EFFECT OF MAT THICKNESS FOR THE DEGREE OF COMPACTION OF ASPHALT PAVEMENTS

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Degree of Master of Engineering

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DECLARATION OFTHE CANDIDATE AND SUPERVISOR

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ABSTRACT

Effect of Mat Thickness for the Degree of Compaction of Asphalt Pavements

Compaction of the hot mix asphalt (HMA) is very important process in the road construction. The ability of the load bearing is greatly dependent on the degree of compaction of the hot mix asphalt pavements (Finn, & Epps, 1980). The degree of compaction depends on the various factors. The thickness of the hot mix asphalt mat is a major factor that affects to the degree of compaction. Temperature of the hot mix asphalt is very much important for the proper compaction. It is mainly governed by the layer thickness. According to previous researches, it has been shown that low thicknesses layers are rapidly drop down its temperature rather than the high thicknesses layers.

This research aims at finding out, what is the optimum mat thickness of the asphalt pavements, which is suitable for the Sri Lankan conditions.

In the compaction process of the hot mix asphalt layers, maximum aggregate size affects the layer thickness. 2.5 times of the maximum aggregate size has been considered as the optimal thickness for the asphalt layer. According to the guidelines of the Road Development Authorities (Sri Lanka), most of the asphalt pavements are constructed with a 50mm or lesser (40-50mm) thick layers.

For this study, four road projects were selected to find out the optimum mat thickness. Thicknesses of the asphalt cores and their degree of compactions were obtained from the above projects. The cores collected in a certain range of breakdown temperatures were selected to maintain the uniformity of the samples. Maximum day time temperature and average monthly velocity details were obtained from the Department of Meteorology. The graph of core thicknesses versus degree of compaction is plotted and optimum compaction range was estimated using the graph.

As per the study, it shows that, mat thicknesses within the range 55-60mm provide highest degree of compaction. It is recommended to have about 55-60mm thick mat thickness instead of having 50mm or lesser mat thicknesses to obtain highest degree of compaction of HMA layers for the selected environmental and laydown conditions.

Key words: Mat, thickness, hot mix asphalt, degree of compaction, maximum aggregate size, core sample

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For most all, I express my sincere thank to Prof. W. K. Mampearachchi, my research supervisor in Department of Civil Engineering for providing necessary guidance to success this research. He always provided his guidance during the difficult times and spend his valuable time discuss the problems encountered during data collection and analysis.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

HMA - Hot Mix Asphalt

ICTAD - Institute for Training and Development

VMA - Voids in Mineral Aggregates

VIM - Air Voids in Total Mix

1 INTRODUCTION

1.1 Background

The compaction of the Hot Mix Asphalt (HMA) pavement is very much important, because the asphalt surfacing layer is the primary load bearing layer of the pavement. The Degree of compaction (in situ density) is the common key parameter used in the field testing. It gives good relationship to identify compaction of the asphalt pavements. Sufficient compaction of asphalt pavement during construction is widely recognized as one of the main factor affecting the ultimate performance of a pavement because it influences strength, smoothness and skid resistance. Adequate level of compaction prevents delayed densification by traffic tending to permanent deformation (rutting). Furthermore, it strengthens the pavement, helps to “waterproof” the pavement, and reduces the air void content to slow binder oxidation which leads to raveling and cracking.

The thickness of the hot mix asphalt mat is a major factor that affects the degree of compaction. The research aim is finding the suitable mat thickness as per the Sri Lankan context. In this study, four road projects were selected in the dry zone. They were Jaffna-Pannai-Kayts road, AP4-Integrated road package of Anuradhapura, KU1- Integrated road package of Kurunegala and PO2- Integrated road package of Polonnaruwa.

1.2 Problem Statement

According to the pavement design, typical thicknesses of wearing course surfaces in Sri Lanka are constructed with a 50mm or lesser (40-50mm) thickness. Compaction issues have been identified in some road projects and low mat thicknesses could be a possible reason for the low degree of compaction.

1.3 Objectives

The research aim is to find out the optimum asphalt thickness to obtain the required degree of compaction under the prevailing environmental and laydown conditions in Sri Lankan Roads.

2 LITERATUREREVIEW

A good road network system is required for a sustainable development of a country, because it supports efficient and reliable national and international trade as well as facilitating personal mobility to citizens. The citizens are able to tolerate their requirements such as accessing employments, markets, educations and health facilities. When there are adequate roads connecting all the relevant places, the road infrastructure can be defined as good and those roads are maintained in service condition. Roads should be constructed in such a way as to extend their durability to keep the pavements in good working condition without the need for regular repairs. The advantages of maximizing the durability of pavements on roads are:

- Reduction latency of road users due to maintenance
- Reduction the maintenance costs to the road authority
- Improvement the sustainability of pavement construction

As per Transport Research Circular, published in 2006, durability is the ultimate goal of the asphalt pavement, because it implies the sustainability of asphalt pavement. Pavement durability depends on the several factors. They are,

- Durability of asphalt
- Traffic and other site conditions
- Performance requirements
- Performance characteristics of the asphalt

Densification, compaction of asphalt pavement is a key factor to achieve the performance requirements and also is required proper control and sophisticated equipments (train of compactors).

2.1 Densification of Asphalt Pavements

Finn, F. N., Epps, J. A. (1980) state, densification of asphalt pavement depends on the several factors. Following are the key factors that influence for the densification process.

- Type of Mix
- Mix Temperature
- Base Temperature
- Mat(Layer) Thickness
- Equipment (Paver, Rollers...)
- Other Environmental factors

2.2 Type of Mix

Different types of mixes are specified in the ICTAD SCA/05 (Standard Specification for Construction & Maintenance of Road & Bridges). Those mix types are customized to achieve specific parameters with the common mandatory properties. Types of wearing courses shown in Table 2.1 are recommended by the ICTAD SCA/05.

Type-1 and Type-3 wearing courses are commonly used in Sri Lanka as per ICTAD. Type-1 is quite finer than the type-3, because it has a little bit higher amount of finer aggregates than the type-3.

Dickson, P.F. and Corlew, J.S. (1970) state, mix aggregate (gradation, particle size, particle shape) and binder properties affects the level of compaction. Binder will act as a lubricant at high temperature and cohesive material at low temperature. So, binder has an effect on aggregates to rearrange its geometrical orientation with the roller load.

As per the Hot-Mix Asphalt Paving Handbook “Gradation affects the way aggregate interlocks and thus the ease with which aggregate can be rearranged under roller loads”. In general, the effects of aggregates on compaction can be categorized by size of aggregate, shape of the aggregates, surface texture and the number of fractured faces. According to the Hot-Mix Asphalt Paving Handbook “Rough surface textures, cubical or block shaped aggregate (as opposed to round aggregate) and highly angular particles (high percentage of fractured faces) will all increase the required compaction effort to achieve a specific density”. The application of the roller load will result the shifting laterally or shove the asphalt layer when presence of high amount of midsize fine and rounded aggregates. This occurs because midsize fine and rounded aggregates fill the voids in mineral aggregates (VMA). Because of low VMA there will be no sufficient space to fill the asphalt cements. Therefore, when the binder content is little bit high, it will completely fill the voids within the mineral aggregates and excess binder will come out and act as lubricating layer. It resists the roller compaction by displacing the aggregate mix laterally. Generally, it is difficult to compact the mix with high fines content rather than the low fine content because they are filling the internal voids.

Table 2-1 Aggregate grading, Binder content and Thickness requirements for Binder course and Wearing courses

Mix classification	**Binder course**	**Wearing course Type 1**	**Wearing course Type 2**	**Wearing course Type 3**	**Wearing course Type 4**
Compacted thickness mm – maximum minimum	75 35	75 35	75 35	75 40	75 40
Sieve Size mm μm					
28	100	100	-	100	100
20	90 - 100	85 - 100	100	93 - 100	95 – 100
14	-	-	82 - 92	-	-
10	56 - 82	66 - 94	61 - 81	59 - 94	58 – 84
5	36 - 58	46 - 74	41 - 66	38 - 69	36 – 66
2.36	21 - 38	35 - 58	27 - 48	25 - 48	23 – 49
1.18	15 - 32	26 - 48	20 - 40	20 - 40	-
600	10 - 26	18 - 38	15 – 35	15 - 32	-
300	6 - 20	11 - 28	10 - 25	10 - 23	5 – 19
150	3 - 13	7 - 20	7 - 17	4 - 15	-
75	1 - 7	3 - 12	5 - 9	3 - 12	2 – 8
Percentage binder content by total weight of mix	3.5 – 5.5	4.0 – 6.5	4.0 – 6.0	4.0 – 6.5	4.0 – 6.0

The effective bitumen content of the asphalt mixture also affects the workability and compactability of the mat. Generally, It is very difficult to compact the mix due to lateral displacement when the binder viscosity is low. Additionally binder is showing low viscous or harder during production process, mix is more resist to roller compaction. The coating thickness on the aggregate particles increases with the binder content. The increased coating thickness enhances the lubricating effect at compaction temperature and it provides support to compact the mat up to certain point.

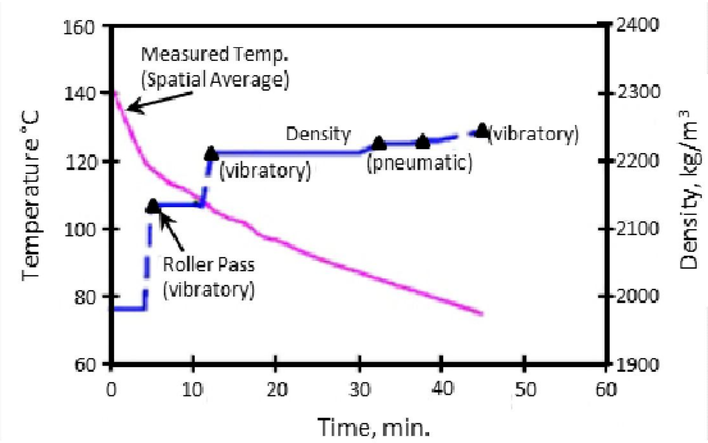
The controlled parameters of the wearing course mixtures are defined in the ICTAD SCA/5. Table 2.2 shows the specified values for the design parameters.

Table 2-2 Requirements of Wearing Courses as per the Traffic

No	Description	Low Traffic	Medium Traffic	High Traffic
1	Marshall stability in kN	Not less than 3.3	Not less than 5.34	Not less than 8.0
2	Marshall flow (0.25mm)	8 to 20	8 to 18	8 to 16
3	Air void in total mix (VIM) (Percent)	3 to 5	3 to 5	3 to 5
4	Voids in mineral aggregate VMA (Percent) For design VIM of 4%	Not less than 13	Not less than 13	Not less than 13

2.3 Mix Temperature

Hot mix asphalt temperature directly affects the viscosity and compaction of asphalt mat. The asphalt binder shows more viscous and resistant to deformation when the HMA temperature decreases. Due to higher viscosity, reduction of the air voids is very small for a given roller compactive effort. Furthermore, as the mix temperature goes down the asphalt binder becomes stiffer and prevents further compaction due to preventing the reduction of air voids. The temperature, this scenario which is transition happen, commonly identified as cessation temperature. As per the Finn, F. N., Epps, J. A. (1980) this is a function of the mix property factors. Commonly it is identified as 79°C (175°F) for dense graded HMA. Smoothness of the layer can be improved by further rolling, but it will not increase the compaction of the asphalt layer. Figure 2.1 illustrate the behavior of mat temperature verses time availability.



Unit Conversion

°F = (°C *9/5) + 32

lb/CF = kg/m³ *0.0624

Figure 2-1 Mat temperature verses Time availability

If the aggregate binder mix shows high fluid (at higher temperature) asphalt mat will not compact and tends to displace or shove the mat. In general, mix shall have a significant amount of viscosity to roller compaction but stiff enough to prevent excessive shoving.

Table 2-3 Temperature requirements on Mix at various stages

Process/ Description	Temperature (°C)	
	Min	Max
Aggregate temperature before mixing	140	170
Binder temperature before mixing	150	170
Mixing temperature	145	170
Temperature @ Paver	135	-
Laying temperature	135	-
Breakdown temperature	135	-
Intermediate temperature	115	-
Final rolling temperature	90	-

Controlled temperature ranges for each process as specified in ICTAD SCA/5 is mentioned in Table 2.3. ICTAD has provided general guideline for temperature requirements. However the maximum temperatures are not mentioned for some processes.

2.4 Base Temperature

The effect of the base temperature is also a highly influential factor which affects the degree of compaction. Time available for compaction will increase the higher base temperatures and that will decrease with lower base temperature.

Dickson and Corlew(1970) state, “To achieve adequate compaction of hot-mix asphalt pavement, the temperature of the mat must be sufficiently high for the period of time necessary to complete rolling”. Thus, with a cold base and a cool mix temperature, a thin lift of HMA would cool rapidly. Dickson and Corlew also stated that “frozen subgrades with high moisture content will decrease time available for compaction significantly compared to placement on an unfrozen subgrade. In addition to rapid cooling, placement of HMA on wet, frozen subgrade also presents the risk of pavement structural failure, due to thawing of the subgrade”. Livneh (1990) stated that, hot and wet (tropical and subtropical) region are mainly characterized by less extreme fluctuations in the temperatures of the asphalt surface during the 24-hour period. As a result of occasional clouding, solar radiation is less intense than in desert regions, and the temperature cycle of the asphalt surface is somewhat moderated.

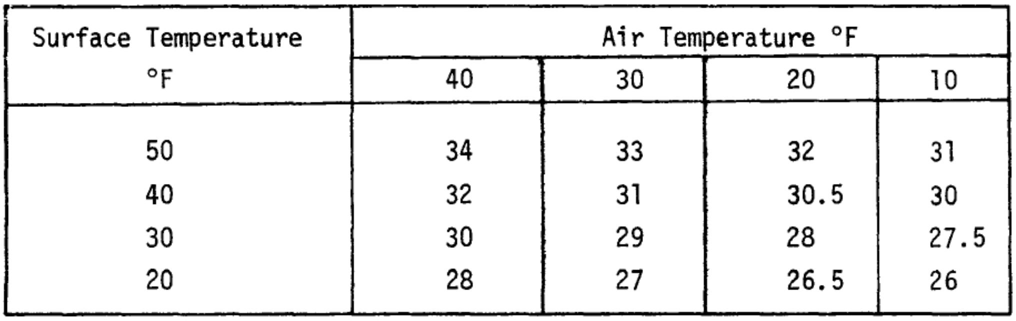
2.5 Mat Thickness

Mat (layer) thickness is the other important factor that affects the degree of compaction. Buchanan et al., 1998, stated that “Lift thickness is widely recognized as a major contributor to the ability to achieve density”. In general, thick asphalt layers are easier to compact, but when the thickness is too high, it is difficult to compact entire layer because of the bottom zone of the layer may be outside the effective roller load and resulting undercompaction. As per the study by Hughes, 1989, “thicker lifts provide more room for aggregate particles to be reoriented and retain heat longer, both of which aid compaction”. Heat retention of the mix is very critical as discussed, because proper temperature of the mix tends to more compaction.

As per the Transportation Research Circular E-C105, Washington, 2006, “if the lift thickness is greater than 2 in., the mix should be able to be placed at the proper density, due to the high retention of heat by the mass of material. However, thinner lifts will require significant effort and attention to detail to achieve proper density of the mix”. In generally mat thickness shall be 2.5 times the maximum aggregate size. The process of designing of wearing course surfaces, generally the mat thickness is limited to the 50mm.

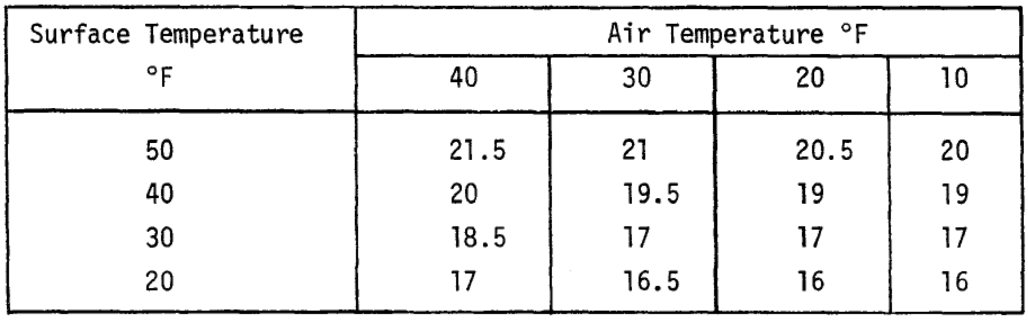
There are few researches related to mat thicknesses versus compaction are available. In such research presented in Engineering Economics and Energy Consideration, Texas, 1975, provides the relationship between mat thicknesses and time availability for compaction.

Table 2-4 Compaction Time (minutes) for 3 inch Mat Thickness



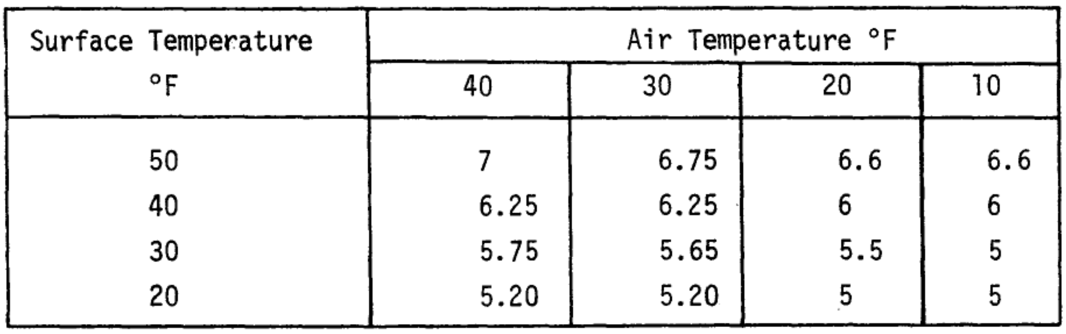
Surface Temperature °F	Air Temperature °F			
	40	30	20	10
50	34	33	32	31
40	32	31	30.5	30
30	30	29	28	27.5
20	28	27	26.5	26

Table 2-5 Compaction Time (minutes) for 2 inch Mat Thickness



Surface Temperature °F	Air Temperature °F			
	40	30	20	10
50	21.5	21	20.5	20
40	20	19.5	19	19
30	18.5	17	17	17
20	17	16.5	16	16

Table 2-6 Compaction Time (minutes) for 1 inch Mat Thickness



Surface Temperature °F	Air Temperature °F			
	40	30	20	10
50	7	6.75	6.6	6.6
40	6.25	6.25	6	6
30	5.75	5.65	5.5	5
20	5.20	5.20	5	5

Table 2-4 to 2-6 shows the time availability for compaction of asphalt mixers with variable mat thicknesses, base temperatures and air temperatures. As per the Engineering Economics and Energy Consideration, Texas, 1975, thicker mat is having higher times availability than the thinner layers, because of the low rate of heat dissipations.

