Mansoura Engineering Journal

Volume 26 | Issue 4 Article 4

2-3-2021

Influence of a Fully Angle Baffled Floor on Scour behind a Hydraulic Structure.

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Recommended Citation
El-Masry, Adel (2021) "Influence of a Fully Angle Baffled Floor on Scour behind a Hydraulic Structure.," *Mansoura Engineering Journal*: Vol. 26 : Iss. 4 , Article 4.
Available at: https://doi.org/10.21608/bfemu.2021.146034

Mansoura Engineering Journal, (MEJ), Vol. 26, No. 4, December 2001.

INFLUENCE OF A FULLY ANGLE BAFFLED FLOOR ON SCOUR BEHIND A HYDRAULIC STRUCTURE

تأثير الفرش المزود بالكامل بعوارض زاوية الشكل على النحر خلف منشأ هيدروليكي

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خلاصة:

تستخدم الكتل الاعتراضية لتشتيت طاقة المياه المتدفقة أسفل البوابات أو المنحدرة على الهدارات. في هذا البحث تمت دراسة معملية لاستخدام فرش منشأ حجز مزود بالكامل بعوارض زاوية الشكل. المتغيرات التي تم مراعاتها هي: ارتفاع العوارض ، معدل السريان ، عمق المياه خلف المنشأ. تمت الدراسة لوضعين مختلفين من أوضاع العوارض. لتمثيل تأثير الأوضاع المقترحة للعوارض تم إجراء واحد وثمانون تجربة عمليه ومثلت النتائج على صورة منحنيات لا بعديه. الاقتراحات المدروسة لها تأثير واضح على تقليل النحر كما أنها من السهل إضافتها لمنشآت قائمة. تم مقارنة نتائج الدراسة الحالية بنتائج دراسات سابقة لاستخدام صف وصفان من العوارض الزاوية.

ABSTRACT

Baffle blocks are used to dissipate the energy of water flow, which pass under gates or over weirs. In this paper, a fully angle baffled apron of a heading-up structure is experimentally studied. Two arrangements are considered. Baffle's height, flow discharge, and downstream water depth are the considered variables. Obtained results from eighty-one runs are graphically represented to illustrate the effect of the suggested systems. The suggested systems are easy to be added to the existed structures without changing their floors. Present results are compared with previous ones for single and double lines of angle baffles.

INTRODUCTION

Scour below heading-up structures results from the erosive power of the flowing water. Protection against scour is afforded by ensuring that the high-velocity flows do not come into contact with the channel bottom or by directing the flow as far away from the structure as possible. When a high-velocity, jet or sheet of water flows over the unprotected riverbed downstream from the structure, it may erode the bed material and carry it either in suspension or as bed load farther downstream.

The use of baffles, steps, or floor blocks to assist in energy dissipation and velocity reduction is well established in hydraulic structures in which high velocity flow occurs. Generally, these appurtenances are used in stilling basins for spillways, outlet works, chute drop structures, vertical drop structures, and other types of water-control structures in which a hydraulic jump occurs. In these structures, the flow entering the stilling basin is supercritical, and the height of the baffle blocks is usually set equal to the jet depth of the approaching flow Elevatorski (1959). This depth is frequently only 10% to 20% of the downstream depth.
So, the baffles are completely submerged Clifford D. Smith and James N.G.Yu (1966).

Accepted December 29, 2001

The baffles are usually spaced so that the width of the spaces is approximately equal to the width of the blocks Blaisdell (1947). With this arrangement, it is possible to use considerably shorter stilling basins than would be required if baffles were not used.

The Indian Standards Institution (1969) has adopted a stilling basin design using baffle piers. Bhowmik (1975) used piers with different inclinations to the incoming flow to reduce the flowing water energy. Pillai (1969) and (1989), Peterka (1978), Vicher and Hagar (1995), EL-Masry and Sarhan (2000), EL-Masry (2001), and EL-Gamal (2001) studied different baffle block shapes. Pillai (1966) used wedge-shaped baffle piers of vortex angle 120° cut back at angle of 90°. Pillai et al (1969) used wedged-shaped baffle pier of vortex angle 150° cut back at angle of 90° with the sides to prevent reattachment with the sides and showed that these types of baffles could be effectively used in a stilling basin for Froude number about 2.85.

EL-Masry and Sarhan (2000) used a single line of angle-shaped baffles with vertical faces to reduce local scour behind heading-up structure, Fig.1. EL-Masry (2001) studied the performance of double lines of angled baffles in reducing the deformed scour hole comparing with the case of no baffles, Fig.1. EL-Gamal (2001) used triple lines of angle baffles to minimize the deformed scour holes.

