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New Approach for Predicting Rectangular and Square Tube Settlers Length.

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NEW APPROACH FOR PREDICTING RECTANGULAR AND SQUARE TUBE SETTLERS LENGTH

تقنية حديثة لدراسة أنابيب الترسيب ذات القطاعات المربعة والمستطيلة

BY AHMED A. ASHRY[1], S. H. BEHIRY[2] AND MOUSA S. ELBISY[3]

ملخص : يتناول هذا البحث تقنية حديثة لدراسة الترسيب فى أنابيب الترسيب ذات القطاعات المربعة والمستطيلة وقد تم أخذ تأثير التغير فى منحنيات السرعة فى منطقة الدخول الهيدروديناميكى على مسار الحبيبات داخل أنابيب الترسيب وتم تحديد أطوال أنابيب الترسيب وكذلك تحديد العوامل التى تؤثر على كفاءة أنابيب الترسيب.

ABSTRACT :- The performance of rectangular and square tube settler modules have been studied and the factors affecting in rectangular and square tube settler performance have been determind, by using new opproach is developed based on the velocity profile vriation through the tube, which calculated by the author's new techniqe. The variation of the velocity encountered by a settling particle results in variations of its settling path.

NOMENCLATURE

X = Settling length (cm)
Y = Settling depth (cm)
L_S = Total settling length (cm)
L_t = Transition length (cm)
U_i = Velocity filed (cm/sec)
U_{av} = Average flow velocity (cm/sec)
V_{SC} = Settling velocity (cm/sec)
θ = Degree of inclination
T = Water Temperature (°c)
t = Detention time (sec.)
a = Width of rectangular tube section.
b = Height of rectangular tube section (cm)

INTRODUCTION

Sedimentation is the separation of suspended particles that are heavier than water from water by gravitational settling. It is one of the most widely used solids-removal process; from aqueous medium approximately one-third of the total capital cost of conventional water treatment plant. Tube settlers are a reccent technology devices that have been widely used, particularly in plant remodeling, to reduce sedimentation costs by reducing the surface area of sedimentation tanks and the liquid retention time

Hazen (1904) suggested the idea of shallow depth settling, Camp (1946) explored it, and Hansen and Culp (1967) demonstrated its practical application. Culp et al. (1968), Yao (1973), Hernandez and Wright (1970), Willis (1978), and Fadel (1985) proposed different design models. Culp and willis considered uniform flow regime with a straight line path for the particles. Hernandz and Wright proposed an empirical equation developed from laboratory and treatment plant data. Yao considered the parabolic velocity profile for the laminar flow regime across the tube and its effect on the particle trajectory Fadel considered the effect of variations in the velocity profile from uniform flow distribution at the tube entrance to a fully developed laminar flow profile at the end of the transition length and its effect on the particle trajectory.

The objective of this work is to develop a basic theoretical model to explain the performance, and assist in the design, of rectangular and square tube settlers.

NEW APPROACH

With the progressive development of computers and with the use of new technique to calculate the velocity profiles at any distant (about one micrometers) along the tube The authors have developed new approach which determines both the particle trajectory and the required tube settling length, and which considers the velocity profile variation through the tube.

The following steps present the suggested new approach :

1- Assume that the particle which it is desired to remove completely will enter the tube at the upper point (A) in the section (I-I), figure (1).

2- Assume that the particle will reach point (B) in section (II-II) in time (dt) equal 0.01 second.

3- By knowing particle settling velocity (V_{SC}), the settling depth can be calculated :

$$Y = V_{sc_y} \times dt \qquad (1\text{-}a)$$

$$V_{sc_y} = V_{sc} \cos\theta \qquad (1\text{-}b)$$

4- From calculated velocity profile, find the local velocity in section (I-I), ($U_{(i)}$). Assume this local velocity constant between two sections (I-I) and (II-II), the distance between two sections can be calculated :

$$x = u_{(i)_x} \times dt \qquad (2\text{-}a)$$

$$u_{(i)_x} = u_{(i)} - V_{sc_x} \qquad (2\text{-}b)$$

$$V_{sc_x} = V_{sc} \, \text{Sin}\theta \qquad (2\text{-}c)$$

5- Repeat step (2) through (4) for the particle movement from point "B" to "C" and so on, until the particle settles to the bottom of the tube at some distance along the tube.

