# EFFECT OF COHESIVE AND NONCOHESIVE SOILS ON EQUILIBRIUM SCOUR DEPTH

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## ABSTRACT

In this research ,the effect of cohesive soils ( clay ) and non –cohesive soils sand on equilibrium scour depth was studied .Experiments were carried out on two types of clay and two types of sand as a bed material using an obstruction ( pier ) to create a local scour. The effect of flow velocity and Froude number on scour depth and the occurrence time of equilibrium scour depth were studied .

The results show that for the same conditions, the rate of scour in the clayey soils is less than in sandy soils. Also the time required for occurrence of the maximum scour depth ( equilibrium depth ) in clayey soils is more than in sandy soils. Two formulas were found to predict the equilibrium scour depth in terms of Froude number ,the first is for clayey soils and the second for sandy soils .

## KEYWORDS

Cohesive soil, Non-cohesive soil , Scour depth .

## NOTATIONS

$d_{50}$ = median particle size

Fr = Froude number

g = acceleration of gravity

T = time

v = flow velocity

$y_1$ = flow depth

$y_s$ = equilibrium scour depth .

## INTRODUCTION

Local scour occurs in the bed of the channel due to the actions of vortex systems induced by the obstructions to the flow [1]. The action of the vortex is to erode materials away from the base region . If the transport rate of sediment away from the local region is greater than the transport rate inside the region , a scour hole develops . As the depth is increased , the action of the vortex is reduced , the transport rate is reduced and equilibrium is reestablished and practically no changes take place either in depth , shape and area of the scour hole and the depth of scour is maximum ( equilibrium depth ) [2]. Scour depth depends on bed materials and other parameters such as flow depth and velocity . There are no general purpose formulas for predicting the maximum depth of scour in a bed of cohesive sediment [3] . In this study , an experimental investigation was carried out to study the effect of cohesive and non cohesive soils on equilibrium scour depth ( maximum scour depth ) .

## EXPERIMENTAL WORK

### The flume

The experimental work was conducted at the Hydraulic Laboratory in the College of Engineering, University of Baghdad. Scour tests were conducted in a flume 5.6 m long , 0.6m wide and 0.2m deep , this flume is a glass fiber molded in steel stiffeners . Water is delivered by a centrifugal pump ( with maximum capacity of 3 L/sec ) water passes through a flexible hose into the upstream stilling tank which contains a perforated baffle fixed at the inlet , as shown in Fig. (1). The depth of flow is controlled by an adjustable overshot tail gate at the downstream portion of the working section which is 4.15 m long , 0.6 m wide and 0.2 m deep . This flow passes over a bed material of 10 cm thickness . An obstruction of a circular pier of 50mm diameter was fixed at a mid of the working section of the flume to create a local scour . A point gauge mounted on a carriage , which can move freely to any position in the working area , was used to measure all the depths in the experimental work .

## The bed soil

The soils used in this study were two clay and two sand . The first clay had a liquid limit (L.L.) 40.40 % , plastic limit (P.L.) 22.4 % and plasticity index 24.6 % , the mean diameter ( $d_{50}$ = 0.0034 mm ) and the second clay had (L. L. = 66% , P.L.= 27.3 % and plasticity index = 41.2% , ($d_{50}$= 0.0012 mm). The mean diameter of the first sand ( $d_{50}$= 0. 45mm) (medium sand ), and the second was equal to ( $d_{50}$ = 0. 16mm) (fine sand). A standard procedure was used to prepare the clay bed in order to produce repeatable scour. The clay was purchased in blocks and stored in a constant temperature room . The clay blocks were placed side by side in the working area of the flume and compacted with a metal plate to remove air voids and to obtain a smooth surface . For the scour tests in sand , the sample was dumped in a loose state into the working area .

## Experimental procedure

After the soil bed was leveled , the bed elevation was measured using a point gauge .The desired flow conditions were established by adjusting the flow rate and water depth . All the experiments were conducted under steady subcritical flow , clear water condition with plain bed . Water surface elevation was measured at the beginning of each experiment using a point gauge. The same water level was maintained throughout the experiment by adjusting a tail gate . At the end of each experimental run , water was slowly drained from the flume . Then the geometry of the scour hole was measured using a point gauge and a ruler . The obtained measurements included the length and width of the scour hole and the maximum depth of the scour hole ( equilibrium scour hole ). The scour rates of the clay were very slow .