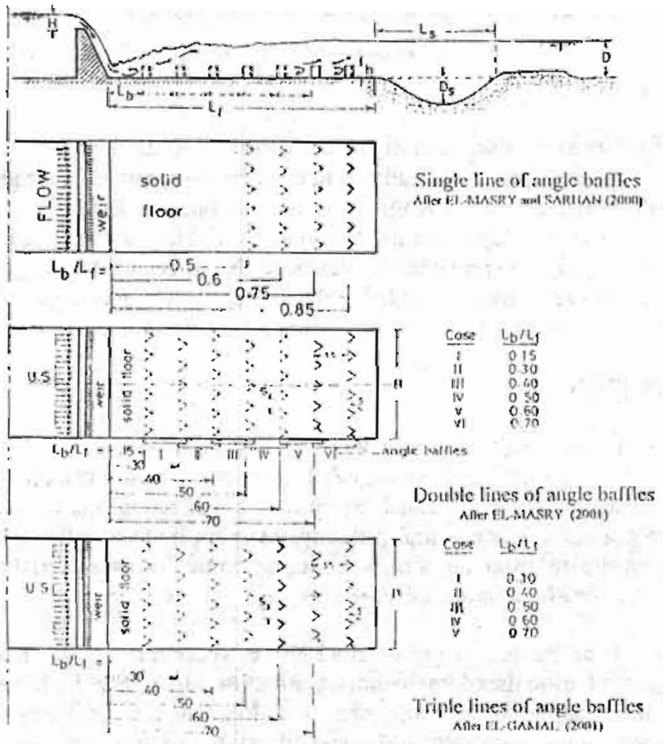

Fig.1 Layout of the system and arrangements of previous studies

The research described in this paper was undertaken to study the effect of a fully baffled floor with angle blocks. Angled baffle blocks are studied in two arrangements. In the first arrangement, the arms of angle baffle are in the front side, i.e., facing the incoming flow with 90° (Case-A). In the second arrangement, the arms of the angle baffles are in opposite side to the incoming flow, i.e., facing the flow with 270° (Case-B), as shown in Fig.2.

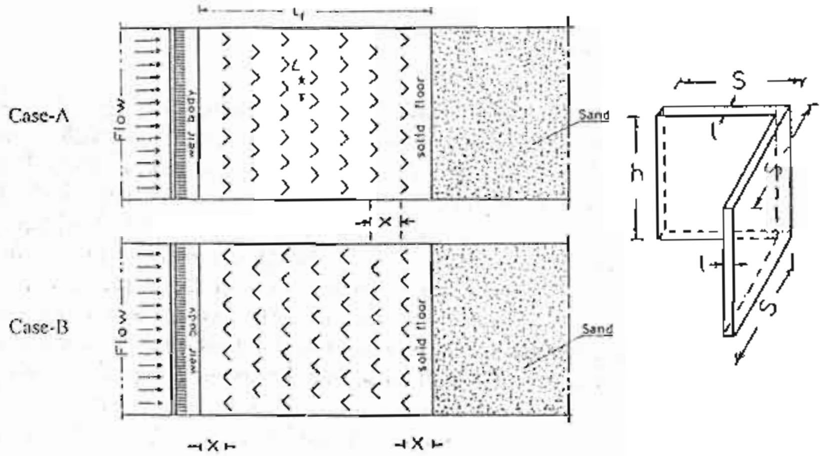

Fig.2- Baffle arrangements for cases under study.

In both cases, baffle blocks are located in a staggered manner with a space perpendicular to the flow equals to the baffle's arm. In the direction of flow, distance between baffle rows is chosen three times the baffle's arm.

Blaisdell (1947) suggested that, the floor blocks should occupy between 40 to 50 per cent of the floor width. Baffles should be easy to construct, maintain, and if possible, should be non-clogging and self-cleaning. In this study, baffles are arranged in seven rows, three have 43 per cent open pass way across their vertical front, the others have 47 per cent. In average, they have about 45 per cent open pass way across their vertical front.

To simplify the investigations, the following assumptions are based on the practical point of view:
$t/S = 0.1$, $S/L = 1.0$,
$h/S = 0.33, 0.66, 1.0,$ and 1.33,
$X/S = 3.0$
Where;
h: height of baffle blocks,
L: space between baffles perpendicular to flow direction,
S: baffle's arm length, t: baffle's arm thickness, and
X: distance between baffles in the direction of flow.