6- The summation of the x's along the tube until the particle reaches the bottom of the tube will equal the required tube settling length.

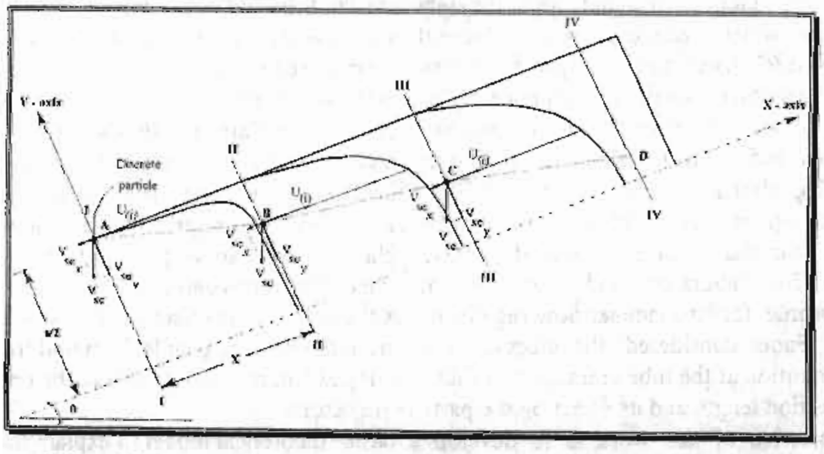
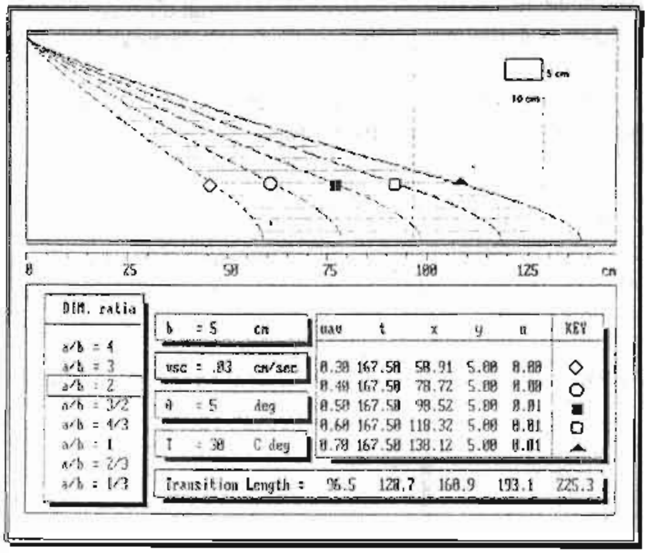
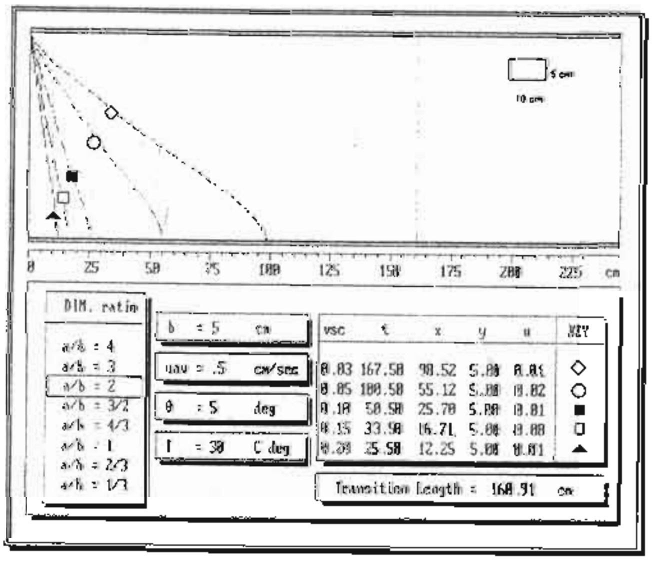


Figure (1) : Diagram showing the particle path inside the tube settler driven from new approach.

