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DEVELOPMENT OF MODEL REFLECTING THE RELATION BETWEEN AIR AMBIENT TEMPERATURE AND ASPHALT LAYERS TEMPERAUTRE IN GAZA STRIP

تطوير نموذج للعلاقة بين درجة حرارة الهواء المحيط ودرجة حرارة طبقات الإسفلت في قطاع غزة

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DEDICATION

To the owner of the glowing hearts and burning vigor ……………

To all martyrs of Palestine……………………………………………

To all who loved Palestine as a home land and Islam as faith a way of life……....

To those who provide me with their support to achieve this thesis successfully….

To beloved my father & my mother ………………………………….....................

To my wife ,my son for their unlimited support ………………………………….....

To my brothers, my sisters, and all my friends…………………………………….…

To my teachers who did all their best in helping me to finish this thesis……….

To all of them,

I dedicate this work

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ABSTRACT

Temperature is one of the most important factors affecting the design and performance of pavement. Temperature variations within the asphalt pavement structure contribute in many different ways to distress and possible failure of that structure. The structural performance of pavements is highly dependent on temperatures to which these pavements are exposed. For a successful pavement design, it is vital to know the range of temperatures over which a pavement will be subjected and it is necessary to determine the distribution of temperatures through the pavement asphalt concrete layers. In this study, the distribution of pavement temperatures at surface and at three depths (2cm, 5.5cm, 7cm) below the pavement surface is determined using the temperature data instrument. Data were analyzed for daily and seasonal variations. Surface temperature was found less than the temperatures in all three depths mentioned above which exist below asphalt surface, especially at hot hours of high ambient. It is clear that the maximum temperature of asphalt pavement occurred at noon time in summer and the minimum temperature occurred at dawn time in winter. The thermal pattern behavior of air ambient temperature and asphalt pavement layers during whole day was in two ways, it started in upward behavior from morning to the noon and reflect to downward behavior from noon to the dawn.

Using correlation and regression method. a relationship for determining the pavement temperature at different asphalt pavement depths (2 cm, 5.5 cm and 7cm) and air temperatures was suggested, taking into account the behavior of temperatures in two different manners.

ملخص البحث

تعتبر درجة الحرارة من أهم العوامل التي تؤثر في تصميم وأداء الرصفة الاسفلتية لان التغيرات في درجة الحرارة داخل بنية الرصف الاسفلتي تساهم في خراب وانهيار لتلك البنية. ولتصميم رصفة اسفلتية ناجحة يجب ان يؤخذ في عين الاعتبار درجات الحرارة التي تتعرض لها هذه الرصفة من خلال قياس درجات الحرارة و تحديدها عند اعماق مختلفة من الطبقات الإسفلتية للرصفة. في هذه الدراسة تم تحديد درجات حرارة سطح الرصفة الاسفلتية وكذلك على ثلاث أعماق مختلفة تحت السطح (2 سم، 5.5سم، 7سم) على التوالي والناتجة عن تأثرها بدرجة حرارة الجو المحيط للرصفة الاسفلتية وذلك باستخدام ترمومتر الكتروني رقمي يسجل بيانات درجات الحرارة الموجودة عند كل عمق. وبعد تحليل بيانات التغيرات الموسمية واليومية تم التوصل الى ان درجة حرارة سطح الرصفة الاسفلتية تكون أقل من درجة الحرارة الأعماق الثلاث وخاصة في ظل الحرارة الساخنة و العالية. وقد اتضح من خلال البحث ان درجة حرارة الاسفلت تبلغ اقصى مدى لها في ظهيرة فصل الصيف وتكون في ادنى حالها قبل شروق شمس الشتاء. وان طبيعة تصرف درجات الحرارة - في الجو المحيط واعماق الرصفة الاسفلتية - خلال اليوم على مدار السنة يكون باتجاهين مختلفين تبدأ تصاعديا من الفجر حتى الظهيرة ثم تنقلب تنازليا الى صباح اليوم التالي.

و باستخدام طريقة الارتباط والانحدار الاحصائية تم التوصل الى علاقات خطية في كل فصل من الفصول السنوية الاربعة تربط درجة حرارة الجو المحيط بدرجة حرارة الرصفة الاسفلتية بأعماق مختلفة (سطح الاسفلت ،2 سم، 5.5 سم و7سم) آخذين في عين الاعتبار طبيعة تصرف درجات الحرارة في الاتجاهين المختلفين.

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CHAPTER ONE: INTODUCTION

1.1. Background

It has been clarified that the progress and welfare of any country depend on the development of infrastructure assets for distributing resources and essential services to the public. Infrastructure assets always reflect the economic strength of a country [1].

Roads and pavement structures are considered one of the greatest investments in infrastructure assets, which is extremely important for the growth and wellbeing, and the expansion of any particular geographic area. So it must be durable, flexible and resilient pavement, and it must perform satisfactorily throughout its service lives [2].

As it is known, that all the pavements in the Gaza Strip consist generally of three or four layers: surface layer which may be asphalt, interlock or concrete, base layer which is almost crushed stone aggregate, sub base which is selected material (kurkar) and the compacted subgrade.

Recently, the pavement problem appeared clearly in the Palestine as the pavement layers which could not serve for the entire design period [3].

This problem appeared in the projects, which were constructed recently. The deformation and cracks appear on these roads few years after construction. These problems occur because asphalt concrete pavements are physical structures responding in a complex way to the influence of many factors (i.e., loads, material, variables, environmental conditions, etc.) and their interactions [4].

The weather and its various effects such as solar radiation, air temperature, humidity, frost and freeze-thaw cycles, along with load and density of traffic, are the main factors in determining the service life of the pavement [5].

Thermal environmental conditions, to which pavements are exposed continuously in the construction and repair phases, as well as the use and fluctuations in ambient air temperatures - diurnal and seasonal-, intensity of solar radiation, convective surface conditions, and precipitation significantly, have impact on pavement stability and therefore the long-term success of pavement design [6].

In tropic zones , increasing in temperature of asphalt is one of the major factor of failure in asphalt pavements. In these areas, high air temperature and severe radiation of solar rays cause increasing in asphalt layer temperature. In this condition, loads made by wheels of heavy vehicles produce vertical strains caused by compression force and would cause rutting in the wheel path and bleeding in the asphalt surface. Moreover skid resistance of asphalt pavement surface decreases with increasing of temperature and this will reduce the safety of road [7].

Many physical properties in asphalt concrete pavement significantly affected by temperature including material stiffness (resilient modulus) which is a measure of materials performance and their ability to spread the applied traffic loading over a specified area [4].

Characterization of the in-situ strength performance of roadways constructed using asphalt pavement is difficult due to the nature of the material. Asphalt pavement is a viscoelastic material; that is, it exhibits the properties of both a viscous and an elastic material. At low temperatures, asphalt pavement acts as an elastic solid in which low amounts of applied strain are recoverable; thus, permanent deformation is not likely to occur until this low strain limit is surpassed. However, at high temperatures, asphalt pavement acts as a viscous fluid in which the material begins to flow with an applied strain. The temperature within a pavement varies due to several factors including ambient temperature, solar radiation, wind speed, and reflectance of the pavement surface. Thus, to study the difference in strength characteristics of various pavement designs, it is imperative to know the temperature distribution within the pavement cross-section [5].

Many methods dealing with prediction of temperature gradients in pavements are based on statistical and probabilistic methods developed based on weather and pavement data. However, such statistical and probabilistic methods display shortcomings in that they tend to either underestimate high pavement temperatures or overestimate low pavement temperatures raising questions about their accuracy and reliability. More detailed methods using energy balance equations to estimate pavement surface temperatures or numerical models that attempt to predict [6].

In addition, an empirical approach also was tried. In this study, daily pavement temperatures were represented as a sine function. Temperature variation with depth was accounted by applying a factor that reduced the amplitude of the sine curve with increasing depth [6].

According to the above, it can be noticed that the importance of studying of the relation between air temperature and asphalt layers temperature in Gaza Strip are due to:

1-The study has not been conducted in the Gaza strip before.

2-The measuring of temperature and its distribution in the asphalt layer is very important for making decision regarding material properties .

1.2. Problem Statement

Climate serves as an essential input in pavement design .Depending on its variability may have significant impact on pavement performance. Climate data for a particular region in which a highway is located provides engineers with useful information when deciding the combination of pavement layers and materials that can withstand the elements of the environment peculiar to that region and perform adequately in the face of adverse weather conditions. Climatic indicators also provide an expectation as to the type and extent of climate induced deterioration that the highway is susceptible to. Pavements are designed based on typical historic climatic patterns, reflecting local climate and incorporating assumptions about a reasonable range of temperature and precipitation levels. Such changes in global and more specifically regional climate have the potential to affect pavement design and subsequent pavement performance once it is put in service [7].

This research explores the effect of air temperature on the pavement layers of roads throughout the year in the Gaza Strip by equations .These can predict the temperature of the asphalt surfaces and its different depths by using the air temperature.

1.3. Aim and Objectives

1.3.1. Aim

- The basic aim in this research is to investigate the relationship between the ambient temperature and the temperature of the asphalt temperature in different depths

1.3.2. Objectives

- To develop model to predict temperature fluctuations at various depths of asphalt layers.
- To determine the change in asphalt temperatures as a result of changes in air temperature in different seasons.

1.4. Importance of the Study

- The study has not been carried out in the Gaza Strip so far.
- There is a direct relationship between temperature of asphalt and Modulus of Elasticity of asphalt
- Temperature measuring in the Gaza Strip will be useful in setting a new asphalt pavement program for "Superpave" .

1.5. Methodology

- To achieve the goals of the study, the following steps were carried out:
    a. Literature review of previous studies.
    b. Identifying optimum place which is exposed to the sun as much possible through visual monitoring in Al-Wadd Street which is located in Beit Hanoun

due to the ease of access to the place.

c. Using a digital thermometer (HANNA instruments-HI 935005) which have a sensitive column to measure temperature manually.
d. Measuring of air temperature.
e. Measuring of the temperature of pavement surface.
f. Measuring of asphalt layers temperatures below pavement surface for three varies depths which have the following characteristics:
   1. The depths are 2.0, 5.5 and 7.0 cm, respectively.
   2. The diameter of each hole is 8 mm
   3. The distance between each hole and to another is 20 cm to maintain the same effect of climatic conditions
g. Mathematical or graphical model for the air temperature and the temperature in the asphalt layers was formed.
h. Analyzing and discussion of testing results .
i. Drawing conclusion and recommendations.
j. Number of samples:
   - Measurement were applied three days a week.
   - Every two hours from 6:00 until 12:00 (18 hours).
   - Every two weeks, a full day of measurement was carried out every two hours.
   - Once from 6:00 am until 4:00 (24 hours) every two weeks throughout the year.

1.6. Study Limitations:

The results of this study depend on set of limitations and criteria that were taken into account during the experimental work. These limitations include:

- Location is chosen based on the largest amount of exposure to sunlight.
- Only one impact on the temperature of the asphalt was studied which is the air temperature
- The composition of the asphalt mixture wasn't taken into account in terms of compounds and the type of mixture and granular gradient.

1.7. Thesis Structure

The thesis includes five chapters and six appendices. A brief description of the chapters contents is presented below:

Chapter 1: Introduction

This chapter is a briefly introduction, which highlights the concept of research. In addition, statement of problem, aim, objectives and methodology of research are described.

Chapter 2: Literature review

Detailed review of different studies and researches about developing a local model reflecting the relation between air temperature and asphalt layers in many countries is presented. This chapter includes background of effect of temperature on asphalt pavement And the development of infrastructure which associate with good temperature.

Chapter (3) Materials and study program

The methodology of developing local model to reach to optimum models for different asphalt layers which are affected with air ambient temperature by using specification and requirements .

Chapter (4) Results and data discussion

The optimum mathematical model for each layer in asphalt pavement is determined using the Correlation and Regression method by using Excel and specialize statistic program ,and making analyze for all output results.

Chapter (5) Conclusion and recommendations.

Conclusions derived from experimental results are presented. Moreover, the recommendations for the present study and other further studies are also provided in this this chapter.

Chapter 2: Literature Review

2.1. Introduction

Temperature is one of the most important environmental factors affecting the design of asphalt pavement distresses such as permanent deformation or rutting (typically associated with high temperature environments), bleeding, and thermal cracking (associated with low temperature environments) [9].

Temperature effects many physical properties in the pavement material. Generally, the stiffness (resilient modulus) of a pavement is a measure of materials performance and their ability to spread the applied traffic loading over a specified area [4].

In order to calculate the pavement thermal effects and the asphalt concrete mix thermal response, it is necessary to evaluate the temperatures distribution at different depths of bituminous layers throughout typical twenty-four hours periods. The temperature distributions which were collected in different times, during the day, allow to calculate of thermal effects in the pavement, mainly in the overlay for rehabilitation studies [12].

The time variation of pavement thermal state is controlled by: climatic conditions, thermal diffusivity of the materials, thermal conductivity, specific heat, density and the depth below the surface [13].

2.2. Temperature-Related Effects and Transportation Infrastructure.

Temperature increases in the MEC (Metropolitan East Coast) region between 1900 and 2000 are estimated at about 0.2 degrees Fahrenheit per decade, and this rate is expected to increase during the 21st century. Many daily and monthly annual and decade averages as well as temperature extremes and the timing of freezing and thawing cycles have been exceeded according to engineers managing regional infrastructure [18]. Materials used in roadways have a limited range of tolerance to heat, and the stress is exacerbated by the length of time temperatures are elevated and by stress factors, such as vehicle loadings on roadways and bridges during periods of congestion.

If these consequences are realized, they can, in turn, have economic and social effects, exacerbating already serious congestion problems in urban areas

2.3. Temperatures Used in Binder Specifications

Three pavement temperatures are required for binder specifications: maximum, intermediate, and minimum pavement design temperatures in keeping with the distress mechanisms. The largest seven-day average of maximum pavement temperatures at 20mm depth is chosen as the maximum pavement design temperature and is used in dynamic shear test to evaluate the suitability of the binder to resist permanent deformation. The minimum pavement design temperature corresponds to the minimum pavement surface temperature over the design life of the pavement and is used in the creep stiffness and direct tension tests to evaluate the binder`s suitability to resist low temperature cracking. An intermediate pavement design temperature, selected as the approximate average of the maximum and minimum pavement design temperatures, is used in the binder specification to specify the fatigue criteria and to control the stiffness of the binder in the middle range of service temperatures. Certain reliability factors may be considered in the selection of the maximum and minimum pavement design temperatures. Reliability is the percent probability in a single year that the actual temperature (one-day low or seven-day average high) will not exceed the design temperatures. For the North America, the SUPERPAVE (Superior Performing Asphalt Pavement) software uses an algorithm to estimate pavement temperature from air temperature and geographical latitude of the location [14].

2.4. Temperature-Related Sensitivities

Temperature-related sensitivities include extreme heat and cold, freeze-thaw cycles, permafrost degradation and reduced ice cover.

2.4.1. Extreme heat and cold

It is likely that climate change will increase the frequency and severity of hot days while the number of extremely cold days will be reduced across much of North America [15]. The following pavement impacts might become more common as extreme heat conditions become more severe and frequent:

- Pavement softening and traffic-related rutting,
- Buckling of pavement (especially older, jointed concrete),
- Flushing or bleeding of asphalt from older or poorly constructed pavements.

This will generally lead to increase maintenance costs wherever pavement thermal tolerances are exceeded—the last issue is also a safety concern. On the positive side, fewer extremely cold days and 'warmer' minimum temperature thresholds may reduce thermal cracking of pavement during winter and offset some of the increased summer maintenance costs

2.4.2. Freeze-thaw cycles

Increased frequencies of freeze-thaw cycles have been related to premature deterioration of road and runway pavements, primarily where subgrades are composed of fine-grained, saturated material—conditions that are conducive to frost heaving and thaw weakening

[15]. Preliminary research reported in Andrey and Mills (2003) suggests that freeze thaw cycles, defined using a 0°C (32°F) daily air temperature threshold [16].

2.5. Pavement Temperature Parameters Related to Thermal Stress and Durability

A number of parameters that characterize pavement temperatures are of interest in the context of pavement durability.

1) The average pavement temperature affects both the tensile/compressive stress level and the mechanical material properties.
2) The temperature gradient over the pavement thickness produces bending stresses, which are a concern for rigid pavement (concrete) but of less importance for flexible pavement (asphalt). Nonetheless, it should be recognized that temperature and stress gradients may be higher at or near the surface than over the thickness of the pavement.
3) The diurnal amplitude of pavement temperature is important for pavement fatigue analysis.
4) The time rate of change of temperature is of interest because fast temperature changes give the material less time for plastic creep, and therefore should give higher stress level [5].

2.5.1. Construction season length /quality

Although infrastructure expansion will likely be driven by non-climate factors (economics, population growth, etc.), warmer temperatures could translate into a longer potential construction season and improved cost efficiencies. Extreme heat and unfavorable working conditions for employees and certain types of construction activities may offset such gains. For example, high temperature, low humidity and high wind are factors that reduce the setting times and strength of concrete [17].

2.6. Studies and Research

After reading numerous literature review related to this study, it wasn't found a study similar to the subject of this thesis in Gaza. The following is a summary of studies close to the topic of this research:

Hassan et al.[9] made investigation related to the applicability of Long-Term Pavement Performance (LTPP) model on Oman's environmental conditions and more generally to the Arabian Gulf climate. They developed models to predict high and low asphalt pavement temperatures in Oman through choosing a location at the Sultan Qaboos University (SQU) campus to monitor air, pavement temperatures and solar radiation. Data were collected for 445 days. Daily minimum and maximum temperatures were recorded. A regression analysis used to develop the low and high pavement temperature model by using air temperature, solar radiation, and duration of solar radiation as independent variables. The results showed that the developed models is more relevance to predict the temperatures of asphalt paving in Oman and the Gulf than (LTPP) model.

Makki and Hamed [4] want to explain the effect of air temperatures on stiffness of asphalt concrete in Iraq, so it is necessary to determine the distribution of temperatures through the pavement asphalt concrete layers .The researchers distributed the pavement temperatures test at three depths (2.0cm ,7.0 cm, 10.0 cm) below the pavement surface and measured it by using the temperature data logger instrument. A relationship for determining pavement temperature as related to depth and air temperature has been investigated .To satisfy the aim of that thesis, the prepared specimens have been tested for indirect tension in accordance with ASTM D4123,using the pneumatic repeated load apparatus, in order to determine the values of resilient modulus at three different temperatures 10, 25, 40 °C.

The results appeared that the resilient modulus decreases with the increasing of test temperature by a rate of 8.78× 10^3 Psi/°C for asphalt concrete wearing courses .

An increase in optimum asphalt content by 0.1% (by weight of total mixture) causes a decrease in resilient modulus by 22% at a temperature of 40C°.

Minhoto et al. [12] have created a finite element model (FEM) to calculate the temperature of an asphalt rubber pavement located in the Northeast of Portugal and gave a good accuracy temperature prediction when compared with the field pavement thermal condition obtained during a year. Input data for solar radiation and temperature in addition to the mean daily values of wind speed was brought by a meteorological station to find the model are the hourly values. FEM (transient thermal analysis) used to model the thermal response of any depths in pavement structure, and each analysis was started with the full depth. constant initial temperature obtained from field measurements.

Seven thermocouples were installed in the asphalt rubber and conventional mix layers, at seven different depths in IP4 main road, near Braganza in the north of Portugal for each day analysis .The researchers concluded, that the 3-D finite-element analysis proved to simulate the transient behavior of asphalt pavements. The presented simulation model can predict the pavement temperature at different levels of bituminous layers with accuracy

Tabatabaie et al. [18] developed a mathematical model through the investigation of asphalt mixtures reactions to temperature increasing. This model makes the prediction of asphalt course temperature in various depths (with different specifications and mix designs) possible. Mercury thermometers are used for measuring surface temperature surface and 2.0, 4.0 and 6.0 cm depths temperature of samples.

Twenty four samples were made with different mix designs and located in its service life in tropical zones. Four variables that were considered for making samples are bitumen percent, bitumen type, level of compaction and gradation of aggregates. By gathering the samples in three different depths and the corresponding air temperatures for nine months, a data-base was made to develop the model using indirect tensile tests in three different temperatures with same of resilient modulus. The results showed that there is a significant correlation between three variables of the study and predicted temperatures. The variables are bitumen percent, bitumen type and level of compaction. Moreover, it was found that, besides temperature, bitumen type is the only variable that appears in the resilient modulus model.

Al-Albdul Wahhab and Balghunain [19] conducted a research in which measured the pavement temperature in a land and a coastal area in Saudi Arabia. In this research for considering the effect of pavement layer`s thickness on distribution of the temperature in depth, different thicknesses were studied. The result of the research providing a profile of temperature distribution in pavement and a profile of annual changes in the pavement temperature which illustrate the asphalt surface temperature less than the temperature at a depth of 2.0 cm only for hot summer months and at hours of high solar radiation and the Pavement temperatures ranged between 3°C and 72°C for coastal slab, and between 4°C and 65°C for inland slabs. This wide range of temperature , over which a pavement will be subjected variation is vital for a successful pavement design because there are a relationship between pavement temperature and variation of asphalt resilient modulus.

Wahhab et al. [20] consider temperature variations across pavement depth in the back-calculation of flexible pavement layer moduli because it contributes in many different ways to distress and possible failure of that pavement structure which strength is significantly reduced by increased temperature , especially when the pavements under loading condition. The researchers developed a prediction model of resilient modulus using statistical procedures to a high degree of reliability through consider the variation of temperature in and arid environment and their implications on the moduli of flexible pavements as independent variables.

Paliukaite1 and Vaitkus [21] described the behavior of asphalt pavement structure under Lithuanian environmental and climatic conditions (temperature, moisture, intensity of sun, etc.), which play a vital role in durability of asphalt pavement and variation in asphalt pavement strength during the year. The researchers interested in analyzing the temperature and moisture which are considered as one of the most important climatic factors because it influence the structural strength of road asphalt pavement .

The results of experimental research succeeded to determine pavement strength and Eo modulus in dependence on moisture and surface temperature, measured by the Falling Weight Deflectometer (FWD) in different seasons. To evaluate the values of road pavement strength and Eo modulus, the obtained measuring results were reduced to their equivalent values under standard temperature and load. Thus, the values of Eo modulus were adjusted to the standard temperature of +20 °C, using the revised temperature correction factor.

Diefenderfer et al. [6] imply to importance of daily model prediction for temperature distribution within the hot-mix asphalt (HMA) layers to determine in-situ strength characteristics of flexible pavement because the (HMA) pavements is a viscoelastic material , and the structural or load-carrying capacity of the pavement varies with the effects of heating and cooling temperatures by ambient temperature in different seasonal. So the researchers said that it is possible to model daily pavement maxima and minima temperature by knowing the maximum or minimum ambient temperatures, data was used from three depths within the pavement for model development: 0.038, 0.063, and 0.188m below the surface and suggested location independent model was successfully validated utilizing data from the Virginia Smart Road and – Long Term Pavement Performance- (LTPP).

2.7. Conclusion

After reviewing the previous studies related to developing model that connect between air temperature and asphalt layers temperature. It is clear that there are different forms for relation models which can predict asphalt temperature, these differences refer to difference of geographical area, the environmental and climatic conditions surrounding, and the change in the quality of asphalt used in roads. These factor have an important effect to determine the relation between the air ambient temperature and the asphalt layers temperature of roads .

Adding to these factors, there are many parameters contribute in the measurement process to reach the required model such as:

1. Measuring methods: In previous studies there are various methods used to reach to the required form such as a manual measuring through use a thermometer - a digital thermometer or mercurial thermometer- to measure the temperature by put the thermometer in the holes and read the result on the glass surface or on digital thermometer screen. Advanced automatic tools can be used through putting the sensor inside the pavement under asphalt surface and receives the signals on the outside screen.
2. Measuring time: Dates and measuring times are vary from study to another, some study have a daily test and the other at spaced intervals .The testing may be once a day or hourly .
3. Drilling depth: Some researches focused on studying the asphalt surface temperature and other studies interested with measuring temperatures at different depths inside asphalt pavement which it may reach to 20.0 cm in a thick layer.

These factors differ from country to another, especially Gaza Strip in which we are studying has a special climate, environmental condition, facilities available that characterize it from other places. In this research, a relation depending on the air ambient temperature was carried out.

Chapter 3: TESTING PROGRAM

3.1. Introduction

This study aims to develop a local model for asphalt pavement in Gaza Strip region according to the effect of air ambient temperature on the asphalt pavement layers of roads.

Studying the effect of weather factors on asphalt pavement layers to reach to the optimum model, needs more time, more effort and advanced technological methods. But all these means aren't available due to different circumstances and abilities for the study.

Therefore, the methodology presented below was designed and taking into consideration the unavailability of all necessary means.

3.2. Selecting Optimum Place

- Identify the optimum place which is exposed to the sun as much as possible through visual monitoring at Al-Wad Street which located in Beit Hanoun city (Figure 1). It should be noted that the selection of this region due to easy reach.
- Beit Hanoun city can be considered as expressive area at the Gaza Strip due to similarity in climate and paving materials.

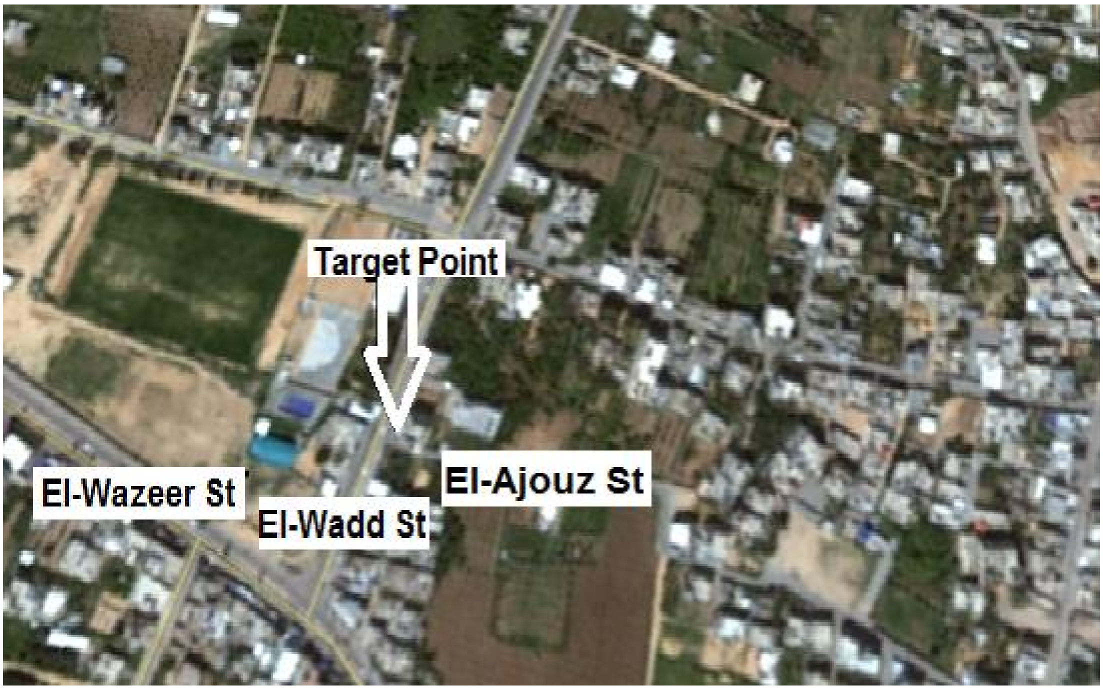

Figure 1: Selecting optimum place

3.3. Testing Holes

Three holes were drilled in asphalt pavement under the asphalt surface at different depths which have the following characteristics. (Figures 2 and 3)

1. The depths are 2 cm, 5.5 cm and 7 cm respectively.
2. The diameter of each hole is 8 mm

3. The distance between each hole is 20 cm to maintain the same effect of climatic condition .Figure (3)

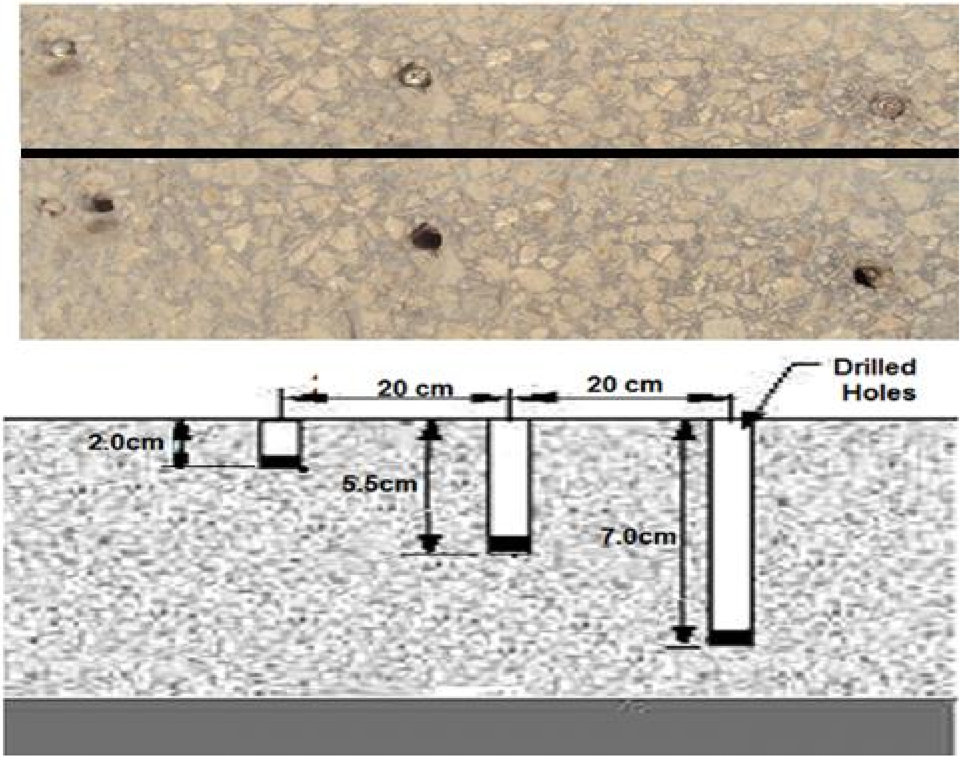

Figure 2: Dimension of holes

3.4. Thermometer Selection

The used thermometer type (HANNA instruments-HI 935005) was used and has following characteristics [11]:

1. High accuracy
2. Good sensitivity to temperature
3. Measures the temperature in all aspects (in the air and fluid).

The device contains a sensor device plugged into it through designated wire.

