Structural Evaluation of Flexible Pavement Using Falling Weight Deflectometer (FWD) Technique

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***Abstract*—For the purpose of providing a method for the structural evaluation and remaining life analysis of flexible pavement, this study makes use of the Falling Weight Deflectometer (FWD) Technique. The portion of the project route that runs along the Aurangabad-Jalgaon Road is where the study is being conducted. This study is being carried out with the intention of determining the amount of the pavement's material life that is still remaining.**

I. INTRODUCTION

A highway pavement is a structure that is made up of layers of processed materials that are layered on top of the natural dirt sub-grade. The major purpose of this construction is to disperse the loads that are produced by vehicles to the sub-grade. An acceptable riding quality, enough skid resistance, favourable light reflecting properties, and minimal noise pollution should be provided by the pavement construction. Additionally, the surface should be able to give a surface that is satisfactory.

Various kinds of pavement:

The two most common forms of pavement that are used in the building of roads are as follows:

Flexible pavement: Flexible pavement is formed from bituminous or unbound material, and the stress is conveyed to the subgrade by the lateral distribution of the applied load with depth throughout the construction process.

The guidelines for the design of flexible pavements are outlined in IRC 37-2018.

Rigid pavement: Rigid pavements are formed by placing slabs of port land cement concrete on top of a subbase of granular material that has been prepared or directly on top of a granular subgrade.

Guidelines for the design of stiff pavement used to highways are outlined in IRC 58-2015.

The structure of flexible pavement is typically made up of the following layers:

Subgrade layer, Subbase layer, Base layer, Binder layer, Surface layer.

II. OBJECTIVE

The primary purpose is to carry out a non-destructive FWD (Falling Weight Deflectometer) test on the existing carriageway at predetermined intervals in accordance with IRC:115-2014, and to collect the deflection readings in addition to other information at each and every place.

An evaluation of the structural condition of the pavement will be carried out with the assistance of a Falling Weight Deflectometer (FWD), and a subsequent analysis will be carried out in order to determine the relative performance of the pavement in relation to the evaluation of its residual life.

FALLING WEIGHT DEFLECTOMETER:

The Falling Weight Deflectometer, often known as the FWD, is a device that is used for impulse loading.

It involves applying a transitory load to the pavement and then measuring the form of the pavement surface after it has been deflected. When measuring the deflected form of the pavement surface, displacement sensors are used. These sensors are positioned at various radial distances, beginning with the centre of the load plate. The fundamental idea behind how each of these FWD models operates is, for the most part, same. After being dropped from a height that has been established in advance, a mass of weights is then deposited on a sequence of springs and buffers that are positioned on top of a loading plate. At a variety of radial positions, the peak load and peak vertical surface deflections that correspond to those places are measured and recorded. Typical Falling Weight Deflectometers (FWD) consist of a circular loading plate with a diameter of 300 millimetres. It is suggested that the load plate be circular.

On bituminous pavements, the objective peak load that should be applied is forty kilonewtons (KN) plus or minus four kilonewtons, which corresponds to the load. In the event that the peak maximum (central) deflection recorded with a load of 40 KN is more than the measuring capacity of the deflection transducer, it is possible to reduce the target peak load in an appropriate manner. There are seven sensors placed at radial distances of 0, 200, 300, 450, 600, 900, and 1500 millimetres. These are the typical geophone position configurations that are used for flexible pavement assessment. The number of sensors and the radial distances measured from the centre of the load plate are also included.

Deflection sensors

•6 – 9 deflection sensors are used in FWD

•6 sensors: 0 200 300 600 900 1200 mm

•6 sensors: 0 300 600 900 1200 1500 mm

•7 sensors: 0 200 300 450 600 900 1500 mm

•7 sensors: 0 200 300 600 900 1500 1800 mm

•9 sensors: 0 200 300 450 600 900 1200 1500 1800

III. CALIBRATION OF FWD

1.Static Calibration

The date of calibration of the load cell should not be earlier than 365 days from the date of structural evaluation of pavements using FWD.