2.6 Equipment

Paving and compacting equipments are the major factors that accounts for the HMA compaction. Compaction equipment compact the HMA by two methods:

- Roller loads apply to the HMA surface and compressing the layer underneath the contacted surface. This compaction effort will be higher when the period of contact is higher. That mean lower roller speed will produce more compaction rather than the greater speed. Further compaction will be achieved by using higher compaction equipment weights.
- Creating a shear stress between the compressed material and the underneath uncompressed materials. This occurs due to the speed of the compaction equipment. The lowering speed of the equipment, shear rate will decrease and increase the shearing stress. Aggregates are tending to rearrange and compact more densely by higher shearing.

The numbers of roller passes and roller speeds have been mentioned in ICTAD SCA/5 as shown in Table 2-7.

Table 2-7 Speed of the rollers

Type of roller	Speed (km/hr)		
	Breakdown	Intermediate	Finish
Steel Wheeled Rollers	3	5	5
Pneumatic Rollers	5	5	8
Vibratory Rollers	5	5	-

The data shown in Table 2-7 are the general condition. However, heavy weight rollers with various vibratory effects are used for the HMA compactions with the technological advancement. So, the speed and number of passes shall be determined by the field trials.

2.7 Other Environmental Factors

Environmental factors are determined by place and time of paving occurs. This factor does not directly affect the HMA compactions. As per the previous research data stated in Hot-Mix Asphalt Paving Handbook, 2000, they have significant effect on the HMA compaction. Following factors are mainly accounted under environmental factors stated in the handbook.

- Ambient temperature
- Higher ambient air temperatures will let to slowly dissipate heat from the mat surface and increase the time available for compaction (TAT). The ambient air temperature of the tropical countries does not vary significantly with compared to other cold countries. Generally, temperature is around 20-35 ^{0}C and does not fall to minus degrees. The effect of dissipating heat from the mat is low since the ambient temperature is high.
- Wind speed

  Higher wind speed will easily dissipate heat from the mat and low wind speed tends to retain the heat of the mat because heat of the mat will be absorbed by wind particles and decrease the surface temperature.
- Solar flux

  Higher amount of solar flux will retain the mat heat and low amount of solar flux will release the heat of the mat

3 METHODOLOGY

Four road construction packages were selected for the study. The main selecting criterion was the mix type. All four packages used Type 3 mixture design and they are within the same aggregate gradation limits. Table 3-1 shows the mix characteristics of asphalt in each project. The selected road construction projects are;

I. JPK-Jaffna- Pannai- Kayts road
II. AP4-Integrated road package of Anuradhapura
III. PO2-Integrated road package of Polonnaruwa
IV. KU1-Integrated road package of Kurunegala

Table 3-1 Mix Characteristic

Mix Properties	**Spec. requirements**	**Tolerance**	**Design Value**			
			JPK	**AP4**	**PO2**	**KU1**
Binder content by weight of mix (%)	4.0-6.5	±0.3	4.7	4.6	4.8	4.7
Mix density (g/cm^3)	~	~	2.415	2.458	2.509	2.52
Effective Sp. gravity of aggregates (g/cm^3)	~	~	2.715	2.734	2.84	2.848
Bulk Sp. Gravity for the total agg. (g/cm^3)	~	~	2.694	2.561	2.81	2.815
Voids in total mix (VIM) (%)	3-5	~	4	4	4.1	4
Voids in Mineral aggregate (VMA)(%)	Not less than 13	~	14.6	14.3	15	14.7
Voids filled with bitumen (VFB) (%)	~	~	72	~	~	~
Marshall Stability (kN)	Not less than 8	~	14	17.3	16.4	14.1
Marshall flow (0.25 mm)	8 - 16	~	12.3	10.8	9.9	10.2
Mix Temp. when emptied from mixer (^{0}C)	145 - 170	± 10	155	155	155	155
Mix Temp. when delivered to the paver (^{0}C)	> 135	± 10	145	145	145	145

*Max aggregate size – 19 mm

In this study, the effects of layer thickness of the asphalt pavement on degree of compaction were considered during road construction process. And the other conditions were maintained within the control range as much as possible. As per the literature survey, there are lots of factors affect the degree of compaction.

The methodology of the study is as follows;

- Thicknesses of the asphalt cores and their degree of compactions were obtained from the above projects
- Cores with the particular range of breakdown temperatures were selected to maintain the uniformity
- Maximum day time temperature details were obtained from the Department of Meteorology
- Seasonal wind velocity details were obtained from the “Weatherspark” website (https://weatherspark.com)
- The graph of core thicknesses versus degree of compaction is plotted and optimum compaction range is measured.

[redacted]

Figure 3-1 Laying of HMA (AP4 Project)

Following factors were considered in selecting the core sample for study to maintain the uniform conditions;.

- Breakdown temperature of the asphalt
- Ambient temperature of the air
- Compaction equipment& compaction process

Breakdown temperature

The breakdown temperatures were selected within the range (135 – 155 ^{0}C)

Ambient temperature

Ambient temperature data was obtained from the Department of the Meteorology (See Annex B)

Compaction equipments & process

The types of rollers, weight of rollers and number of passes were not same in all four projects (details are mentioned in Table 3.2). However, those were almost same within a project unless any fault with the equipment during the construction.

Table 3-2 Compaction Equipment and Roller Passes

Project	Compaction/Equipment Details					
	Break down (Tandem)		Compaction (PTR)		Finishing (PTR)	
	Weight	No. of Passes	Weight	No. of Passes	Weight	No. of Passes
JPK	10 Ton	5-6	3 numbers 16 Ton with Additional weight	20-25	16 Ton without load	6-7
AP4	10 Ton	5-6	2 numbers 16 Ton	20-25	16 Ton without load	4-5
PO2	10 Ton	4-5	2 numbers 16 Ton	18-23	16 Ton without load	4-5
KU1	10 Ton	4-5	2 numbers 16 Ton	18-23	16 Ton without load	4-5

Figure 3-2 Compaction of HMA (AP4 Project)

4 TEST RESULTS AND DISCUSSION

4.1 Ambient Temperature

Ambient temperature details were obtained for the above four packages with relevant to the HMA paving time periods from the Department of Meteorology. They were plotted in the graphs to perform better analysis. They were shown in Figure 4.1 to Figure 4.4 and maximum and minimum temperatures are mentioned in Table 4.1. The obtained temperature data shows the maximum day time temperatures of each area. Temperature gauges were not placed at HMA laying site and the selected data recorders were at the nearest city areas.

Table 4-1 Ambient temperature variations at sites location

Project	Construction Period (Asphalt Paving)	Weather Station	Ambient Temperature (^{0}C)	
			Minimum	Maximum
JPK	2015.01.01 – 2015.05.31	Jaffna	27.9	35.7
AP4	2017.09.12 – 2018.03.01	Anuradhapura	25.9	34.7
PO2	2018.02.01 – 2018.06.21	Polonnaruwa	25.9	36.2
KU1	2017.08.01 – 2017.12.31	Kurunegala	26.6	34.5

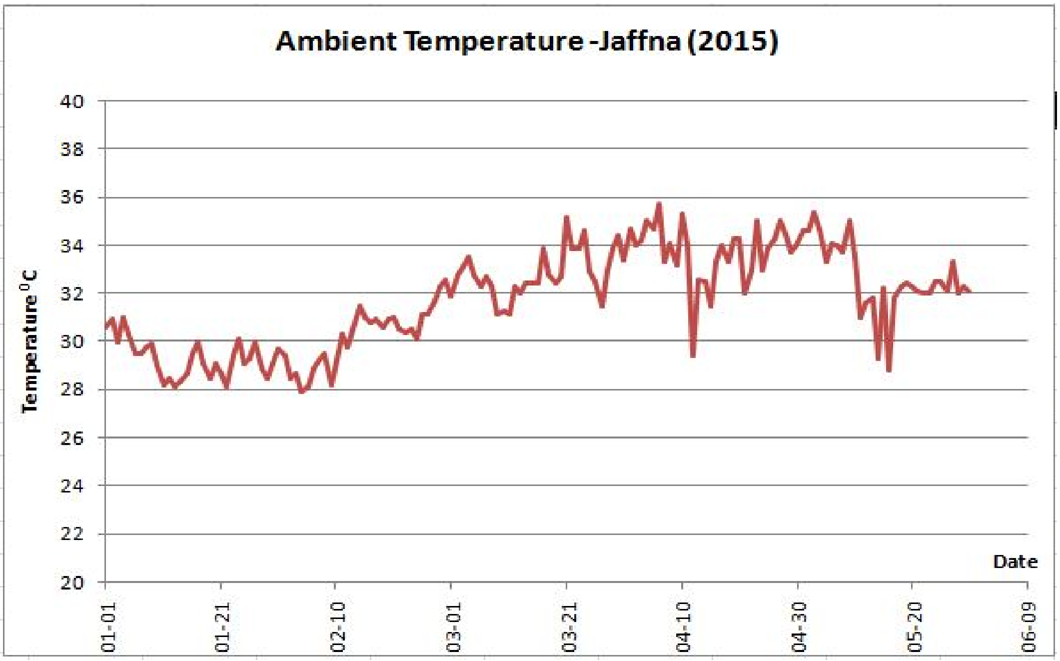


Figure 4-1 Ambient temperature variation in Jaffna

The purpose of analyzing the ambient temperature was to ensure that there were no significant changes in the period of analysis. As per the graphs, there were no significant differences of the ambient temperature. Ambient temperatures of all packages were altered within 10 ^{0}C such that the lowest value is around 25 ^{0}C and the highest value is around 35 ^{0}C. As stated in Hot Mix Asphalt Paving Handbook (2000), there will not be significant effect for the compaction changes within 10 ^{0}C difference of ambient temperature.

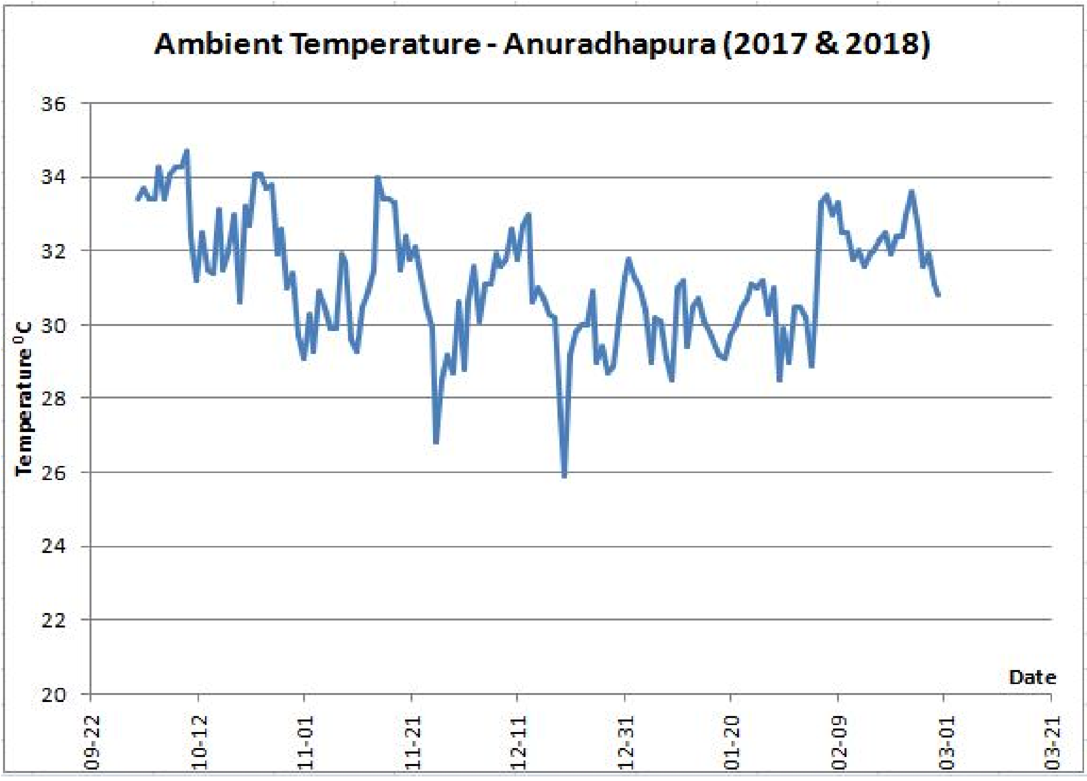


Figure 4-2 Ambient temperature variation in Anuradhapura

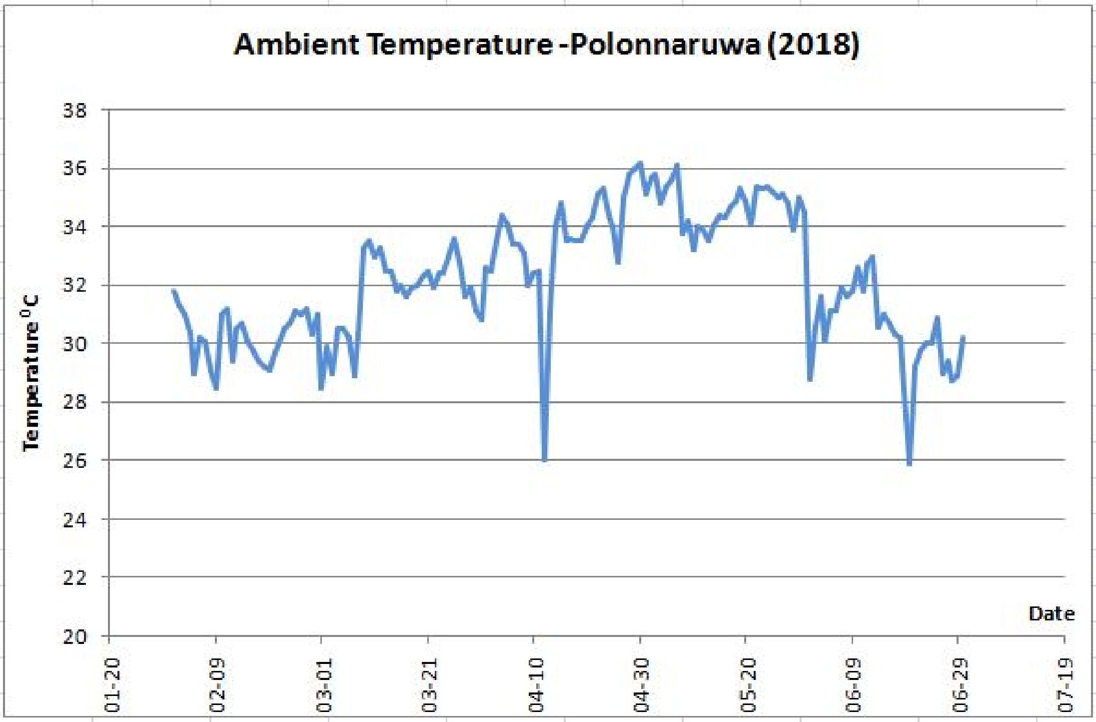


Figure 4-3 Ambient temperature variation in Polonnaruwa

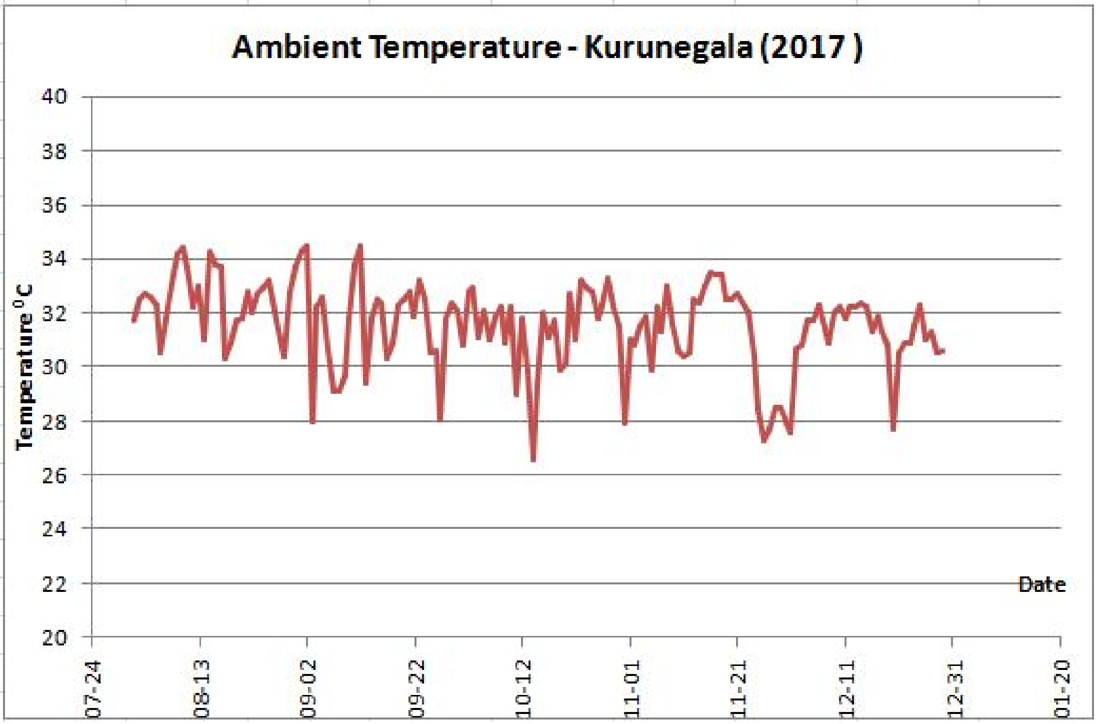


Figure 4-4 Ambient temperature variation in Kurunegala

4.2 Wind Velocity

Wind velocity details were obtained from the Weatherspark website, because adequate data were not available at the Department of Meteorology. The data obtained from the website represent seasonal variations. Figure 4-5 to Figure 4-8 represent the annual velocity distribution and Table 4-2 represent the minimum and maximum wind speed related to the construction periods. Average wind speeds of all four areas are within 5mph to18mphrelevant to the construction periods. That means all four packages were not significantly affected by wind.