3.5. Temperature Measurement

The following represents the methodology by which aim can be achieved in order to study the effect of ambient air temperature on the asphalt layers of roads throughout the year in Gaza Strip:

3.5.1. Air temperature

Measuring the ambient temperature at the target points was measured, through exposing the sensor to the ambient until stabilize the numbers on the device screen which take a little time approximately 4 minutes.

3.5.2. Asphalt surface temperature

Measuring the temperature of the asphalt surface every two hours by placing a sensor head at the asphalt surface without touching the sensor with gravels.

3.5.3. Pavement temperatures

Temperature is measured, through placing the sensor needle inside three holes 2.0 cm 5.5 cm 7.0 cm, respectively, where the measuring time lasted 4 minutes at least until stability of the numbers on the HANNA screen.

Before start measuring, the holes should be free of sand, aggregate, impurities and water in order not to be any effect on the temperature of the pavement by impurities. This process is done by blowing the air by a tube into these holes to expel exotic objects. Where the holes are closed after finishing the measurement process by suitable bolts which work to reduce impurities that enter inside the holes.

3.5.4. The time of the measurement process

- Measuring period extended from 10.03.2012 to 28.02.2013 and almost one year study.
- The temperatures three days a week were measured.
- Measuring is done every two hours from 6:00 to 24:00 (18 hours), and once from 6:00 to 4:00 next day (24 hours) every two weeks.
- Each measurement takes about 4 minutes to stabilize the reading on the devices screen.
- Sometimes the previous procedures didn't apply due to some conditions such as:
  (1) At the beginning of the measuring -March and April- the measurement was daily.
  (2) Due to the Israeli occupation (Warplanes), measurement sometime was stopped.
  (3) Sometimes political occasions, social issues and feasts days stop measuring process.

3.6. Data Recording and analysis

- Measuring and recording temperatures values of air, asphalt surface and depths layers inside pavement at (2.0 cm, 5.5 cm and 7.0 cm).
- Using Excel and the statistical program -Edition Mnitap15- to drawing and analysis the data, to reach to the needed models .

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Introduction:

Temperature is known to be one of the most important factors affecting the design and performance of asphaltic concrete pavement. For a successful pavement design, it is vital to know the range of temperatures over which a pavement will be subjected.

This chapter aims to analyzing the thermal data, which obtained from the measurement of temperature for asphalt pavement at different layers, in order to achieve the study objectives which include the effect of air temperature on the asphalt layers of roads throughout the year in the Gaza strip.

Fieldwork results are presented in this chapter in four stages (four seasons) which extended over a whole year from 10.03.2012 to 28.02.2013. But the focus was done on the winter and the summer, which considered as the most significant due to containment of the maximum and minimum temperature ambient throughout the year.

4.2. General Form of Climate Variability on Pavement

Knowledge of past climate variability is crucial for understanding and modeling current and future climate trends. With the changing ambient temperature the temperature condition of pavement are changed in all depths (Figures 3, 4, 5 and 6). Roads are continuously and intensively influenced by climatic factors, high temperature in summer, low temperature in winter.

Analysis of data, collected in the Road Weather in Gaza Strip, shows that in Summer, the pavement temperature being about 54°C, temperature of road pavement surface falls to 6 °C in winter, at air temperature of (5–40) °C, road pavement surface temperature heats up to (7–53) °C and the other depths heat up as the follow figures:

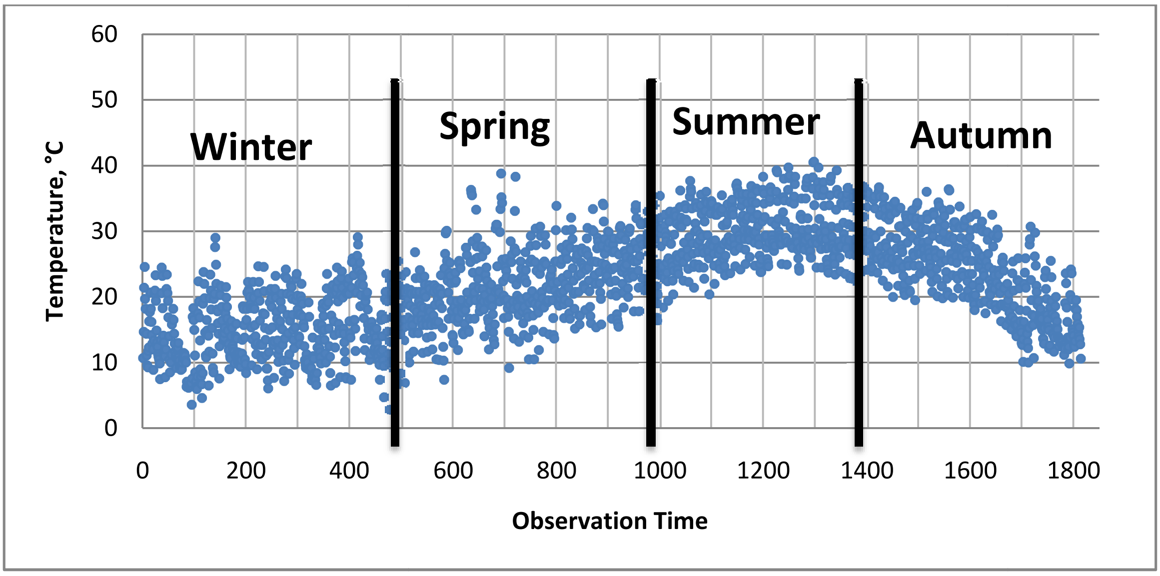

Figure 3: Air Temperature a Whole Year

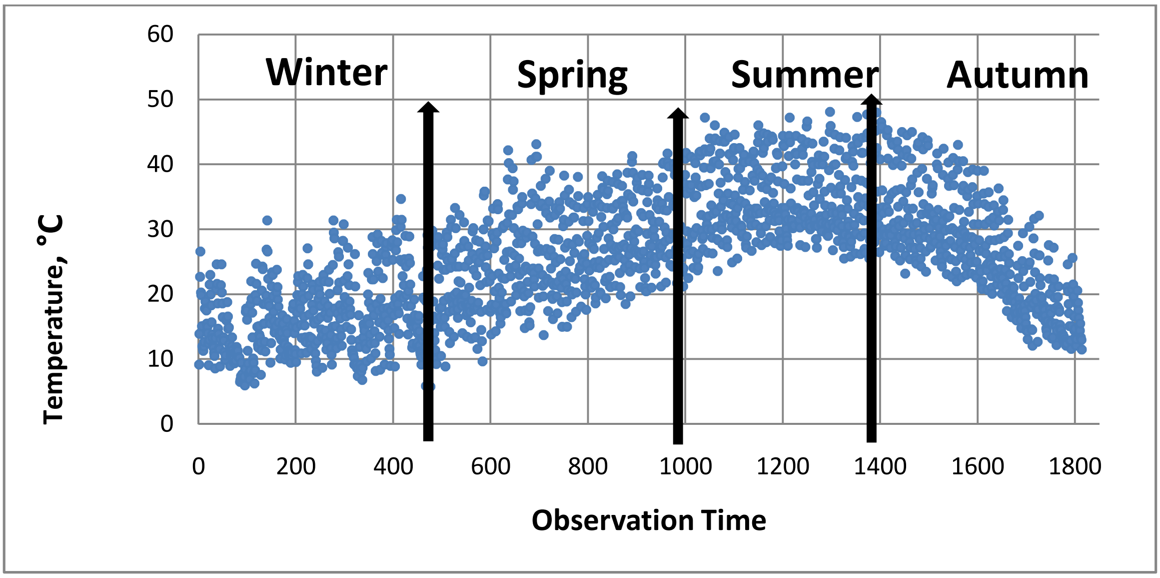

Figure 4: Surface Temperature a Whole Year

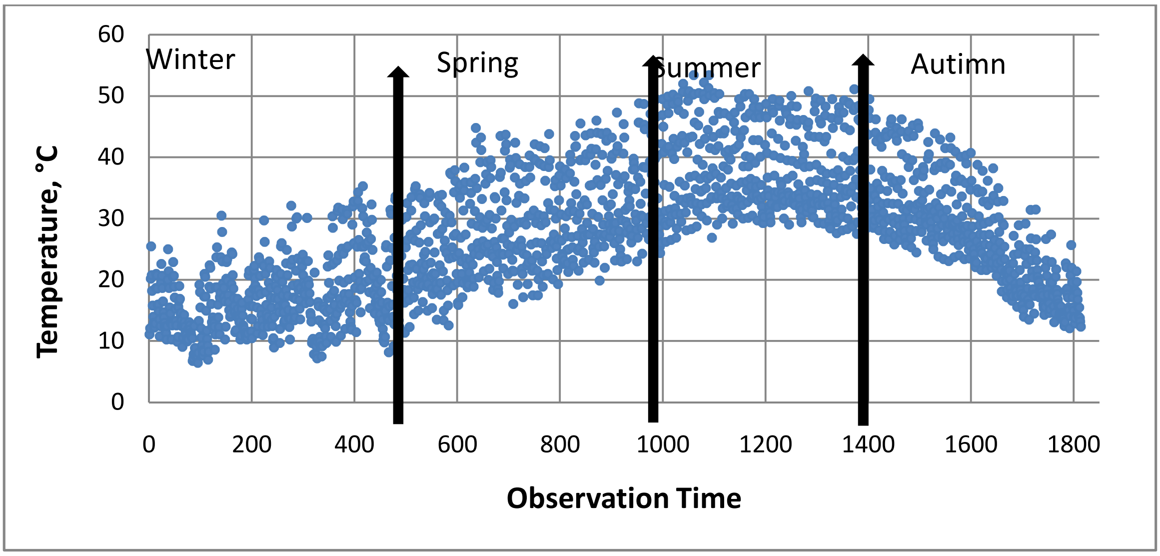

Figure 5: At 2 cm Temperature a Whole Year

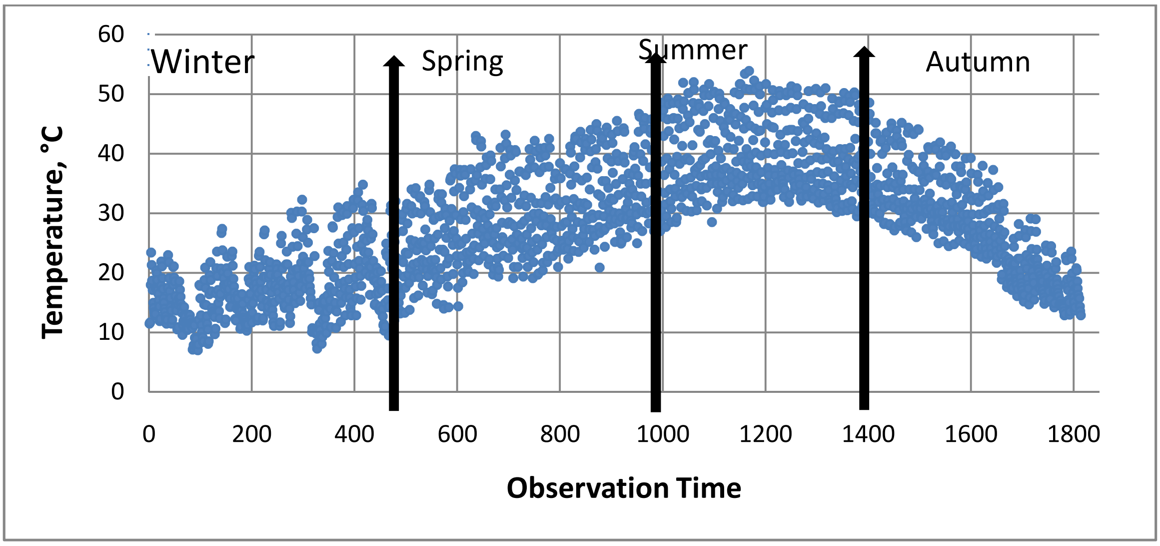

Figure 6: At 5.5 cm Temperature a Whole Year

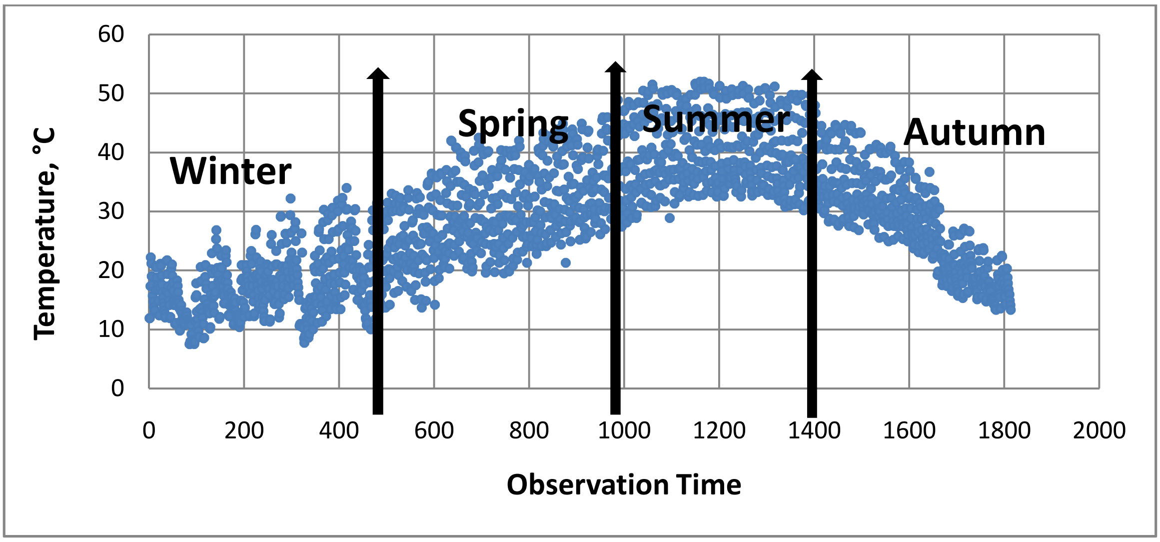

Figure 7: At 7 cm Temperature a Whole Year

4.3. The Winter Season's Results and Discussion:

The winter seasons (21 December to 20 March) temperatures is considered as minimum temperatures throughout the year. The low temperature causes differential settlements and pavement roughness and causing a physical damage for asphalt pavement such as shrinkage cracking, potholes (chuck holes) and rutting (Permanent deformation), however at low temperatures, asphalt pavement acts as an elastic solid in which low amounts of applied strain are recoverable; thus, permanent deformation is not likely to occur until this low strain limit is surpassed [22]. So the studying of low temperature has a great importance due to its impact on durability and length paving life. And It is noted that the fluctuations of the temperatures of the asphalt pavement is divided into maximum temperatures and the minimum temperatures during the day and night, respectively [23].

4.3.1. Fluctuations Temperature in Asphalt Pavements

Fluctuation in temperatures significantly affects pavement stability and the selection of asphalt grading to be used in pavements. Ability to accurately predict the asphalt pavement temperature at different depths and horizontal locations based on ambient air temperatures will greatly help pavement engineers in performing back-calculations of pavement modulus values.

In addition, it will help engineers in selecting the asphalt grade to be used in various pavement lifts. The top pavement layer normally is exposed to greater temperature fluctuations than the layers below it. Knowledge of the temperature distribution in asphalts will allow for a more sophisticated specification of asphalt for lower lifts (through specification of less expensive asphalt binders in lower lifts) and thus provide an economical solution to rising pavement construction costs [7].

The daily mean temperature is determined by averaging the 24 hourly readings or by adding the maximum and minimum temperatures for a 24-hour period and dividing by two. The daily temperature range is computed by finding the difference between the maximum and minimum temperatures. Other temperature data involving longer periods include the monthly mean temperature (the sum of the daily means for each day of the month divided by the number of days in the month), the annual mean temperature (the average of the twelve monthly mean temperatures), and the annual temperature range (the difference between the warmest and coldest monthly mean temperatures) [24] .

Through the measurement of temperature in the winter season, the maximum temperature rang were recorded for asphalt pavement . According to the (Table1),it can be noticed:

- The maximum hourly temperature rang in asphalt pavement in winter is 7.3°C Occurred in 12.3.2012 at 18:00.
- The maximum hourly temperatures rang and average daily temperature range has occurred in different period.
- The maximum hourly, daily and weekly temperatures range in asphalt pavement temperatures occurred in March..
- Differences in temperature range is relatively small.

Table 1:Maximum Temperature Rang in Winter

	Range	Time	Date
Hourly temperature range	7.3	18:00	12.3.2012
Average daily temperature range	4.28	Whole Day	18.3.2012
Average weekly temperature range	3.4	Whole Week	16 to 20.3.2012
Average monthly temperature range	2.82	Whole Month	24.2 to 20-3.2012
Average seasonally temperature range	2.36	Winter Season	21.12 to 20.3

4.3.2. The highest and lowest temperature reads in asphalt pavement :

Through the measurement of temperature in winter (21 December to 20 March), the height temperatures were recorded for all points (surface ,2.0 cm , 5.5 cm ,7.0 cm). According to the (Table 2),it can be noticed:

- The maximum temperature in asphalt pavement in winter is 35.3 °C.
- Maximum temperature in all depths of the asphalt pavement has occurred in the same date and time with the maximum air ambient temperature.
- There is a proportional relation between the air ambient temperatures and asphalt pavement temperatures.

- In winter, the maximum temperatures value for the asphalt depths were at 14:00 in march month.

Table 2: Highest temperature for each depth in winter season

	Degree	Date	Time
Ambient Temperature	29.1	11.3.2012	14:00
Surface of asphalt	34.7	11.3.2012	14:00
2.0 cm in asphalt	35.3	11.3.2012	14:00
5.5 cm in asphalt	34.8	11.3.2012	14:00
7.0 cm in asphalt	34	11.3.2012	14:00

Additionally, the lowest temperatures were recorded in winter season for the points (surface, 2.0cm, 5.5 cm ,7.0 cm) according to the (Table 3),it can be noticed:

- The minimum temperature in asphalt pavement temperatures at the winter is 5.8°C.
- The asphalt surface is rapidly affected by the air ambient temperature. So the asphalt gets the surrounding temperature.
- Minimum temperatures at air and pavement layers were at 6:00, before sunrise.

Table 3: Lowest temperature for each depths in winter season

	Degree	Date	Time
Ambient Temperature	2.8	19.3.2012	6:00
Surface of asphalt	5.8	19.3.2012	6:00
2 cm in asphalt	6.5	12.1.2013	6:00
5.5 cm in asphalt	7	12.1.2013	6:00
7 cm in asphalt	7.5	12.1.2013	6:00

- From (Table 3), the minimum temperature of the ambient is coinciding with the same time and date of the minimum temperature in the surface temperature , but it is different with all asphalt pavement depths at time or date.

  This difference refer to:

  - Asphalt pavement characterized with a high density and a good thickness, so the temperature needs some time to transmit into the inside the asphalt layers.
  - Ambient temperature fluctuation in a little time prevent the heat transferring into inside the asphalt layers.
  - The temperature needs a while to move inside asphalt pavement before changing in temperature degree, either upward or decline.
  - Temperature of ambient degree 2.8 °C may be quick or abnormal or instantaneous, Therefore, it does not effect on temperature of the asphalt layers through short period.
  - Ambient temperature should be continue for a while before change in to reach the temperature waves into the depths of asphalt pavement .

- Temperature fluctuations throughout the days leads to instability of temperatures inside the asphalt pavement .
- Human mistake in manually measuring temperature due to the worst dealing.
- Human error in measuring of temperatures due to improper handling with tools.

- So the temperature 3.6°C can be considered as the lowest ambient temperature which replace the previous lowest temperature of 2.8°C
  - The associated temperatures with the lowest air ambient temperature (3.6 °C) in all depths are 5.9 , 6.5 , 7 and 7.5 respectively which have been in 12.1.2013 at 6:00 which can considered the lowest temperatures in the asphalt pavement layers according to (Table 4), it can be noticed:
    - There are agreement between the lowest ambient temperatures and the lowest temperatures in all depths of asphalt pavement layers.
    - The minimum temperatures at surface, 2.0 cm, 5.5 and 7 cm respectively were at 6:00 in the morning time which is usually the lowest temperatures in ambient temperature at January month.

Table 4: The new lowest temperatures in winter

	Degree	Date	Time
Ambient Temperature	3.6	12.1.2013	6:00
Surface	5.9	12.1.2013	6:00
2.0 cm in asphalt	6.5	12.1.2013	6:00
5.5 cm in asphalt	7	12.1.2013	6:00
7.0m in asphalt	7.5	12.1.2013	6:00

4.3.3. Maximum and minimum temperature levels

Maximum and Minimum temperature levels have great importance in the designing process of asphalt pavement in terms of maintaining and avoiding the destruction of the asphalt pavement layers due to various factors during the pavement design.

These levels are representing the maximum and minimum temperatures of asphalt pavement which depend on local climatic for the hottest and coldest times of the year which are different from time to time.

4.3.3.1. The maximum temperature levels in winter season

Table (5) shows the maximum temperature degrees for different depth in the asphalt pavement layers during any measuring time at the winter season and can be noticed that :

- The highest temperature of asphalt pavement is 35.3 in depth 2.0cm at14:00.
- The maximum temperature sin the (surface, 2.0cm, 5.5cm and 7.0 cm) are (34.7, 35.3, 34.8 and 34) °C respectively, at time 14:00 which associated with maximum ambient air temperature 29.1 °C.

- Maximum temperatures occurred in the asphalt pavement at 14:00 (at noon), that time the sun is perpendicular to the ground and the temperatures is the highest .
- the surface is influenced by the ambient temperature more than the depths.
- This table do not represent the days behavior in winter season but it for max periods.

Table 5: The maximum temperatures level in winter

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	19.7	19.5	19.7	20.1	20.5
8:00	21.4	21.4	23	22	21.8
10:00	27.6	28.2	29	27.5	26.6
12:00	29	31.4	33.1	32.2	31.2
14:00	29.1	34.7	35.3	34.8	34
16:00	28	31.5	30.4	30.4	30.4
18:00	24	25	25.4	25.8	27.2
20:00	22	22.8	23.2	23.5	23.8
22:00	25.2	25	23.7	23.5	23.5
24:00	16.5	16.6	17.7	19.1	19.3
2:00	14.9	13.8	14.6	16.8	17.1
4:00	14.3	13.5	14.2	15.7	16

4.3.3.2. The minimum temperature levels in winter season

Table (6) shows the minimum temperatures degrees for different depths in the asphalt layers during measuring time in the winter season, and can be noticed that:

- The lowest temperature of asphalt pavement is 5.9 °C in the surface at 6:00.
- The minimum temperature degrees in the (surface, 2.0 cm, 5.5cm and 7.0 cm) are (5.9, 6.5, 7 and 7.5) °C respectively, at time 6:00 which associated with minimum ambient air temperature 3.6 °C .
- The minimum temperature occurred in the asphalt pavement at 6:00 (at dawn), before sunrise time and the temperatures is the lowest. (Table 6)

Table 6: The minimum temperatures level in winter

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	3.6	5.9	6.5	7	7.5
8:00	7.1	6.8	7.2	7.3	7.5
10:00	6.4	7.4	7.9	7.9	8
12:00	7.1	9.2	9.7	10.4	10.7
14:00	6.2	7.38	7.9	9.1	9.2
16:00	6.4	7.7	8.9	9.1	9.2
18:00	6.6	7	7.7	8.9	8.2
20:00	6.5	6.9	7.5	7.7	7.9
22:00	6.5	6.9	7.4	7.7	7.9
24:00	6.3	7.3	7.6	7.8	8
2:00	8.8	9.8	10.2	11.3	11.4
4:00	7.3	9	10.5	10.5	10.6

4.3.3.3. Average temperature level in winter season

Average daily temperatures of air ambient and asphalt pavement are very important for civil engineers when they want to design the roads and airports . The designers want to avoid the destruction of asphalt facilities by knowing the behavior reaction of asphalt pavement throughout whole year due to climatic factors.

Average asphalt temperatures in Gaza strip are varied between. 23.84°C at 5.5 cm depth, as maximum average temperature asphalt and 10.3°C at surface depth, as minimum average temperature (Table 7). Where researcher determined the average of all hourly temperatures for each point in asphalt pavement layers, through a whole time in the winter.

Table 7: Average daily temperature level in winter

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	9.44	10.3	11.3	12	12.31
8:00	14	14.1	13.7	13.33	13.3
10:00	17.9	19.6	19.2	17.98	17.47
12:00	20.2	22.5	23.7	22.55	21.81
14:00	19.8	22.4	23.5	23.84	23.37
16:00	17.9	19.7	20.3	20.98	21.01
18:00	15.1	15.9	17	17.99	18.29
20:00	13.3	14.4	15.5	16.33	16.64
22:00	12.1	13.2	14.2	15.19	15.54
24:00	10.7	11.9	13	13.92	14.22
2:00	10.5	11.7	12.6	13.84	14.16
4:00	9.45	10.8	12.1	13.03	13.38

4.3.4. Daily cycle of thermal behavior:

In regions that experience large daily temperatures variations or extremely low temperatures, the thermal conditions plays a major role in the reflective cracking response of a multilayered pavement structure. On one hand, binder properties (stiffness, ageing, penetration, etc.) are sensitive to temperature variations. On the other hand the combination of the two most important effects - wheel loads passing above (or near) the crack and the tension increase in the material above the crack (in the overlay) due to rapidly decreasing of temperatures- have been identified as the most likely causes of high states of stress and strain above the crack and responsible by the reflective cracking [25].

Daily temperature variations have an important influence in the pavement thermal state in a depth of few decimeters below the surface. Depending on the temperature variation level, stresses are induced in the overlay in two different ways, which need to be distinguished: through restrained shrinkage of the overlay and through the existing movements of slabs, due to the thermal shrinking phenomenon [26].

Daily cycle temperatures in the winter are moving in a different shape and variable pattern in each moment during a day, whether increasing or decreasing in the temperature degrees.