## RESULTS

It seems from the results that the equilibrium scour depths are increased with time and at the same time it can be seen that the higher velocity gives the greater rate of scour depth as shown in Fig (2). Also , it was found , in the two types of soil the scour depth increases with increase in the particle size of soil at the same conditions, as shown in Fig.(3) and Fig.(4) . From these tests it was noticed that the scour depth in sand soil is greater than in clay soil under the same conditions as shown is Fig .(5). The study shows that the Froude number is a significant parameter which affects the scour depth , In order to deduce the effect of Froude number ( Fr) on the scour depth , the results were used to plot a relationship between the ratio of scour depth ( $y_s$ ) to flow depth ($y_1$) and Froude number , as shown in Fig (6), this relationship can be described by the expression :

$$\frac{y_S}{y_1} = 2.6\ Fr^{0.4} \quad \text{for clay soil} \qquad (1)$$

$$\frac{y_S}{y_1} = 4.3\ Fr^{0.34} \quad \text{for sand soil} \qquad (2)$$

Where Fr = v/ $\sqrt{g y_1}$

In order to illustrate the scatter in the other data , a plot of the calculated using eq . (1) and eq. (2) versus the observed scour depths are presented in Figs. (7) and (8) . From these figures, agreement can be seen a good between the calculated and observed results.

## CONCLUSIONS

The following main conclusions can be drawn from this investigation :

1- The time required to reach equilibrium scour depth is much longer in cohesive soil than in non – cohesive soil .

2- The equilibrium scour depths are smaller in cohesive soil than in noncohesive soils under the same conditions .

3- The Froude number is a significant parameter to calculate the scour depth .

4- The type of the bed material has an important effect on the equilibrium scour depth

5- The derived formulas, for the maximum scour depth ( equilibrium depth) eqs .(1) and (2) are restricted to the laboratory data , the formulas give an idea to evaluate the maximum scour depth for conditions similar to those covered in this study.

