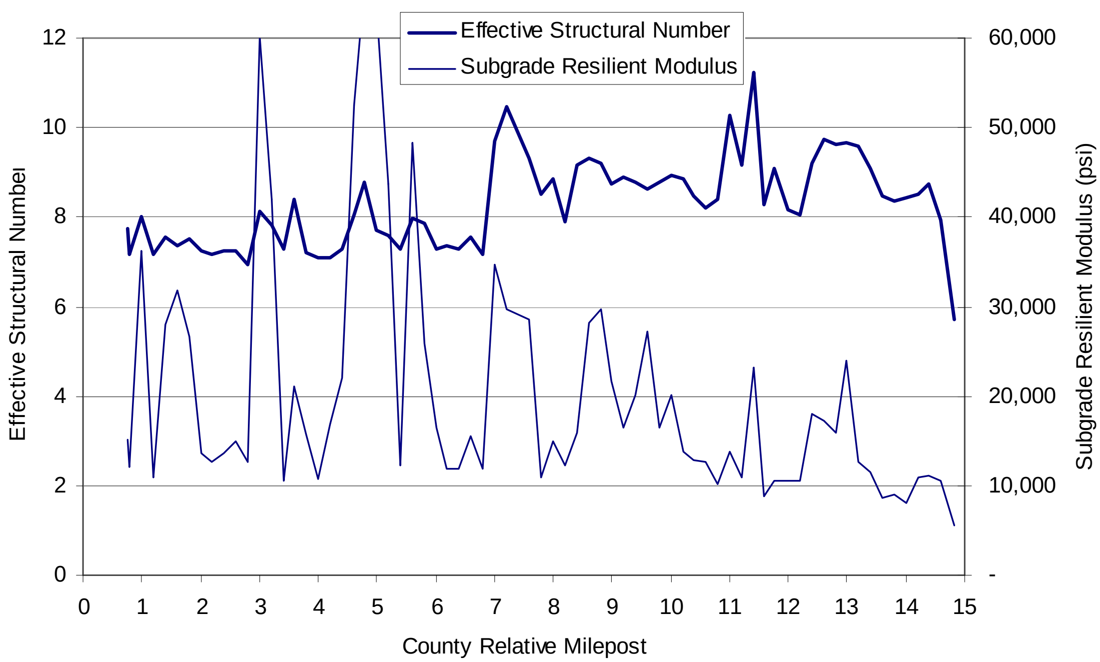

Figure C.40. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-66, Warren County (Maintenance Jurisdiction 093)

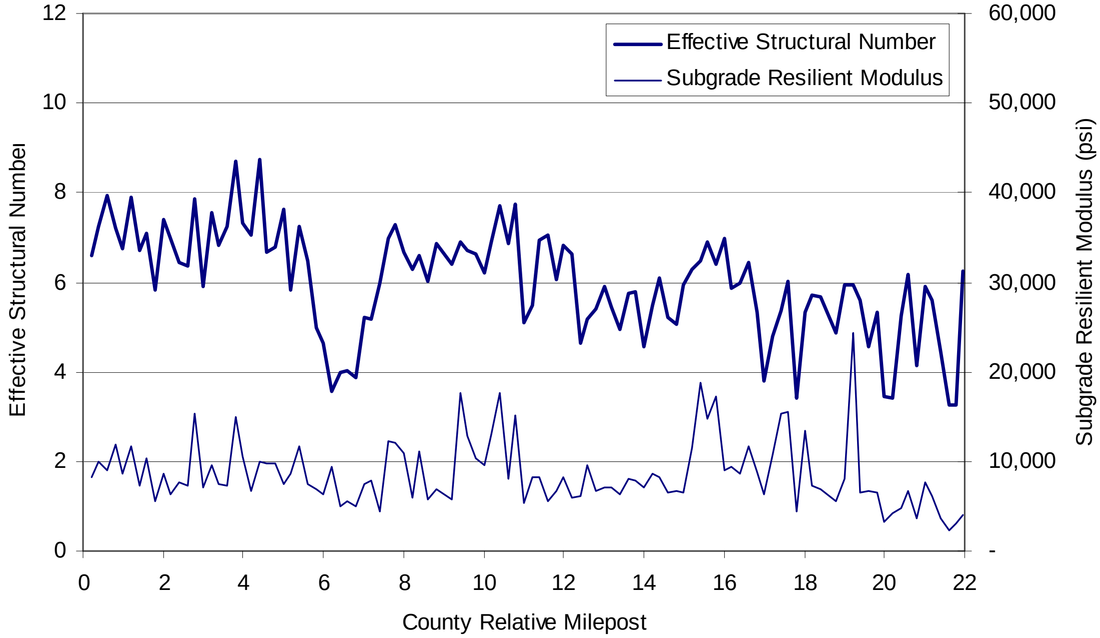

Figure C.41. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-66, Fauquier County (Maintenance Jurisdiction 030)

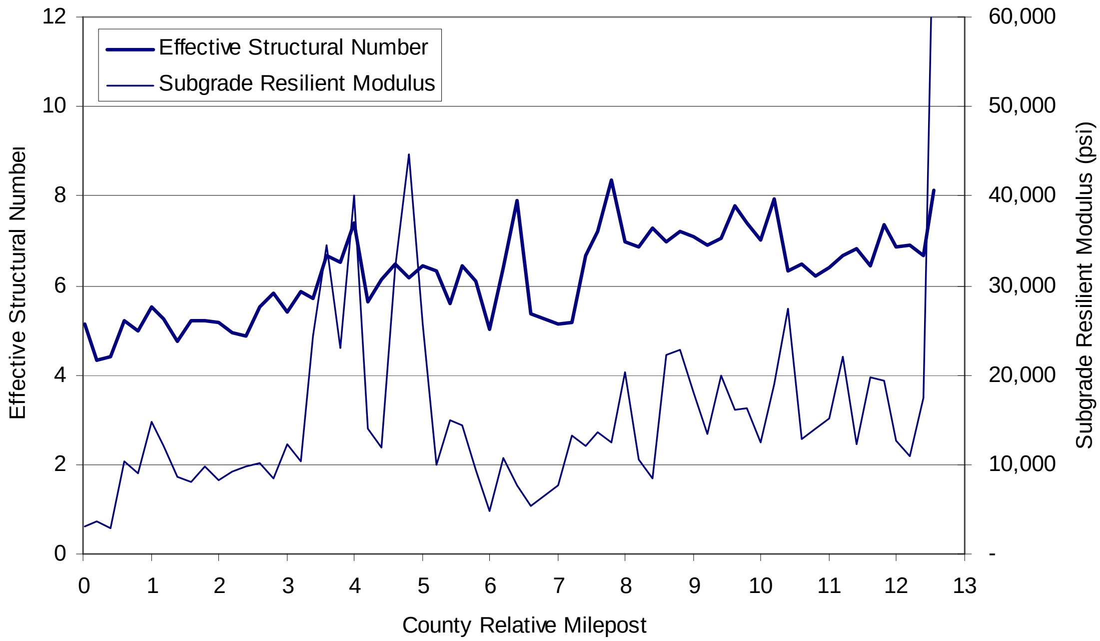

Figure C.42. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-66, Prince William County (Maintenance Jurisdiction 076)

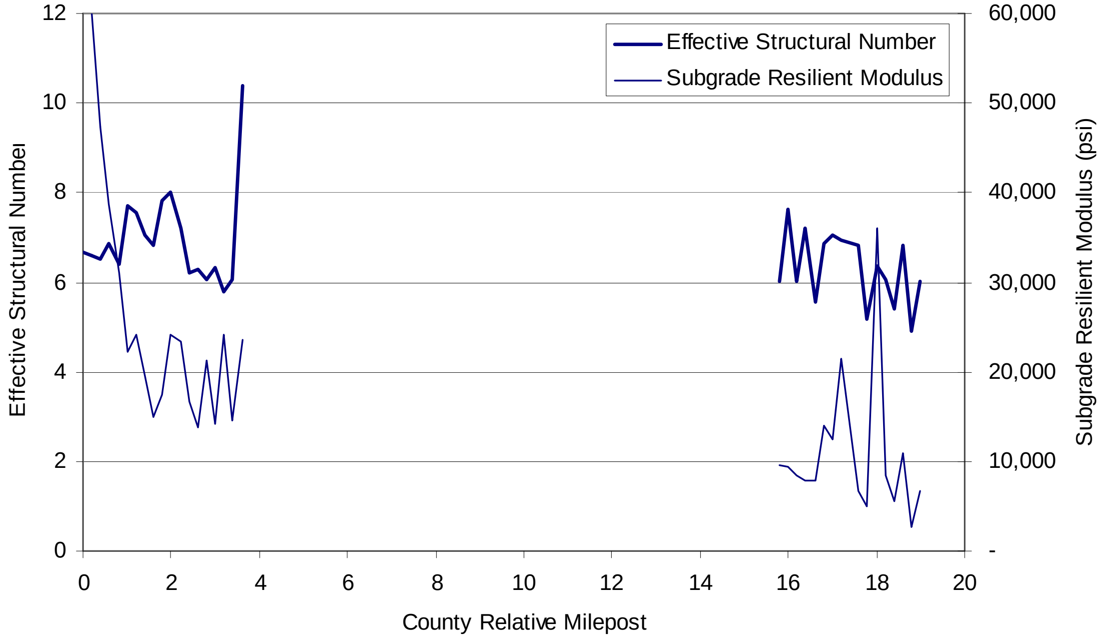

Figure C.43. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-66, Fairfax County (Maintenance Jurisdiction 029)

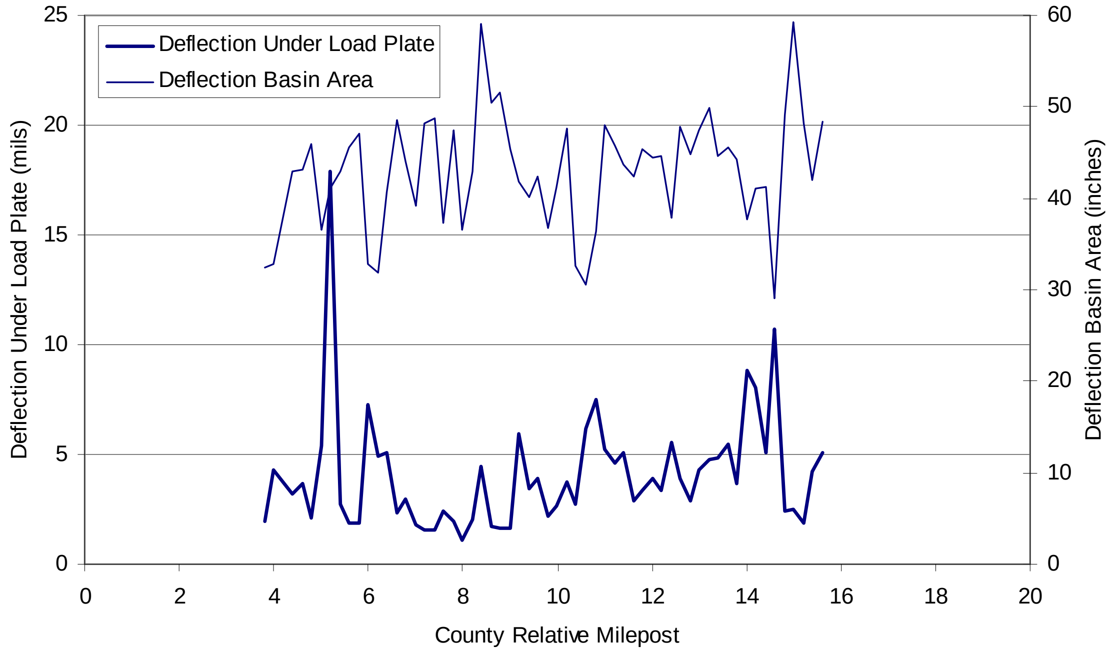

Figure C.44. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-66, Fairfax County (Maintenance Jurisdiction 029)

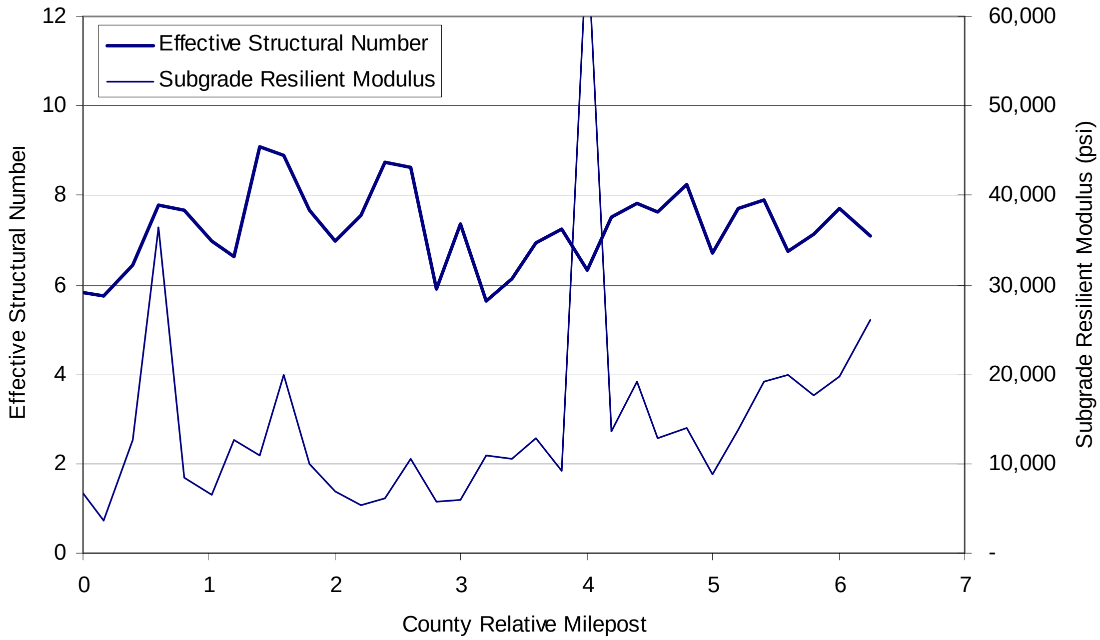

Figure C.45. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-66, Arlington County (Maintenance Jurisdiction 000)

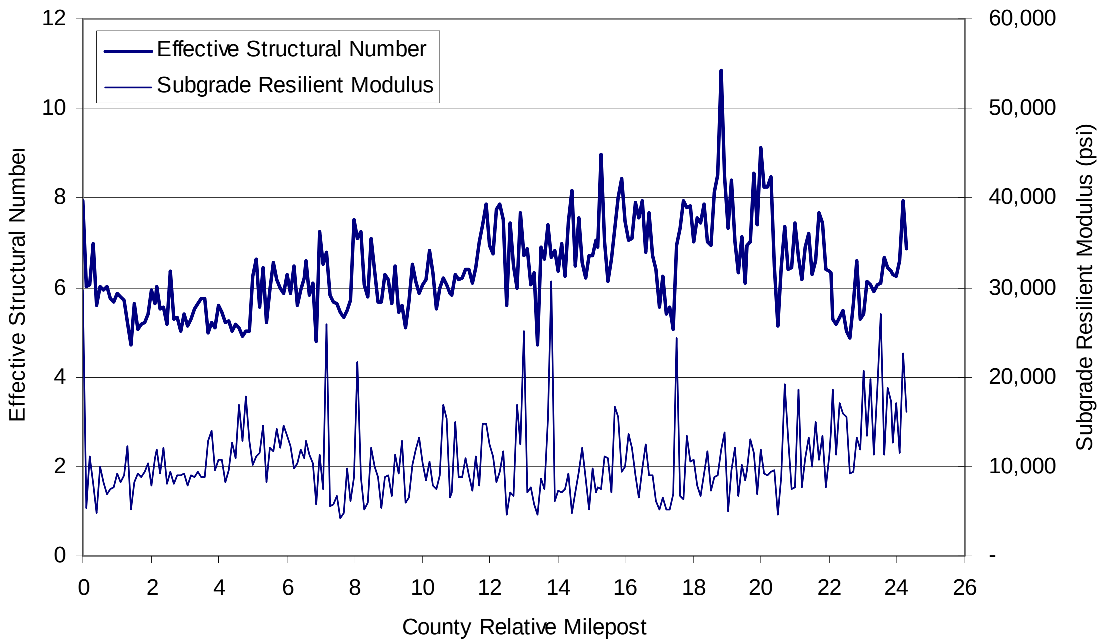

Figure C.46. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-77, Carroll County (Maintenance Jurisdiction 017)

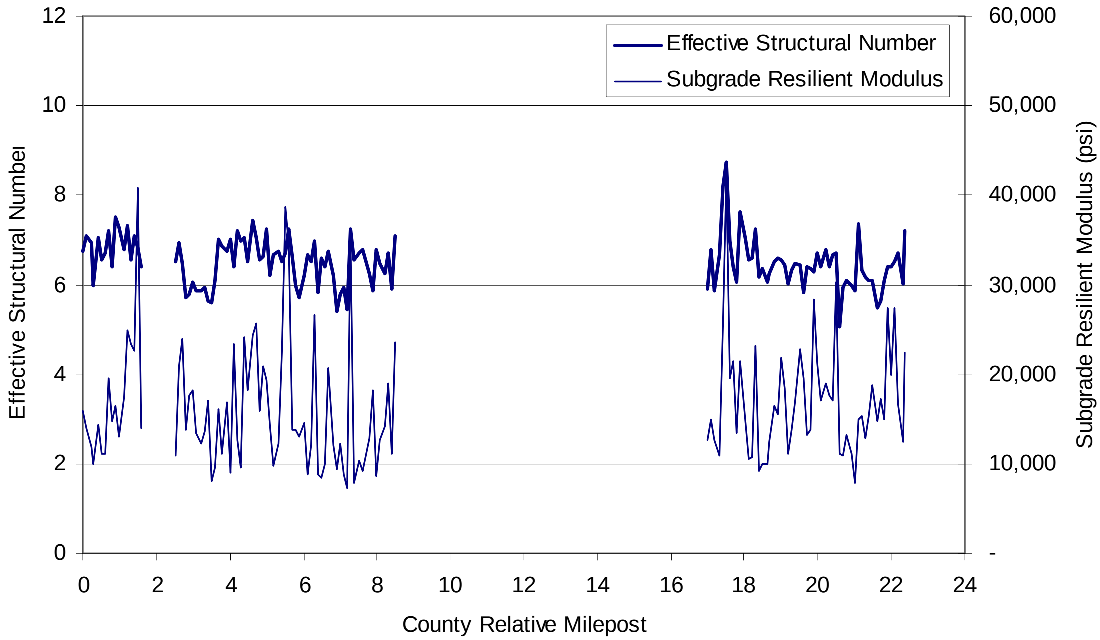

Figure C.47. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-77, Wythe County (Maintenance Jurisdiction 098)

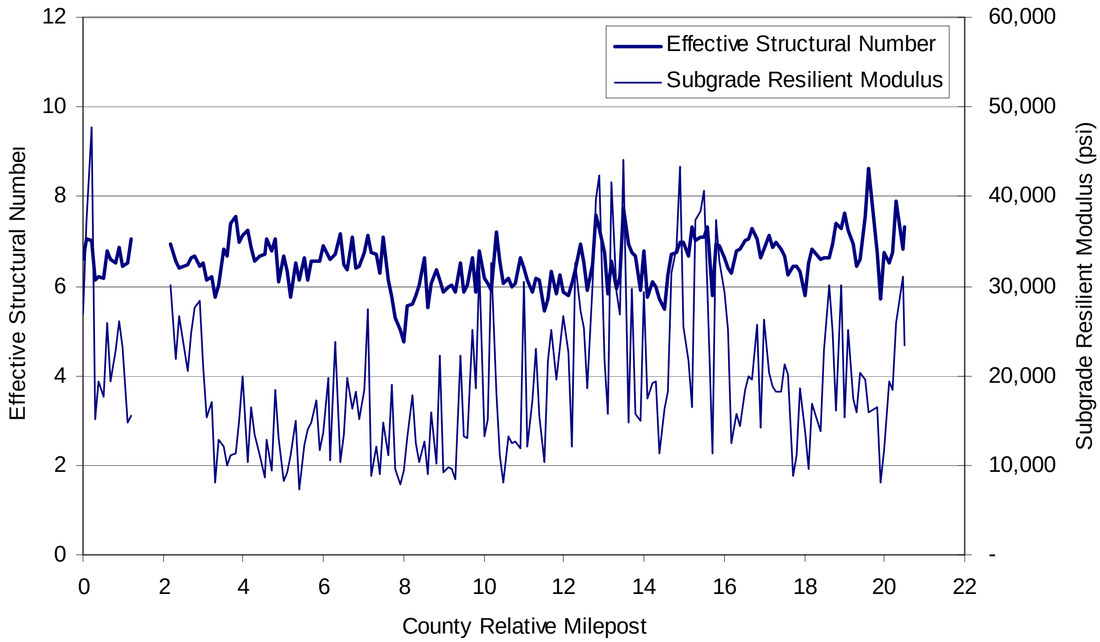

Figure C.48. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-77, Bland County (Maintenance Jurisdiction 010)

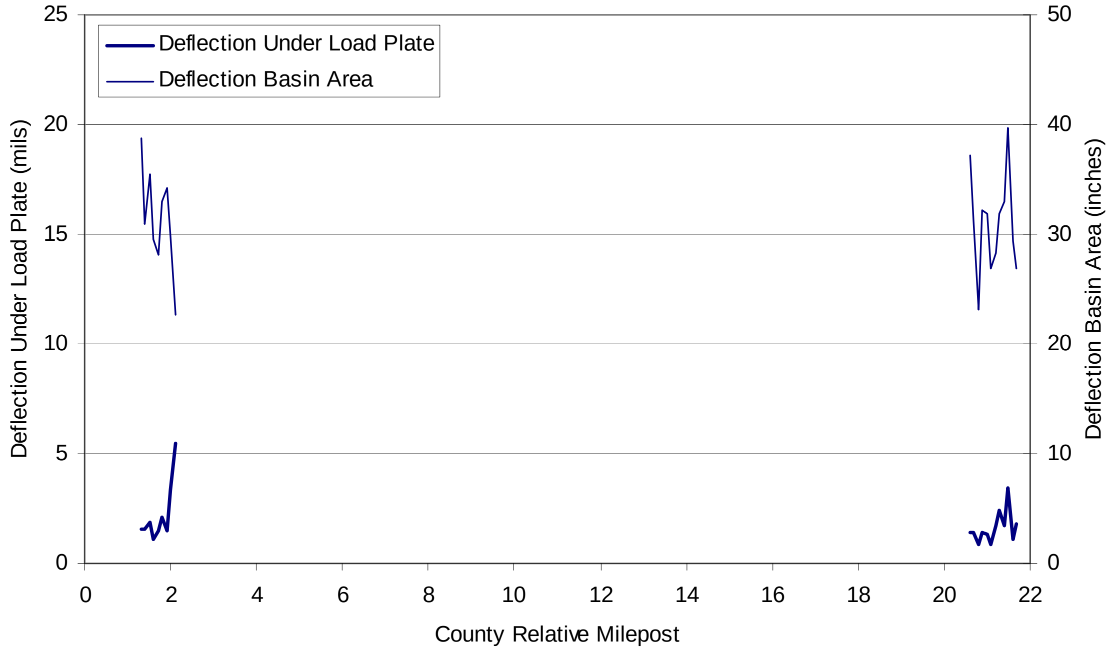

Figure C.49. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-77, Bland County (Maintenance Jurisdiction 010)

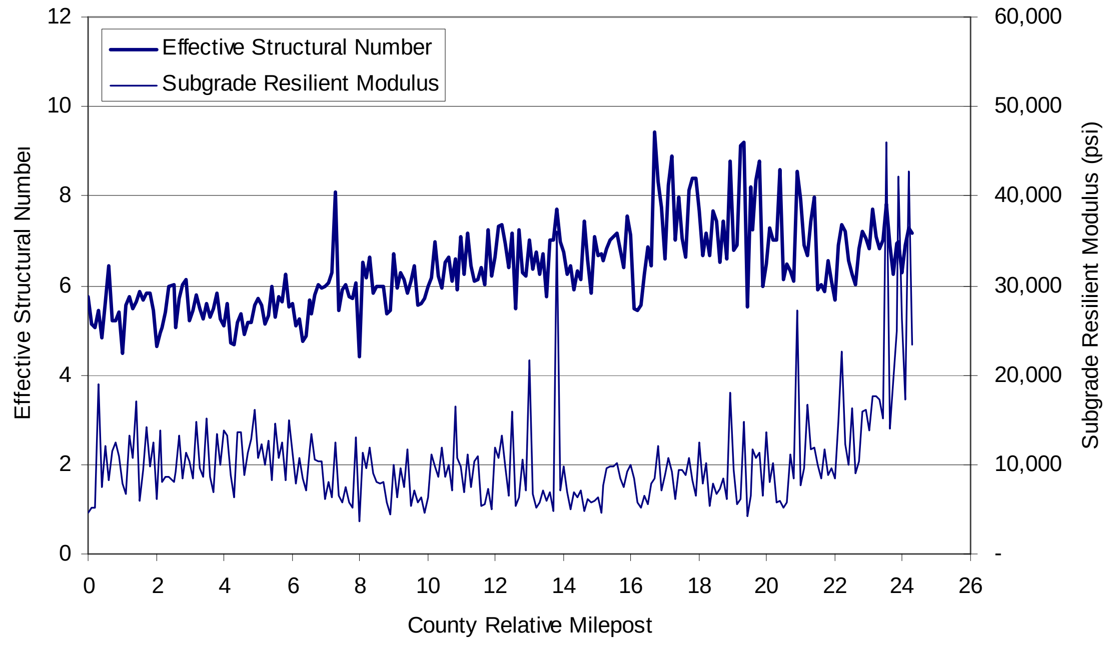

Figure C.50. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-77, Carroll County (Maintenance Jurisdiction 017)

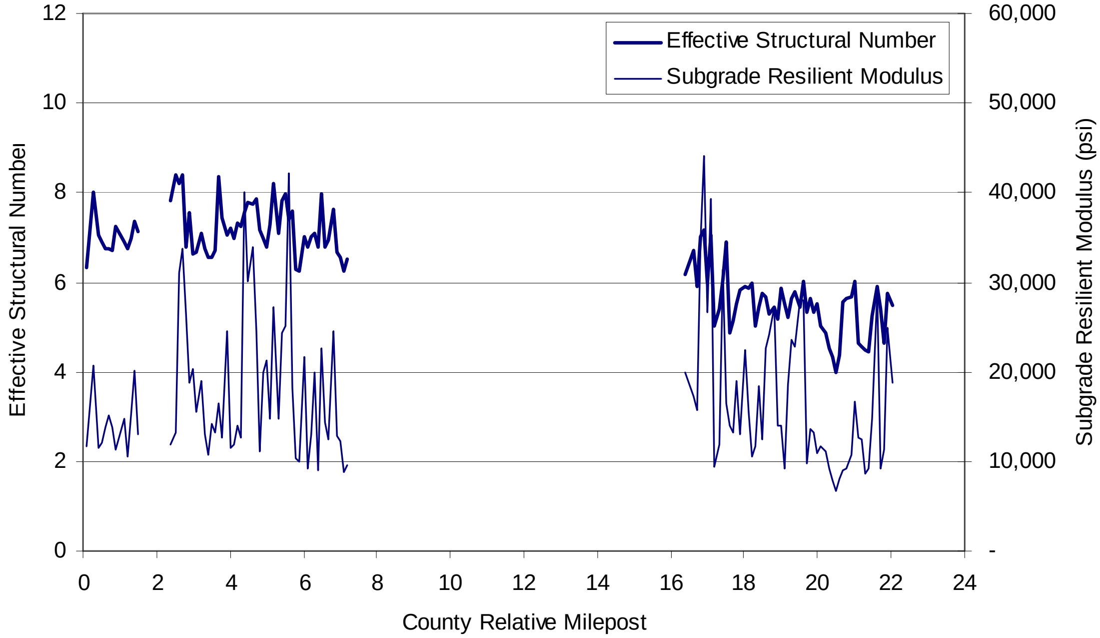

Figure C.51. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-77, Wythe County (Maintenance Jurisdiction 098)

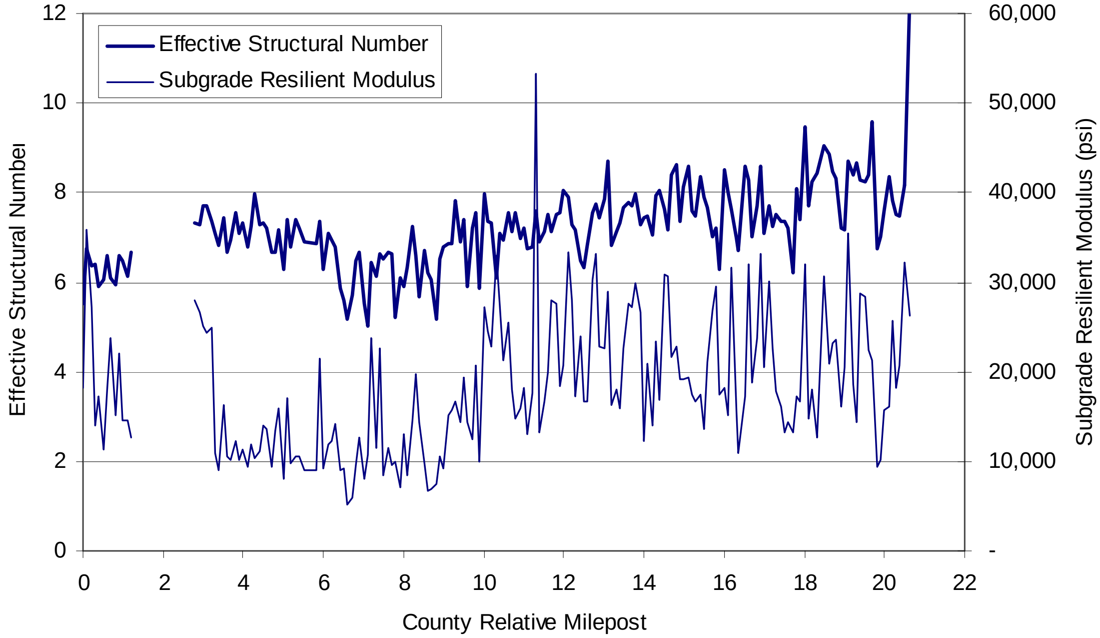

Figure C.52. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-77, Bland County (Maintenance Jurisdiction 010)

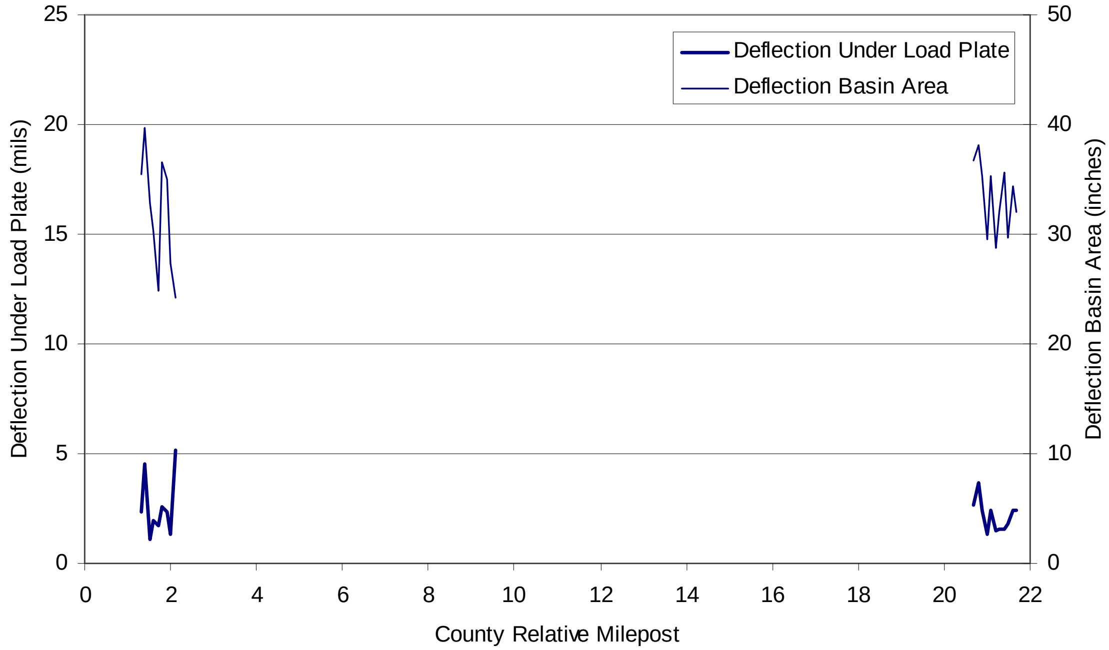

Figure C.53. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-77, Bland County (Maintenance Jurisdiction 010)

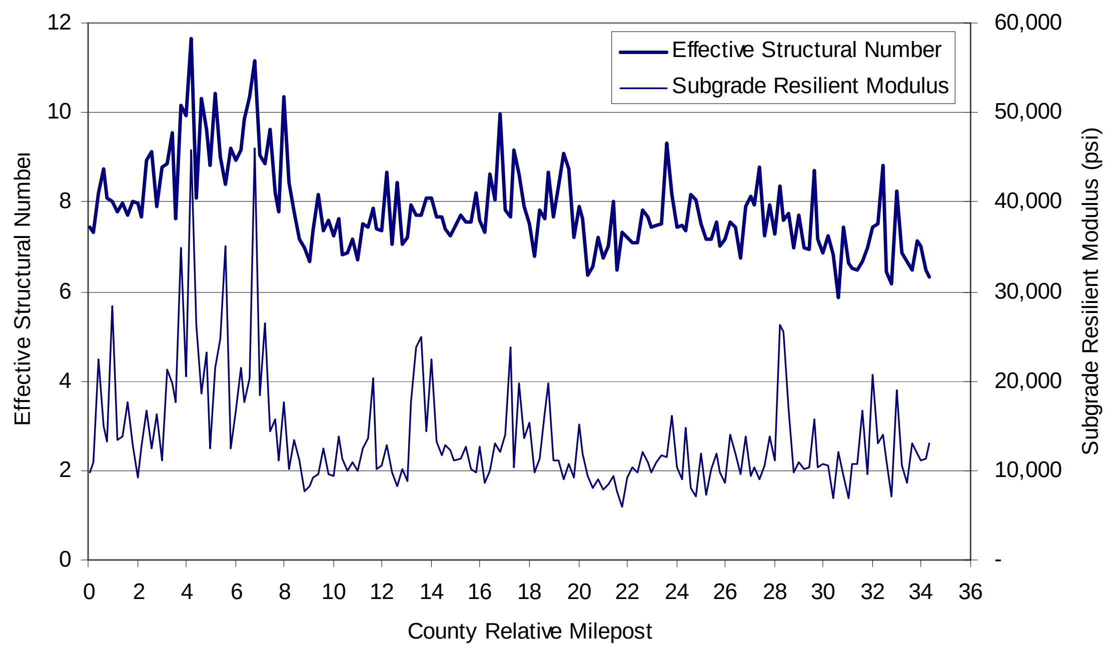

Figure C.54. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Washington County (Maintenance Jurisdiction 095)