- Asphalt surfaces and pavement layers temperatures are influenced by the ambient temperatures
- There are many behaviors in temperatures through the day, every behavior needs a period of time to take their own pattern for responding to ambient temperature.
- The research have many graphics for daily temperature patterns- Appendix A- which visualized the form of the temperature behaviors, so it is difficult to analyzed every day by day.
- In this study 31.01.2013 as an example of fieldwork in a winter season (Table 8, Figure 4) was chosen and the rest of tables and figures related for daily measurement are shown in Appendix A.

Table 8: Daily cycle of thermal behavior in winter on 31.01.2013

Time	Air	Surface	2.0 cm	5.5 cm	7.0 cm
6:00	9.9	10	10.3	10.6	10.8
8:00	11.1	10.6	10.9	11	11.1
10:00	14	14.5	15.3	13.8	13.4
12:00	15.9	16.2	16.3	16.4	15.2
14:00	13.7	14	14.2	14.8	14.5
16:00	11.3	11.6	12.6	13.1	13.1
18:00	11.6	11.9	12.2	12.5	12.5
20:00	10	10.7	11.8	12.1	12.1
22:00	11	11.4	11.9	12.1	12.1
24:00	11.5	11.1	11.4	11.7	11.7
2:00	10.1	10.2	10.9	11.3	11.4
4:00	9.4	9.5	10.5	10.5	10.6

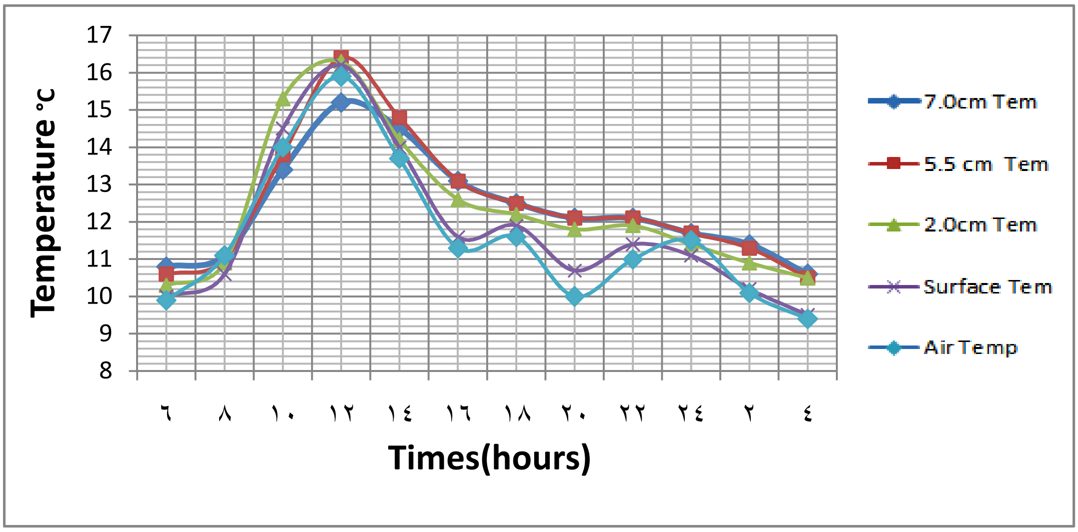

Figure 8:Daily cycle of thermal behavior at winter in 31.01.2013

According to Table 7 and figure 3, daily cycle of thermal behavior divided into three parts:

A. Dawn to Morning (6:00 -8:00)

- The measurement and recording is starting at 6:00.
- The asphalt pavement layers are warmer than the air ambient
- Temperatures were arranged from low to high as follows:
    - Air temperature
    - Surface temperature
    - Temperature at depth 2.0 cm.
    - Temperature at depth at 5.5 cm.
    - Temperature at depth at 7.0 cm.
- In this period, the temperatures of asphalt pavement layers are increasing gradually by increasing of air ambient
- Temperatures increase, according to the depth of asphalt pavement layers, where the asphalt surface is affected by temperature air ambient before depth.
- All temperatures converge to one point at 8:00 .
- Temperatures at 8:00 are almost the coup point to rearrange the temperatures.

B. Morning to Noon (8:00 -14:00):

- The temperatures behavior are differed from the previous conduct**.**
- Increasing in temperature will continue in all depths, but with different levels.
- The temperatures at depths 5.5 cm and 2.0 cm are raised to the maximum temperatures
- The temperature at depth 5.5 cm is the highest temperature in the pavement structure.
- The ambient temperature has moved from the highest at the beginning to the lowest in the end
- The ambient temperature is less than the asphalt temperature due to:
    - Asphalt has the ability to absorption and maintain the temperature
    - Asphalt is made of the petroleum products which are quickly influenced by the temperatures.
- The temperatures reach to maximum degrees in the ambient air and all asphalt pavement layers at the period of 12:00 – 14:00.

C. Noon to midnight (16:00 to 24:00)

- At this period the temperatures decrease gradually in the ambient air and in all layers asphalt pavement

- Temperature were arranged from low to high as follows:
  - Air temperature.
  - Surface temperature.
  - Temperature at depth 2.0 cm.
  - Temperature at depth at 5.5 cm.
  - Temperature at depth at 7.0 cm
- Temperatures continue to decline with the passage of time.
- The maximum drop in temperatures at dawn time.

4.3.5. Relationship between air ambient temperature and the asphalt pavement temperatures at different depths.

There is a direct proportional relationship between air temperature and asphalt pavement temperatures where the asphalt temperatures are increasing by the increasing of air ambient temperatures. Additionally the relationship between the two variables are linear. The pervious resulting graphs show that the relationship between air ambient temperatures and asphalt pavement temperatures are divided into two parts:

A. Partition upward - incremental - (dawn to noon)
B. Partition downward - decreasing - (afternoon to dawn)

Each part contains four depths in the asphalt pavement which are:

a. Asphalt surface
b. A depth of 2 cm
c. A depth of 5.5 cm
d. A depth of 7 cm.

Thus, there are eight relationships between ambient air ambient temperature (independent variable) and asphalt pavement temperature (dependent variable) in different depths at surface, 2.0cm, 5.5cm, 7.0cm, respectively. A correlation and regression method to find the relationships between the independent and non-independent variables by using a statistical program (Minitab 14) were used. The Minitab is a specialized statistical program which has many advantages such as:

a. Easy and Fast.
b. Accurate
c. Gives an evidence for accuracy of the data
d. Indicates to inaccurate data, which leads to an imbalance in the results.
e. Gives a several outputs at same time.

Table (9) shows the relationships between ambient temperature and the temperatures measurement in all depths (surface , 2.0 cm,5.5 cm ,7.0cm) at daily period (6:00 to 14:00) in winter season.

Table 9: Regression relation in winter

Regression relations in Winter (21 December to 20 March) (6:00 to 14:00)				
(Y)	X	Function relation	Regression R(%)	P value
Surface Temperature	Air Temp	Y = - 0.3466 + 1.116 X	90.5	0.000
2.0 cm Temperature	Air Temp	Y = 0.6630 + 1.085 X	78.8	0.000
5.5 cm Temperature	Air Temp	Y = 1.953 + 0.9593 X	73.6	0.000
7.0 cm Temperature	Air Temp	Y = 2.752 + 0.9182 X	71.4	0.000

For example, Figure (9) illustrates the relationship between air ambient temperature and asphalt surface temperatures in winter .The Figures of all models which illustrate the remaining relationships are in Appendix B

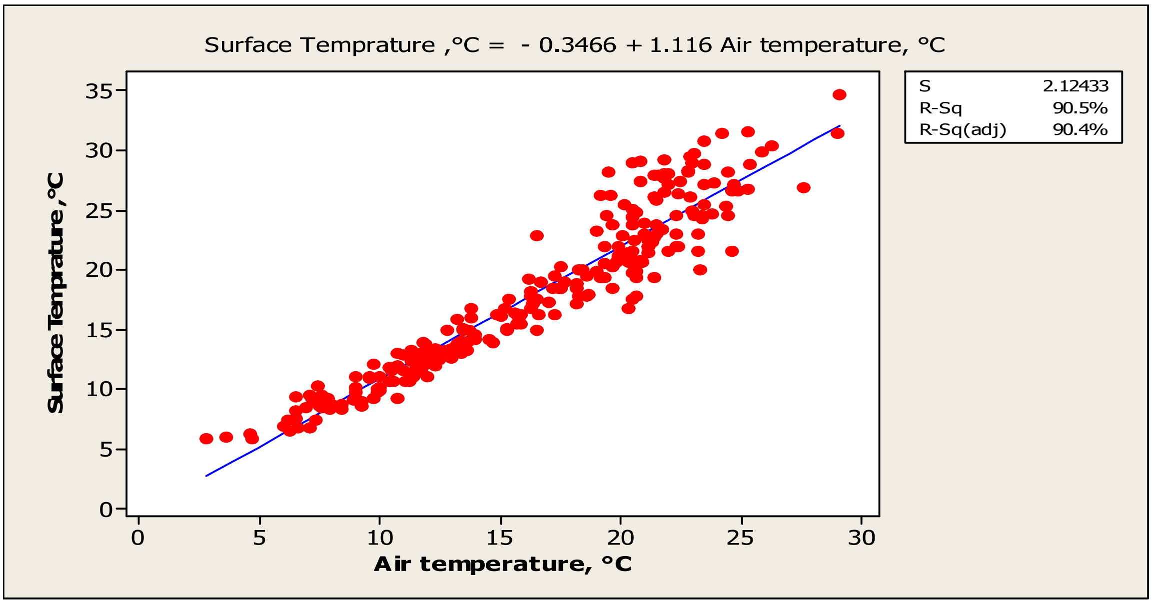

Figure 9: Relationship between air ambient and asphalt surface temperatures in winter season

Table (10) shows all relationships between ambient temperature and the temperatures measurement in all depths (surface, 2.0 cm, 5.5 cm and 7.0cm) at decreasing daily period (16:00 to 24:00) in winter season.

Table 10: Regression relations in winter season

Relations in Winter (21 December to 20 March) (16:00 to 24:00)				
(Y)	X	Function relation	Regression R(%)	P value
Surface Temperature	Air Temp	Y = 0.7509 + 1.032 X	91.4	0.000
2.0 cm Temperature	Air Temp	Y = 2.573 + 0.9724 X	85.5	0.000
5.5 cm Temperature	Air Temp	Y = 3.649 + 0.9589 X	79.1	0.000
7.0 cm Temperature	Air Temp	Y = 4.104 + 0.9451 X	76.6	0.000

For example, Figure (10) illustrates the relationship between air ambient temperature and asphalt surface temperatures in winter .The Figures of all models are illustrated in Appendix B

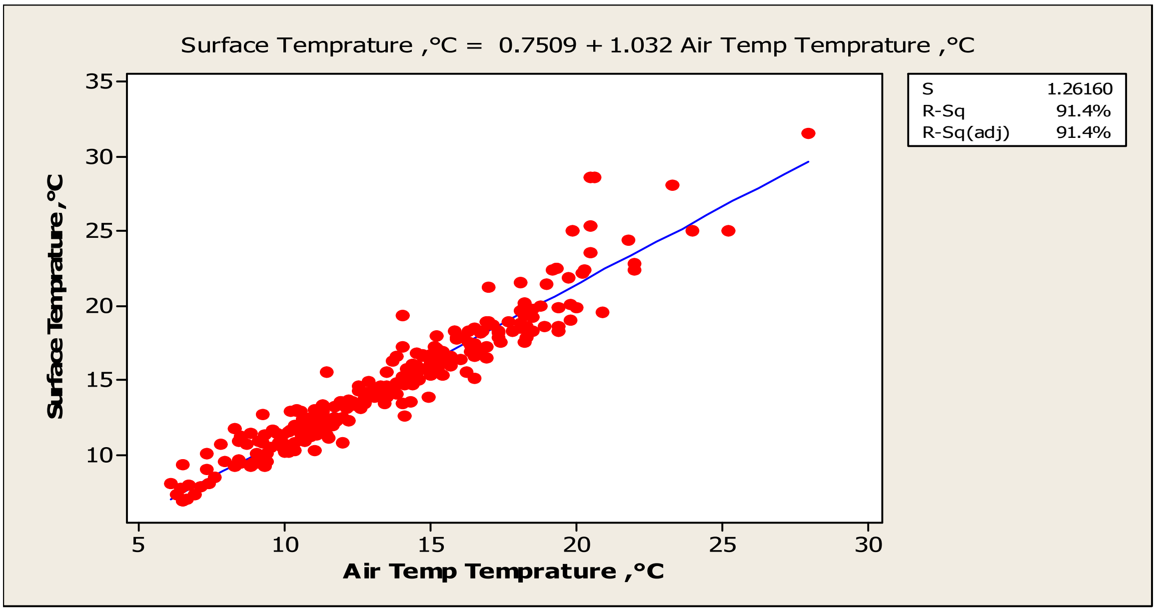

Figure 10: Relationship between air ambient and Asphalt surface temperatures in winter season

4.4. The Summer Season's Results and Discussion

At high temperatures in summer (21 June to 21September), asphalt pavement acts as a viscous fluid in which the material begins to flow with an applied strain. The temperature within a pavement varies due to several factors including ambient temperature, solar radiation, wind speed, and reflectance of the pavement surface which be caused some disasters for asphalt pavement such as thermal fatigue cracks, bleeding (Excess Surface Asphalt), rutting (Permanent deformation) and Reflective Cracking.

Thus, to study the strength characteristics of asphalt pavement, it is imperative to know the temperature distribution within the pavement cross-section [27].

4.4.1. Fluctuations Temperature in Asphalt Pavements

Through the measurement of temperature in the summer season, the maximum temperature rang were recorded for asphalt pavement . According to the (Table11),it can be noticed:

- The maximum hourly temperature rang in asphalt pavement in winter is 16°C Occurred in 10.07.2012 at 12:00.
- The maximum hourly temperatures rang and average daily temperature range has occurred in the same day.
- The maximum daily temperatures rang and average weekly temperature range has occurred in the same week.
- The maximum hourly, daily and weekly temperatures range in asphalt pavement temperatures occurred in July.

- Differences in temperature range is relatively big.
- Temperatures rang in the asphalt increases with rising ambient temperature.

Table 11:Maximum Temperature Rang in Summer

	Range	Time	Date
Hourly temperature range	16	12:00	10.07.2012
Average daily temperature range	9.16	Whole Day	10.07.2012
Average weekly temperature range	6.475	Whole Week	8 to 14.7.2012
Average monthly temperature range	6.12	Whole Month	23.6 to 23-7.2012
Average seasonally temperature range	5	Summer Season	21.6 to 21.9.2012

4.4.2. The highest and lowest temperature in asphalt pavement:

The maximum daily temperature haven't a high variation in the summer, the hour after noon to reach the maximum temperature which is measured in Gaza to be one hour after noon and the time in hours before sunrise to reach the minimum temperature which is chosen to be the lowest.

Through the measurement of temperature in summer (21 June to 21 September) the height temperatures were recorded for all point (surface, 2.0cm, 5.5 cm,7.0 cm) according to the Table (12), it can be noticed:

- The maximum temperature in asphalt pavement temperatures in summer is 53.9°C.
- The maximum temperatures have occurred in each depths on the asphalt pavement in the same time at 14:00.Table(12)
- The maximum temperature has occurred in different date.
- This difference results due to the reasons mentioned previously in winter season.

Table 12: Highest temperature in each depth in summer

	Degree	Date	Time
Ambient	40.5	8.8.2012	14:00
Surface of asphalt	48.1	8.8.2012	14:00
2.0 cm in asphalt	53.4	23.6.2012	14:00
5.5 cm in asphalt	53.9	18.7.2012	14:00
7.0 cm in asphalt	52	18.7.2012	14:00

Additionally the lowest temperatures were recorded in summer season inside the all points (surface ,2.0cm , 5.5 cm ,7.0 cm) according to the Table(13), it can be noticed:

- The minimum temperature in asphalt pavement temperatures at the winter is 20°C.
- The minimum temperature that occurred in each depths of the asphalt pavement had got in the same date and time of the maximum temperature of the ambient.
- There is a proportional relation between the air temperatures and surface temperatures
- Minimum value of the temperatures for the asphalt pavement depths occurred at 6:00.

Table 13: Lowest temperature in each depths in summer

	Degree	Date	Time
Air	20	18.9.2012	6:00
Surface of asphalt	23.2	18.9.2012	6:00
2.0 cm in asphalt	25.8	18.9.2012	6:00
5.5 cm in asphalt	27.1	18.9.2012	6:00
7.0 cm in asphalt	27.6	18.9.2012	6:00

4.4.2.1. Maximum and minimum temperatures levels

An assessment of the impact of high temperature on various pavement depths, in Gaza Strip is possible with a high degree of accuracy. The high temperatures are causing a various ruins of the asphalt pavement and influence on pavement materials, such as dense and open- graded asphalt mixes, thus the maximum temperatures of the pavement is considered as a major source of concern for pavement engineers .The engineers were keen to predict the temperature of the asphalt pavement to help them in asphalt pavement design[7] . It was found that predicted of asphalt surface temperature isn't sensitive to the initial input values, but as depth increases the inside temperature becomes more critical to the accuracy of the prediction. Because of this, detailed knowledge of the temperature distribution in asphalt layers allows to use a model for asphalt pavement temperature

4.4.2.2. The maximum temperature levels in summer season

Table (14) shows the maximum temperature degrees at each point in any depth in the asphalt pavement layers during measuring time in the summer season- different days- and can be noticed that:

- The highest temperature of asphalt pavement is 53.9°C in depth 5.5cm at 14:00.
- The maximum temperature degrees in the (surface, 2cm , 5.5cm and 7cm) is (48.1 , 53.4 , 53.9 and 52°C) respectively at time14:00 which was associated with ambient temperature 40.5 °C .
- The maximum temperatures occurred in the asphalt pavement at 14:00 (At Noon), that time the sun is perpendicular over the ground and the temperatures are the highest degree.
- Table (14) don't represent the days behavior in the summer season, but it may instantaneous periods

Table 14: The maximum temperatures level in summer

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	27.8	30.6	32.5	34	34.9
8:00	31.8	36.5	38.5	41	42.1
10:00	37	43.2	45.4	46.6	47.3
12:00	39.7	45.8	51.3	50	49.8
14:00	40.5	48.1	53.4	53.9	52
16:00	40.5	45.9	50.3	51.7	51.3
18:00	35.6	40.5	45.7	47.2	49.4
20:00	30.6	35.2	37.3	40.8	41.3
22:00	29.5	33	35.5	38.1	38.7
24:00	29.3	32.8	34.5	36.5	37.6
2:00	28.5	31.2	33	35.6	36.3
4:00	30.98	36.49	40.8	41.16	41.27

4.4.2.3. The minimum temperature levels

Table (15) shows minimum temperature degrees at each point in any depth in the asphalt layers during any measuring time in the summer season and can be noticed that:

- The lowest temperature of asphalt pavement is 23.2 °C in the surface at 6:00.
- The minimum temperature degrees in the (surface, 2 cm, 5.5cm and 7 cm) are (23.2, 25.8, 27.1 and 27.6°C), respectively at time 6:00 which associated with ambient temperature 20 °C .
- The minimum temperature occurred in the asphalt pavement at 6:00 (At Dawn), that time the temperatures is the lowest.
- the surface is influenced by the ambient temperature more than other regions.

Table 15: The minimum temperatures level in summer

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	20	23.2	25.8	27.1	27.6
8:00	24.2	26	27.2	27.7	28
10:00	28.5	32.7	33.8	34.5	34.3
12:00	31	33.1	40	41	40.5
14:00	31.4	33.2	39.9	42.4	42.1
16:00	30.8	36.6	40.5	41.3	41.9
18:00	27.9	33.2	34.1	36.5	37.2
20:00	26.9	30.7	31.6	32.3	32.2
22:00	25.7	27.7	29.9	31.8	32.3
24:00	22.8	27	28.8	30.5	31
2:00	23.2	27	28	29.5	30
4:00	21.9	25.8	26.9	28.5	29

4.4.2.4. Average temperature levels in summer season

Average asphalt temperatures in Gaza Strip in summer are varied between 49.41°C as maximum average temperature asphalt and 27.12°C as minimum average temperature (Table 16). Where according to the table (13), it can be noticed:

- The average of all hourly temperatures for each point in asphalt pavement layers were calculated, through a whole time in the Summer.
- Average daily cycle temperatures in the summer season are moving in a same orientation and one pattern during a day ,whether increasing or decreasing in the temperature degrees . (Table16)
- Average daily pattern of the average graph can be divided into two phases

Table 16: Daily Average temperature in summer

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	23.9	27.12	29.15	31.21	31.74
8:00	28.3	31.01	32.32	33.09	33.28
10:00	33.7	38.08	41.02	40.43	40.01
12:00	35.5	42.21	46.58	46.05	45.41
14:00	35.9	44.15	48.56	49.41	49.12
16:00	34.4	42.02	45.88	47.97	48.15
18:00	31	36.22	39.16	42.24	43.14
20:00	28.8	32.88	35.41	37.97	38.78
22:00	27.7	31.21	33.38	35.83	36.5
24:00	26.6	30.02	32.17	34.34	34.95
2:00	26.3	29.46	31.32	33.74	34.51
4:00	25.9	29.34	31.43	33.31	34.02

4.4.3. Daily cycle of thermal behavior:

Daily cycle temperatures in the summer season are moving in a same orientation and one pattern during a day ,whether increasing or decreasing in the temperature degrees and according to (Figure 7 and table 17) ,it can be noticed that:

- Asphalt surfaces and asphalt pavement layers temperatures are influenced by the ambient temperatures.
- The study contained many tables and graphics for daily temperature patterns -Appendix A- which visualized the form of the temperature behaviors, so it is difficult to analyzed every day by day
- There are many behaviors in temperatures through a day, every behavior needs a period of time to take their own pattern for responding to the ambient temperature.
- In this study 26.07.2012 as an example of fieldwork in a summer season (Table 17, Figure 11) was chosen and the rest of tables and figures related for daily measurement are shown in Appendix A.

Table 17: Daily cycle of thermal behavior at summer in 26.07.2012

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	27.8	30.6	31.9	34	34.7
8:00	31	33	34.3	35.3	35.7
10:00	36	40	43	41.5	40.9
12:00	39.3	41.8	48.4	47.3	46.3
14:00	39	44.4	49.2	50.5	50.7
16:00	34.6	41.6	46	49.8	49.7
18:00	31.9	37.7	39.9	43.2	44.3
20:00	30	33.3	36	40.3	40.9
22:00	29.4	33	35.5	38.1	38.7
24:00	29	32.8	34.2	36.5	37
2:00	28.5	31.2	33	35.6	36.1
4:00	28	31.5	33.6	35	35.5

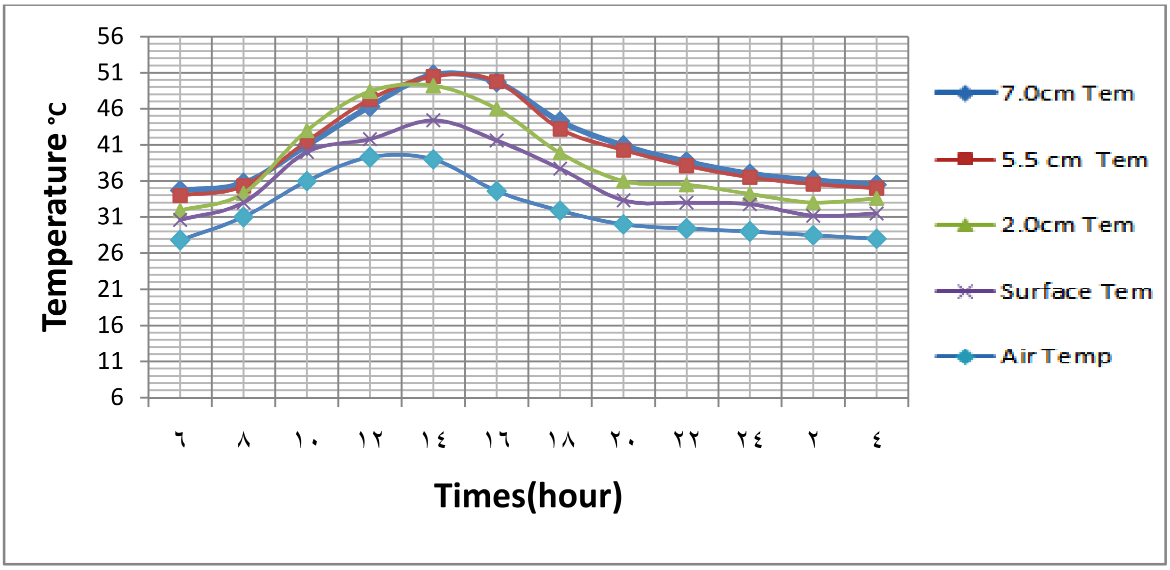

Figure 11: Daily cycle of thermal behavior at summer in 26.07.2012

According to Table 8 and Figure 4, daily cycle of thermal behavior in summer divided two parts:

A. Dawn to Morning (6:00 -14:00)

- The measurement and recording is starting at 6 :00Am.
- The asphalt pavement layers is warmer than the air ambient
- Temperatures were arranged from low to high as follows:
  - Air Temperature
  - Surface Temperature
  - Ranging between temperature at 2.0 cm, 5.5 cm and 7.0 cm
- The temperatures of asphalt pavement layers are increasing gradually by increasing of air ambient.
- Temperatures increase, according to the depth of asphalt pavement layers, where the asphalt surface is affected by temperature air ambient before the depth

- The temperatures reach to a maximum degrees in the ambient air and all asphalt pavement layers at (12:00 – 14:00).
- Temperature in depth 7.0 cm is the highest temperatures at 14:00.

B. Noon to midnight (16:00 to 24:00)

- At this period the temperatures decrease gradually in the ambient air and in all layers asphalt pavement
- The temperatures continue to decrease in the same previous pattern.
- Temperature were arranged from low to high as follows:
    - Air temperature
    - Surface temperature
    - Temperature at depth 2.0 cm.
    - Temperature at depth at 5.5 cm.
    - Temperature at depth at 7.0 cm
- The maximum drop in temperatures at dawn time.
- Temperature changes in the summer are nearly twice as large as in the winter .

4.4.4. Relationship between air ambient temperatures and the asphalt pavement temperatures at different depths.

- There is a proportional relationship between ambient air temperature and the temperature of the asphalt
- The relationship between the two variables is linear.
- Asphalt temperatures are increasing by increasing the air ambient temperatures.
- The resulting graphs show that the relationship between air ambient temperatures and asphalt pavement temperatures is divided into two parts:
    A. Partition upward - increasing - (dawn to noon)
    B. Partition downward - decreasing - (afternoon to dawn)

Table (18) shows all relationships between ambient temperature and the temperatures measurement in all depths (surface, 2.0 cm, 5.5 cm,7.0cm) at incremental daily period (6:00 to 14:00) in summer season.

