Manufacturing of Temperature Controller Device for Creep Testing of Subgrade Pavement Layer

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Abstract:

We offer through this paper a new innovation through which contribute in supplying the march of scientific research in the field of highway and transportation engineering with ideas and various supplies that help engineers, researchers and graduate students to develop the field of scientific research thereby contributing to solving the problems facing the engineer on site, Which summarized this study manufactures electrical electronic device with ideas Iraqi cashed and potential available locally to control on (install heat of the sample to temperatures up to 70 ° C) to know its impact on the amount of creep of soil sample and for long periods so that the degree examination temperature remains constant throughout the laboratory testing period, To evaluate and study the behavior of the creep of the soil under the influence of changing temperatures and to reach for realistic solutions to treatment this impact and ensuring the sustainability of subgrade pavement layer.

Keyword: *Creep, Temperature, Controller Device, Subgrade.*

1. Introduction

The creep of clayey subgrade soils is understood to be a process of deformation progressing in time under a constant stress and temperature. Owing to the creep of subgrade layer, stress redistribution occurs with a subsequent drop of the strength, and hence decreases in the value of the safety factor of the pavement structure. In addition, the seasonal variation in temperature in the subgrade layer tends to change throughout the pavement's life. The influence of temperature on the behavior and properties of subgrade soils influences pavement performance, and distress of pavement structures.

Experimental investigation of creep in a clayey subgrade layer under constant stress, with consideration of variation of temperature and dry density is a very difficult task. Therefore, despite of urgency of the problem, not published on this matter. And because of the unavailability of the required devices to measure the effect of changing temperature on the creep subgrade layer, therefore it is important to investigate, and study effects of combined temperature and creep characteristics of the response of subgrade pavement layer performance throughout a design temperature controller device to control on temperature during experimental test period and used oedometer apparatus to analysis creep behavior of pavement layers.

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The measurement system for temperature of water in the cell of the soil is a critical task in this study. In this paper designed and implemented water temperature controller to increased water temperature and system measurement using a standard PID temperature controller (MTA-48) and thermocouple type (k) as a temperature sensor. The designing system is used to measure the temperature value of water in the cell. If the temperature value reaches the set value high temperature relay board becomes ON to control the water temperature value and makes the decision to turn off the heater. This value is controlled manually based on the requirement of temperature. Temperature monitoring is the operation of reading temperatures over a specified period of time. The temperature controller is a process in which variation of temperature of water in the cell and objects collectively there within is measured adjusted to achieve a desired temperature.

2. Aims and scope of the study

The main objective of the presented study to evaluate the effect of creep characteristics on the response of subgrade pavement layer under the influence of static stress with variation in degrees of temperature throughout designed and implemented temperature controller device.

3. System Requirements

The water temperature control system is implemented depends on PID temperature controller (MTA-48) to control and stability of the value of temperature in the cell of apparatus. Using the PID temperature controller (MTA-48) system in the control device is very practical because of its flexibility, low cost and keeping the temperature of the cell fixed all the time. Figure (1) shows the block diagram for the system.

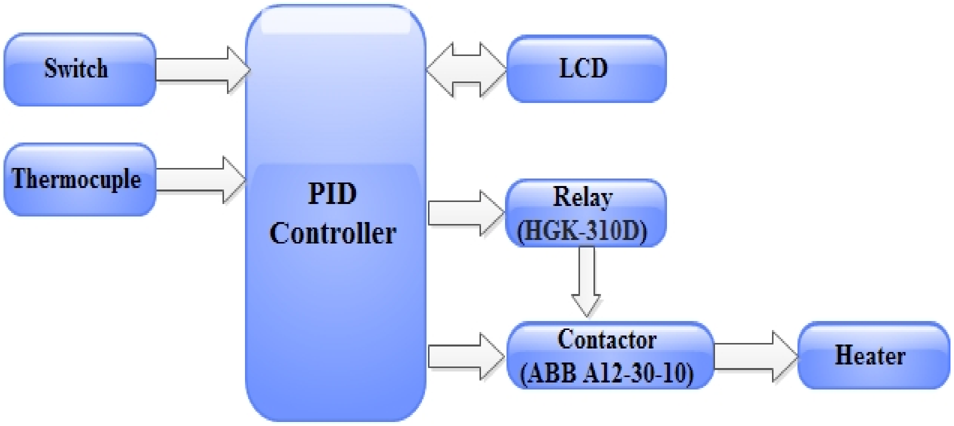


Figure (1). The Block Diagram for the System.