2. Load Repeatability:

Peak deflection 250 to 600 um

Standard Deviation for min. of 12 load drops <5% of the mean peak load.

3.Absolute calibration of deflection transducers:

Should be accurate to 2%.

The resulting load-deflection data can be interpreted through appropriate analytical techniques, such as back calculation technique, to estimate the elastic moduli of the pavement layers.

The computed moduli are, in turn, used for
(i) The strength evaluation of different layers
(ii) The estimation of the remaining life
(iii) Determination of strengthening requirement
(iv) Evaluation of different rehabilitation alternatives (overlay, recycling, partial reconstruction, etc.).

The test spot should be marked on the pavement.

Over the test point, position the load plate of the calibrated FWD so that it is horizontal.

Place the loading plate on the pavement when it is lowered. It is important that the loading plate is in appropriate contact with the surface of the pavement.

The frame that is holding the displacement transducers (geophones) should be lowered so that the transducers may make contact with the surface of the pavement.

Raise the mass to the height that has been specified in advance in order to generate a goal load of forty kilonewtons.

In order to descend, raise the mass. Through the use of a data gathering system, load and deflection data should be recorded into the relevant computer.

As you travel to the next test site, raise the geophone frame and load plate to the appropriate height.

At hourly intervals, take a temperature reading of the air.

It is possible to determine the temperature of the pavement surface layer at hourly intervals by drilling holes into the pavement surface layer that are forty millimetres deep. One drop of glycerol should be used to fill the hole. The thermometer should be inserted into the hole, and the temperature should be recorded after three minutes have passed.

In the event that the temperature of the pavement is higher than 45 degrees Celsius, deflection measurements should not be taken.

IV. DATA COLLECTION

For the purpose of deflection testing, prepare the FWD unit.

At the beginning of the test section, bring the front-wheel drive vehicle to a halt, position it so that it is centred on the outer wheel path (or a certain place), and then take a measurement by applying load in the following sequence:

Just one drop of settling liquid to guarantee correct contact.

Three drops with a weight of forty kilonewtons plus or minus four kilonewtons (or the given load).

With the exception of the settling drop, the sensors that are situated in the middle of the loading plate are responsible for recording the deflections of each respective drop.

In addition to this deflection data, other parameters such as chainage, temperature, date and time, and the location of sensors will also be collected.

Drive the front-wheel drive (FWD) ahead to the next measurement point after each new measurement.

V. PAVEMENT EVALUATION SURVEY

The following is a list of the major categories that pertain to the activities of surveying, investigating, and collecting data:

Information about to the pavement's history.

To identify uniform areas of the pavement that have conditions that are comparable, a condition survey of the pavement was conducted.

The thickness and composition of the pavement layer, as well as the features of the subgrade.

1. Information pertaining to the pavement's history

It is possible that it will be helpful in determining the causes for various distresses and in determining whether the distresses were caused by deficiencies in design, poor material selection, faulty construction, or other factors such as a high water table and inadequate drainage.

Survey of the state of the pavement

A pavement condition *study is required to take* place before to the actual deflection measurement. This survey is mostly comprised of visual observations, and it is supported with measurements that are used to estimate cracking, rutting, and other distresses in the pavement.

The inquiry also includes other types of examinations, such as laboratory tests and test pits

