# INFILTRATION CHARACTERISTICS OF COMPACTED SAMPLES OF SUB-BASE MATERIALS

# خصائص الترشح لعينة مختبرية من مادة السبيس

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**ABSTRACT**

Many problems are generated by the presence of water from different sources in a pavement structure. The infiltration characteristics of the sub-base are an important component of the hydrological conditions. They are one of the components of the water balance and are necessary to describe the runoff response by a runoff model, in addition to describe the effect of water movement on changing the soil properties within infiltration.

The present work emphasis on the characteristics of the infiltration by using laboratory model. This model is performed on compacted sub-base samples of specific density and different heights, 10, 15, and 20cm, for different heads of water, 10, 15, and 20cm. The results revealed that there is a significant effect of water head and height of sub-base layer on the infiltration with high interaction of the wetting conditions of the sample. A statistical analysis was made to develop a relationship among the different studied parameters.

**Keywords:** infiltration, sub-base, water movement, pavement, rate of infiltration.

**الخلاصــة**

إن خصائص الترشح للتربة هي من مركبات الظروف الهيدرولوجية، حيث إنها من مركبات التوازن المائي وهي أيضا ضرورية لوصف المياه الجارية فوق السطح في النماذج الصغيرة، بالإضافة إلى وصف دور حركة الماء في تغيير خصائص التربة التي يخترقها الماء.

العمل الحالي يؤكد على خصائص الترشح باستخدام الانموذج المختبري. العمل تم على أنموذج سبيس مقولب بكثافة معينة وبارتفاعات مختلفة، 10، 15، و20سم معرضة لعمود ماء بارتفاعات مختلفة، 10، 20، و30 سم. بينت النتائج انه هناك تأثير واضح لارتفاع عمود الماء وارتفاع طبقة السبيس على الترشح مع ارتباط بحالة الترطيب لنموذج التربة. أجريت عملية تحليل إحصائي للنتائج لتطوير علاقة رياضية لمختلف الخصائص المدروسة.

## SYMBOLS

Hs: height of sub-base layer;
Hw: height of water;
FHWA: Federal Highway Administration
I: cumulative infiltration in cm;
$T_{av}$: average time;

## 1. INTRODUCTION

The movement of water into soil is called infiltration, whereas, downward movement of water within the soil is called percolation.

The movement of water in soils is a complicated phenomenon to be described because soil surfaces interact with the water being transferred and the soil changes during the water movement process. Water can move in either the liquid or vapor phase, with the latter being more important for partially saturated soil. Various driving forces in water flow exist in the soil, including differences in water content, salt content, temperature, and void size distribution. An overall description is required to encompass this flow system.[3 & 8]

The infiltration rate is the rate at which a soil, in a given condition, can absorb water. It is defined as the volume of water passing into a unit area of soil per unit time, with dimensions of velocity ($LT^{-1}$).[3 & 8]

The infiltration rate is generally highest when the soil is dry. As the soil becomes wet, the infiltration rate slows to the rate at which water moves through the most restrictive layer, such as a compacted layer or a layer of stiff clay. Infiltration rates decline as water temperature approaches freezing. Little or no water penetrates the surface of frozen or saturated soils.[3 & 8]

An ideal cumulative infiltration curve, based on theoretical analysis, is illustrated in Fig. 1, whereas Fig. 2 shows the ideal infiltration rate with time.[3 & 8]