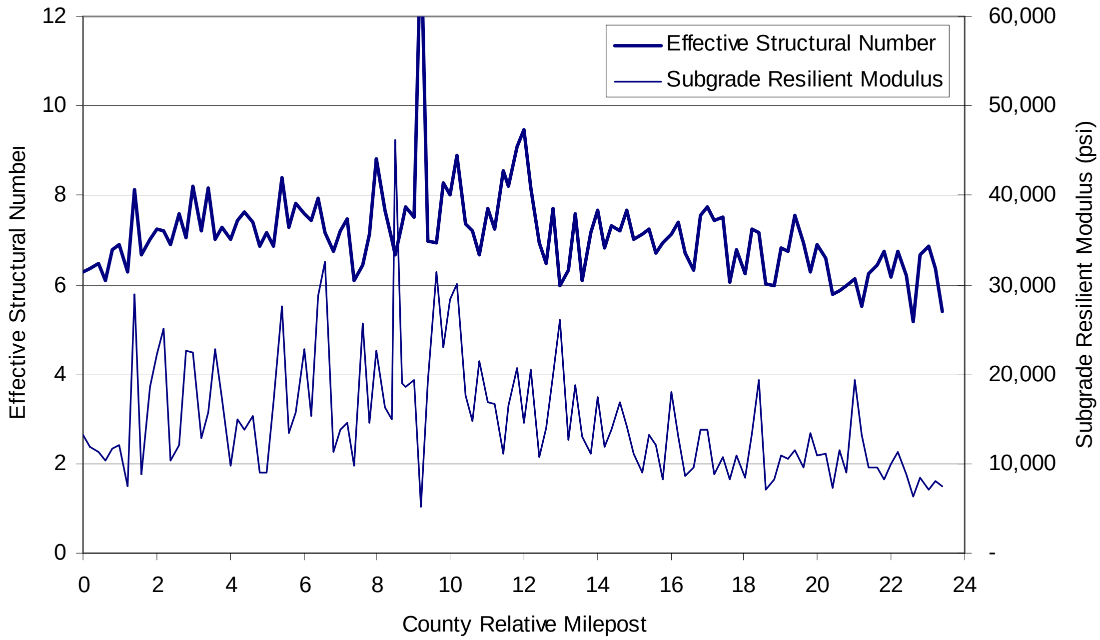

Figure C.55. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Smyth County (Maintenance Jurisdiction 086)

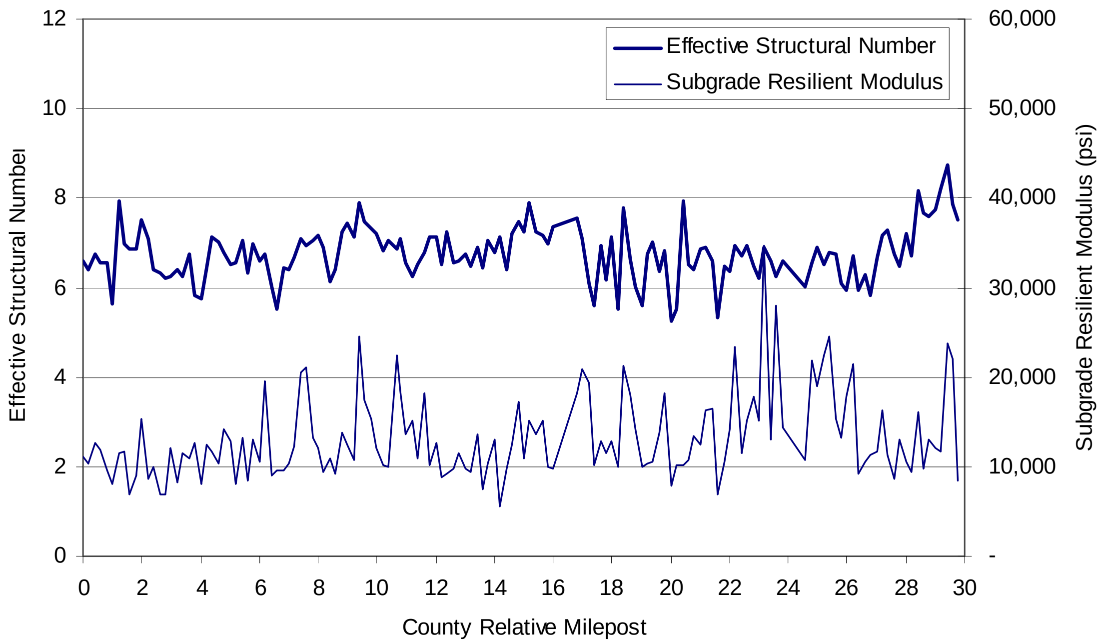

Figure C.56. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Wythe County (Maintenance Jurisdiction 098)

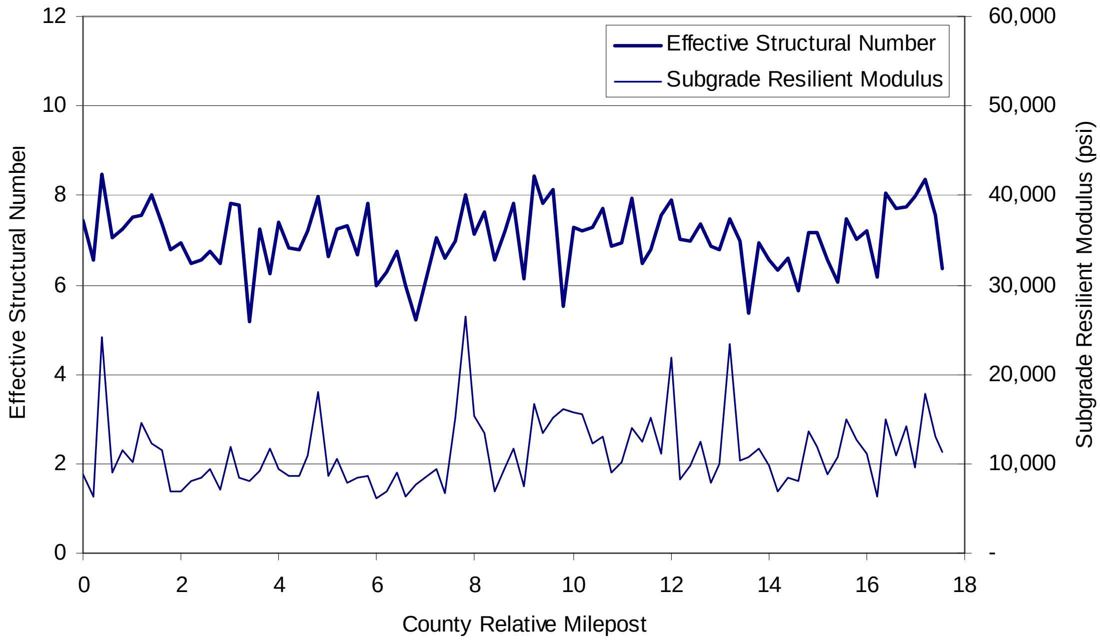

Figure C.57. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Pulaski County (Maintenance Jurisdiction 077)

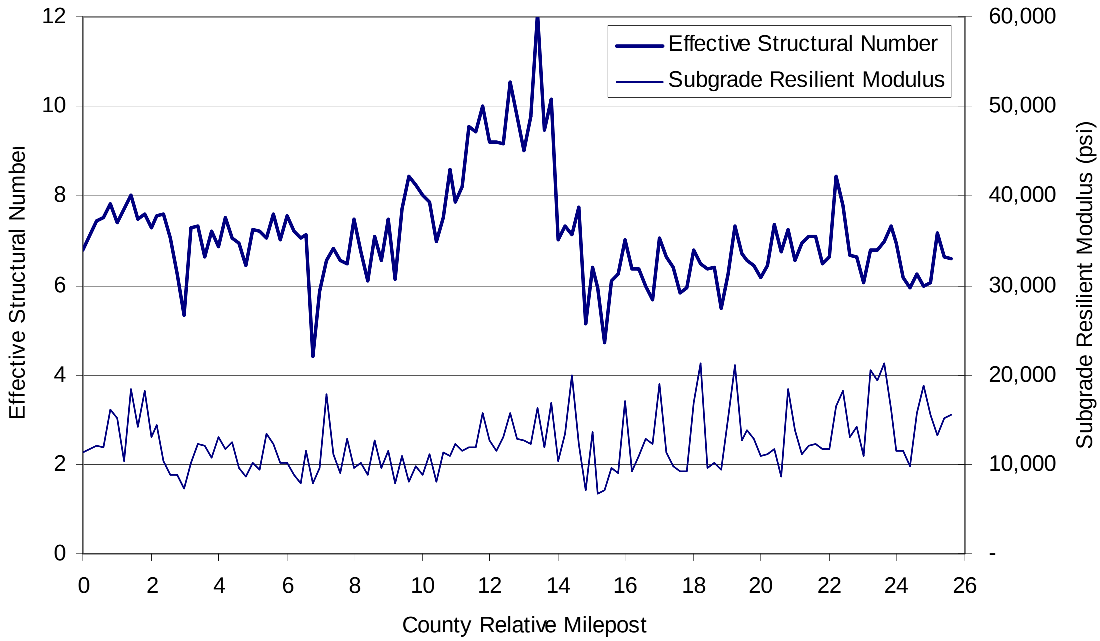

Figure C.58. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Montgomery County (Maintenance Jurisdiction 060)

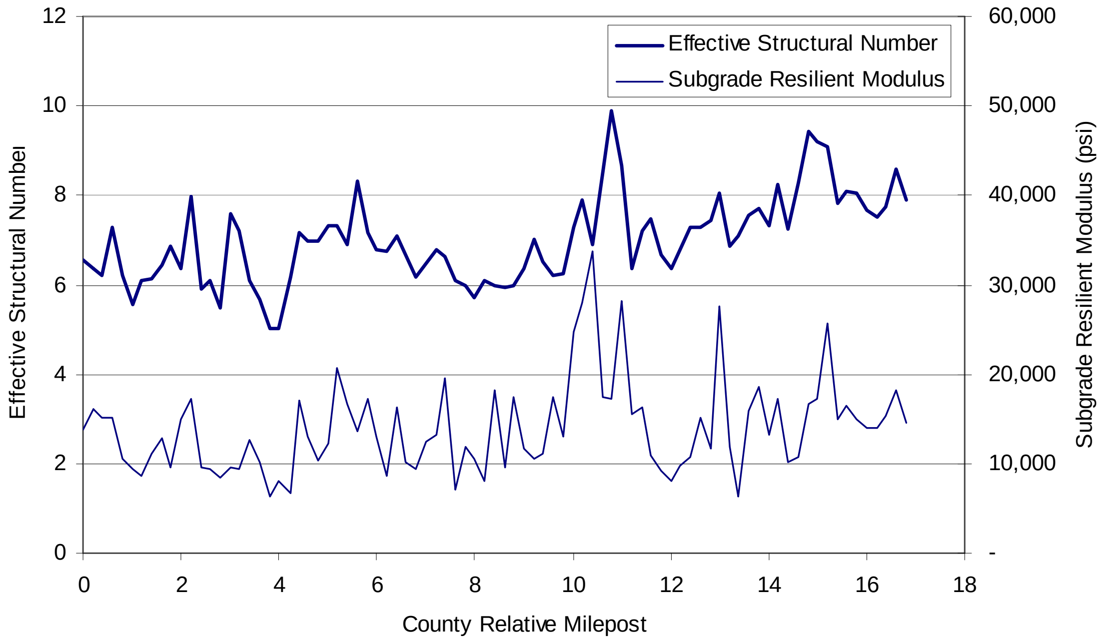

Figure C.59. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Roanoke County (Maintenance Jurisdiction 080)

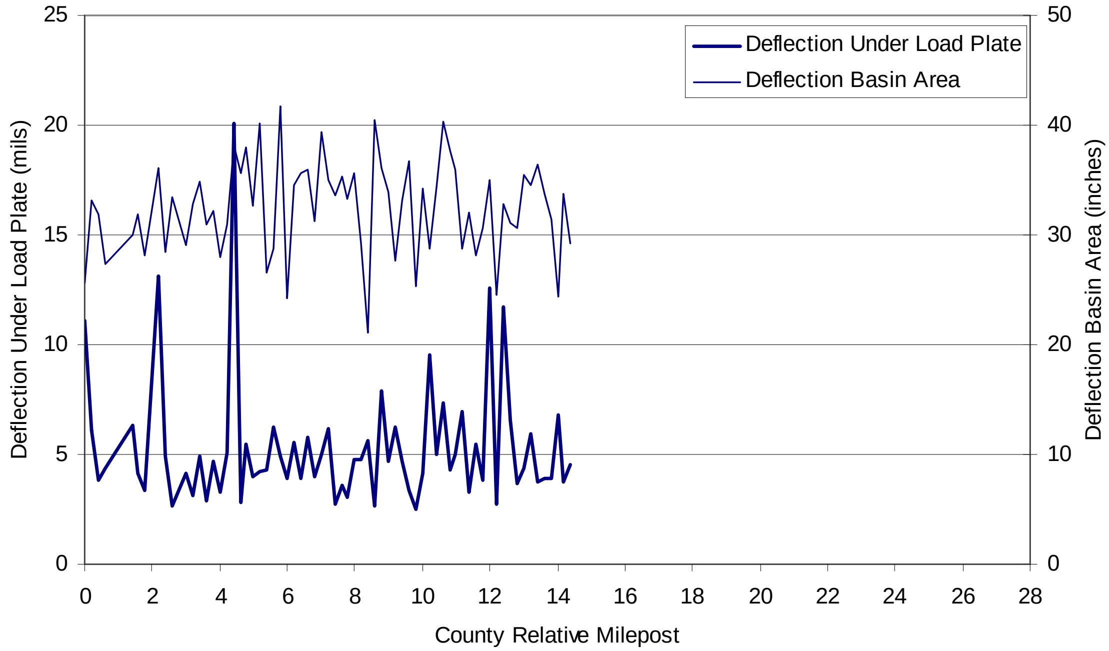

Figure C.60. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-81, Botetourt County (Maintenance Jurisdiction 011)

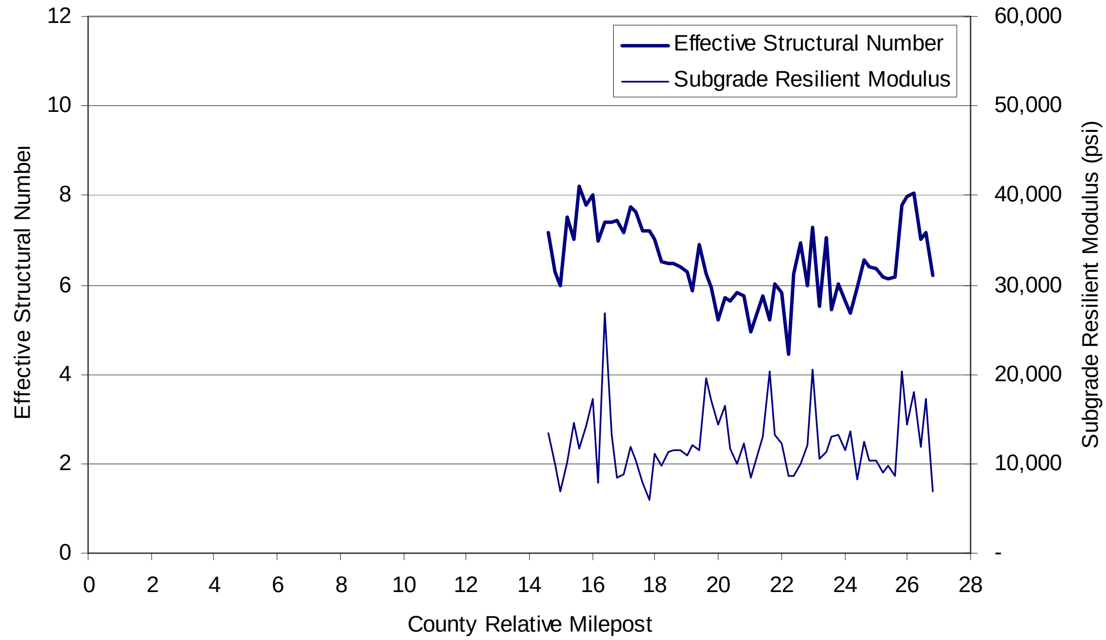

Figure C.61. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Botetourt County (Maintenance Jurisdiction 011)

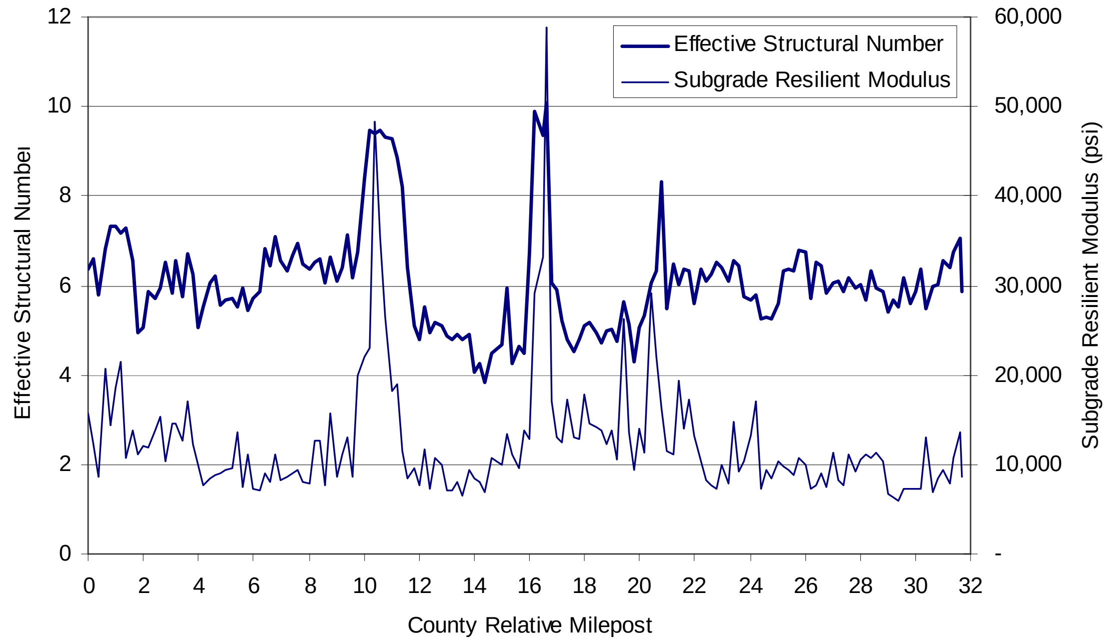

Figure C.62. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Rockbridge County (Maintenance Jurisdiction 081)

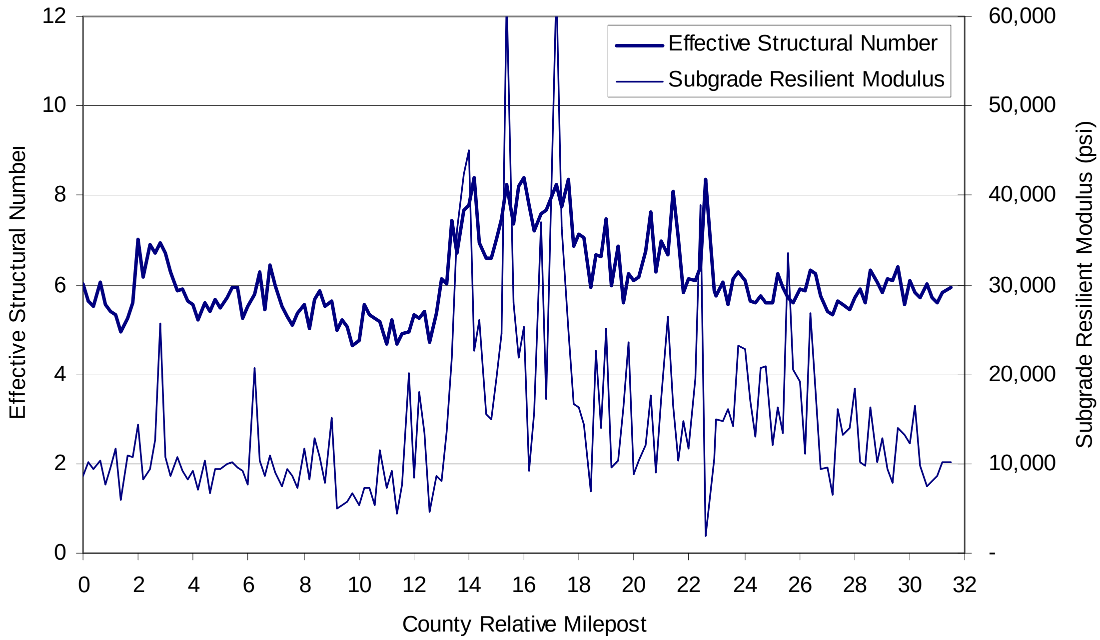

Figure C.63. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Augusta County (Maintenance Jurisdiction 007)

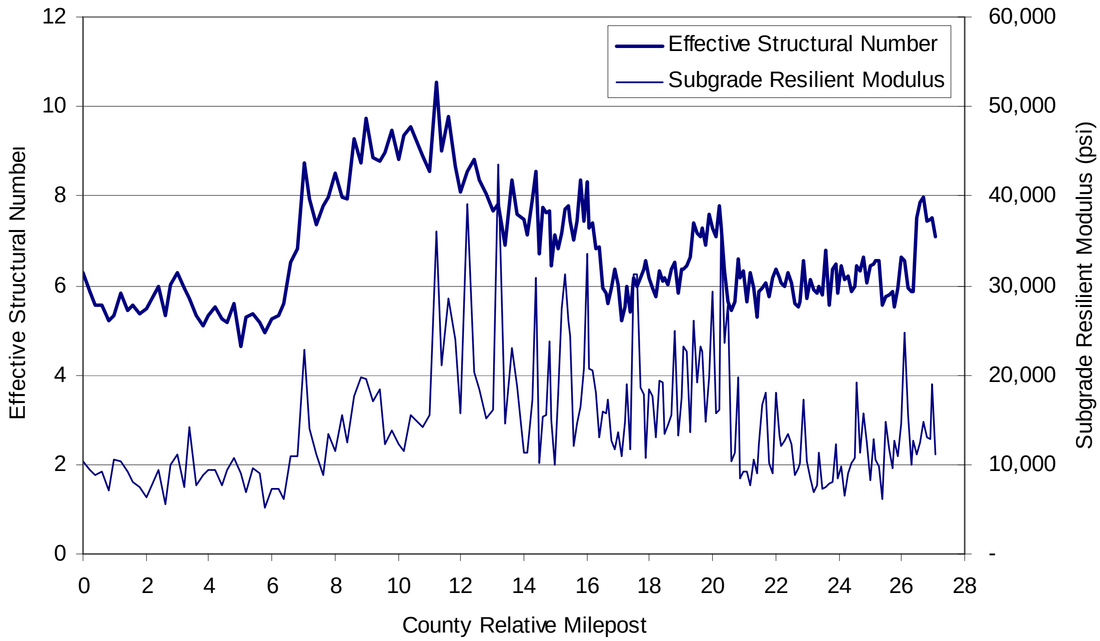

Figure C.64. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Rockingham County (Maintenance Jurisdiction 082)

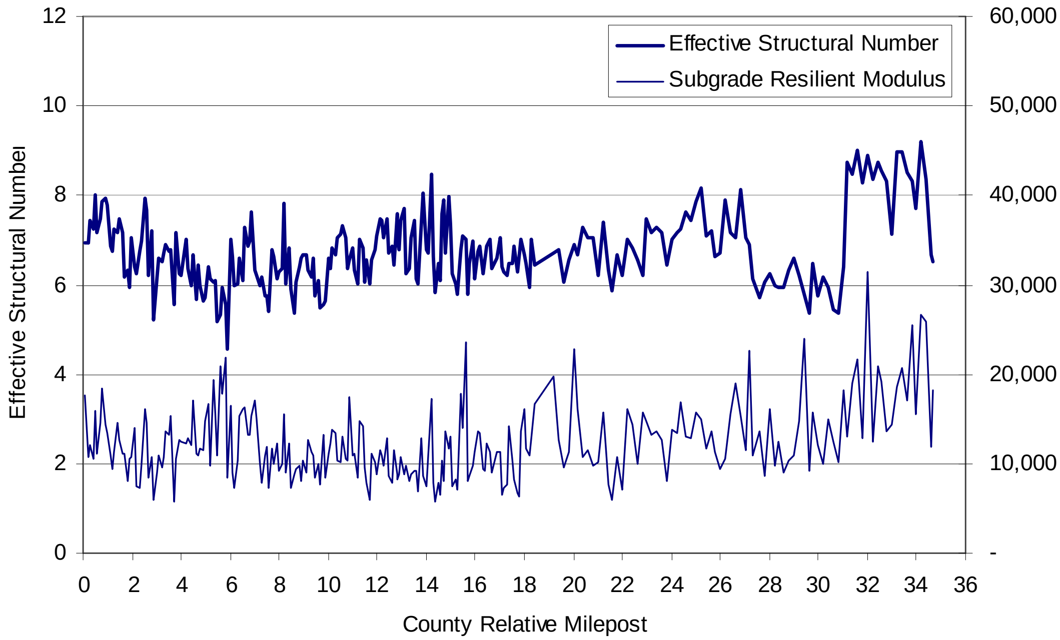

Figure C.65. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Shenandoah County (Maintenance Jurisdiction 085)

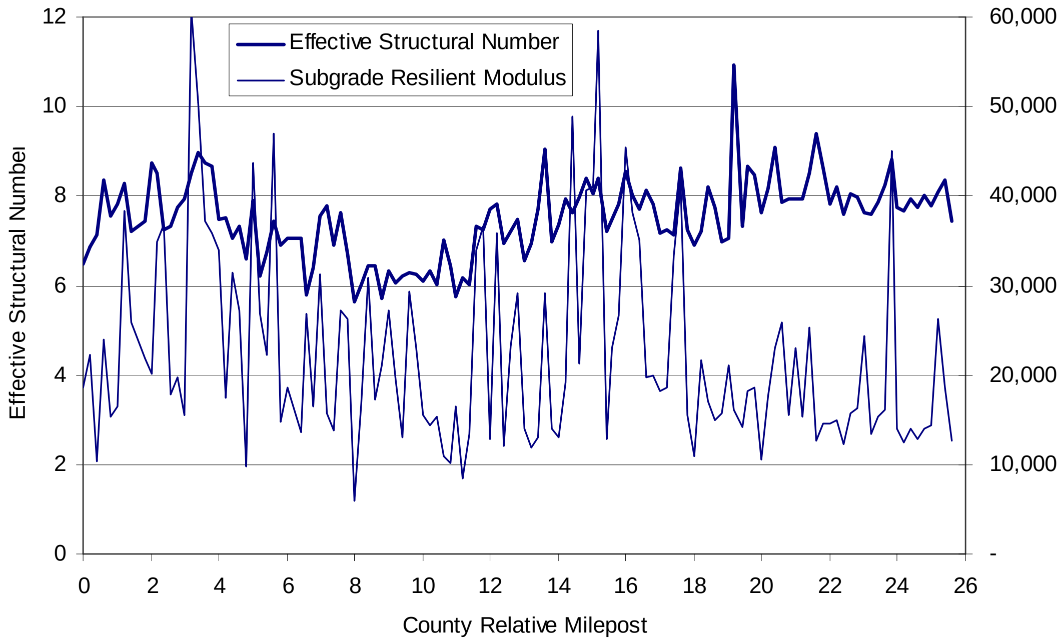

Figure C.66. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-81, Frederick County (Maintenance Jurisdiction 034)

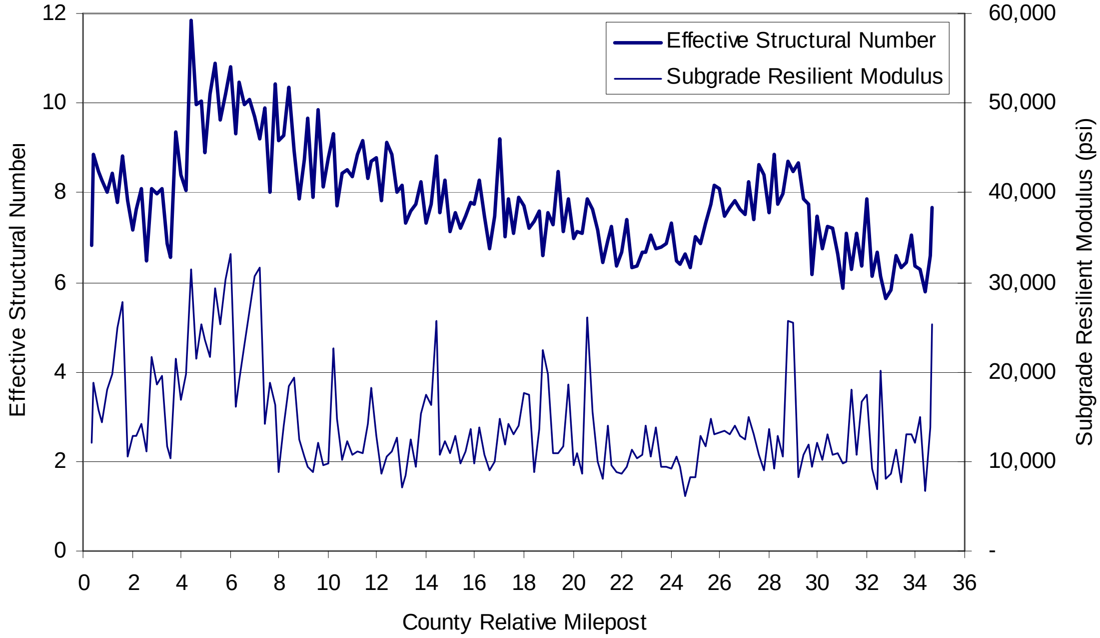

Figure C.67. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Washington County (Maintenance Jurisdiction 095)

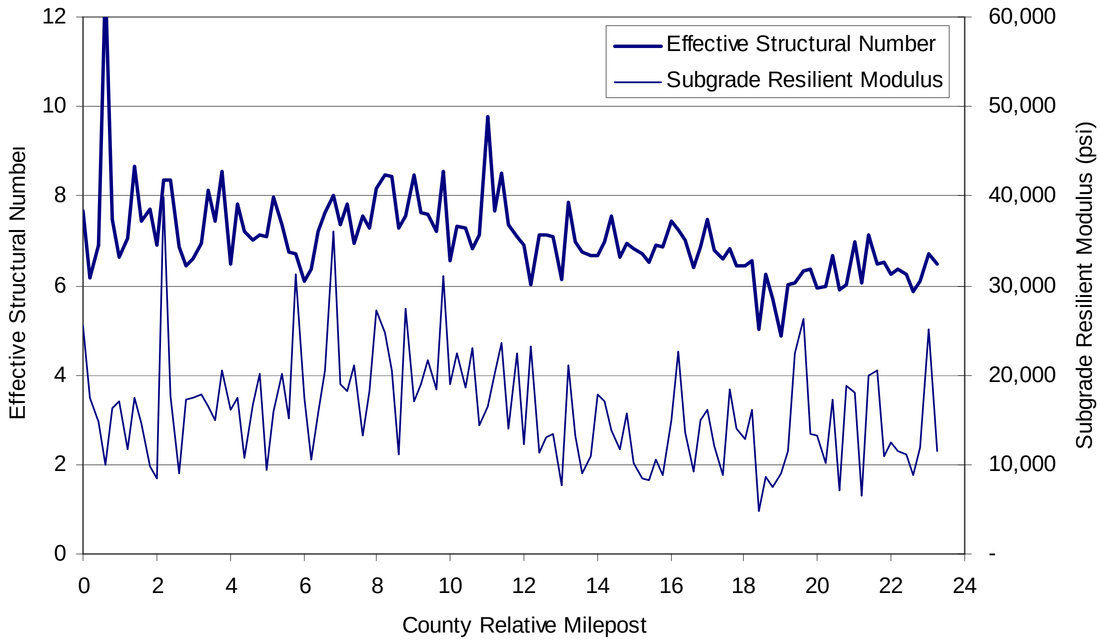

Figure C.68. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Smyth County (Maintenance Jurisdiction 086)

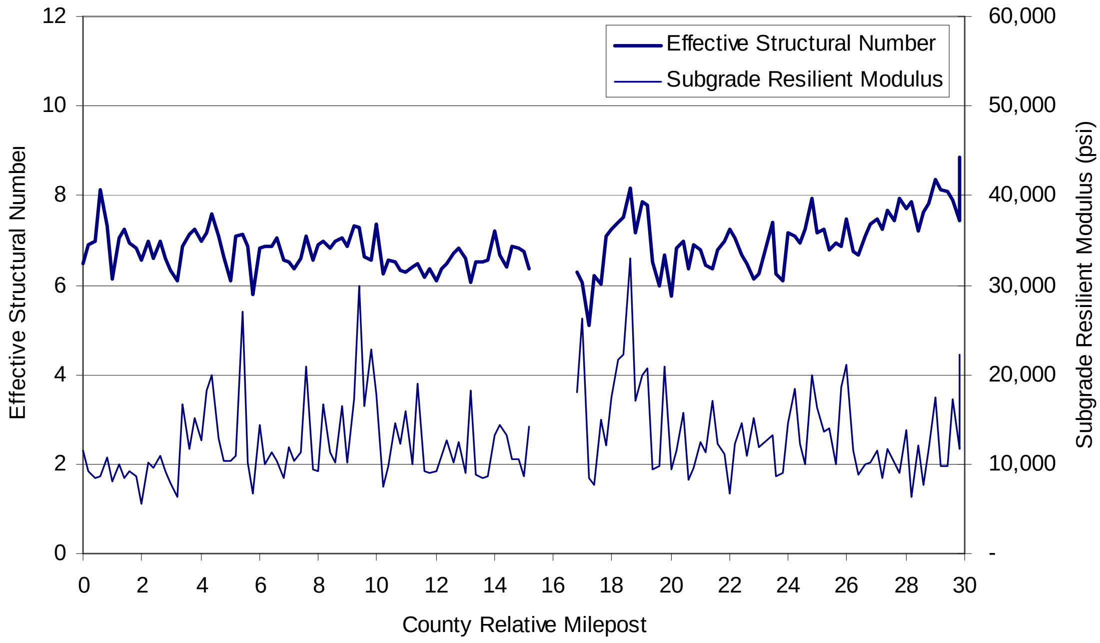

Figure C.69. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Wythe County (Maintenance Jurisdiction 098)

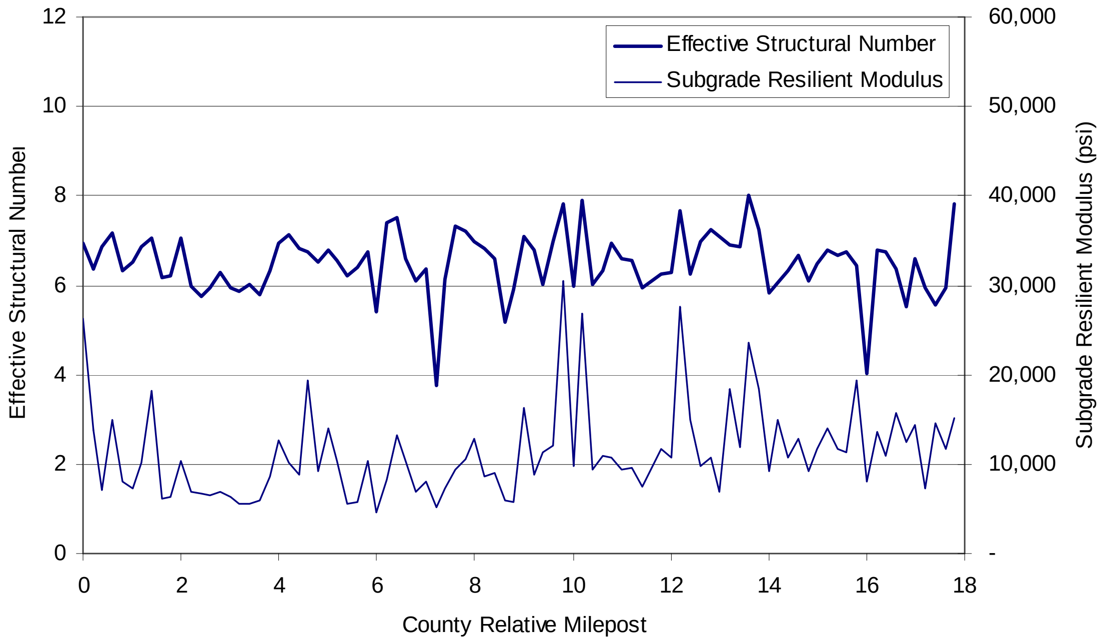

Figure C.70. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Pulaski County (Maintenance Jurisdiction 077)