Table 18: Regression relations in summer

Incremental regression relations in summer (21 June to 21September) (6:00 to 14:00)				
Y	**X**	**Function relation**	**Regression R(%)**	**P value**
Surface Temperature	Air Temp	Y = -4.282 + 1.297 X	89.1	0.000
2.0 cm Temperature	Air Temp	Y = -6.842 + 1.474 X	84.2	0.000
5.5 cm Temperature	Air Temp	Y = -1.747 + 1.392 X	78.8	0.000
7.0 cm Temperature	Air Temp	Y = 0.87 + 1.241 X	75.6	0.000

For example ,Figure (12) illustrates the relationship between air ambient temperature and asphalt surface temperatures in summer. The Figures of all models which illustrate the remaining relationships in Appendix B

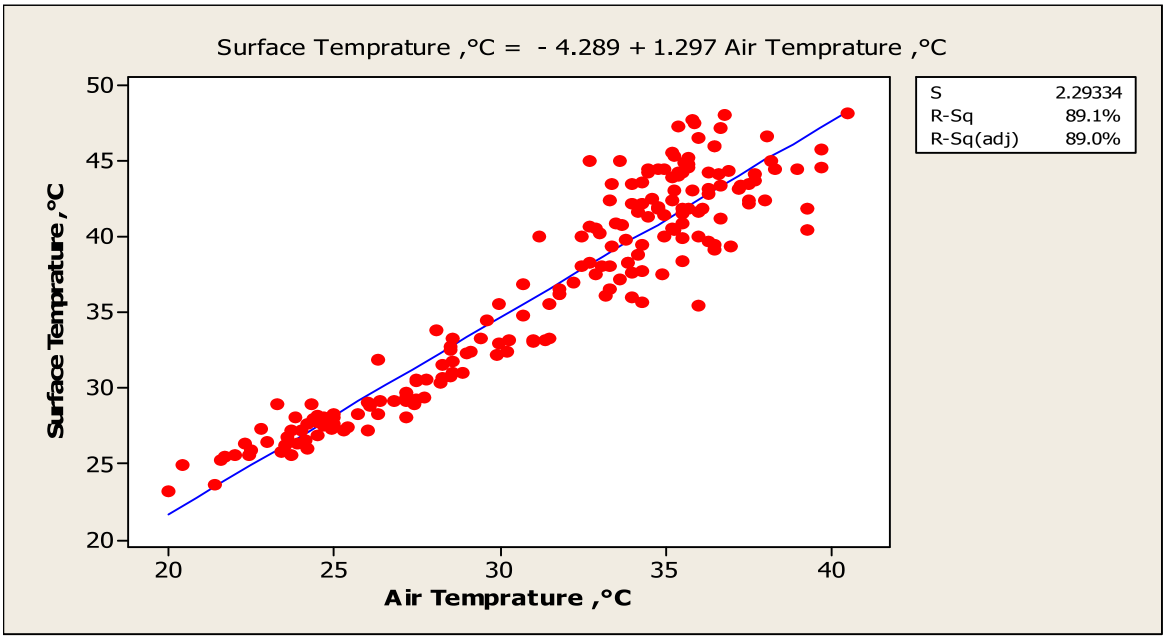

Figure 12: Relationship between air ambient and the asphalt surface temperatures in Summer

Table (19) shows all relationships between ambient temperature and the temperatures measurement in all depths (surface, 2.0 cm, 5.5 cm,7.0cm) at decreasing daily period **(**16:00 to 24:00) in summer season.

Table 19: Regression relations in summer

Regression relations in summer (21 June to 21September) (14:00 to 24:00)				
Y	X	Function relation	Regression R(%)	P value
Surface Temperature	Air Temp	Y = -4.110 + 1.297X	85.7	0.000
2.0 cm Temperature	Air Temp	Y = -7.409+ 1.499X	84.3	0.000
5.5 cm Temperature	Air Temp	Y = -6.674+ 1.557X	87.1	0.000
7.0 cm Temperature	Air Temp	Y = -5.190 + 1.528X	86.6	0.000

For example, Figure (13) illustrates the relationship between air ambient temperature and asphalt surface temperatures in summer. The Figures of all modules which illustrate the remaining relationships in Appendix B

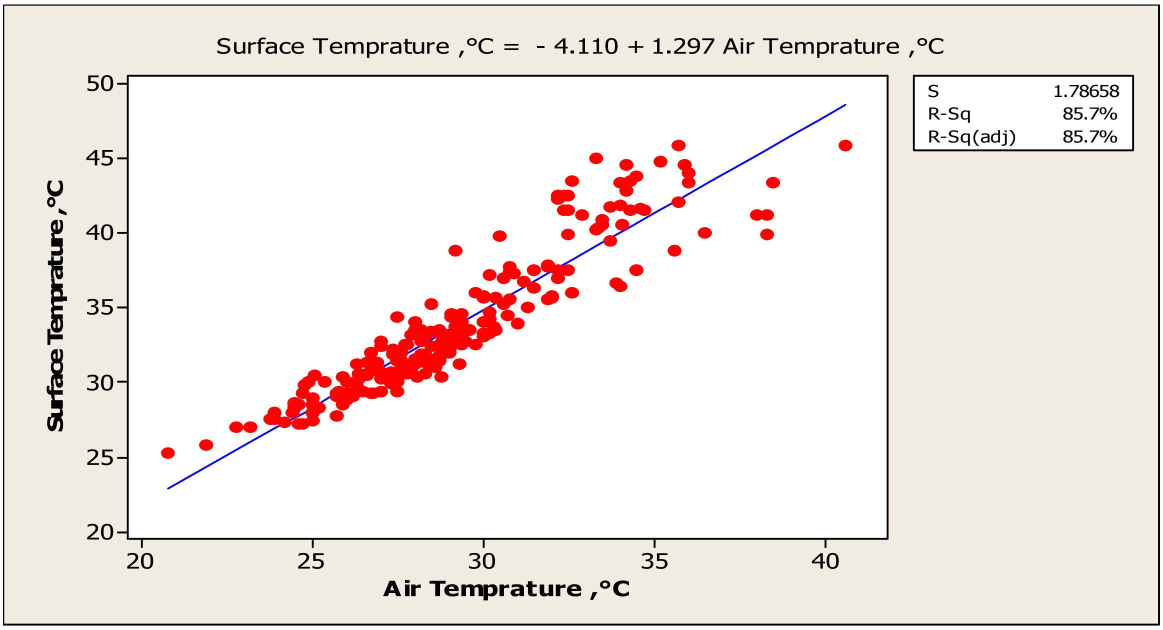

Figure 13: Relationship between air ambient and the asphalt surface temperatures in Summer

4.5. The Spring Season's Results and Discussion

In the spring season (21 March to 22 June), the subgrade is weaken during the thawing period by the frost action. The soil and moisture conditions that cause frost heaving are just as severe for thawing damage. The greatest loss of subgrade support is encountered when a wet fall is followed by a winter with many freeze–thaw cycles.[28]

The thawing of the roadbed in the spring occurs from the top down and usually starts under the center of the roadway. The shoulders stay frozen and trap water in the base and subgrade, because snow is left mounded there. The saturated material is very weak and will probably fail prematurely [29].

Removal of excess water can be done either by day lighting or installing subsurface drains to help remove the free water. Therefore, the temperatures in the spring is playing an important role in getting rid of drainage water under or inside Asphalt Pavement [31].

4.5.1. Fluctuations Temperature in Asphalt Pavements

Through the measurement of temperature in the spring, the maximum temperature rang were recorded for asphalt pavement . According to the (Table20),it can be noticed:

- The maximum hourly temperature rang in asphalt pavement in winter is 13.7°C Occurred in 13.06.2012 at 14:00.
- The maximum hourly temperatures rang and average daily temperature range has occurred in the same day.
- The maximum daily temperatures rang and average weekly temperature range has occurred in the same week.

- The maximum hourly, daily and weekly temperatures range in asphalt pavement temperatures occurred in June.
- Differences in temperature range is relatively medium.
- Temperatures rang in the asphalt increases with rising ambient temperature.

Table 20:Maximum Temperature Rang in Spring

	Range	Time	Date
Hourly temperature range	13.7	14:00	13.06.2012
Average daily temperature range	7.42	Whole Day	13.06.2012
Average weekly temperature range	6.30	Whole Week	7 to 13.06.2012
Average monthly temperature range	5.65	Whole Month	23 . 5 to 21.6.2012
Average seasonally temperature range	4.7	Spring Season	21. 3 to 22. 6

4.5.2. The highest and lowest temperature in asphalt pavement:

Through the measurement of temperatures in spring (21 March to 22 June) the height temperatures were recorded for all point (surface, 2.0cm, 5.5 cm, 7.0 cm) according to the Table (21), it can be noticed:

- The maximum temperature in asphalt pavement temperatures in summer is 52°C.
- The maximum temperatures have occurred in each depths on the asphalt pavement in the same time at 14:00 except the temperature of ambient occurred at 12:00.
- The maximum temperatures occurred in different date except ambient temperature.
- This difference results due to the reasons mentioned previously in winter season.

Table 21: Highest temperature in each depth in spring season

	Degree	Date	Time
Ambient	36.2	18.6.2012	14:00
Surface of asphalt	47.2	18.6.2012	14:00
2 cm in asphalt	52	18.6.2012	14:00
5.5 cm in asphalt	51.9	18.6.2012	14:00
7 cm in asphalt	50.5	18.6.2012	14:00

The lowest temperatures were recorded in spring season inside the all points (surface , 2.0cm, 5.5 cm,7.0 cm) according to the Table(22), it can be noticed:

- The minimum temperature in asphalt pavement temperatures at the winter is 6.9°C.
- The minimum temperature that occurred in each depths of the asphalt pavement has got in the same time at 6:00 and at two different days.
- This difference results due to the reasons mentioned previously in winter season

Table 22: Lowest temperature in each depths in spring season

	Degree	Date	Time
Air	8.3	21.3.2012	6:00
Surface of asphalt	10.5	21.3.2012	6:00
2 cm in asphalt	11.4	21.3.2012	6:00
5.5 cm in asphalt	13.3	21.3.2012	6:00
7 cm in asphalt	13.7	21.3.2012	6:00

4.5.3. Maximum and minimum temperature levels in spring season

Spring in the Gaza Strip is characterized by moderate temperatures, therefore the effect of temperatures on the asphalt pavement are being little, but its effect on drainage water which is formed in winter as a result of water blocks forming in the soil under the pavement. Water grow in the downward direction (just as water in a pond freezes), and are fed by water drawn up from below by capillary action

4.5.3.1. The maximum temperature levels in spring season

- Table (23) shows the maximum temperatures at each point in any depth in the asphalt layers during any time in the spring season .
- The highest temperature of asphalt pavement is 52 °C in depth 5.5 cm at14:00.
- The maximum temperature degrees in the (surface, 2.0 cm, 5.5cm and 7.0cm) are (47.2, 52, 51.9 and 50.5 °C) respectively at time14:00 .
- The maximum temperatures in asphalt pavement occurred in the asphalt pavement at 14:00 (At Noon), that time sun is perpendicular to the ground and the temperatures are the highest.

Table 23: The maximum temperatures level in spring season

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	23.5	27	29.5	31	31.4
8:00	29.9	33.5	35.9	34.8	34.5
10:00	33.4	39.5	43.5	41.3	40.4
12:00	38.8	42.3	50.7	47.5	46.4
14:00	36.2	47.2	52	51.9	50.5
16:00	35.5	42.4	50.8	50.2	50.3
18:00	31.5	39.4	43.2	45.3	45.8
20:00	27.2	33.7	36.8	39	39.5
22:00	26.5	30.8	33.4	36	36.5
24:00	25.3	30	32.9	34.2	34.7
2:00	21	28.3	33.9	33.2	32.4
4:00	19.7	23.5	28.3	29.7	29.7

4.5.3.2. The minimum temperature levels in spring season

- Table (24) shows the minimum temperatures at each point in any depth in the asphalt layers during all time in the spring season .
- The lowest temperature of Asphalt pavement is 8.9 °C in the surface at 6:00
- The minimum temperature degrees in the (surface,2.0 cm, 5.5cm and 7.0 cm) is (8.9, 11.4, 13.3 and 13.7 °C) respectively at time 6:00.
- The minimum temperature occurred in the asphalt pavement at 6:00 (At Dawn), that time the temperatures is the lowest.

Table 24: The minimum temperatures level in spring season

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	6.9	8.9	11.4	13.3	13.7
8:00	15.3	17.2	15	14	13.7
10:00	17.2	18.6	21.1	20.6	20.2
12:00	20.4	25	26.4	27.5	27.2
14:00	20.2	25.2	30	29.2	28.5
16:00	17.8	21	24.5	25.8	25.9
18:00	15.8	17.6	21	22.2	22.5
20:00	14.2	16.4	18.3	19.7	20.2
22:00	10.5	13.4	16.7	18.3	18.7
24:00	10.3	12.8	15.8	17.7	18.1
2:00	14.3	15.5	18.8	20.5	21
4:00	14.4	16.5	19.5	20.2	20.6

4.5.3.3. Average temperature levels in spring season

Average asphalt temperatures in Gaza Strip in spring are varied between 40.8°C as maximum average temperature asphalt and 18.4°C as minimum average temperature (Table 25). Where according to the Table (25) ,it can be noticed:

- The average of all hourly temperatures for each point in asphalt pavement layers were calculated, through a whole time in the spring.
- Daily cycle temperatures in the spring season are moving in a same orientation and one pattern during a day - look like a summer behaviors.
- Daily pattern of the average table in the spring can be divided into two phase as follow table.

Table 25: Daily Average temperature in spring season

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	15.5	18.4	20.5	22.1	22.5
8:00	22	24.5	24.9	24.9	24.8
10:00	25.5	30	32.2	31.3	30.6
12:00	28.5	34.2	38.6	37.6	36.8
14:00	27.9	35.4	40.8	40.5	39.9
16:00	25.9	33.2	37.7	38.9	38.8
18:00	22.9	27.9	31.4	33.5	33.9
20:00	20.6	24.3	27.1	29.1	29.6
22:00	19.1	22.5	25.1	26.9	27.4
24:00	19.4	22.9	25.5	27.4	27.8
2:00	17.6	22.1	25.6	27	27.6
4:00	16.7	20.8	24	25.7	26.1

4.5.4. Daily cycle of thermal behavior

Daily cycle temperatures in the spring season are moving in a same orientation and one pattern during a day, whether increasing or decreasing in the temperature degrees and according to (Figure 14 and Table 26), it can be noticed that:

- Asphalt pavement layers temperatures are influenced by the ambient temperatures.
- The research includes many graphics for daily temperature patterns -Appendix A- which visualized the form of the temperature behaviors, so it is difficult to analyzed every day by day
- There are many behaviors in temperatures through a day, every behavior needs a period of time to take their own pattern for responding to ambient temperature.
- In this study 07.06.2012 as an example of fieldwork in a spring season (Table 26, Figure 14) was chosen and the rest of tables and figures related for daily measurement are shown in Appendix A.

Table 26: Daily cycle of thermal behavior at spring in 07.06.2012

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	17.7	21.7	27.7	27	27.4
8:00	26.2	33.2	35.9	34.8	34.5
10:00	31.1	35.2	39.7	38.4	37.5
12:00	34.2	40.8	42.3	43	44.2
14:00	33.9	41.9	49.5	48.9	48.9
16:00	31	41.5	46.6	47.5	47
18:00	28.7	35.8	40.3	42.9	42.9
20:00	24.4	30.5	33.3	36.4	36.8
22:00	23.4	28.3	31	33.7	34.3
24:00	21.6	25.6	28.5	31.4	31.8
2:00	19	24.2	27.4	29.5	30
4:00	16.8	23.5	25.4	27.8	28.5

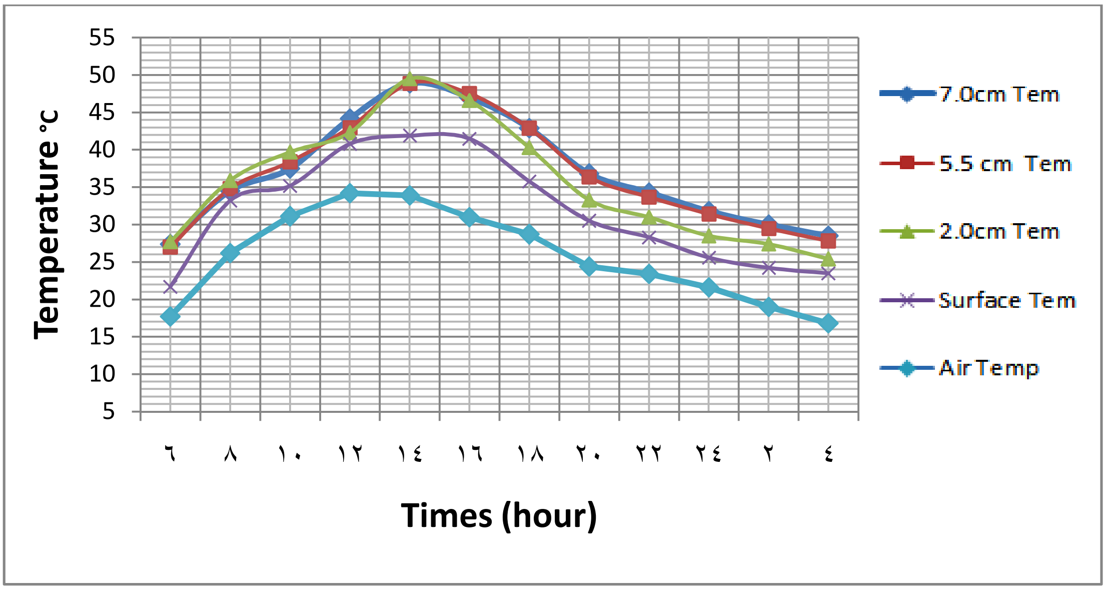

Figure 14: Daily cycle of thermal behavior at spring in 07.06.2012

According to Table 26 and figure 9, daily cycle of thermal behavior in spring divided to three parts :

A. Dawn to Morning (6:00 -8:00)

- The measurement and recording is starting at 6 :00Am.
- The asphalt pavement layers is warmer than the air ambient
- Temperatures were arranged from low to high as follows:
    - Air temperature
    - Surface temperature
    - Temperature at depth 2.0 cm
    - Temperature at depths 5.5 cm and 7.0 cm.
- In this period the temperatures of asphalt pavement layers are increasing gradually by increasing of air ambient
- Temperatures increase, according to the depth of asphalt pavement layers, where the asphalt surface is affected by temperature ambient before the depth.

B. Morning to Noon (8:00 -14:00):

- The temperatures behavior are differed from the previous conduct**.**
- Increasing in temperature will continue in all depths, but with different levels.
- The surface temperatures and the temperatures at depth 2 cm are raised to the maximum temperatures
- The temperature at depth 2 cm is the highest temperature from the other temperatures on depths surface, 5.5 cm and 7cm respectively
- The ambient temperature is less than the asphalt temperatures.
- The temperatures reach to a maximum degrees in the ambient air and all asphalt pavement layers at (12:00 – 14:00)

C. Noon to midnight (16:00 to 24:00)

- At this period the temperatures decrease gradually in the ambient air and in all layers asphalt pavement
- Temperatures were arranged from low to high as follows:
    - Air temperature
    - Surface temperature
    - Temperature at depth 2.0 cm.
    - Temperature at depth at 5.5 cm.
    - Temperature at depth at 7.0 cm.
- Temperatures continue to decline with the passage of time.
- The maximum drop in temperatures at dawn time

4.5.5. Relationship between air ambient temperatures and the asphalt pavement temperatures at different depths.

- There is a proportional relationship between ambient air temperature and the temperature of the asphalt
- The asphalt temperatures are increasing by the increasing of air ambient temperatures
- The relationship between the two variables is linear
- The resulting graphs show that the relationship between air ambient temperatures and asphalt pavement temperatures is divided into two parts:
  - A. Partition upward - Incremental - (dawn to noon)
  - B. Partition downward - decreasing - (afternoon to dawn)

Table (27) shows all relationships between ambient temperature and the temperatures measurement in all depths (surface, 2.0 cm, 5.5 cm, 7.0cm) at incremental daily period (6:00 to 14:00) in spring season.

Table 27: Regression relations in spring season

Regression relations in Spring (21 March to 22 June) (6:00 to 14:00)				
Y	X	Function relation	Regression R(%)	P value
Surface Temperature	Air Temp	Y =0.9914 + 1.152 X	89.1	0.000
2.0 cm Temperature	Air Temp	Y = -0.2596 + 1.352	80.8	0.000
5.5 cm Temperature	Air Temp	Y = 2.787 + 1.191 X	77	0.000
7.0 cm Temperature	Air Temp	Y = 3.771 + 1.136 X	75.5	0.000

For example, Figure (15) illustrates the relationship between air ambient temperature and asphalt surface temperatures in spring. The Figures of all models which illustrate the remaining relationships in Appendix B

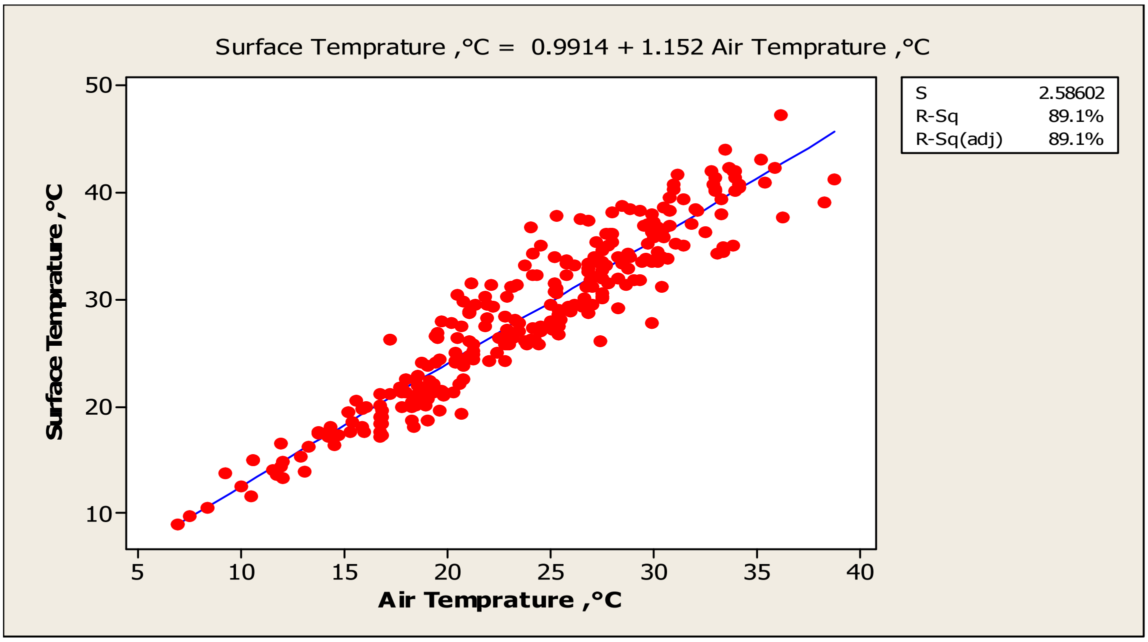

Figure 15: The relationship between air ambient and the asphalt surface temperatures in spring

Table (28) shows all relationships between ambient temperature and the temperatures measurement in all depths (surface, 2.0 cm, 5.5 cm, 7.0cm) at decreasing daily period **(**16:00 to 24:00**)** in spring season.

Table 28: Regression relations in spring

Regression relations in Spring (21 December to 20 March) (16:00 to 24:00**)**				
Y	X	Function relation	Regression R(%)	P value
Surface Temperature	Air Temp	Y = -1.564 + 1.288X	92.2	0.000
2.0 cm Temperature	Air Temp	Y = -0.9476 + 1.410 X	88.1	0.000
5.5 cm Temperature	Air Temp	Y = 1.284+ 1.390 X	87.4	0.000
7.0 cm Temperature	Air Temp	Y = 2.375+ 1.354 X	87.2	0.000

For example, Figure (16) illustrates the relationship between air ambient temperature and asphalt surface temperatures in summer. The Figures of all models which illustrate the remaining relationships in Appendix B.

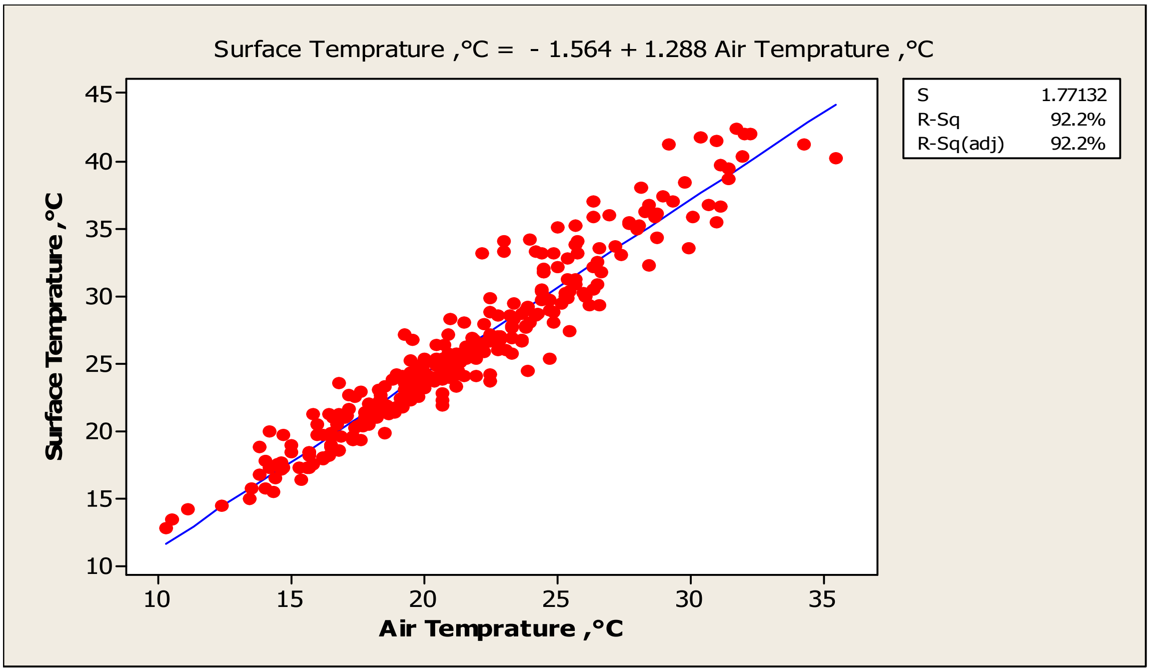

Figure 16:Relationship between air ambient and the asphalt surface temperatures in spring

4.6. The Autumn Season's Results and Discussion:

Temperatures in autumn season (21September to 21 December) are trending downward significantly, because this season is transitional and heavily exposed to the beginning of the arrival of the depressions that run on air temperature reduction [30].

Descending the maximum temperature curve at this season is a significant steeper because of the beginning of the impact of air cold masses with the increasing decline of the high pressure semi-orbital of the region during the autumn, as well as the growing number of depressions air with associated disorders whenever be closer to the winter.

Therefore, the difference between the average maximum temperatures between the months of October and November will be greater than the difference between the averages of October and September [31]. Therefore, the beginning of autumn be closer to the behavior of the summer, and the end of autumn be closer to the behavior of winter. Thus, a rainy autumn may increase the risk of damage the roads. Variation of the content of water in the soil, and causing some devastation like Potholes(Chuck hole) [32].

4.6.1. Fluctuations Temperature in Asphalt Pavements

Through the measurement of temperature in the Autumn, the maximum temperature rang were recorded for asphalt pavement . According to the (Table29),it can be noticed:

- The maximum hourly temperature rang in asphalt pavement in winter is 8.9°C Occurred in 04.10.2012 at 14:00.
- The maximum hourly temperatures rang and average daily temperature range has occurred in the same day.
- The maximum daily temperatures rang and average weekly temperature range has occurred in the same week.
- The maximum hourly, daily and weekly temperatures range in asphalt pavement temperatures occurred in October.
- Differences in temperature range is relatively medium.
- Temperatures rang in the asphalt increases with rising ambient temperature.

Table 29:Maximum Temperature Rang in Autumn

	Range	Time	Date
Hourly temperature range	8.9	14:00	04.10. 2012
Average daily temperature range	3.75	Whole Day	04.10. 2012
Average weekly temperature range	2.9	Whole Week	02.10-09.10. 2012
Average monthly temperature range	2.63	Whole Month	23.9 to 22.10.2012
Average seasonally temperature range	2.33	Winter Season	21.12 to 20.3.2013

4.6.2. The highest and lowest temperature in asphalt pavement :

Through the measurement of temperature in autumn (22 September to 21 December) the height temperatures were recorded for all point (surface, 2.0cm, 5.5 cm,7.0 cm) according to the Table(30), it can be noticed

- It is clear that maximum temperature 45.5 °C occurred at afternoon time.
- The maximum temperatures have occurred in each depths on the asphalt pavement in the different time. Table (30)
- This difference results due to the reasons mentioned previously in winter season

Table 30: Highest temperature in each depth in autumn season

	Degree	Date	Time
Ambient	34.3	27-09-2012	12:00
Surface of asphalt	43.7	27-09-2012	12:00
2 cm in asphalt	45.5	27-09-2012	12:00
5.5 cm in asphalt	44.1	27-09-2012	14:00
7 cm in asphalt	43.3	27-09-2012	14:00

The lowest temperatures were recorded in autumn season inside the all points (surface, 2.0cm, 5.5 cm, 7.0 cm) according to the Table(31), it can be noticed:

- The minimum temperature in asphalt pavement temperatures at the winter is 9.9°C.
- The minimum temperature that occurred at each depths in the asphalt pavement has got in the same time at 6:00 and the same day at 18.12.2012.
- The minimum value of the temperatures for the asphalt pavement depths was occurred at 6:00.