Table 4-2 Annual Wind Speed at Site Locations

Project	Analyzed Period (Asphalt Paving)	Weather Station	Wind speed (mph)	
			Minimum	Maximum
JPK	Jan – May	Jaffna	8.9	18
AP4	September – March	Anuradhapura	5.7	14.5
PO2	February – June	Polonnaruwa	5.5	15
KU1	August – December	Kurunegala	7	14

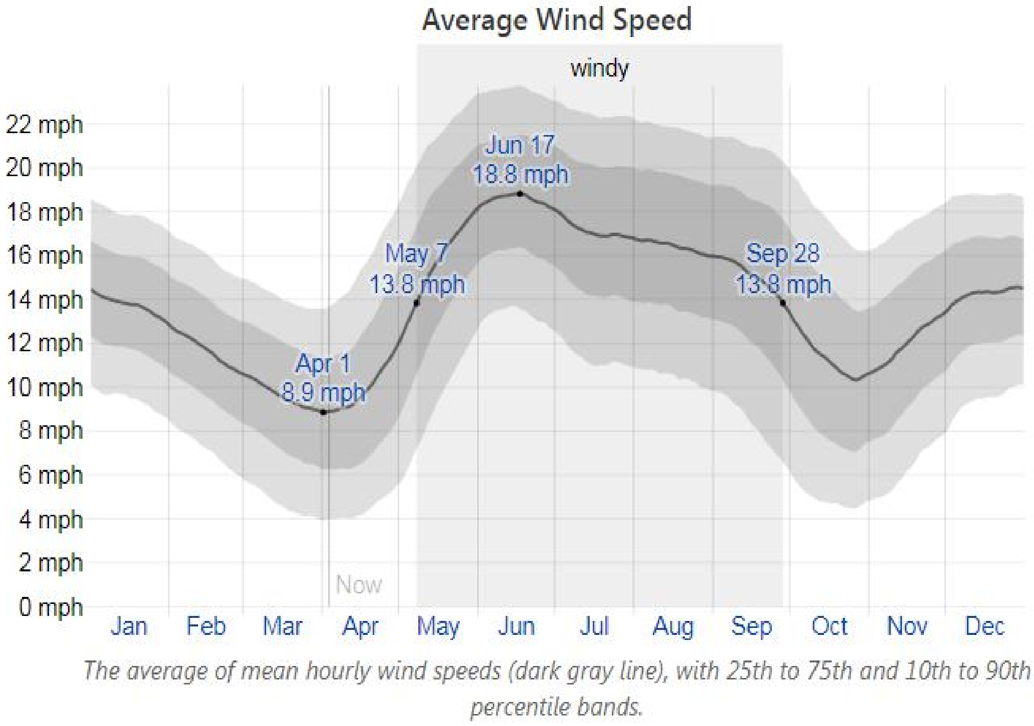
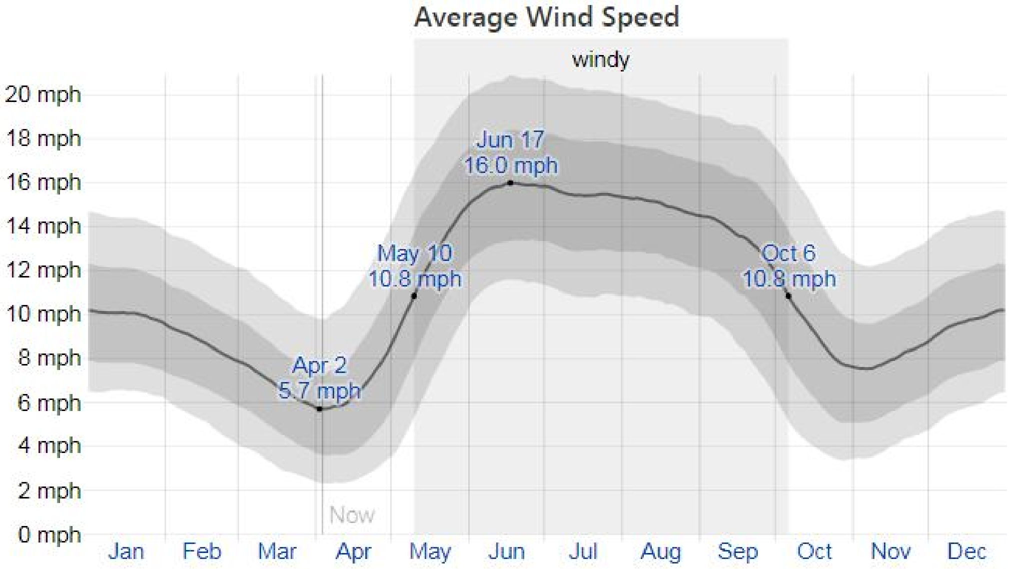
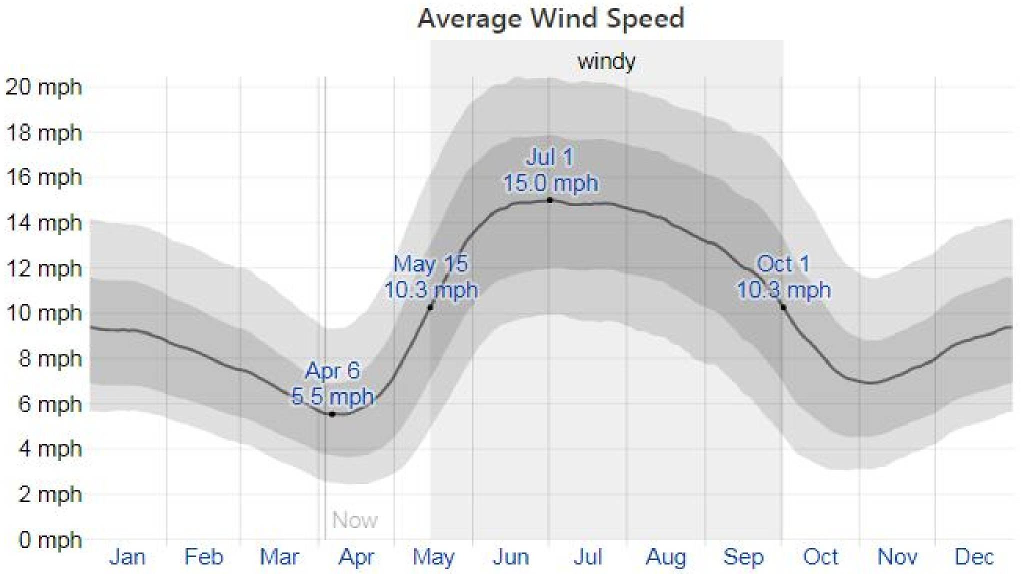


Figure 4-5 Annual average Wind Speed in Jaffna



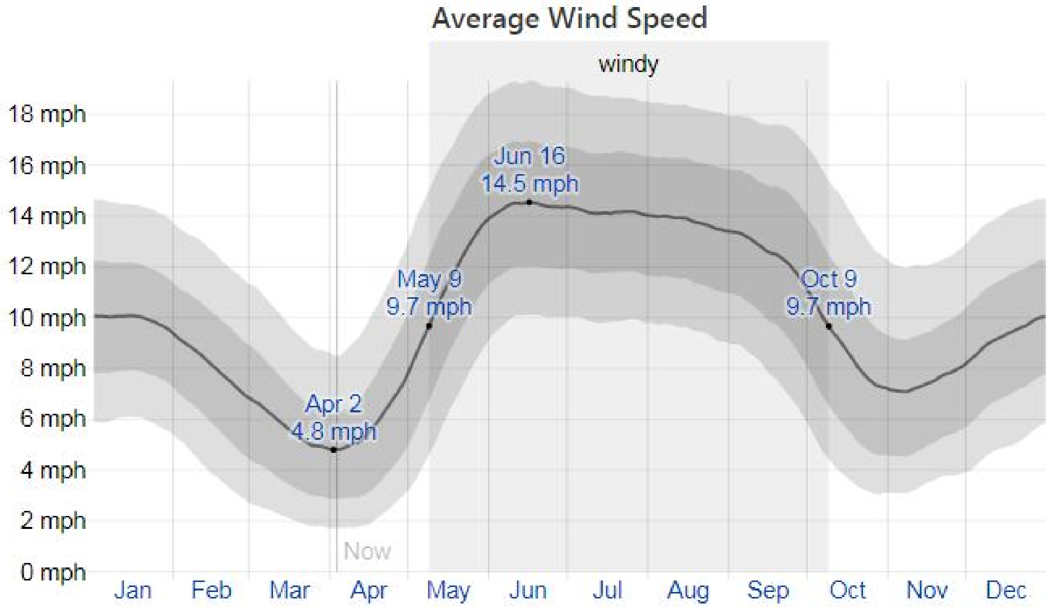
The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

Figure 4-6 Annual average Wind Speed in Anuradhapura



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

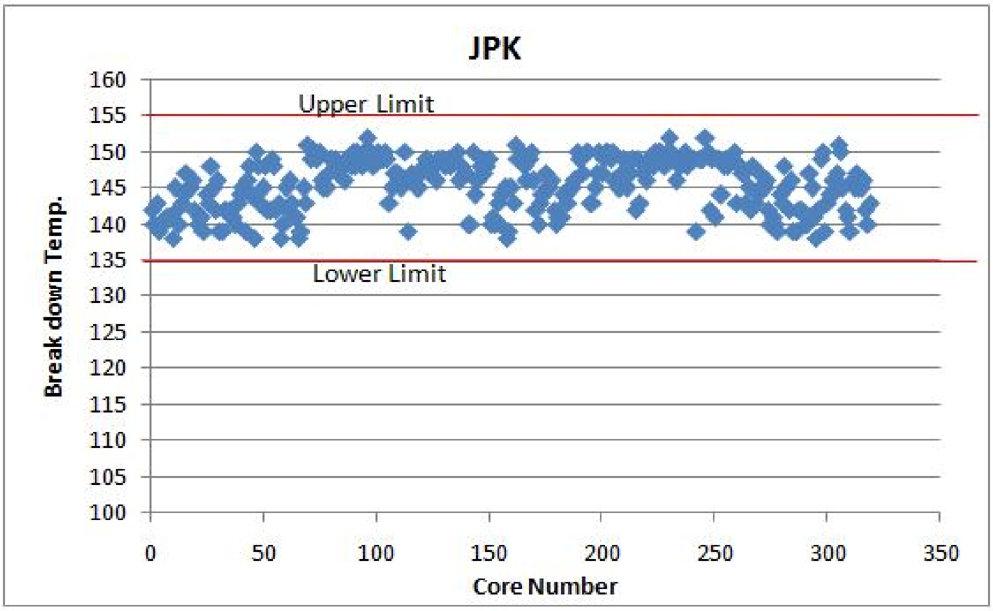
Figure 4-7 Annual average Wind Speed in Polonnaruwa



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

Figure 4-8 Annual average Wind Speed in Kurunegala

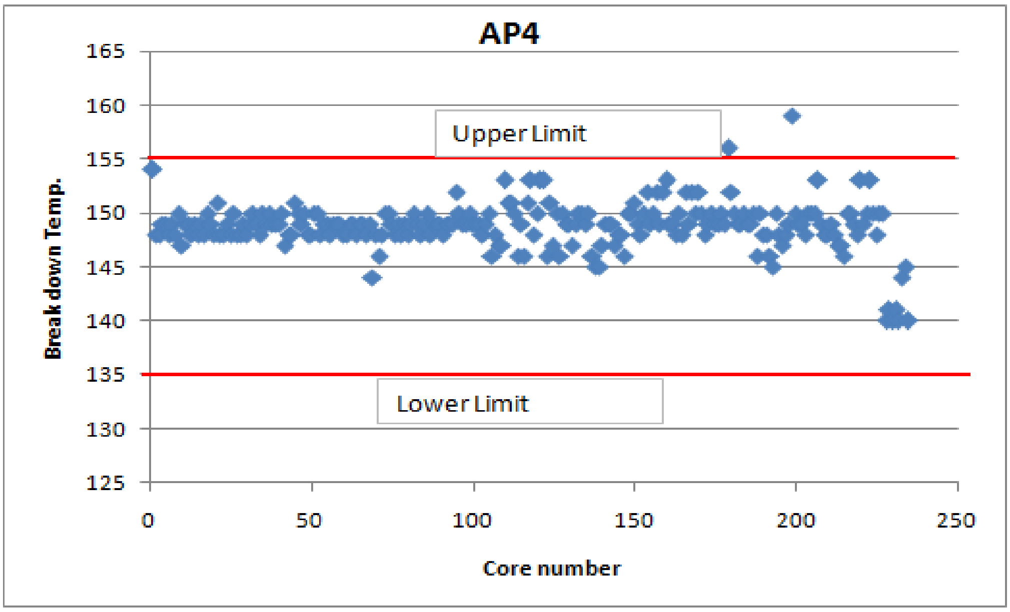
4.3 Break Down Temperatures



Mean Tem (^{0}C)	146
Standard Deviation	3.58
Minimum Tem (^{0}C)	138
Maximum Tem (^{0}C)	152

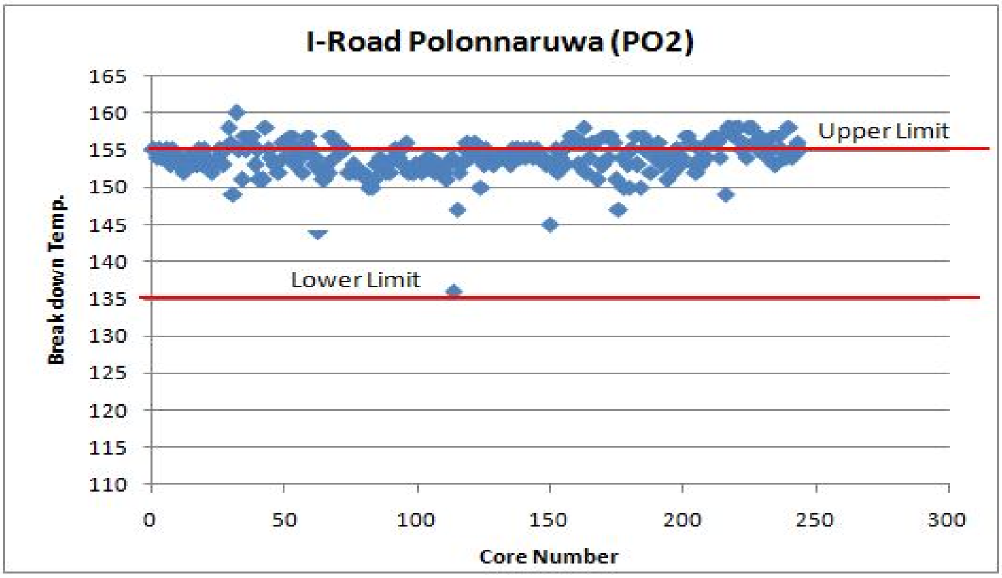
Figure 4-9 Break down temperatures of JPK Package

Breakdown temperatures were obtained from the laying records and shown in Figure 4-9 to Figure 4-12. The breakdown temperatures of the selected cores were within the specified values except for the PO2 package. Break down temperatures of the PO2 package were laid around the upper limit.



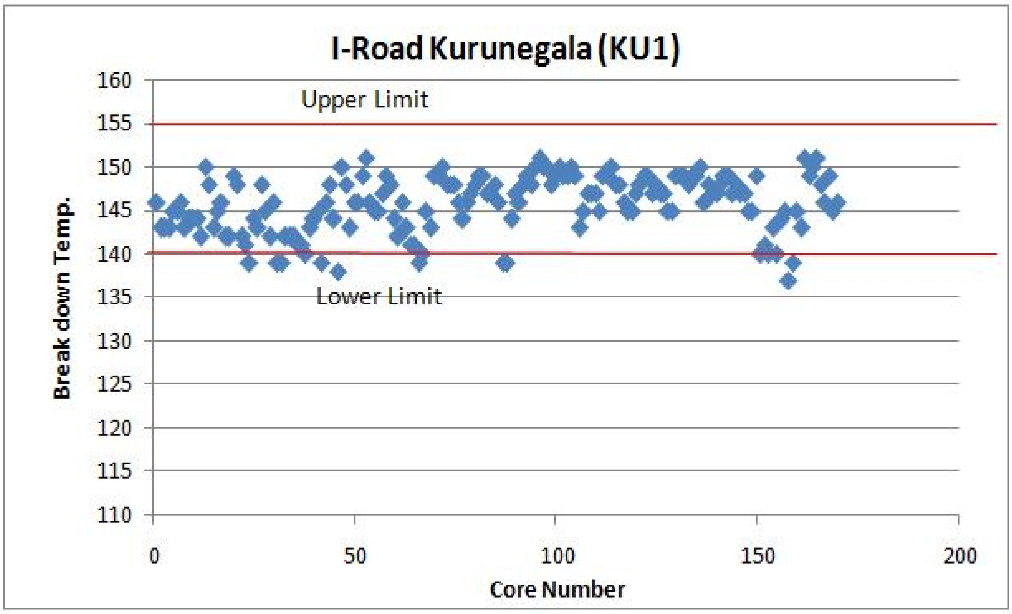
Mean Tem (^{0}C)	149
Standard Deviation	2.27
Minimum Tem (^{0}C)	140
Maximum Tem (^{0}C)	159

Figure 4-10 Break down temperatures of AP4 Package



Mean Tem (^oC)	154
Standard Deviation	2.48
Minimum Tem (^oC)	136
Maximum Tem (^oC)	160

Figure 4-11 Break down temperatures of PO2 Package

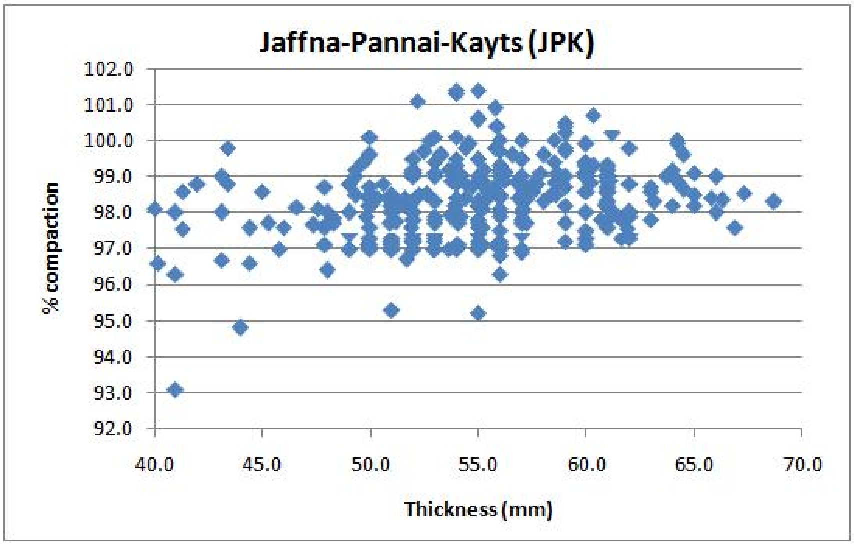


Mean Tem (^oC)	146
Standard Deviation	3.26
Minimum Tem (^oC)	137
Maximum Tem (^oC)	151

Figure 4-12 Break down temperatures of KU1 Package

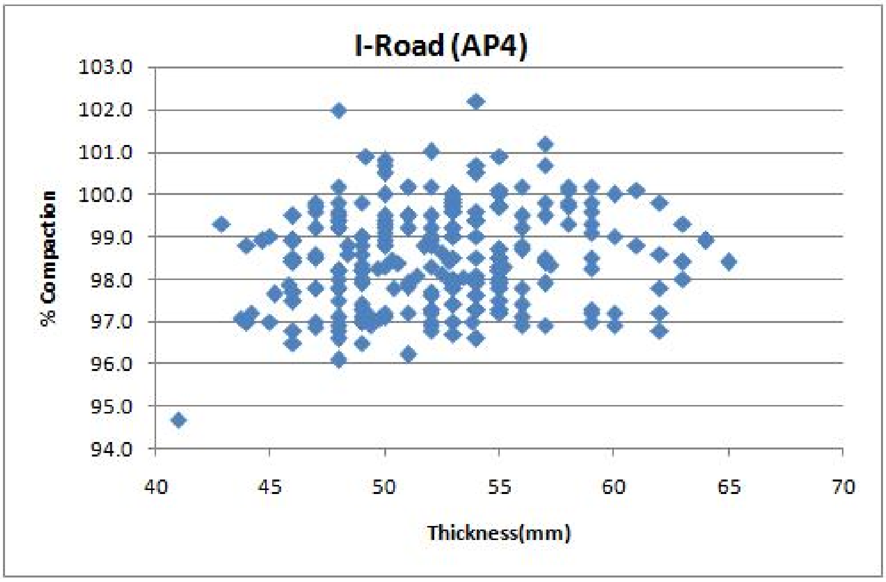
4.4 Relationship between Degree of Compaction versus Mat Thicknesses

The graphs of degree of compaction versus mat thicknesses (core thicknesses) were plotted for all four packages as shown in Figure 4-13 to Figure 4-16.