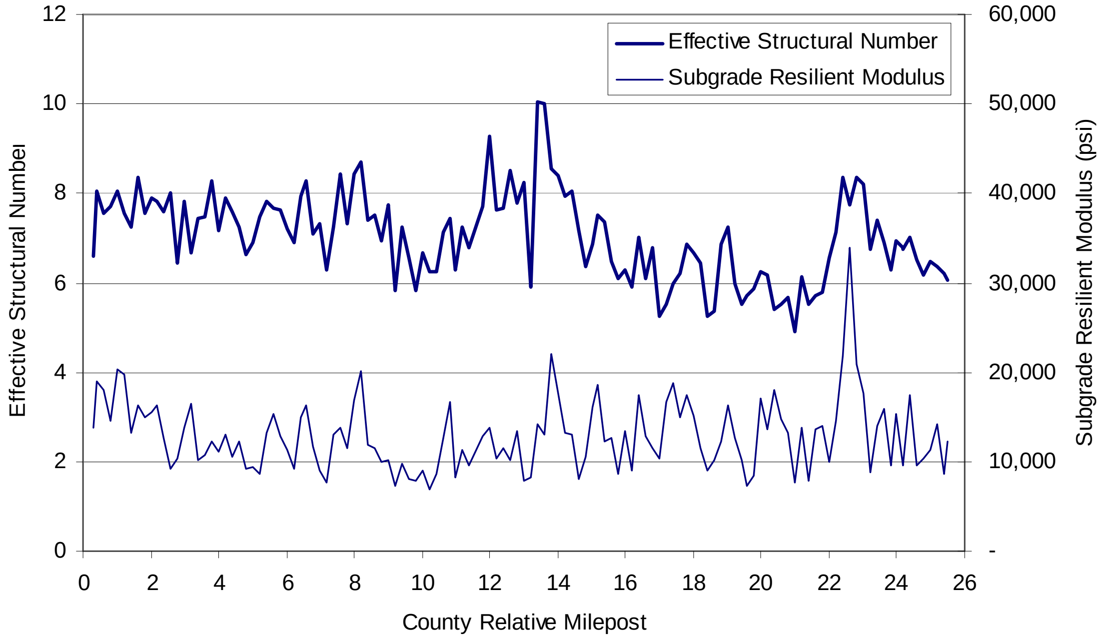

Figure C.71. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Montgomery County (Maintenance Jurisdiction 060)

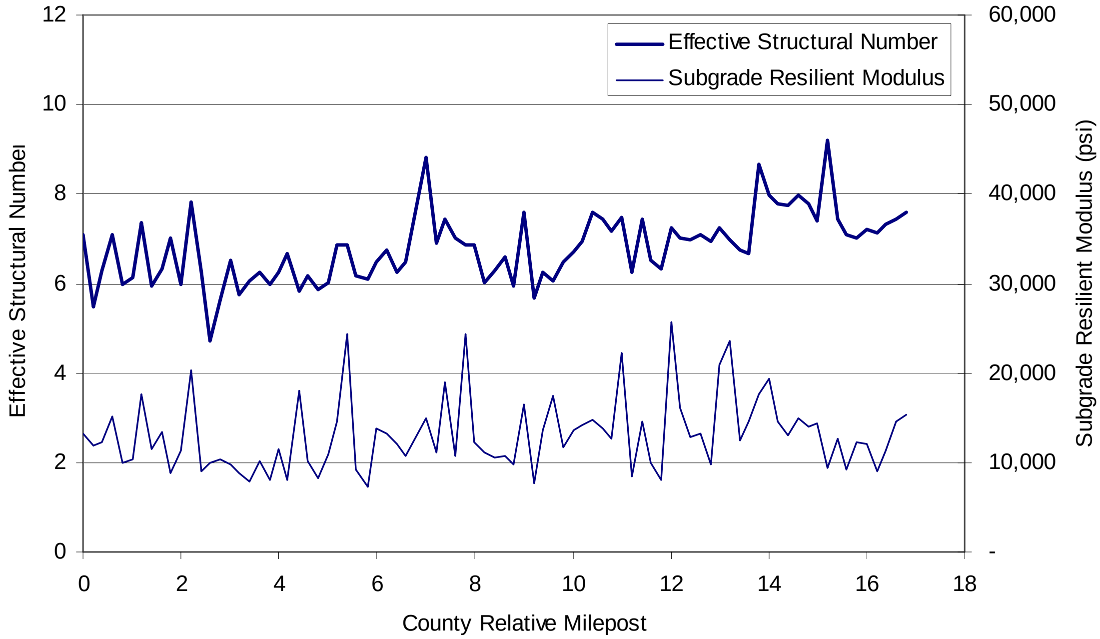

Figure C.72. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Roanoke County (Maintenance Jurisdiction 080)

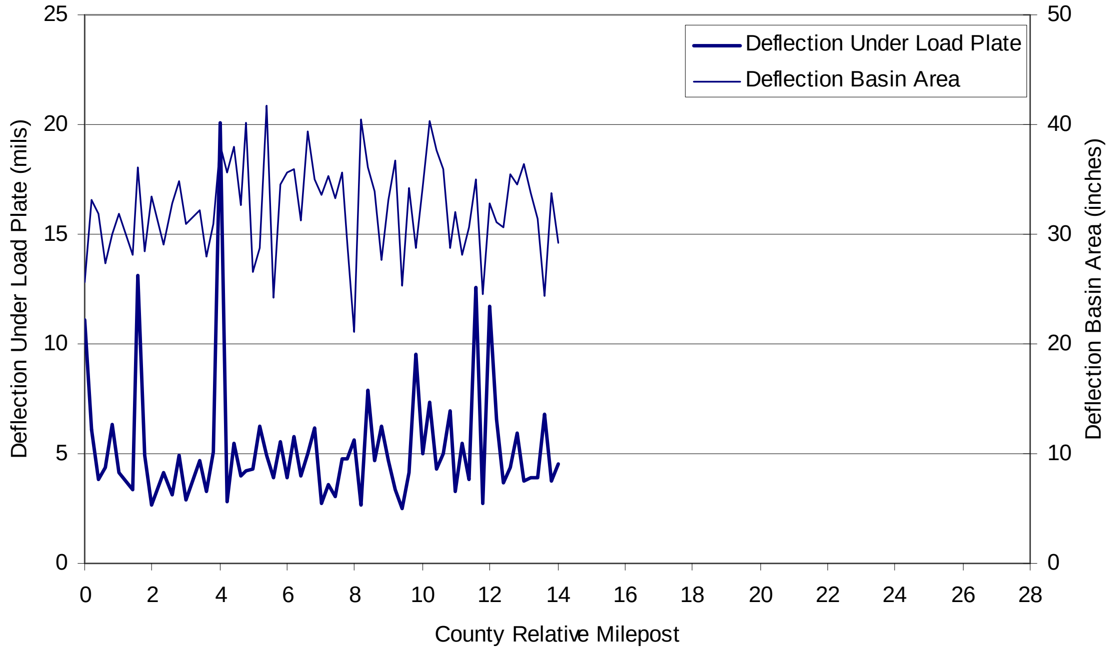

Figure C.73. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-81, Botetourt County (Maintenance Jurisdiction 011)

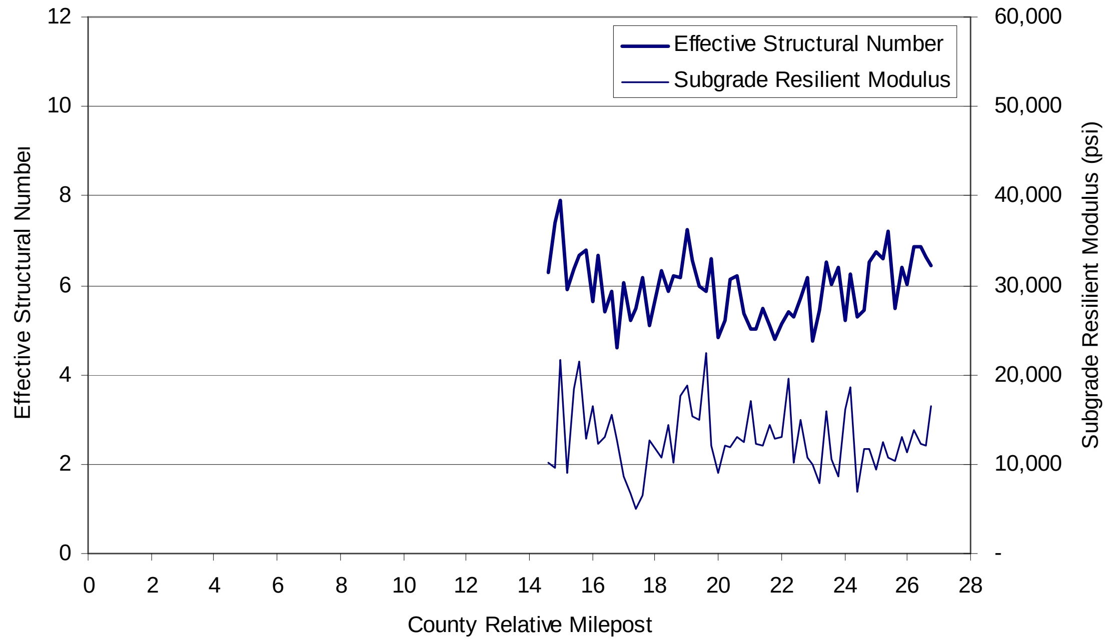

Figure C.74. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Botetourt County (Maintenance Jurisdiction 011)

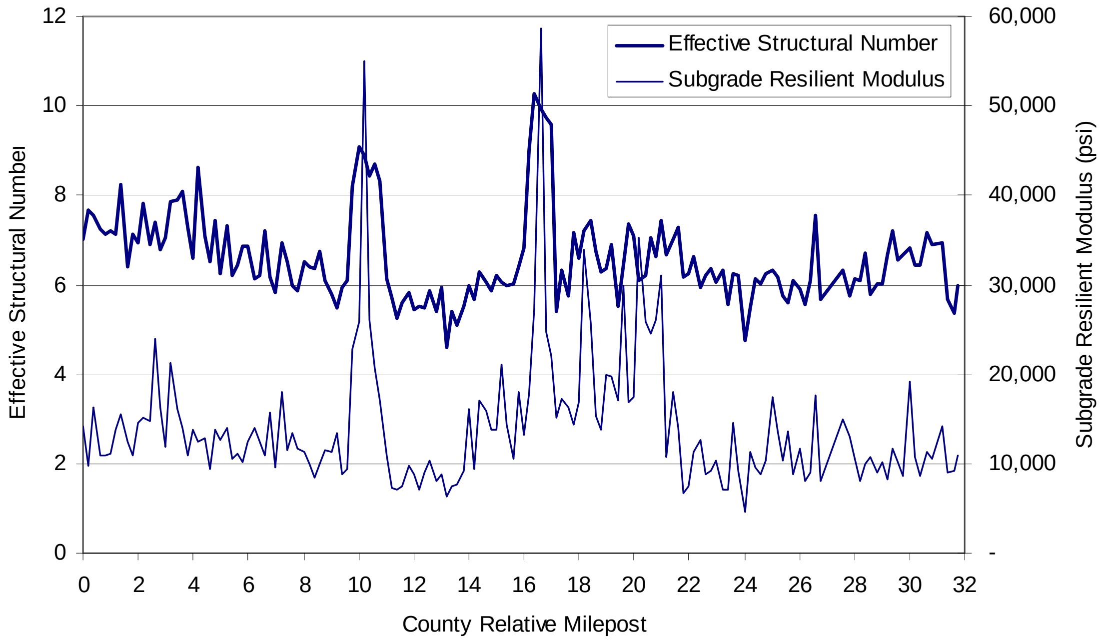

Figure C.75. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Rockbridge County (Maintenance Jurisdiction 081)

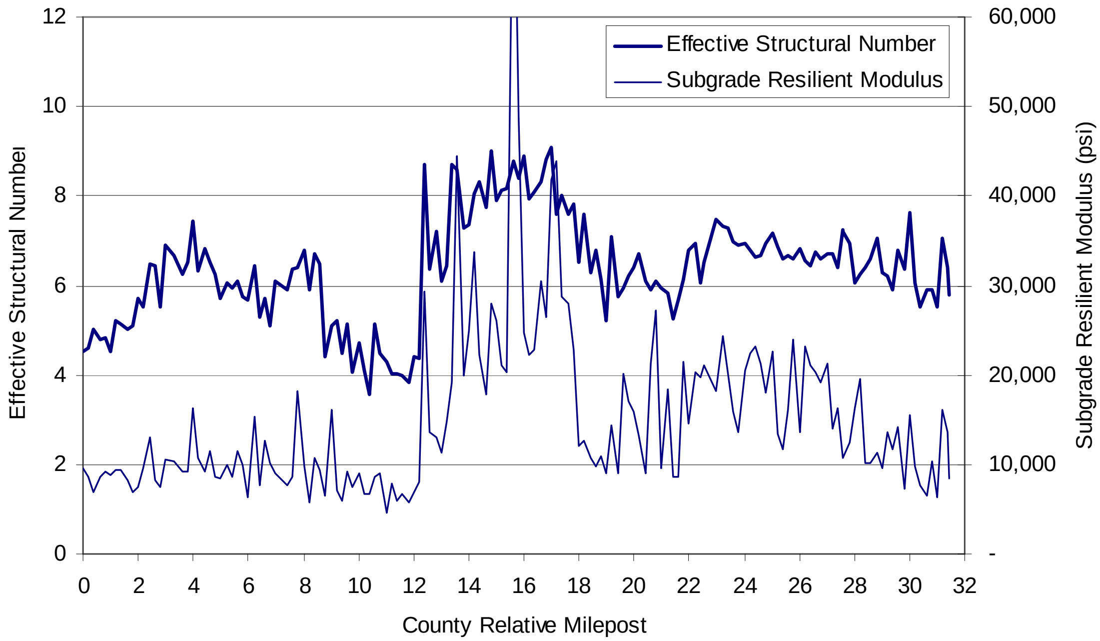

Figure C.76. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Augusta County (Maintenance Jurisdiction 007)

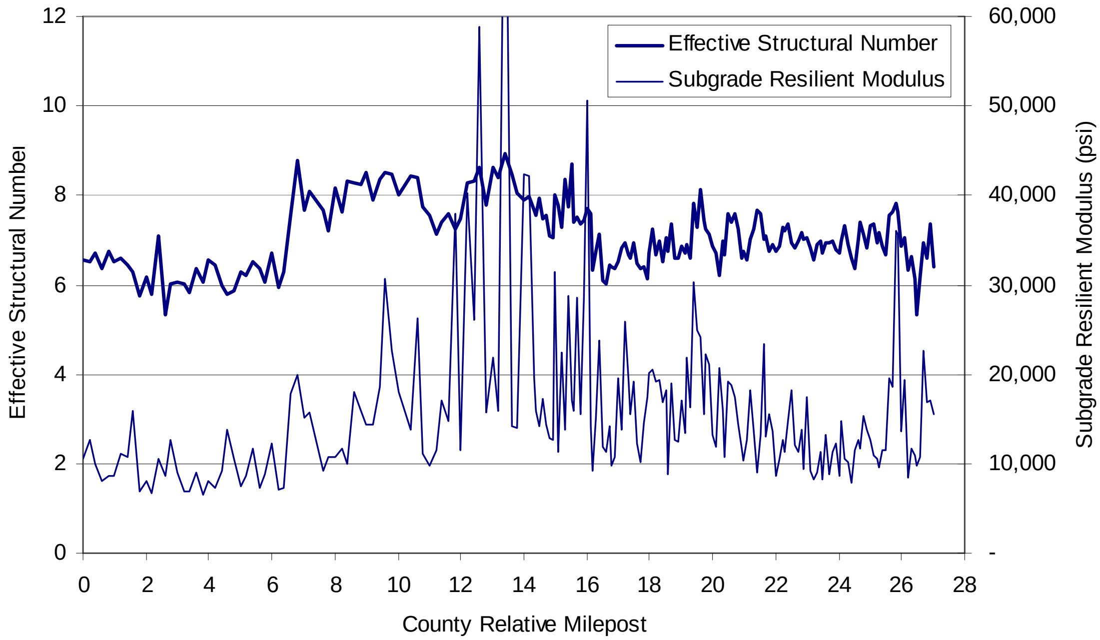

Figure C.77. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Rockingham County (Maintenance Jurisdiction 082)

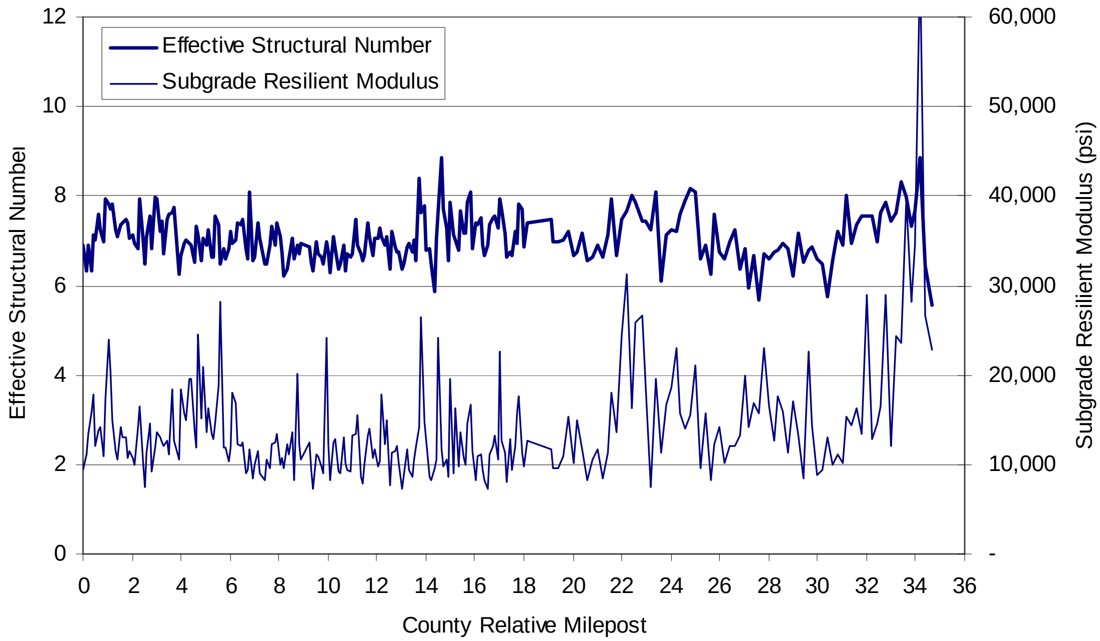

Figure C.78. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Shenandoah County (Maintenance Jurisdiction 085)

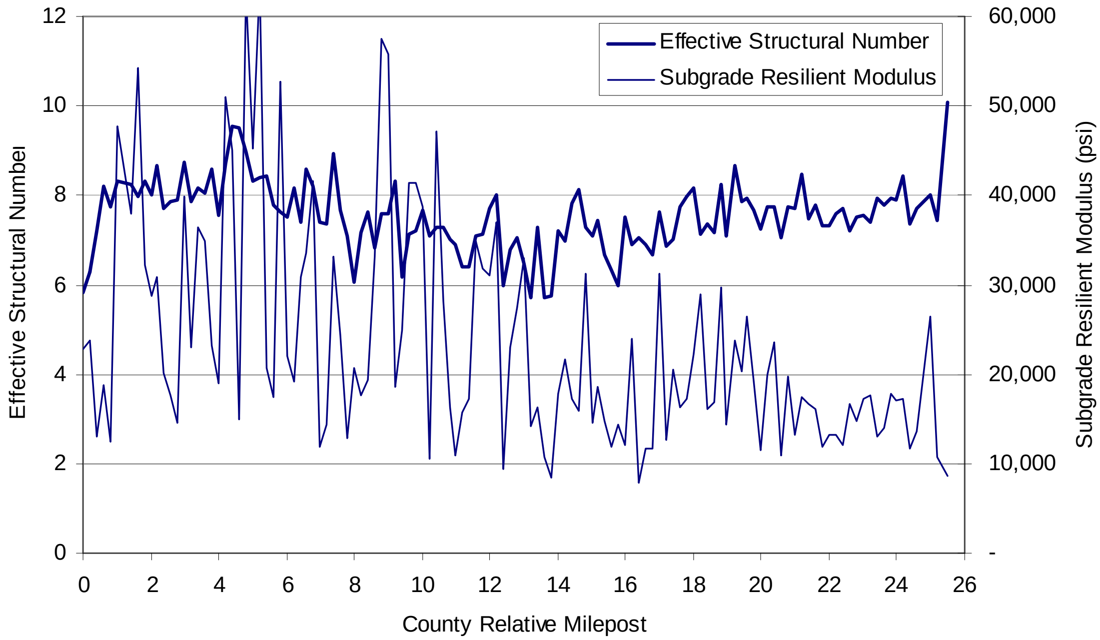

Figure C.79. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-81, Frederick County (Maintenance Jurisdiction 034)

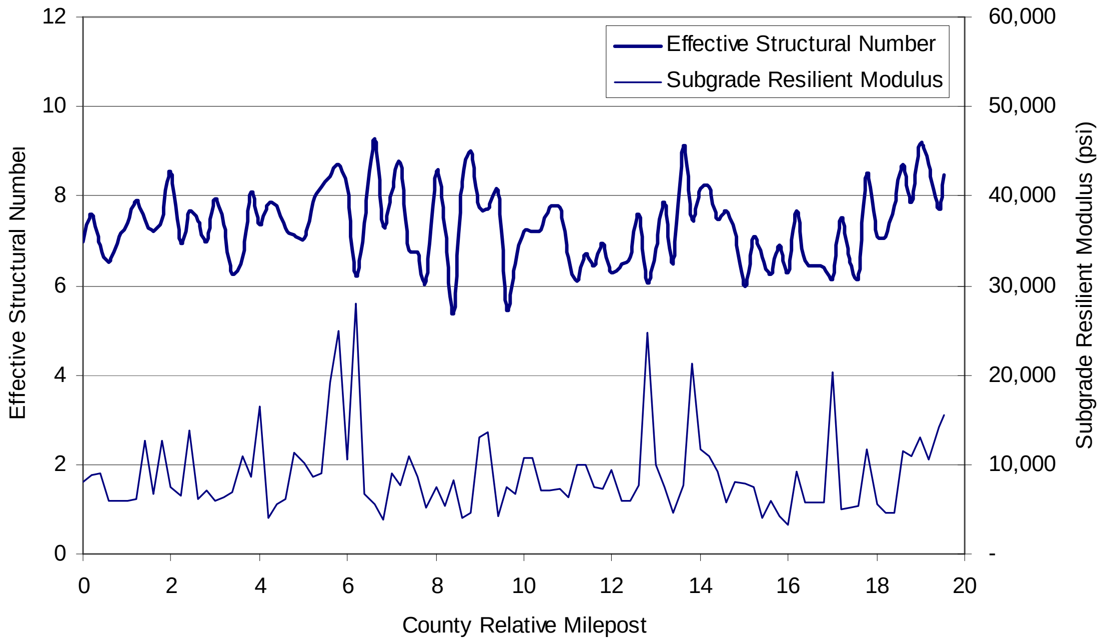

Figure C.80. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-85, Mecklenburg County (Maintenance Jurisdiction 058)

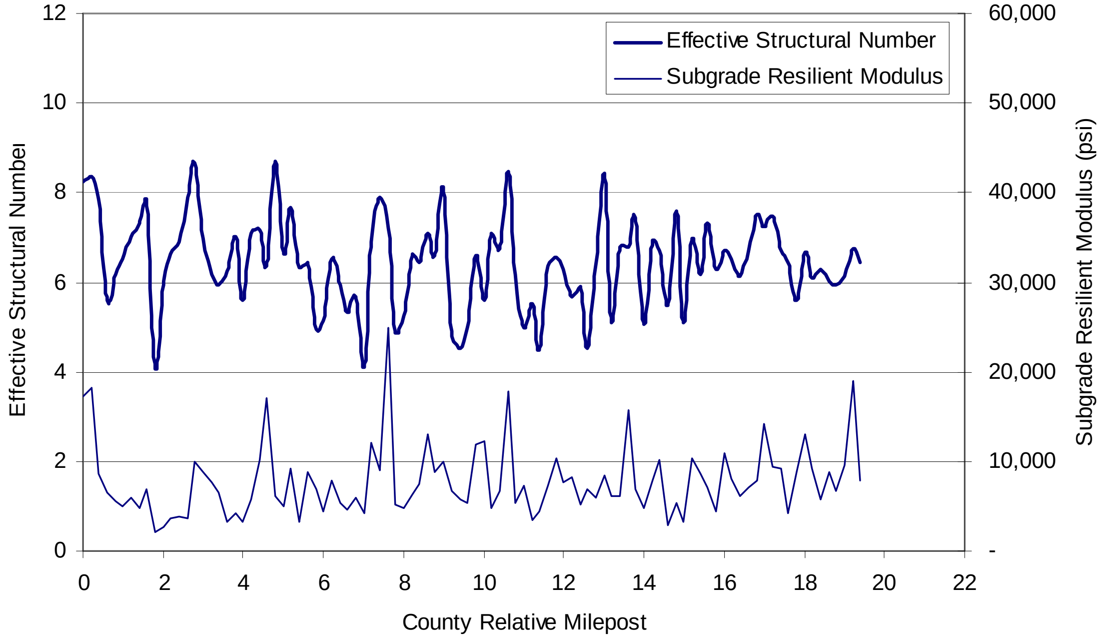

Figure C.81. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-85, Brunswick County (Maintenance Jurisdiction 012)

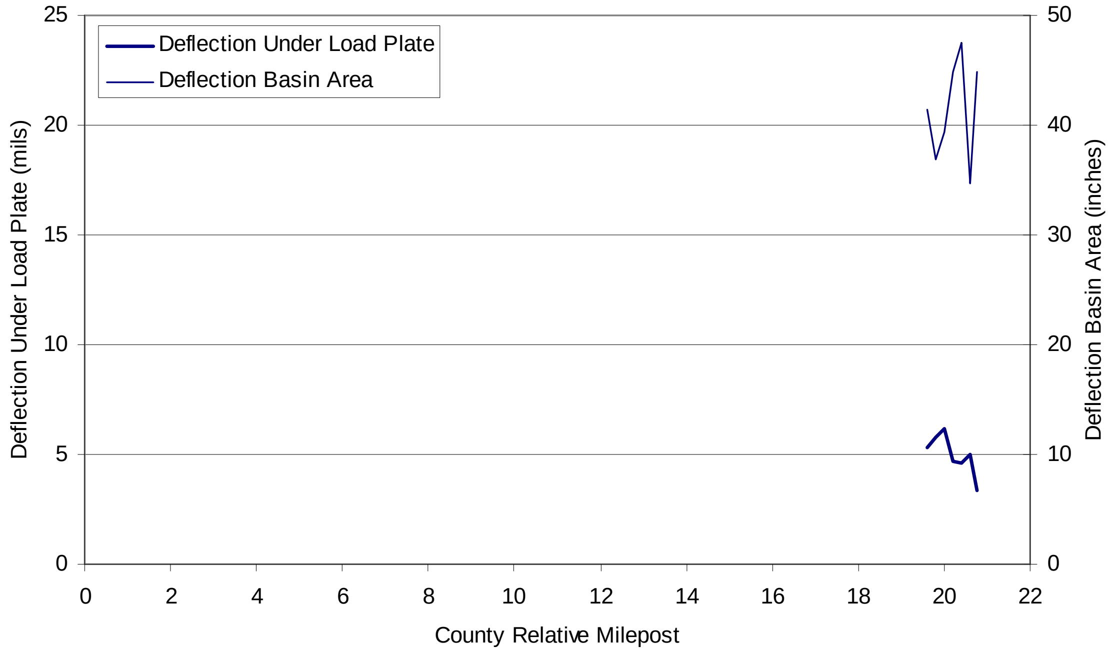

Figure C.82. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-85, Brunswick County (Maintenance Jurisdiction 012)

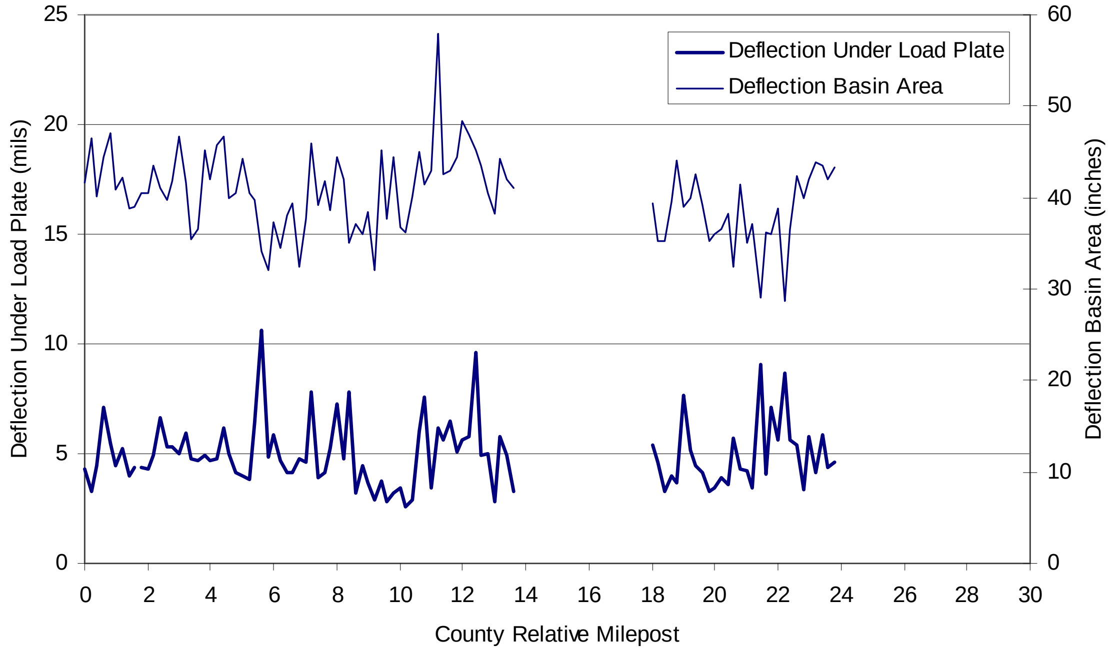

Figure C.83. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-85, Dinwiddie County (Maintenance Jurisdiction 026)

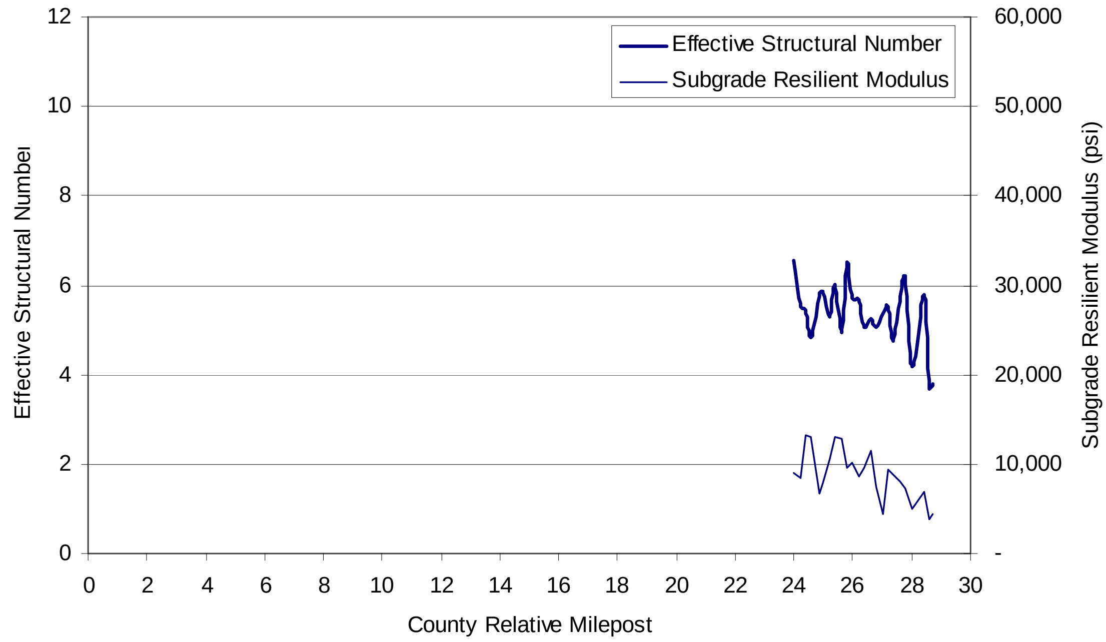

Figure C.84. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-85, Dinwiddie County (Maintenance Jurisdiction 026)

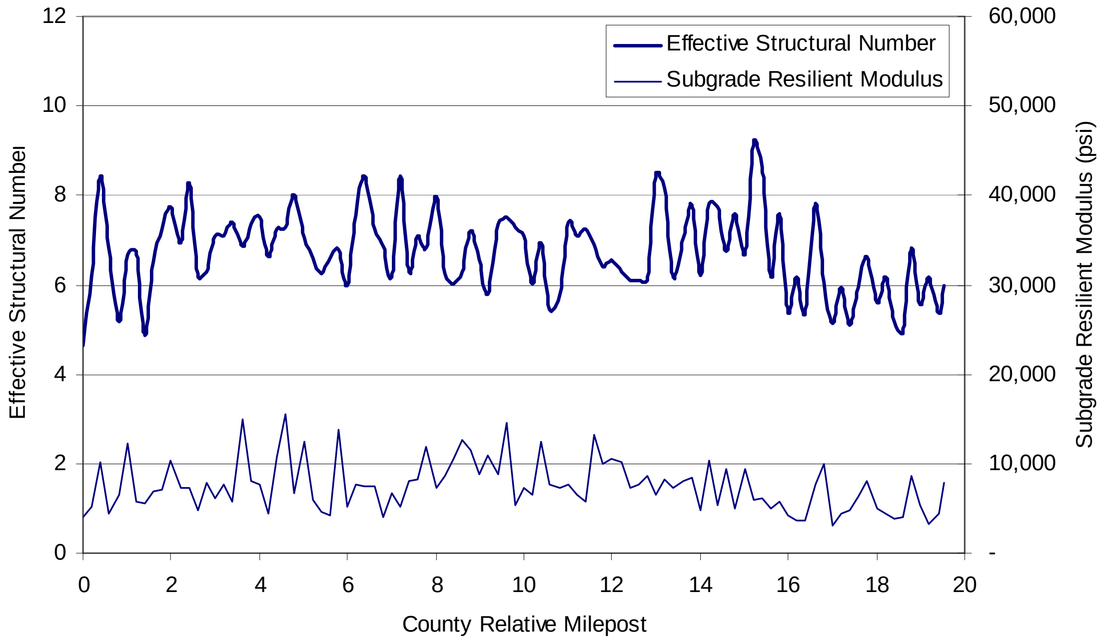

Figure C.85. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-85, Mecklenburg County (Maintenance Jurisdiction 058)