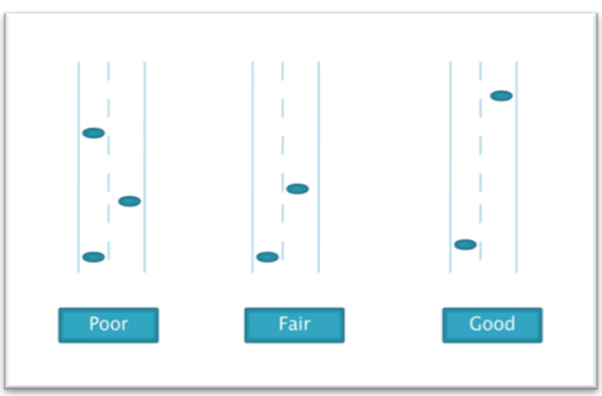
Classification	Pavement Condition
Good	Isolated cracks of less than 3.0 mm width in less than 5% area of total paved surface AND average rut depth less than 10 mm
Fair	Isolated or interconnected cracks of less than 3.0 mm width in 5 to 20% area of total paved surface AND/OR average rut depth between 10 to 20 mm
Poor	Wide interconnected cracking of more than 3.0 mm width in 5 to 20% area (include area of patching and raveling in this) of paved area OR cracking of any type in more than 20% area of paved surface AND/OR average rut depth of more than 20 mm

Criteria of classification of pavement section

Guidelines for selecting of deflection measurement scheme:

Type of Carriageway	Recommended measurement scheme	Maximum Spacing[1] (m) for test points along selected wheel path for pavements of different classification		
		Poor	Fair	Good
Single-lane two-way	i) measure along both outer wheel paths	60	130	500
Two-lane two-way single carriageway	i) measure along both outer wheel paths	60	130	500
Four-lane single carriageway	i) measure along outer wheel paths of outer lanes	30	65	250
	ii) measure along the outer wheel path of more distressed inner lane	60	130	500
	iii) measure along the centre line of paved shoulder (in case of widening projects)[2]	120	260	500
Four-lane Dual (divided) carriageway (Measurement scheme given for each carriageway)	i) measure along outer wheel paths of outer lanes	30	65	250
	ii) measure along the outer wheel path of inner lane	60	130	500
	iii) measure along the centre line of paved shoulder (in case of widening projects)[2]	120	260	500

For Two lane/ Single carriage-way



Determination of Pavement Layer Thickness

In the process of back calculating layer moduli, which is then used to estimate the remaining life of the in-service pavement and the overlay needs, the thicknesses of the pavement layers are crucial inputs that are required. When it comes to layer thicknesses, then, it is essential that reliable information be gathered.

Historical data, the excavation of test pits, or the use of non-destructive procedures are all viable options for determining the thickness of a layer.

Extraction of test pits at appropriate spacing and subsequent measurement of the layer thicknesses has shown to be the most efficient way for estimating the thicknesses of all of the layers.

Excavation of test pits of 0.6 by 0.6 metres should be carried out at intervals of 1.0 km or at acceptable longer intervals, as suggested.

Moduli value ranges for three layers:

•As per Appendix III of IRC 115: 2014; the different ranges for the moduli values of different layers are as follows:

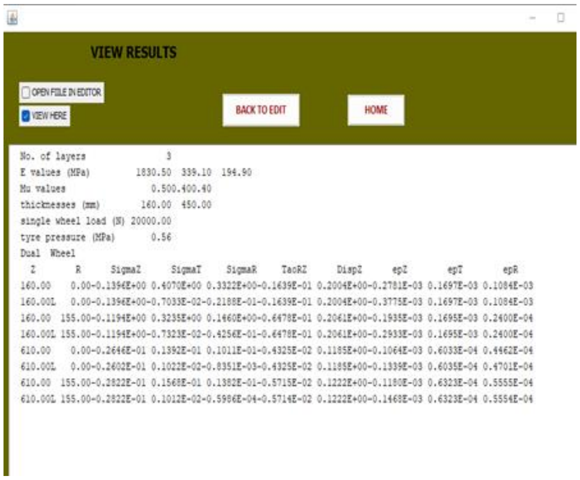
•Bituminous Layer: 750 to 3000 Mpa

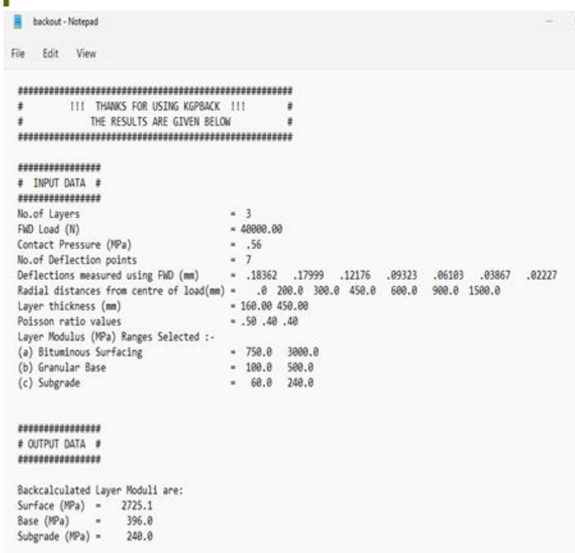
•Granular Layer: 100 to 500 Mpa

•Subgrade: 5xCBR value to 20xCBR value. (as per appendix III of IRC 115:2014)

VI. ANALYSIS OF FIELD DATA

- Processing of load and deflection data
- Back calculation of Layer Moduli
- Correction for Temperature
- Correction for Seasonal Variation
- IITPAVE for overlay requirement

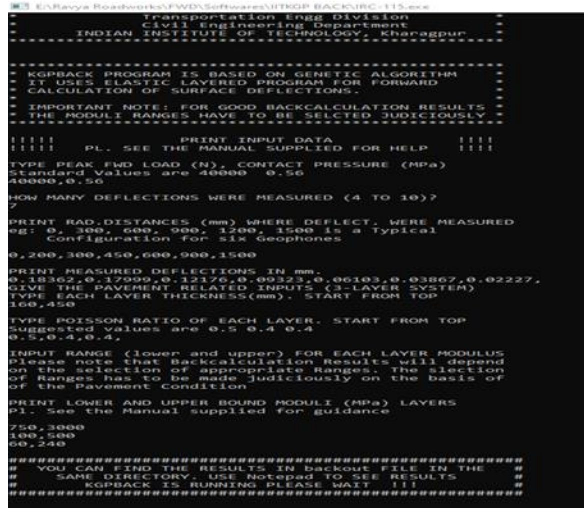




[12] J. Williams, –Narrow-bandanalyzer, ‖Ph.D.dissertation,Dept.Elect.Eng.,

Opening page of IITPAVE Software

IITPAVE SOFTWARE



VII. CONCLUSION

- By using FWD we can determine the elastic moduli of pavement layers and using these moduli as inputs to a pavement design model for overlay requirement.
- And we can also estimate the residual life of an existing pavement.
- Remaining life is greater than design MSA (50), so there is no requirement of overlay.

	FWD 1																					
SN	MV 21-344																					
Sensors	7																					
Sensor position	0	200	300	450	600	900	1500															
	Location	Section	Lane	Station	Up/Down	Lat	Lon	Drop ID	Surface Temp	Ambient Temp	Asphalt Temp	Force	Pressure	D1	D2	D3	D4	D5	D6	D7	Remark	Pulse time
ABR COLLAGE ROAD		2 Lane	LHS	0	+	15.39	79.546	1	35.5	32.3	37.6	39.9	563.9	604	465.1	361.5	226.5	148.4	73.3	48.3		26.4
ABR COLLAGE ROAD		2 Lane	LHS	0	+	15.39	79.546	2	35.5	32.6	37.6	39.8	563.5	594.2	457.2	358.1	228.8	148.9	78.4	46.3		26.4
ABR COLLAGE ROAD		2 Lane	LHS	0	+	15.39	79.546	3	34.3	32.3	37.6	40	566.3	591.7	455.4	355.4	232.4	149.1	75.8	45.6		26.1
ABR COLLAGE ROAD		2 Lane	LHS	0.03	+	15.39	79.546	1	38.5	33.9	38.6	38.9	550.7	513.9	332.1	238.3	134.2	84.1	45.4	38.1		23.9
ABR COLLAGE ROAD		2 Lane	LHS	0.03	+	15.39	79.546	2	35.4	33.2	38.6	38.8	549.2	497.4	327.1	233.7	133.2	85.2	45.4	39.4		24.1
ABR COLLAGE ROAD		2 Lane	LHS	0.03	+	15.39	79.546	3	35.4	33.5	38.6	38.9	550.7	493	325.8	233.4	130.7	84	43.8	38.6		23.8
ABR COLLAGE ROAD		2 Lane	LHS	0.06	+	15.389	79.547	1	33.5	32.8	37.6	40.5	572.6	343.9	230.8	162.5	99.9	66.2	34.7	27.4		25.4
ABR COLLAGE ROAD		2 Lane	LHS	0.06	+	15.389	79.547	2	35.6	32.7	37.6	40.7	575.9	332.6	226	161.3	97.6	65.4	35.7	28.9		25.9
ABR COLLAGE ROAD		2 Lane	LHS	0.06	+	15.389	79.547	3	36.3	32.4	37.6	40.7	576	332.4	222.9	157.7	101.2	71.1	37.1	27.1		25.9
ABR COLLAGE ROAD		2 Lane	LHS	0.09	+	15.389	79.547	1	34.3	33.8	38.6	40.4	571.6	579.8	349	247.5	140.2	72.6	70.8	23.8		25.2
ABR COLLAGE ROAD		2 Lane	LHS	0.09	+	15.389	79.547	2	37.4	33.9	38.6	40.5	573	560.	346.	248.	145	75.4	69.8	24		25.3