In order to study the influence of the suggested systems, the following dimensionless parameters are considered: D_s/D, D_s/d_{sw}, $\lambda^{-1} = 1/F^2$, L_s/D, L_s/L_{sw}, h/S, where;

D: downstream water depth,
D_s: maximum scour hole depth,
D_{sw}: maximum scour hole depth for the case of floor without baffles,
L_s: scour hole length along the centerline of the channel,
L_{sw}: scour length for the case of floor without baffles,
L_f: floor length (kept constant),
F : Froude number = $V/(gD)^{1/2}$
V : mean flow velocity, and
λ : kinetic-flow factor = F^2

EXPERIMENTAL SET-UP

Experimental runs are conducted in the hydraulic laboratory in EL-Mansoura University. The flume shown in Fig.3 was constructed from timber with 8.m. long, 45 cm. wide and 40 cm deep. The flume was constructed inside a wider channel. The apparatus mainly consists of head and tail tanks and the flume itself through which the flow is conveyed. Water is pumped to the head tank from ground sump. The head tank consists of two adjacent tanks connected together through submerged holes. The pump supplies the first tank with the pumped water. Consequently, water level of the adjacent tank rises. This procedure is followed to damp water fluctuations. The second tank is provided with two weirs, one of them is calibrated to measure the flow that feeds the flume, the other one is to allow excess water overflow and to be drained into the ground sump. Thus, water head over the calibrated weir can be maintained at a constant level despite any fluctuations in the pumped rate. The flow feeds the flume through an inlet screen to absorb any water eddies.

Heading-up structure is modeled using timber as a Fayoum type weir. The floor of the model is punched to fix the baffles in seven rows. Each row is fixed staggered with respect to next one. The movable bed was simulated by graded sand of mean particle size D_{50} = 0.56 mm and standard deviation σ_g =1.6, mixed sand. Precise point gauge mounted on the x-y carriage is used to measure both of water levels and scour hole profile. For all runs, the floor length and baffle dimensions except its height are kept constant. Baffle heights are changed to give the relative heights h/S = 0.33, 0.66, 1.0 and 1.33. Downstream water depth is controlled using a hinged gate.

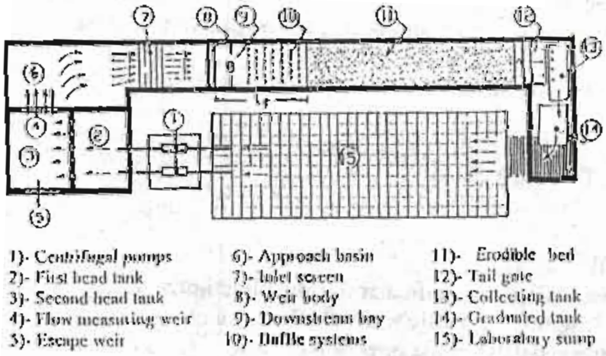

Fig.3- Experimental set-up

THE EXPERIMENTAL APPROACH

In this study, eighty-one run were conducted using three discharges (Q= 6.3, 8.0, and 10.1 Lits/sec). For each discharge, three water depths in downstream side were considered. Thirty-six run were conducted for case-A, Fig. 2, where baffle arms face the incoming flow. Also, thirty-six runs were conducted for case-B where the baffle arms are in the backside of the incoming flow. Nine runs were considered for flat floor without baffles to compare the influence of the other cases with them.

For each run, backwater feeding is started first until its depth reaches higher than the required downstream water depth, then upstream feeding is started. Tailgate is screwed gradually until the required downstream water depth is adjusted. After many trials, two hours are chosen as a constant time for all runs because there was no appreciable change in scour hole dimensions. Scour hole profile is recorded along the center of the flume.

EXPERIMENTAL RESULTS AND ANALYSIS

Data from 81 tests were reduced to dimensionless form and graphically represented to illustrate the influence of the considered cases. Froude number just D.S. the weir ranged from 3.86 to 4.2. The considered dimensionless parameters were D_s/D, D_s/D_{sw}, $\lambda^{-1} = 1/F^2$, L_s/D, L_s/L_{sw}, h/S, where w refers to the case of floor without baffles, and F is the Froude number = $V/(gD)^{1/2}$, V is the mean flow velocity.

From the recorded scour hole profiles, Fig.4 shows some of the illustrated scour holes for λ^{-1}equals 2.5, 5.1, and 6.9, respectively considering both cases of baffle arrangements. From this figure, it is clear that, for $\lambda^{-1} = 6.9$, increasing baffle height increases scour hole depth and length. Case B gives deeper and longer scour holes as case A dissipate more energy, EL-Masry & Sarhan (2000). For $\lambda^{-1} = 5.1$, one can observe that, the influence of changing baffle heights is more clear than that of the above mentioned cases because Froude number is the most effective parameter. For $\lambda^{-1}= 2.5$, scour hole profiles are deeper and longer than the above recorded similar cases.