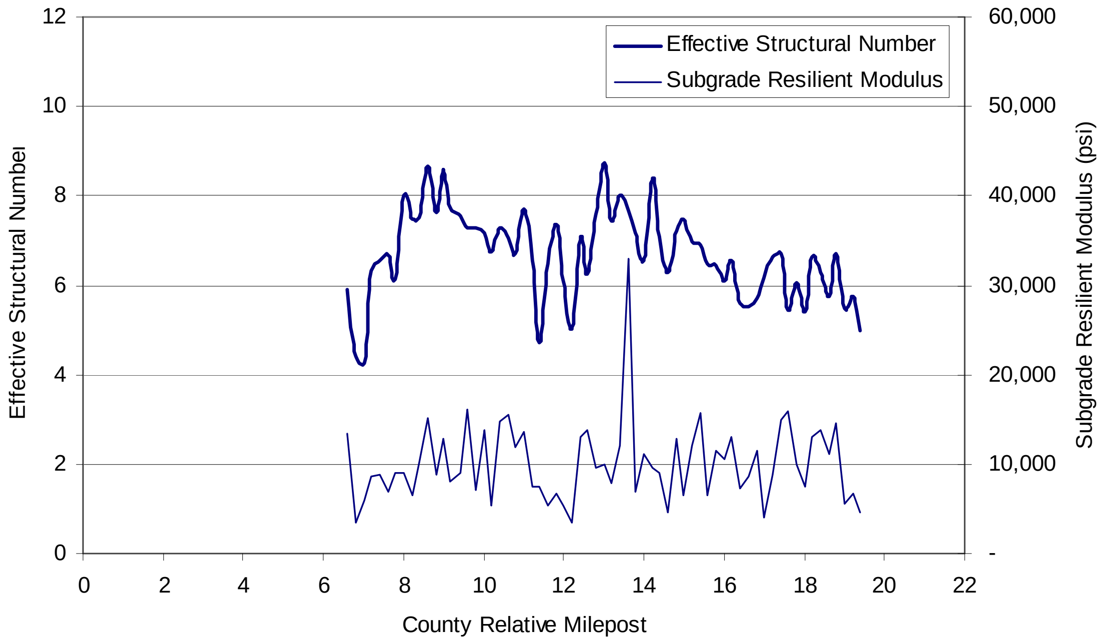

Figure C.86. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-85, Brunswick County (Maintenance Jurisdiction 012)

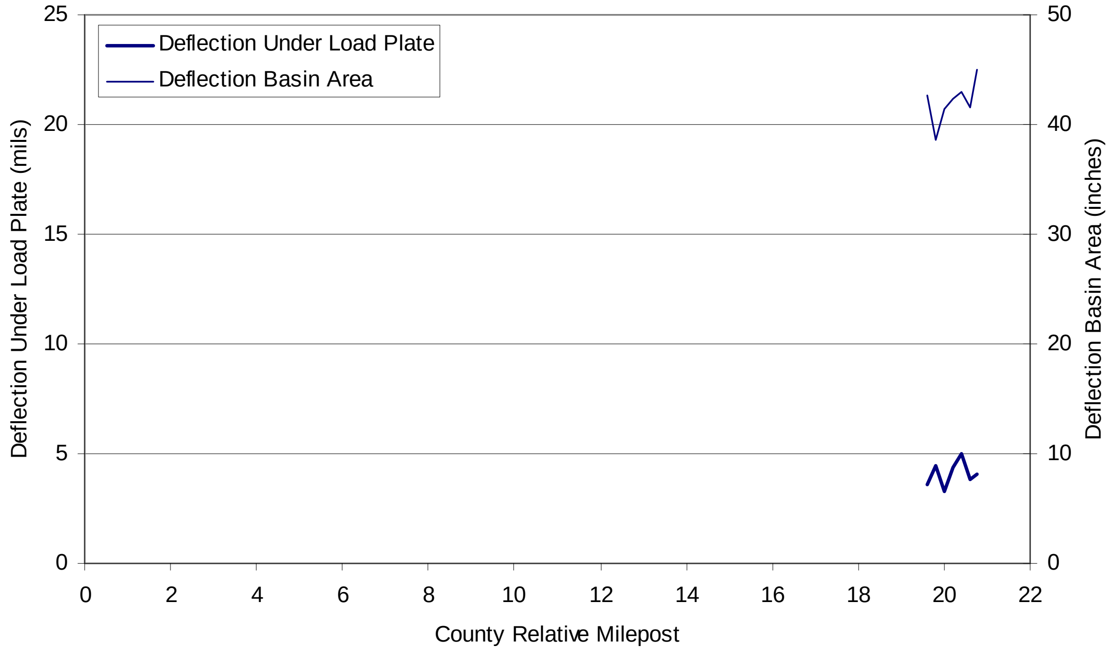

Figure C.87. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-85, Brunswick County (Maintenance Jurisdiction 012)

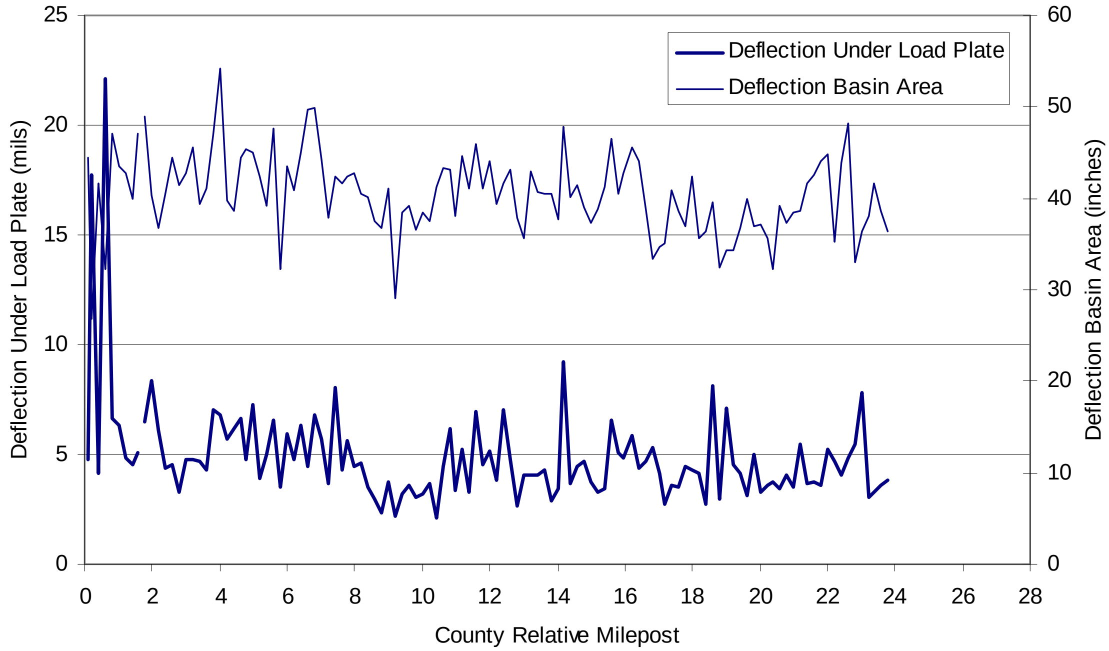

Figure C.88. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-85, Dinwiddie County (Maintenance Jurisdiction 026)

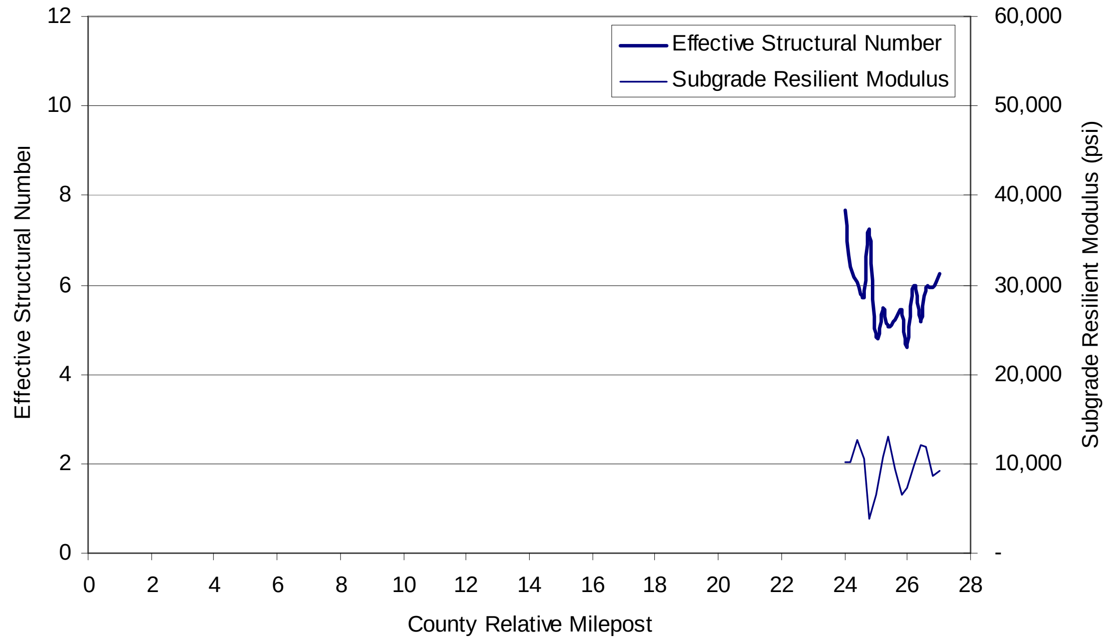

Figure C.89. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-85, Dinwiddie County (Maintenance Jurisdiction 026)

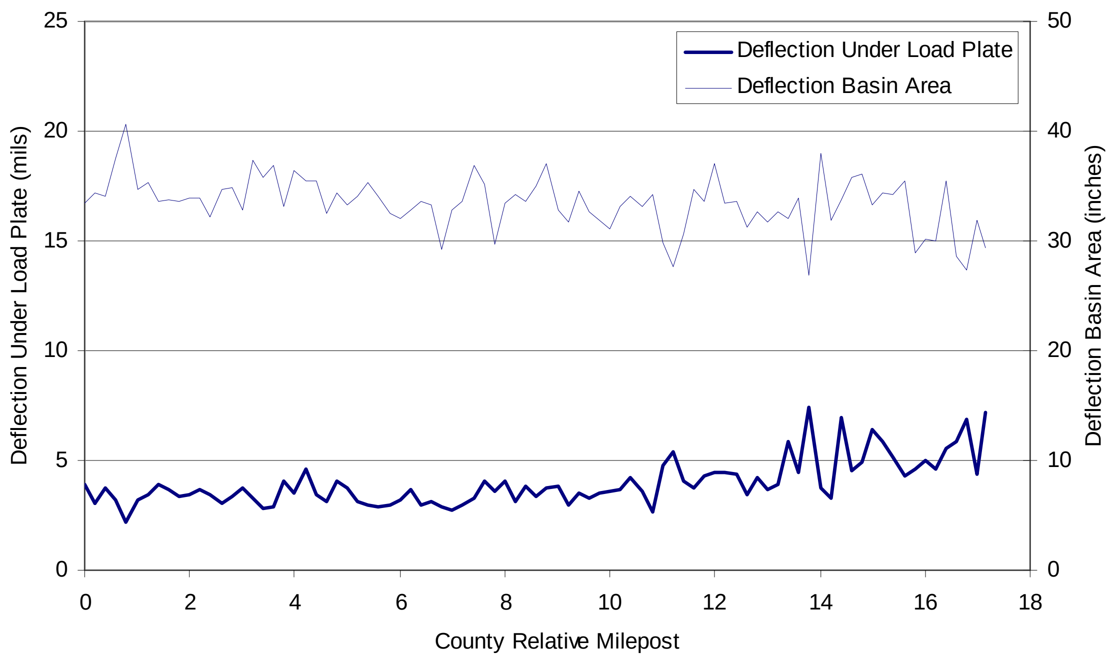

Figure C.90. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Greensville County (Maintenance Jurisdiction 040)

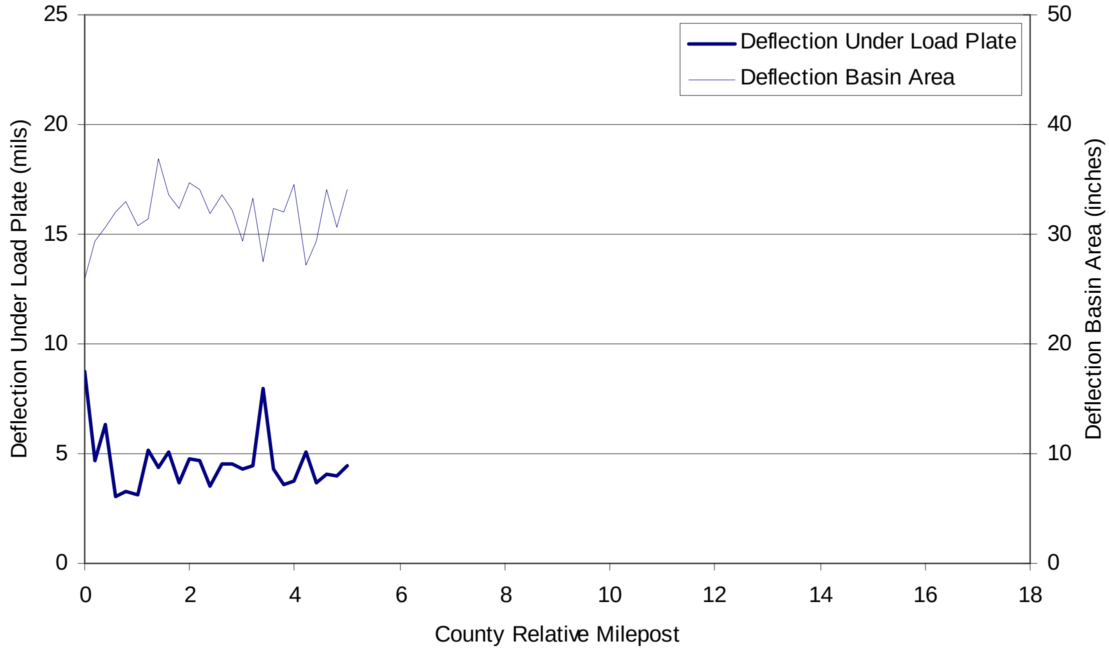

Figure C.91. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Sussex County (Maintenance Jurisdiction 091)

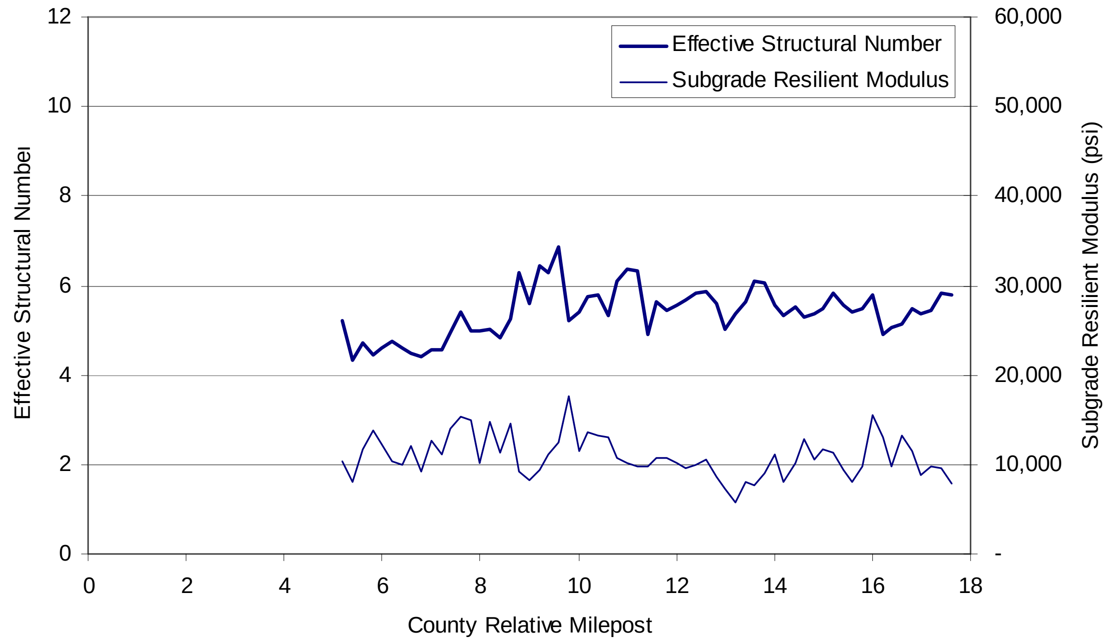

Figure C.92. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Sussex County (Maintenance Jurisdiction 091)

Figure C.93. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Prince George County (Maintenance Jurisdiction 074)

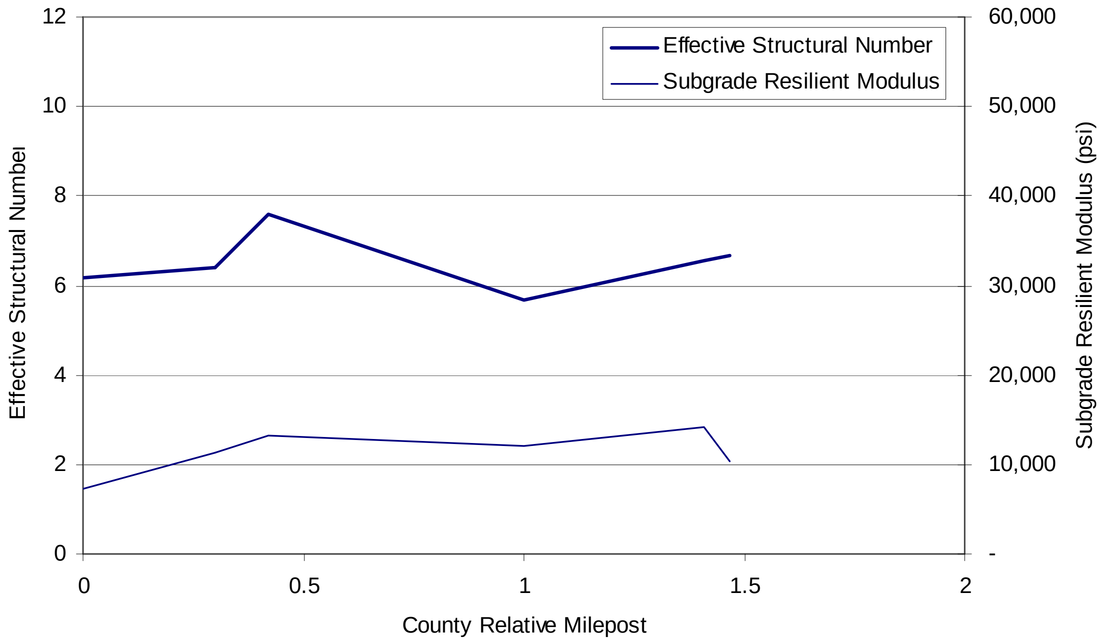

Figure C.94. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Dinwiddie County (Maintenance Jurisdiction 026)

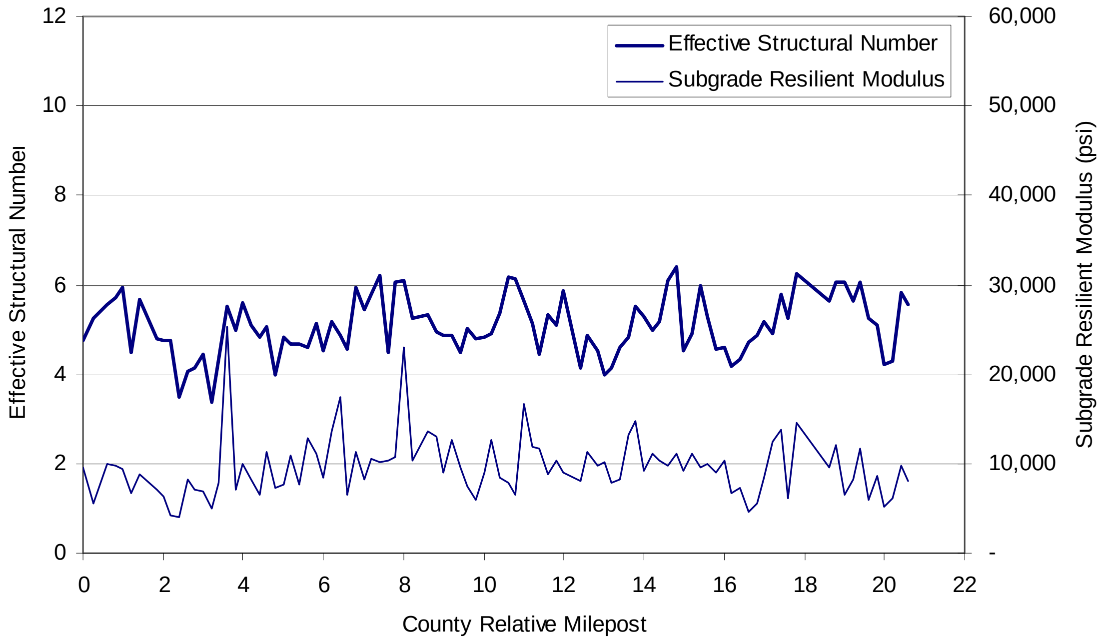

Figure C.95. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Chesterfield County (Maintenance Jurisdiction 020)

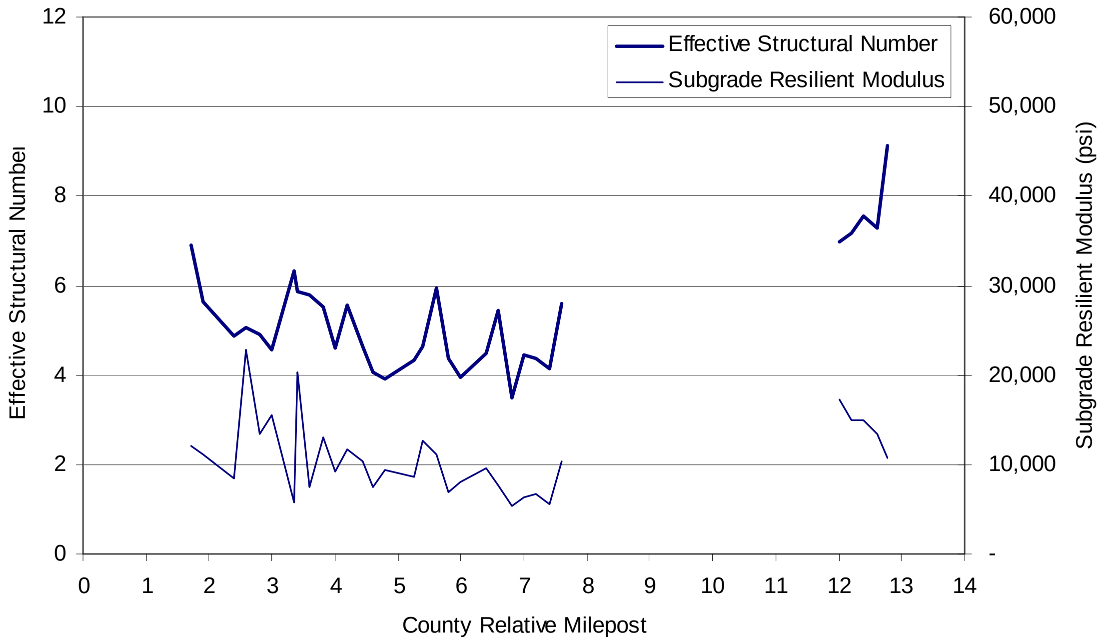

Figure C.96. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Henrico County (Maintenance Jurisdiction 043)

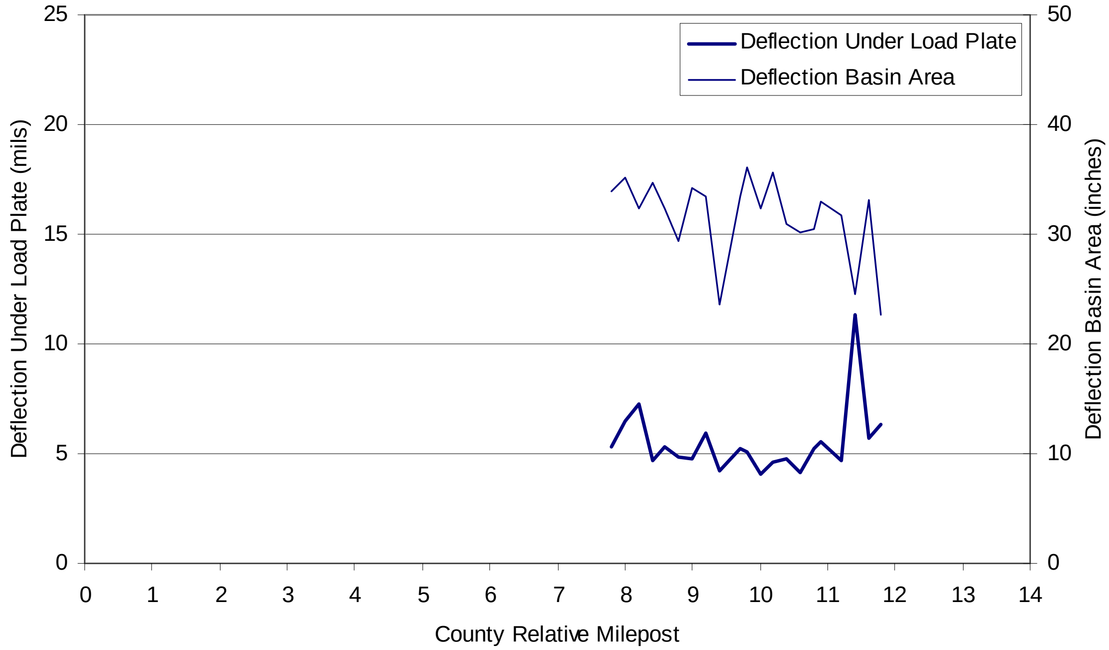

Figure C.97. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Henrico County (Maintenance Jurisdiction 043)

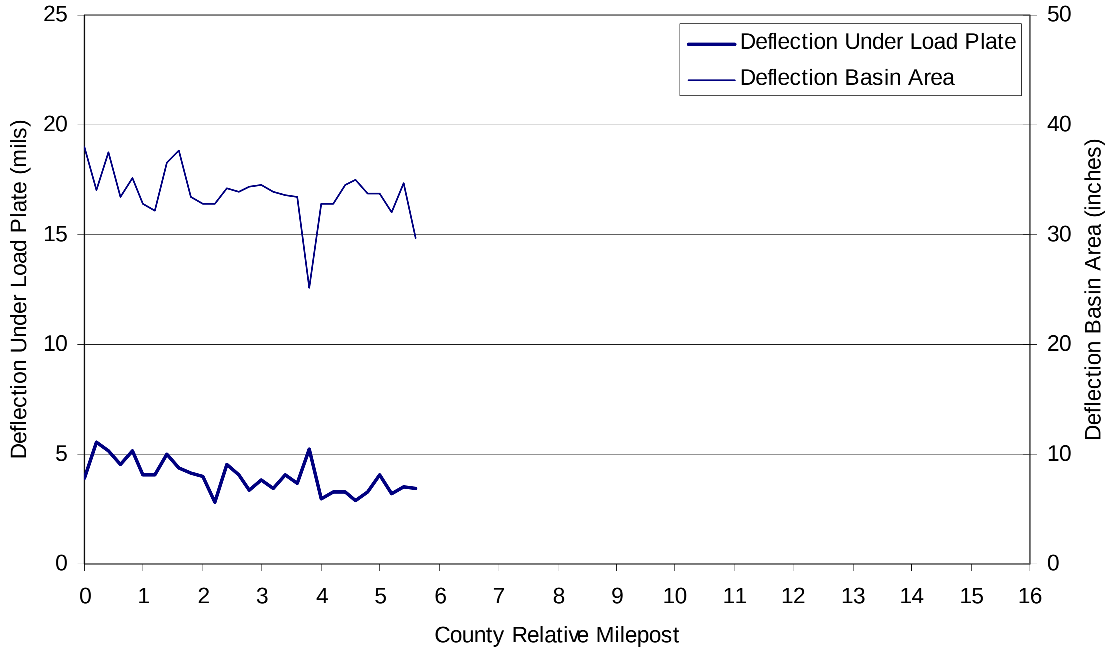

Figure C.98. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Hanover County (Maintenance Jurisdiction 042)

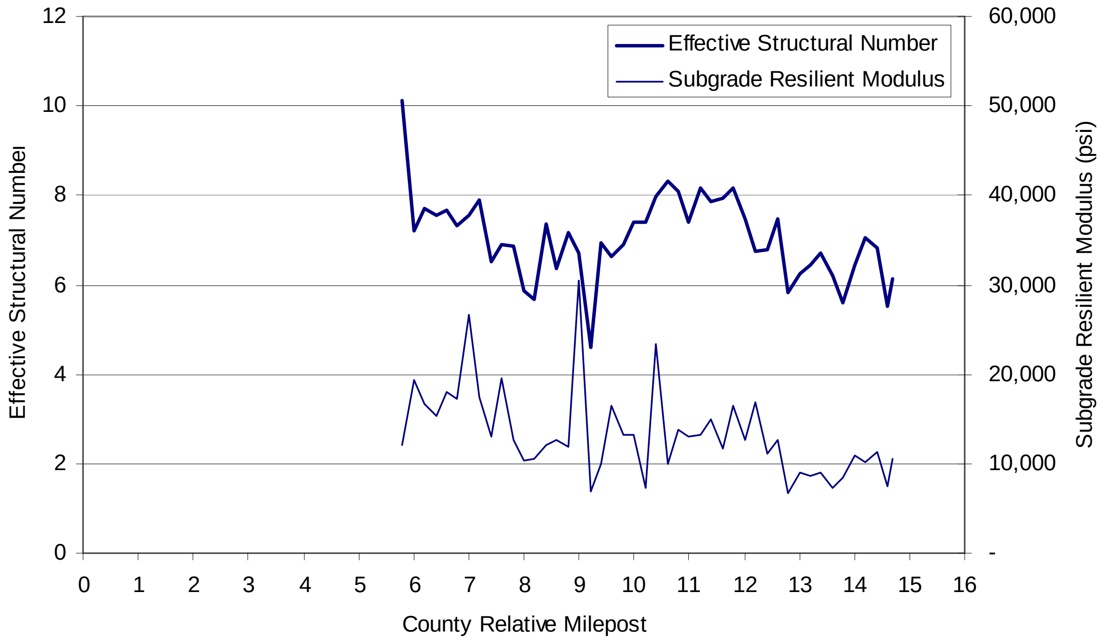

Figure C.99. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Hanover County (Maintenance Jurisdiction 042)

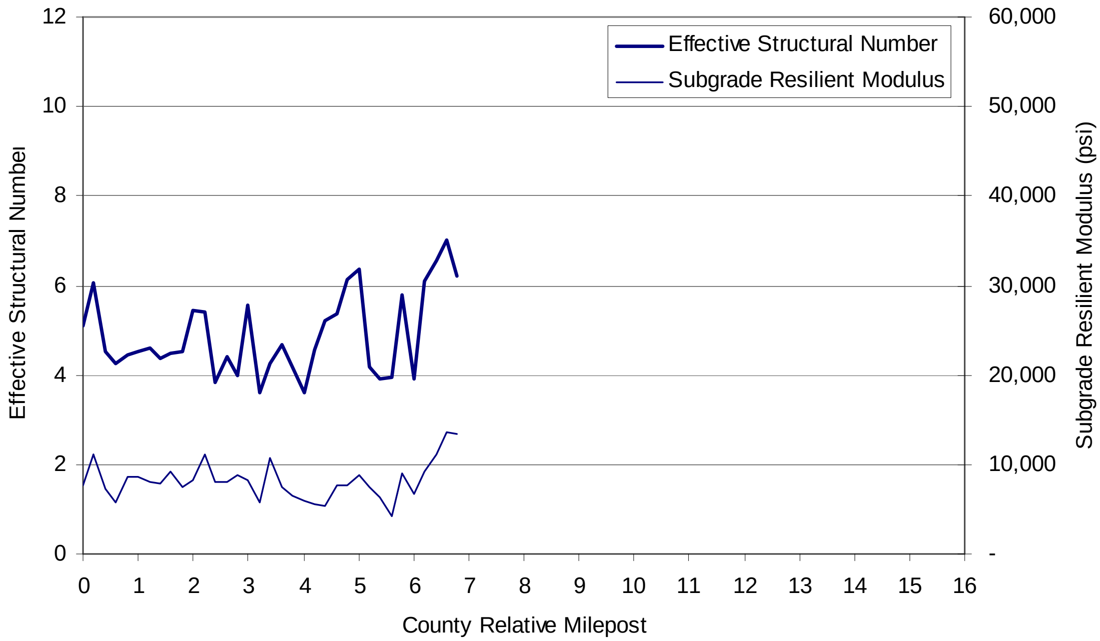

Figure C.100. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Caroline County (Maintenance Jurisdiction 016)

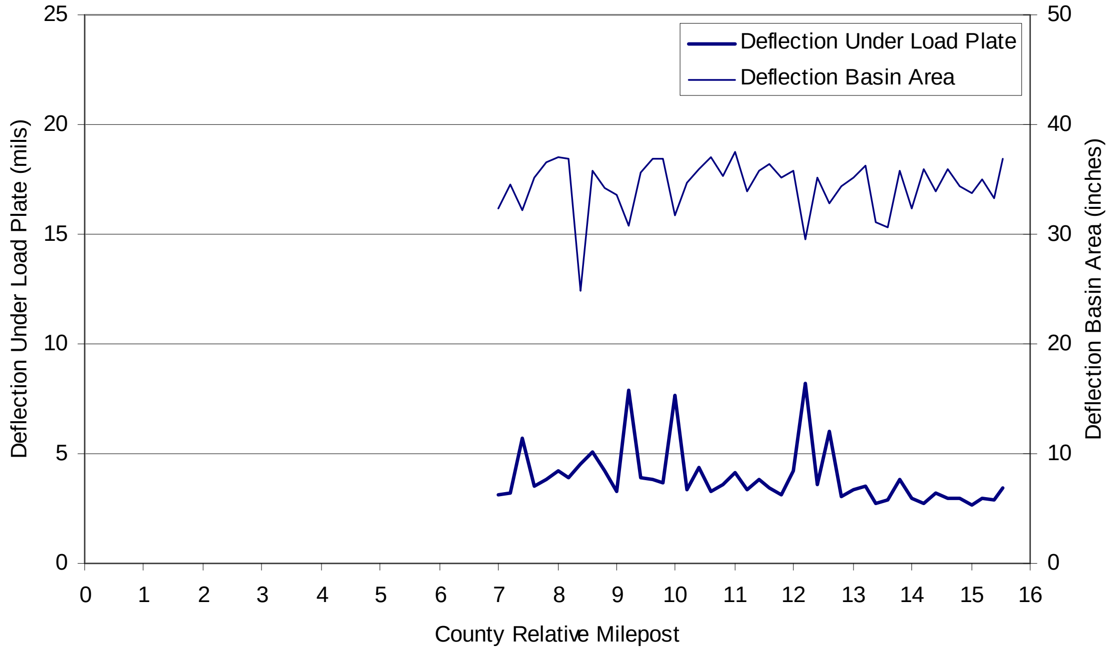

Figure C.101. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Caroline County (Maintenance Jurisdiction 016)