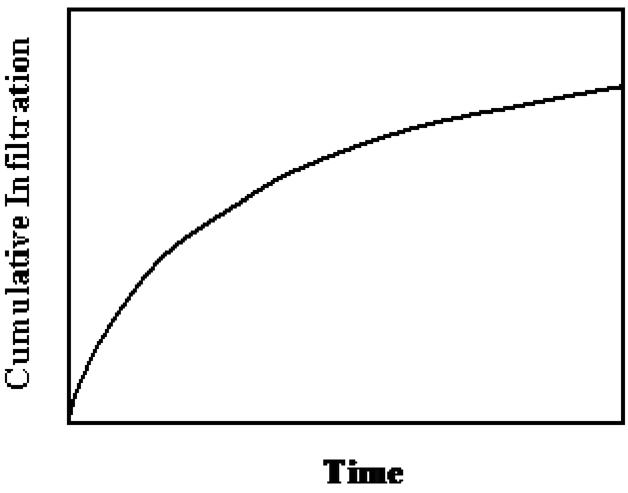


**Figure 1: Ideal Infiltration Curve.**[3 & 8]

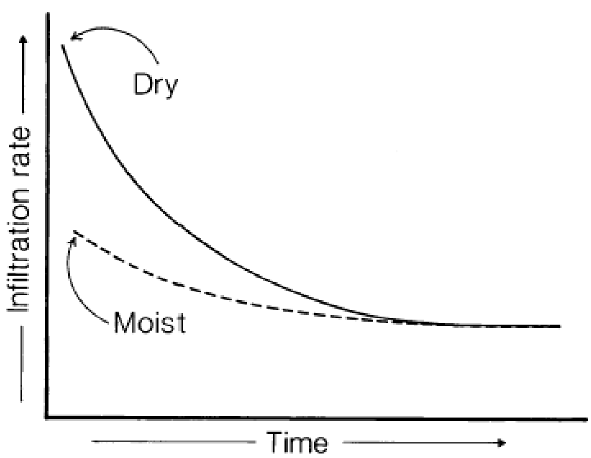


**Figure 2: Ideal Infiltration Rate Curve.**[3 & 8]

## 2. SOURCES AND DAMAGES OF WATER

The primary source of water in pavement structure is rainwater, which infiltrates through the pavement layers from many unreliable regions due to their wide, flat dimensions and holding much pores. So, water inflows from many sources, such as:[2]

1- Downward flow through porous surfaces, open construction joints, open shrinkage cracks, and so on;
2- Lateral flow into the sections from water ponded on high medians, flooded outer edges, or unpaved shoulders;
3- Capillary suction from underlying water tables, and
4- Less effect, condensation because of fluctuation in atmospheric temperature and pressure.

In addition to the above natural sources, some pavements are subjected to man-made supplies that can keep structural sections filled with water throughout the "dry" parts of the year. Figure 3 shows ways in which water can enter and leave road subgrade.[2]

Extensive studies have been done to examine and quantify surface infiltration of rainwater through the pavement layers. FHWA after extensive study of numerous pavement sections found that (33-50)% of the precipitation water falling on an asphalt concrete pavement and (50-67)% of that water falling on Portland cement concrete pavement can infiltrate through the pavement to the road base. Similar results were also reported for edgedrain effectiveness, in individually monitored rainfall events, edgedrain recovered very high percentage, up to 80% comparing to the total amount of rainfall for a year showed as highly as 32% recovery of water that infiltrated through the pavement in this study.[2]