Relationship between $\lambda^{-1}$and D_s/D for the considered cases and baffle heights is illustrated in Fig.5. From this figure it is clear that, for both cases of baffle blocks, increasing Froude number increases the relative depth of scour hole. Scour hole depths for case B are greater than those for case A. For case A, increasing baffle heights increases the relative depth of scour hole except for h/S = 0.66 and 1.33. For h/S = 0.66, changing λ^{-1} from 2.0 to 5.0 gives scour hole depth smaller than the previous baffle height, h/S = 0.33. For the relative height of baffles h/S = 1.33, the recorded scour hole depth is smaller than that of 1.0. For case B, increasing the relative height of baffles increases the relative depth of scour hole except for h/S = 1.33 which gives smaller depths comparing with the result of h/S=1.0.

Relationship between $\lambda^{-1}$and D_s/D_{sw} is illustrated in Fig.6 considering baffle cases and heights, (h/S = 0.33, 0.66, 1.0, and 1.33). From this figure, it is clear that, most of the obtained data refers to the fact that, most of the tested baffle heights and arrangements decreases the recorded scour depth comparing with the case of scour due to flat floor (without baffles), i.e. $D_s/D_{sw}<1.0$. For the same height of baffles, scour depth for case A is lesser than that of case B.

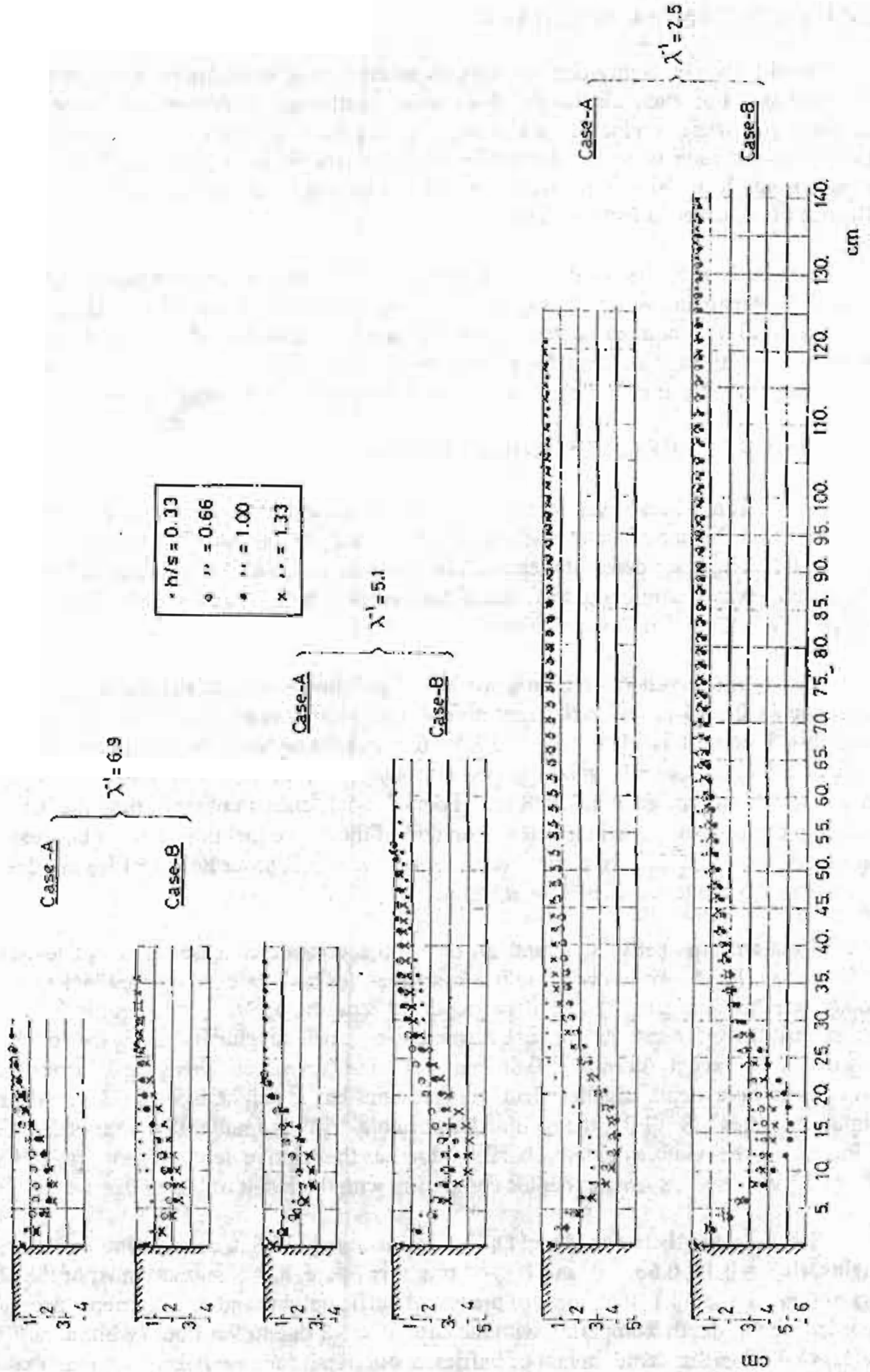

Fig.4- Scour hole profiles for some cases.

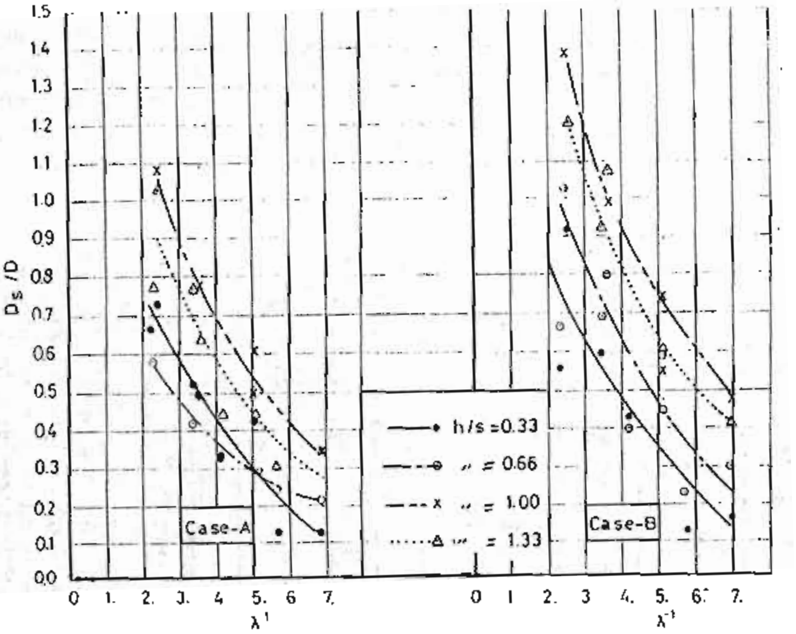

Fig.5- Variation of D_s/D with λ^{-1} for values of h/S and baffle arrangements.

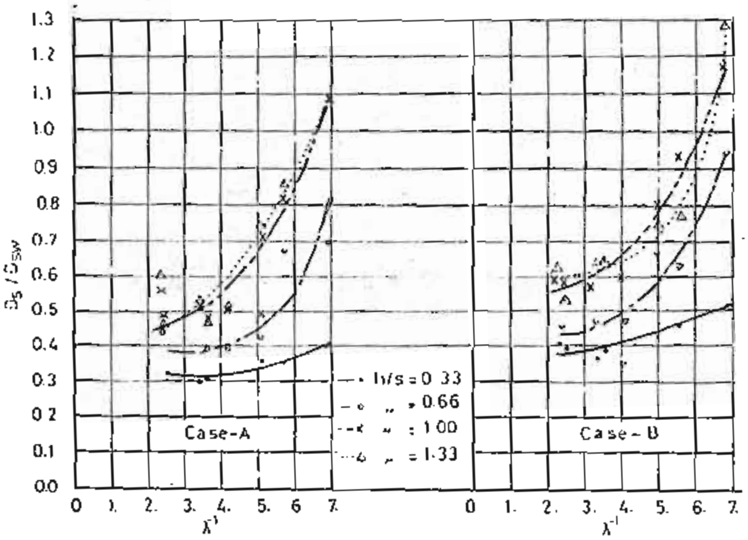

Fig.6- Variation of D_s/D_{sw} with λ^{-1} for the considered cases and baffle heights.

Figure 7 shows the relation between L_s/D and λ^{-1} for the cases of baffle blocks and their heights. From this figure it is clear that, increasing Froude number increases the recorded scour hole length. For case A the relative height of baffles equals to 0.33 gives the smaller length of scour hole, and h/S=1.33 gives smaller values of scour length comparing with the cases of 0.66 and 1.0. For case B, the results are close to each other but in general h/S = 0.33 and 0.66 give the smaller values comparing with the other two heights.