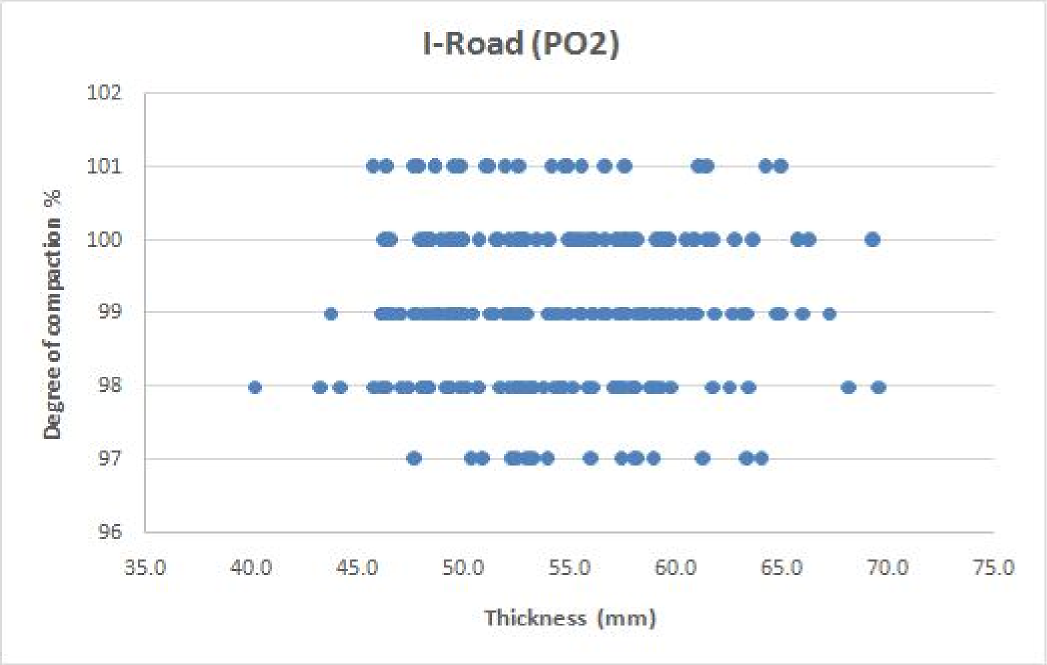
Mean Compaction	98.3	Minimum Compaction	93.1
Standard Deviation	1.07	Maximum Compaction	101.4

Figure 4-13 Degree of compaction versus Mat Thickness of JPK



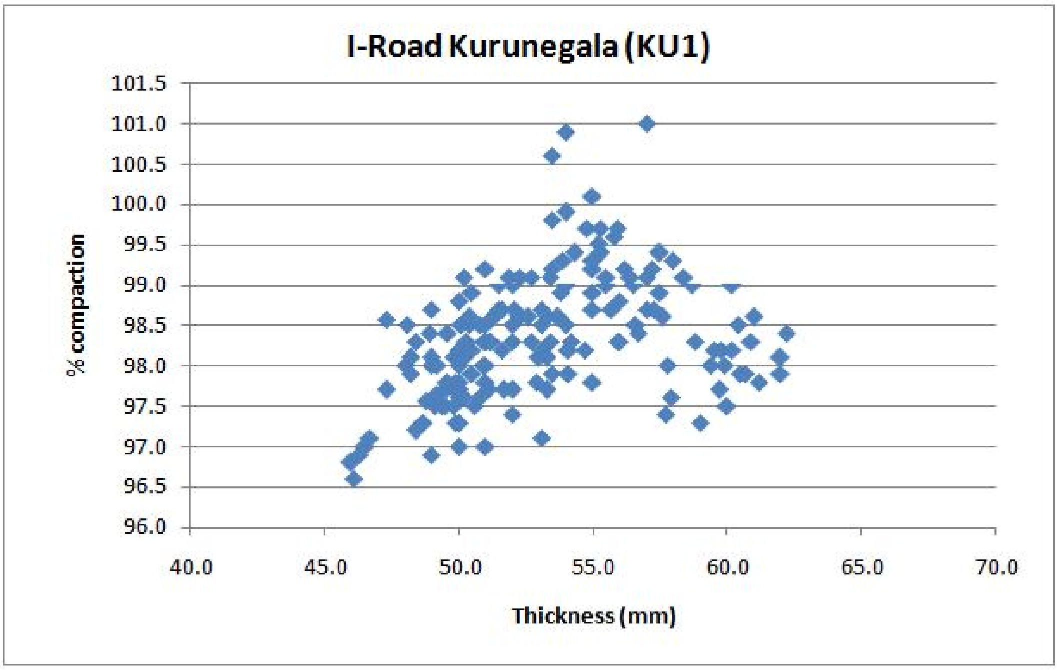
Mean Compaction	98.5	Minimum Compaction	94.7
Standard Deviation	1.18	Maximum Compaction	102.2

Figure 4-14 Degree of compaction versus Mat Thickness of AP4



Mean Compaction	99.1	Minimum Compaction	97.0
Standard Deviation	1.08	Maximum Compaction	101.0

Figure 4-15 Degree of compaction versus Mat Thickness of PO2

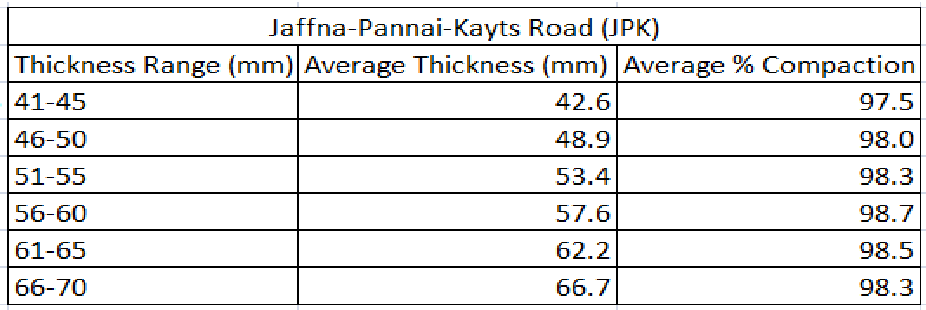


Mean Compaction	98.3	Minimum Compaction	96.6
Standard Deviation	0.77	Maximum Compaction	101.0

Figure 4-16 Degree of compaction versus Mat Thickness of KU1

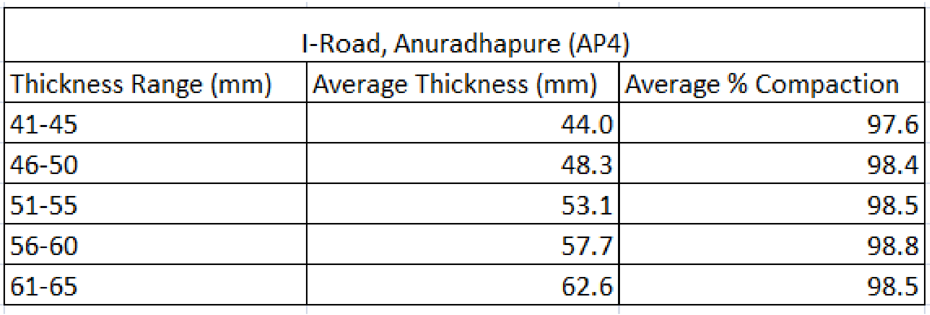
Core sample thicknesses were categorized into thickness group to analyses their compaction level. Core thicknesses were divided into class size of five millimeters and average degree of compactions were categorized as per the thickness classes shown in Table 4-3 to Table 4-6. Summarized data were used to plot the graphs of average degree of compactions versus average thicknesses. The plotted graphs are shown in Figure 4-17 to Figure 4-20.

Table 4-3 Summarized core sample data of JPK Package



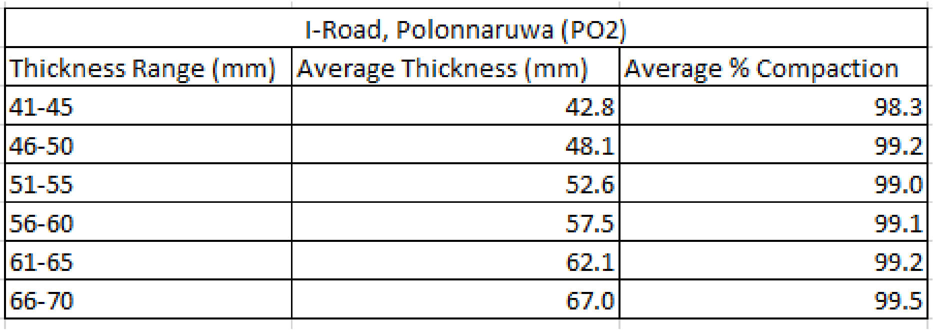
Jaffna-Pannai-Kayts Road (JPK)		
Thickness Range (mm)	Average Thickness (mm)	Average % Compaction
41-45	42.6	97.5
46-50	48.9	98.0
51-55	53.4	98.3
56-60	57.6	98.7
61-65	62.2	98.5
66-70	66.7	98.3

Table 4-4Summarized core sample data of AP4 Package



I-Road, Anuradhapure (AP4)		
Thickness Range (mm)	Average Thickness (mm)	Average % Compaction
41-45	44.0	97.6
46-50	48.3	98.4
51-55	53.1	98.5
56-60	57.7	98.8
61-65	62.6	98.5

Table 4-5 Summarized core sample data of PO2 Package



I-Road, Polonnaruwa (PO2)		
Thickness Range (mm)	Average Thickness (mm)	Average % Compaction
41-45	42.8	98.3
46-50	48.1	99.2
51-55	52.6	99.0
56-60	57.5	99.1
61-65	62.1	99.2
66-70	67.0	99.5

Table 4-6 Summarized core sample data of KU1 Package

I-Road Kurunegala (KU1)		
Thickness Range (mm)	Average Thickness (mm)	Average % Compaction
46-50	49.3	97.8
51-55	53.2	98.7
56-60	58.3	98.5
61-65	61.7	98.2

More than 300 core results were analyzed from Jaffna Pannai Kayts road project. Figure 4-17 shows low average degree of compaction at the low core thicknesses (mat thickness). When the core thicknesses are within 55 mm to 60 mm, the average degree of compaction value reached to its peak value. Again, it is decreasing with increasing of core thicknesses. The peak value was achieved at average core thickness of 58 mm and the average degree of compaction was 98.7% at this status.

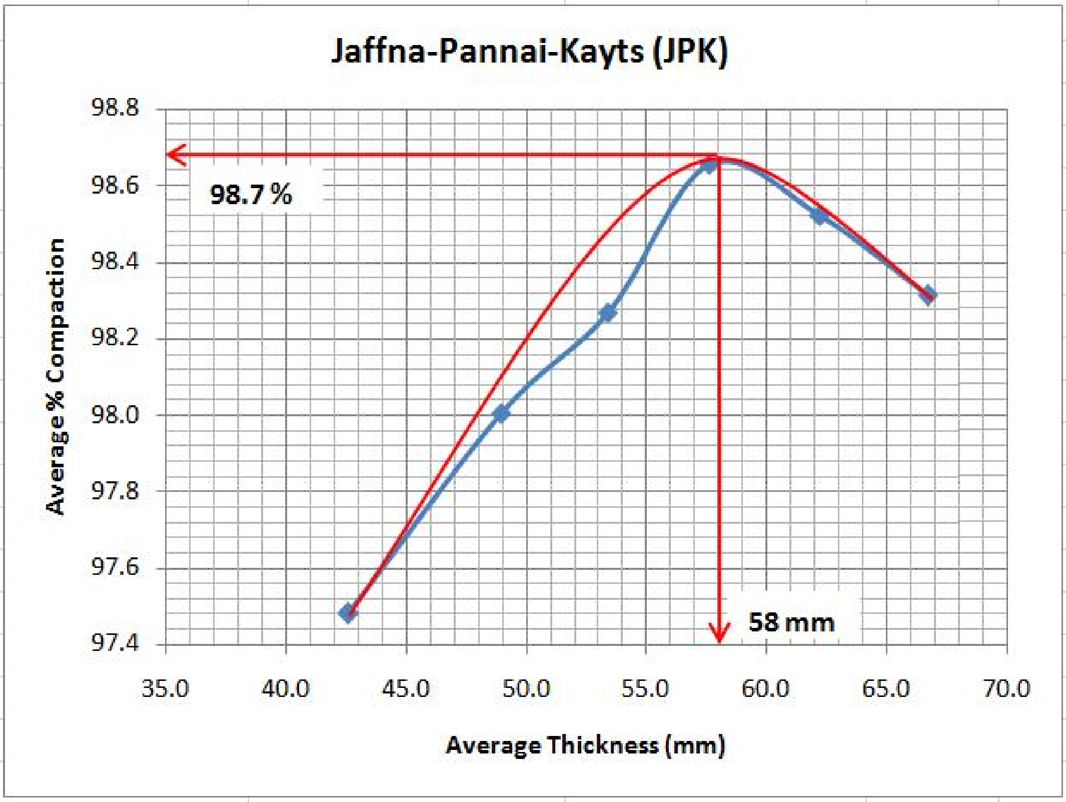


Figure 4-17 Average Degree of compaction versus Average Thickness of JPK

Figure 4-18 shows the average degree of compaction versus average thickness graph with relevant to the AP4 (Anuradhapura) package. Around 250 core results were analyzed from AP4 road package. Like as JPK project here also it shows lower average degree of compaction values at low core thicknesses. The peak value was achieved at average core thickness of 58 mm and the average degree of compaction was 98.8%. When the average core thickness was increasing more than 60 mm, the average degree of compaction was decreasing.

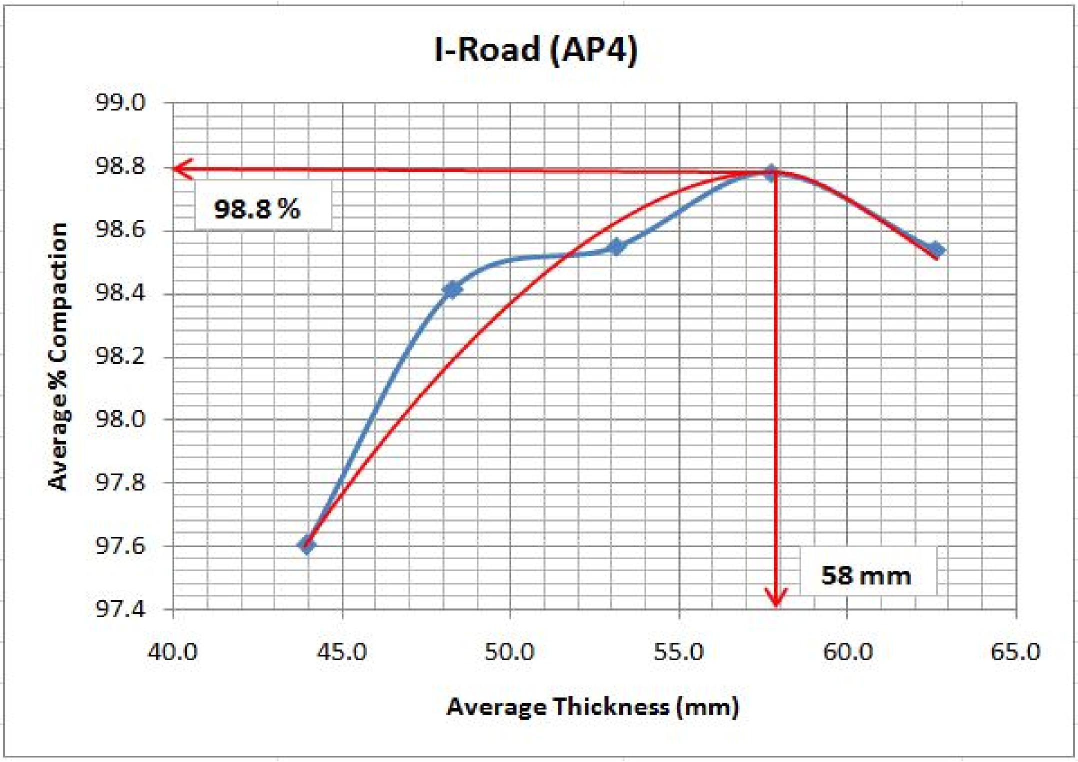


Figure 4-18 Average Degree of compaction versus Average Thickness of AP4

Average degree of compaction versus average thickness graph of the PO2 package is shown on Figure 4-19. In this graph, results show skew shape relationship with maximum is shifted to the right side along the x –axis. This may be due to the error in data recording, because they were rounded off to the nearest integer. But the usual manner is to record to the nearest first decimal place. Figure 4-20 shows the graph of average degree of compaction versus average thickness of mat in Kurunegala I-road (KU1) package. There were only few cores with thicknesses lower than the 50 mm.

The shape of this curve is pretty much similar to the JPK package and AP4 package. Only difference is, the peak was shifted to the left side of the graph. It has 98.7% of highest average degree of compaction at the average thickness of 54 mm.

