Mansoura Engineering Journal, (MEJ), Vol. 26, No. 2, June 2001.

EFFECT OF USING THREE-LINES OF ANGLE BAFFLES ON SCOUR DOWNSTREAM HEADING-UP STRUCTURES

تأثير استخدام صفوف ثلاثية من الرءوس زاوية الشكل علي النحر خلف منشآت الحجز

By

El-Gamal, M. M.
Irrigation & Hydraulics Dept.
Mansoura University
Faculty of Engineering

خلاصة :

تم دراسة تأثير استخدام صفوف ثلاثية من الرءوس زاوية الشكل علي النحر خلف منشآت الحجز وذلك باجراء مائة وثمانون تجربة تم فيها تغيير ترتيب وارتفاعات الصفوف الثلاثية مع التصرفات المختلفة للسريان ومقارنة النحر الحادث خلف صفوف ثلاثية من الرءوس زاوية الشكل مع النحر الذي يتكون خلف منشآت الحجز بدون وجود صفوف ثلاثية من الرءوس زاوية الشكل

ABSTRACT

The effect of using three lines of angle baffles on scour downstream heading-up structure was conducted. Hundred eighty runs were conducted considering various heights and positions of the angle baffles with different flow conditions. Cases of flat floor without baffles are included to estimate the influence of the suggested system. Results were analyzed and graphically represented.

INTRODUCTION

Large-scale erosion caused by fluid flow local to hydraulic structures is of obvious concern because the foundation can be undermined leading to structure failure. One of the situations that have attracted considerable attention is the scour downstream heading-up structures. The safety of apron downstream heading-up structures and of energy dissipating devices can also be threatened by the erosion of sediments in their vicinity. The hydraulic jump used for energy dissipation is usually confined partly or entirely to a channel reach that known as the stilling basin. Stilling basin is seldom designed to confine the entire length of a free hydraulic jump on the paved apron, because such a basin would be too expensive. Consequently, accessories to control the jump are usually installed in the basin. The main purpose of such control is to shorten the range with in which the jump will take place and thus to reduce the size and cost of stilling basin. Baffle piers are installed in aprons principally to stabilize the formation of the jump and increase the turbulence. The Indian Standards Institution (1969) has adopted a stilling basin design using baffle piers. Studies were conducted by Bhowmik (1975) using piers with different inclinations to the incoming flow. Pillai (1967) shows that, flow filaments deflected outward at the front corners of the conventional rectangular baffle piers and reached to the sides further downstream causing reduction in drag force due to decrease in wake area. Different baffle block shapes have been studied by Pillai (1966) and (1969), Peterka (1978), Vicher, and Hager (1995), and EL-Masry (2001). Pillai (1969) used wedge-shaped

Accepted June 23, 2001

In this paper three rows of angle baffles were used to minimize the scour hole as shown in Fig. (1)

FLOW BOUNDARIES AND VARIABLES

Referring to Fig. 1, the following parameters are used;

L_b : distance between intermediate baffle line and the toe of the weir,
L_f : length of floor downstream the structure,
X : the distance between baffle rows in flow directions,
S : the baffle arm length,
L : the space between baffles perpendicular to flow direction,
T : baffle' s arm thickness,
H : the height of the baffle blocks,
θ : the angle between baffle arms.

To simplify the investigations, the following assumptions are considered:

T/S is kept constant = 0.10,
S/l is kept constant = 1.0,
$\theta = 90^\circ$,
$h/S = 0.33, 0.66, 1.0,$ and 1.33,
$L_b/L_f = 0.30, 0.40, 0.50, 0.60, 0.70$ and
$X = 3S$.

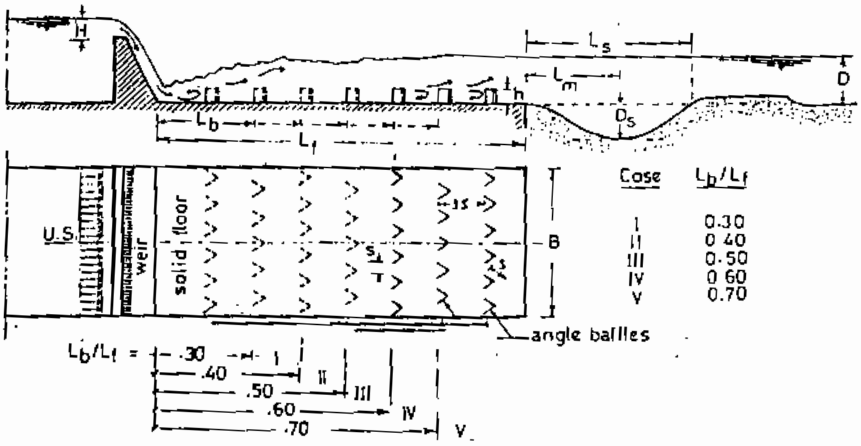


Fig.1 - Variables and flow boundaries

Baffles are arranged in three rows, one of them has 43% open pass way across its vertical front, the others have 47%, or the inverse. In average, they have 45% open pass way across their vertical front.

In order to illustrate the influence of the suggested baffle system, the following dimension-less parameters are considered:
D_s/D, $1/Fr^2$, L_s/D, L_m/D, L_b/L_f, h/s, D_s/D_{sw}, L_s/L_{sw}, and L_m/L_{mw}.
Where
D is the tail water depth,
D_s is the maximum scour depth,
Fr is Froude number = $v/(gD)^{0.5}$
L_s is length of scour hole,
L_m is the length to the location of maximum scour depth,
D_{sw} is the maximum scour depth for the cases of floor without baffles,
L_{sw} is the maximum scour length for the cases of floor without baffles,
L_{mw} is the distance to position of maximum scour depth for the cases of floor without baffles.