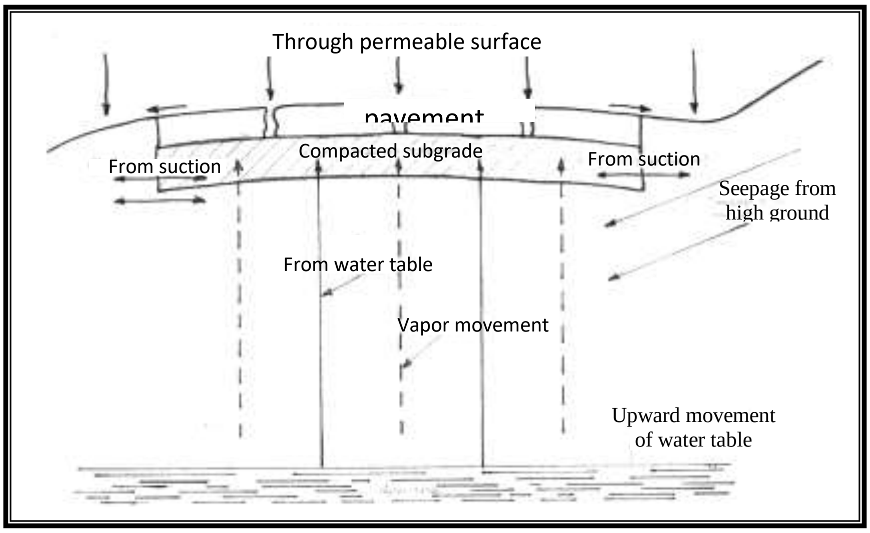


**Figure 3: Ways in Which Water Can Enter and Leave Road Subgrade.[2]**

Many problems are generated by the presence of water in a pavement structure. If a pavement sub-base become saturated, pore water pressure due to traffic loading can neglect the load supporting function of the sub-base materials. Consequently, the traffic load will be applied to the subgrade over a small area. This localized loading may exceed the load carrying capacity of the subgrade causing progressive failure of the pavement. If a pavement base is saturated as little as 10% of the time, the useful life of the pavement can be reduced by 50%. The decrease in life is greatest for high values of severity factors and defined as the "relative rate of damage per load application" during a given environmental condition as compared with another. Thus when free water is present, damage is 5 times greater than when there is no free water, the severity factor is 5.0. The results of cyclic load tests on crushed stone and on gravel suggest that saturation levels above about (60-70)% can result in large deformations. Pore pressure can also result in significant scouring and jetting pressure. Water jetting from cracks or joints can transport base and subgrade materials to the road surface, creating voids under the pavement and eventual pavement failure.[2]

## 3. EXPERIMENTAL WORK

Several infiltration tests were made on the sub base material to examine the water infiltration characteristics of the material. The test was made by subjecting the surface of the compacted sample to the head of water and recording the changing of the water.

### 3.1. Soil used and Test Program

A steel container was used to perform the experiments on the sample. Figure 4 shows the dimensions of the container.

The sample was sub base material available in the transportation laboratory/engineering college/university of Kufa. Figure 5 shows the particle size distribution by sieve analysis. The classification of the soil is Class B according to AASHTO.

Figure 6 shows the results of Proctor test on the sample, the maximum dry density is 2.241 gm/cm$^3$, and the optimum moisture content is 7.2 %.

Table 1 illustrates the tests program performed in this paper to examine the infiltration characteristics of the sub base material.