Table 31: Lowest temperature in each depths in autumn season

	Degree	Date	Time
Air	9.9	18.12.2012	6:00
Surface of asphalt	11.5	18.12.2012	6:00
2 cm in asphalt	12.1	18.12.2012	6:00
5.5 cm in asphalt	12.9	18.12.2012	6:00
7 cm in asphalt	13.3	18.12.2012	6:00

4.6.3. Maximum and minimum temperatures levels:

Autumn season is a transitional phase with unclearly definition between the summer heat and winter cold or vice versa, and it usually described as moderate temperature with an abundance of low and high thermal vibrational during this season due to exchange of the different atmospheric pressure centers.

4.6.3.1. The maximum temperature levels in autumn season

Table (32) shows the maximum temperature degrees at each point in any depth in the asphalt pavement layers during any measuring time in the autumn season and can be noticed that :

- Highest temperature of Asphalt pavement is 45.5°C in depth 2.0 cm at 12:00.
- The maximum temperature degrees in the (surface, 2.0cm , 5.5cm and 7.0cm) is(44.2 , 45.5 , 44.4 and 44.5 °C) respectively at different time .
- The maximum temperatures in asphalt pavement occurred in the asphalt pavement at 12:00 (At Noon), that time the sun is perpendicular to the ground and the temperatures are the highest.

Table 32: The maximum temperatures level in autumn season

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	26.7	27.4	27.8	29.1	29.5
8:00	30.9	32.5	33	31.8	31.8
10:00	36.4	40	39.9	38.8	38.8
12:00	36.2	44.2	45.5	44.1	43.7
14:00	34.3	43.3	44.8	44.4	44.5
16:00	29.2	35.7	38.4	39.8	40.4
18:00	27.4	32.3	32.5	34	34.8
20:00	27.2	30.3	31.5	32.5	32.9
22:00	26.3	28.9	29.9	31.3	31.8
24:00	26	28	29	30	30.3
2:00	24.5	26.6	27.3	28.7	29.4
4:00	23.5	25.8	26.6	27.8	28.3

4.6.3.2. The minimum temperature levels in autumn season

Table (33) shows the minimum temperatures degrees at each point in any depth in the asphalt layers during measuring time in the autumn season, and can be noticed that :

- Lowest temperature of asphalt pavement is 11.5°C on the surface at 6:00.
- The minimum temperature degrees in the (surface, 2.0m, 5.5cm and 7.0cm) is (11.5 , 12.1 ,12.9 and 13.3 °C) respectively at time 6:00 associated with air ambient 9.9 °C.
- The minimum temperature occurred in the asphalt pavement at 6:00 Am (At Dawn), that time the temperatures is the lowest.
- This table does not represent the days behavior in the autumn season but it may an instantaneous periods.

Table 33: The minimum temperatures level in autumn

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6	9.9	11.5	12.1	12.9	13.3
8	12.1	12.4	13.1	13.1	13.5
10	13.2	13.2	14.7	15	15.2
12	13.4	13.8	15.7	15.4	15.4
14	13	13.4	14.6	14.8	15.1
16	13.2	13.5	14.3	14.5	14.8
18	13.1	13	14	14.2	14.3
20	12.5	12.9	13.9	14.1	14.2
22	12	12.9	13.7	14.1	14.3
24	12.2	12.7	13.2	13.6	14
26	13	13.4	13.8	14.4	14.9
28	12.7	13	13.2	13.6	14.1

4.6.3.3. Average Temperature levels in autumn season

Average asphalt temperatures in Gaza Strip in autumn are varied between 33.8°C as maximum average temperature and 18.7°C as minimum average temperature (Table 34). According to the table (34), it can be noticed:

- The average of all temperatures for each point in asphalt pavement layers were calculated, through a whole time in the autumn.
- Daily cycle temperatures in the autumn season are moving in different pattern during average day as a normal day in the autumn season and look like behaviors of winter season.
- Daily pattern of the average temperature in the autumn can be divided into two phase as follow in (Table 34)

Table 34: Daily cycle of thermal behavior in autumn

Time	Air	Surface	2.0cm	5.5 cm	7.0cm
6:00	16.92	18.8	19.66	20.67	21.1
8:00	22.05	22.95	22.89	22.43	22.4
10:00	26.76	29.98	29.64	28.13	27.4
12:00	28	33.1	33.8	32.64	31.8
14:00	26.87	29.58	31.05	31.41	31.4
16:00	23.94	26.11	27.12	28.06	28.4
18:00	21.97	23.94	24.81	25.72	26.2
20:00	20.72	22.49	23.54	24.32	24.7
22:00	19.33	21.16	22.26	23.31	23.8
24:00	18.72	20.56	21.68	22.66	23.1
2:00	17.75	19.1	20.08	21.25	21.8
4:00	16.98	18.7	19.45	20.43	21

4.6.4. Daily cycle of thermal behavior

Daily cycle temperatures in the autumn season are moving in a same orientation and one pattern during a day, whether increasing or decreasing in the temperature degrees and according to (Figure 17 and table 35), it can be noticed that

- The research consists of graphics and table for daily temperature patterns- Appendix A- which visualized the form of the temperature behaviors
- There are many behaviors in temperatures through a day, every behavior needs a period of time to take their own pattern for responding to the ambient temperature.
- In this study 20.10.2012 as an example of fieldwork in autumn season (Table 35 and Figure 17) was chosen and the rest of tables and figures related for daily measurement are shown in Appendix A.

Table 35: Daily cycle of thermal behavior at autumn in 20.10.2012

Time	Air	Surface	2.0cm	5.5 cm	7.7cm
6:00	19.9	22.6	23.5	24.5	24.9
8:00	23.5	25	25.7	26	26
10:00	29.1	35.1	34.7	32.9	32.2
12:00	32.2	39	40.7	39.3	38.3
14:00	30.2	34	36.2	36.7	36.9
16:00	27.7	30.8	30.9	32.2	32.5
18:00	25.5	28.3	28.7	29.8	30.5
20:00	23.5	26.7	27.1	28	28.8
22:00	21.8	23.9	25	26.7	27.3
24:00	20.2	23.5	24.2	25.7	26.2
2:00	19.9	22	23.2	24.8	25.3
4:00	18.9	21.5	22.8	23.9	24.5

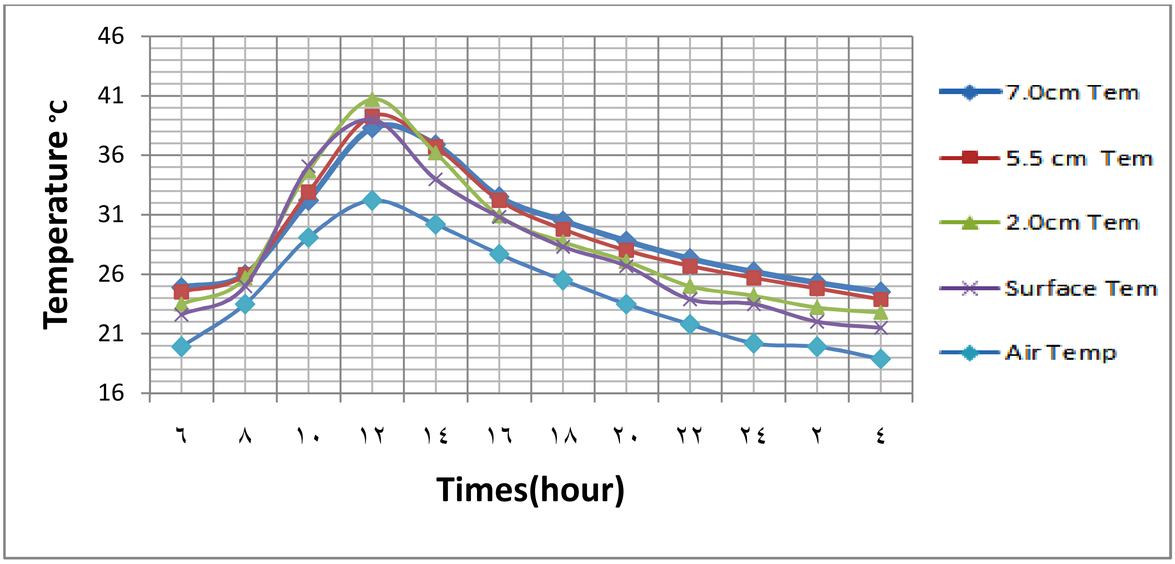

Figure 17: Daily cycle of thermal behavior at autumn in 20.10.2012

According to Table 35 and Figure 17, the daily cycle of thermal behavior in autumn divided to three parts:

A. Dawn to Morning (6:00 -8:00)

- The measurement and recording is starting at 6:00.
- Temperatures were arranged from low to high as follows:
  - Air temperature
  - Surface temperature
  - Temperature at depth 2.0 cm.
  - Temperature at depth at 5.5 cm.
  - Temperature at depth at 7.0 cm.
- In this period the temperatures of asphalt pavement layers are increasing gradually by increasing of air ambient
- Temperatures increase, according to the depth of asphalt pavement layers, where the asphalt surface is affected by temperature ambient before the depth.

- All temperatures converge to one point at 8:00.
- The temperatures at 8:00 is a reflection point to rearrange the temperatures

B. Morning to Noon (8:00 -14:00):

- The temperatures behavior are differed from the previous conduct**.**
- Increasing in temperature will continue in all depths, but with different levels.
- The surface temperatures and the temperatures at depth 2 cm are raised to the maximum temperatures
- The temperature at depth 2 cm is the highest temperature from the temperature on depths surface, 5.5 cm and 7cm respectively
- The ambient temperature is less than the asphalt temperatures.
- The temperatures reach to a maximum degrees in the ambient air and all asphalt pavement layers at period 12:00 – 14:00.

C. Noon to midnight (16:00 to 24:00)

- At this period the temperatures decrease gradually in the ambient air and in all layers in asphalt pavement
- Temperature were arranged from low to high as follows:
    - Air temperature
    - Surface temperature
    - Temperature at depth 2.0 cm.
    - Temperature at depth at 5.5 cm.
    - Temperature at depth at 7.0 cm.
- Temperatures continue to decline with the passage of time.
- The maximum drop in temperatures at dawn time.

4.6.5. Relationship between air ambient temperatures and the asphalt pavement temperatures at different depths

- There is a proportional relationship between ambient air temperature and the temperature of the asphalt
- The relationship between the two variables is linear
- The asphalt temperatures are increasing by the increasing of air ambient temperatures
- The resulting graphs show that the relationship between air ambient temperatures and asphalt pavement temperatures is divided into two parts:
    C. Partition upward - Incremental - (dawn to noon)
    D. Partition downward - decreasing - (afternoon to dawn)

Table (36) shows all relationships between ambient temperature and the temperatures measurement in all depths (surface, 2.0 cm, 5.5 cm, 7.0cm) at incremental daily period (6:00 to 14:00) in autumn season.

Table 36: Regression relations in autumn

Regression relations in autumn(22 September to 21 December)(6:00to 14:00)				
Y	X	Function relation	Regression R(%)	P value
Surface Temperature	Air Temp	Y =-2.677+ 1.266X	92.6	0.000
2.0 cm Temperature	Air Temp	Y = -2.466+ 1.239X	90.5	0.000
5.5 cm Temperature	Air Temp	Y = -0.7616+ 1.153X	86.6	0.000
7.0 cm Temperature	Air Temp	Y = -0.0891+1.115 X	84.1	0.000

For example, Figure (18) illustrates the relationship between air ambient temperature and asphalt surface temperatures in autumn. The Figures of all models which illustrate the remaining relationships in Appendix B

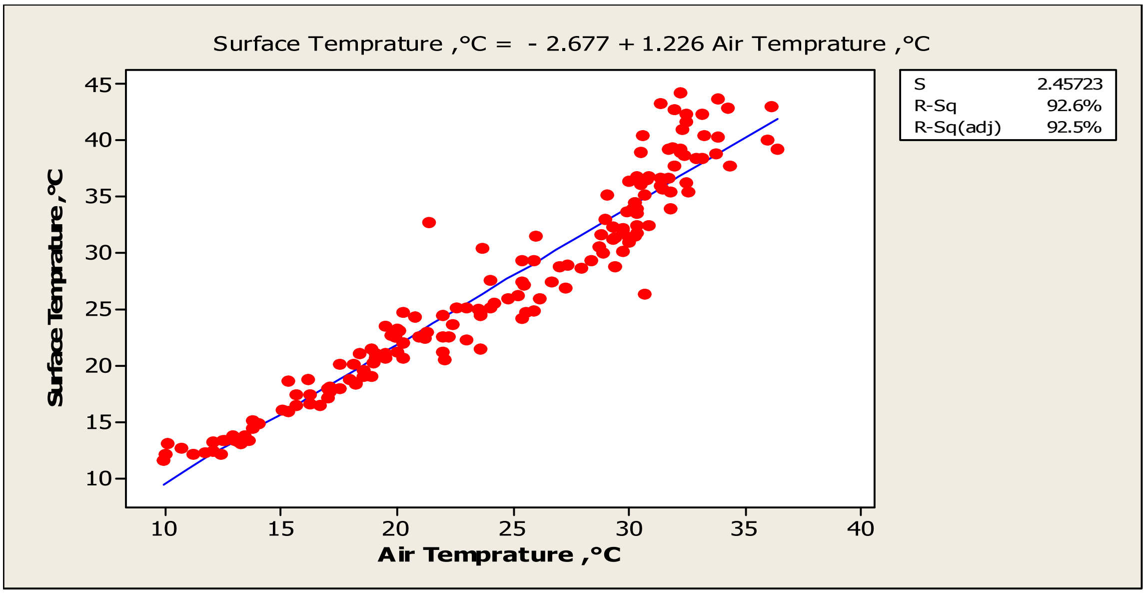

Figure 18: Relationship between air ambient and the asphalt surface temperatures in autumn

Table (37) shows all relationships between ambient temperature and the temperatures measurement in all depths (surface, 2.0 cm, 5.5 cm, 7.0cm) at decreasing daily period (16:00 to 24:00) in autumn season.

Table 37: Regression relations in autumn

Regression relations in autumn (22 September to 21 December)(6:00 to 14:00)				
Y	X	Function relation	Regression R(%)	P value
Surface Temperature	Air Temp	Y = -1.808+1.179X	97.1	0.000
2.0 cm Temperature	Air Temp	Y = 1.040+1.191X	95.4	0.000
5.5 cm Temperature	Air Temp	Y = -1.116+1.24X	94.7	0.000
7.0 cm Temperature	Air Temp	Y = -0.9783+1.255X	94.4	0.000

For example, Figure (19) illustrates the relationship between air ambient temperature and asphalt surface temperatures in autumn. The Figures of all modules which illustrate the remaining relationships in Appendix B

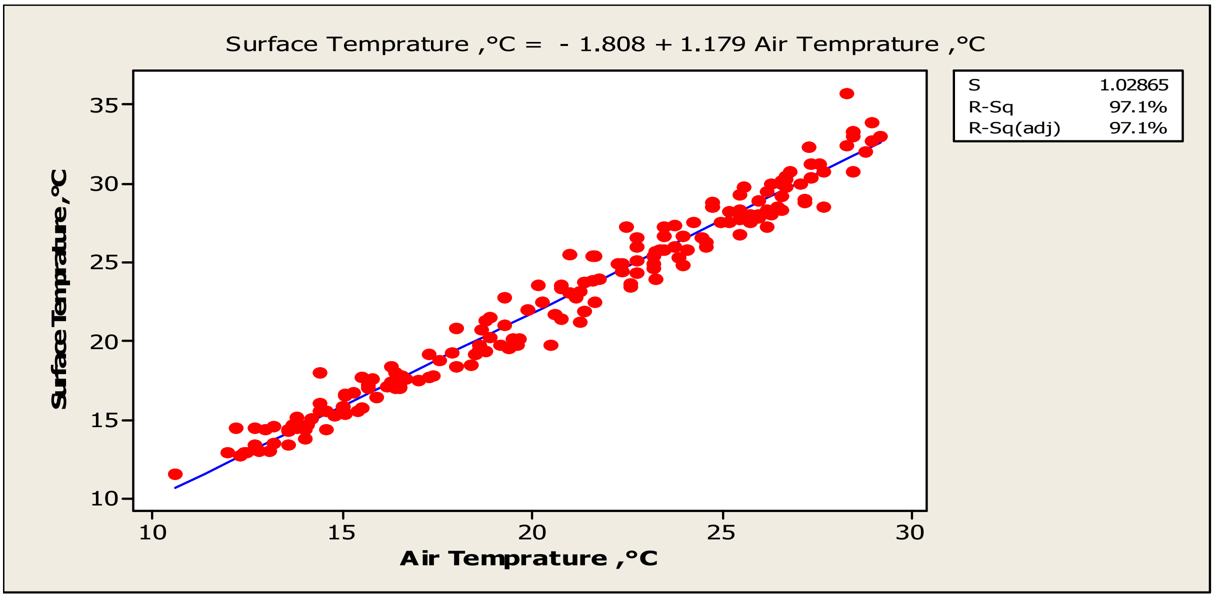

Figure 19: Relationship between air ambient and the asphalt surface temperatures in Autumn

4.7. Other Regression relations (one equation)

In additional to the pervious linear relationships, other models are found. They illustrate the relationships the temperature in any depth as a function of air ambient temperature.

The relationships are divided into two parts:

A. Partition upward (6:00-14:00) .

B. Partition downward (14:00-24:00).

Table (38) shows the relationships between ambient temperature and the temperatures measurement in any depths at daily period (6:00 to 14:00) in whole year.

Table 38: Relationships between ambient temperature and the temperatures measurement in any depths at daily period (6:00 to 14:00)

Season	T (z)	X	Z	Function relation
Winter	Temperature at Z depth	Air Temp	The depth	**Y(z)= 1.0265X -0.0302 Z +1.365**
Sumer	Temperature at Z depth	Air Temp	The depth	**Y(z)= 1.336 X +0.43 Z -4.559**
Spring	Temperature at Z depth	Air Temp	The depth	**Y(z)= 1.201X +0.280 Z +0.806**
Autumn	Temperature at Z depth	Air Temp	The depth	**Y(z)= 1.360 X +0.726 Z -2.346**

Table (39) shows the relationships between ambient temperature and the temperatures measurement in any depths at daily period (14:00 to 24:00) in whole year

Table 39:Relationships between ambient temperature and the temperatures measurement in any depths at daily period (14:00 to 24:00)

Season	T (z)	X	Z	Function relation
Winter	Temperature at Z depth	Air Temp	The depth	**Y(z)=0.977 X -0.0302 Z +1.676**
Sumer	Temperature at Z depth	Air Temp	The depth	**Y(z)= 1.4730 X +0.993 Z -8.934**
Spring	Temperature at Z depth	Air Temp	The depth	**Y(z)= 1.360 X +0.726 Z -2.346**
Autumn	Temperature at Z depth	Air Temp	The depth	**Y(z)= 1.216 X +0.330 Z -2.431**

The statistics parameter for the relationship between air ambient temperature and asphalt pavement temperatures in any depth at time (6:00-14:00 and 14:00 - 24:00) in all season are mentioned in Appendix C

4.8. Average Temperature in All Seasons a Year at Different Depths in Asphalt Pavement Structure

It is important to evaluate how climate has varied and changed in the past. The monthly mean temperature data can be written to show the baseline climate , for specific years, and for temperature. The table (38) shows mean historical seasonal temperature for Gaza Strip during the time period 1.3.2012 – 28.2.2013. According to (table 34), it can be noticed that:

- There are about 9060 reading of the temperature in all aspect.
- The measurements number are different from season to another due to different circumstances.
- The difference between average temperatures of spring season and average temperatures of autumn season in the asphalt pavement was relatively wide but it is small between two averages air ambient temperature
- The difference between the average maximum temperature of the summer and the average minimum temperature of the winter in the asphalt pavement is relatively large, as well as in the difference between the average ambient temperatures
- Asphalt pavement temperature increases with increasing ambient temperature
- Ambient temperature increases its impact on asphalt with increasing depth.
- The average ambient temperature in the summer is twice the average ambient temperature in winter.
- The annual average temperature of the asphalt is 27.45 °C and the annual average of ambient temperature is 22.28 ° C

Table 40: Medium temperature in the seasons of the year at different depths

	Surface		At 2 cm		At 5.5cm		At 7 cm		Average	Air	
	Average Temp	Number	Average Temp	Number	Average Temp	Number	Average Temp	Number	Asphalt	Average Temp	Number
Winter	16.3	495	17.1	495	17.37	495	17.35	495	17.03	15	495
Spring	27.33	555	30.41	555	31.2	555	31.2	555	30.04	22.71	555
Summer	35.01	421	37.8	421	39.34	421	39.6	421	37.94	30.23	421
Autumn	24.7	341	25.4	341	25.75	341	25.86	341	25.43	22.34	341
Sum		1812		1812		1812		1812			1812
Average	25.6		27.548		28.28		28.36		27.45	22.28	

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

- There is a proportional relation between the air ambient temperatures and asphalt pavement temperatures. Consequently, if the air ambient increase, the asphalt temperatures increase.
- The asphalt surface is rapidly affected by the air ambient temperature. So the asphalt absorbs the surrounding temperature.
- Temperatures rang in the asphalt increases with rising ambient temperature.
- Asphalt pavement characterized with the high density and good thickness, so the temperature needs some time to transmit into the inside the asphalt layers.
- The maximum temperature have a high variation in the summer, the hour after noon of the sun to reach the maximum temperature which is measured in Gaza to be one hours after the noon of the sun and the time in hours before sunrise to reach the minimum temperature which is chosen to be the lowest.
- Daily cycle temperatures in the winter are moving in a different shape and variable pattern in each moment during a day, whether increasing or decreasing in the temperature degrees.
- Daily cycle temperatures in the summer season are moving in a same orientation and one pattern during a day, whether increasing or decreasing in the temperature degrees
- The maximum temperatures in summer occurred in the asphalt pavement at 14:00, where the sun is perpendicular over the ground and the temperatures are the highest degree.
- Minimum temperatures at air and asphalt pavement layers were at 6:00, before sunrise in winter.
- There are many behaviors in temperatures through a day. Every behavior needs a period of time to take their own pattern for responding to the ambient temperature.
- The model predictions (temperatures) are strongly dependent on climate data in addition to accurate knowledge of the thermal properties of pavement materials and pavement geometry.
- Variations of temperature across pavement depth must be considered in the back-calculation of flexible pavement layer moduli.
- For pavements in surface, middle and low layers regions, the heat transfer model using different algorithms to predict the temperature

- The relationship between air ambient temperature and asphalt pavement temperature is nearly linear
- The average ambient temperature in the summer has twice value of the average ambient temperature in winter season.
- The difference between average temperatures in spring season and autumn season in the asphalt pavement was relatively wide but difference small between average air ambient temperatures.
- Daily pavement temperatures were represented as a sine function. Temperature variation with depth was accounted by applying a factor that reduced the amplitude of the sine curve with increasing depth. The method provided the greatest accuracy during the warming period at the surface, but had decreasing accuracy with increasing depth
- It must be taken into consideration that there are some uncertainties with regard to some environmental inputs such as percentage sunshine and thermal properties. The assumptions made in that regard can affect the final results reported in this study.

5.2. Recommendations

- To satisfy more accurate design, it is recommended to use a mathematical model for simulating pavement response rather than predicting values for pavement.
- More field data with more comprehensive measurements on environmental conditions need to be analyzed to establish the best values for thermal properties, and to investigate the reliability of the model in simulating pavement temperature.
- It is recommended to study West Bank case as done in the Gaza Strip. This was not included in this thesis because of the unavailability of temperature data for the West Bank.
- The related government agency (Department of Meteorology at the Ministry of Transportation) should continuously collect detailed temperature data for all the West Bank and Gaza regions since such data is needed for good transportation system.
- Further studies are needed in this aspect related to effective utilization and best technical means in asphalt pavements to achieve the desired objectives.
- It is recommended to conduct similar studies on the asphalt pavement to reach to steady criteria to the predicted temperature in the asphalt by knowing ambient temperature.

- It is recommended to use other statistical methods to link the ambient temperature and the temperature of asphalt pavement.
- Finally, it should be realized that various inputs other than regional climate data and potential climate change impact are critical in designing pavements. Such inputs include local material characterization, construction specifications and pavement preservation and maintenance practices. Future research is required to include all these inputs such as those listed above in combination with climate change parameters and subsequently into the local calibration procedure.