So the components required to implement the system are:

a) PID Temperature Controller (MTA-48)

The PID algorithm is the most common feedback controller applied within the process industries. It has been successfully utilized for over 50 years. It is a robust easily comprehended algorithm that can supply excellent control performance in spite of the different dynamic characteristics of plant operation. A PID controller persistently calculates an error magnitude as the variance between a measured operation variable and a demand set point. The controller tries to reduce the error over time through modification of a control variable ***(Sarhan, 2014)***.

The PID controller algorithm includes three constant separate parameters: (the proportional, the integral and derivative values, indicated P, I, and D), these values may be explicated in terms of time; P based on the current error, I depend on the accumulation of bygone errors, and D is estimation of future errors, depend on current rate of variation. The total weighted of these three actions is utilized to modify the process by a control element in the system. Through setting the three parameters in the PID temperature controller, this controller can supply control action designed for particular operational requirements. The reply of the controller may be expressed in terms of the responsiveness of the controller to an error, the degree of system oscillation, and the degree to which the controller overshoots the set point ***(Santos and Rodrigues, 1999)***.

In general, the block diagram of PID controller is shown in Figure (2), where $y(t)$ is the system output signal (process variable pv), $u(t)$ is the controller output signal, $r(t)$ is the reference (setpoint sp) input of the system, and $e(t)$ is the error signal, which is the difference between $r(t)$ and $y(t)$.

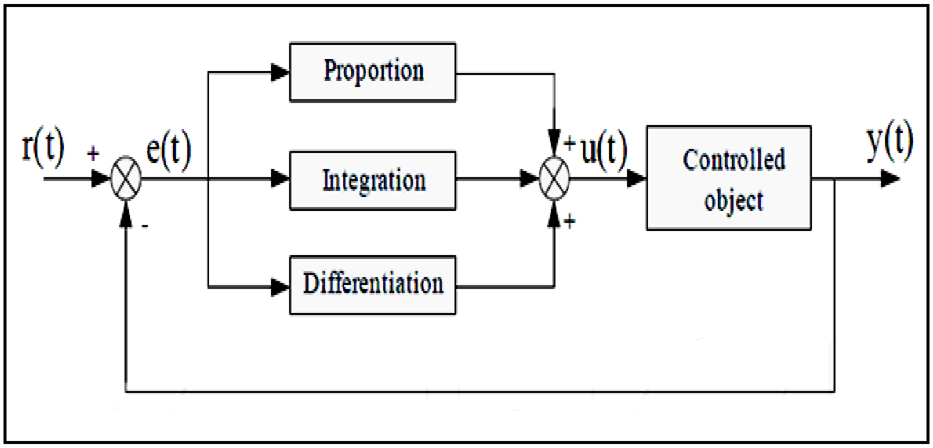


Figure (2). Block Diagram of PID Controller ***(Sarhan, 2014)***.

The relative error is defined as:

$$e(t) = \frac{r(t) - y(t)}{r(t)} = \frac{sp - pv}{sp} \quad (1)$$

The algorithm of PID controller can be given as ***(Sarhan, 2014)***:

$$u(t) = K_p\, e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt} \qquad (2)$$

Where:

K_p = The proportional gain, K_i = Integral gain, K_d = Derivative gain and t is a time.
The PID temperature controller (MTA-48) can be shown in Figure (3).

Figure (3). PID Temperature controller (MTA-48).

b) Relay (HGK-310D):

A solid state contactor is a heavy-duty solid state relay, containing the essential heat sink, used when frequent on/off cycles are wanted, such as with electric lighting loads and heaters. There is no contact bounce due to shaking and there are no moving parts to wear out. They are activated through DC control signals or AC control signals from the microcontroller. HGK-310D can be shown in Figure (4). The specification of this device is 10Amp 3-32VDC- 480VAC 50/60Hz and produced by FR electronic systems solid state relay.

Figure (4). HGK-310D.

c) Contactor (ABB A12-30-10)

A contactor is an electrically controlled switch, applied for switching an electrical energy circuit. This contactor operates with higher current ratings than relay, and has a much lower energy level than the switched circuit.