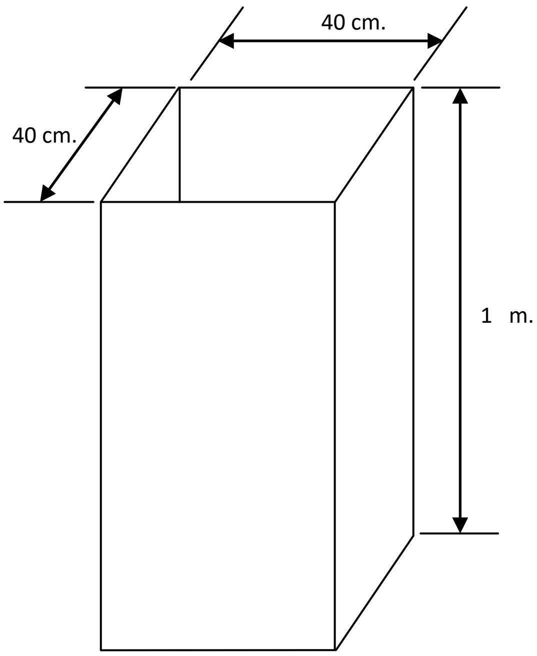


**Figure 4: The Dimensions of The Test Steel Container.**

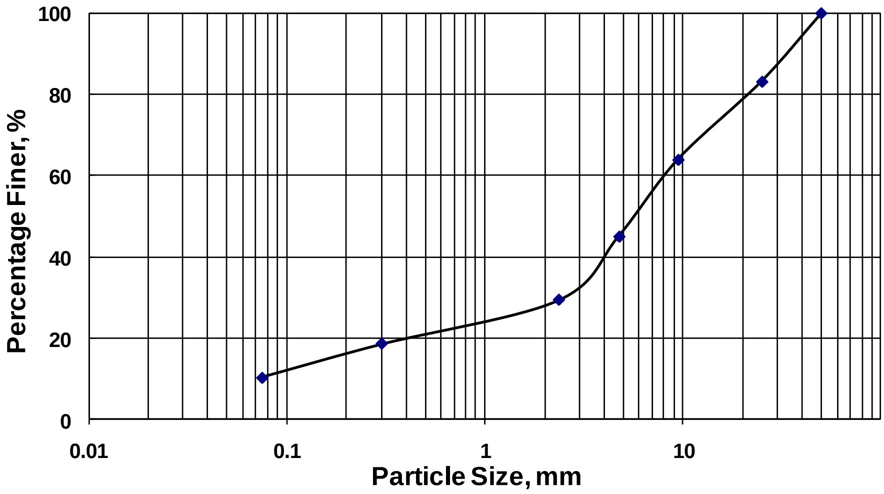


**Figure 5: Particle Size Distribution of The Sample.**

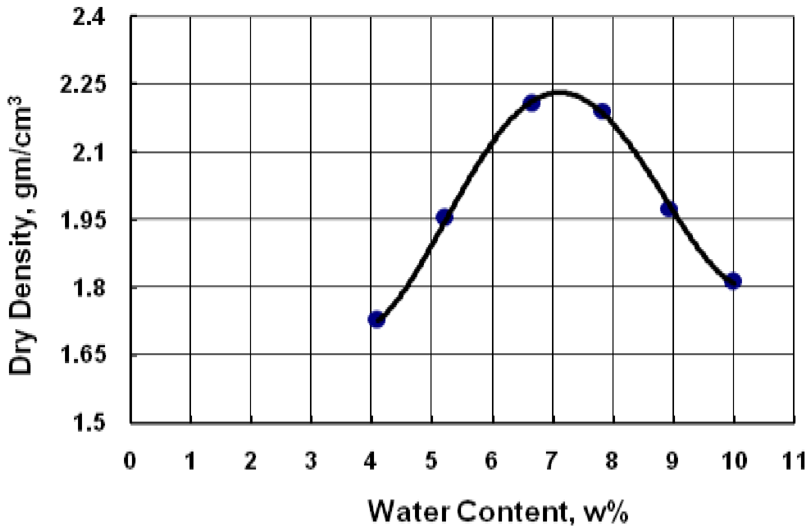


**Figure 6: Results of Proctor Test.**

**Table 1: Test Program.**

| *Case No.* | *Soil Sample Thickness (Hs), cm* | *Water Head (Hw), cm* |
|---|---|---|
| 1 | 10 | 10 |
| 2 | 10 | 15 |
| 3 | 10 | 20 |
| 4 | 15 | 10 |
| 5 | 15 | 15 |
| 6 | 15 | 20 |
| 7 | 20 | 10 |
| 8 | 20 | 15 |
| 9 | 20 | 20 |

## 4. PRESENTATION OF RESULTS

### 4.1. Infiltration of 10 Cm. Thick Layer

Figure 7 shows the results of accumulative infiltration with time for a layer of sub base of 10 cm. thickness for different water head 10, 15 and 20 cm. respectively. The sample changed at each water head , i.e. the tests start with dry sample for each water head. This procedure of testing is performed to make a comparison among the different water heads.

The figure shows clearly the effect of water head, cumulative infiltration increased for same time period for the different water head, but the behavior of the infiltration at the start of tests is so close for the different cases of water head. The trend of infiltration curve is similar to the ideal curve, figure 1.

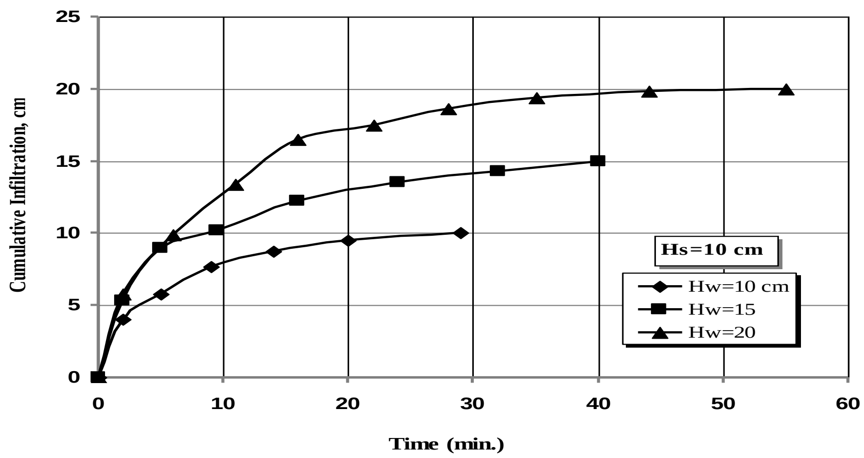


**Figure 7: Accumulative Infiltration with Time for a Layer of Subbase of 10 cm.**

Figure 8 shows the infiltration rate with time for different mentioned water heads. There is a clear decreasing in infiltration rate with increasing the water heads. The trend of all curves is similar to the ideal curve of the infiltration rate, figure 2.