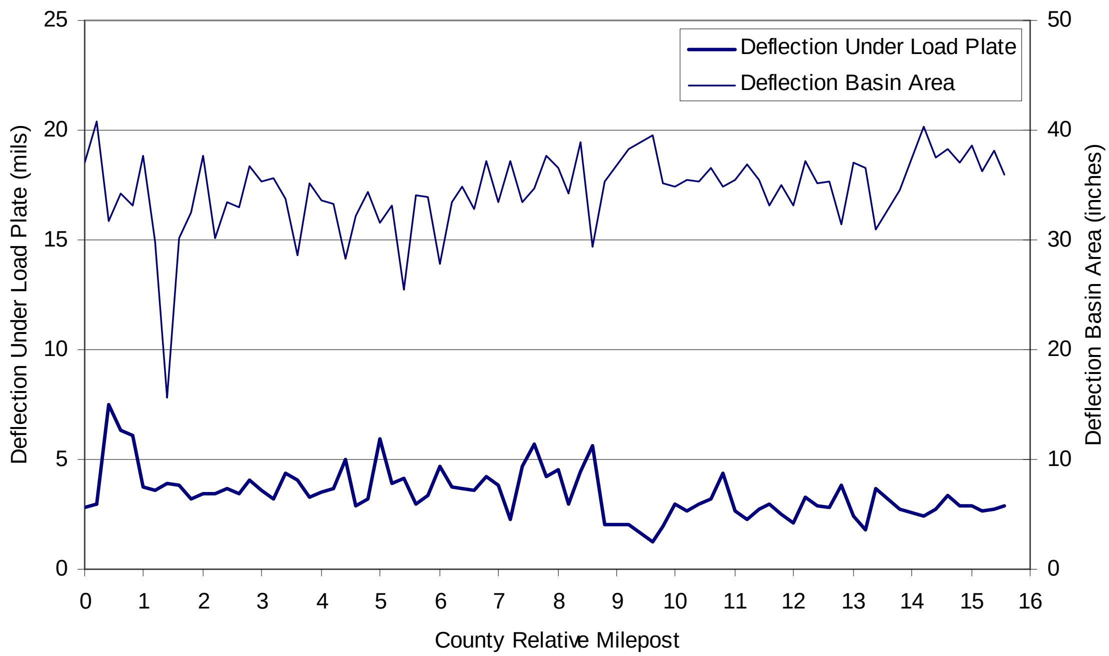

Figure C.102. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Spotsylvania County (Maintenance Jurisdiction 088)

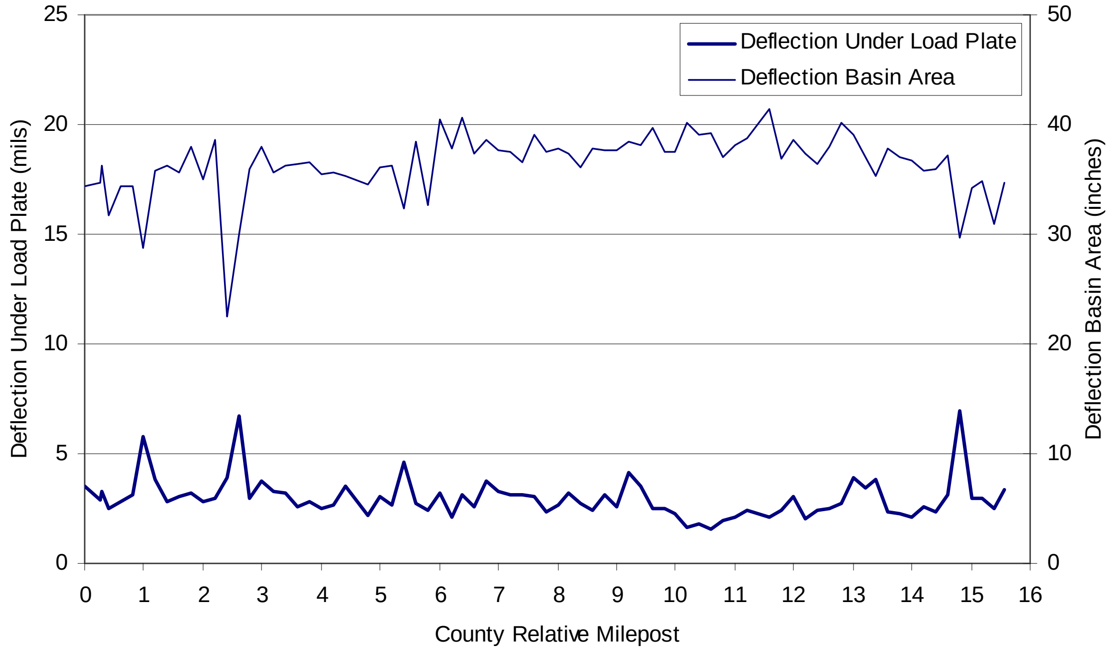

Figure C.103. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Stafford County (Maintenance Jurisdiction 089)

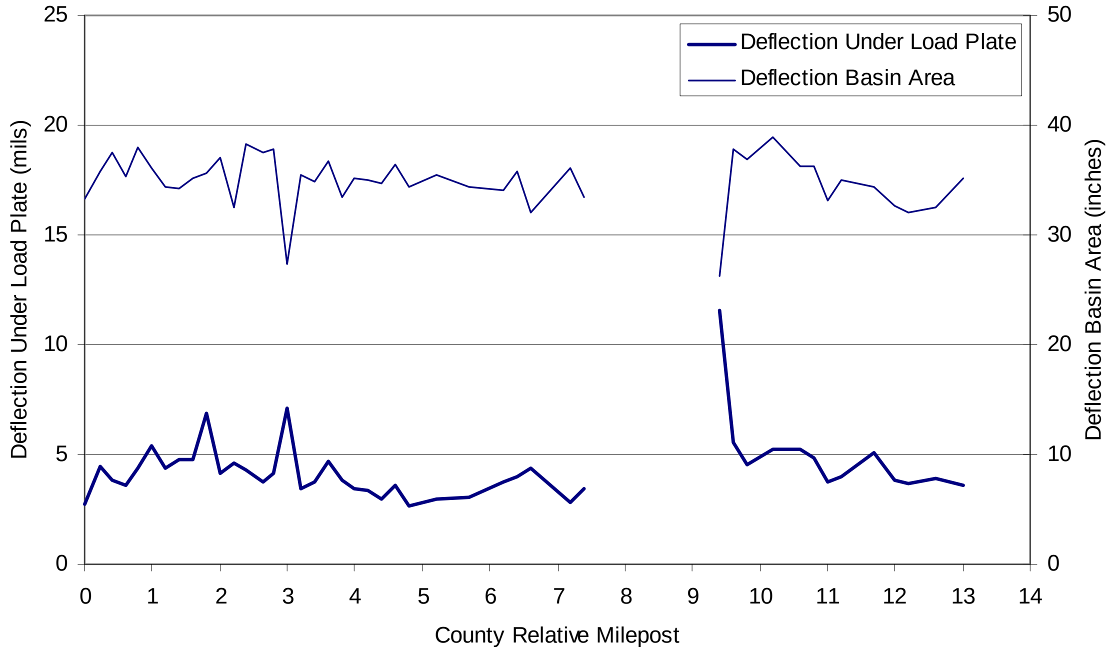

Figure C.104. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Prince William County (Maintenance Jurisdiction 076)

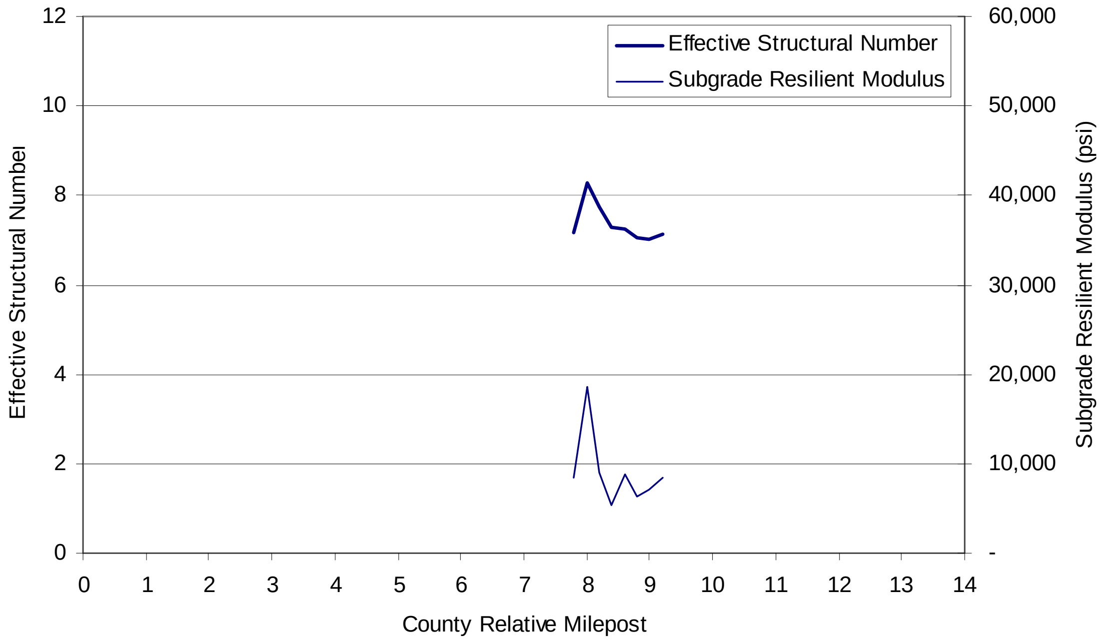

Figure C.105. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Prince William County (Maintenance Jurisdiction 076)

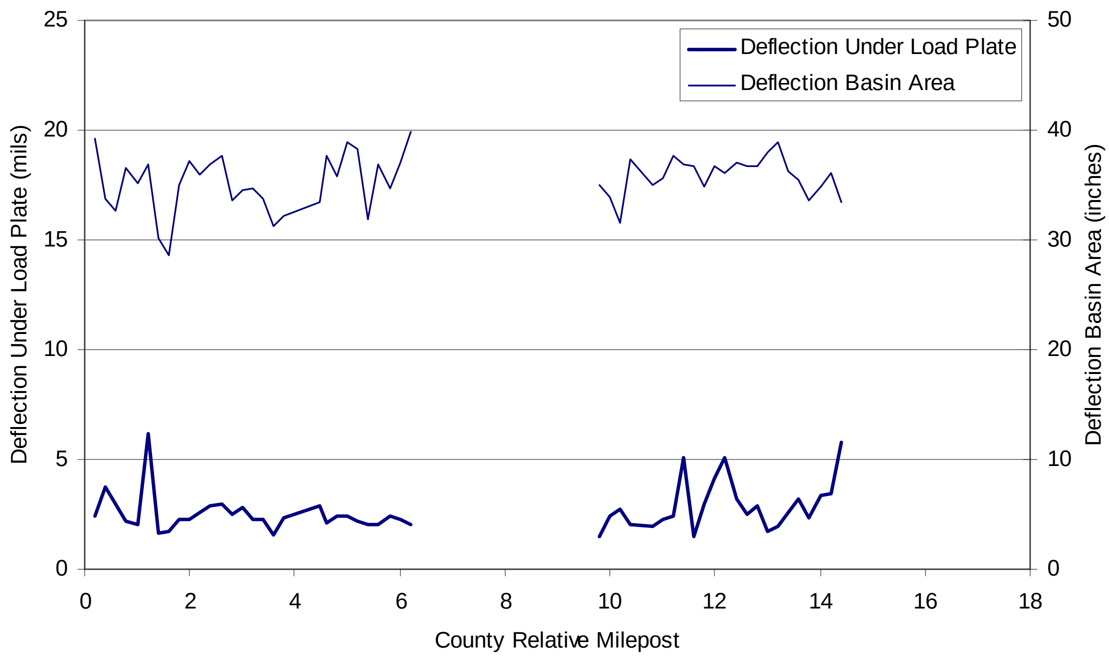

Figure C.106. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-95, Fairfax County (Maintenance Jurisdiction 029)

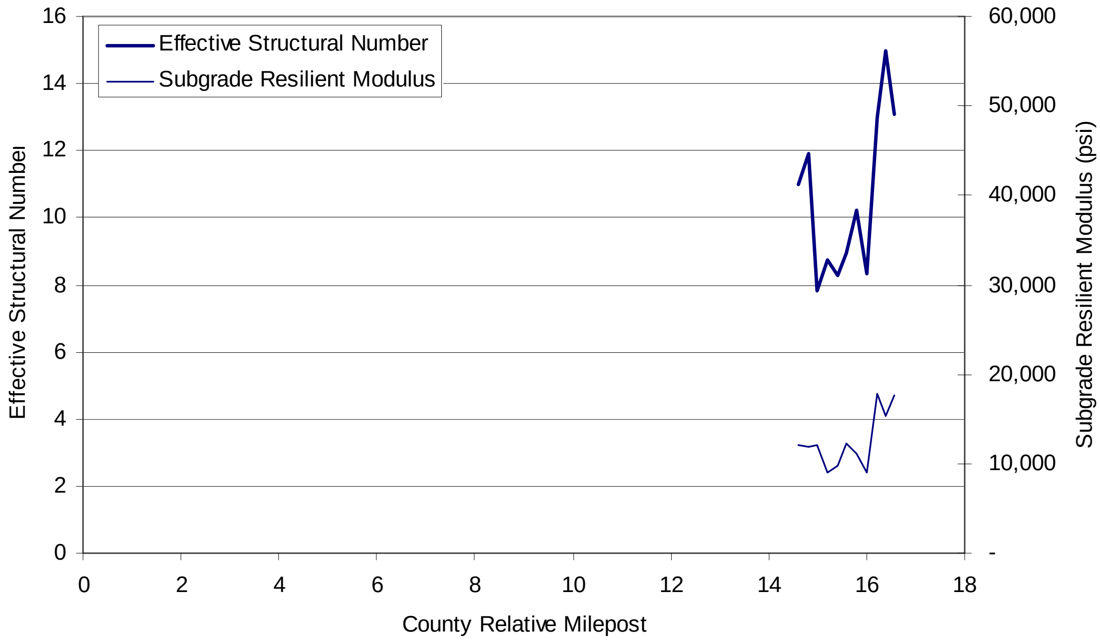

Figure C.107. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-95, Fairfax County (Maintenance Jurisdiction 029)

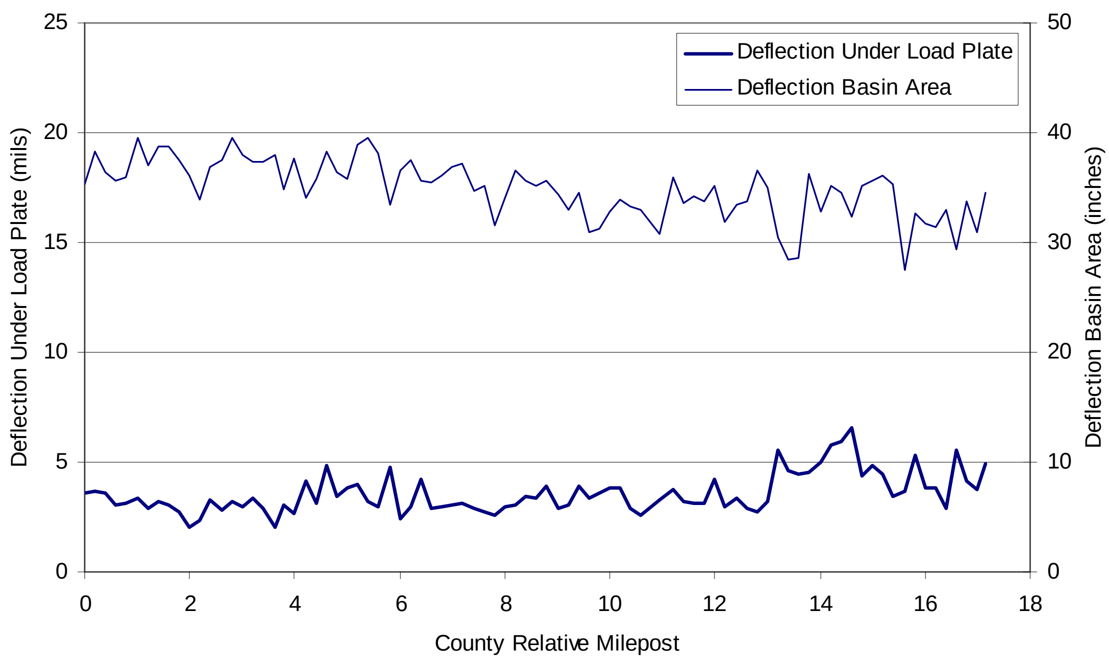

Figure C.108. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Greensville County (Maintenance Jurisdiction 040)

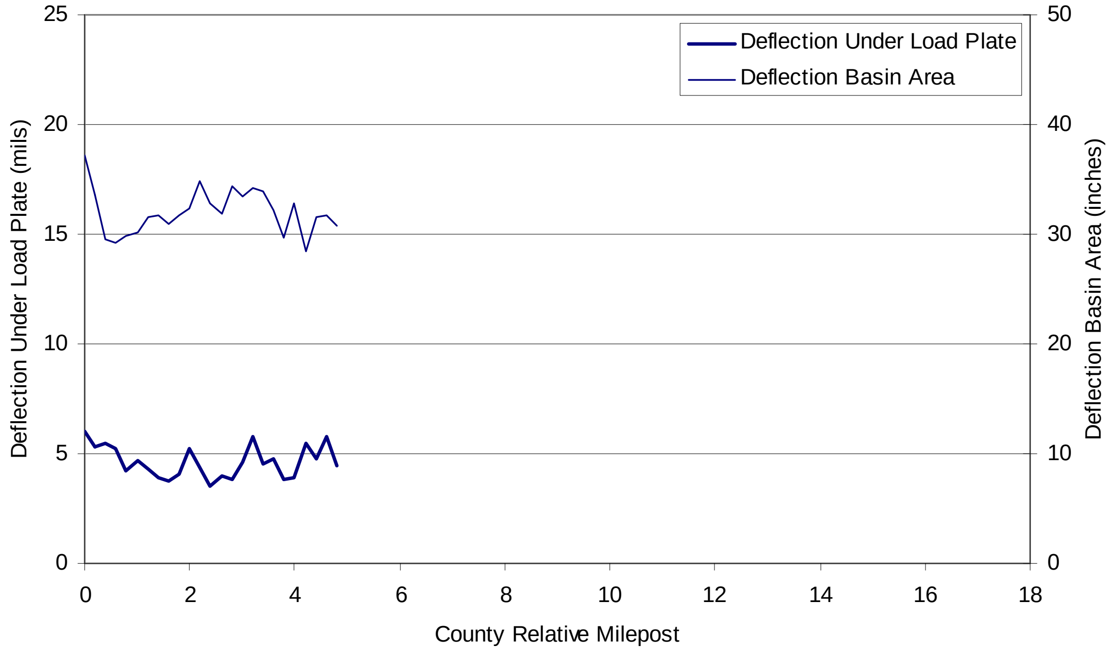

Figure C.109. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Sussex County (Maintenance Jurisdiction 091)

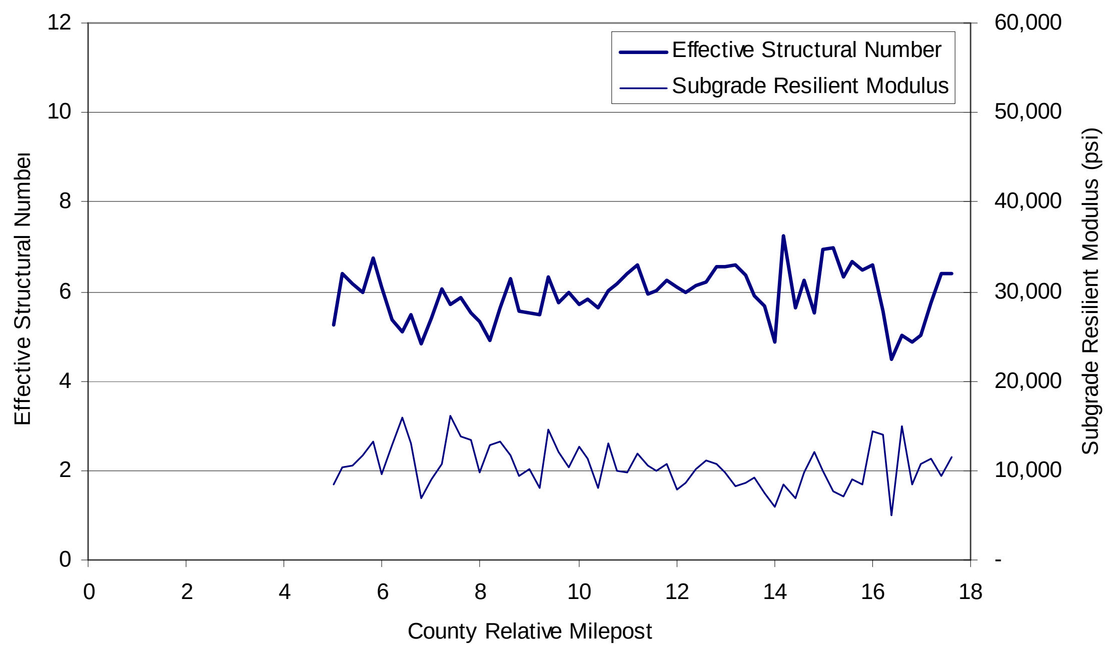

Figure C.110. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Sussex County (Maintenance Jurisdiction 091)

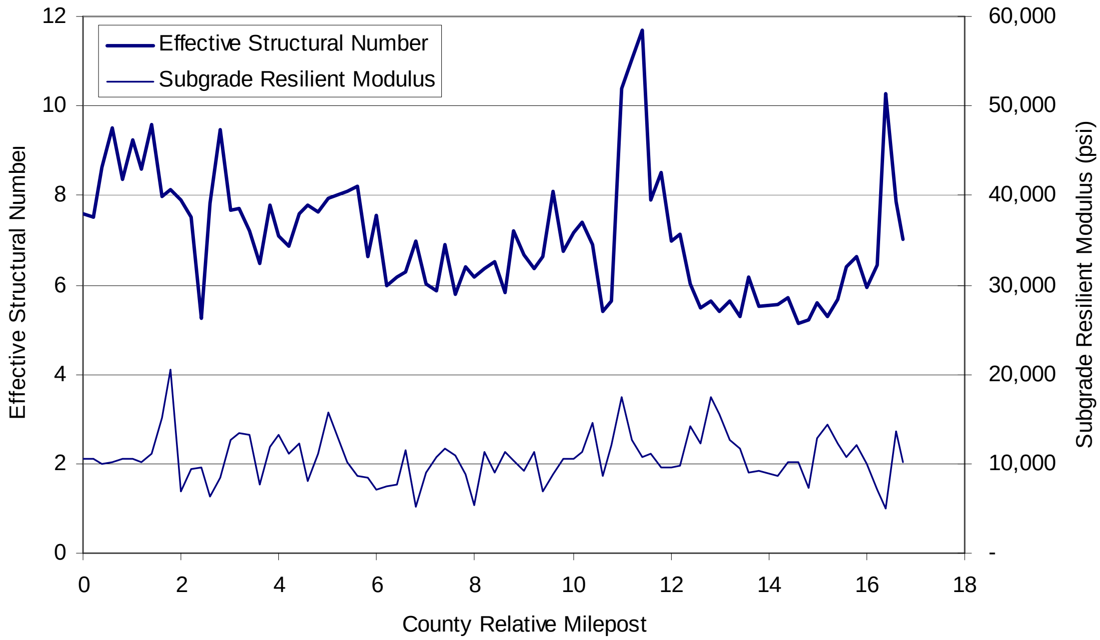

Figure C.111. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Prince George County (Maintenance Jurisdiction 074)

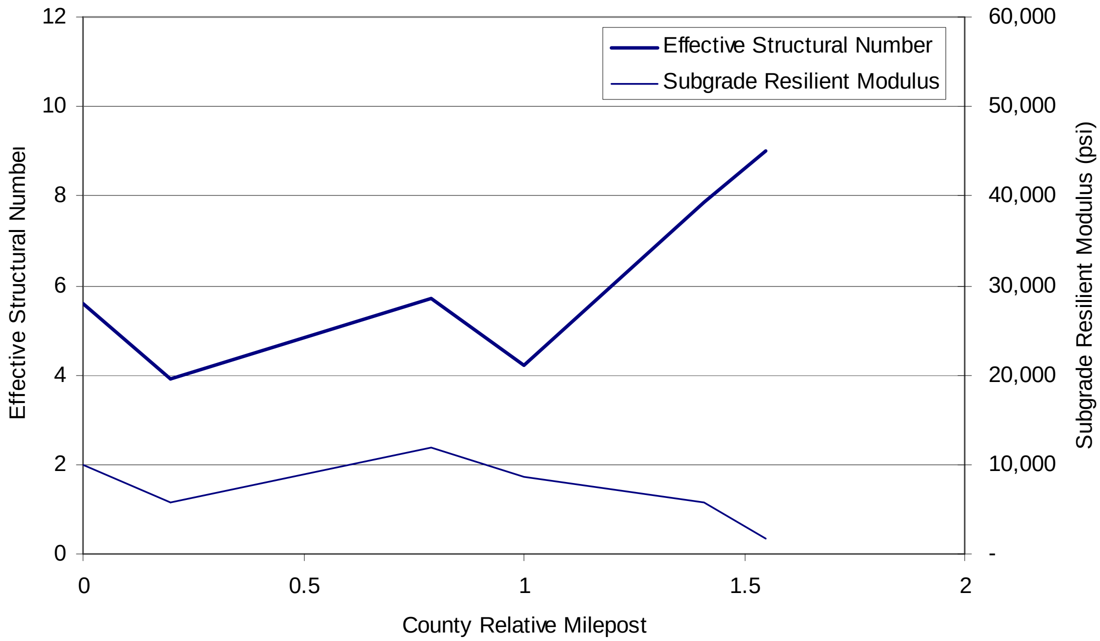

Figure C.112. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Dinwiddie County (Maintenance Jurisdiction 026)

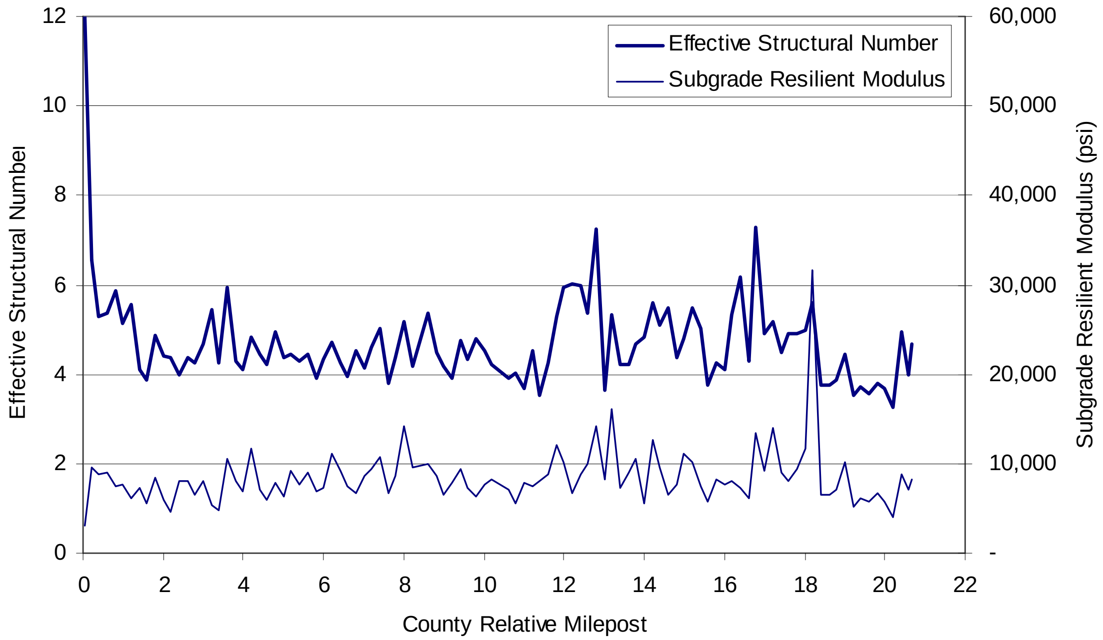

Figure C.113. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Chesterfield County (Maintenance Jurisdiction 020)

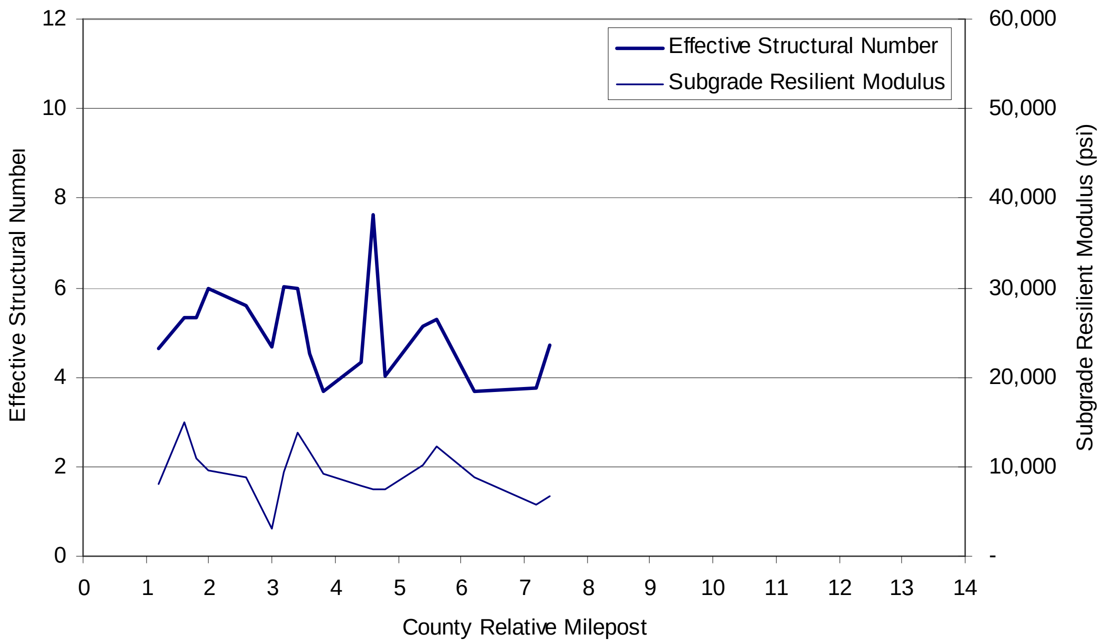

Figure C.114. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Henrico County (Maintenance Jurisdiction 043)

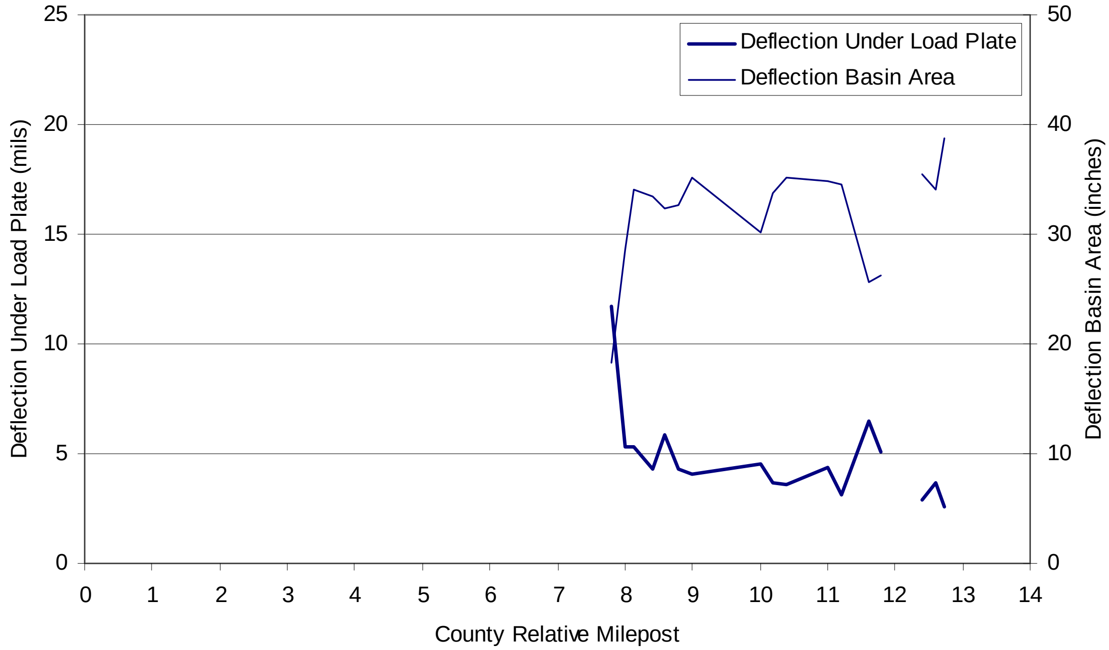

Figure C.115. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Henrico County (Maintenance Jurisdiction 043)

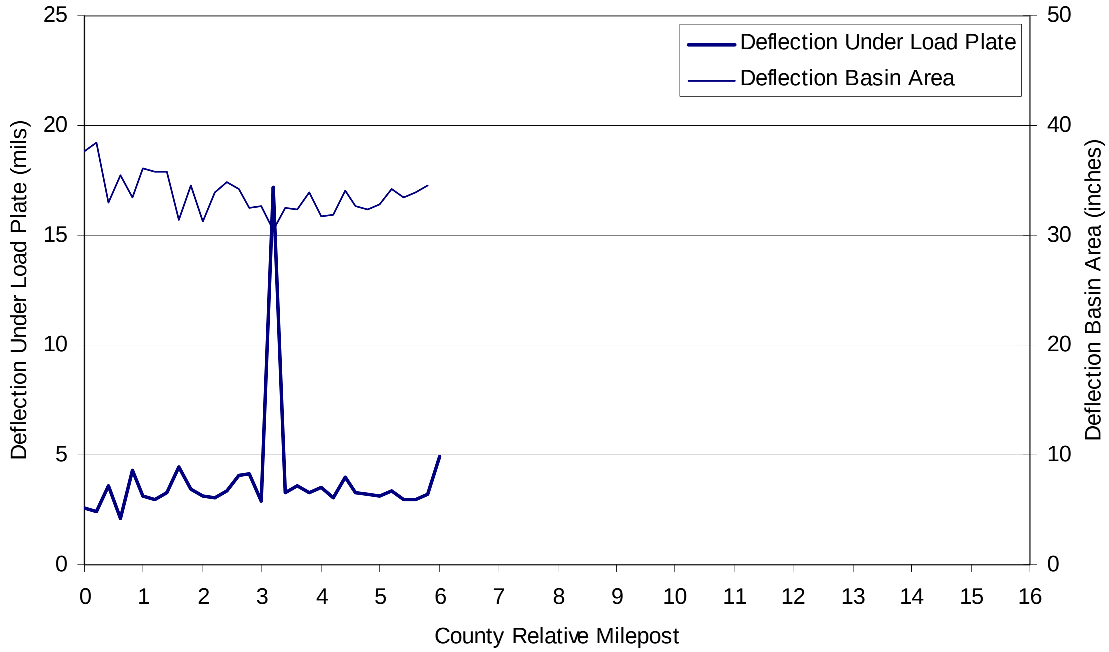

Figure C.116. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Hanover County (Maintenance Jurisdiction 042)