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[31] Knut Makowski 2009," The daily temperature amplitude and surface solar radiation", A dissertation submitted to ETH ZURICH for the degree of doctor of sciences , DISS. ETH NO. 18319,Swiss

[32] Torbjörn Jacobson," cold Recycling Of Asphalt Pavement –mix plant ", Swedish National Road and Transport Research Institute, SE-581 95 Linköping , Sweden

Appendices

Appendix B

Relationship between air ambient temperatures and the asphalt pavement temperatures at different depths

1. **The Winter (21 December to 20 March):**

Incremental (6:00 to 14:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

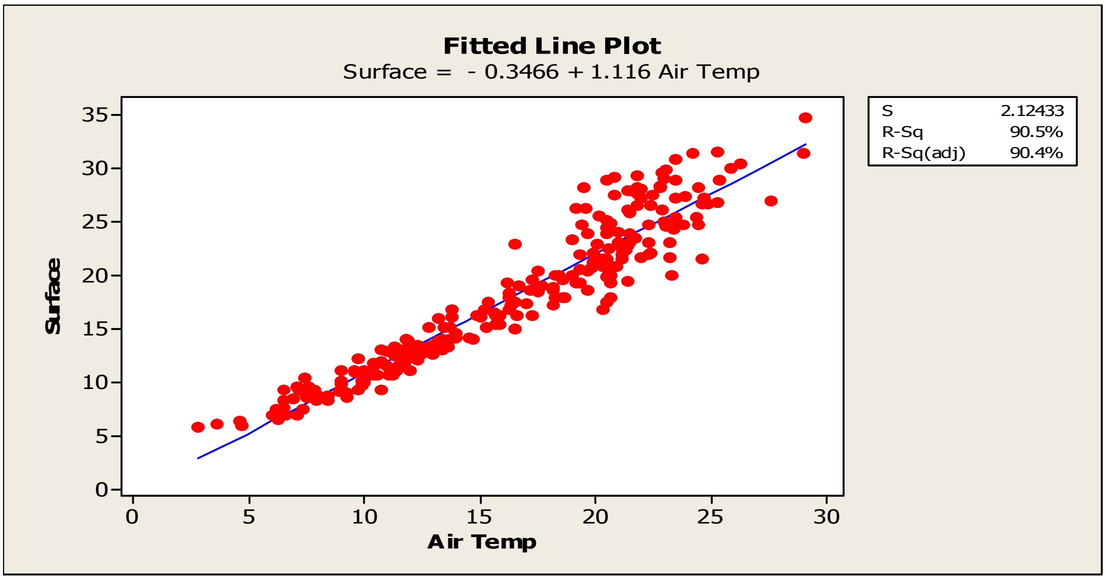

Figure B20:Incremental relationship between ambient and Asphalt surface temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	10427.9	10427.9	2310.75	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

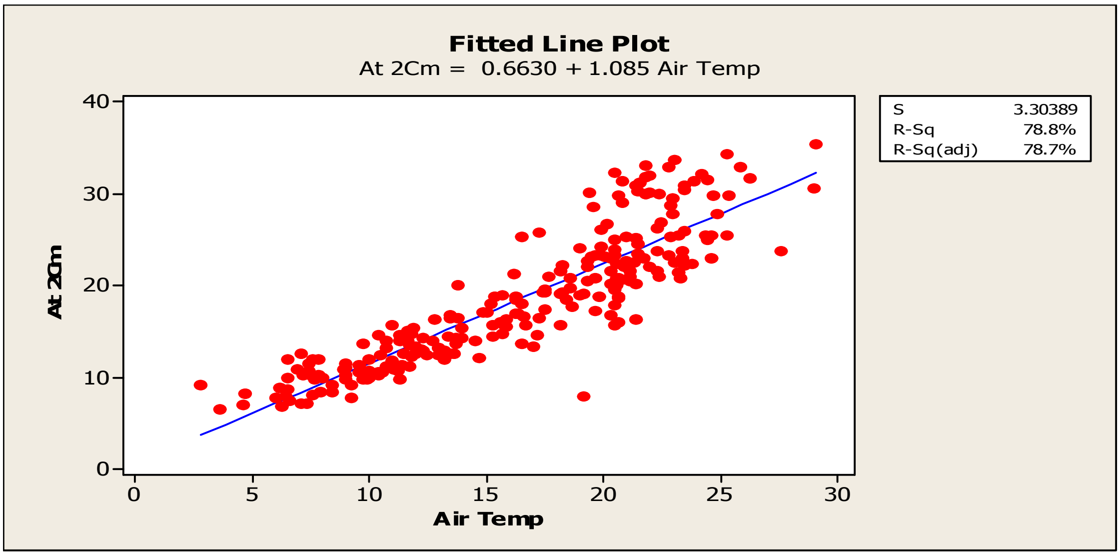

Figure B21:Incremental relationship between ambient and Asphalt at 2Cm temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	9859.3	9859.28	903.22	0.000

C. **Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature:**

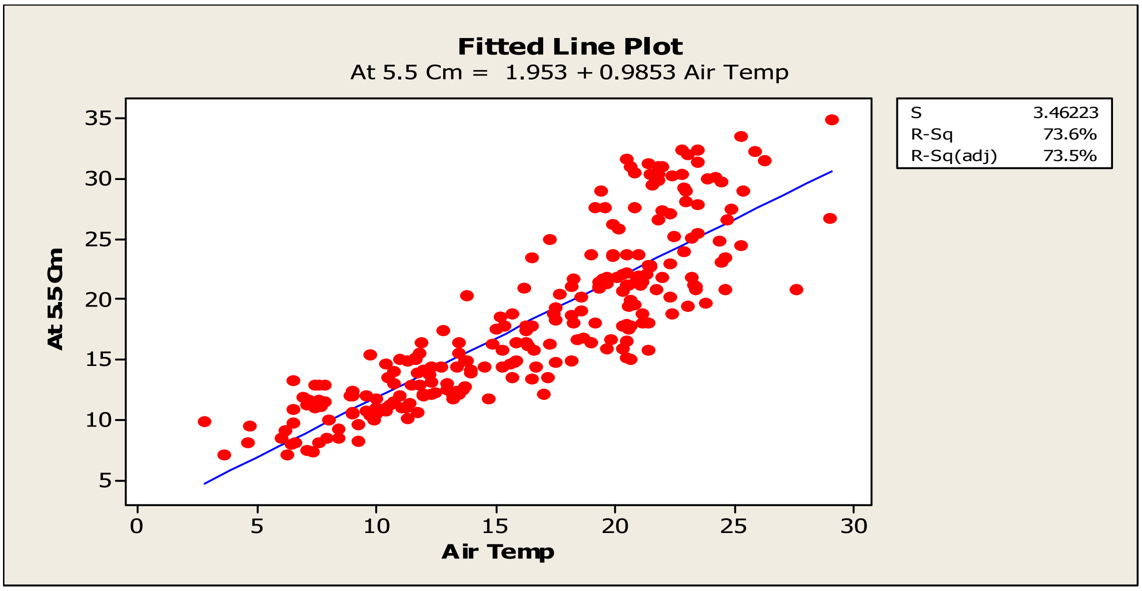

Figure B22:Incremental relationship between ambient and Asphalt at5.5Cm temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	8132.3	8132.29	678.42	0.000

D. **Regression Analysis: At 7 Cm of asphalt temperature vs ambient temperature:**

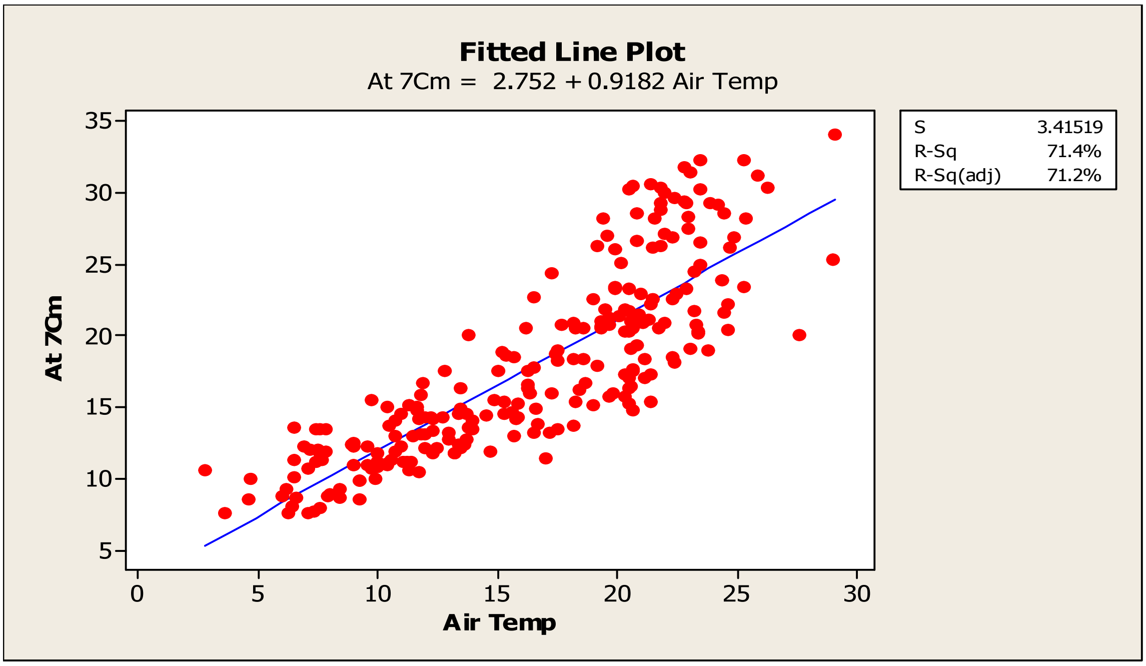

Figure B23:Incremental relationship between ambient and Asphalt at 7Cm temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7062.51	7062.51	605.52	0.000

Decreasing (16:00 to 24:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

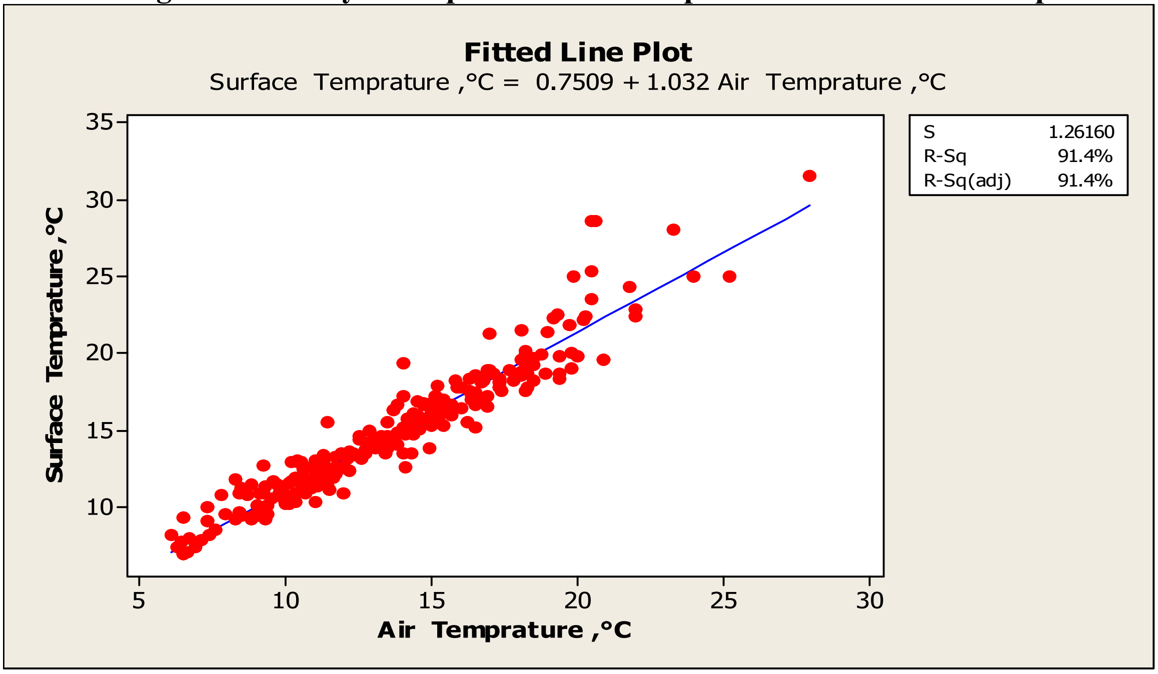

Figure B24: Decreasing relationship between ambient and Asphalt surface temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	4196.68	4196.68	2636.69	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

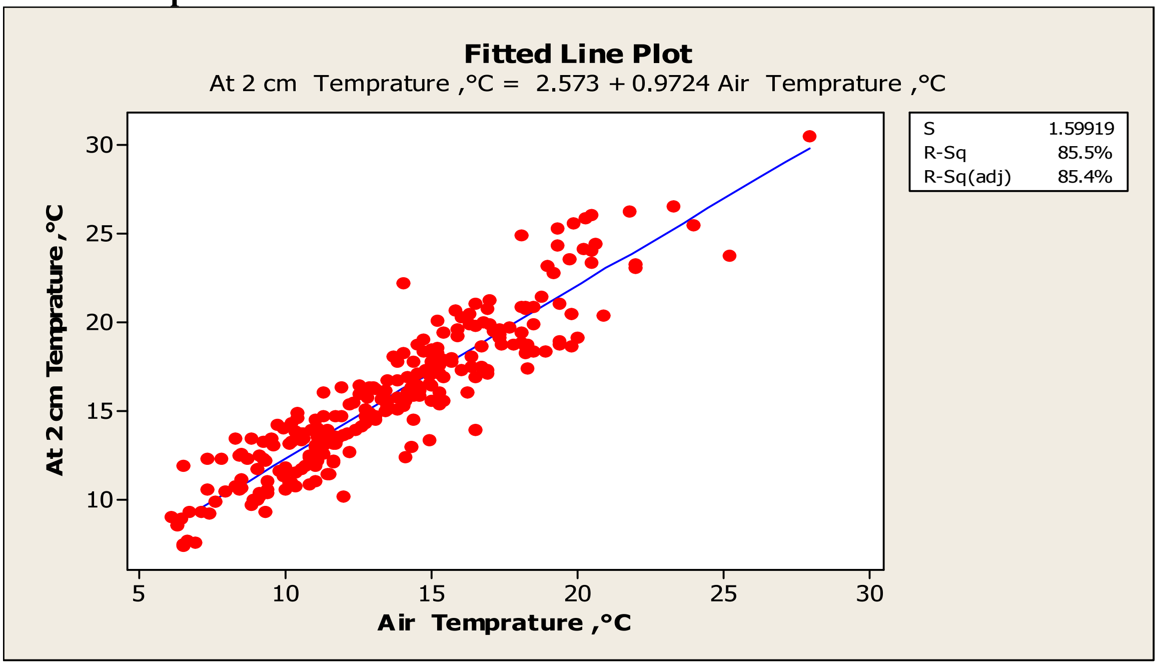

Figure B25: Decreasing relationship between ambient and Asphalt at 2Cm temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3727.02	3727.02	1457.34	0.000

C. **Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature**

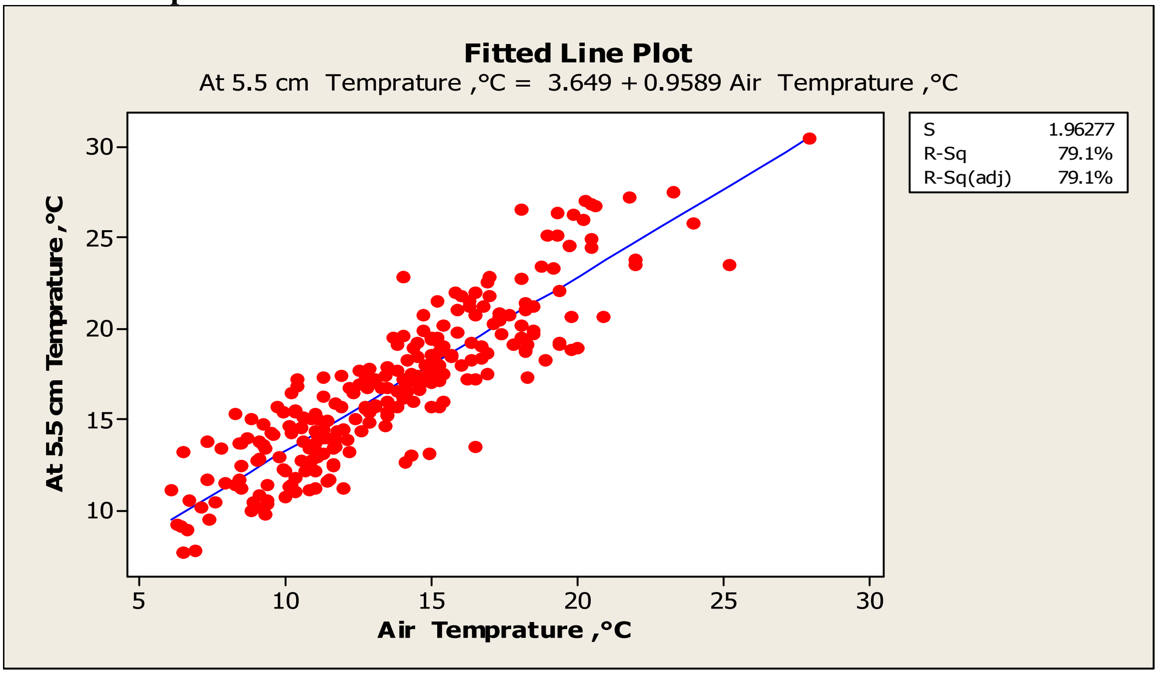

Figure B 26: Decreasing relationship between ambient and Asphalt at 5.5Cm temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3624.21	3624.21	940.75	0.000

D. **Regression Analysis: At 7 Cm of asphalt temperature vs ambient temperature**

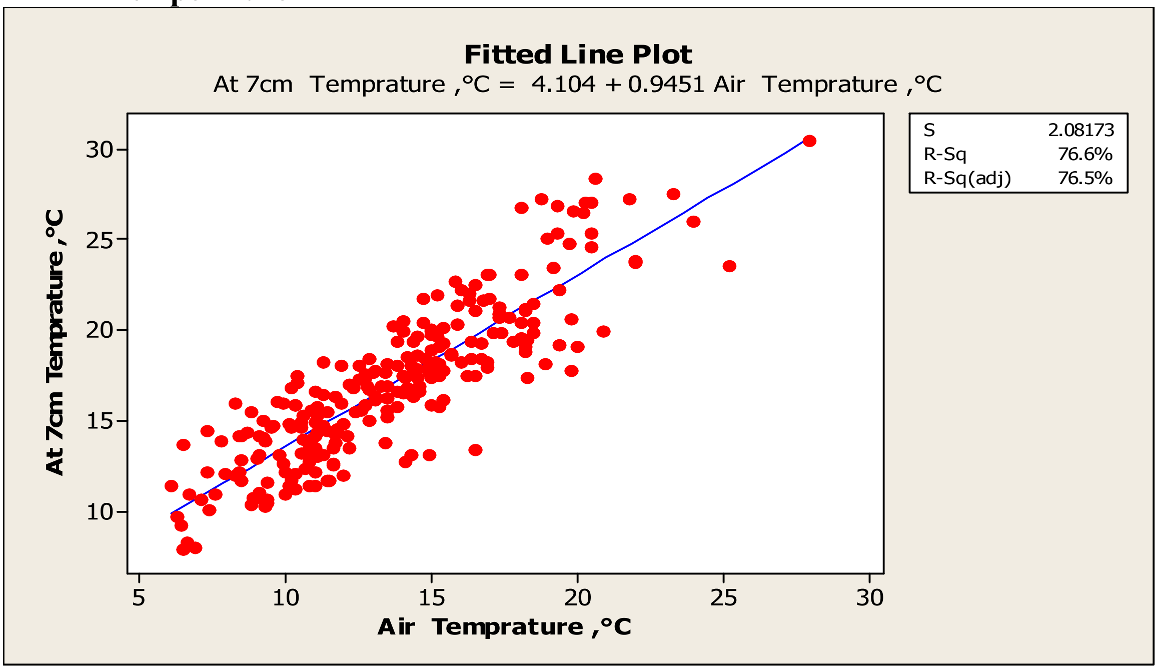

Figure B27: Decreasing relationship between ambient and Asphalt at 7Cm temperatures in winter

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3624.21	3624.21	940.75	0.000

2. **The Summer (21 June to 21September):**

2.1. Incremental (6:00 to 14:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

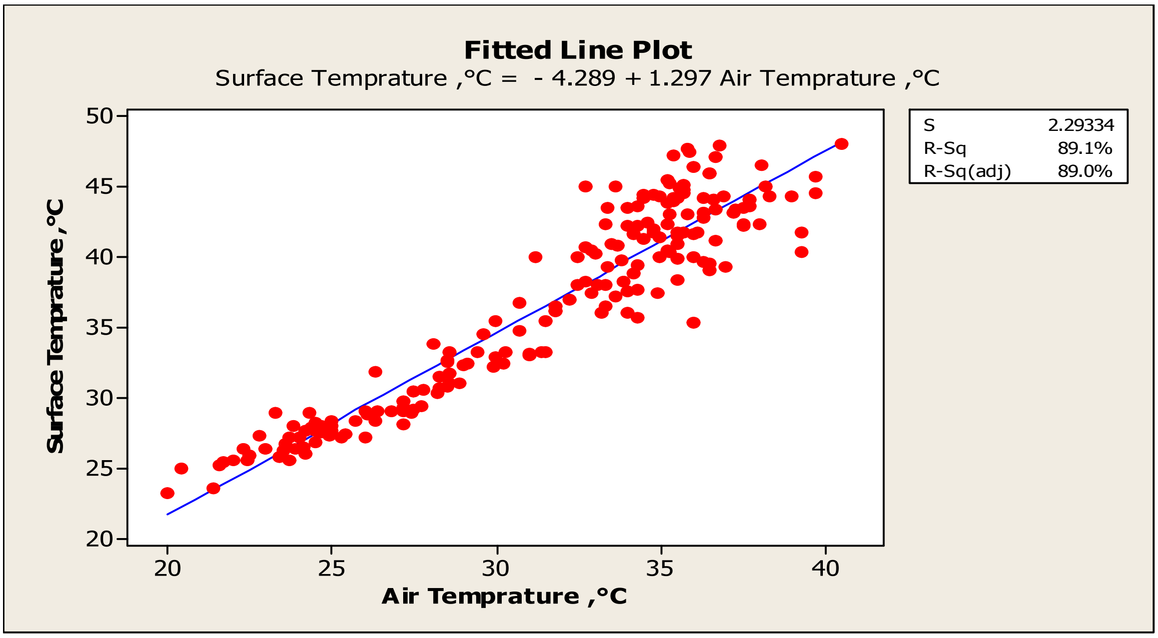

Figure B28: Incremental relationship between ambient an asphalt surface temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	8271.11	8271.11	1572.63	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

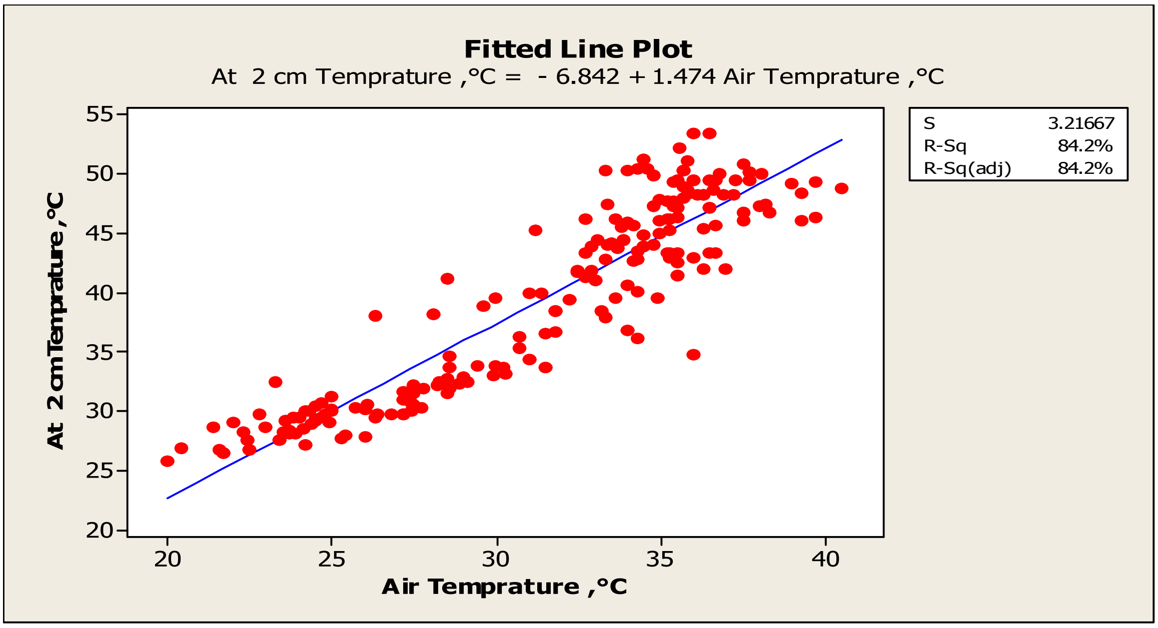

Figure B29:Incremental relationship between ambient and asphalt at 2cm temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	10682.1	10682.1	1032.40	0.000

C. Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature:

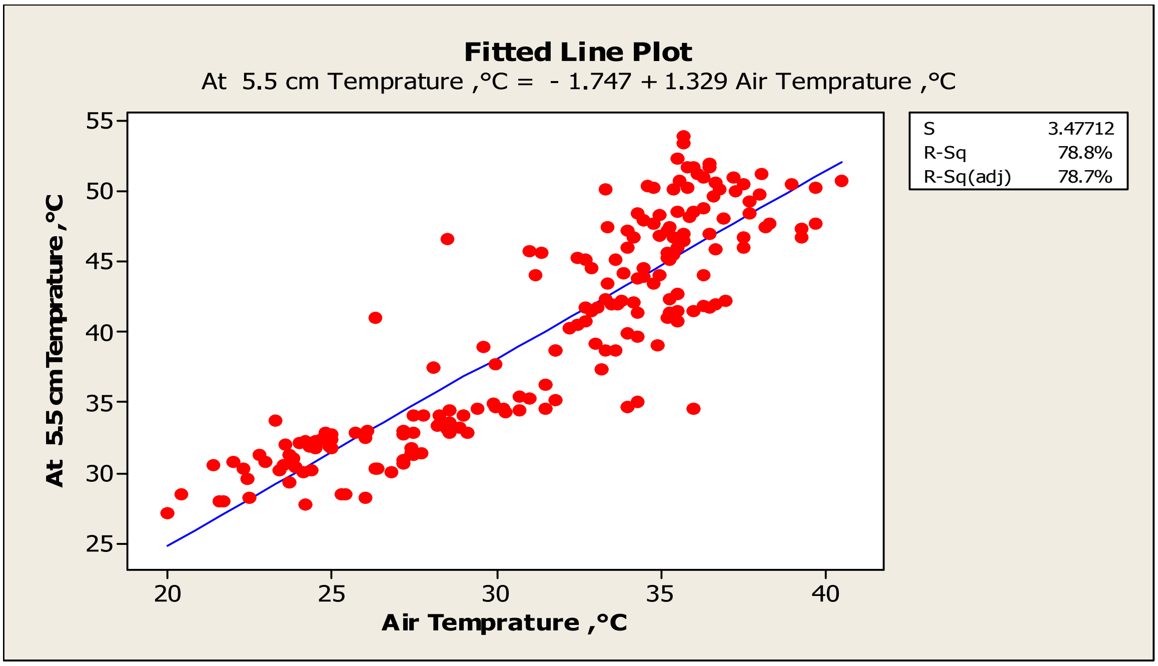

Figure B30:Incremental relationship between ambient and asphalt at 5.5Cm temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	8674.8	8674.75	717.49	0.000

D. Regression Analysis: At 7 Cm of asphalt temperature vs ambient temperature:

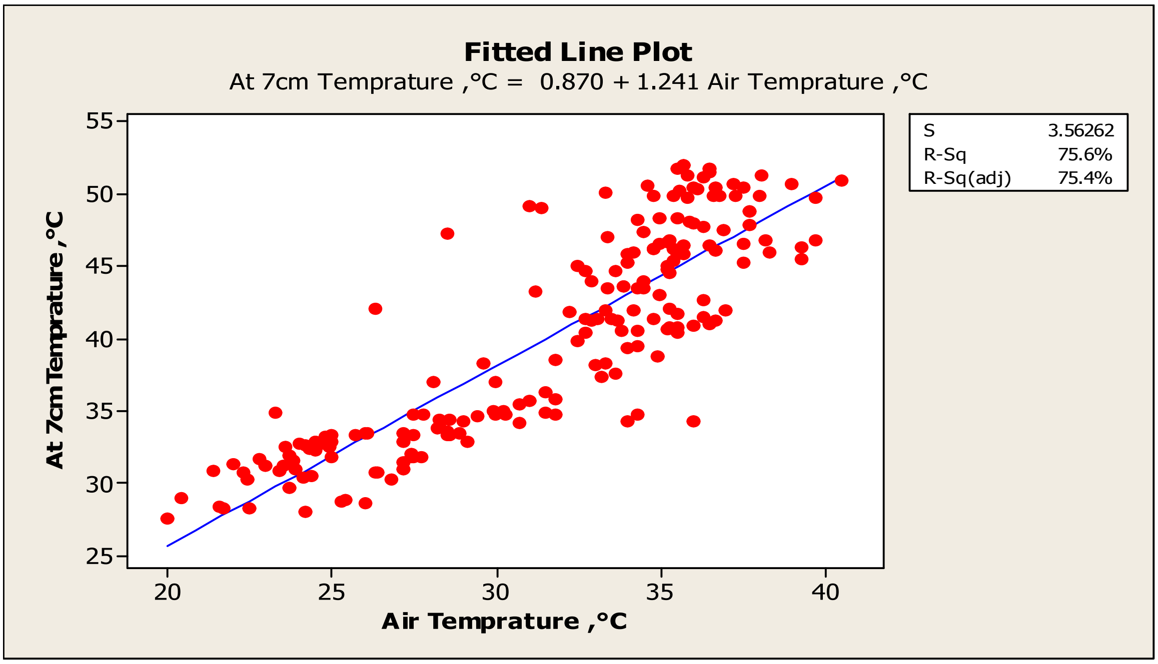

Figure B31:Incremental relationship between ambient and asphalt at 7 Cm temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7571.8	7571.84	596.57	0.000

2.2. Decreasing (16:00 to 24:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

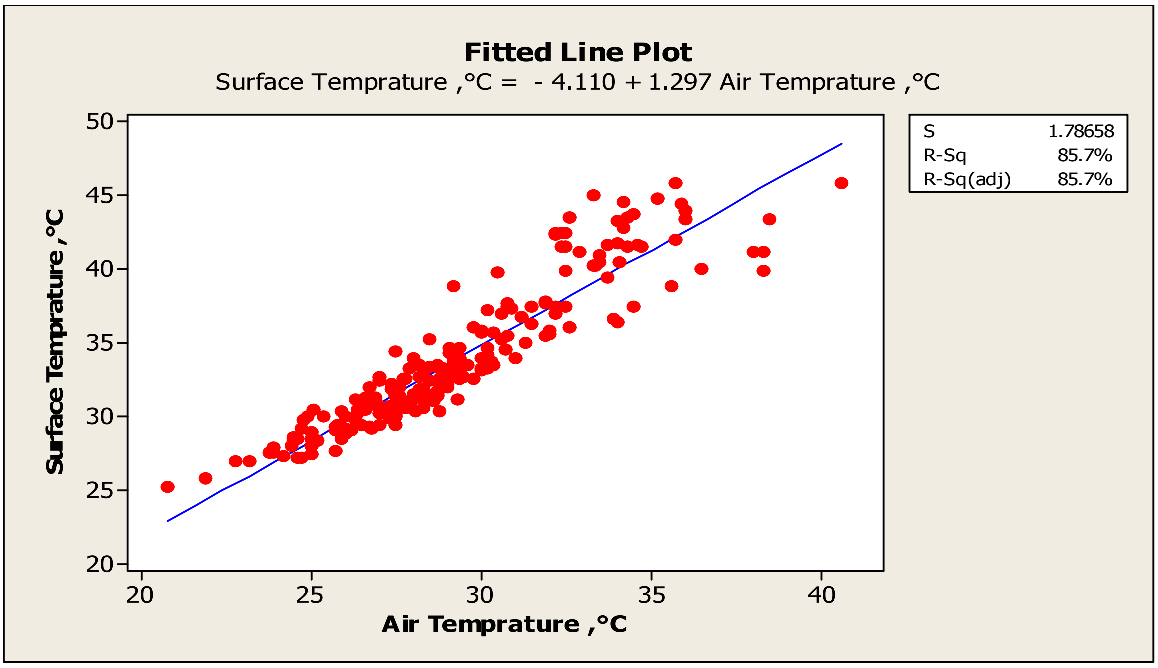

Figure B32:The Decreasing relationship between ambient and asphalt surface temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	4292.05	4292.05	1344.68	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