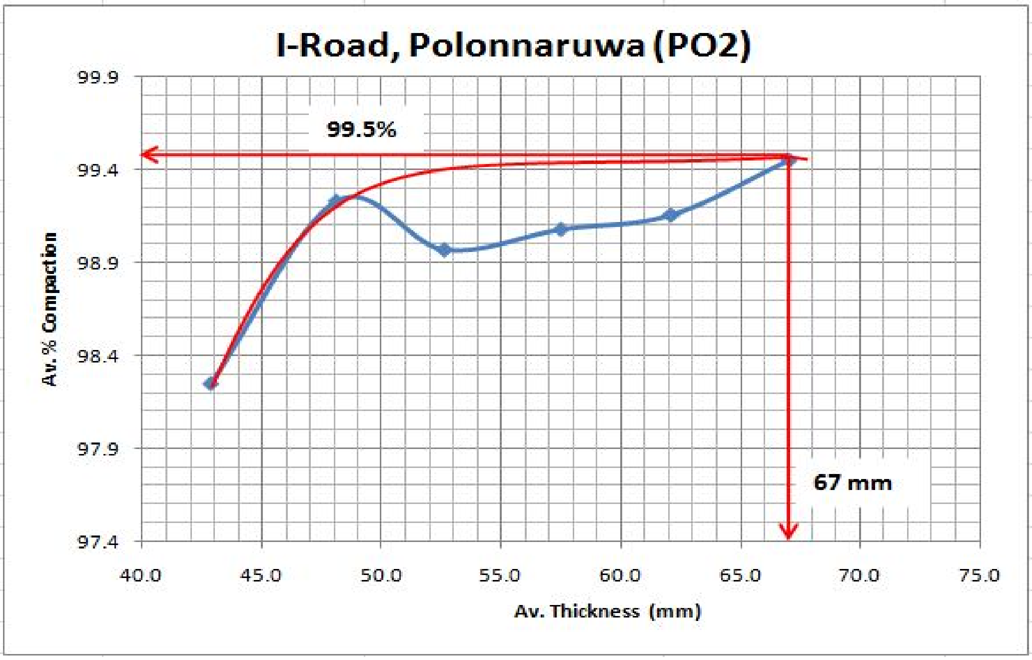


Figure 4-19 Average Degree of compaction versus Average Thickness of PO2

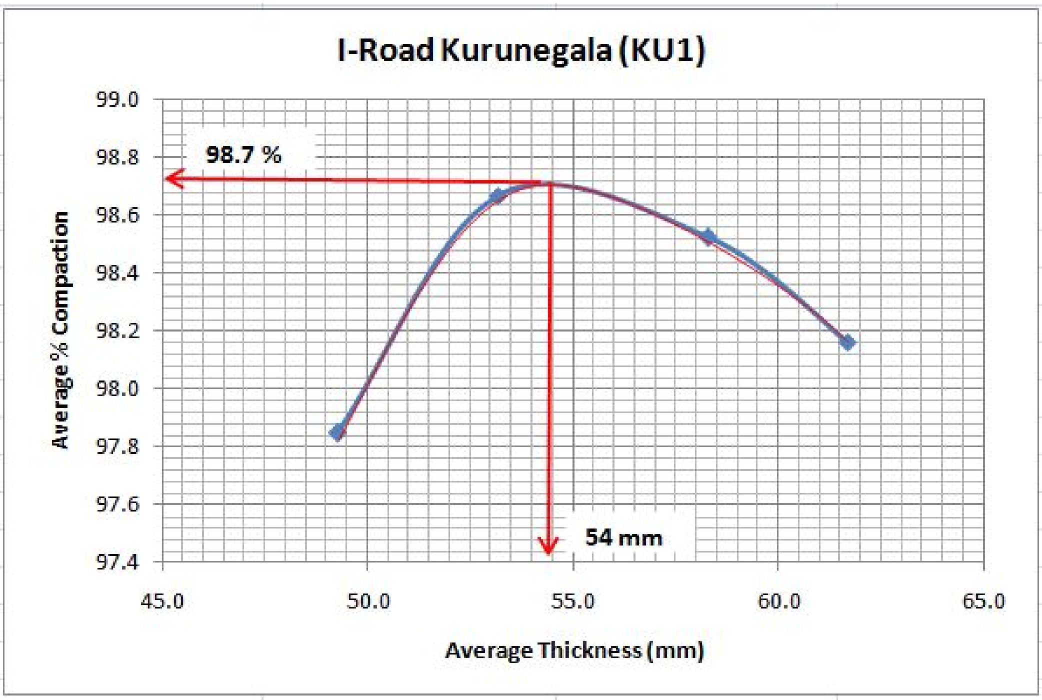
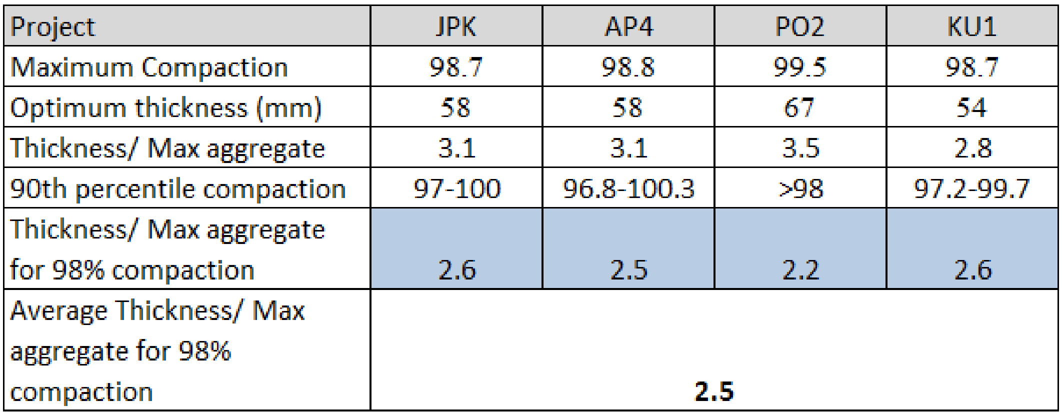


Figure 4-20 Average Degree of compaction versus Average Thickness of KU1

Table 4-7 Summary of the Optimum average thickness value

Project/Package	Maximum average Degree of compaction %	Optimum average Thickness mm
JPK	98.7	58
AP4	98.8	58
PO2	99.5	67
KU1	98.7	54

Table 4-8 Required Layer Thicknesses for 98% Compactions

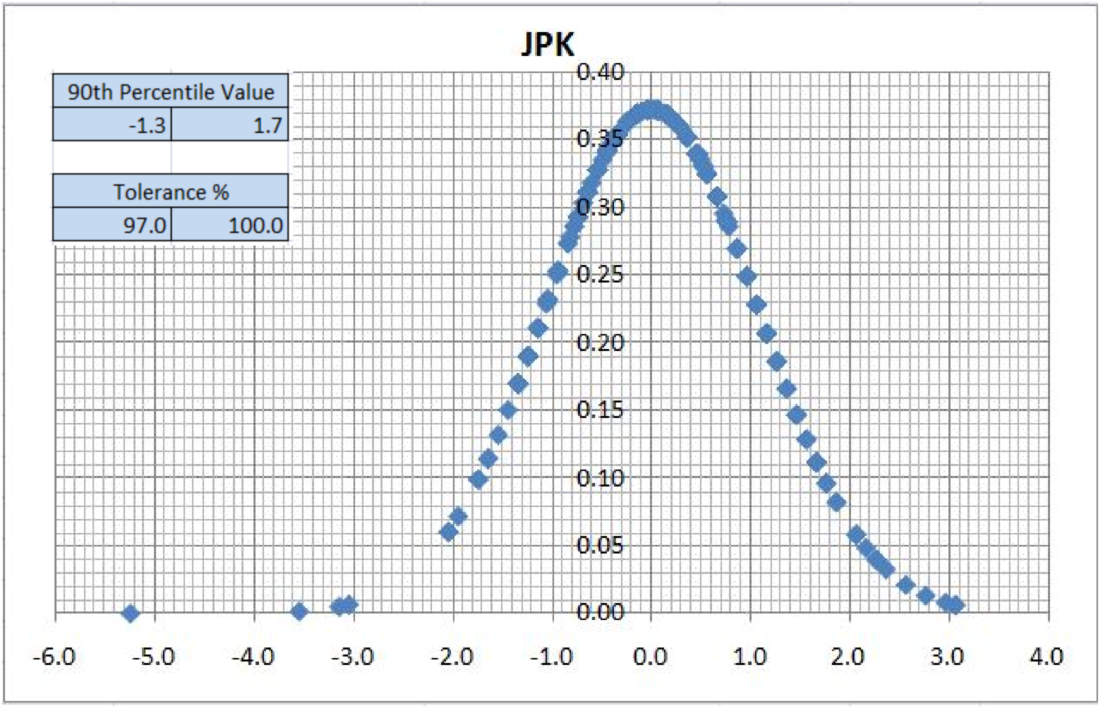


Project	JPK	AP4	PO2	KU1
Maximum Compaction	98.7	98.8	99.5	98.7
Optimum thickness (mm)	58	58	67	54
Thickness/ Max aggregate	3.1	3.1	3.5	2.8
90th percentile compaction	97-100	96.8-100.3	>98	97.2-99.7
Thickness/ Max aggregate for 98% compaction	2.6	2.5	2.2	2.6
Average Thickness/ Max aggregate for 98% compaction	**2.5**			

As per the Table 4-7, maximum average degrees of compactions were achieved when the mat thicknesses were around 55 mm in JPK, AP4 and KU1 projects. The average breakdown temperatures of all three projects are very much similar to each other's since the difference is only 3^0C. That indicates the similar pattern and the time available for compaction is little bit lower than the PO2 project. The laying temperatures were maintained at high side in PO2 package. In addition, ambient temperatures were high and wind velocities were low compared to the other locations. All these factors contributed to increase the time available for compaction. It clearly shows the environmental factors significantly contributed the compaction level.

Standard normal distribution curves were generated for better analysis of the results. Figure 4-21 to Figure 4-23 shows the standard normal distribution curves with relevant to average degree of compaction variation of each package. 90th percentile compaction values were calculated to check whether the optimum thickness values are satisfying the required degree of compactions. Table 4-8 represent the required layer thicknesses to achieve 98% compactions and the ratio between average layer thicknesses to maximum aggregate size is equal to the 2.5.

Figure 5-1 indicates the relationship of Layer thickness/Maximum aggregate size verses expected degree of compactions. Layer thickness shall be at least 2.5 times of the maximum aggregate size to achieve the 98% compactions and when it is more the possibility of achievable compaction is very high (highlighted in green colour). The Figure 5-1 shows that compacted layer thickness shall be at least 2.4 times from the maximum aggregate size to achieve the 97% compaction (highlighted in red colour).



90th Percentile Value	
-1.3	1.7

Tolerance %	
97.0	100.0

Figure 4-21 Average Degree of Compaction Variation of JPK

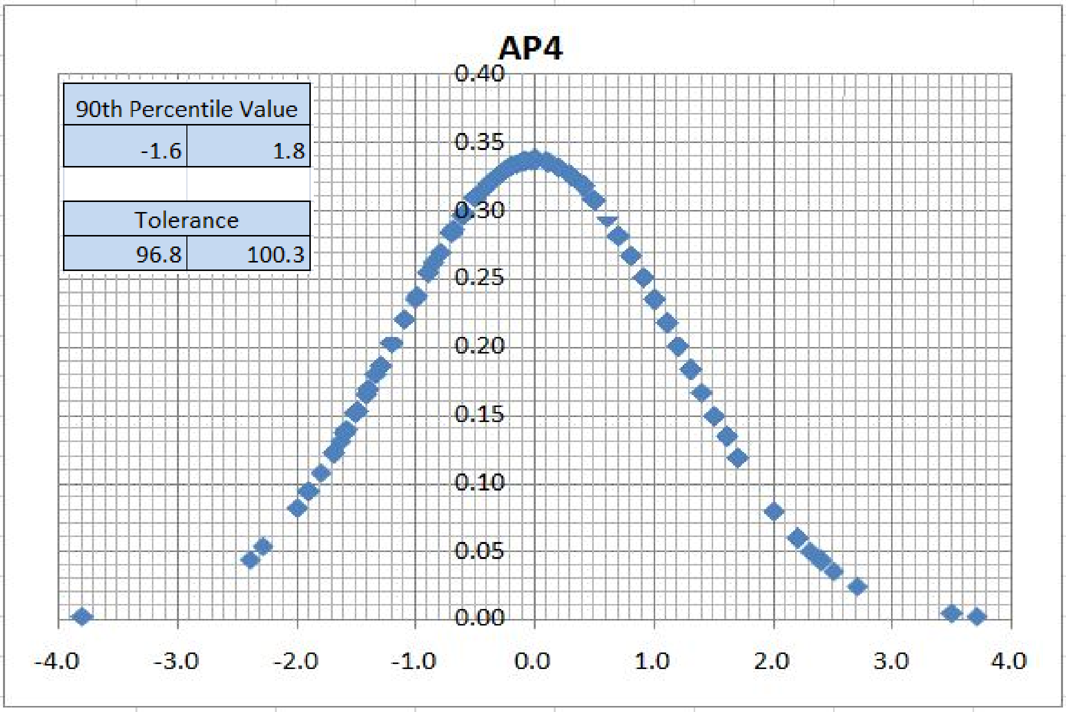


Figure 4-22 Average Degree of Compaction Variation of AP4

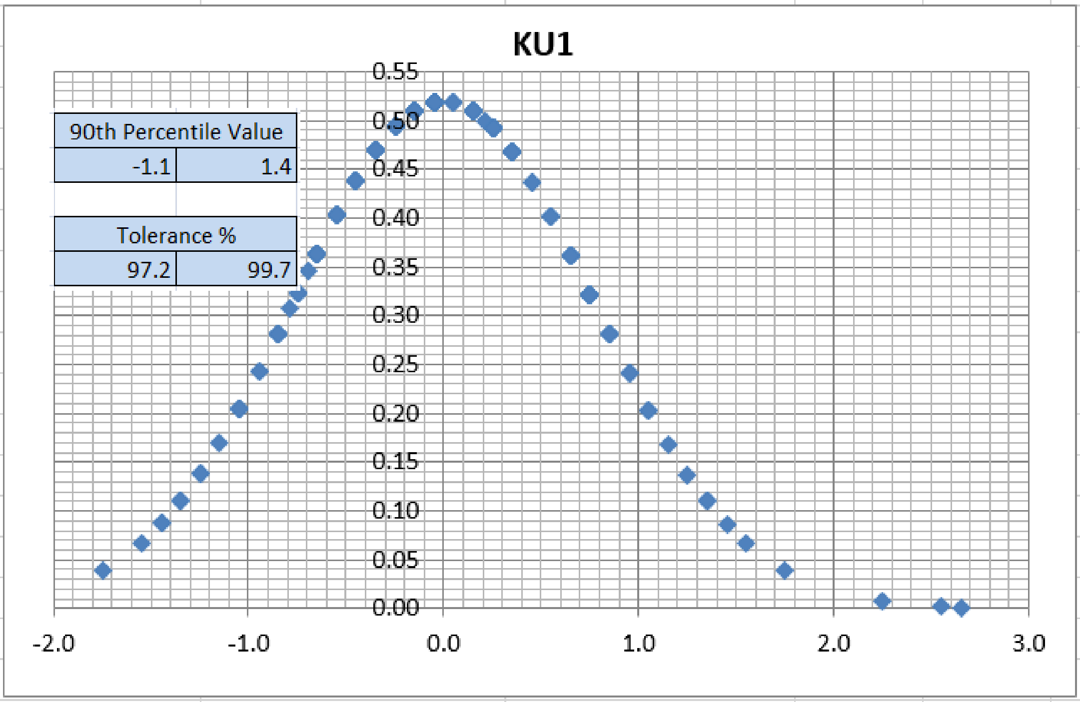


Figure 4-23 Average Degree of Compaction Variation of KU1

As per the calculated 90th percentile values, average degree of compactions values are satisfying the required levels. That mean when the mat thicknesses are around 55 mm, then the degree of compactions values will achieve required levels.

4.5 Effect of Temperature

Furthermore, analysis is done for the various temperatures ranges to identify the effect of temperature in compaction in each package. The results are shown in Table 4-9 to 4-12 and figure 4-24 to 4-27 respectively.