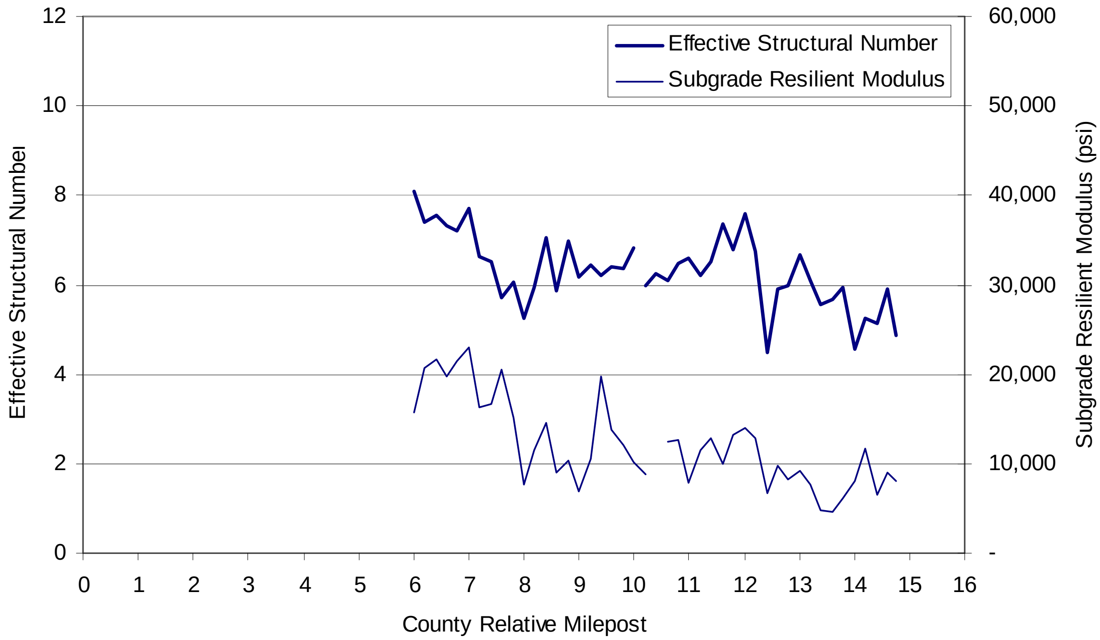

Figure C.117. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Hanover County (Maintenance Jurisdiction 042)

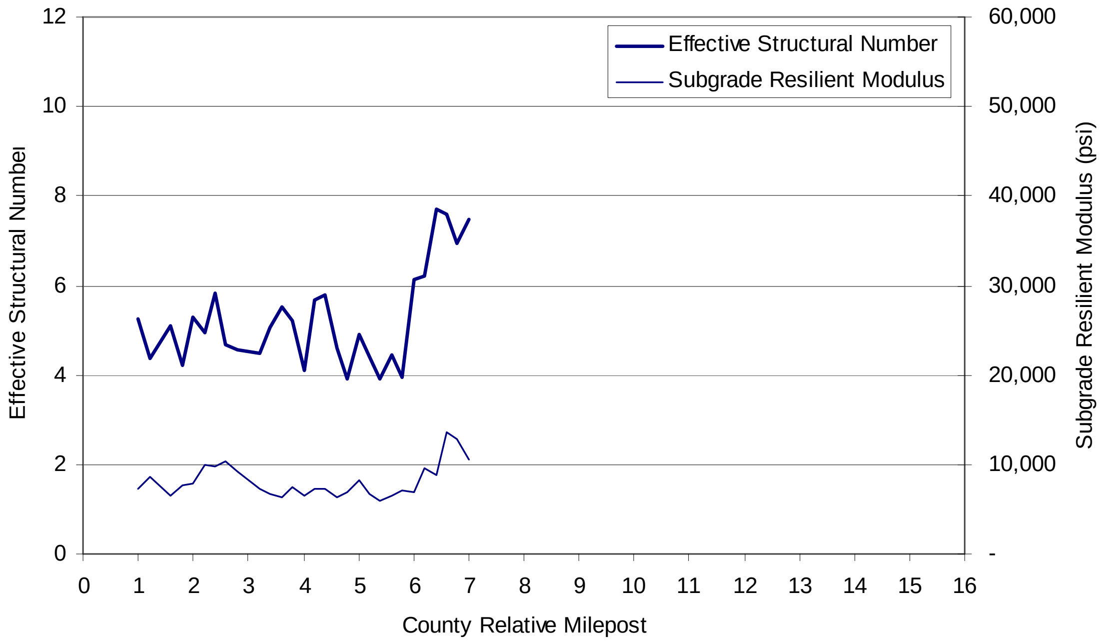

Figure C.118. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Caroline County (Maintenance Jurisdiction 016)

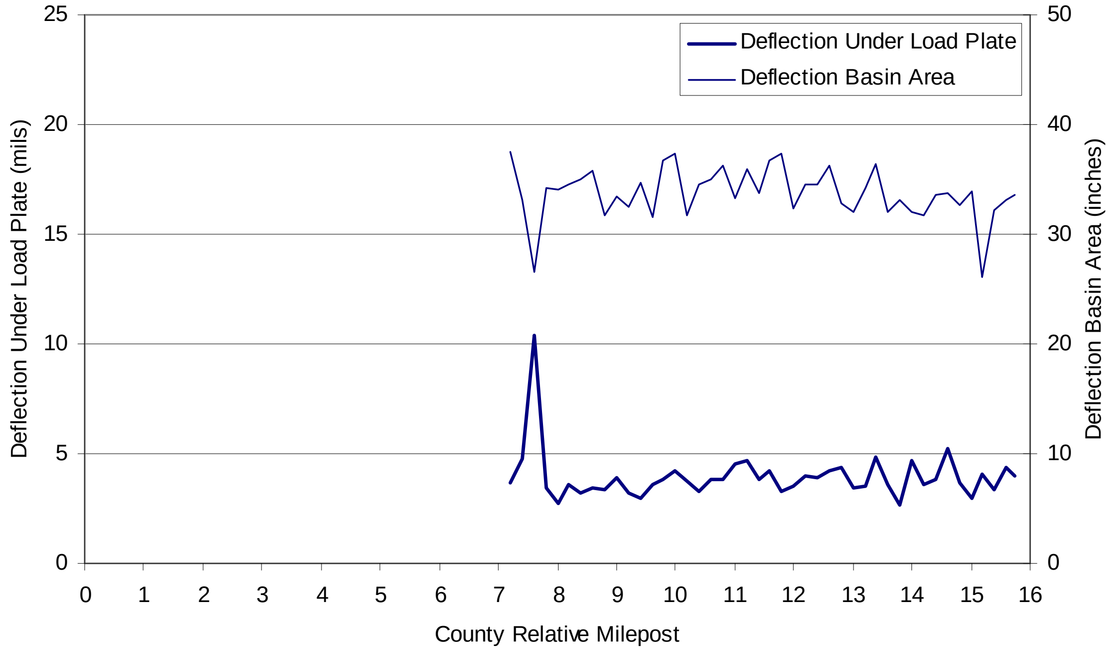

Figure C.119. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Caroline County (Maintenance Jurisdiction 016)

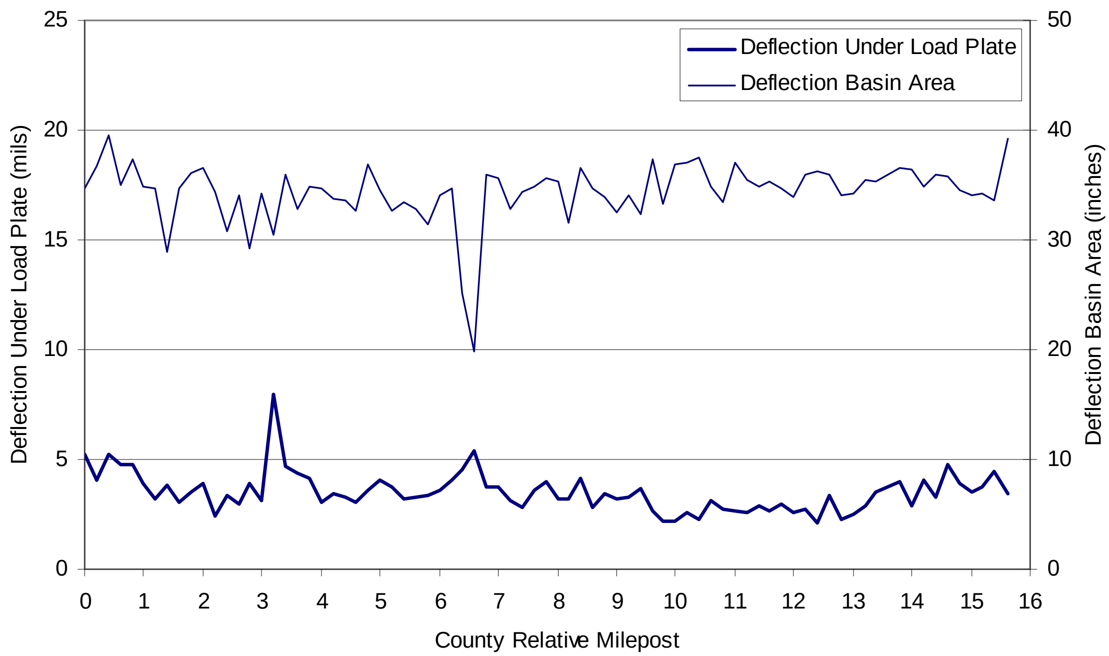

Figure C.120. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Spotsylvania County (Maintenance Jurisdiction 088)

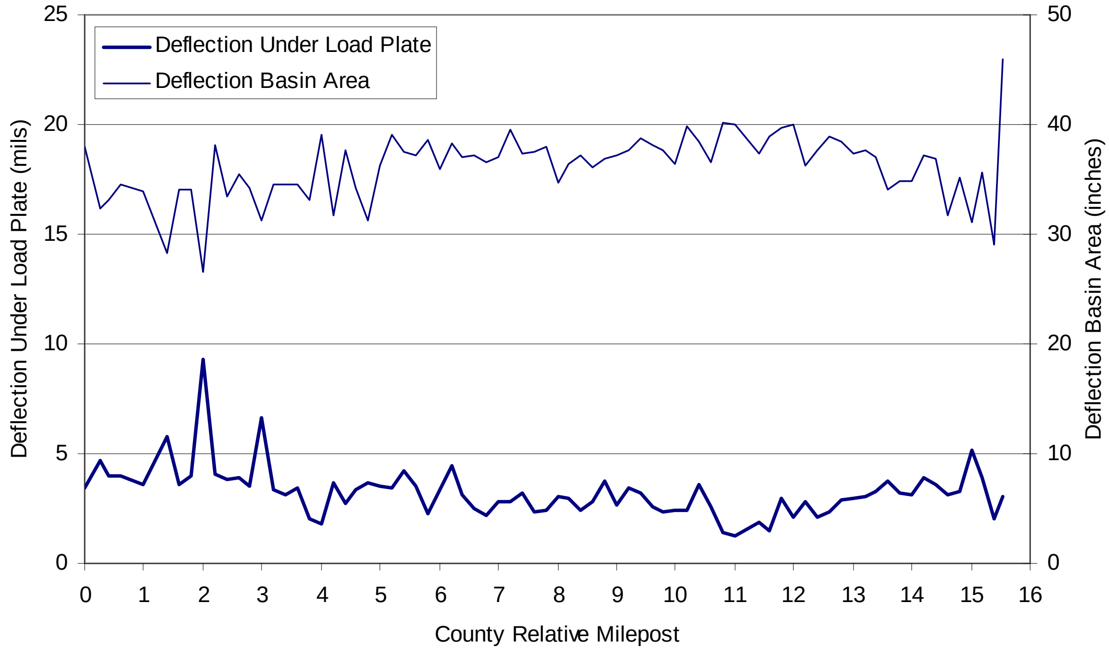

Figure C.121. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Stafford County (Maintenance Jurisdiction 089)

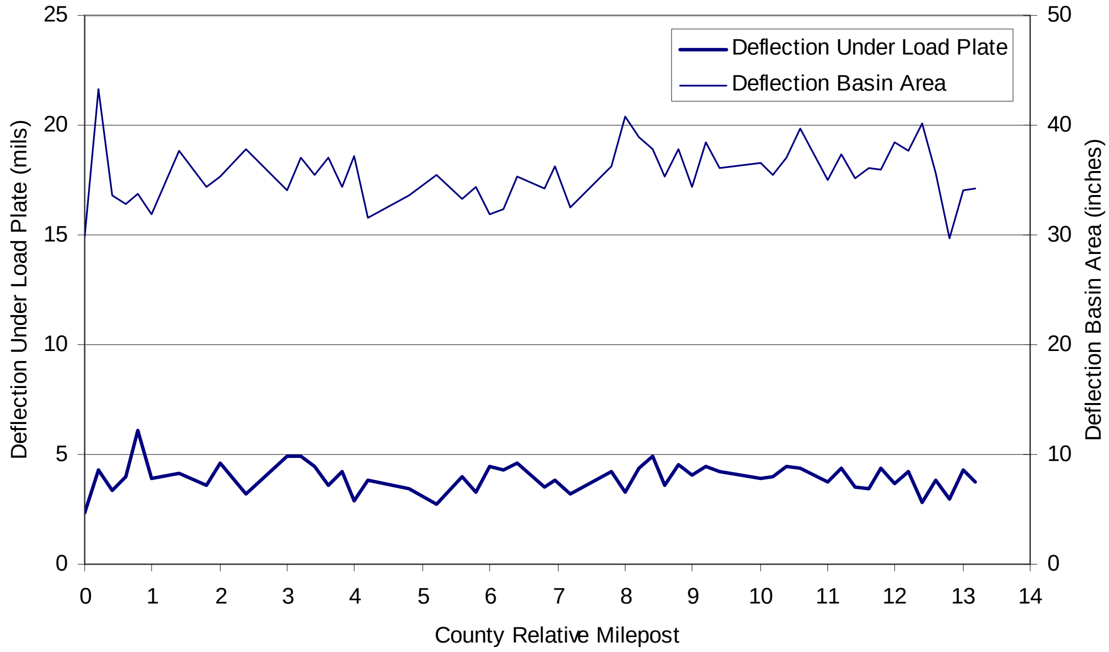

Figure C.122. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Prince William County (Maintenance Jurisdiction 076)

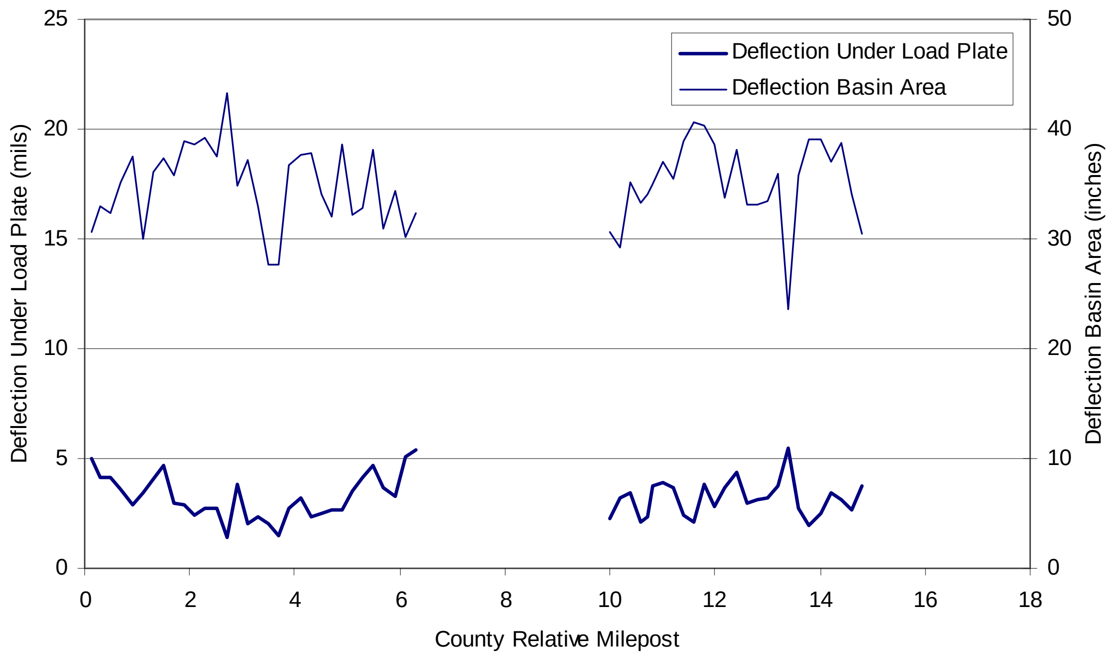

Figure C.123. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-95, Fairfax County (Maintenance Jurisdiction 029)

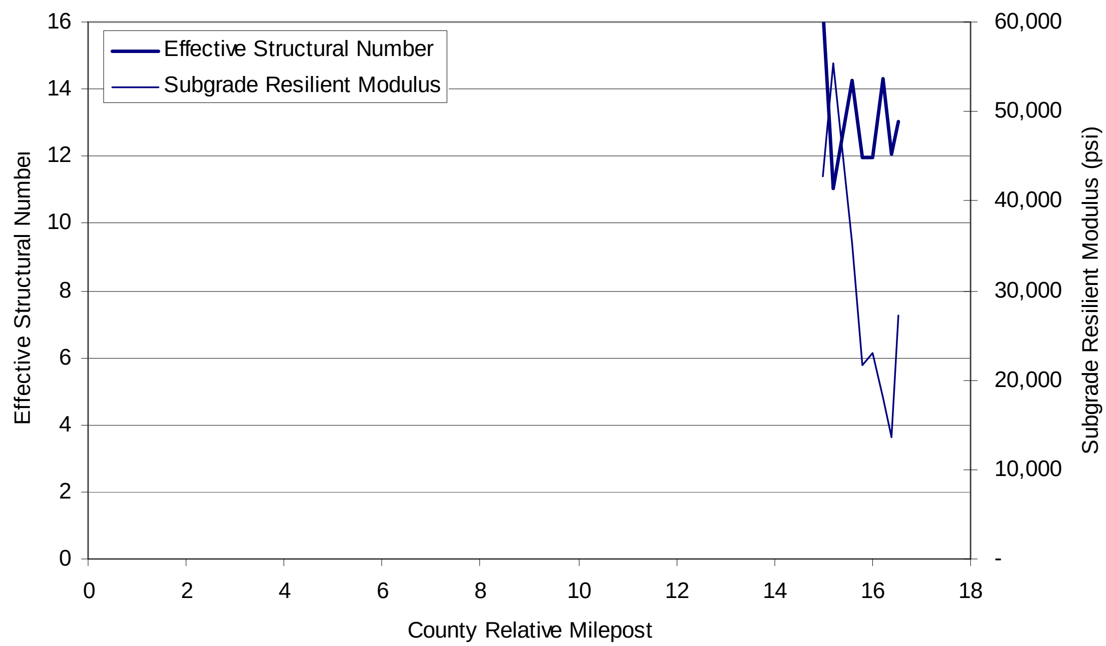

Figure C.124. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-95, Fairfax County (Maintenance Jurisdiction 029)

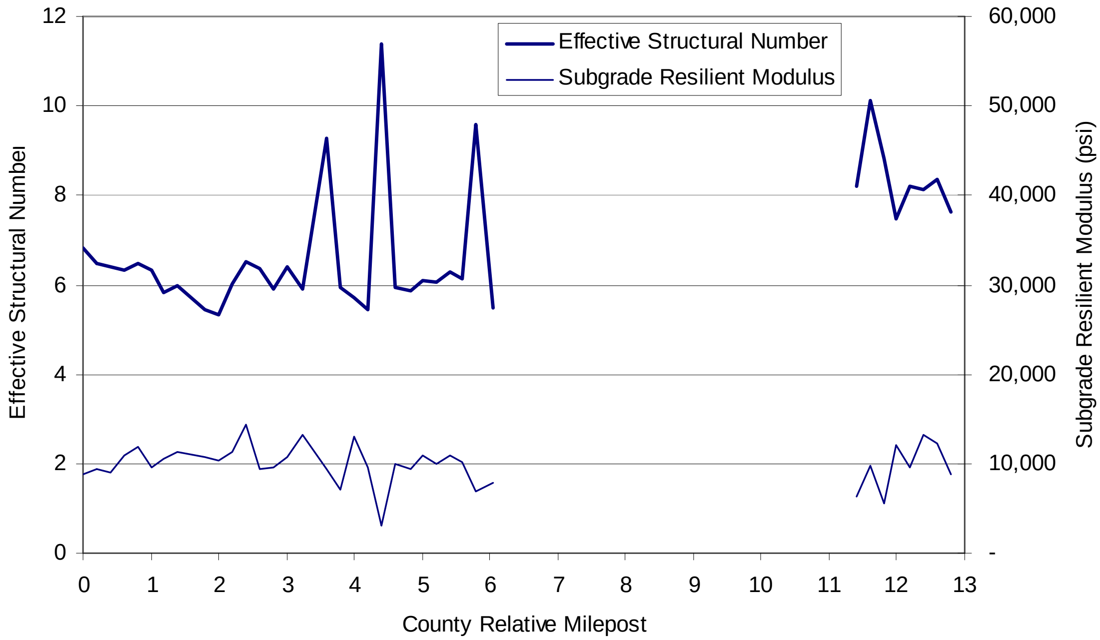

Figure C.125. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-264, City of Portsmouth (Maintenance Jurisdiction 064)

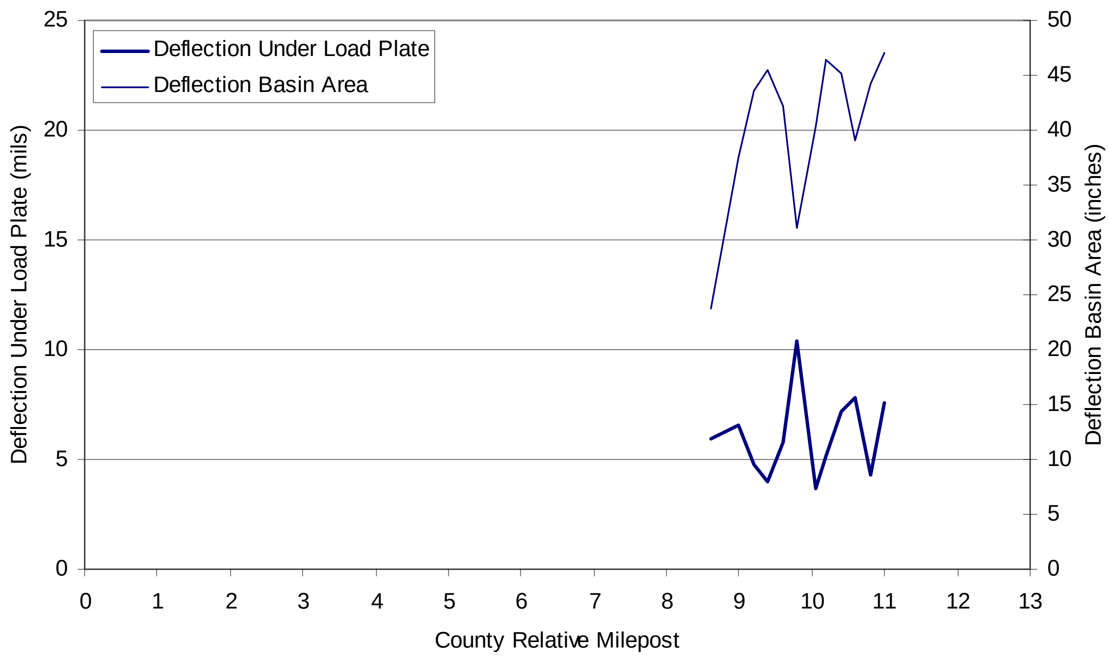

Figure C.126. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-264, City of Portsmouth (Maintenance Jurisdiction 064)

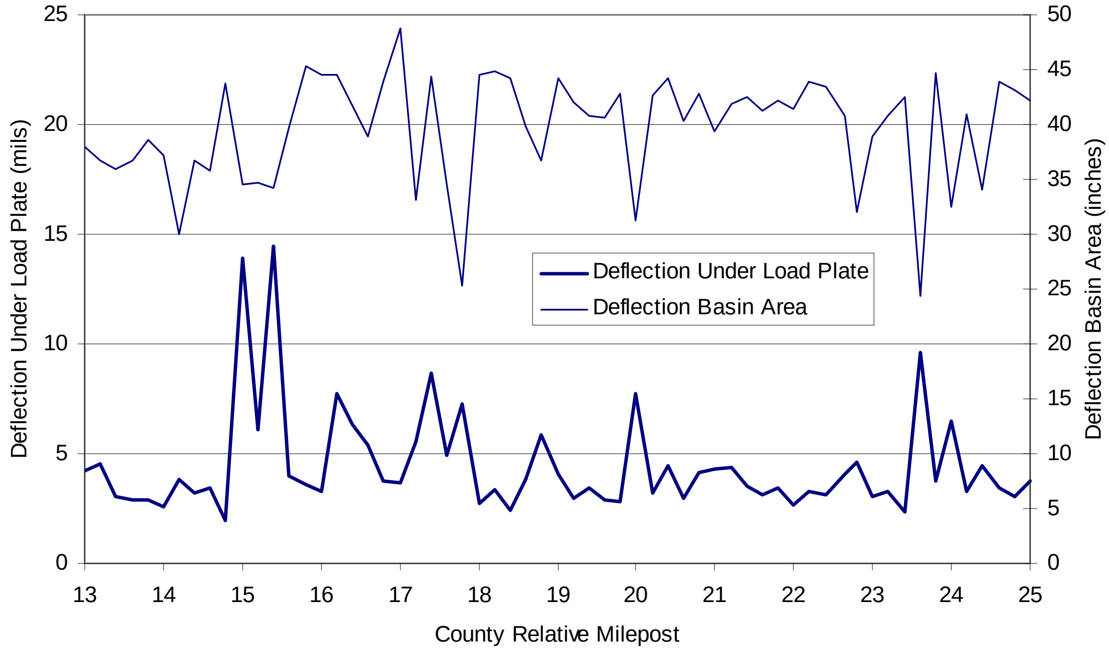

Figure C.127. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-264, City of Virginia Beach (Maintenance Jurisdiction 075)

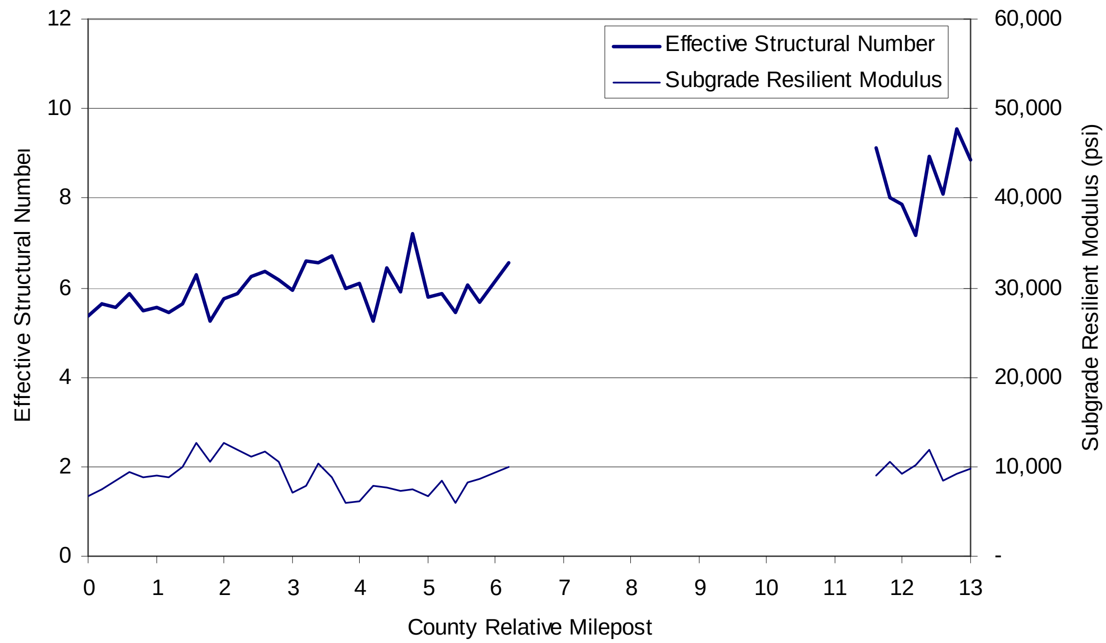

Figure C.128. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-264, City of Portsmouth (Maintenance Jurisdiction 064)

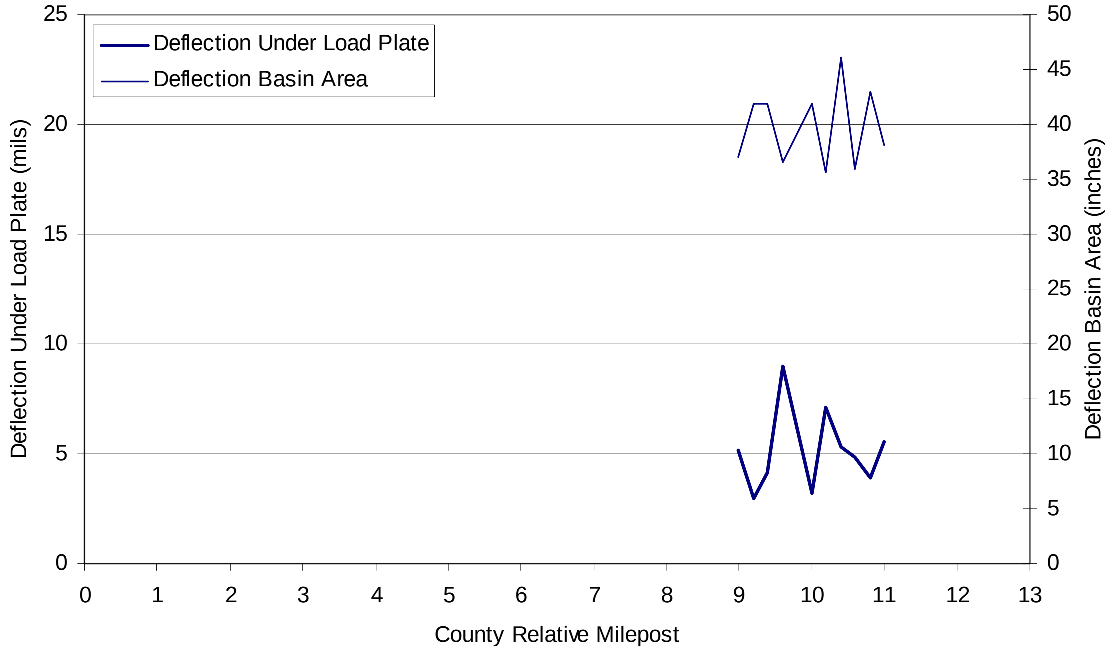

Figure C.129. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-264, City of Portsmouth (Maintenance Jurisdiction 064)

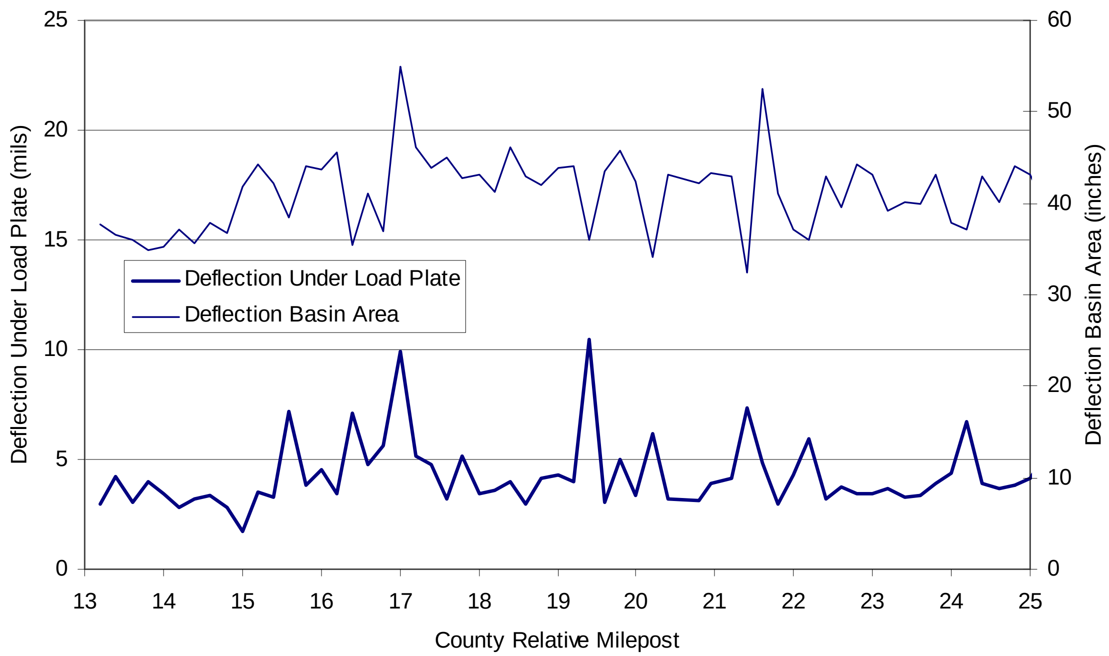

Figure C.130. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-264, City of Virginia Beach (Maintenance Jurisdiction 075)

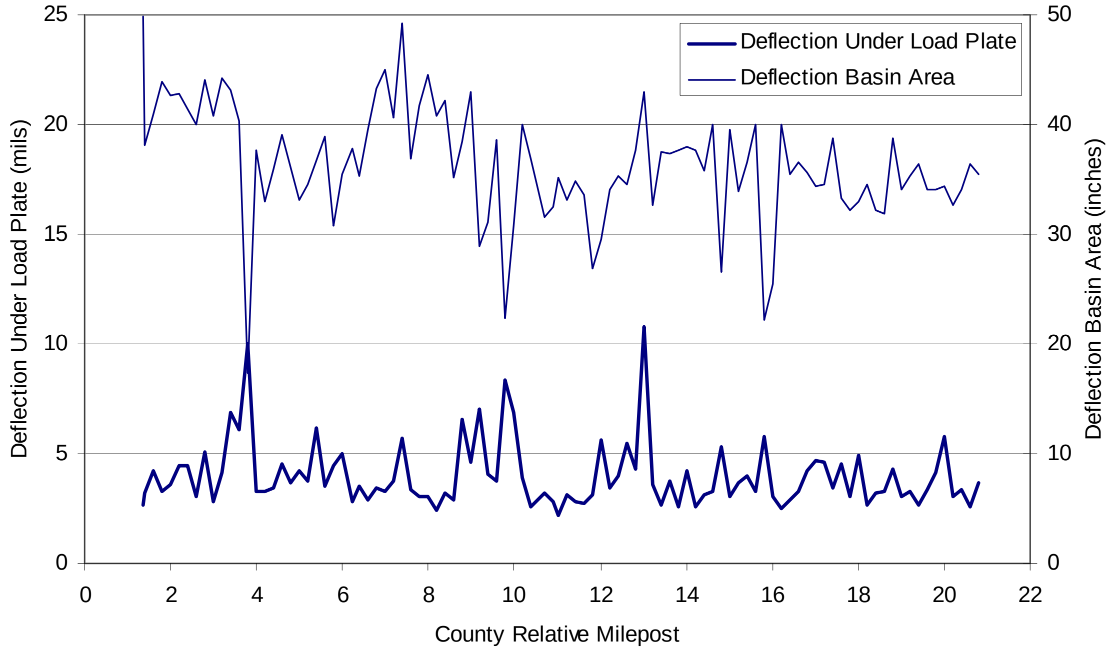

Figure C.131. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-295, Henrico County (Maintenance Jurisdiction 043)