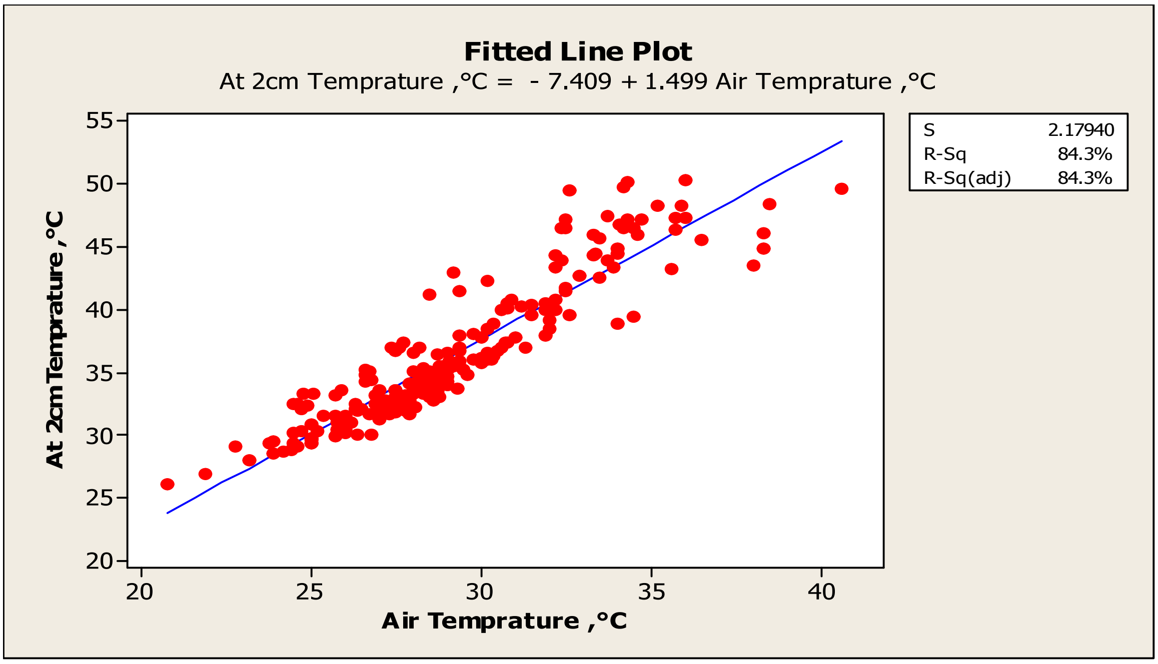

Figure B 33:The Decreasing relationship between ambient and asphalt At 2 Cm temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5733.38	5733.38	1207.09	0.000

C. Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature

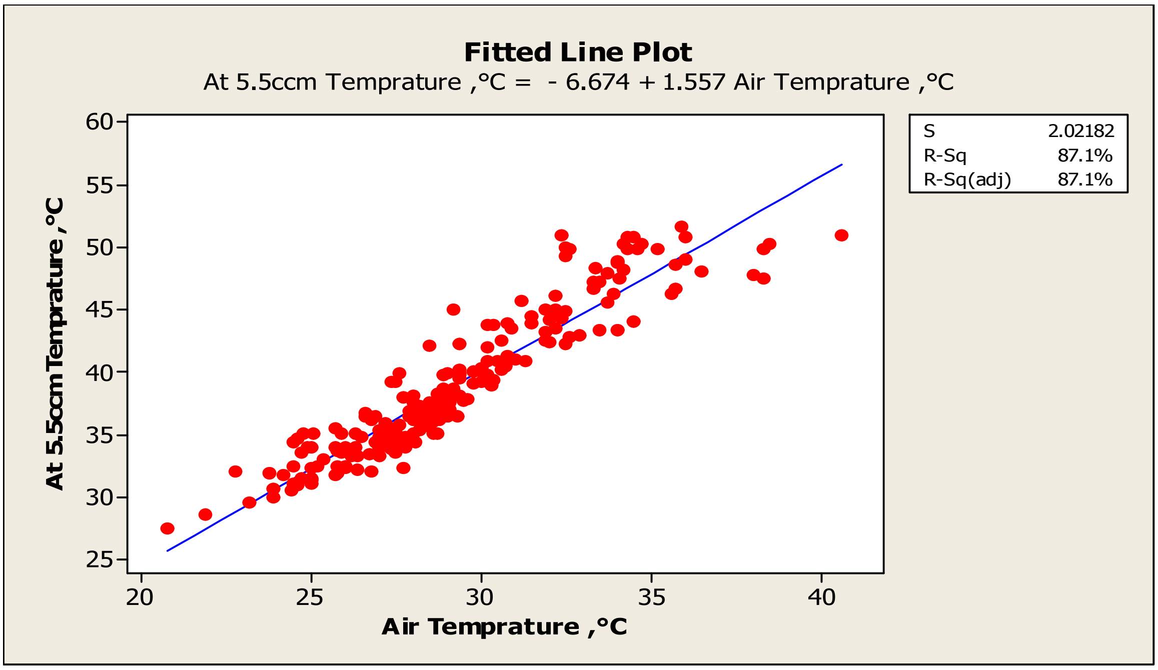

Figure B34:The Decreasing relationship between ambient and asphalt at 5.5Cm temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6187.35	6187.35	1513.64	0.000

D. Regression Analysis: At 7 Cm of asphalt temperature vs ambient temperature

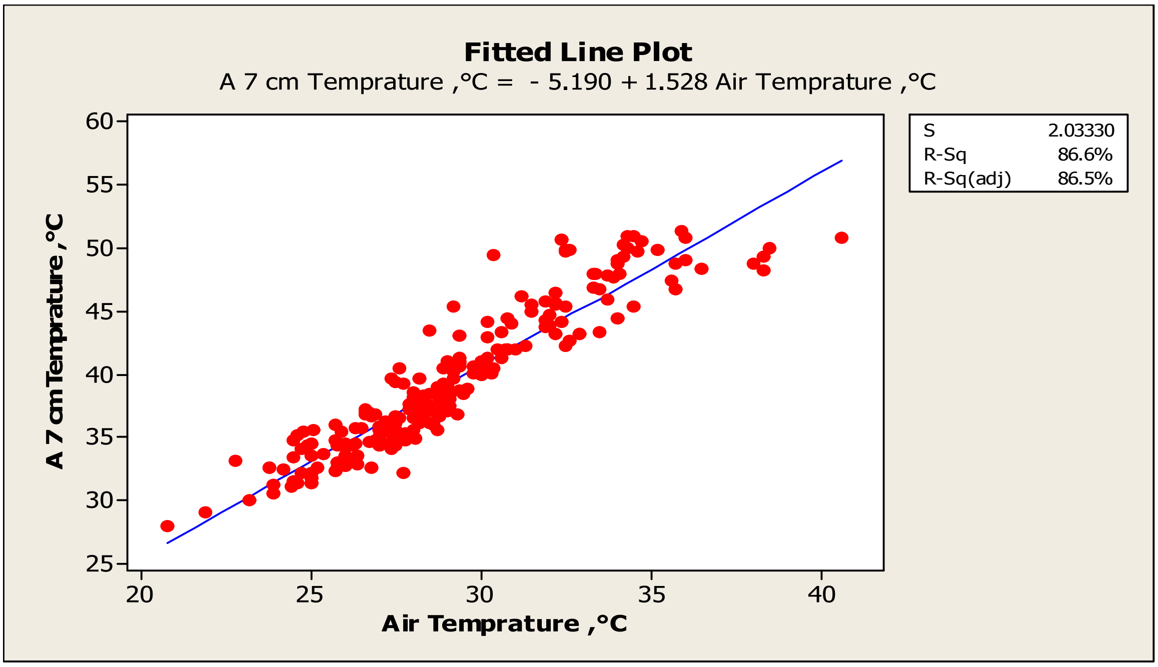

Figure B35:The Decreasing relationship between ambient and asphalt at 7 Cm temperatures in Summer

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5961.04	5961.04	1441.85	0.000

3. The spring (21 March to 22 September) :

3.1. Incremental (6:00 to 14:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

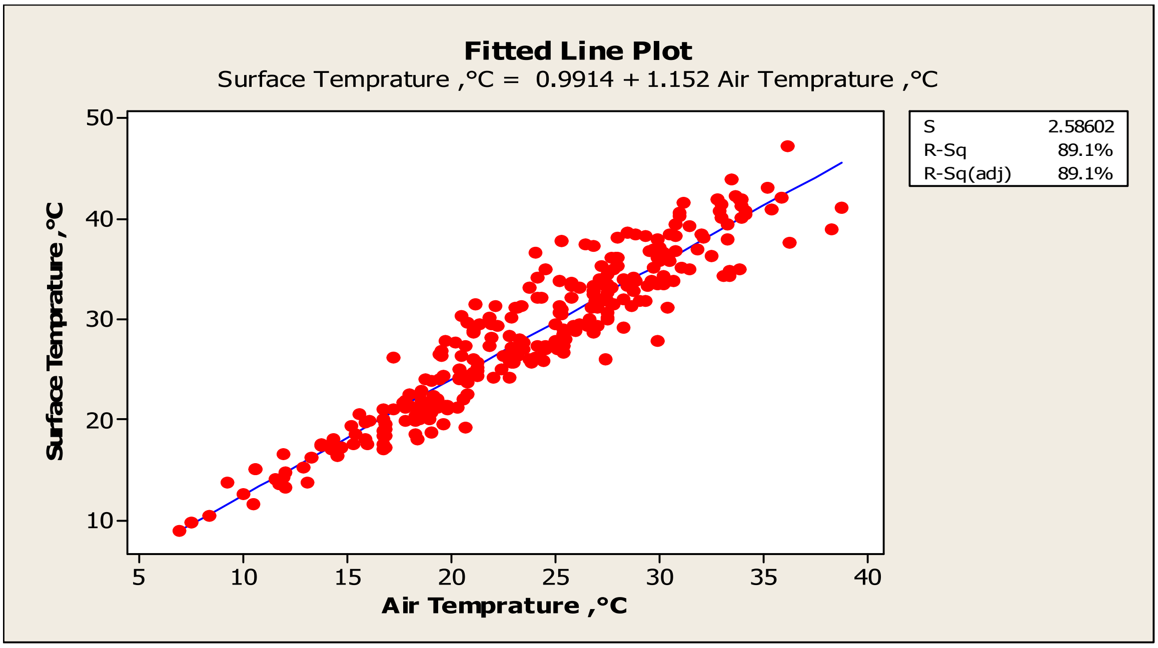

Figure B36:Incremental relationship between ambient and asphalt surface temperatures in spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	15185.1	15185.1	2270.67	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

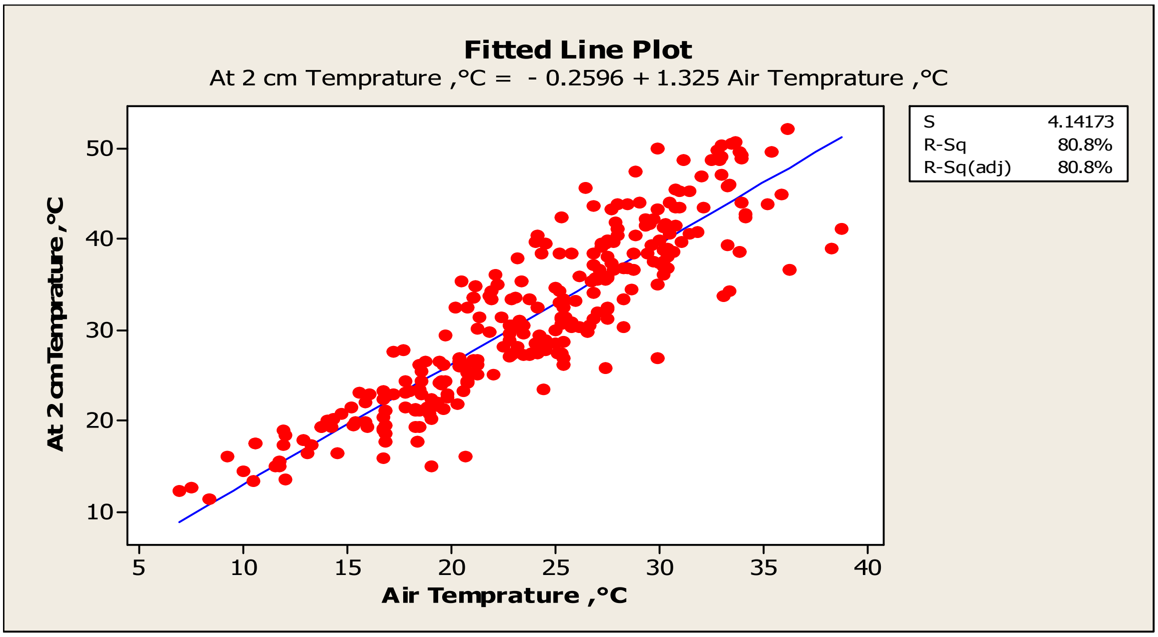

Figure B37:Incremental relationship between ambient and asphalt at 2 Cm temperatures in Spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	20115.6	20115.6	1172.65	0.000

C. **Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature:**

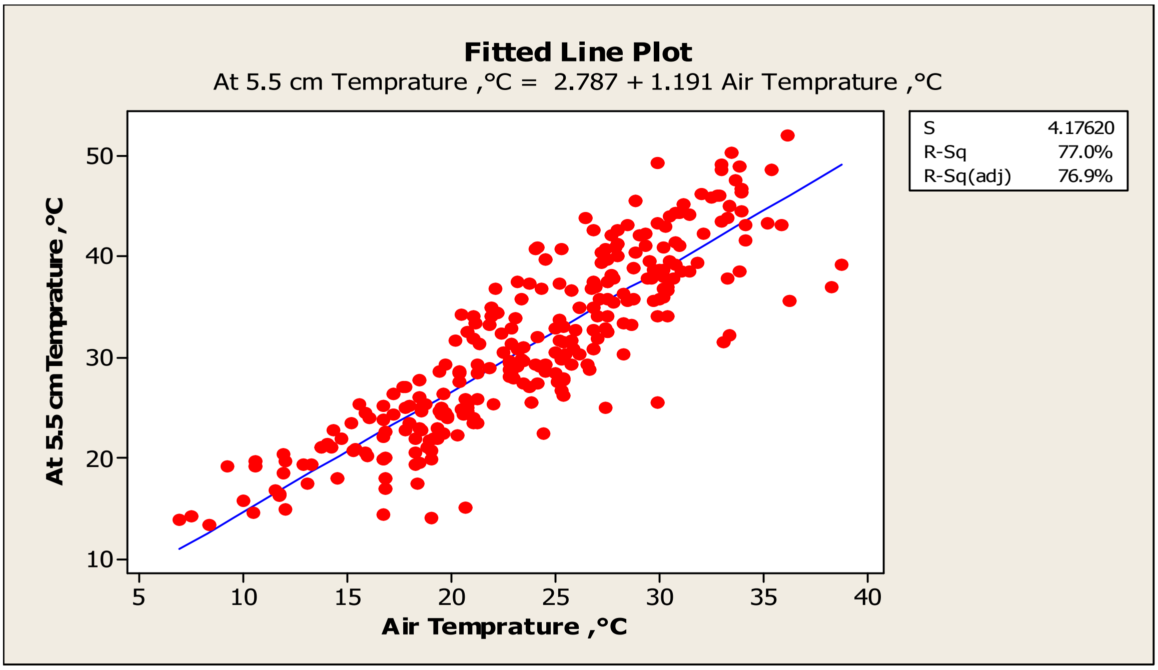

Figure B38:Incremental relationship between ambient and asphalt at 5.5 Cm temperatures in Spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	16250.0	16250.0	931.73	0.000

D. **Relation between air temperature and 7 Cm of Asphalt :**

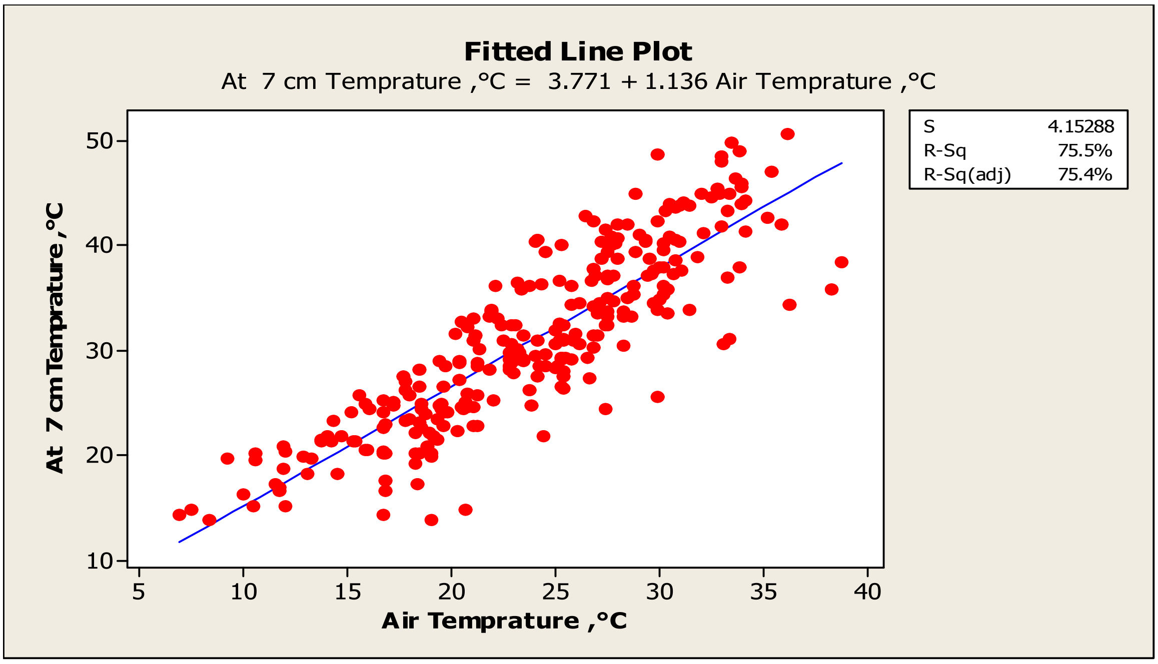

Figure B39::Incremental relationship between ambient and asphalt at 7Cm temperatures in Spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	14789.2	14789.2	857.52	0.000

3.2. Decreasing (16:00 to 24:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

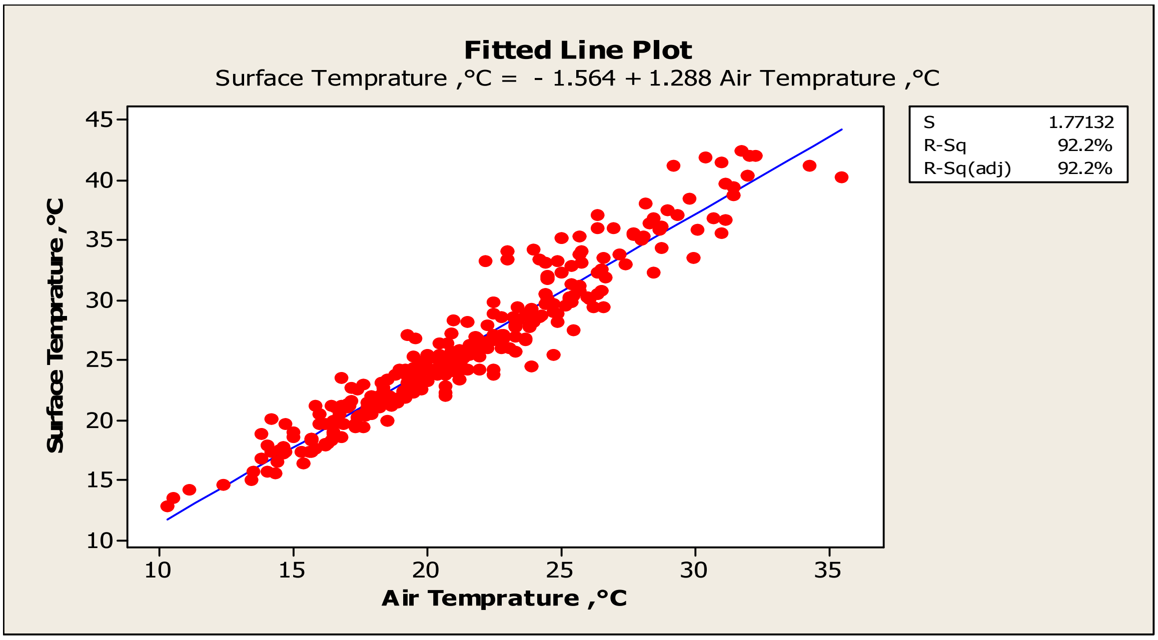

Figure B40: Decreasing relationship between ambient and asphalt surface temperatures in Spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	4292.05	4292.05	1344.68	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

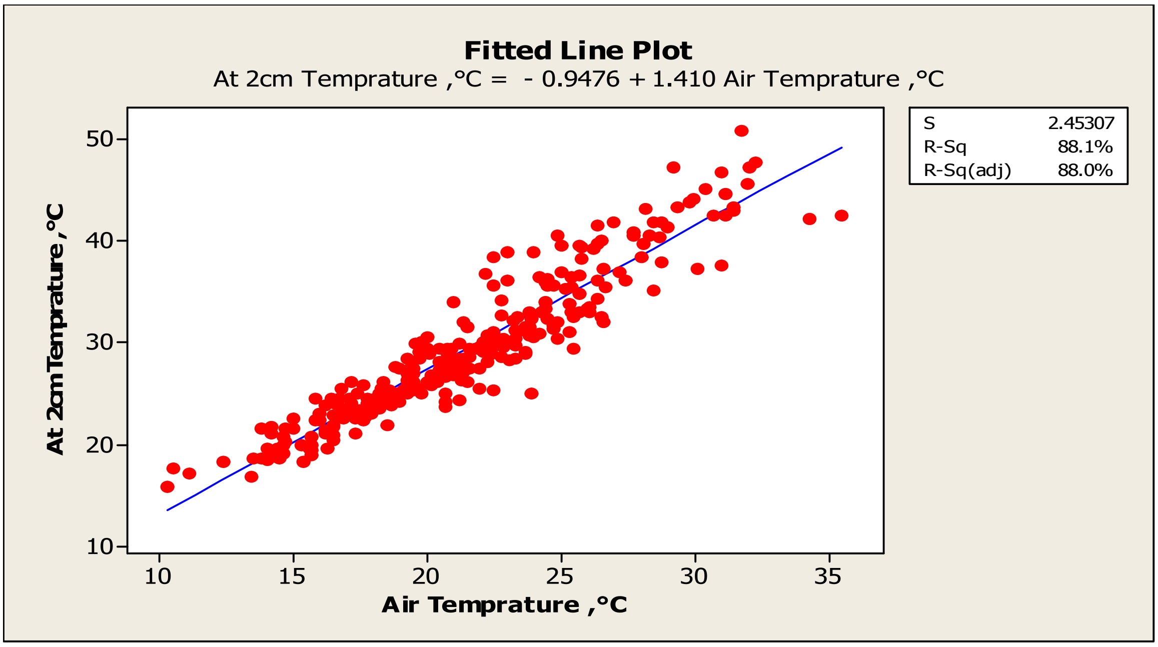

Figure B41: Decreasing relationship between ambient and asphalt at 2 Cm temperatures in Spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5733.38	5733.38	1207.09	0.000

C. Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature

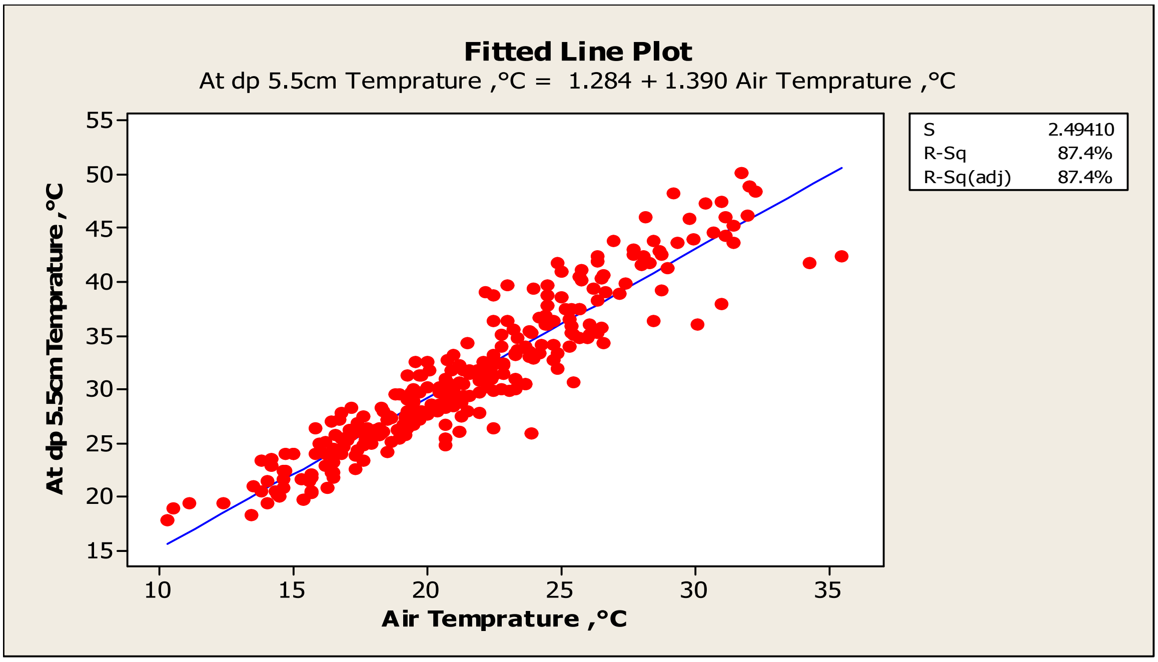

Figure B42: Decreasing relationship between ambient and asphalt 5.5Cm temperatures in Spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6187.35	6187.35	1513.64	0.000

D. Regression Analysis: At 7 Cm of asphalt temperature vs ambient temperature

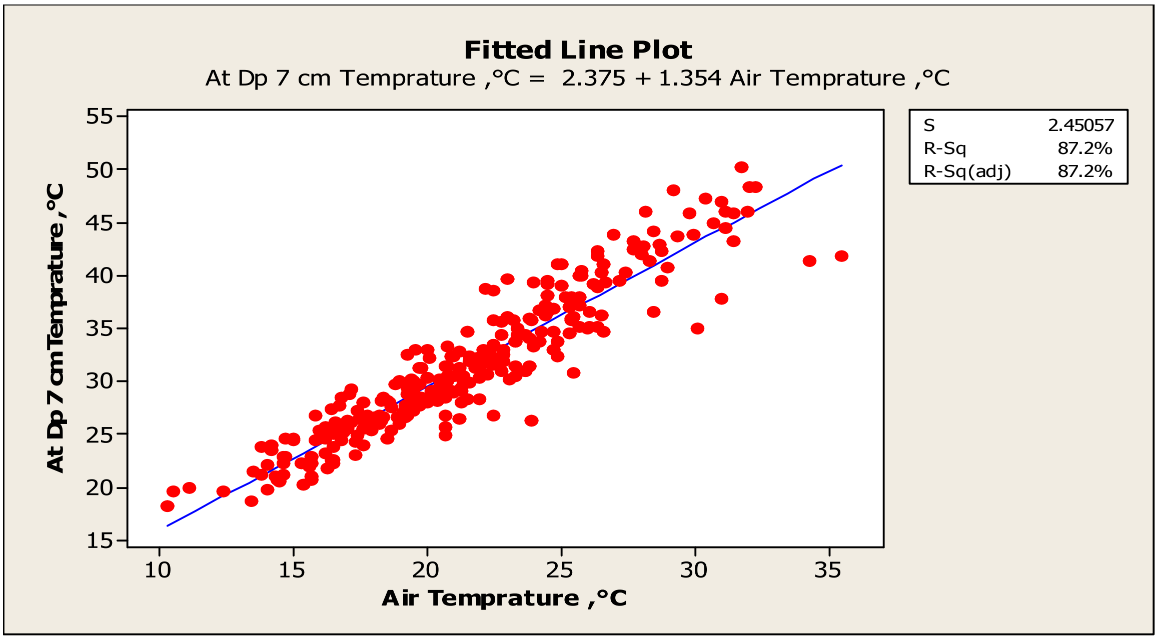

Figure B43: Decreasing relationship between ambient and asphalt 7 Cm temperatures in Spring