Table 4-9 Average Compaction with Variable Temperature Ranges of JPK

Temperature Range (^{0}C)					
136 -140		141-145		146-152	
Thickness (mm)	% Compaction	Thickness (mm)	% Compaction	Thickness (mm)	% Compaction
41.7	97.2	42.7	97.7	44.4	96.6
48.6	97.9	48.7	98.0	49.2	97.8
53.5	98.2	52.9	98.0	53.3	98.4
56.8	98.0	56.9	98.5	57.5	98.6
62.4	98.2	62.6	98.5	63.0	98.9

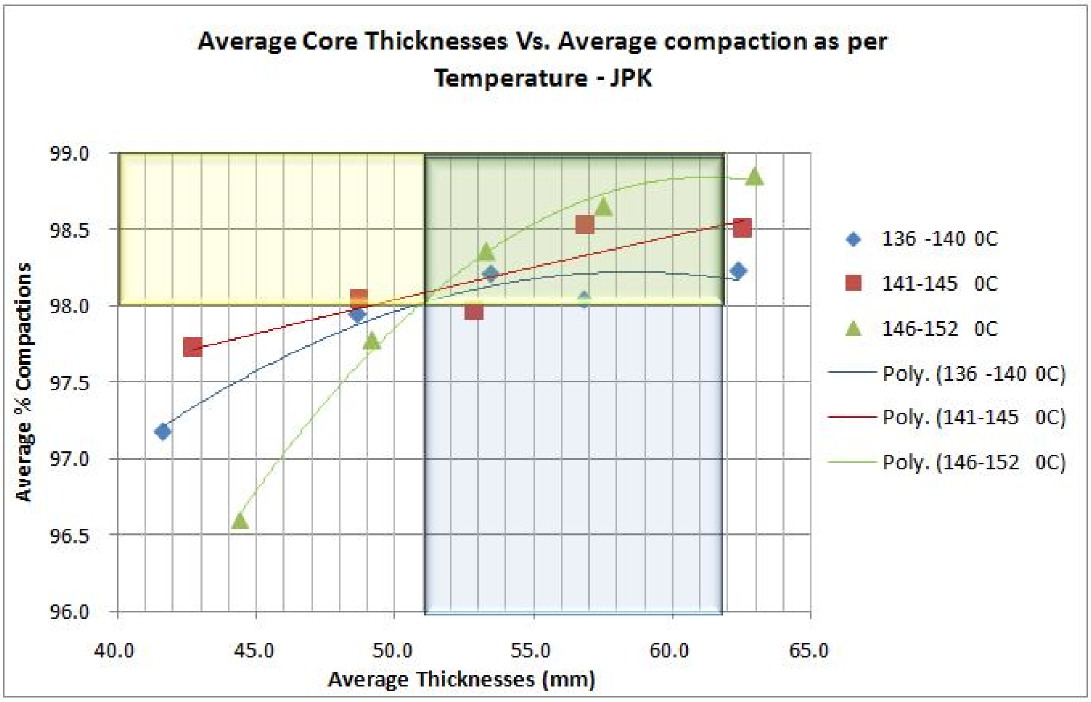


Figure 4-24 Average core thicknesses versus Average compaction as per various Temperatures (JPK Road)

Table 4-10 Average Compaction with Variable Temperature Ranges of AP4

Temperature Range (^{0}C)					
140 -145 ^{0}C		146-150 ^{0}C		151-160 ^{0}C	
Thickness (mm)	% Compaction	Thickness (mm)	% Compaction	Thickness (mm)	% Compaction
		44.3	97.9	41.0	94.7
49.0	98.8	48.3	97.8	48.0	98.7
53.0	97.5	53.1	98.0	53.4	98.1
56.0	98.8	57.7	98.0	59.0	98.8
63.3	98.2	61.8	98.0		

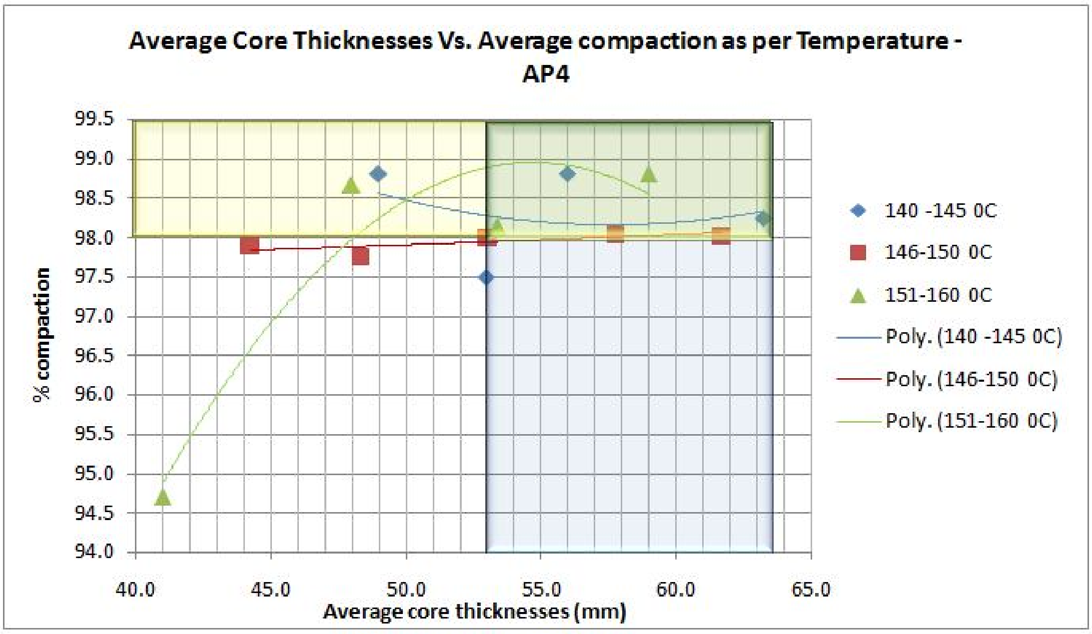


Figure 4-25 Average core thicknesses versus Average compaction as per various Temperatures (AP4 Road)

Table 4-11 Average Compaction with Variable Temperature Ranges of PO2

Temperature Range (^{o}C)			
151 -155 ^{o}C		156-160 ^{o}C	
Thickness (mm)	% Compaction	Thickness (mm)	% Compaction
42.8	98.3		
48.1	99.4	48.6	98.8
52.7	99.0	52.9	98.9
57.6	99.2	57.5	98.8
62.4	99.3	61.9	98.7
67.1	99.5	69.2	100.0

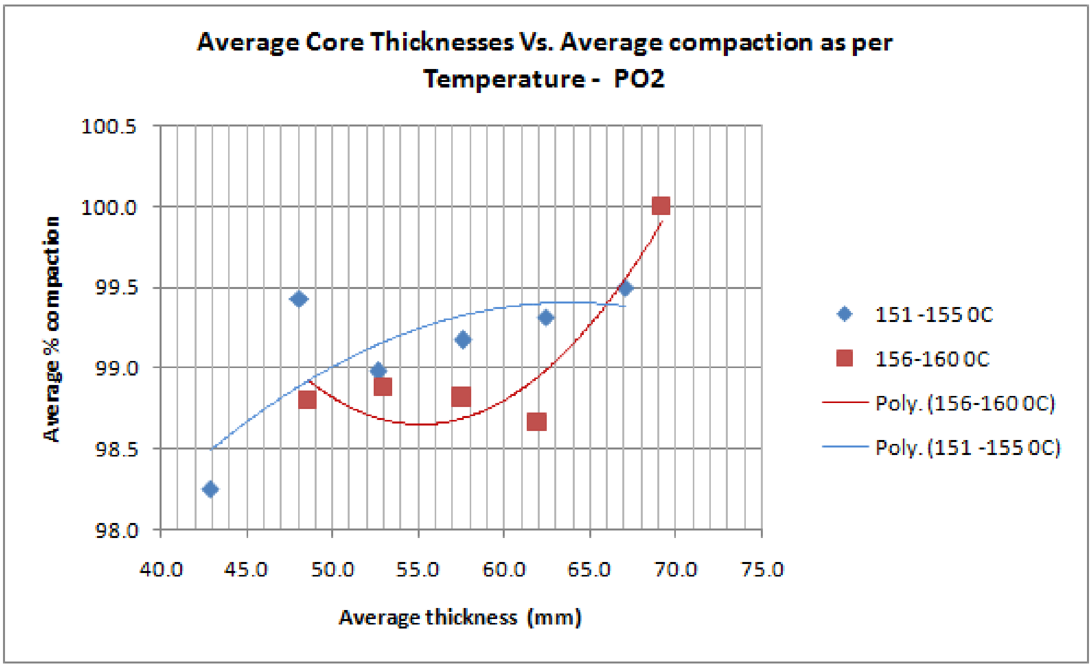


Figure 4-26 Average core thicknesses versus Average compaction as per various Temperatures (PO2 Road)

The green coloured areas of each graphs shows the safe side which the compaction is higher than 98%. This area cannot be identified in graphs related to PO2 package, because all degree of compactions are greater than 98%. The reason may be due to the higher breakdown temperatures of the HMA. The required average core thicknesses to achieve 98% compactions were mentioned in Table 4-13. It clearly shows that mat thickness is greater than 50 mm in every case except for PO2 road package. Anyhow, further analyses have been done to get better idea of the effect of temperature.

Table 4-12 Average Compaction with Variable Temperature Ranges of KU1

Temperature Range (ºC)					
136 -140 ºC		141-145 ºC		146-151 ºC	
Thickness (mm)	% Compaction	Thickness (mm)	% Compaction	Thickness (mm)	% Compaction
49.8	97.4	48.8	97.7	48.5	97.7
51.6	98.1	52.0	98.5	52.6	98.6
59.4	98.0	58.2	98.6	56.6	98.9
		60.8	98.4	61.1	98.2

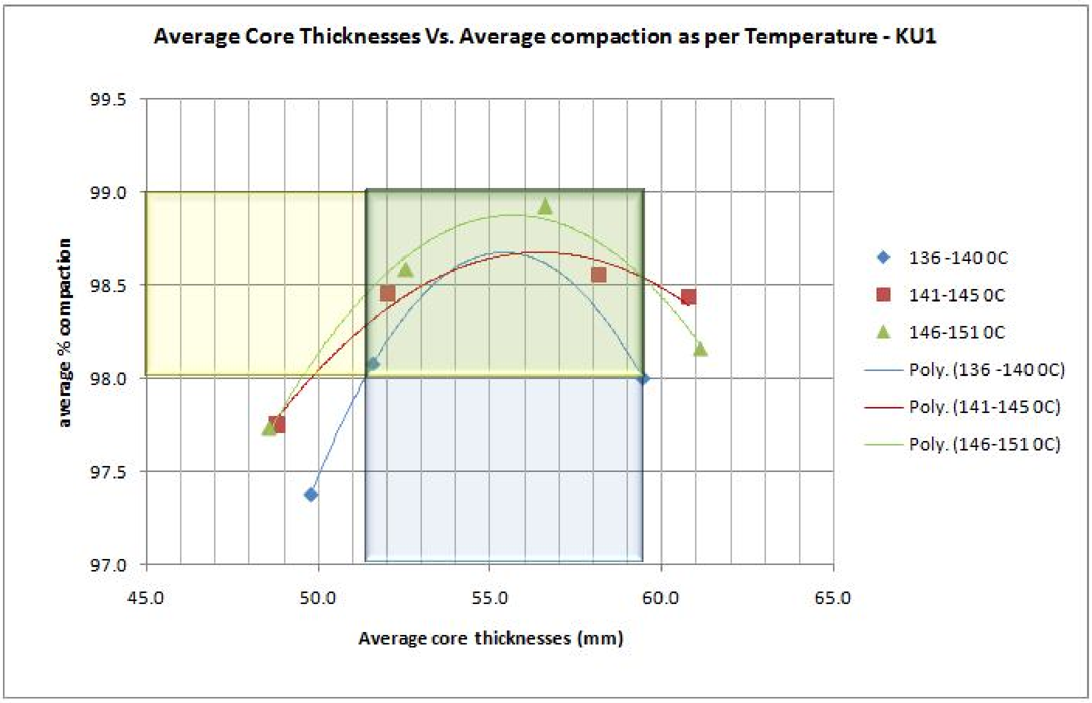


Figure 4-27 Average core thicknesses versus Average compaction as per various Temperatures (KU1 Road)

Table 4-13 Required Average Core Thicknesses to achieve 98% Compaction

Package	Average core thickness to achieve 98% compaction (mm)
JPK	51
AP4	53
PO2	-
KU1	51

5 CONCLUSIONS

Following conclusions were noted from the analyzing of the nearly thousand core details of four road packages.

- Compaction of the Asphalt pavement is directly dependent on the mat thickness.
- For the better compaction, mat thickness should be within the optimum range.
- Mat thicknesses within the range 55-60mm have the highest degree of compaction.
- It is recommended to have 55-60mm thick mat thickness instead of 50mm or lesser mat thicknesses for the mix of maximum aggregate size of 19 mm.
- Figure 5-1 showsthe relationship of Layer thickness/Maximum aggregate size verses expected degree of compactions.
- Layer thickness shall be at least 2.5 times of the maximum aggregate size to achieve the 98% compactions.
- Compacted layer thickness shall be at least more than 2.4 times of the9 maximum aggregate size to achieve the 97% compaction.
- There should be at least 2.5 times of the maximum aggregate size to achieve the 98% compactions at various temperatures.
- Breakdown temperatures are important for better compaction and furthermore analysis is required for better results.

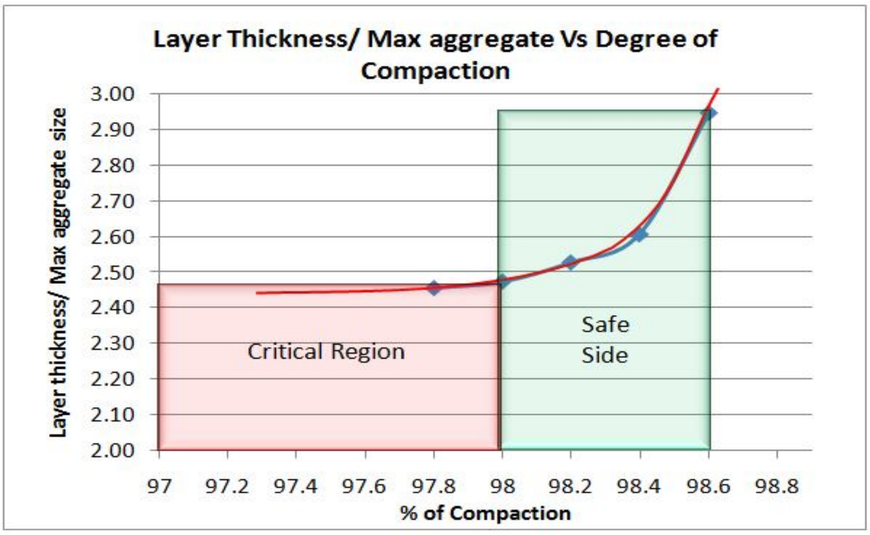


Figure 5-1 Layer Thickness/ Max aggregate Vs Degree of Compaction

REFERENCE LIST

Institute for Training and Development (2009). *Standard Specification for Highway Construction and Maintenance of Roads and Bridges*, Second Edition (ICTAD SCA/05), Ministry of Construction and Engineering Services, Sri Lanka.

Transportation Research Board (TRB). (2006). *Factors Affecting Compaction of Asphalt Pavements*. Transportation Research Board, National Research Council. Washington, D.C.

Transportation Research Board (TRB). (2000). *Hot-Mix Asphalt Paving Handbook 2000*. Transportation Research Board, National Research Council. Washington, D.C.

Finn, F. N., Epps, J. A. (1980). *Compaction of Hot Mix Asphalt Concrete*. Texas Transportation Institute. Texas.

Hughes, C.S. (1989). National Cooperative Highway Research Program Synthesis of Highway Practice.

Buchanan, S., Mallick, R. B., Brown, E. R., and Huner, M. (1998). An Evaluation of Superpave Gyratory Compaction of Hot-Mix Asphalt.

Dickson, P.F. and Corlew, J.S. (1970). Thermal Computations Related to the Study of Pavement Compaction Cessation Requirements, Association of Asphalt Paving Technologists.

Livneh, M. (1990). Asphalt Mix Design for Hot Climate Regions. Australian Road Research.

Smith, R. A., Epps, J. (1975). Engineering Economics and Energy Considerations. Texas Transportation Institute. Texas.

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ANNEXURE A: Core Result Summary

Nmbers	Jaffna-Pannai-Kayts Road (JPK)		
	Breakdown T (^{0}C)	Thickness (mm)	Degree of compaction %
1	142	40.0	98.1
2	140	40.2	96.6
3	143	41.0	96.3
4	139	41.0	98.0
5	140	41.0	93.1
6	140	41.3	97.6
7	141	41.3	98.6
8	141	42.0	98.8
9	141	43.1	96.7
10	138	43.1	98.0
11	145	43.1	99.0
12	142	43.4	98.8
13	140	43.4	99.8
14	143	44.0	94.8
15	144	44.4	97.6
16	147	44.4	96.6
17	145	45.0	98.6
18	145	45.3	97.7
19	146	45.8	97.0
20	142	46.0	97.6
21	140	46.6	98.1
22	141	47.4	97.7
23	141	47.6	98.1
24	139	47.9	97.6
25	144	47.9	98.7
26	143	47.9	97.1
27	148	48.0	96.4
28	145	48.0	97.7
29	142	48.0	98.0
30	146	48.3	97.8
31	139	48.3	97.7
32	139	49.0	97.4
33	142	49.0	98.8
34	142	49.0	97.0
35	142	49.0	98.8
36	141	49.0	98.0
37	141	49.0	97.0
38	140	49.0	97.0
39	143	49.3	98.5
40	144	49.3	99.0
41	145	49.3	99.2
42	139	49.7	99.4
43	146	49.8	97.9
44	148	49.9	97.1
45	144	50.0	97.6
46	138	50.0	98.4
47	150	50.0	100.1

48	148	50.0	98.4
49	143	50.0	98.2
50	145	50.0	99.6
51	148	50.0	98.7
52	142	50.0	97.1
53	142	50.0	97.3
54	149	50.0	98.5
55	148	50.0	97.0
56	142	50.0	98.2
57	143	50.3	98.4
58	138	50.6	98.8
59	140	50.9	97.7
60	145	51.0	98.2
61	142	51.0	98.0
62	146	51.0	97.3
63	143	51.0	97.0
64	141	51.0	98.5
65	141	51.0	95.3
66	138	51.0	98.5
67	139	51.0	97.2
68	145	51.0	97.0
69	143	51.0	98.3
70	151	51.0	97.1
71	149	51.2	97.7
72	150	51.3	98.2
73	150	51.6	98.2
74	149	51.6	98.4
75	150	51.7	96.7
76	146	51.9	97.6
77	145	52.0	97.3
78	145	52.0	99.0
79	147	52.0	99.2
80	149	52.0	99.5
81	149	52.0	97.0
82	149	52.0	97.2
83	147	52.0	98.3
84	148	52.0	99.1
85	148	52.0	98.0
86	146	52.0	97.4
87	149	52.0	97.8
88	149	52.0	97.2
89	148	52.0	99.1
90	150	52.2	101.1
91	148	52.3	98.5
92	150	52.5	99.7
93	149	52.6	98.5
94	148	52.6	98.5
95	150	52.8	100.0
96	152	52.9	97.0
97	150	53.0	97.4

98	150	53.0	97.4
99	148	53.0	97.0
100	149	53.0	99.1
101	150	53.0	97.2
102	149	53.0	98.3
103	149	53.0	97.9
104	150	53.0	100.1
105	149	53.0	97.7
106	143	53.0	97.2
107	145	53.0	97.0
108	147	53.0	99.4
109	147	53.0	99.0
110	147	53.0	97.8
111	145	53.0	99.1
112	146	53.0	97.3
113	150	53.3	99.6
114	139	53.6	97.0
115	146	53.6	99.2
116	147	53.7	97.9
117	146	53.8	98.9
118	145	53.9	98.2
119	145	54.0	101.3
120	147	54.0	99.0
121	148	54.0	101.4
122	149	54.0	97.0
123	149	54.0	98.0
124	147	54.0	97.1
125	148	54.0	98.2
126	148	54.0	98.8
127	146	54.0	100.1
128	149	54.0	99.3
129	149	54.0	97.0
130	149	54.0	98.0
131	148	54.0	98.4
132	149	54.0	99.5
133	148	54.1	97.1
134	149	54.1	97.7
135	149	54.2	99.1
136	150	54.2	97.9
137	146	54.4	99.8
138	148	54.4	98.4
139	147	54.4	98.8
140	147	54.6	99.9
141	140	54.7	98.7
142	140	55.0	99.5
143	150	55.0	101.4
144	144	55.0	98.3
145	146	55.0	97.4
146	148	55.0	97.0
147	149	55.0	97.1