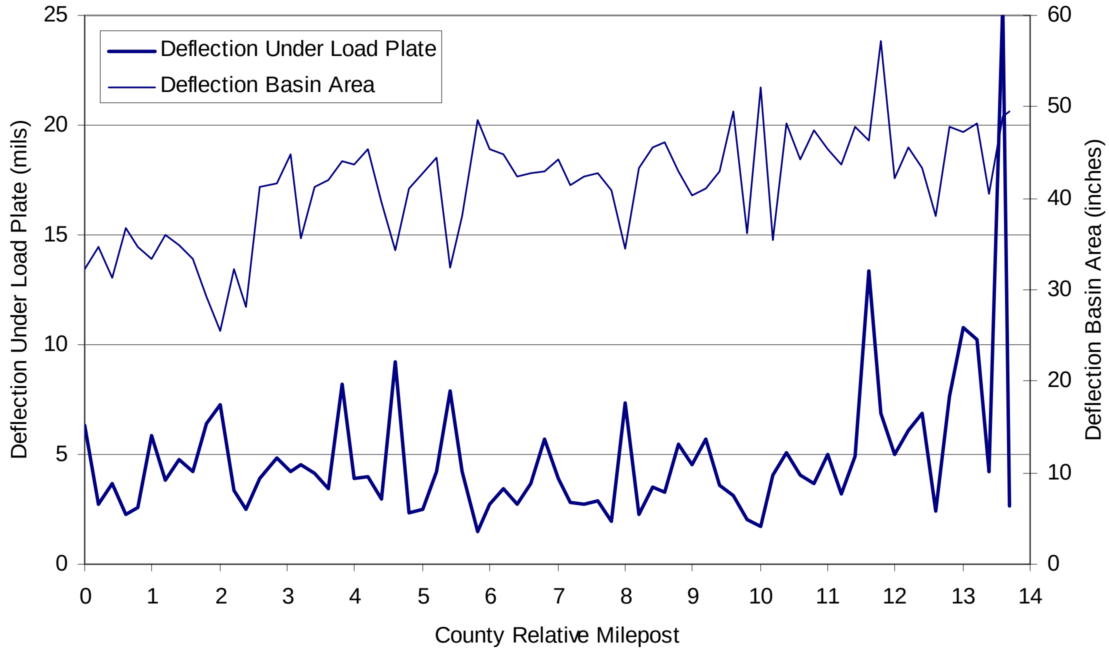

Figure C.132. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-295, Hanover County (Maintenance Jurisdiction 042)

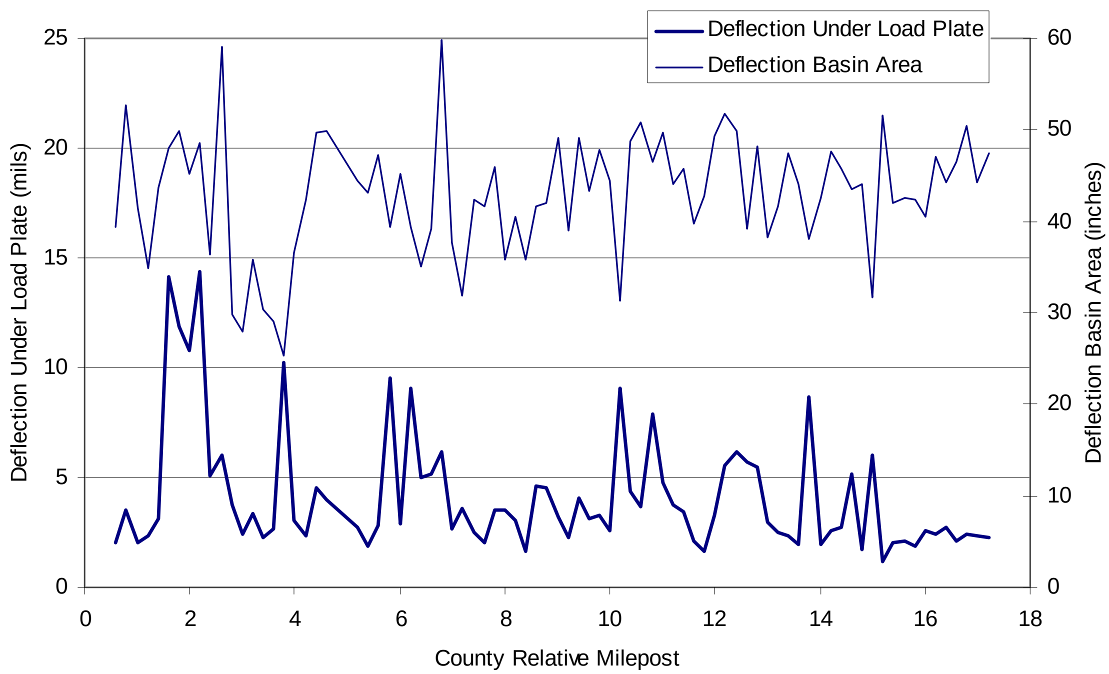

Figure C.133. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-295, Chesterfield County (Maintenance Jurisdiction 020)

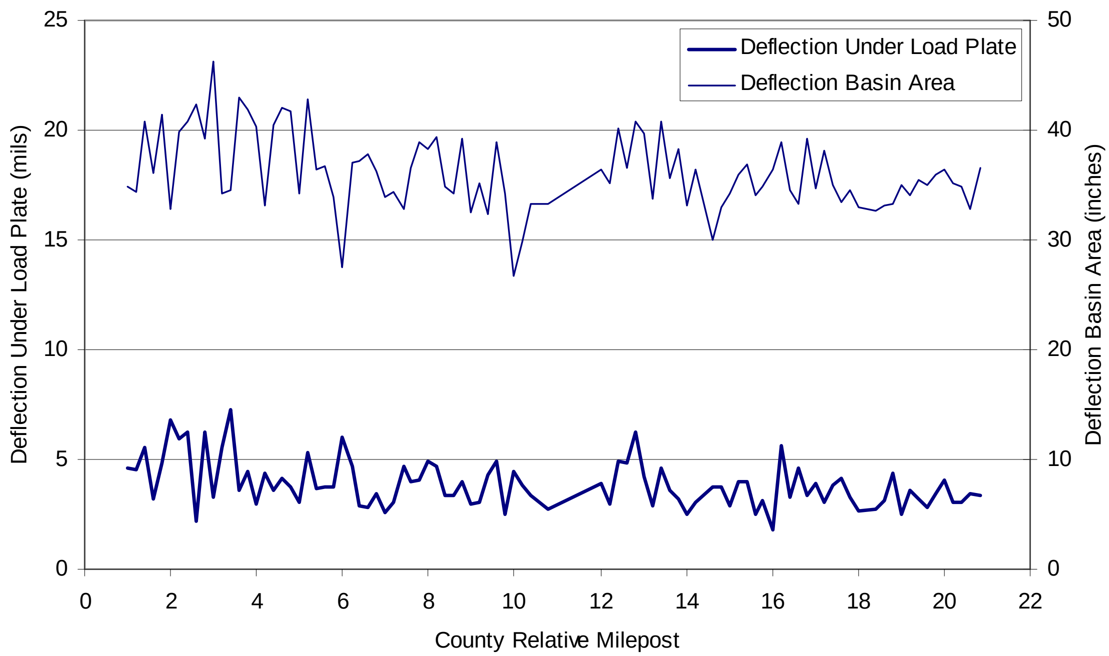

Figure C.134. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-295, Henrico County (Maintenance Jurisdiction 043)

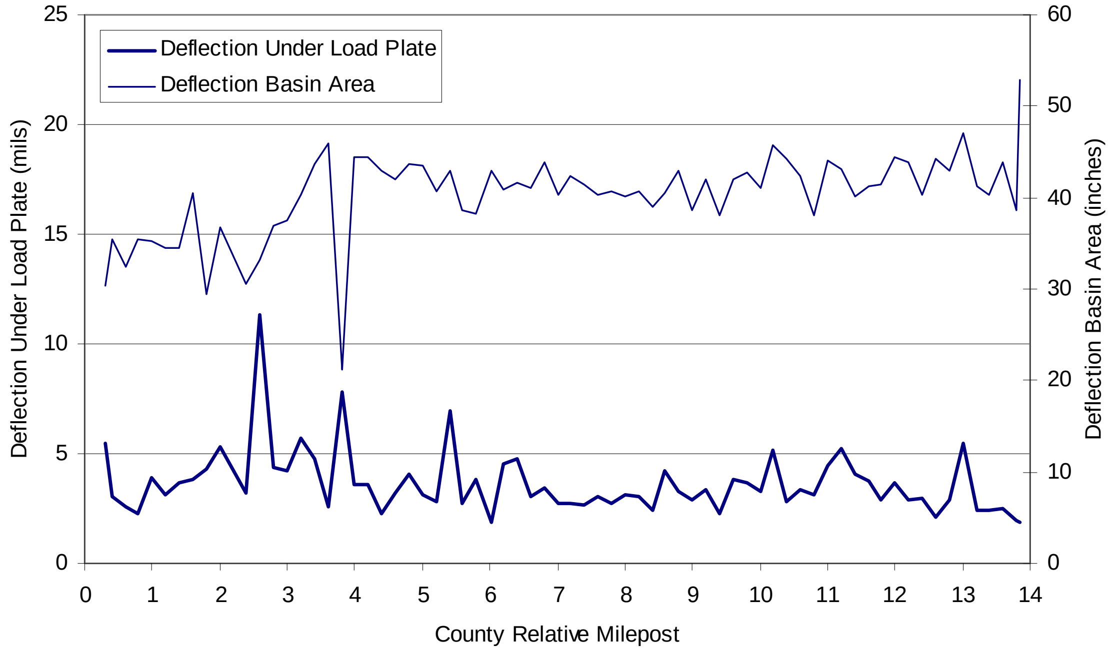

Figure C.135. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-295, Hanover County (Maintenance Jurisdiction 042)

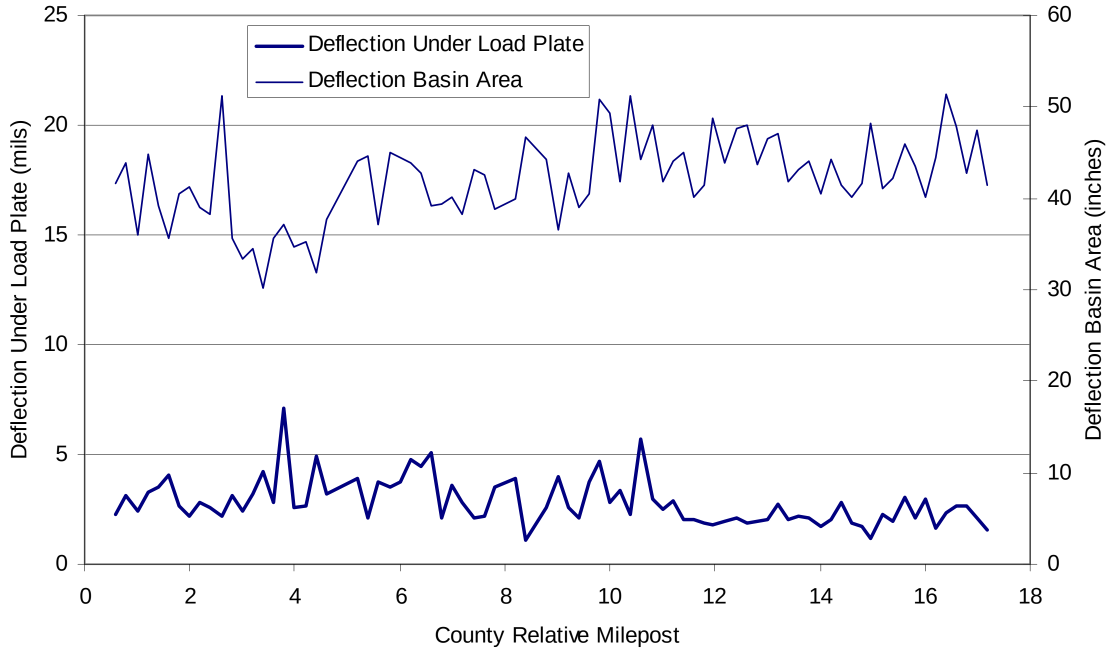

Figure C.136. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-295, Chesterfield County (Maintenance Jurisdiction 020)

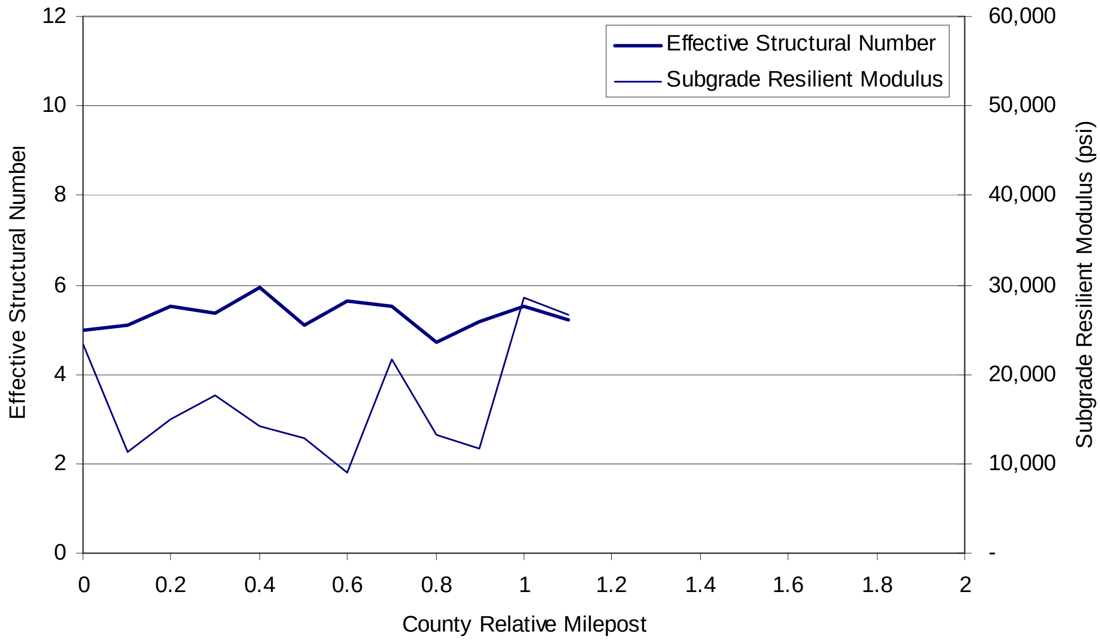

Figure C.137. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-381, Washington County (Maintenance Jurisdiction 095)

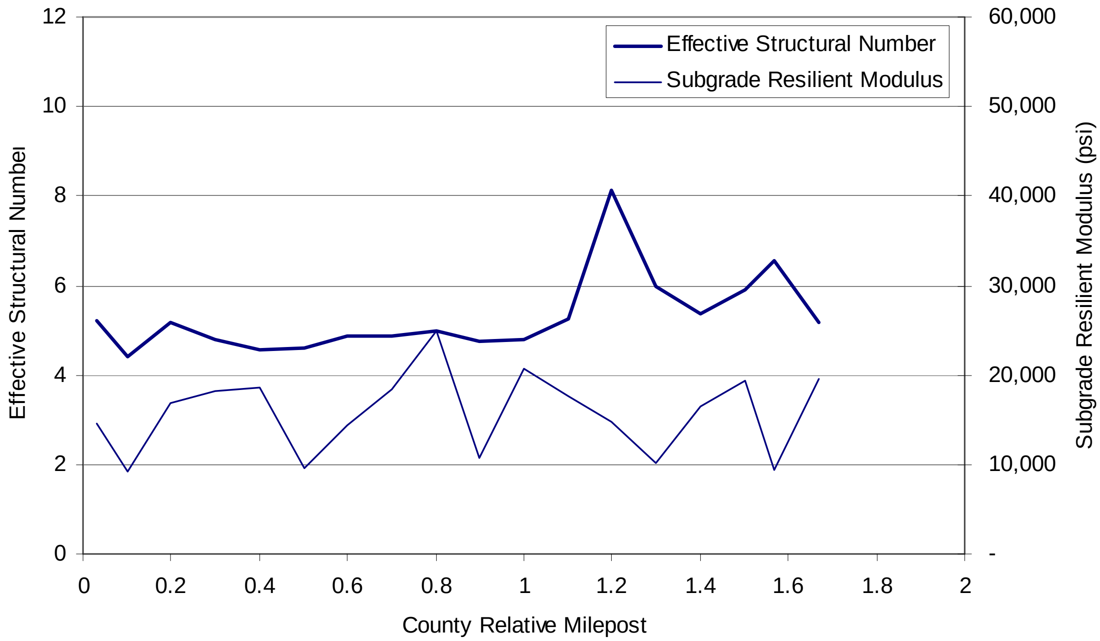

Figure C.138. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-381, Washington County (Maintenance Jurisdiction 095)

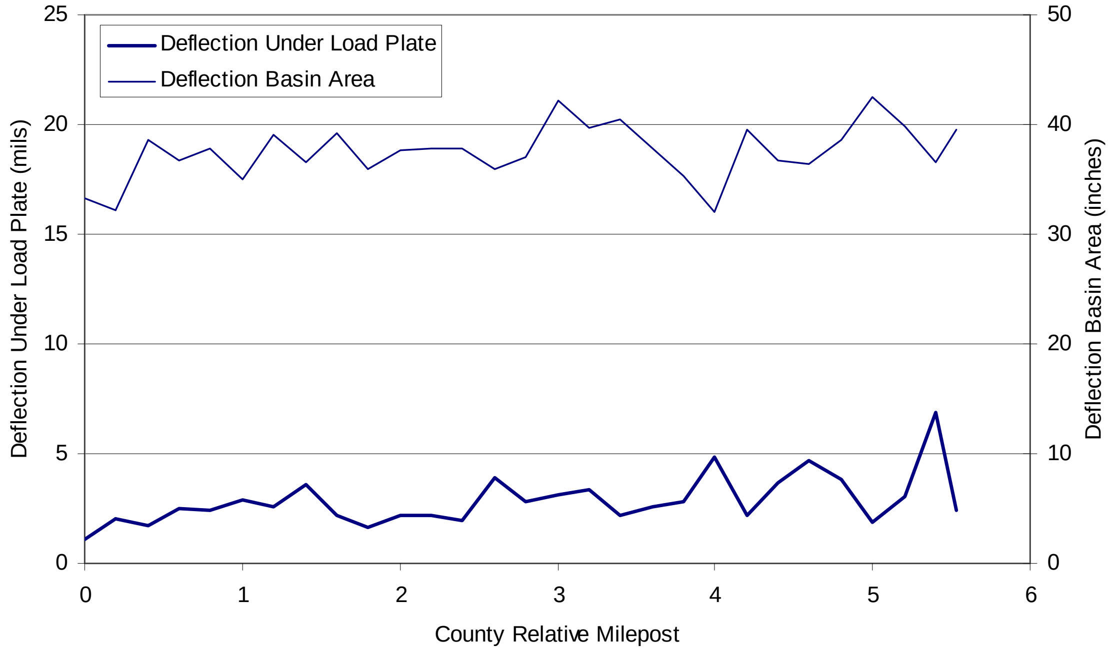

Figure C.139. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-395, Fairfax County (Maintenance Jurisdiction 029)

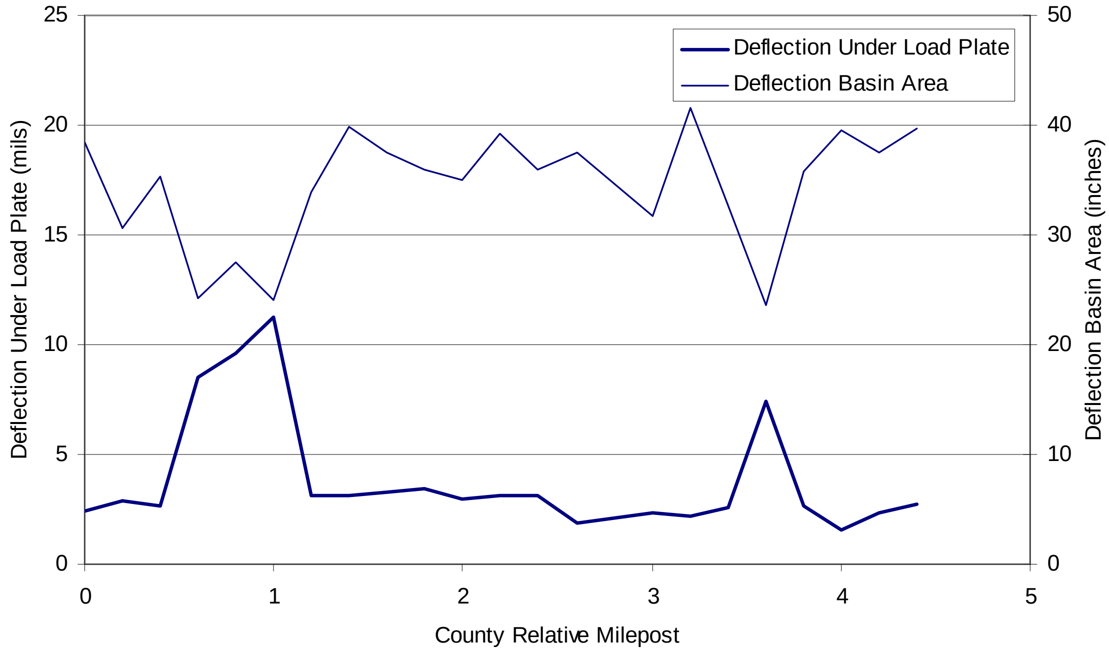

Figure C.140. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-395, Arlington County (Maintenance Jurisdiction 000)

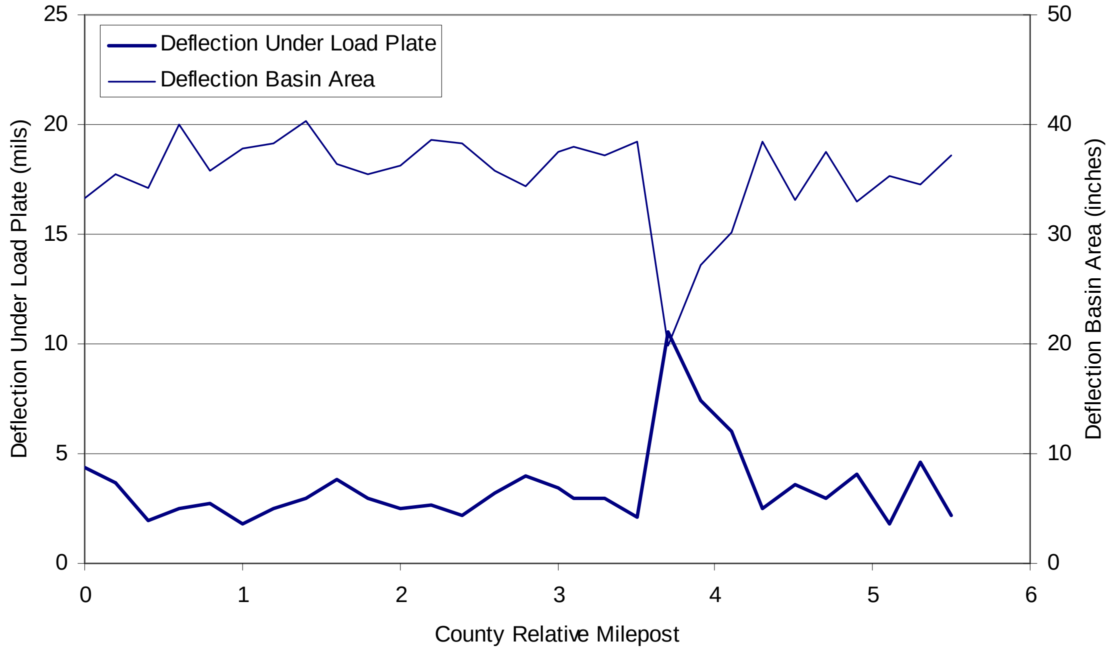

Figure C.141. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-395, Fairfax County (Maintenance Jurisdiction 029)

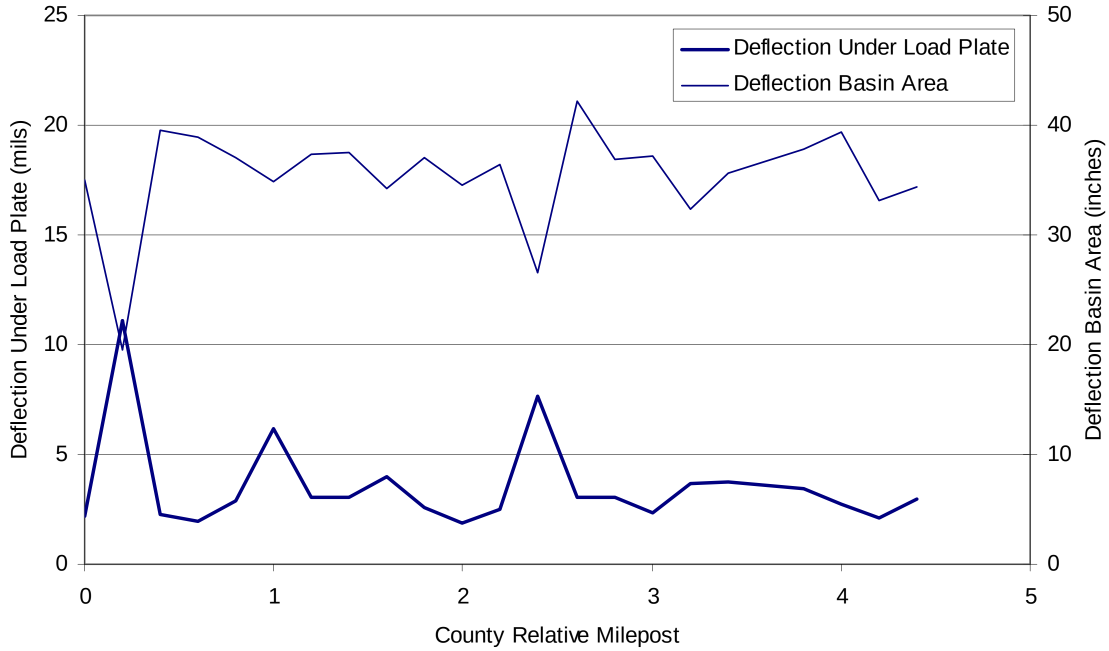

Figure C.142. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-395, Arlington County (Maintenance Jurisdiction 000)

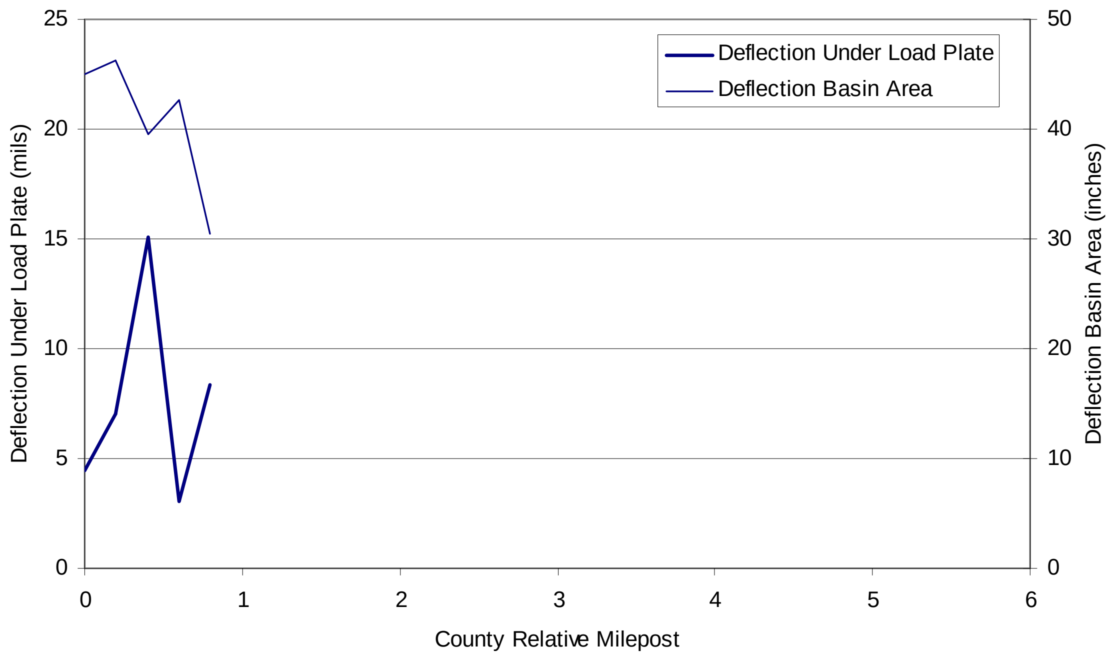

Figure C.143. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-464, City of Portsmouth (Maintenance Jurisdiction 064)

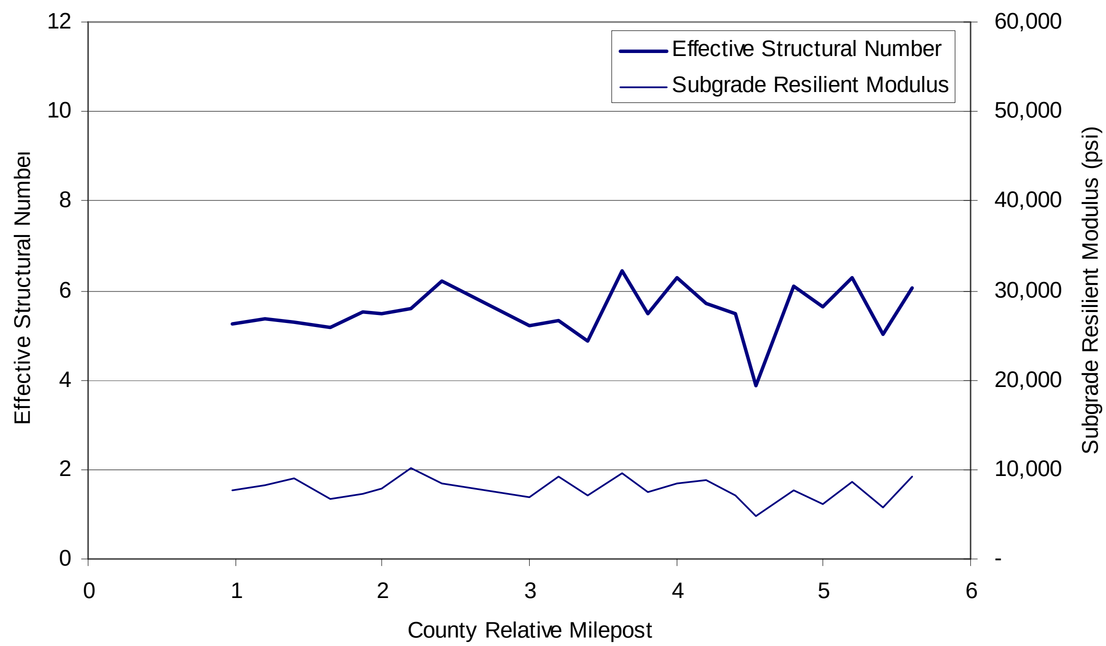

Figure C.144. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-464, City of Portsmouth (Maintenance Jurisdiction 064)

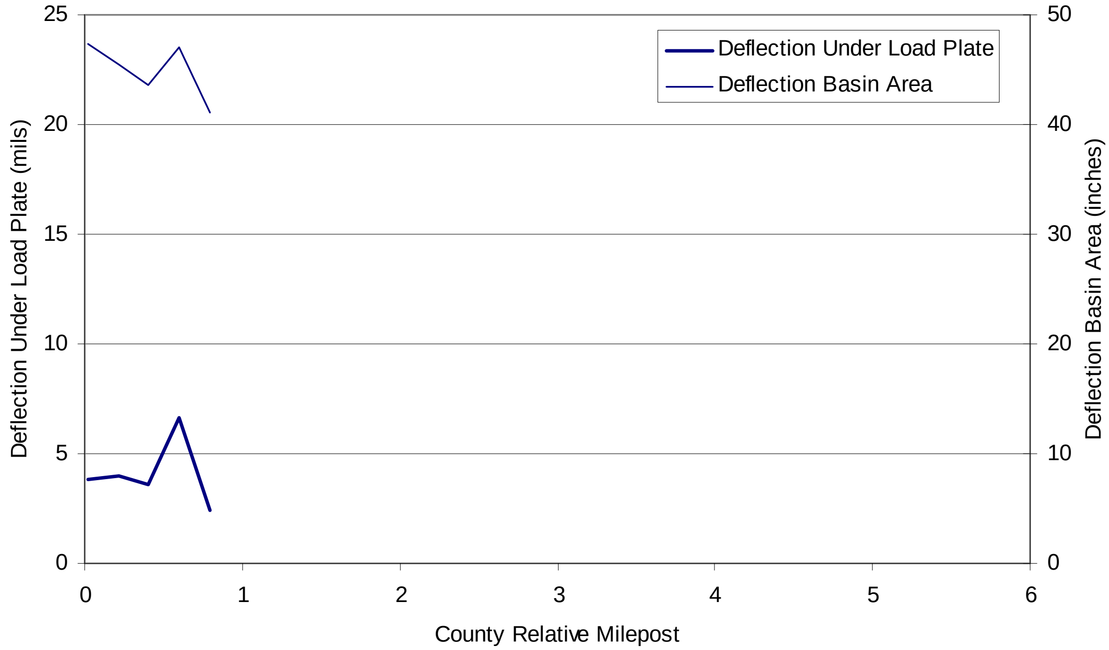

Figure C.145. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-464, City of Portsmouth (Maintenance Jurisdiction 064)