New approach is easy to follow and use. Users of the computer program should enter the desired flow velocity, particle settling velocity, water temperature, and the required tube cross section dimension to obtain the particle trajectory, tube settling length (cm) and detention time (sec) from the computer program Examples of the computer program for the new approach is presented in Figures (2,3)



Figure(2) The effect of increasing the flow velocity on the required tube settling length, for (a/b = 2).



Figure(3) : The effect of increasing the particle settling velocity on the required tube settling length, for (a/b = 2).

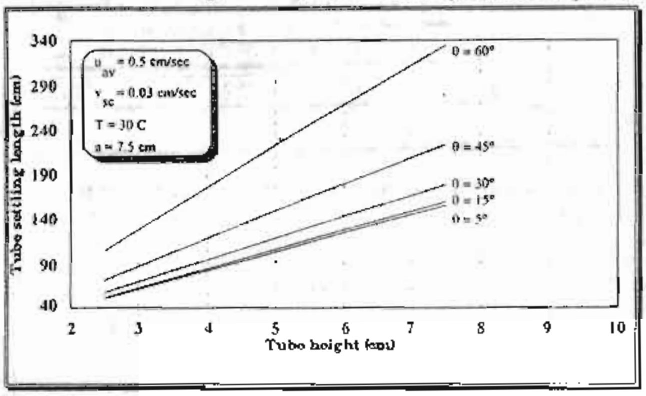
Design charts have been developed from successive computer solution which allow the designer to obtain the required tube settling length for different cross sectional dimention, average flow velocity, particle settling velocity, degree of inclination and water temperature. The designer using these charts should first establish a value for the following parameters to be evaluated in tube design.

(1) Angle of inclination, (2) Tube cross sectional dimension,
(3) Average flow velocity, (4) Minimum expected particle settling velocity, and
(5) Water temperature.

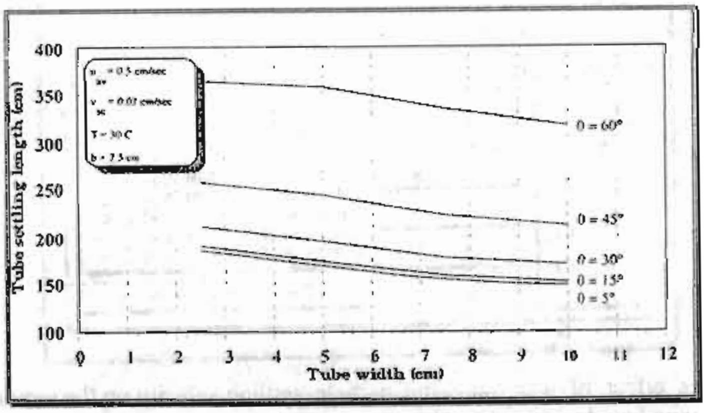
Five factors on the rectangular tube settler performance may be predicated on the basis of computer solutions of the New approach:

(1) Cross-sectional dimension :

Figure(4) represents the effect of increasing the tube height on the required tube settling length, with constant tube width. The results, Figure (4), show that large tube heights require longer tube settling length; small tube heights yield better performance, which matches the results of [7], [8], and [12]. Figure (5) represents the effect of increasing the tube width on the required tube settling length. The results, Figure [5] show that with constant tube height. Large tube widths yield better performance



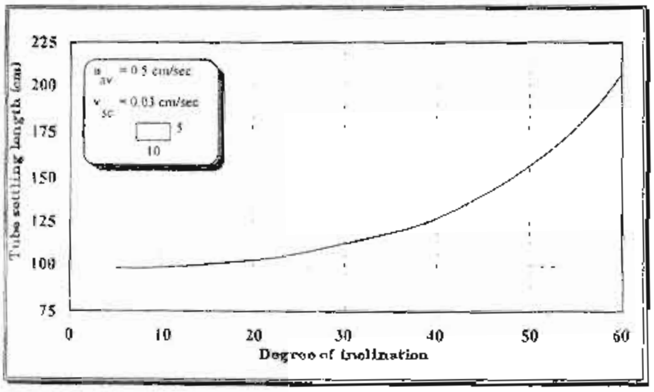
Figure(4) : The effect of increasing tube height on the required tube settling length.