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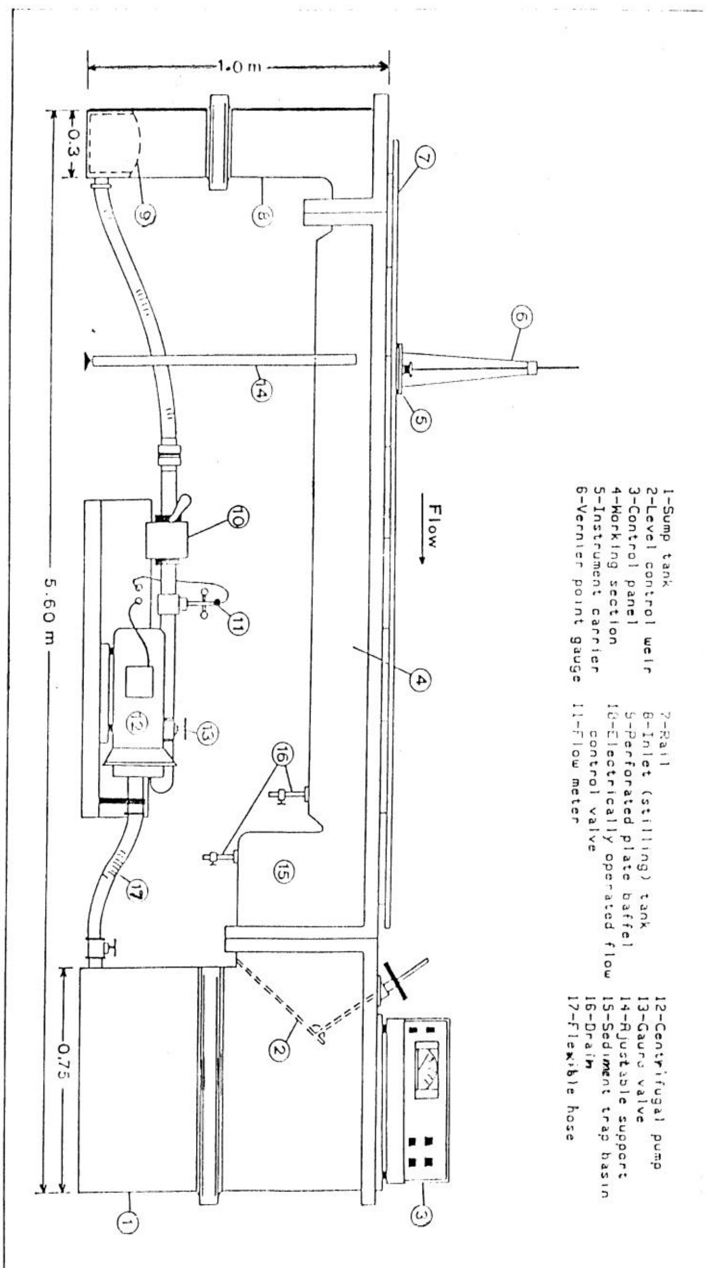
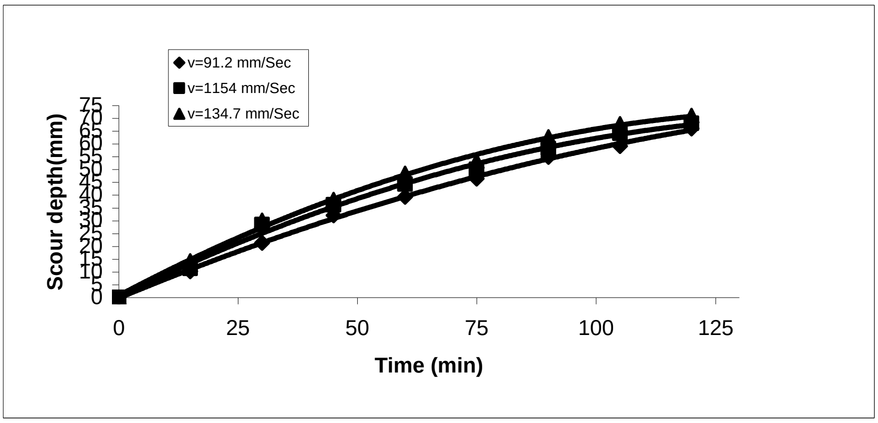
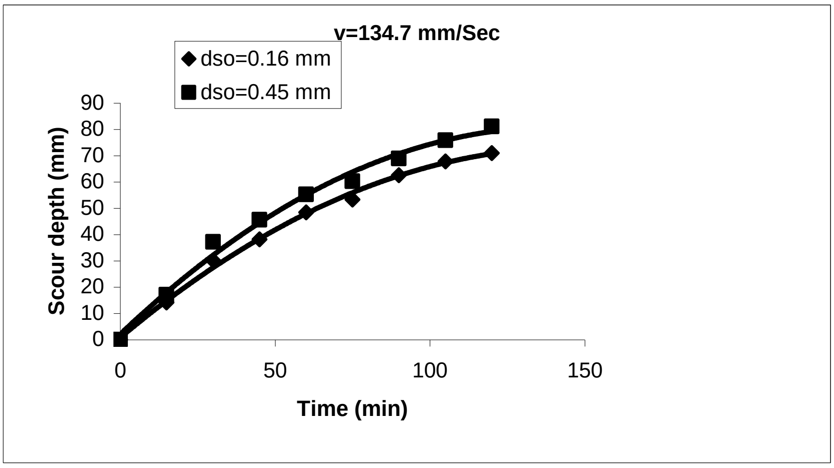