													2	2	8						
ABR COLLAGE ROAD	2 Lane	LHS	0.09	+	15.389	79.547	3	37.4	33.5	38.6	40.7	575.4	552.8	346	250.5	144.7	76.7	68.4	22.7		25.4
ABR COLLAGE ROAD	2 Lane	LHS	0.12	+	15.389	79.547	1	35.3	33.1	38.6	39.1	553.1	558.5	349.2	230.1	113.4	54.2	33.9	25.2		24.9
ABR COLLAGE ROAD	2 Lane	LHS	0.12	+	15.389	79.547	2	36.5	33.5	38.6	40.4	571.9	536.5	335.2	216.3	116.2	54.4	34.6	26.4		24.8
ABR COLLAGE ROAD	2 Lane	LHS	0.12	+	15.389	79.547	3	38.4	33.4	38.6	39.5	558.5	534.2	340.5	226	118.1	55.3	32.4	24.6		24.5
ABR COLLAGE ROAD	2 Lane	LHS	0.15	+	15.389	79.547	1	36.4	32.4	37.6	42.3	598	636.2	345.2	329.8	248.2	159.5	73.5	49.6		24.9
ABR COLLAGE ROAD	2 Lane	LHS	0.15	+	15.389	79.547	2	33.4	33.0	37.6	39.9	564.6	605.3	333.5	329.5	224.5	150.7	70.8	47.9		24.9
ABR COLLAGE ROAD	2 Lane	LHS	0.15	+	15.389	79.547	3	36.5	32.7	37.6	42.4	600.3	666.6	343.3	334.9	231.3	157.8	76.7	50.9		24.9
ABR COLLAGE ROAD	2 Lane	LHS	0.18	+	15.389	79.548	1	35.4	33.2	38.6	40.8	576.5	458.9	343.8	249.2	146.1	93.4	36.4	26.8		23.8
ABR COLLAGE ROAD	2 Lane	LHS	0.18	+	15.389	79.548	2	37.4	33.1	38.6	38.9	550.5	453.8	313.9	248.9	147.1	92.3	37.1	26.5		23.9
ABR COLLAGE ROAD	2 Lane	LHS	0.18	+	15.389	79.548	3	35.4	33.7	38.6	39.7	562.3	445.8	311.1	248.4	148.8	92.7	37.9	25.8		24
ABR COLLAGE ROAD	2 Lane	LHS	0.21	+	15.389	79.548	1	35.4	32.1	37.6	40.9	578.1	316.5	245.8	195.4	147.3	91.8	56.8	44.2		27
ABR COLLAGE ROAD	2 Lane	LHS	0.21	+	15.389	79.548	2	34.6	32.4	37.6	40.9	578.1	318.4	243.1	197.7	144.2	95.7	54	43		26.6
ABR COLLAGE ROAD	2 Lane	LHS	0.21	+	15.389	79.548	3	33.3	32.5	37.6	40.5	573.5	314	241.2	194.8	132.5	94.2	53.7	42.2		26.7
ABR COLLAGE ROAD	2 Lane	LHS	0.24	+	15.389	79.548	1	34.5	33.5	38.6	40.6	574	452.3	295.2	268.9	204.8	147.8	79.2	46.8		23.9
ABR COLLAGE ROAD	2 Lane	LHS	0.24	+	15.389	79.548	2	36.3	33.7	38.6	40.6	574.9	448.	288.	258.	210.	148.	78.9	49.3		23.7