148	147	55.0	98.9
149	148	55.0	99.5
150	149	55.0	99.0
151	140	55.0	97.4
152	141	55.0	97.6
153	140	55.0	100.6
154	143	55.0	98.2
155	140	55.0	98.3
156	144	55.0	100.6
157	145	55.0	97.7
158	138	55.0	97.0
159	139	55.0	97.8
160	145	55.0	95.2
161	143	55.0	97.8
162	151	55.0	98.2
163	149	55.0	98.2
164	150	55.0	97.2
165	149	55.0	97.0
166	148	55.2	98.1
167	146	55.2	97.6
168	149	55.2	98.9
169	150	55.2	97.1
170	146	55.3	99.2
171	142	55.3	98.7
172	140	55.4	98.4
173	143	55.4	98.4
174	144	55.4	98.6
175	147	55.7	98.7
176	145	55.8	100.9
177	145	55.8	99.8
178	146	55.9	100.4
179	142	55.9	97.1
180	140	56.0	98.5
181	141	56.0	98.5
182	141	56.0	98.5
183	144	56.0	99.7
184	144	56.0	97.2
185	143	56.0	96.3
186	145	56.0	99.2
187	145	56.0	97.1
188	146	56.0	99.3
189	150	56.0	100.0
190	149	56.0	99.1
191	149	56.0	97.9
192	147	56.0	98.0
193	150	56.0	97.0
194	150	56.0	98.4
195	143	56.0	99.0
196	143	56.0	97.5
197	145	56.0	98.5

198	147	56.0	97.1
199	150	56.0	98.1
200	147	56.0	96.8
201	149	56.2	99.1
202	150	56.2	99.1
203	150	56.2	98.9
204	149	56.6	99.6
205	150	56.8	98.8
206	146	56.8	98.9
207	145	56.9	98.4
208	145	57.0	98.8
209	147	57.0	97.4
210	149	57.0	99.0
211	145	57.0	99.5
212	147	57.0	96.9
213	147	57.0	99.5
214	149	57.0	97.8
215	142	57.0	100.0
216	149	57.0	98.3
217	143	57.0	97.7
218	147	57.0	98.7
219	148	57.0	98.0
220	146	57.0	97.0
221	149	57.0	97.0
222	149	57.0	98.5
223	148	57.1	98.1
224	150	57.2	98.4
225	150	57.2	98.4
226	150	57.2	97.7
227	149	57.5	98.6
228	148	57.5	98.6
229	150	57.5	98.8
230	152	57.7	98.8
231	150	57.9	99.1
232	149	58.0	99.6
233	146	58.0	98.3
234	149	58.4	98.5
235	148	58.5	99.4
236	149	58.5	100.0
237	150	58.6	98.9
238	148	58.6	98.9
239	149	58.6	98.8
240	149	58.6	98.5
241	149	58.7	99.1
242	139	59.0	97.2
243	149	59.0	100.5
244	149	59.0	98.7
245	149	59.0	99.0
246	152	59.0	99.8
247	150	59.0	100.2

248	142	59.0	97.7
249	149	59.0	99.7
250	141	59.0	100.4
251	149	59.0	98.2
252	149	59.9	99.1
253	144	60.0	97.3
254	148	60.0	99.1
255	149	60.0	99.0
256	148	60.0	99.4
257	149	60.0	98.6
258	149	60.0	99.4
259	150	60.0	99.0
260	143	60.0	97.5
261	148	60.0	99.3
262	147	60.0	98.6
263	147	60.0	97.1
264	143	60.0	98.0
265	145	60.0	99.9
266	142	60.2	98.8
267	148	60.3	100.7
268	143	60.3	99.3
269	144	60.7	97.8
270	147	60.9	98.2
271	145	60.9	98.2
272	145	61.0	98.6
273	146	61.0	98.3
274	142	61.0	98.6
275	140	61.0	98.7
276	141	61.0	99.2
277	140	61.0	97.8
278	139	61.0	97.6
279	144	61.0	99.0
280	143	61.0	98.9
281	148	61.0	98.2
282	145	61.0	99.0
283	142	61.0	99.3
284	146	61.1	98.9
285	139	61.1	98.1
286	139	61.2	100.2
287	142	61.5	97.9
288	142	61.6	97.3
289	142	61.6	97.8
290	140	61.9	97.5
291	140	62.0	97.9
292	147	62.0	99.8
293	145	62.0	98.0
294	141	62.0	97.4
295	138	62.0	97.3
296	142	62.0	98.0
297	149	62.0	98.8

298	150	63.0	98.6
299	139	63.0	97.8
300	143	63.0	98.7
301	144	63.1	98.3
302	144	63.7	99.0
303	146	64.0	99.2
304	147	64.0	98.2
305	151	64.2	98.9
306	150	64.2	100.0
307	145	64.2	99.9
308	142	64.5	98.6
309	141	64.5	99.6
310	139	65.0	99.1
311	146	65.0	98.2
312	145	65.0	98.5
313	147	65.8	98.4
314	145	66.0	98.0
315	145	66.0	99.0
316	146	66.3	98.3
317	142	66.9	97.6
318	140	67.3	98.5
319	143	68.7	98.3

Numbers	Breakdown T (^{0}C)	I-Road, Anuradhapure (AP4)	
		Thickness (mm)	Degree of compaction %
1	154	41	94.7
2	148	42.9	99.3
3	148	43.7	97.1
4	149	44	98.8
5	149	44	97.0
6	148	44	97.0
7	149	44.2	97.2
8	148	44.7	98.9
9	150	45	97.0
10	147	45	99.0
11	149	45	97.6
12	149	46	97.9
13	148	46	99.5
14	149	46	98.9
15	148	46	97.5
16	149	46	96.8
17	148	46	98.5
18	150	46	98.4
19	149	46	96.5
20	148	46	98.9
21	151	46	97.7
22	148	46	98.4
23	148	46	98.9
24	149	47	99.8
25	148	47	98.5
26	150	47	97.8
27	148	47	97.8
28	148	47	98.5
29	149	47	97.0
30	148	47	98.6
31	149	47	99.2
32	150	47	99.6
33	149	47	96.9
34	148	47	99.7
35	150	48	99.5
36	149	48	99.4
37	150	48	97.1
38	149	48	96.8
39	149	48	97.5
40	149	48	99.2
41	150	48	97.8
42	147	48	100.2
43	148	48	96.1
44	148	48	99.4
45	151	48	97.8
46	150	48	98.2
47	149	48	99.6
48	150	48	99.8
49	148	48	98.2

50	148	48	98.0
51	150	48	99.2
52	150	48	96.6
53	148	48	96.9
54	149	48	102.0
55	149	48	98.8
56	148	48	98.6
57	149	49	97.1
58	149	49	97.4
59	149	49	97.9
60	148	49	97.0
61	148	49	97.3
62	149	49	99.8
63	149	49	98.3
64	148	49	97.0
65	149	49	98.2
66	149	49	98.2
67	148	49	98.6
68	149	49	97.0
69	144	49	98.8
70	148	49	99.0
71	146	49	99.0
72	148	49	98.0
73	150	49	98.2
74	150	49	96.5
75	149	49	98.0
76	148	49	100.9
77	149	49	97.2
78	148	49	96.9
79	149	50	98.3
80	148	50	97.1
81	149	50	99.3
82	150	50	100.8
83	149	50	100.0
84	148	50	98.9
85	149	50	99.4
86	150	50	99.2
87	148	50	98.8
88	149	50	97.1
89	149	50	97.2
90	149	50	98.8
91	148	50	98.3
92	149	50	100.7
93	149	50	99.1
94	149	50	99.5
95	152	50	100.5
96	150	50	98.5
97	149	50	97.8
98	149	51	98.4
99	150	51	100.2
100	149	51	97.2
101	149	51	100.2

102	149	51	99.2
103	148	51	97.8
104	149	51	96.2
105	150	51	99.5
106	146	51	99.5
107	148	51	97.9
108	147	51	98.1
109	147	52	98.8
110	153	52	97.6
111	151	52	97.3
112	151	52	97.7
113	150	52	100.2
114	146	52	96.9
115	149	52	99.2
116	146	52	99.0
117	151	52	97.3
118	153	52	98.3
119	148	52	101.0
120	150	52	97.2
121	153	52	98.8
122	153	52	97.0
123	146	52	96.8
124	151	52	98.8
125	147	52	99.5
126	150	52	98.9
127	146	52	99.0
128	150	53	98.1
129	149	53	98.6
130	149	53	98.4
131	147	53	99.9
132	149	53	99.0
133	150	53	98.5
134	150	53	99.0
135	149	53	99.7
136	150	53	99.6
137	146	53	97.9
138	145	53	97.0
139	145	53	98.0
140	147	53	97.4
141	149	53	99.8
142	149	53	98.0
143	149	53	97.8
144	147	53	99.2
145	148	53	97.9
146	148	53	100.0
147	146	53	96.7
148	150	53	99.6
149	150	53	98.1
150	151	54	97.0
151	149	54	100.7
152	148	54	98.5
153	150	54	99.4
154	152	54	99.6

155	149	54	98.0
156	150	54	97.6
157	152	54	97.3
158	149	54	99.0
159	152	54	98.1
160	153	54	97.9
161	149	54	99.4
162	149	54	96.6
163	148	54	97.3
164	150	54	100.5
165	148	54	102.2
166	152	55	100.9
167	149	55	97.3
168	152	55	98.5
169	150	55	97.8
170	152	55	98.2
171	150	55	100.0
172	148	55	98.7
173	149	55	98.2
174	150	55	100.1
175	149	55	97.5
176	149	55	99.7
177	150	55	98.3
178	149	55	99.7
179	156	55	98.0
180	152	55	98.0
181	150	55	97.2
182	149	55	97.9
183	149	55	98.5

184	150	55	98.3
185	149	56	97.1
186	149	56	97.8
187	150	56	99.2
188	146	56	99.5
189	150	56	100.2
190	148	56	96.9
191	148	56	98.7
192	146	56	97.4
193	145	56	98.8
194	150	57	99.5
195	148	57	98.5
196	147	57	100.7
197	148	57	99.8
198	149	57	98.4
199	159	57	98.4
200	150	57	97.9
201	149	57	96.9
202	149	57	101.2
203	148	57	98.3
204	150	58	99.7
205	150	58	100.1
206	150	58	99.3
207	153	58	99.8
208	149	58	100.2
209	148	59	99.6
210	148	59	99.8
211	149	59	97.3
212	148	59	98.5
213	147	59	97.2
214	147	59	99.3
215	146	59	99.1
216	150	59	97.0
217	150	59	98.3
218	149	59	100.2
219	148	60	100.0
220	153	60	96.9
221	149	60	99.0
222	150	60	97.2
223	153	61	100.1
224	150	61	98.8
225	148	62	98.6
226	150	62	97.8
227	150	62	99.8
228	140	62	96.8
229	141	62	97.2
230	140	63	99.3
231	141	63	98.0
232	140	63	98.4
233	144	64	98.9
234	145	64	98.9
235	140	65	98.4

I-Road, Polonnaruwa (PO2)			
Numbers	Breakdown T (0C)	Thickness (mm)	Degree of compaction %
1	154	40.1	98
2	152	43.3	98
3	153	43.7	99
4	152	44.2	98
5	154	45.7	101
6	144	45.8	98
7	153	46.2	99
8	152	46.2	99
9	157	46.2	98
10	154	46.3	100
11	157	46.4	99
12	154	46.4	101
13	153	46.4	100
14	154	46.4	98
15	154	46.6	99
16	153	46.6	100
17	152	46.7	99
18	151	46.9	99
19	152	47.0	99
20	153	47.0	98
21	154	47.4	98
22	154	47.7	101
23	150	47.7	97
24	153	47.7	99
25	155	47.8	99
26	153	47.9	101
27	155	48.0	100
28	154	48.1	98
29	154	48.1	98
30	155	48.2	100
31	154	48.2	99
32	152	48.3	100
33	156	48.4	98
34	153	48.4	98
35	155	48.4	98
36	160	48.5	100
37	155	48.5	100
38	152	48.5	99
39	153	48.6	101
40	153	48.6	101
41	152	48.7	99
42	158	48.7	99
43	153	48.8	99
44	155	48.9	100

45	153	49.2	99
46	157	49.2	98
47	156	49.3	98
48	154	49.3	100
49	154	49.4	99
50	153	49.4	100
51	156	49.4	98
52	149	49.5	99
53	157	49.5	99
54	152	49.6	100
55	153	49.6	101
56	154	49.8	99
57	155	49.9	99
58	157	49.9	101
59	153	49.9	100
60	154	49.9	98
61	136	50.0	100
62	154	50.0	100
63	155	50.1	99
64	155	50.2	98
65	155	50.3	97
66	156	50.4	99
67	153	50.6	98
68	154	50.7	100
69	154	50.7	98
70	155	50.9	97
71	153	51.1	101
72	155	51.2	101
73	154	51.3	99
74	155	51.5	99
75	154	51.6	100
76	153	51.7	100
77	154	51.8	98
78	156	51.9	101
79	145	51.9	99
80	154	52.1	100
81	158	52.1	99
82	155	52.1	98
83	155	52.2	97
84	158	52.2	99
85	155	52.3	99
86	151	52.4	98
87	155	52.5	97
88	152	52.5	100
89	155	52.6	100
90	153	52.6	98
91	151	52.6	99

92	156	52.6	98
93	155	52.6	101
94	154	52.6	98
95	153	52.7	98
96	152	52.7	99
97	156	52.7	100
98	154	52.8	100
99	156	52.9	100
100	156	52.9	99
101	156	52.9	99
102	157	52.9	100
103	156	53.0	97
104	153	53.0	99
105	157	53.0	98
106	152	53.3	98
107	154	53.3	98
108	151	53.3	97
109	151	53.5	100
110	156	53.7	98
111	154	53.9	100
112	156	53.9	97
113	158	53.9	99
114	154	54.0	100
115	155	54.1	101
116	157	54.2	99
117	153	54.3	98
118	157	54.5	99
119	150	54.6	98
120	154	54.6	98
121	153	54.7	98
122	153	54.7	98
123	153	54.8	101
124	153	54.9	99
125	154	54.9	101
126	154	54.9	101
127	150	55.0	100
128	153	55.0	99
129	156	55.1	100
130	154	55.2	100
131	153	55.2	98
132	154	55.3	100
133	154	55.4	99
134	155	55.4	99
135	153	55.5	101
136	157	55.5	99
137	155	55.5	100
138	147	55.5	99

139	153	55.8	98
140	156	55.8	100
141	151	56.0	97
142	155	56.1	100
143	154	56.1	98
144	157	56.1	99
145	156	56.1	99
146	155	56.2	100
147	156	56.6	99
148	152	56.7	101
149	154	56.7	100
150	157	56.7	99
151	152	56.8	99
152	151	57.0	98
153	156	57.0	98
154	154	57.1	100
155	153	57.2	98
156	155	57.2	100
157	157	57.2	98
158	156	57.2	98
159	155	57.2	99
160	154	57.4	99
161	153	57.4	97
162	153	57.4	99
163	157	57.4	98
164	155	57.5	100
165	154	57.5	100
166	155	57.5	98
167	154	57.6	101
168	152	57.6	99
169	157	57.6	100
170	154	57.7	99
171	158	57.8	100
172	153	57.9	98
173	151	58.1	97
174	158	58.1	98
175	151	58.1	100
176	154	58.1	100
177	157	58.1	98
178	157	58.2	97
179	155	58.2	100
180	155	58.2	99
181	155	58.5	99
182	155	58.6	99
183	153	58.6	99
184	158	58.7	98
185	153	58.8	98

186	154	58.9	97
187	155	58.9	99
188	154	59.0	100
189	156	59.0	98
190	155	59.1	100
191	156	59.1	100
192	153	59.1	100
193	156	59.2	100
194	155	59.3	98
195	155	59.3	99
196	158	59.3	100
197	153	59.4	99
198	152	59.4	100
199	154	59.5	100
200	152	59.7	100
201	155	59.7	100
202	152	59.8	99
203	158	59.8	98
204	147	60.3	99
205	154	60.4	100
206	153	60.6	99
207	152	60.7	99
208	157	60.8	99
209	155	60.8	100
210	154	60.9	100
211	153	61.0	99
212	152	61.1	101
213	153	61.3	97
214	155	61.5	101
215	149	61.5	100
216	152	61.8	100
217	156	61.8	98
218	155	61.9	99
219	152	62.5	98
220	153	62.7	99
221	154	62.8	100
222	156	63.2	99
223	154	63.4	97
224	152	63.4	99
225	150	63.5	98
226	153	63.7	100
227	155	64.0	97
228	152	64.2	101
229	155	64.8	99
230	152	65.0	101
231	152	65.0	99
232	153	65.7	100

233	154	65.7	100
234	150	66.0	99
235	154	66.3	100
236	154	67.2	99
237	154	68.2	98
238	158	69.2	100
239	151	69.3	100
240	150	69.6	98

I-Road Kurunegala (KU1)			
Numbers	Breakdown T (^{0}C)	Thickness (mm)	Degree of compaction %
1	146	46.0	96.8
2	143	46.1	96.6
3	143	46.3	96.9
4	143	46.5	97.0
5	145	46.7	97.1
6	145	47.3	98.6
7	146	47.3	97.7
8	143	48.0	98.0
9	144	48.1	98.5
10	144	48.2	97.9
11	144	48.2	98.1
12	142	48.4	97.2
13	150	48.4	98.3
14	148	48.7	97.3
15	143	48.8	97.6
16	145	48.9	98.4
17	146	49.0	98.0
18	142	49.0	98.7
19	142	49.0	96.9
20	149	49.0	98.1
21	148	49.1	97.5
22	142	49.2	97.7
23	141	49.2	98.0
24	139	49.4	97.5
25	144	49.5	97.5
26	143	49.5	97.7
27	148	49.6	98.4
28	145	49.6	97.8
29	142	49.8	98.1
30	146	49.8	97.5
31	139	49.8	97.7
32	139	49.9	97.3
33	142	49.9	97.8
34	142	50.0	97.3
35	142	50.0	97.8
36	141	50.0	97.6
37	141	50.0	98.8
38	140	50.0	97.7
39	143	50.0	98.2
40	144	50.0	98.0
41	145	50.0	97.3
42	139	50.0	97.0
43	146	50.1	98.5
44	148	50.1	98.2
45	144	50.2	97.6
46	138	50.2	98.1
47	150	50.2	99.1

48	148	50.3	98.3
49	143	50.4	98.5
50	146	50.4	98.6
51	146	50.5	98.9
52	149	50.5	97.9
53	151	50.5	98.2
54	146	50.6	97.5
55	145	50.8	97.6
56	145	50.8	98.5
57	147	50.9	98.0
58	149	51.0	98.3
59	148	51.0	98.3
60	144	51.0	98.0
61	142	51.0	97.8
62	146	51.0	98.3
63	143	51.0	97.0
64	141	51.0	99.2
65	141	51.0	98.3
66	139	51.0	98.5
67	140	51.1	97.7
68	145	51.2	98.3
69	143	51.2	98.3
70	149	51.3	98.6
71	149	51.5	99.0
72	150	51.5	98.7
73	148	51.6	98.2
74	148	51.6	98.7
75	148	51.7	97.7
76	146	51.9	99.1
77	144	52.0	98.3
78	146	52.0	98.5
79	147	52.0	97.7
80	148	52.0	99.0
81	149	52.0	97.4
82	149	52.1	98.7
83	147	52.3	98.6
84	147	52.3	99.1
85	148	52.6	98.6
86	146	52.7	99.1
87	139	52.7	98.3
88	139	52.9	97.8
89	144	53.0	98.1
90	147	53.1	97.1
91	146	53.1	98.7
92	148	53.1	98.5
93	149	53.1	98.2
94	148	53.3	97.7
95	150	53.3	98.1
96	151	53.3	98.6
97	150	53.4	99.1