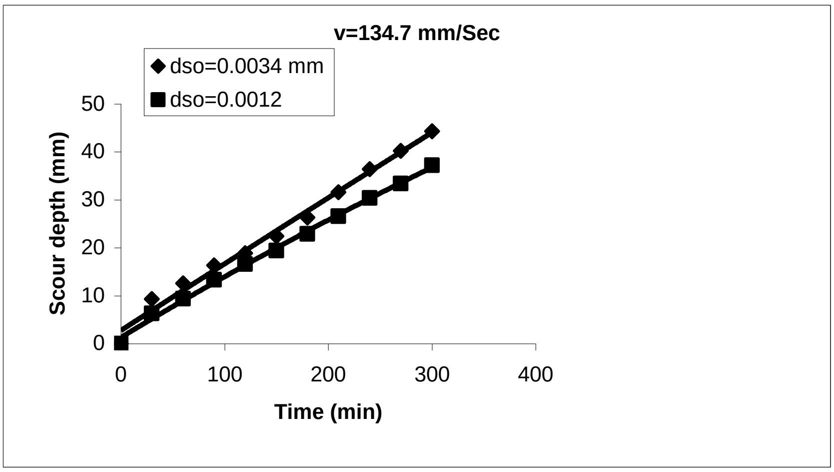

:Detail drawing of a laboratory flume.




**Fig(2) Measured scour depth versus time in sand bed material ($d_{50}$=0.45 mm)**




**Fig(3) Scour depth versus time in sand bed material .**




Fig(4) Scour depth versus time in clay bed material .