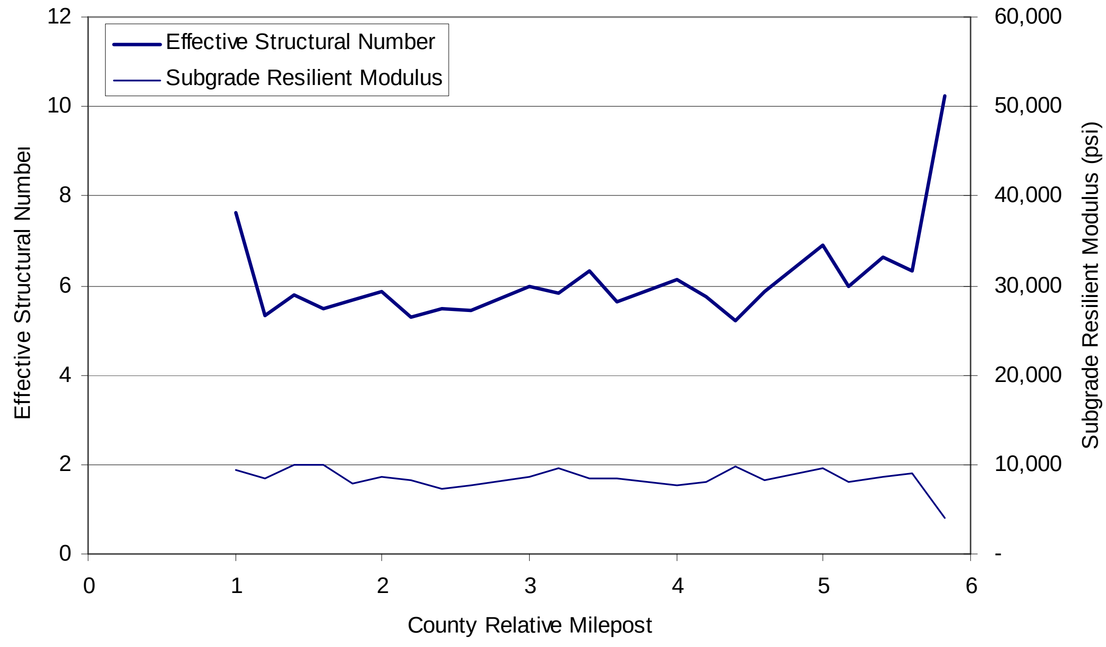

Figure C.146. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-464, City of Portsmouth (Maintenance Jurisdiction 064)

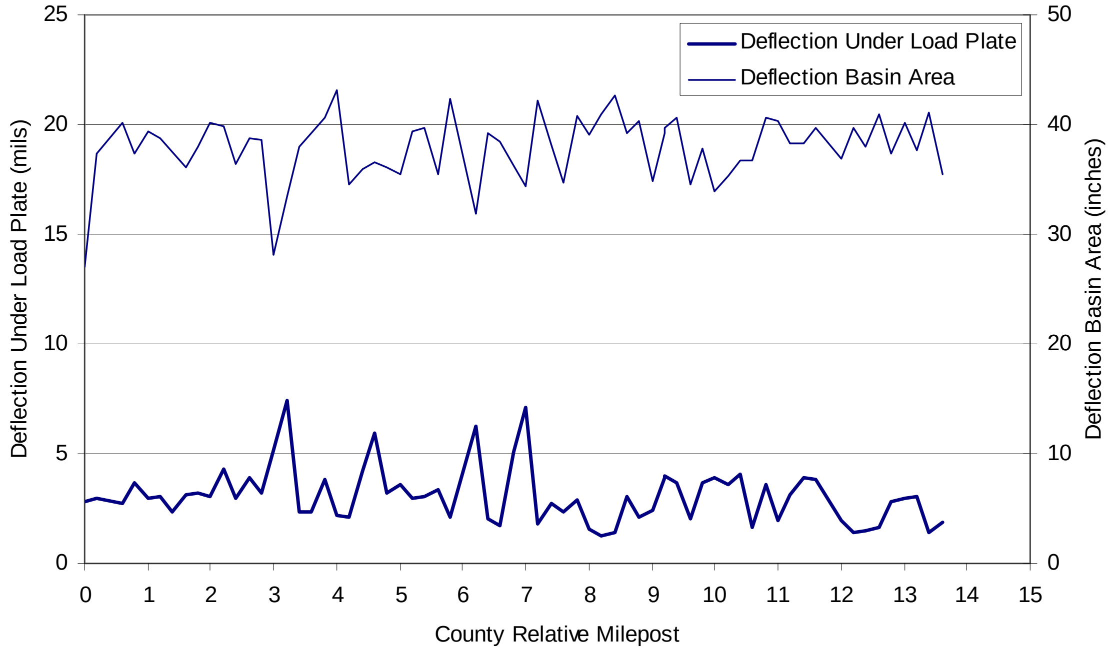

Figure C.147. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-495, Fairfax County (Maintenance Jurisdiction 029)

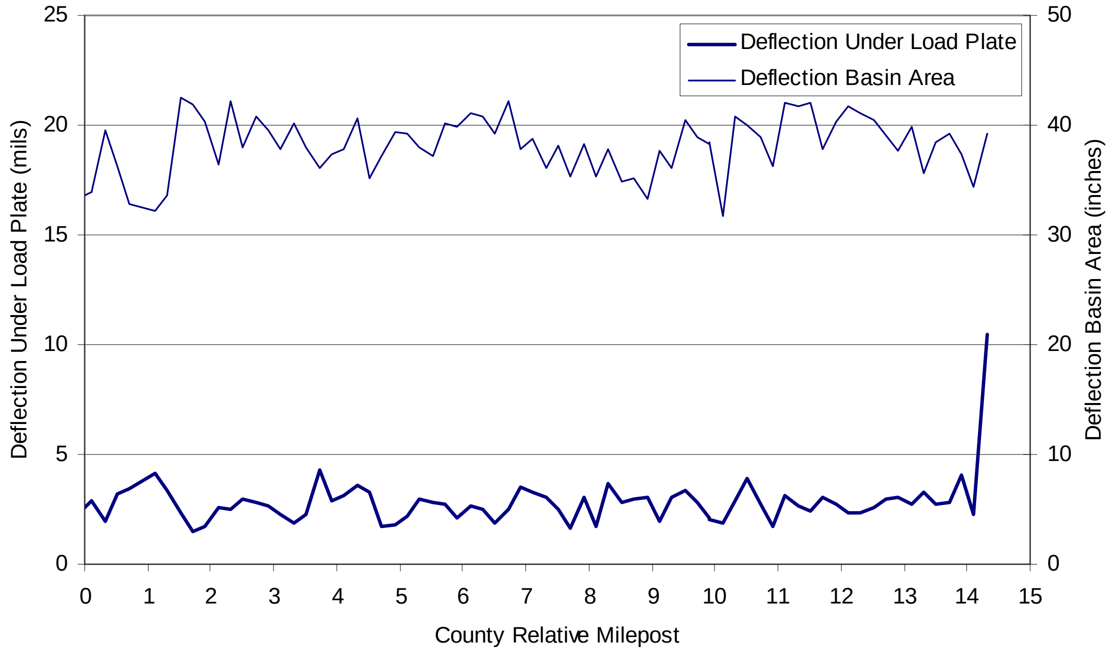

Figure C.148. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-495, Fairfax County (Maintenance Jurisdiction 029)

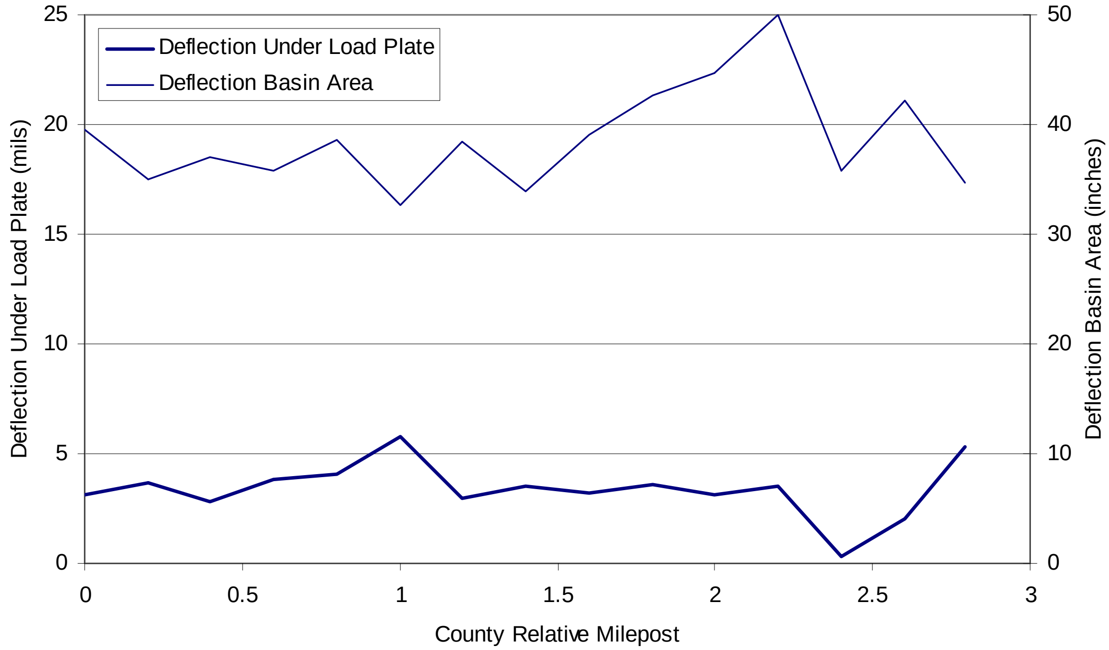

Figure C.149. Deflection Under Load Plate (D_0) and Deflection Basin Area: Northbound I-564, City of Portsmouth (Maintenance Jurisdiction 064)

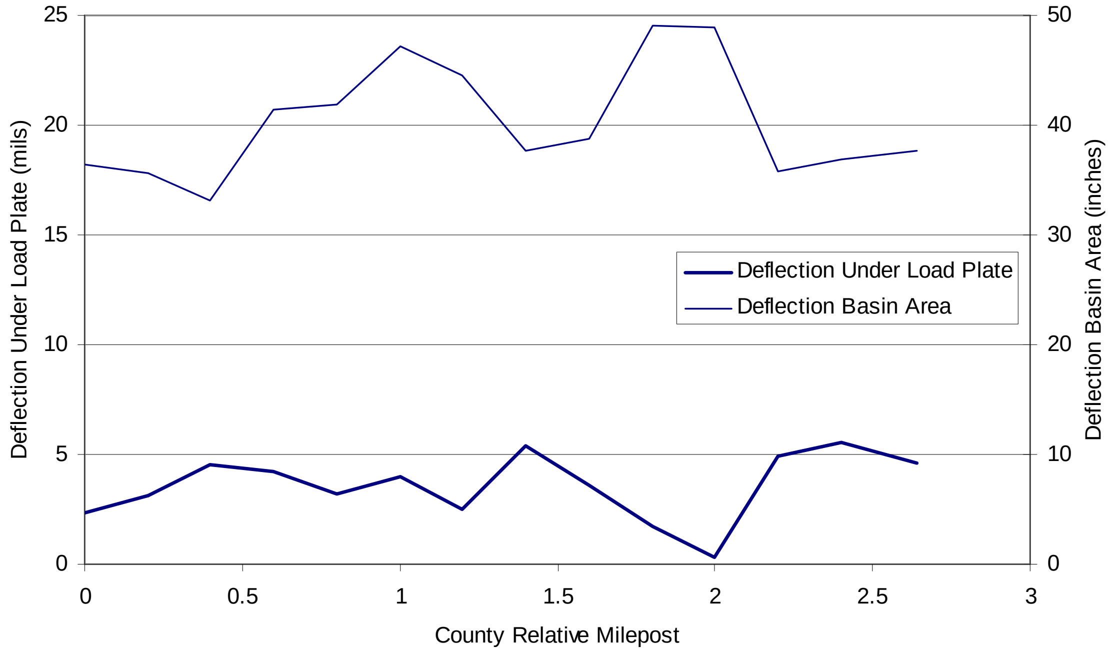

Figure C.150. Deflection Under Load Plate (D_0) and Deflection Basin Area: Southbound I-564, City of Portsmouth (Maintenance Jurisdiction 064)

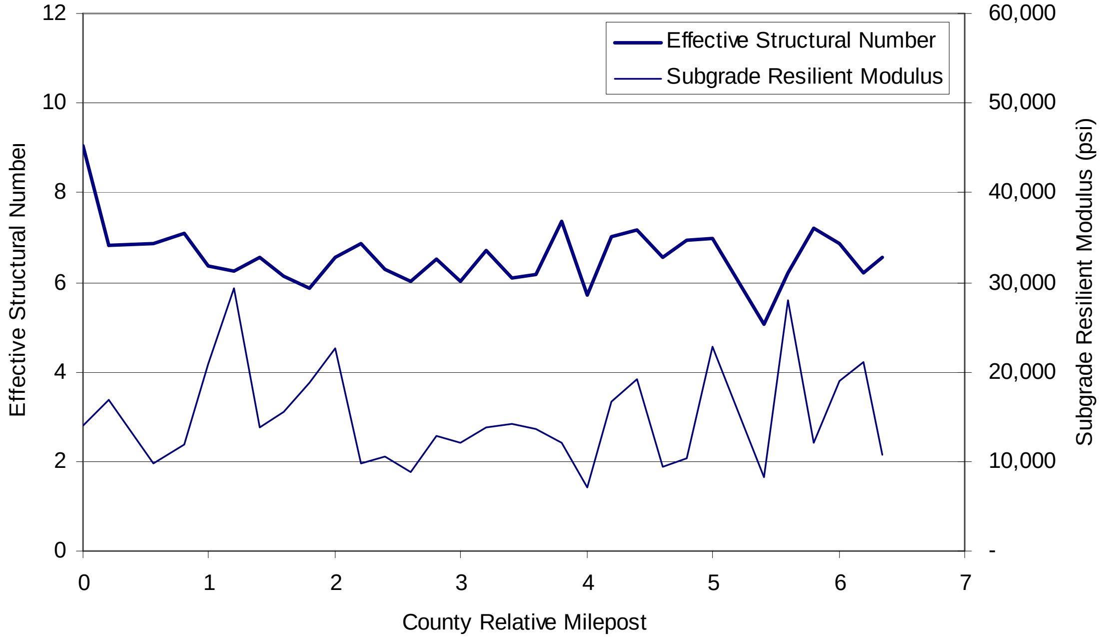

Figure C.151. Effective Structural Number and Subgrade Resilient Modulus: Northbound I-581, Roanoke County (Maintenance Jurisdiction 080)

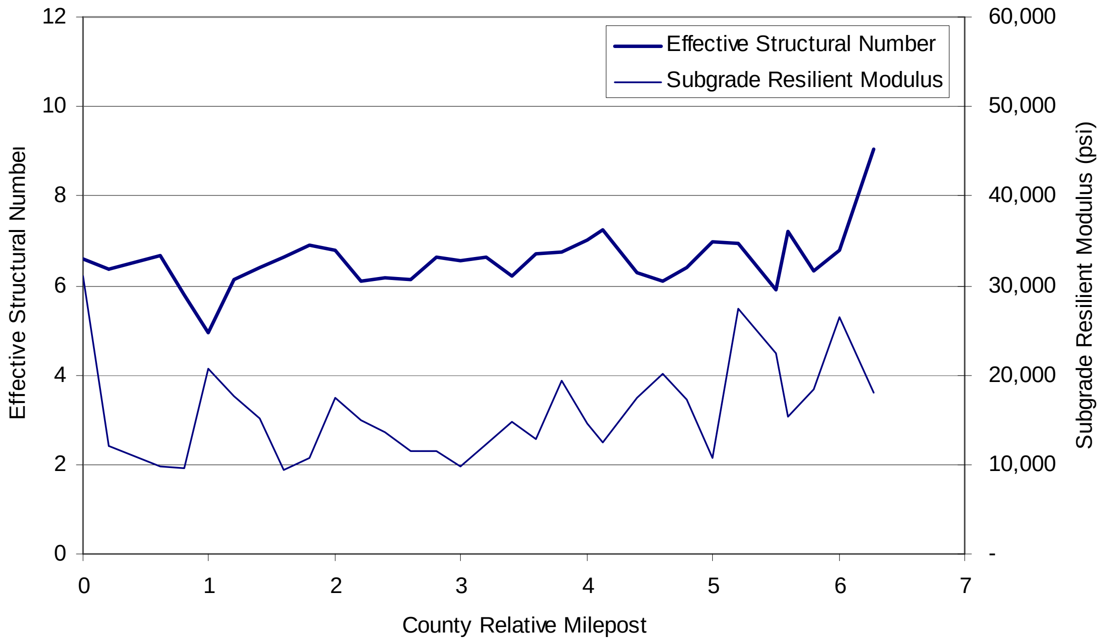

Figure C.152. Effective Structural Number and Subgrade Resilient Modulus: Southbound I-581, Roanoke County (Maintenance Jurisdiction 080)

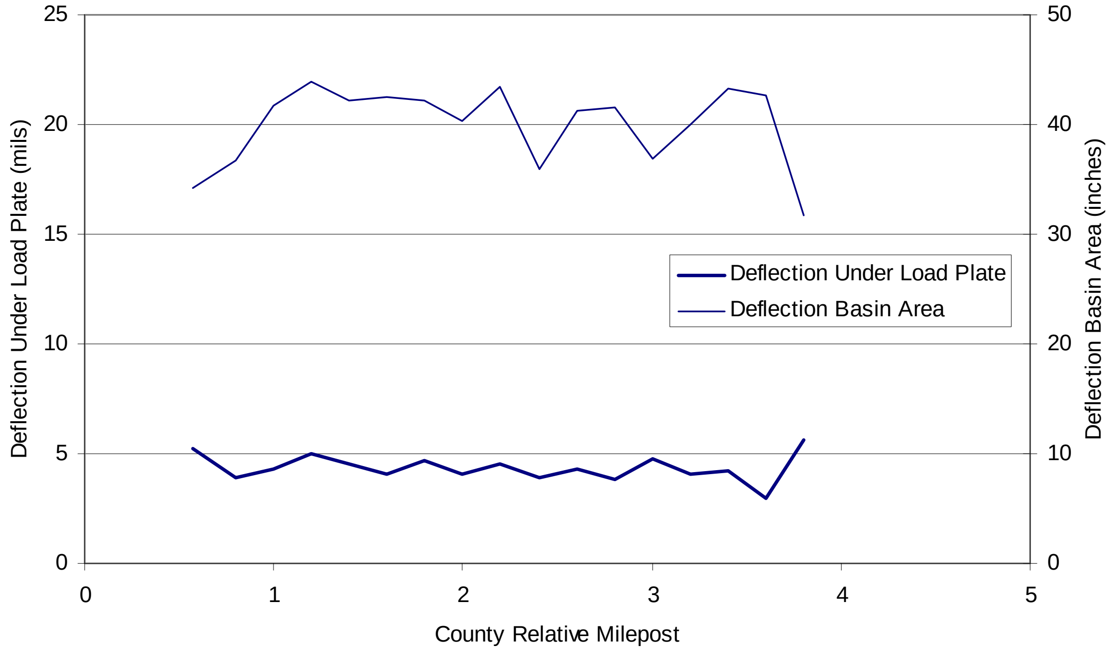

Figure C.153. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-664, York County (Maintenance Jurisdiction 099)

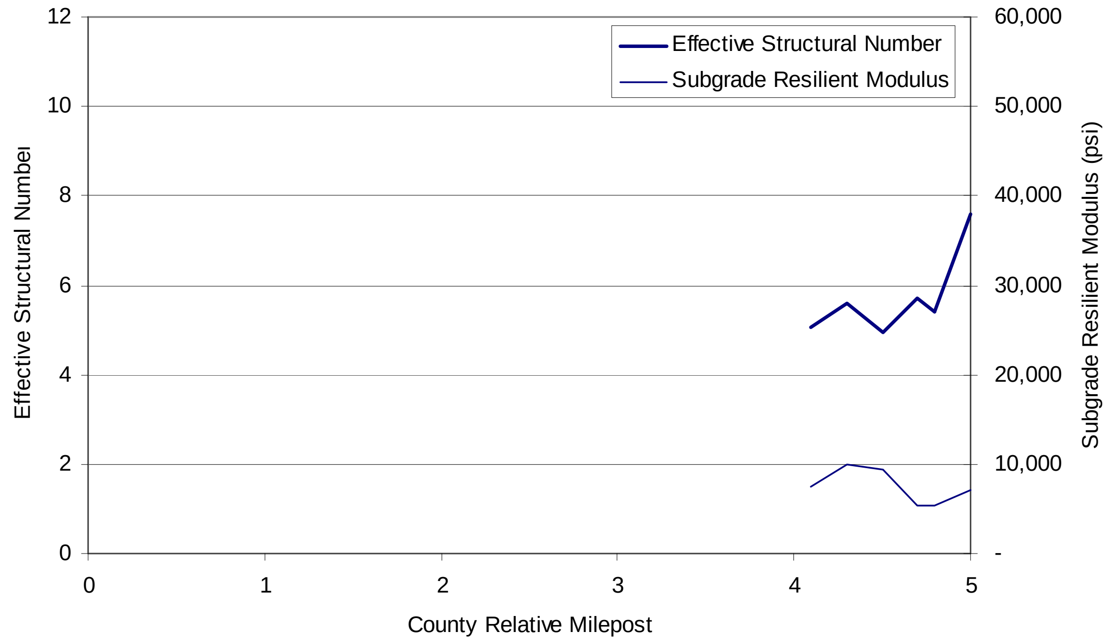

Figure C.154. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-664, York County (Maintenance Jurisdi1ction 099)

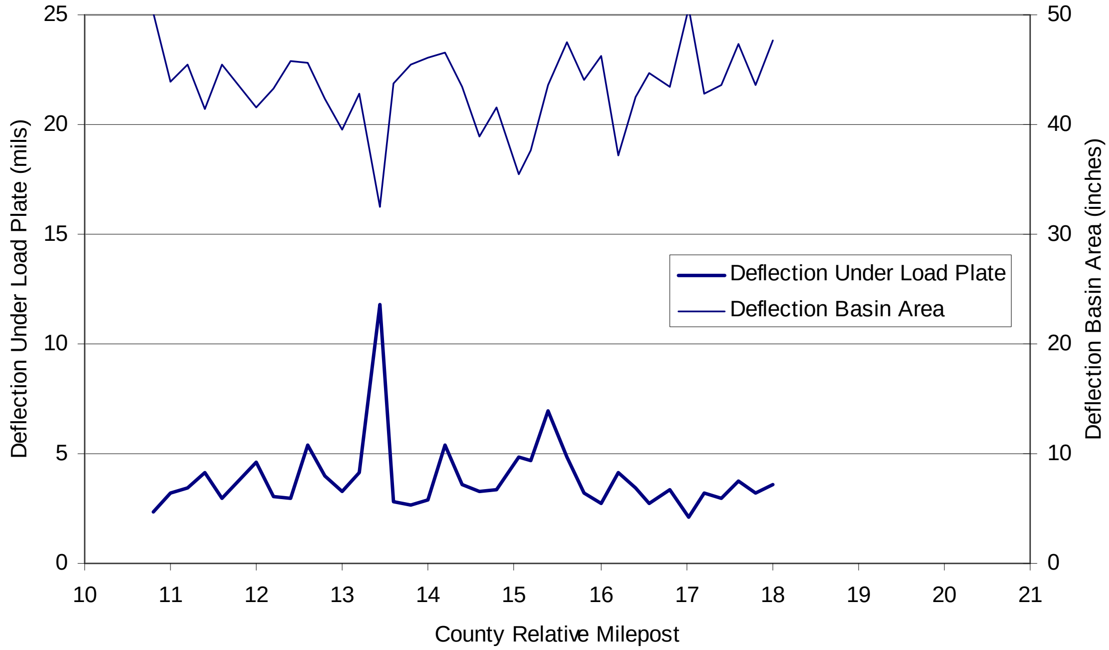

Figure C.155. Deflection Under Load Plate (D_0) and Deflection Basin Area: Eastbound I-664, City of Suffolk (Maintenance Jurisdiction 061)

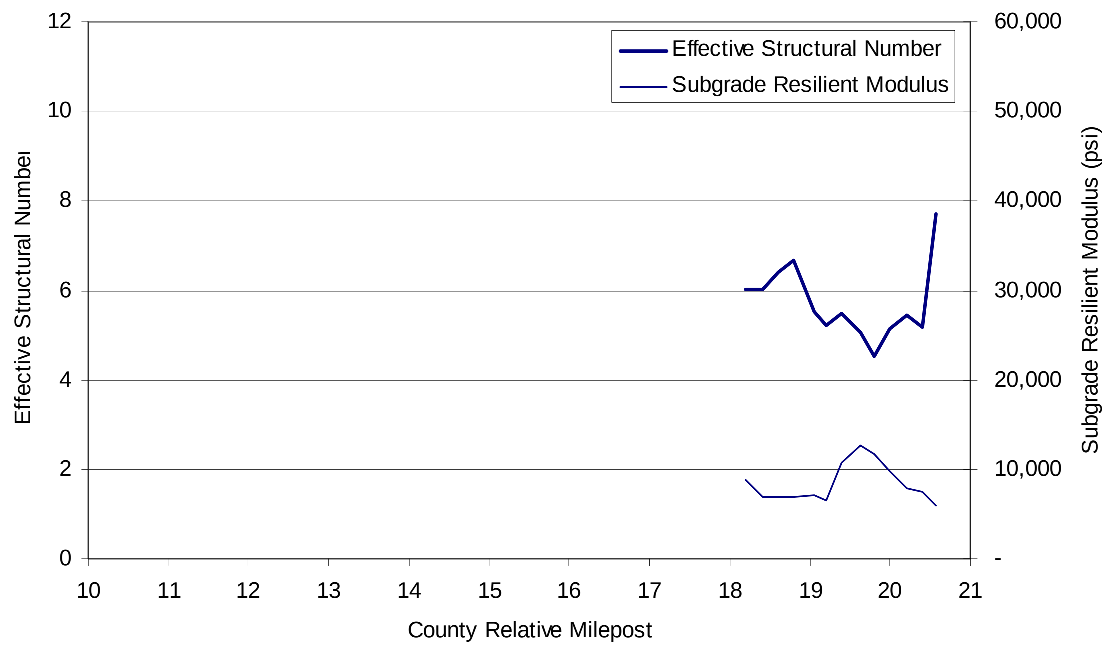

Figure C.156. Effective Structural Number and Subgrade Resilient Modulus: Eastbound I-664, City of Suffolk (Maintenance Jurisdiction 061)

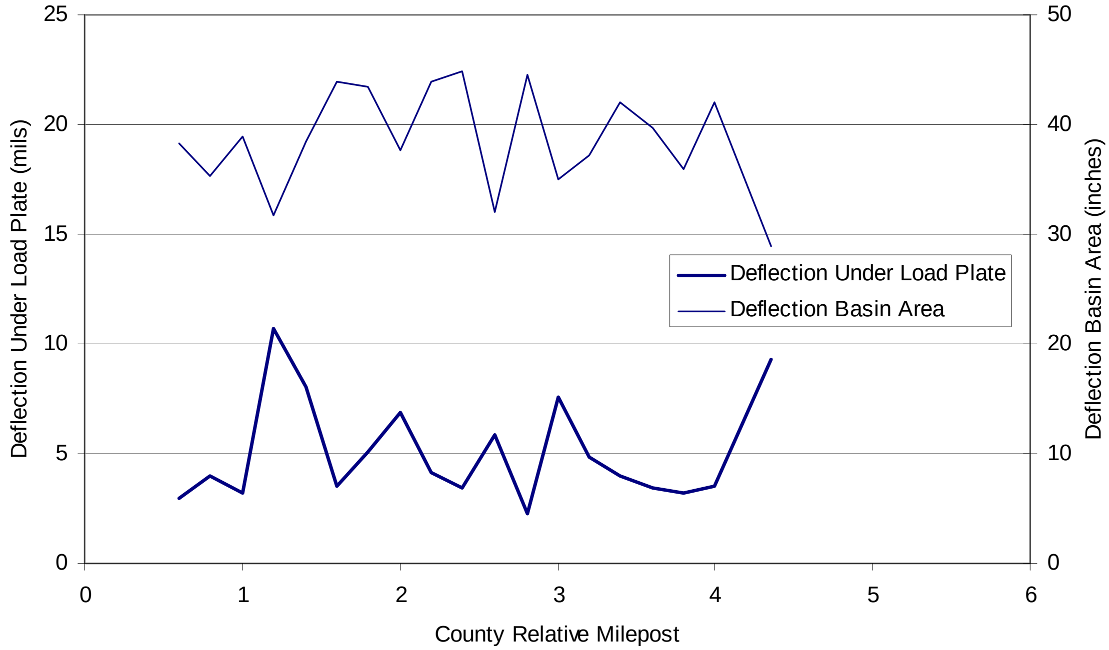

Figure C.157. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-664, York County (Maintenance Jurisdiction 099)

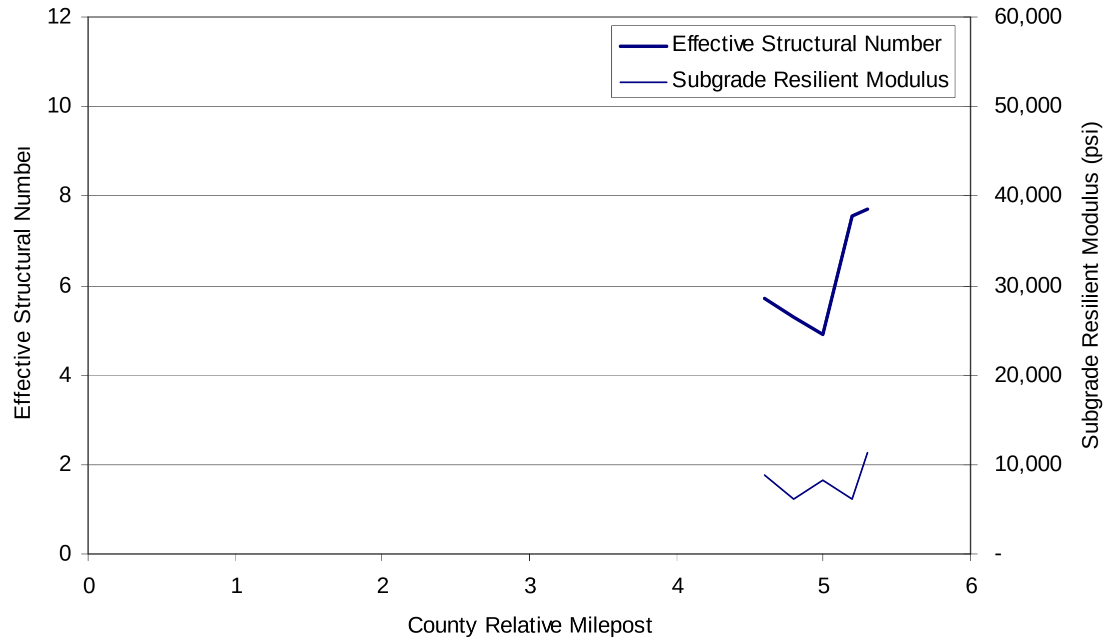

Figure C.158. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-664, York County (Maintenance Jurisdi1ction 099)

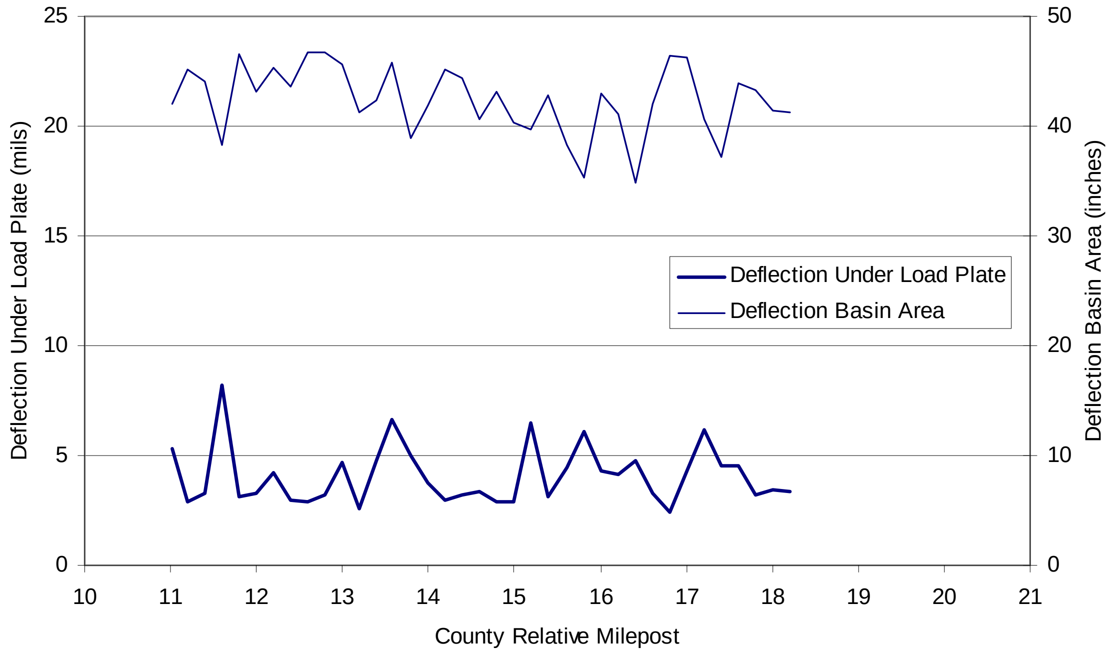

Figure C.159. Deflection Under Load Plate (D_0) and Deflection Basin Area: Westbound I-664, City of Suffolk (Maintenance Jurisdiction 061)

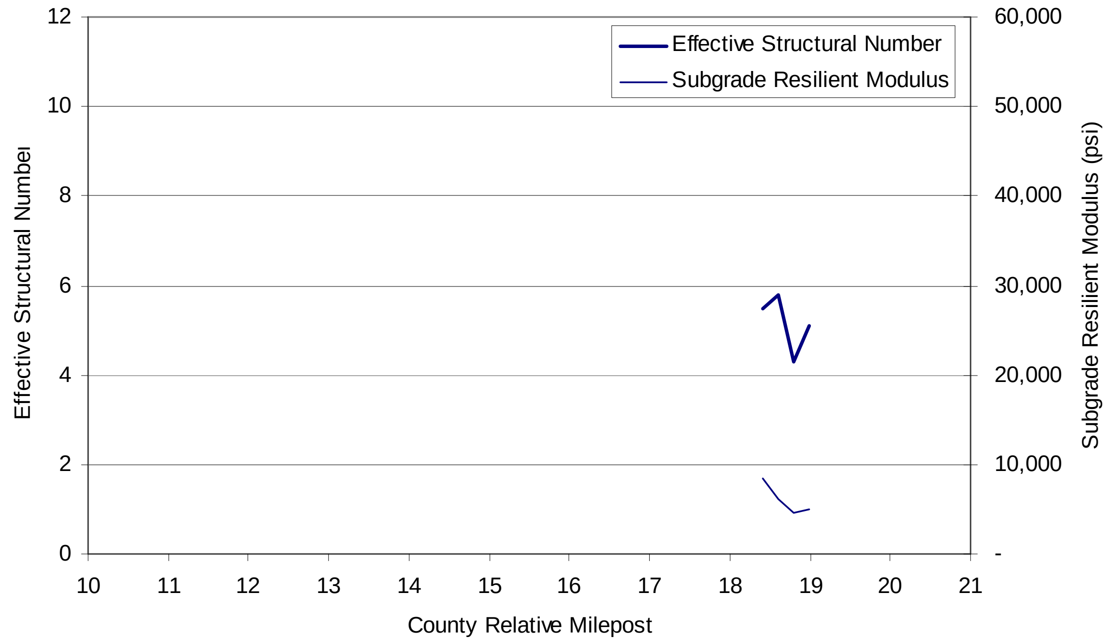

Figure C.160. Effective Structural Number and Subgrade Resilient Modulus: Westbound I-664, City of Suffolk (Maintenance Jurisdiction 061)