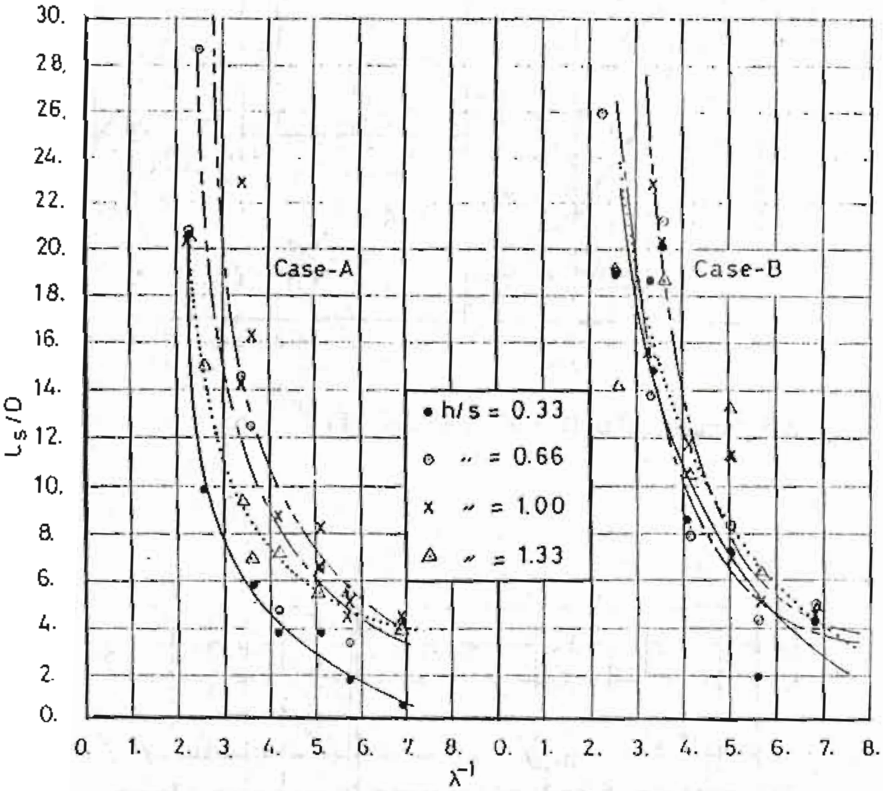

Fig.7- Variation of Ls/D with λ^{-1} for baffle cases and heights.

Figure 8 shows the variation of L_s/L_{sw} with λ^{-1} for both cases of baffle blocks and heights. From this figure it is clear that, increasing Froude number increases scour hole length in general, but most of the tested cases give values lesser than those of the case of flat floor, (without baffles), i.e. L_s/L_{sw} <1.0. That is because the presence of the baffles dissipates a part of the water energy. For case A, increasing baffle height increases the relative scour hole length except for h/S = 1.33 which reduces the relative scour hole length comparing with the heights h/S=0.66, and 1.0. For case B, the relative height of baffle blocks h/S = 1.33 reduces scour hole length comparing with the relative heights of baffles h/S=0.66 and 1.0. for λ^{-1}<4.5. After that, it gives the bigger relative length of scour hole but still shorter than that length of scour obtained for flat floor.