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ABR COLLAGE ROAD	2 Lane	LHS	0.24	+	15.389	79.548	3	38.3	33.8	38.6	40.4	571.9	434.2	281.3	276.2	207.1	145.8	78.4	47		23.7
ABR COLLAGE ROAD	2 Lane	LHS	0.27	+	15.389	79.548	1	38.4	34.0	38.6	41.5	586.5	469.2	339.4	284.5	164.9	105.2	53.8	36.2		23.7
ABR COLLAGE ROAD	2 Lane	LHS	0.27	+	15.389	79.548	2	34.4	33.3	38.6	40.3	569.4	475.4	347.3	260.7	167.7	103.4	51	35.4		23.8
ABR COLLAGE ROAD	2 Lane	LHS	0.27	+	15.389	79.548	3	35.3	33.6	38.6	40.7	575.5	466.7	342.7	262	161.8	103.5	52.4	33.4		23.8
ABR COLLAGE ROAD	2 Lane	LHS	0.3	+	15.388	79.549	1	37.3	32.8	37.6	40.4	571.2	755.2	586.8	447.8	283.2	229.1	121.7	91.4		26.2
ABR COLLAGE ROAD	2 Lane	LHS	0.3	+	15.388	79.549	2	34.6	32.5	37.6	39.8	563.7	754.1	577.6	444.9	281.2	220.3	119.6	89.1		25.9
ABR COLLAGE ROAD	2 Lane	LHS	0.3	+	15.388	79.549	3	36.4	32.3	37.6	42.3	598.6	775.3	586.2	454.2	286.2	225.4	129.2	93.1		25.5
ABR COLLAGE ROAD	2 Lane	LHS	0.33	+	15.388	79.549	1	36.3	33.4	38.6	39.2	554.5	455	303.3	214.1	129.5	82.3	41.8	28.1		24.3
ABR COLLAGE ROAD	2 Lane	LHS	0.33	+	15.388	79.549	2	36.3	34.0	38.6	39.5	559.1	443.7	295.6	210.2	127.4	79.5	42.2	28		24.4
ABR COLLAGE ROAD	2 Lane	LHS	0.33	+	15.388	79.549	3	37.3	33.4	38.6	40.1	566.8	433.7	290.1	207.9	126.2	79.9	41.2	27.9		24.5
ABR COLLAGE ROAD	2 Lane	LHS	0.36	+	15.388	79.549047°	1	34.6	33.0	37.6	37.9	536.6	247.9	174.2	136.4	112.5	62.4	36	23.6		26.2
ABR COLLAGE ROAD	2 Lane	LHS	0.36	+	15.388	79.549047°	2	36.5	32.3	37.6	39.6	559.9	243.3	182.4	139.5	110.9	63.3	36.4	24		25.5
ABR COLLAGE ROAD	2 Lane	LHS	0.36	+	15.388	79.549047°	3	37.5	32.2	37.6	39.7	561.7	239.1	176.4	137.3	112.1	65.3	35.2	23.4		25.4
ABR COLLAGE ROAD	2 Lane	LHS	0.39	+	15.388	79.549	1	36.4	33.6	38.6	41.1	581.7	155.5	115.5	94.5	82.4	50.6	37.9	11.6		23.8
ABR COLLAGE ROAD	2 Lane	LHS	0.39	+	15.388	79.549	2	34.5	34.0	38.6	41.6	588.2	152.	117.	95.2	83.9	49.5	38.5	11.7		23.8