Contactors come in numerous forms with different features and capacities. A contractor different from a circuit breaker, and is not aiming to cut a short circuit current. The actual size of contactors varieties from a device small sufficient to pick up by one hand, to large devices about one meter, the Contactor (ABB A12-30-10) shown in Figure (5).

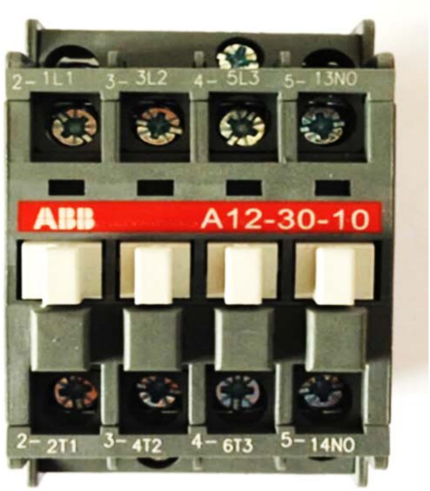


Figure (5). Contactor (ABB A12-30-10).

d) Thermocouple K type

The thermocouple is uncomplicated, more used component for gauging temperature. Thermocouples became the standard -industry method for effective-cost measurement of a large range of temperatures with sensible accuracy. They are employed in a different of applications up to about +2500°C in boilers, ovens, water heaters, and aircraft engines. The most common thermocouple is the kind K, containing of Alumel and Chromel (trademarked nickel alloys consisting aluminum and chromium, silicon, and manganese), with a measurement about of (–200°C to +1250) °C ***(Duff and Towey, 2010)***.

Type K is the most prevalent general objective thermocouple with sensitivity about (41 µV/°C). The Thermocouple type K can be shown in figure (6).

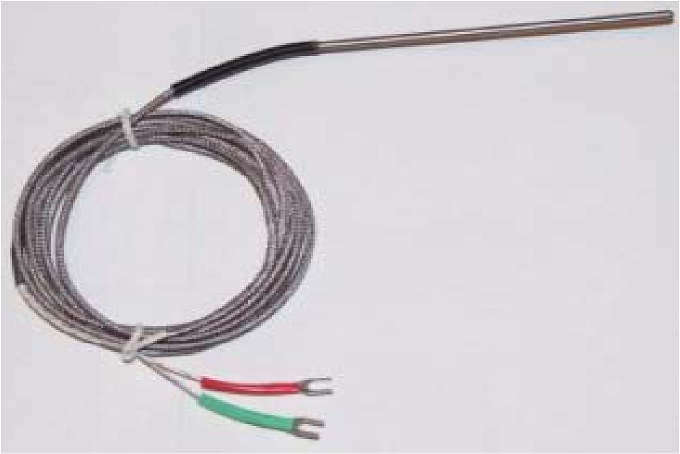


Figure (6). Thermocouple Type K.

e) Heater

The electric heating ring is applied in heating container of water dispenser. This heater is used in this work to heat the water surrounding of the samples in the cell because this product is unique in low power consumption, long-life, low noise, anti-dry protection, saving of energy, safety and reliability, can be shown in Figure (7).

Figure (7). Ring Heater.

f) Switch: employed to open and close the electrical circuit.

Finally, all components can grouped in a system called temperature control system as shown in Figure (8).