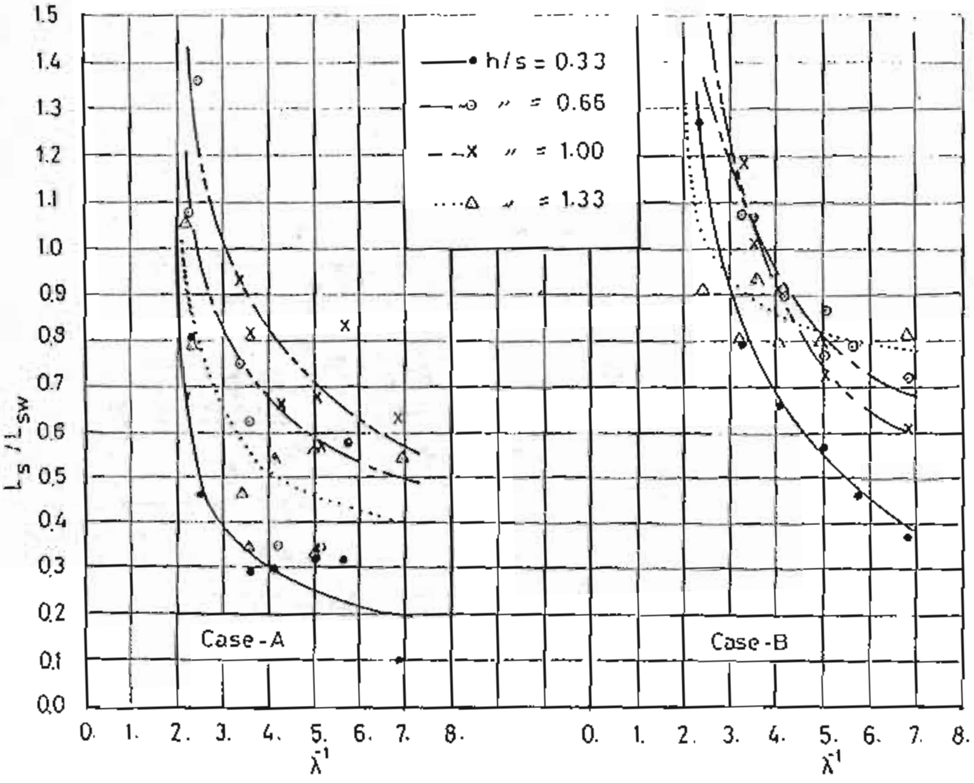

Fig.8- Variation of L_s/L_{sw} with λ^{-1} for baffle cases and heights.

Figures 9, 10, and 11 demonstrate the variations of D_s/D_{sw} with h/S for $\lambda^{-1} = 2.5, 5.1, 6.9$, respectively. Results of single and double lines of angle blocks are considered, with A and B cases to compare the influence of them. The single and double rows of baffles are considered for L_b/L_f from 0.3 to 0.85.

From figure 9, it is clear that, for cases A and B, increasing h/S increases the relative depth of scour hole. For the case of single lines, increasing h/S increases the relative depth of scour hole till h/S = 0.66 after that, increasing the value of h/S decreases the relative depth of scour. For double lines of baffle blocks, increasing h/S decreases the relative depth of scour hole. For all cases, all results indicated that, single, double and full baffled aprons clearly reduce scour hole depth comparing with the case of flat floor (without baffles), i.e. $D_s/D_{sw} < 1.0$.

Figure 10 also shows that, for $\lambda^{-1} = 5.1$, using the suggested case A or B reduces the recorded scour hole depth comparing with the case of no baffles. Case A reduces scour hole depth more than case B. Case A reduces scour hole depth to about 40% in average from the case of no baffles. Single and double rows of baffle blocks are considered to illustrate their influence comparing with the present results.

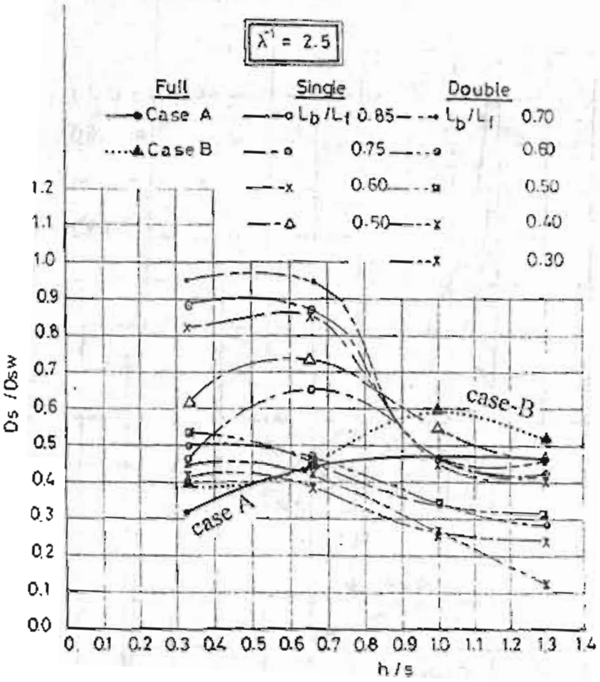

Fig. 9- Variation of D_s/D_{sw} with h/S for $\lambda^{-1} = 2.5$.