98	150	53.4	98.3
99	148	53.5	99.8
100	149	53.5	100.6
101	150	53.5	99.2
102	149	53.5	97.9
103	149	53.7	98.6
104	150	53.8	98.9
105	149	53.9	99.3
106	143	54.0	100.9
107	145	54.0	99.0
108	147	54.0	99.9
109	147	54.0	98.5
110	147	54.1	97.9
111	145	54.1	98.2
112	149	54.2	98.3
113	149	54.3	99.4
114	150	54.7	98.2
115	148	54.8	99.7
116	148	55.0	97.8
117	146	55.0	98.7
118	145	55.0	99.2
119	145	55.0	99.3
120	147	55.0	98.9
121	148	55.0	100.1
122	149	55.2	99.5
123	149	55.3	99.4
124	147	55.3	99.7
125	148	55.5	99.0
126	147	55.5	99.1
127	147	55.7	98.7
128	145	55.8	99.6
129	145	55.9	99.7
130	149	55.9	98.3
131	149	56.0	98.3
132	149	56.0	98.8
133	148	56.2	99.2
134	149	56.4	99.1
135	149	56.5	99.0
136	150	56.6	98.5
137	146	56.7	98.4
138	148	57.0	98.7
139	147	57.0	99.1
140	147	57.0	101.0
141	148	57.2	99.2
142	149	57.3	98.7
143	149	57.5	99.4
144	147	57.5	98.9
145	148	57.6	98.6
146	147	57.7	97.4
147	147	57.8	98.0

148	145	57.9	97.6
149	145	58.0	99.3
150	149	58.4	99.1
151	140	58.7	99.0
152	141	58.8	98.3
153	140	59.0	97.3
154	143	59.4	98.0
155	140	59.5	98.2
156	144	59.7	97.7
157	145	59.8	98.2
158	137	59.9	98.0
159	139	60.0	97.5
160	145	60.2	98.2
161	143	60.2	99.0
162	151	60.4	98.5
163	149	60.5	97.9
164	150	60.7	97.9
165	151	60.9	98.3
166	148	61.0	98.6
167	146	61.2	97.8
168	149	62.0	97.9
169	145	62.0	98.1
170	146	62.2	98.4

ANNEXURE B: Ambient Temperature Details

Jaffna	
Date	Max T (^{0}C)
2015-1-1	30.6
2015-1-2	30.9
2015-1-3	30
2015-1-4	31
2015-1-5	30.3
2015-1-6	29.5
2015-1-7	29.5
2015-1-8	29.8
2015-1-9	29.9
2015-1-10	29
2015-1-11	28.2
2015-1-12	28.5
2015-1-13	28.1
2015-1-14	28.3
2015-1-15	28.7
2015-1-16	29.5
2015-1-17	30
2015-1-18	29.1
2015-1-19	28.5
2015-1-20	29.1
2015-1-21	28.7
2015-1-22	28.1
2015-1-23	29.4
2015-1-24	30.1
2015-1-25	29.1
2015-1-26	29.3
2015-1-27	30
2015-1-28	28.9
2015-1-29	28.5
2015-1-30	29.1
2015-1-31	29.7
2015-2-1	29.4
2015-2-2	28.5
2015-2-3	28.7
2015-2-4	27.9
2015-2-5	28.1
2015-2-6	28.9
2015-2-7	29.2
2015-2-8	29.5
2015-2-9	28.2
2015-2-10	29.2
2015-2-11	30.3
2015-2-12	29.8
2015-2-13	30.5

Anuradhapura	
Date	Max T (^{0}C)
2017-10-01	33.4
2017-10-02	33.7
2017-10-03	33.4
2017-10-04	33.4
2017-10-05	34.3
2017-10-06	33.4
2017-10-07	34.1
2017-10-08	34.3
2017-10-09	34.3
2017-10-10	34.7
2017-10-11	32.4
2017-10-12	31.2
2017-10-13	32.5
2017-10-14	31.5
2017-10-15	31.4
2017-10-16	33.1
2017-10-17	31.5
2017-10-18	32
2017-10-19	33
2017-10-20	30.6
2017-10-21	33.2
2017-10-22	32.7
2017-10-23	34.1
2017-10-24	34.1
2017-10-25	33.7
2017-10-26	33.8
2017-10-27	31.9
2017-10-28	32.6
2017-10-29	31
2017-10-30	31.4
2017-10-31	29.7
2017-11-01	29.1
2017-11-02	30.3
2017-11-03	29.3
2017-11-04	30.9
2017-11-05	30.5
2017-11-06	29.9
2017-11-07	29.9
2017-11-08	31.9
2017-11-09	31.7
2017-11-10	29.6
2017-11-11	29.3
2017-11-12	30.5
2017-11-13	30.9

Polonnaruwa	
Date	Max T (^{0}C)
2018-02-01	31.8
2018-02-02	31.3
2018-02-03	31
2018-02-04	30.4
2018-02-05	29
2018-02-06	30.2
2018-02-07	30.1
2018-02-08	29.1
2018-02-09	28.5
2018-02-10	31
2018-02-11	31.2
2018-02-12	29.4
2018-02-13	30.5
2018-02-14	30.7
2018-02-15	30.1
2018-02-16	29.8
2018-02-17	29.4
2018-02-18	29.2
2018-02-19	29.1
2018-02-20	29.7
2018-02-21	30
2018-02-22	30.5
2018-02-23	30.7
2018-02-24	31.1
2018-02-25	31
2018-02-26	31.2
2018-02-27	30.3
2018-02-28	31
2018-03-01	28.5
2018-03-02	29.9
2018-03-03	29
2018-03-04	30.5
2018-03-05	30.5
2018-03-06	30.2
2018-03-07	28.9
2018-03-08	30.3
2018-03-09	33.3
2018-03-10	33.5
2018-03-11	33
2018-03-12	33.3
2018-03-13	32.5
2018-03-14	32.5
2018-03-15	31.8
2018-03-16	32

Kurunegala	
Date	Max T (^{0}C)
2017-08-01	31.7
2017-08-02	32.5
2017-08-03	32.7
2017-08-04	32.6
2017-08-05	32.3
2017-08-06	30.5
2017-08-07	31.8
2017-08-08	33.1
2017-08-09	34.2
2017-08-10	34.4
2017-08-11	33.3
2017-08-12	32.2
2017-08-13	33
2017-08-14	31
2017-08-15	34.3
2017-08-16	33.8
2017-08-17	33.7
2017-08-18	30.3
2017-08-19	30.9
2017-08-20	31.7
2017-08-21	31.8
2017-08-22	32.8
2017-08-23	32
2017-08-24	32.7
2017-08-25	32.9
2017-08-26	33.2
2017-08-27	32.1
2017-08-28	31
2017-08-29	30.4
2017-08-30	32.8
2017-08-31	33.7
2017-09-01	34.3
2017-09-02	34.5
2017-09-03	28
2017-09-04	32.2
2017-09-05	32.6
2017-09-06	30.7
2017-09-07	29.1
2017-09-08	29.1
2017-09-09	29.7
2017-09-10	31.8
2017-09-11	33.8
2017-09-12	34.5
2017-09-13	29.4

2015-2-14	31.5
2015-2-15	31
2015-2-16	30.8
2015-2-17	30.9
2015-2-18	30.6
2015-2-19	30.9
2015-2-20	31
2015-2-21	30.5
2015-2-22	30.4
2015-2-23	30.5
2015-2-24	30.1
2015-2-25	31.1
2015-2-26	31.1
2015-2-27	31.7
2015-2-28	32.3
2015-3-1	32.6
2015-3-2	31.9
2015-3-3	32.8
2015-3-4	33.1
2015-3-5	33.5
2015-3-6	32.8
2015-3-7	32.3
2015-3-8	32.7
2015-3-9	32.3
2015-3-10	31.1
2015-3-11	31.3
2015-3-12	31.1
2015-3-13	32.3
2015-3-14	32
2015-3-15	32.4
2015-3-16	32.4
2015-3-17	32.4
2015-3-18	33.9
2015-3-19	32.8
2015-3-20	32.4
2015-3-21	32.7
2015-3-22	35.2
2015-3-23	33.9
2015-3-24	33.9
2015-3-25	34.6
2015-3-26	32.9
2015-3-27	32.5
2015-3-28	31.5
2015-3-29	33
2015-3-30	33.9
2015-3-31	34.4
2015-4-1	33.4

2017-11-14	31.5
2017-11-15	34
2017-11-16	33.4
2017-11-17	33.4
2017-11-18	33.3
2017-11-19	31.5
2017-11-20	32.4
2017-11-21	31.8
2017-11-22	32.1
2017-11-23	31.3
2017-11-24	30.5
2017-11-25	29.9
2017-11-26	26.8
2017-11-27	28.5
2017-11-28	29.2
2017-11-29	28.7
2017-11-30	30.6
2017-12-01	28.8
2017-12-02	30.6
2017-12-03	31.6
2017-12-04	30.1
2017-12-05	31.1
2017-12-06	31.1
2017-12-07	31.9
2017-12-08	31.6
2017-12-09	31.8
2017-12-10	32.6
2017-12-11	31.8
2017-12-12	32.7
2017-12-13	33
2017-12-14	30.6
2017-12-15	31
2017-12-16	30.7
2017-12-17	30.3
2017-12-18	30.2
2017-12-19	27.5
2017-12-20	25.9
2017-12-21	29.2
2017-12-22	29.8
2017-12-23	30
2017-12-24	30
2017-12-25	30.9
2017-12-26	29
2017-12-27	29.4
2017-12-28	28.7
2017-12-29	28.9
2017-12-30	30.2

2018-03-17	31.6
2018-03-18	31.9
2018-03-19	32
2018-03-20	32.3
2018-03-21	32.5
2018-03-22	31.9
2018-03-23	32.4
2018-03-24	32.4
2018-03-25	33
2018-03-26	33.6
2018-03-27	32.8
2018-03-28	31.6
2018-03-29	31.9
2018-03-30	31.1
2018-03-31	30.8
2018-04-01	32.6
2018-04-02	32.5
2018-04-03	33.5
2018-04-04	34.4
2018-04-05	34.1
2018-04-06	33.4
2018-04-07	33.4
2018-04-08	33.1
2018-04-09	32
2018-04-10	32.4
2018-04-11	32.5
2018-04-12	26
2018-04-13	31.1
2018-04-14	34
2018-04-15	34.8
2018-04-16	33.5
2018-04-17	33.6
2018-04-18	33.5
2018-04-19	33.5
2018-04-20	34
2018-04-21	34.3
2018-04-22	35.1
2018-04-23	35.3
2018-04-24	34.4
2018-04-25	34
2018-04-26	32.8
2018-04-27	35
2018-04-28	35.8
2018-04-29	36
2018-04-30	36.2
2018-05-01	35.1
2018-05-02	35.7

2017-09-14	31.8
2017-09-15	32.5
2017-09-16	32.4
2017-09-17	30.3
2017-09-18	30.9
2017-09-19	32.3
2017-09-20	32.5
2017-09-21	32.8
2017-09-22	31.9
2017-09-23	33.2
2017-09-24	32.5
2017-09-25	30.5
2017-09-26	30.6
2017-09-27	28.1
2017-09-28	31.8
2017-09-29	32.4
2017-09-30	32.1
2017-10-01	30.8
2017-10-02	32.8
2017-10-03	32.9
2017-10-04	31.1
2017-10-05	32.1
2017-10-06	31
2017-10-07	31.9
2017-10-08	32.2
2017-10-09	30.9
2017-10-10	32.2
2017-10-11	29
2017-10-12	31.8
2017-10-13	29.8
2017-10-14	26.6
2017-10-15	29.3
2017-10-16	32
2017-10-17	31.1
2017-10-18	31.7
2017-10-19	29.9
2017-10-20	30.1
2017-10-21	32.7
2017-10-22	31
2017-10-23	33.2
2017-10-24	32.9
2017-10-25	32.8
2017-10-26	31.8
2017-10-27	32.3
2017-10-28	33.3
2017-10-29	32.2
2017-10-30	31.5

2015-4-2	34.7
2015-4-3	34
2015-4-4	34.2
2015-4-5	35
2015-4-6	34.7
2015-4-7	35.7
2015-4-8	33.3
2015-4-9	34.1
2015-4-10	33.2
2015-4-11	35.3
2015-4-12	34
2015-4-13	29.4
2015-4-14	32.6
2015-4-15	32.5
2015-4-16	31.5
2015-4-17	33.3
2015-4-18	34
2015-4-19	33.3
2015-4-20	34.3
2015-4-21	34.3
2015-4-22	32
2015-4-23	33
2015-4-24	35
2015-4-25	33
2015-4-26	33.9
2015-4-27	34.3
2015-4-28	35
2015-4-29	34.5
2015-4-30	33.7
2015-5-1	34
2015-5-2	34.6
2015-5-3	34.6
2015-5-4	35.4
2015-5-5	34.7
2015-5-6	33.3
2015-5-7	34.1
2015-5-8	34
2015-5-9	33.7
2015-5-10	35
2015-5-11	33.5
2015-5-12	31
2015-5-13	31.6
2015-5-14	31.8
2015-5-15	29.3
2015-5-16	32.2
2015-5-17	28.8
2015-5-18	31.8

2017-12-31	31.3
2018-01-01	31.8
2018-01-02	31.3
2018-01-03	31
2018-01-04	30.4
2018-01-05	29
2018-01-06	30.2
2018-01-07	30.1
2018-01-08	29.1
2018-01-09	28.5
2018-01-10	31
2018-01-11	31.2
2018-01-12	29.4
2018-01-13	30.5
2018-01-14	30.7
2018-01-15	30.1
2018-01-16	29.8
2018-01-17	29.4
2018-01-18	29.2
2018-01-19	29.1
2018-01-20	29.7
2018-01-21	30
2018-01-22	30.5
2018-01-23	30.7
2018-01-24	31.1
2018-01-25	31
2018-01-26	31.2
2018-01-27	30.3
2018-01-28	31
2018-01-29	28.5
2018-01-30	29.9
2018-01-31	29
2018-02-01	30.5
2018-02-02	30.5
2018-02-03	30.2
2018-02-04	28.9
2018-02-05	30.3
2018-02-06	33.3
2018-02-07	33.5
2018-02-08	33
2018-02-09	33.3
2018-02-10	32.5
2018-02-11	32.5
2018-02-12	31.8
2018-02-13	32
2018-02-14	31.6
2018-02-15	31.9

2018-05-03	35.8
2018-05-04	34.8
2018-05-05	35.4
2018-05-06	35.6
2018-05-07	36.1
2018-05-08	33.8
2018-05-09	34.2
2018-05-10	33.2
2018-05-11	34
2018-05-12	33.9
2018-05-13	33.5
2018-05-14	34.1
2018-05-15	34.4
2018-05-16	34.3
2018-05-17	34.7
2018-05-18	34.9
2018-05-19	35.3
2018-05-20	34.9
2018-05-21	34.1
2018-05-22	35.4
2018-05-23	35.3
2018-05-24	35.4
2018-05-25	35.2
2018-05-26	35
2018-05-27	35.1
2018-05-28	34.8
2018-05-29	33.9
2018-05-30	35
2018-05-31	34.5
2018-06-01	28.8
2018-06-02	30.6
2018-06-03	31.6
2018-06-04	30.1
2018-06-05	31.1
2018-06-06	31.1
2018-06-07	31.9
2018-06-08	31.6
2018-06-09	31.8
2018-06-10	32.6
2018-06-11	31.8
2018-06-12	32.7
2018-06-13	33
2018-06-14	30.6
2018-06-15	31
2018-06-16	30.7
2018-06-17	30.3
2018-06-18	30.2

2017-10-31	27.9
2017-11-01	31
2017-11-02	30.8
2017-11-03	31.5
2017-11-04	31.9
2017-11-05	29.9
2017-11-06	32.2
2017-11-07	31.3
2017-11-08	33
2017-11-09	31.6
2017-11-10	30.6
2017-11-11	30.4
2017-11-12	30.5
2017-11-13	32.5
2017-11-14	32.4
2017-11-15	33
2017-11-16	33.5
2017-11-17	33.4
2017-11-18	33.4
2017-11-19	32.5
2017-11-20	32.5
2017-11-21	32.7
2017-11-22	32.4
2017-11-23	32
2017-11-24	30.4
2017-11-25	28.4
2017-11-26	27.3
2017-11-27	27.7
2017-11-28	28.5
2017-11-29	28.5
2017-11-30	27.9
2017-12-01	27.6
2017-12-02	30.7
2017-12-03	30.8
2017-12-04	31.7
2017-12-05	31.7
2017-12-06	32.3
2017-12-07	31.7
2017-12-08	30.9
2017-12-09	32
2017-12-10	32.2
2017-12-11	31.8
2017-12-12	32.2
2017-12-13	32.2
2017-12-14	32.4
2017-12-15	32.2
2017-12-16	31.3

2015-5-19	32.3
2015-5-20	32.4
2015-5-21	32.3
2015-5-22	32.1
2015-5-23	32
2015-5-24	32
2015-5-25	32.5
2015-5-26	32.5
2015-5-27	32.1
2015-5-28	33.3
2015-5-29	32
2015-5-30	32.3
2015-5-31	32.1

2018-02-16	32
2018-02-17	32.3
2018-02-18	32.5
2018-02-19	31.9
2018-02-20	32.4
2018-02-21	32.4
2018-02-22	33
2018-02-23	33.6
2018-02-24	32.8
2018-02-25	31.6
2018-02-26	31.9
2018-02-27	31.1
2018-02-28	30.8

2018-06-19	27.5
2018-06-20	25.9
2018-06-21	29.2
2018-06-22	29.8
2018-06-23	30
2018-06-24	30
2018-06-25	30.9
2018-06-26	29
2018-06-27	29.4
2018-06-28	28.7
2018-06-29	28.9
2018-06-30	30.2

2017-12-17	31.9
2017-12-18	31.3
2017-12-19	30.8
2017-12-20	27.7
2017-12-21	30.5
2017-12-22	30.9
2017-12-23	30.9
2017-12-24	31.5
2017-12-25	32.3
2017-12-26	31
2017-12-27	31.3
2017-12-28	30.5
2017-12-29	30.6
2017-12-30	31.6
2017-12-31	31.8