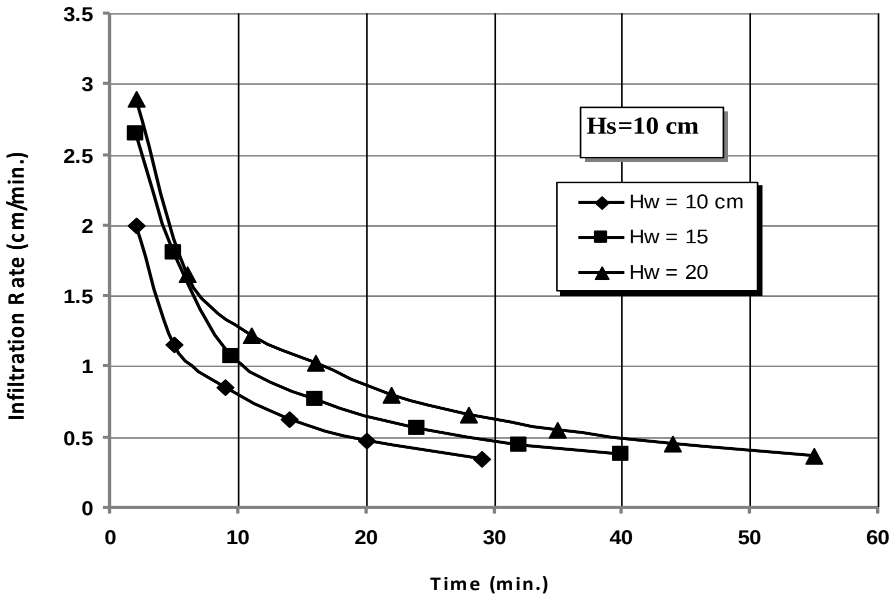


**Figure 8: The Infiltration Rate with Time for Different Water Heads and for Subbase Layer of 10 cm.**

### 4.2. Infiltration of 15 Cm Thick Layer

Figure 9 shows the results of accumulative infiltration with time for a layer of 15 cm thick for different water heads, 10, 15 and 20 cm. One can notice that there are interaction among the trends of the curves for different water heads. This interaction may be caused by increasing the thickness of material from 10 to 15 cm. The water is moving in different directions, vertically and horizontally, and increasing of thickness delays the movement perpendicular to bed.

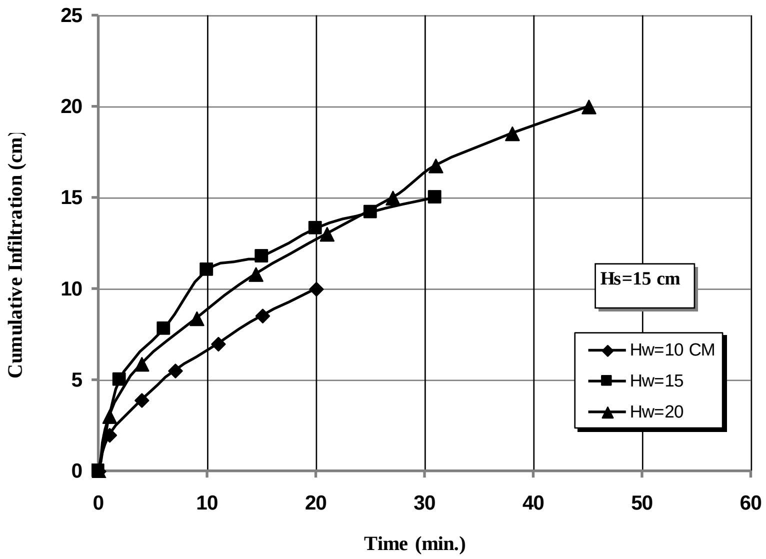


**Figure 9: Accumulative Infiltration with Time for a Layer of Subbase of 15 cm.**

Figure 10 shows the infiltration rate with time. As one can see, the figure shows, approximately, same trend among the different curves and that can be interpret by the increasing of the height of the layer which absolutely restricting the water movement. The different curves were near each other with advancing time.