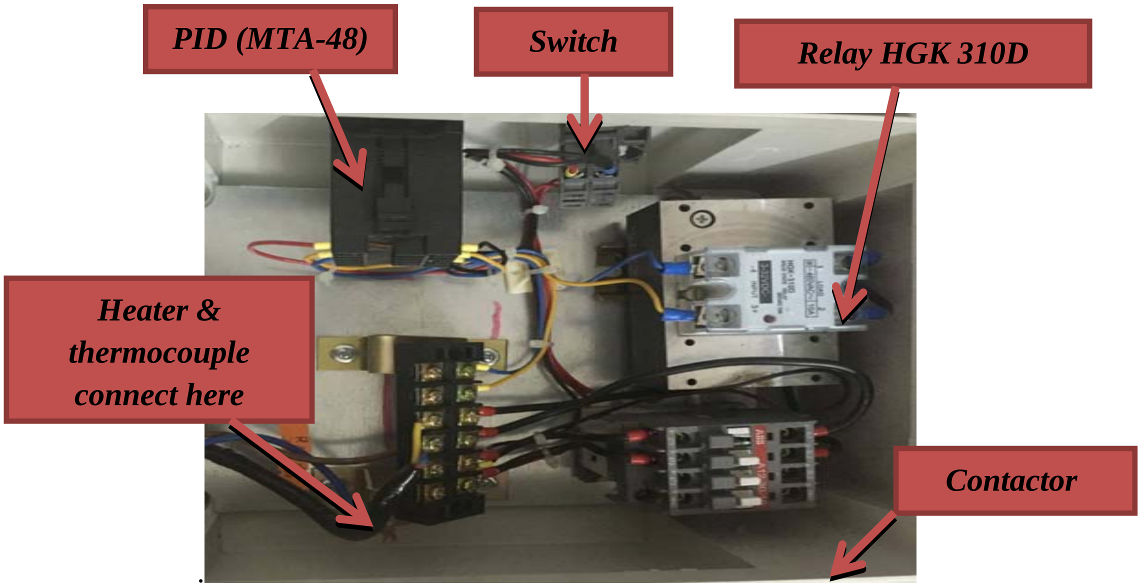


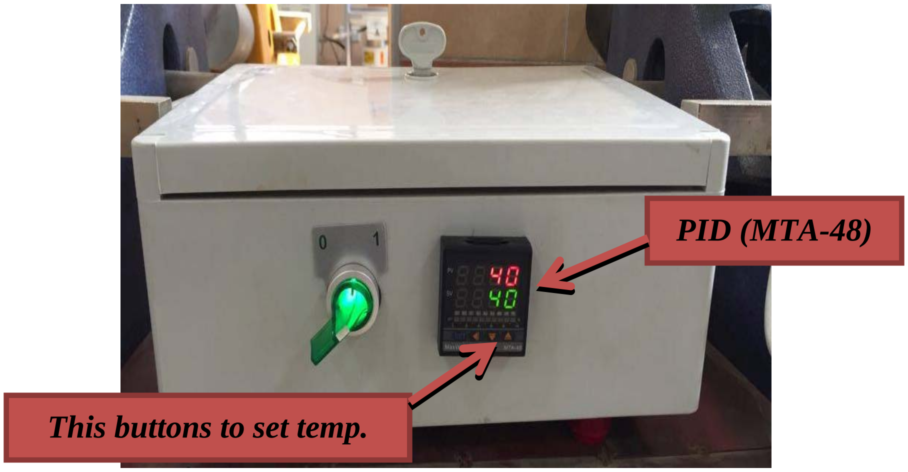
Figure (8). Temperature Control System.

4. Operational of the System

The aim of the temperature control system to gauge the temperature of the cell for the oedometer device by used thermocouple and using a special heater to raise the temperature of the water in the cell and maintained this degree through used controller device. To insure that actual heat transfer between the heater and the water in the cell, need at first to remanufactures of the cell and using steel cell. The heater surrounds of the cell of the oedometer device to certain that the heat transferred regularly inside the cell, as displayed in Figure (9).

Figure (9). Heater around the Cell.

By using the manufacturer controller we can control the temperature of the cell and gives the desired degree formed from controller and converted and checked to give the desired temperature to conduct of the test, as shown in Figure (10).



PID (MTA-48)

This buttons to set temp.

Figure (10). Controller Fixed at 40˚C.

5. Creep Test

This test is carried out to study the effect of static load and temperature over a specified period of time and measurement of the resulting strain.

The oedometer apparatus for soils is employed to perform this test. The creep test specimens, 75mm in diameter and 19 mm in height, are prepared in accordance with ***(ASTM D2435)*** at optimum moisture content (13.5%) of the modified compaction curve and maximum dry unit weight is (18.8 kN/m^3). The soil sample is classified as lean clay with low plasticity (CL) according to Unified Soil Classification System ***(U.S.C.S)***. While it's classified as ***(A-6)*** according to ***AASHTO*** soil classification system ***(AASHTO M145-82, 1993)***.

All the specimens had been allowed to be saturated under the effect of various temperatures (20, 40, 60 and 70°C); each degree of temperature remained constant until the end test for each specimen by using designed controller device. Then, the samples are loaded with (100 kPa) static constant stresses. Creep tests continued under the effect of the constant stated stress and temperature for period seven days.