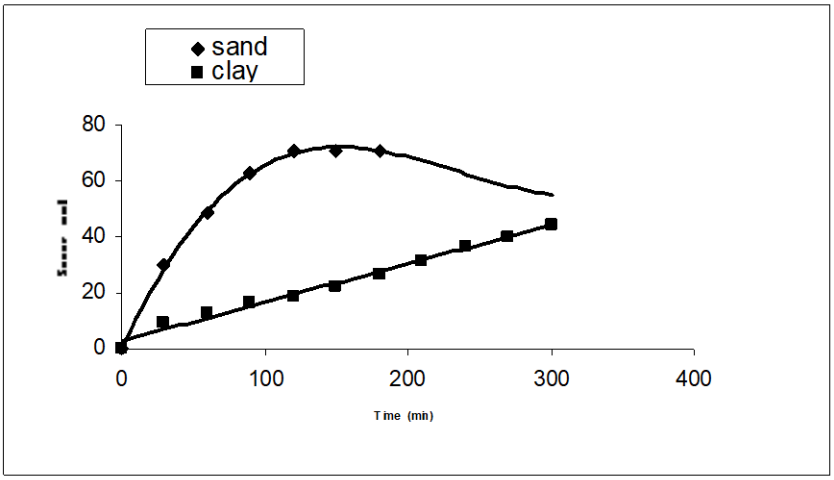



Fig . (5). Comparison of scour depth between sand and clay beds

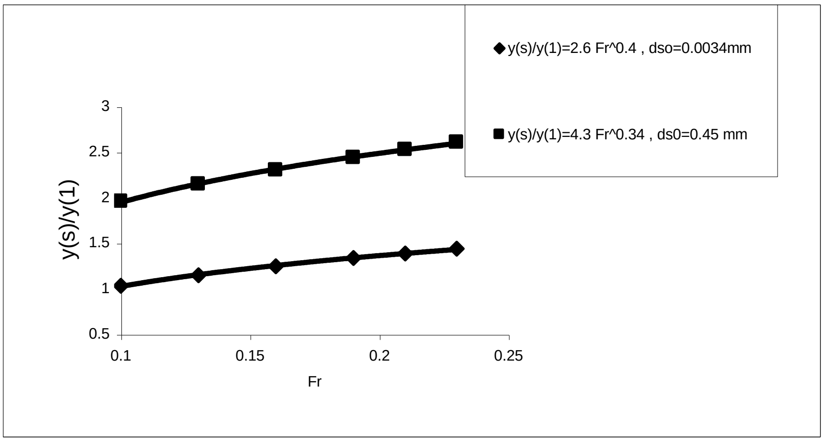



Fig (6) Variations in relative scour depth with Froude number

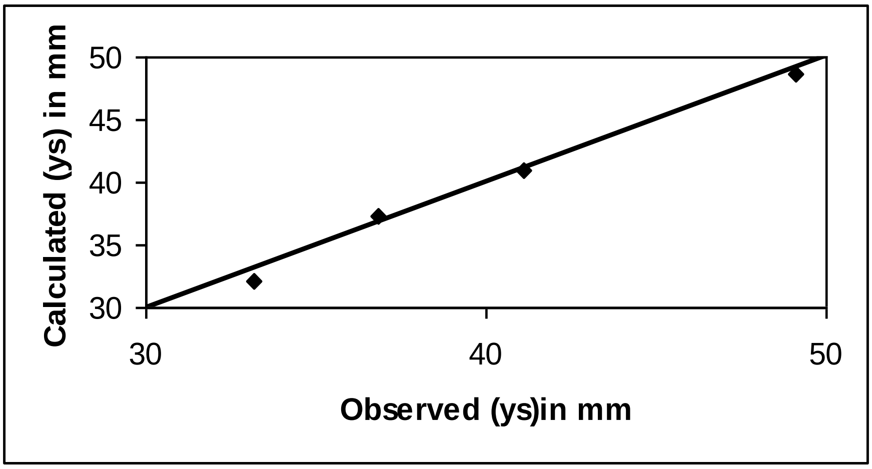



**Fig. (7): Calculated scour depth versus observed scour depth in clay soil.**

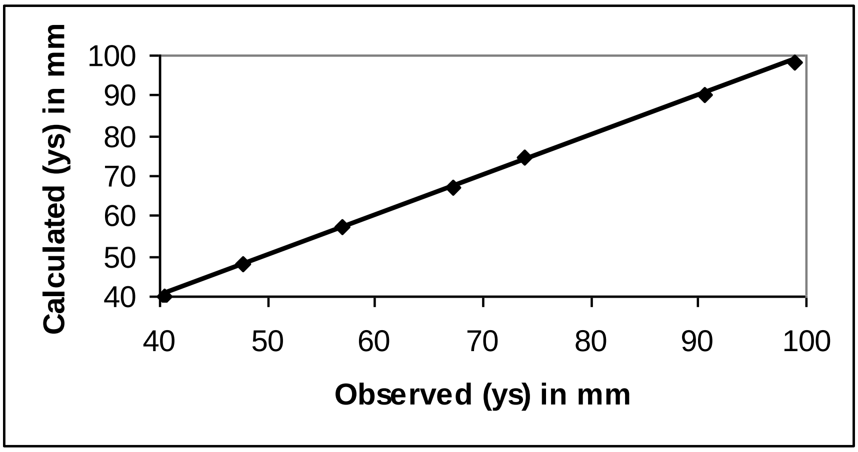



**Fig . (8) : Calculated scour depth versus observed scour depth in sand soil**

# تأثير الترب المتماسكة وغير المتماسكة على عمق الانجراف المتوازن

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**الخلاصة**

في هذا البحث ، تم دراسة تأثير الترب المتماسكة ( الطينية ) والترب غير المتماسكة ( الرملية ) على عمق الانجراف المتوازن ، حيث تم إجراء تجارب مختبرية على نوعين من الترب الطينية وعلى نوعين من الترب الرملية كمادة للقاع بوضع عائق خلال الجريان ( دعامة ) يحدث انجراف موقعي فيه و بحث تأثير سرعة الجريان ورقم فرود على عمق الانجراف وعلى وقت حدوث عمق الانجراف المتوازن . وتبين من خلال البحث إن معدل الانجراف في الترب الطينية يكون اقل مما هو عليه في الترب الرملية وان الوقت اللازم لحدوث أقصى عمق انجراف ( العمق المتوازن ) في الطينية أطول مما هو عليه في الترب الرملية ولنفس ظروف الجريان . وقد تم التوصل إلى معادلتين لإيجاد قيمة عمق الانجراف بربط عمق الانجراف نسبة إلى عمق الجريان ورقم فرود لكل من التربة الطينية و الرملية وقد تم التحقق من صحتها فكانت النتيجة جيدة .

**الكلمات الدالة**

التربة المتماسكة ، التربة غير المتماسكة ، عمق الانجراف.