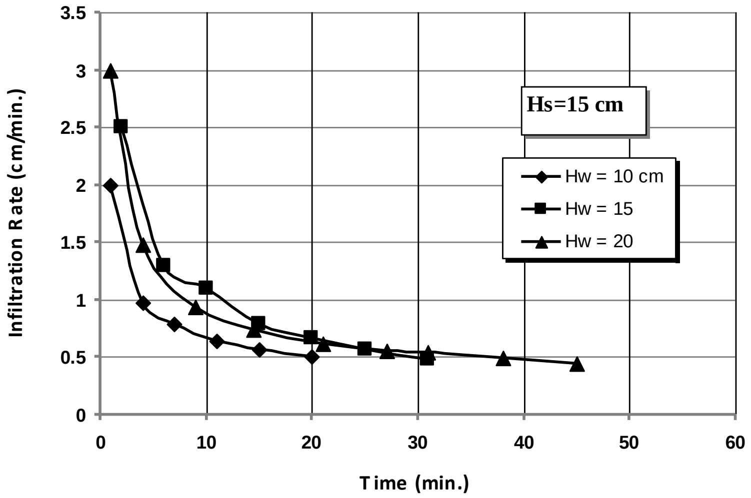


**Figure 10: The Infiltration Rate with Time for Different Water Heads and for Subbase Layer of 15 cm.**

### 4.3. Infiltration of 20 Cm. Thick Layer

Figure 11 shows the results of accumulative infiltration with time for a layer of 20 cm. thick for different water heads, 10, 15 and 20 cm. the behavior of the infiltration is more interacted than the above and that may be results of increasing of the layer height, from 15 to 20cm. the water tried to move in all direction but the movement was restricted by the structure of the layer, so, needed more time to infiltrate.

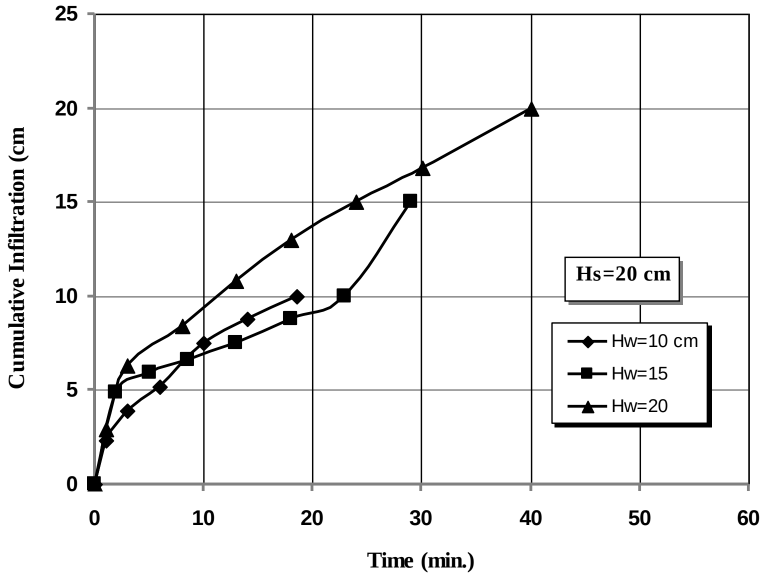


**Figure 11: Accumulative Infiltration with Time for a Layer of Subbase of 20 cm.**

Fig. 12 shows the infiltration rate with time. The figure shows the same trend in the previous case, figure 10.