6. Result and Discussion

Secondary settlement, this type of settlement is defined as the reduction of volume at the influence of the continuous increase of effective stress due to adjustment of the soil structure which continues even after the essential dissipation of the excess pore water pressure. In the time-dependent deformation (secondary consolidation), the coefficient of Secondary consolidation $C\alpha$, is helpful in determining the creep settlement at the end of primary consolidation and is often considered to be the slope of the linear portion of the void ratio (or compression) versus the logarithm of time curve in the secondary compression region. It is noted that the secondary consolidation is the creep settlement after the end of the primary consolidation. The coefficient of Secondary consolidation can be calculated from applying:

$$C\alpha = \frac{\frac{\Delta H}{H}}{\Delta \log t} \qquad (3)$$

Figure (11) displays the deformation-log time curves for defining the coefficient of secondary consolidation under constant pressure100 kPa for various temperatures, the value of $C\alpha$ at 70°C is found to be (0.021) and reductions gradually with temperatures (60, 40and 20°C) to (0.018, 0.014 and 0.011) respectively. Figure (12) shows the correlation between the cumulative strain and log time for soil samples at different degrees of temperature. For 70°C the strain is the highest one if compared with the other temperatures and reductions gradually with temperatures; (60, 40and 20°C) respectively. In figure (13) shows the relationship between the cumulative deformation and log time, it can be noticed that, the deformation for soil increases with increase temperatures.

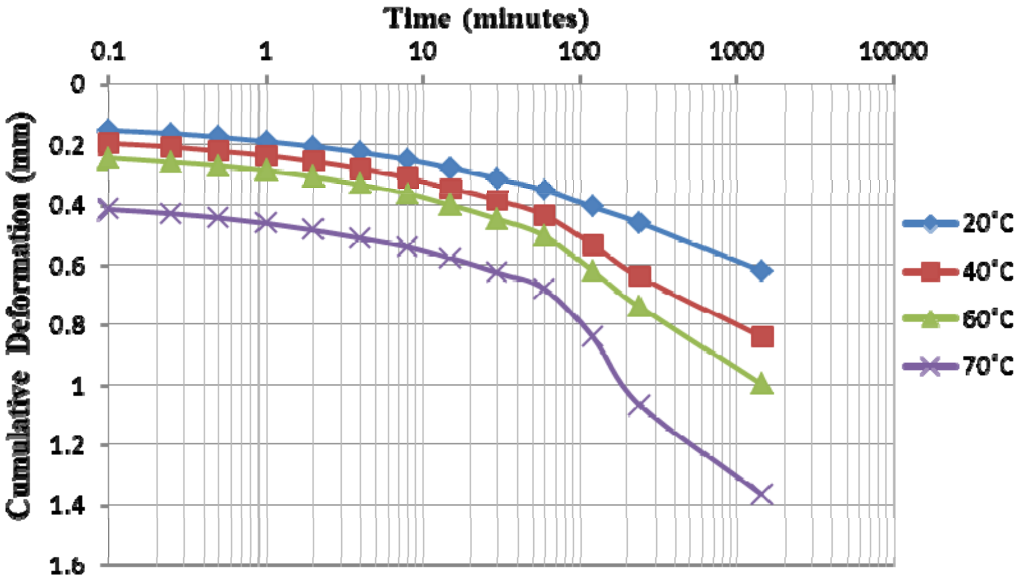


Figure 11. Log Time-Deformation Curve at Different Degrees of Temperature for Constant Stress 100kpa.