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5961.04	5961.04	1441.85	0.000

4. **The Autumn (22September to 21 December):**

4.1. Incremental (6:00 to 14:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

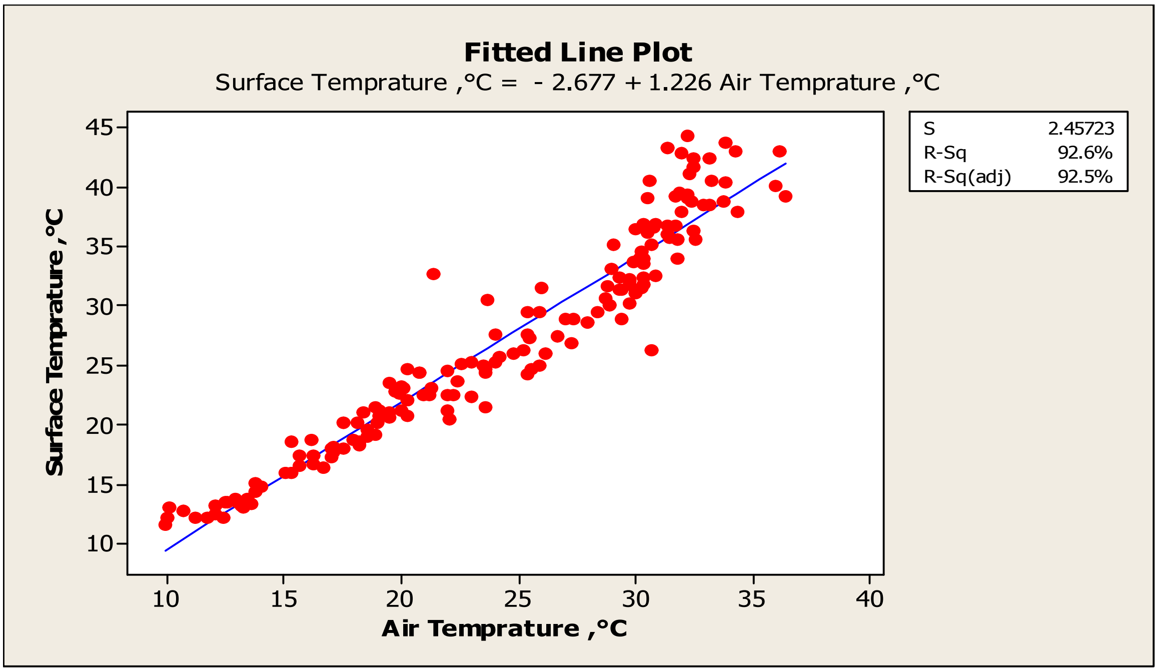

Figure B44:Incremental relationship between ambient and asphalt surface temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	12246.0	12246.0	2028.16	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

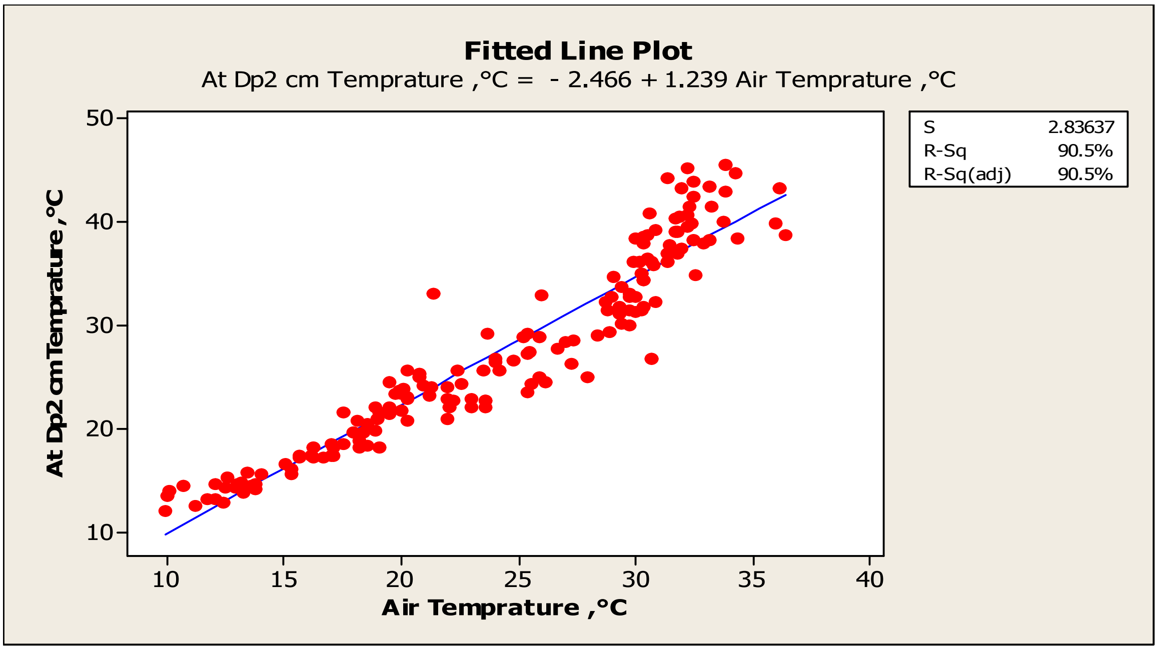

Figure B45: Incremental relationship between ambient and asphalt at 2 Cm temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	12508.5	12508.5	1554.82	0.000

C. Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature:

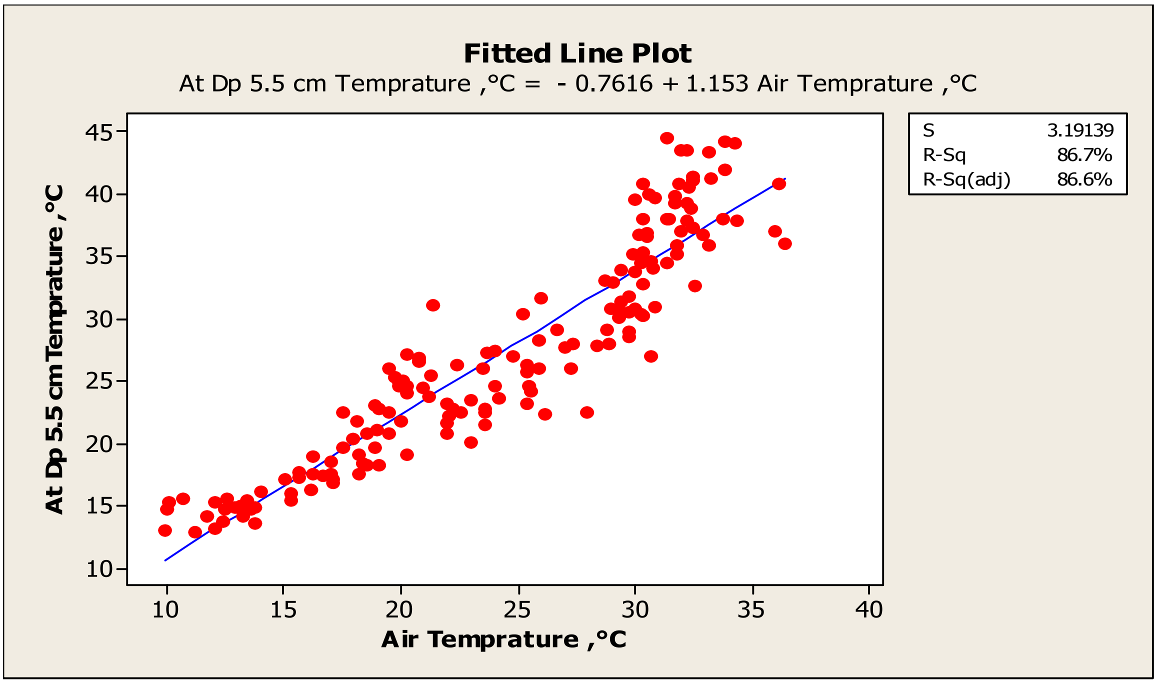

Figure B46:Incremental relationship between ambient and asphalt at 5.5Cm temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	10844.8	10844.8	1064.78	0.000

D. Regression Analysis: At 7 Cm of asphalt temperature vs ambient temperature:

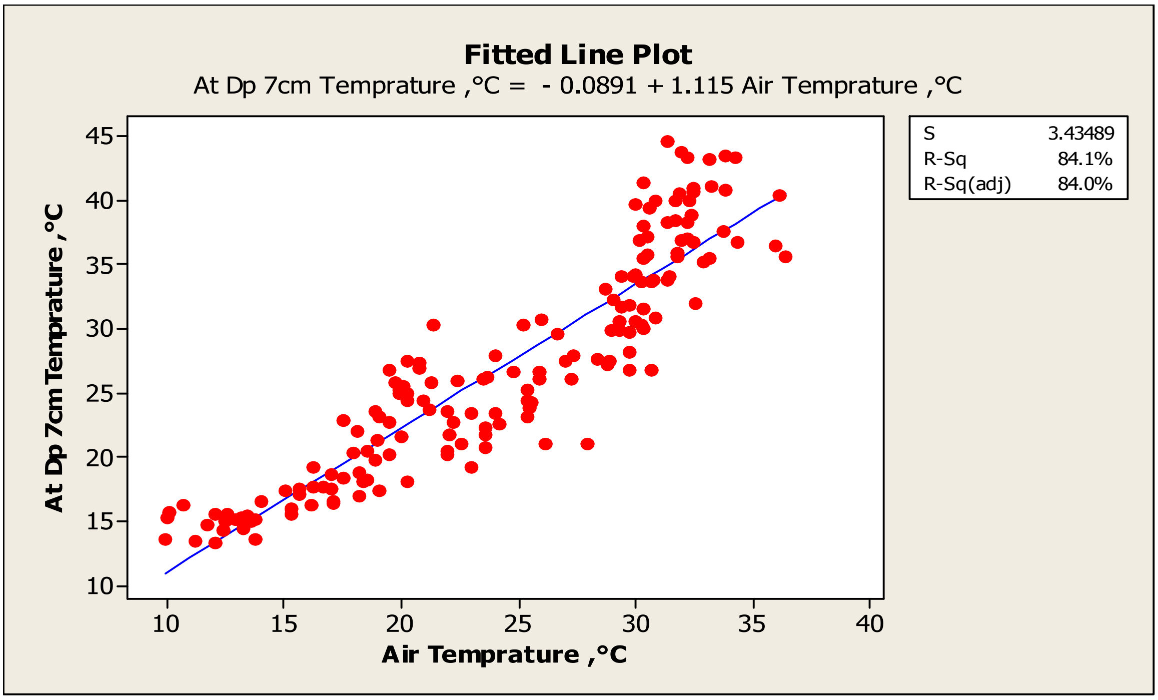

Figure B47:Incremental relationship between ambient and asphalt at7Cm temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	10143.6	10143.6	859.74	0.000

4.2. Decreasing (16:00 to 24:00)

A. Regression Analysis: Asphalt surface temperature vs ambient temperature:

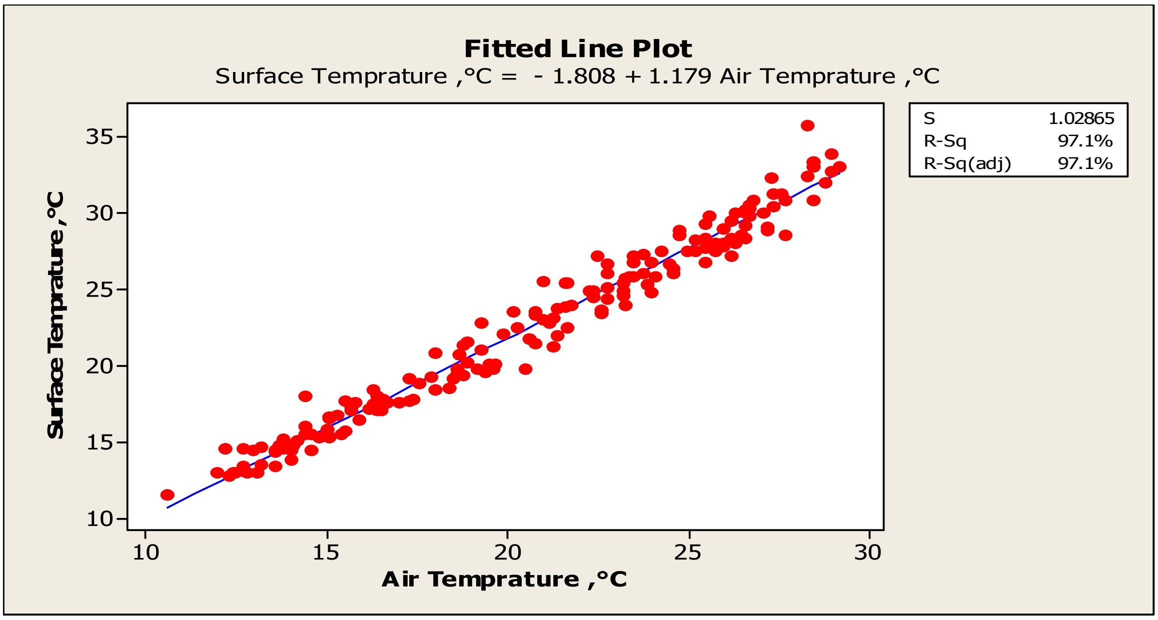

Figure B48: Decreasing relationship between ambient and asphalt surface temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6205.30	6205.30	5864.50	0.000

B. Regression Analysis: At 2 Cm of asphalt temperature vs ambient temperature:

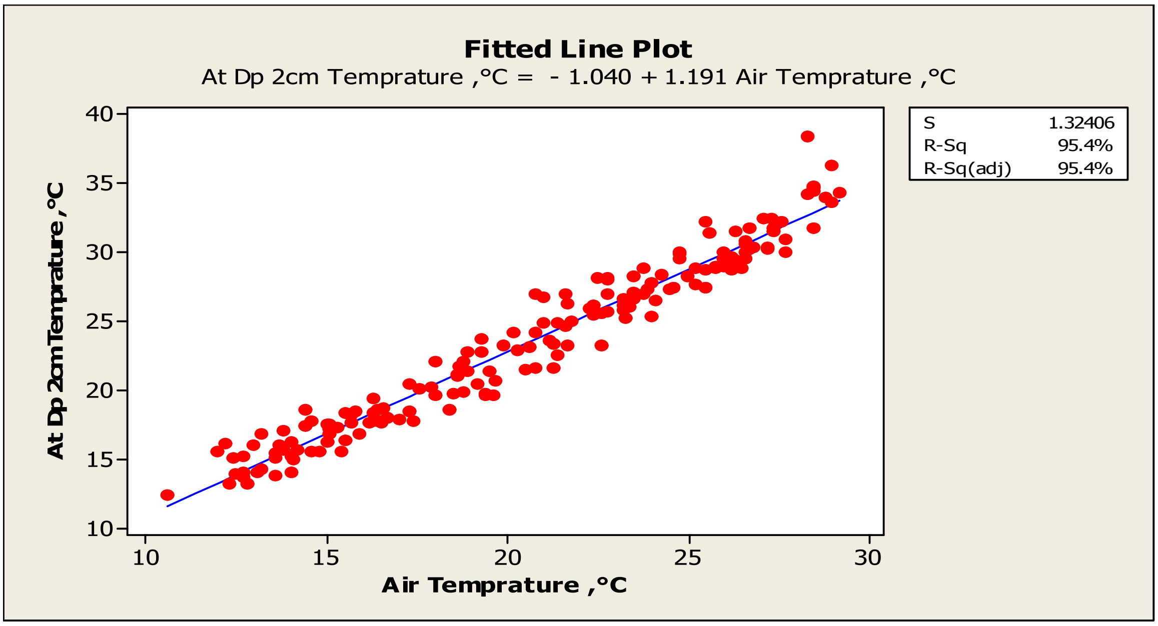

Figure B49: Decreasing relationship between ambient and asphalt at 2Cm temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6335.26	6335.26	3613.69	0.000

C. Regression Analysis: At 5.5 Cm of asphalt temperature vs ambient temperature

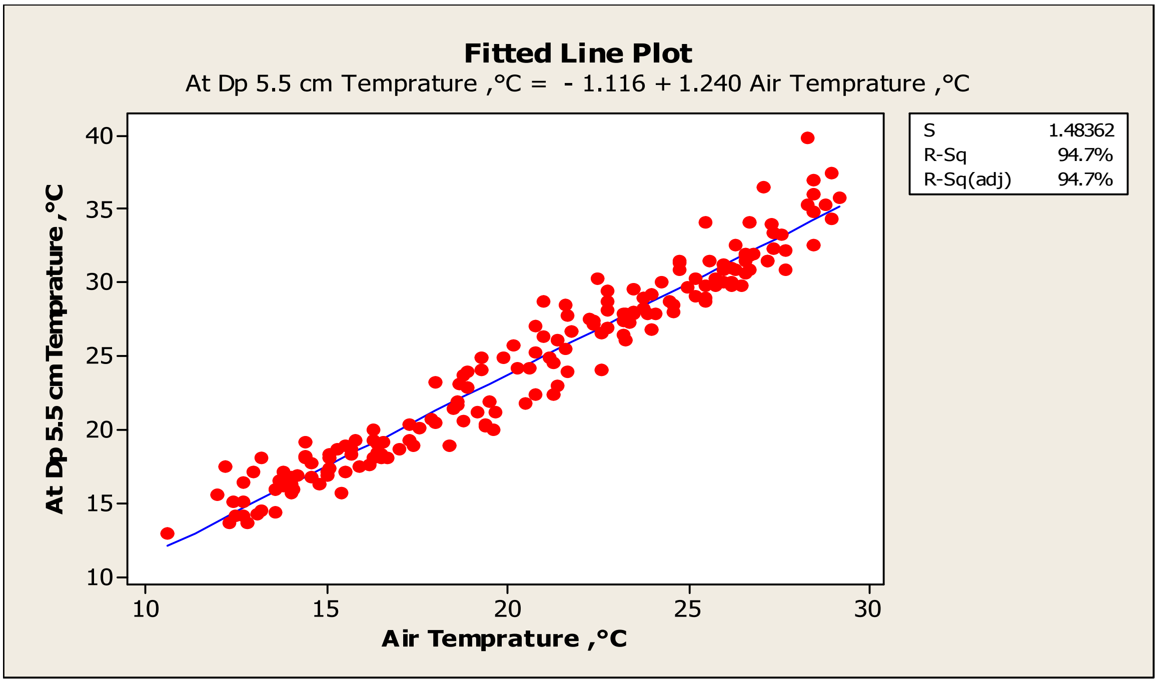

Figure B50: Decreasing relationship between ambient and asphalt at 5.5Cm temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6870.52	6870.52	3121.34	0.000

D. Regression Analysis: At 7 Cm of asphalt temperature vs ambient temperature

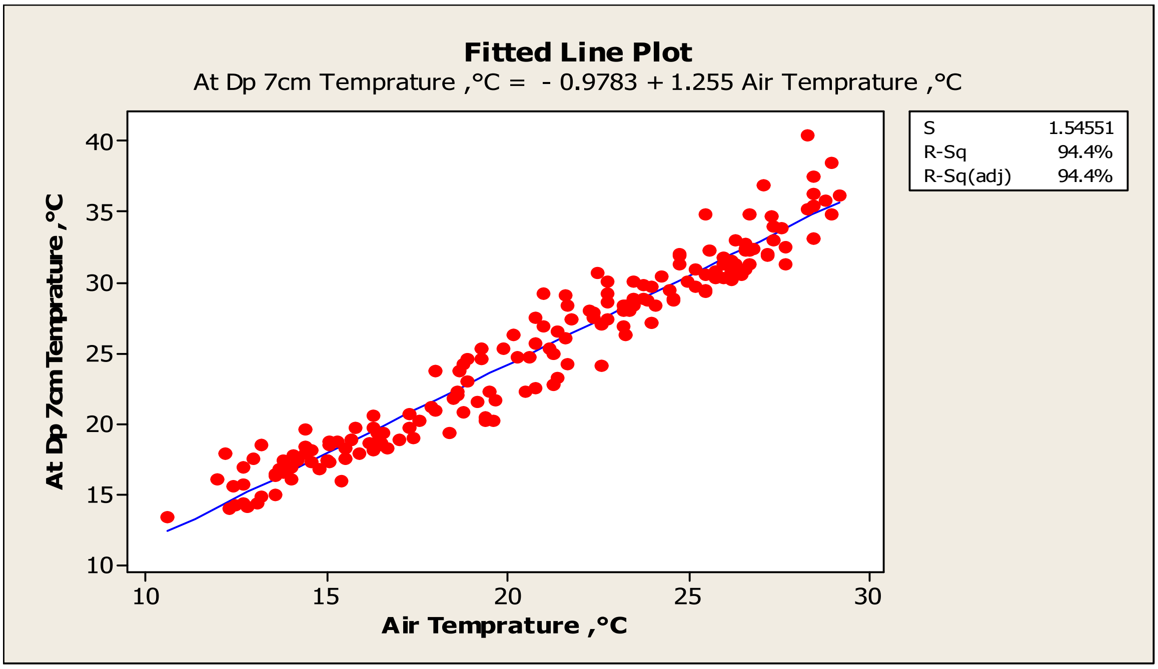

Figure B51: Decreasing relationship between ambient and asphalt at 7Cm temperatures in Autumn

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7032.15	7032.15	2944.04	0.000

Appendix C

Other Regression Relations

Table 1 : Upward regression relation between ambient and pavement depths temperature in winter season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.885124
R Square	0.783445
Adjusted R	0.783001
Standard E	3.159396
Observatio	980

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regressio	2	35281.09	17640.55	1767.275	0
Residual	977	9752.199	9.98178		
Total	979	45033.29			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.364712	0.327107	4.172067	3.29E-05	0.72279878	2.0066244	0.72279878	2.00662435
Z	-0.03017	0.036437	-0.82802	0.407862	-0.10167372	0.0413331	-0.1016737	0.04133306
Air temper	1.026005	0.017259	59.44631	0	0.99213571	1.0598751	0.99213571	1.05987509

Y(z)= 1.026005X -0.03017 Z +1.364712

Table 241 :Downward regression relation between ambient and pavement depths temperature in winter season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.914026
R Square	0.835444
Adjusted R	0.835114
Standard E	1.763953
Observatio	1000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regressio	2	15749.67	7874.836	2530.857	0
Residual	997	3102.194	3.111529		
Total	999	18851.87			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.675811	0.212258	7.895177	7.61E-15	1.259288482	2.0923344	1.2592885	2.092334353
Z	0.301679	0.020139	14.97991	6.6E-46	0.262159654	0.3411987	0.2621597	0.341198717
Air	0.977098	0.014049	69.55082	0	0.949530088	1.0046669	0.9495301	1.004666907

Y(z)=0.977098 X -0.0301679 Z +1.675811

Table 3:Upward regression relation between ambient and pavement depths temperature in

summer season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.900119
R Square	0.810214
Adjusted R	0.809726
Standard E	3.301556
Observatio	780

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regressio	2	36157.23	18078.62	1658.547	4E-281
Residual	777	8469.513	10.90027		
Total	779	44626.75			

	Coefficient	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-4.55834	0.765787	-5.95249	4E-09	-6.0616	-3.05508	-6.061596197	-3.05508145
Z	0.429359	0.04268	10.06005	1.83E-22	0.345578	0.51314	0.345578192	0.51314028
Air	1.335347	0.023547	56.70881	2.1E-278	1.289122	1.381571	1.289122487	1.38157071

Y(z)= 1.335347 X +0.429359 Z -4.55834

Table 4:Downward regression relation between ambient and pavement depths temperature in summer season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.935642
R Square	0.875427
Adjusted R	0.875106
Standard E	2.062308
Observatio	780

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regressio	2	23223.22	11611.61	2730.143	0
Residual	777	3304.671	4.253115		
Total	779	26527.9			

	Coefficient	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-8.93439	0.657347	-13.5916	6.68E-38	-10.2248	-7.64399801	-10.22477255	-7.64399801
Z	0.893278	0.028337	31.52374	4E-141	0.837652	0.94890312	0.837652152	0.94890312
Air	1.473041	0.022229	66.26683	0	1.429405	1.51667693	1.429405159	1.51667693

Y(z)= 1.473041 X +0.993278 Z -8.93439

Table 5:Upward regression relation between ambient and pavement depths temperature in spring season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.890666
R Square	0.793287
Adjusted R	0.792917
Standard E	3.946438
Observatio	1120

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regressio	2	66761.42	33380.71	2143.31	0
Residual	1117	17396.58	15.57438		
Total	1119	84157.99			

	Coefficients	*tandard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.806081	0.480698	1.676897	0.093842	-0.13709	1.74925411	-0.1370918	1.74925411
Z	0.280394	0.042574	6.586027	6.94E-11	0.19686	0.36392847	0.19686001	0.36392847
Air	1.201174	0.01844	65.14018	0	1.164993	1.23735454	1.16499332	1.23735454

$$Y(z)= 1.201174\ X +0.280394\ Z +0.806081$$

Table 6 :Downward regression relation between ambient and pavement depths temperature in spring season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.940838
R Square	0.885176
Adjusted R	0.884967
Standard E	2.422033
Observatio	1100

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regressio	2	49609.55	24804.78	4228.392	0
Residual	1097	6435.269	5.866243		
Total	1099	56044.82			

	Coefficients	*tandard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2.34617	0.355141	-6.60631	6.13E-11	-3.0430007	-1.6493367	-3.0430007	-1.64933673
Z	0.726342	0.026365	27.54914	2.1E-127	0.674609647	0.77807393	0.67460965	0.77807393
Air	1.360456	0.015506	87.73727	0	1.330031614	1.39088126	1.33003161	1.390881257

$$Y(z)= 1.360456\ X +0.7263424\ Z -2.34617$$

Table 7:Upward regression relation between ambient and pavement depths temperature in autumn season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.940838
R Square	0.885176
Adjusted R	0.884967
Standard E	2.422033
Observatio	1100

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regressio	2	49609.55	24804.78	4228.392	0
Residual	1097	6435.269	5.866243		
Total	1099	56044.82			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2.34617	0.355141	-6.60631	6.13E-11	-3.0430007	-1.649337	-3.0430007	-1.64933673
Z	0.726342	0.026365	27.54914	2.1E-127	0.67460965	0.7780739	0.67460965	0.77807393
Air	1.360456	0.015506	87.73727	0	1.33003161	1.3908813	1.33003161	1.39088126

Y(z)= 1.360456 X +0.726342 Z -2.34617

Table 8:Downward regression relation between ambient and pavement depths temperature in autumn season

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.976325
R Square	0.953211
Adjusted R	0.953078
Standard E	1.37149
Observatio	708

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regressio	2	27015.98	13507.99	7181.339	0
Residual	705	1326.094	1.880985		
Total	707	28342.07			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2.43138	0.228188	-10.6551	1.11E-24	-2.879385196	-1.983364901	-2.879385196	-1.983364901
Z	0.329887	0.018609	17.7272	1.99E-58	0.29335124	0.366423002	0.29335124	0.366423002
Air	1.216342	0.010262	118.526	0	1.196194196	1.236490606	1.196194196	1.236490606

Y(z)= 1.216342 X +0.329887 Z -2.43138