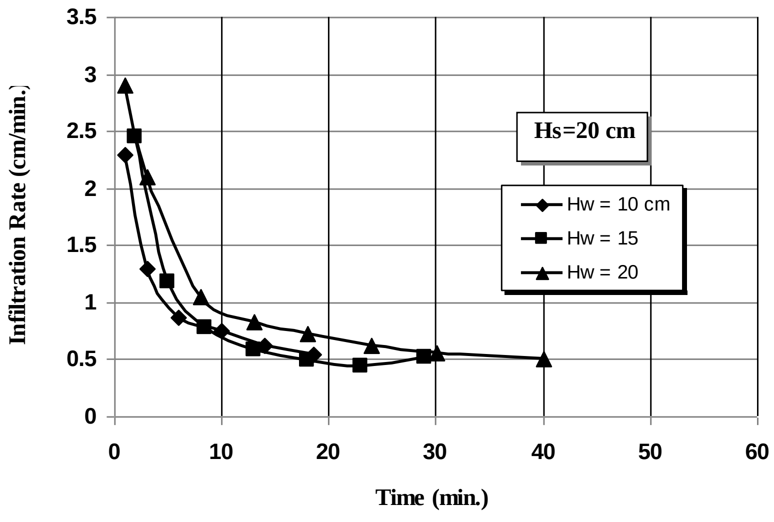


**Figure 12: The Infiltration Rate with Time for Different Water Heads and for Subbase Layer of 20 cm.**

## 5. RESULTS INTERPRETATION

From the above results, one can reveal the behavior of water infiltration through the sub-base materials, where the infiltration began quickly then reduced with water advanced through the material for different cases. This is caused by the dry condition of the material initially, but with infiltration processes, the material condition became gradually in saturation level and this is quite as in literature for ideal infiltration curve. In this case the water will restricted within the material of small saturated zone.

The condition of saturation and presence of water in sub-base materials, as used in this paper, will generating a pore water pressure with existence of the loading of traffic. This generating of pressure affect the pavement structure causing progressive failure of the pavement.

**6. STATISTICAL ANALYSIS**

To use the experimental data, a statistical analysis was performed to verify an useful equation for predicting needed time (T) to water infiltration for any ratio of water head to soil thickness (Hw/Hs) using MS. Excel computer program. The resulted equation is in Eq. 1 with $R^2$ equal to 0.8. Figure 13 shows the experimented and predicted (equation 1) data.

**T = 30.47 * (Hw/Hs) …(1)**

Practically, we can use this calculated time to estimate the effect of water on stability of sub-base and pavement, i. e., less time means less accumulative water near sub-base. The chosen time must achieve the suitable case (no accumulation water).

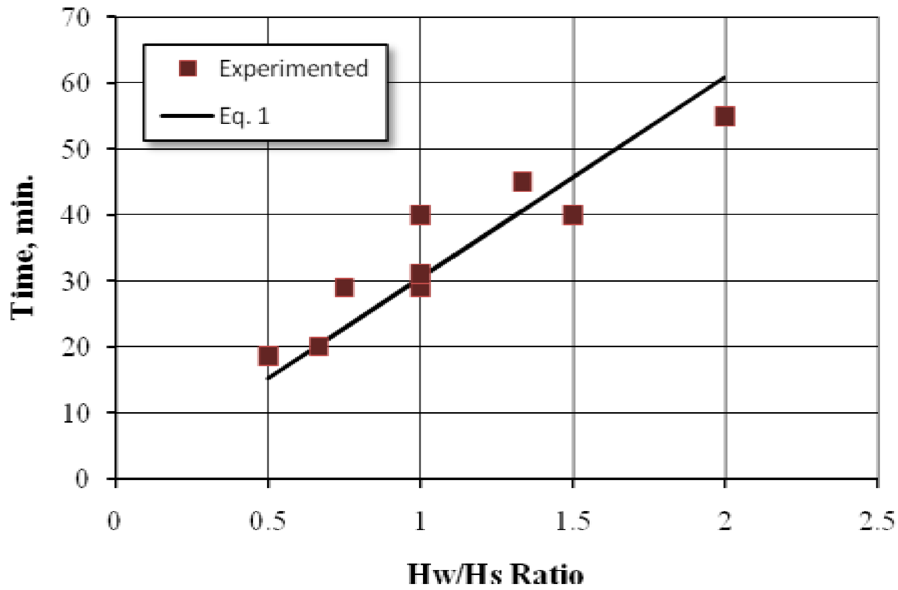


**Figure 13: Results of Statistical Analysis.**

**7. CONCLUSIONS**

1- There were interacted trends from different water head, 10, 15, and 20cm that subjected to different thickness of sub-base material, 10, 15, and 20cm especially for thicker layer with same initial conditions for all cases, this behavior may be a result of material gradation.
2- The infiltration and rate of infiltration are decreased with time advancing where the wet condition of the material was progressing for all cases.
3- For different studied cases, with decreasing of infiltration rate, the water found to be within a restricted small depth of the sub-base material (Hs), used in present paper, which may causes many structural problems to the pavement by generating a pore water pressure.
4- As a result of the statistical analyses on the experimental data, an equation was found to relate the average needed time ($T_{av}$) to water infiltration for any ratio of water head to soil thickness (Hw/Hs) with $R^2$=0.999.

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