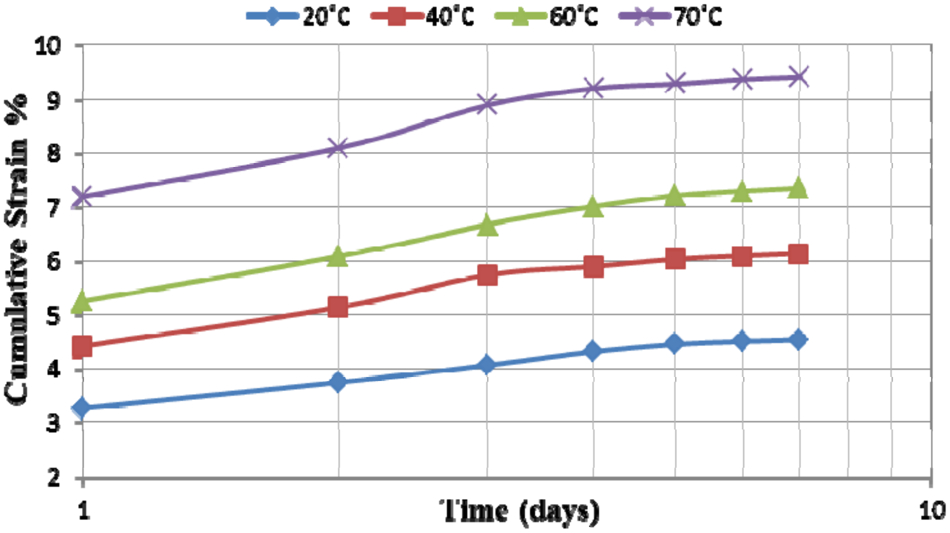


Figure 12. Cumulative Strain versus Log Time for soil Samples.

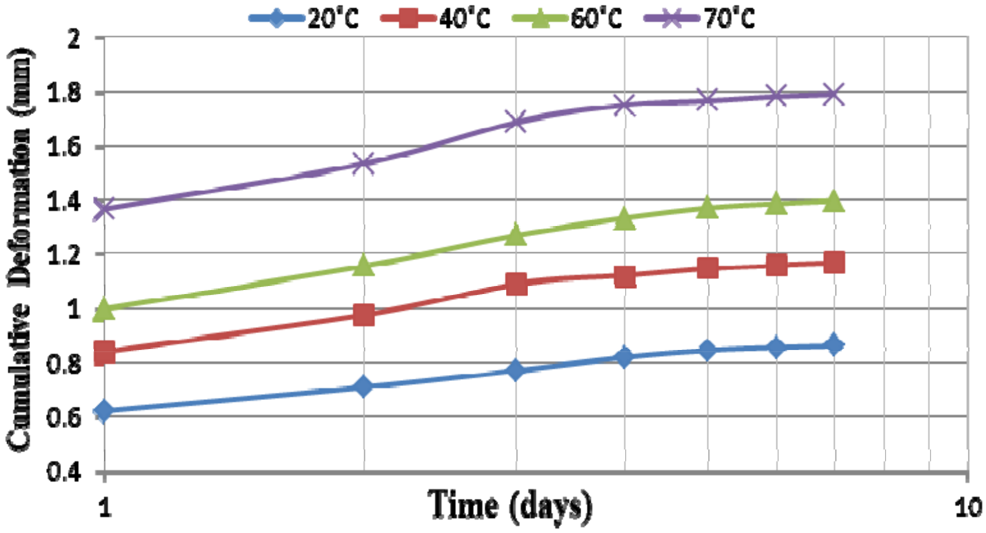


Figure (13). Cumulative Deformation versus Log Time at Different Temperatures for Soil Samples.

In the above figures (11), (12) and (13) it is clearly noticed that the creep in high temperatures is higher than creep in low temperatures. The reason for the increases creep with increases temperatures for soil samples may be caused by continued reorientation of particles which are influenced by water bleeding out of soil skeleton. Viscosity depends on temperature, and the viscosity of water at 35°C is about half that at 5°C ***(Head, 1982)***. So, when increases temperatures the viscosity of the water decreases and the time for dissipation of pore water pressure from soil skeleton was faster, allowing the solid particles to move closer together, and hence increases settlement.

7. Conclusions

1. Creep behavior of clayey subgrade in particular is starting to be more and more significant in theoretical and practical Geotechnical engineering. Increasing vehicle movement on the clay subgrade demand a better understanding of creep phenomenon and more powerful devices for the analysis and prediction of creep behavior.
2. by manufacturing electrical electronic device we could control on (install heat of the sample to temperatures up to 70° C) to know its impact on the amount of creep of soil sample and for long periods, so that the degree of examination temperature remained constant throughout the laboratory testing period, To evaluate and study the behavior of the creep of the soil under the influence of changing temperatures.
3. When control on test temperature will we can solve the problems that facing the engineer in the site and reach to realistic solutions to treatment this impact and ensuring the sustainability of subgrade pavement layer.

8. References

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