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ABR COLLAGE ROAD	2 Lane	LHS	0.39	+	15.388	79.549	3	37.5	34.0	38.6	41.1	581.5	1533.5	1112.4	92	78.6	49.1	36.2	11.9		23.7
ABR COLLAGE ROAD	2 Lane	LHS	0.42	+	15.388	79.55	1	35.5	33.6	38.6	40.1	567.6	394.6	286.9	231.8	161.3	116.8	71.2	47.7		24.1
ABR COLLAGE ROAD	2 Lane	LHS	0.42	+	15.388	79.55	2	36.3	33.2	38.6	40.4	571.4	392.6	279.1	233.3	156.1	116.2	74.2	47.4		24.1
ABR COLLAGE ROAD	2 Lane	LHS	0.42	+	15.388	79.55	3	36.4	33.6	38.6	40	566.2	389.8	277.1	229.2	158.8	115.8	73.5	48.6		24.1
ABR COLLAGE ROAD	2 Lane	LHS	0.45	+	15.388	79.55	1	35.4	32.9	37.6	38.6	545.6	170.8	108.7	94.6	71	51.9	36.1	22.8		25.7
ABR COLLAGE ROAD	2 Lane	LHS	0.45	+	15.388	79.55	2	33.6	32.1	37.6	42	594.1	175.9	112.9	104	75.4	53.9	36.7	22.8		25.4
ABR COLLAGE ROAD	2 Lane	LHS	0.45	+	15.388	79.55	3	34.3	32.7	37.6	38.9	549.8	169.8	111.8	102	72.6	49.6	35.6	21.3		25.5
ABR COLLAGE ROAD	2 Lane	LHS	0.48	+	15.388	79.55	1	35.4	33.6	38.6	40.1	567.2	459.9	310.2	255.6	177.3	127.5	76.7	52.3		23.9
ABR COLLAGE ROAD	2 Lane	LHS	0.48	+	15.388	79.55	2	35.3	33.8	38.6	40.1	567.8	455.1	282.8	257.2	175.8	128.4	79.5	53.1		24.1
ABR COLLAGE ROAD	2 Lane	LHS	0.48	+	15.388	79.55	3	36.4	33.3	38.6	40.5	572.3	459.9	296.3	244.4	178.6	129.7	78.2	54.3		24.4
ABR COLLAGE ROAD	2 Lane	LHS	0.51	+	15.388	79.55	1	36.3	32.6	37.6	40.6	574.8	148.6	124.4	106	89.6	59.5	40.7	11.7		25.5
ABR COLLAGE ROAD	2 Lane	LHS	0.51	+	15.388	79.55	2	34.5	32.4	37.6	41.7	589.9	146.3	121.5	100.8	88.6	57	42.7	11.6		25.2
ABR COLLAGE ROAD	2 Lane	LHS	0.51	+	15.388	79.55	3	36.6	32.1	37.6	41.5	587.8	140.5	123.6	101.5	84.8	56.7	43.8	11.6		25.2
ABR COLLAGE ROAD	2 Lane	LHS	0.54	+	15.388	79.551	1	36.5	33.7	38.6	43.4	614.1	181.3	97	65.9	50.6	48.1	36.2	32.2		24
ABR COLLAGE ROAD	2 Lane	LHS	0.54	+	15.388	79.551	2	38.3	33.9	38.6	42.2	597.3	173.	94.4	66.2	49.4	45.9	34.1	31.5		24.1

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ABR COLLAGE ROAD	2 Lane	LHS	0.54	+	15.388	79.551	3	35.3	33.1	38.6	41.9	592.1	168.6	97.1	61.8	48.5	46.9	35.2	30.7		23.9