Figure(5) : The effect of increasing tube width on the required tube settling length

(2) Degree of inclination :

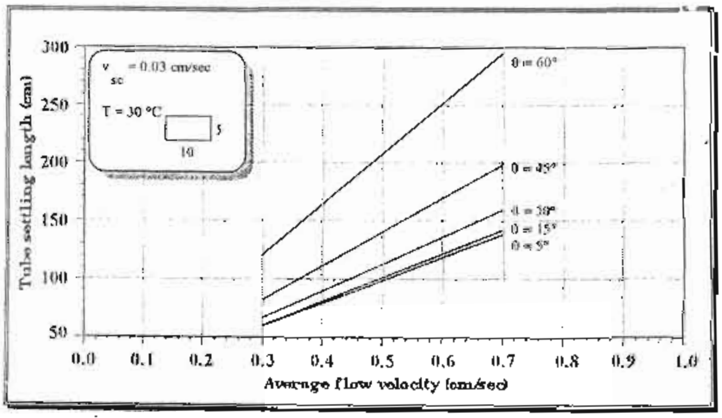
Figure (6) represents the effect of inclination on the requried tube settling length Angles in the ranges of 5 to 15 degrees from the horizontal have little influence on the required tube setting length. However, the requried tubes setting length increases significantly at angles of 15 degrees or more; at 60 degrees, the the required tube setting length is almost (2.1) that of tube on an inclination of 5 degrees.



Figure(6) : The effect of inclination on the required tube setting length.

(3) Averge flow velocity :

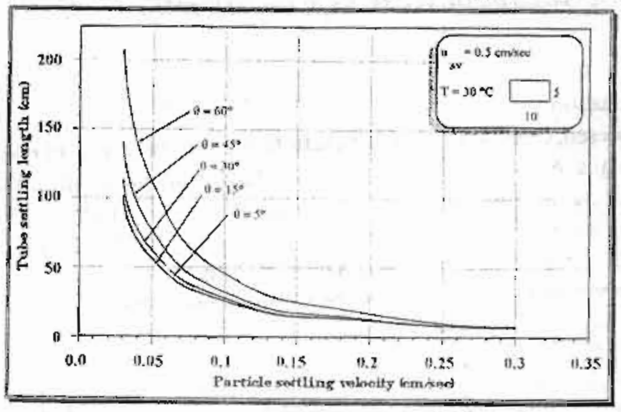
Figure (7) represents the effect of average flow velocity on the required tube settling length. The results, Figure (7) show that higher flow velocities require longer tubes



Figure(7) . The effect of increasing the flow velocity on the required tube settling length.

(4) Particle settling velocity :

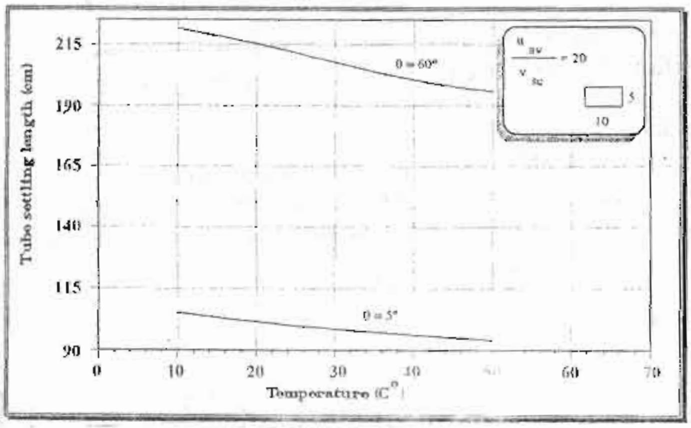
Figure (8) represents the effect of lowering the particle settling velocity on the required settling length. The results, Figure (8) show that lower particle settling velocities also require longer tube.



Figure(8) : The effect of increasing the particle settling velocity on the required tube settling length.

(5) Temperature :

Figure (9) represents the effect of temperature on the required settling length. The results, Figure (9) show that the lower water temperature, the longer tubes settling length.



Figure(9) : The effect of temperature increase on the required tube settling length.

CONCLUSIONS

The study, conducted to improve tube settler design, has yielded the theoretical model, has been developed for predicting the performance of rectangular and square tube settlers on the basis of the effect of variations in the velocity profile from uniform flow distribution at the entrance tube to a fully developed laminar flow profile at the end of the transition length.

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