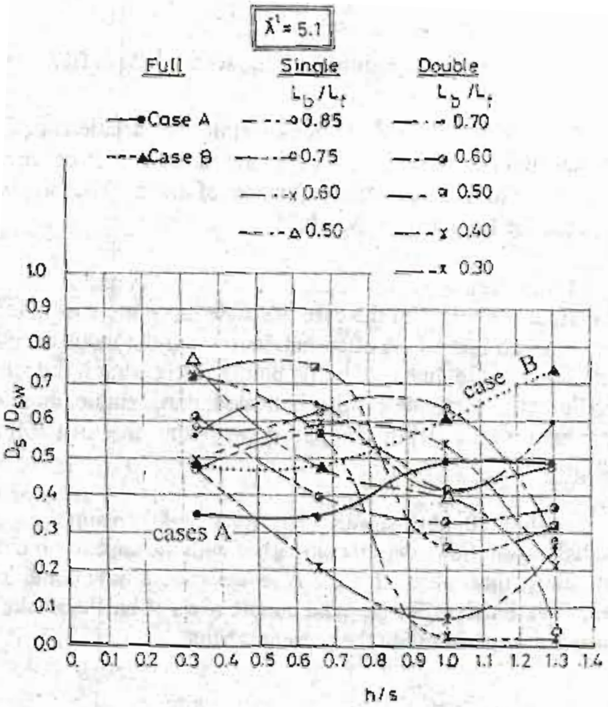

Fig. 10- Variation of D_s/D_{sw} with h/S for $\lambda^{-1} = 5.1$.

Figure 11 shows the relation between D_s/D_{sw} and h/s for $\lambda^{-1} = 6.9$. From this figure, it is clear that, case A increases scour hole depth more than the case of no baffles at baffle relative heights greater than 0.9 while case B at 0.75. Most of the recorded results show that, the case of single line of baffles reduces the depth of maximum scour. For $\lambda^{-1} = 6.9$, case of double rows of baffle blocks increases the maximum depth of scour hole comparing with the case of no baffles.

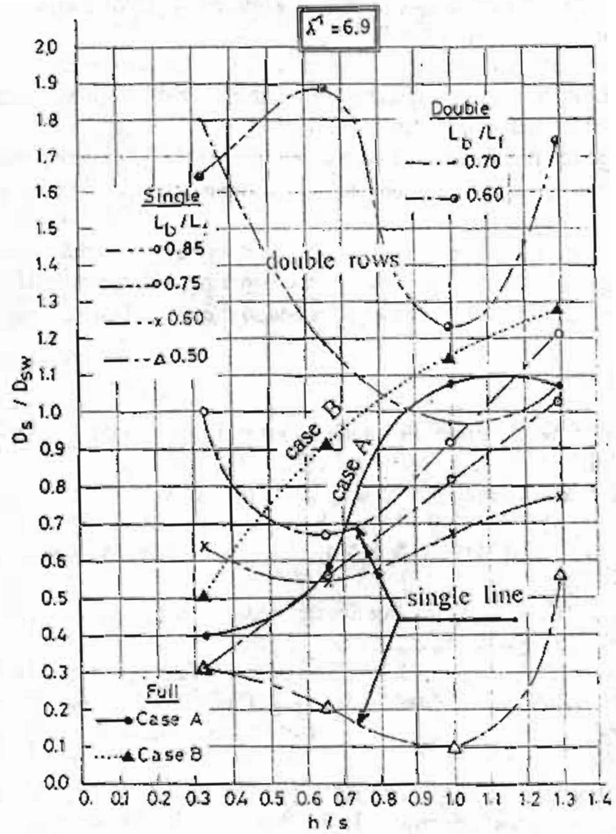

Fig. 11- Variation of D_s/D_{sw} with h/S for $\lambda^{-1} = 6.9$.

CONCLUSIONS

To reduce scour hole dimensions, a system of fully angle baffled apron was studied experimentally. Eighty-one run were conducted. Two arrangements were considered. The cases of flat floor without baffles were considered to illustrate the influence of the suggested arrangements. Previous studies for single and double rows of angle baffles were included for comparative purposes. From the experimental tests, obtained data were graphically represented and discussed. The following conclusions could be summarized:

- The tested angle baffle arrangements reduced scour hole depth and length comparing with the case of flat floor.
- The arrangements of baffles that facing the flow with the baffle arms reduced scour hole dimensions more than the opposite ones.
- The systems of fully baffled aprons are suitable for all flow conditions as the discharge and water levels change during operating conditions. Single, double, and triple lines of baffles are suitable for specific conditions of flow.
- Increasing Froude number increased the recorded scour hole dimensions.
- The relative height of baffles equals or smaller than one gave smaller scour hole dimensions.
- For $\lambda^{-1} = 5.1$, $F=0.44$, the tested arrangements of angle baffles that facing the incoming flow reduced scour hole depth to about 40% comparing with the case of flat floor.
- The tested arrangements are easy to be added to the existed structures.

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