EXPERIMENTAL SET-UP

Fig. (2) shows the apparatus used in this study. The flume, 45 cm wide, 40 cm deep and 9.0 m long were constructed from timber inside a wider channel. The flume consists of head and tail tanks and the flume itself. A centrifugal pump is used to supply water to the head tank from ground sump. Water is controlled using a control valve installed on delivery pipe connected to the feeding pump. The head tank consists of two adjacent tanks connected together with holes. The pumped water supplies the first tank; consequently, the level of the adjacent tank rises. This procedure is to absorb water fluctuations. Second tank has two weirs, the first is calibrated to measure the flow that feed the flume., the other is to allow excess water overflow and be drained to ground sump, keeping the head of water constant. A vertical scale is used to measure the head over the calibrated weir. The flow enter the flume through an inlet screen to absorb any water eddies.

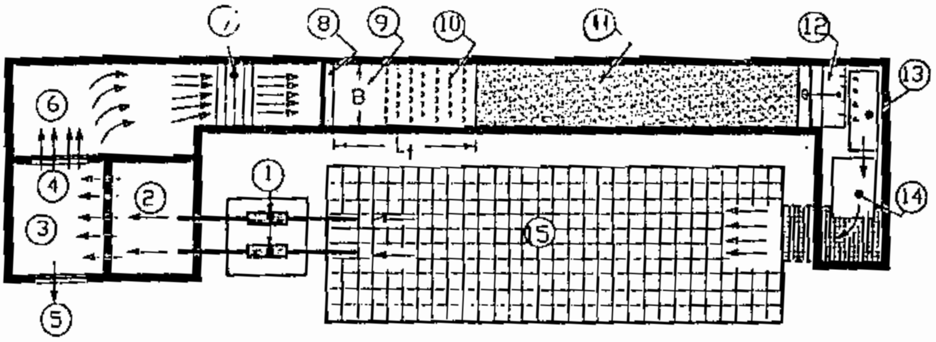
The model is made of timber. Downstream apron is punched to fix baffle blocks. To represent the erodable bed the rear portion of the channel is filled with sand with D_{50} = 0.56 mm. Precise point gauge in installed to measure the depth of water. The gauge is mounted on x-y carriage. The carriage travels on two sets of rails. Downstream water depth is controlled using hinged gate. For all runs, the downstream floor length, L_f, is kept constant.

EXPERIMENTAL PROCEDURE:

To study the influence of the suggested baffle system, three discharges are considered (Q= 6.30, 8.0, and 10.10 Lit/sec.). For each discharges, three water depths downstream the structure are used. The system of angle baffles that consists of three rows is located at five positions as mentioned above. The considered length,

L_b, is measured to the middle of the baffle system. For each baffle position, the height of baffles is changed four times, h/s = 0.33,0.66, 1.0, and 1.33, to estimate the best height that leads to the maximum reduction on scour hole.

Hundred eighty runs were conducted including nine runs without baffles to estimate the influence of the suggested system. For each run, backwater feeding is stared first until its depth reaches higher than required downstream water depth, D, then upstream feeding is started. To adjust the depth of tail water, the tailgate is screwed gradually until the required depth arrived at.



1)- Centrifugal pumps
2)- First head tank
3)- Second head tank
4)- Flow measuring weir
5)- Escape weir
6)- Approach basin
7)- Inlet screen
8)- Weir body
9)- Downstream bay
10)- Baffle systems
11)- Erodable bed
12)- Tail gate
13)- Collecting tank
14)- Graduated tank
15)- Laboratory sump

Fig. 2 Experimental set-up

Two hours after many trails was chosen as a constant time for all runs. After this time, here was no appreciable change in scour hole dimensions. After the running time, the run was stopped and the flume was evacuated. Scour hole profile along the centerline of the flume was recorded with the precision point gauge.

RESULTS AND ANALYSIS:

Experimental results were expressed in dimensionless forms and graphically represented to study the effects of the suggested system on scour hole dimensions, D_{sb}, L_{sb}, and L_m. The considered dimensionless terms are listed before.

Relationships between the values of D_{sb}/D and $1/Fr^2$ are illustrated as shown in Fig. 3 considering the values of, L_b/L_f and h/s. From this figure it is clear that, the value of h/s=1.0 gives the minimum values of D_{sb}/D except for L_b/L_f = 0.40. For L_b/L_f = 0.40, the minimum value of D_{sb}/D occurs at h/s= 0.66.

Fig. 4 shows the relation between D_{sb}/D and L_b/L_f for different Froude number values, and h/s. It is evident that the minimum scour depth occurs at a position of baffle system near the weir. In the other hand, the maximum scour depth occurs at a position of baffle system near the floor end.

Fig. 5 shows the relation between D_{sb}/D_{sw} and $1/Fr^2$ for different values of L_b/L_f, and h/s. From this figure it is clear that, for all values of L_b/L_f the suggested system gives a good reduction on scour hole depth for $1/Fr^2 < 5$.

Fig. 6 shows the variation of L_{sb}/D with $1/Fr^2$ for the considered values of L_b/L_f and h/s. From this figure, it is clear that, the value of h/s=1.0 gives the minimum values of L_{sb}/D except for $L_b/L_f = 0.30$. For $L_b/L_f = 0.30$, the minimum value of L_{sb}/D occurs at h/s= 1.33. Also, it is clear that, increasing the values of $1/Fr^2$, decreases the relative length of scour hole.

The recorded values of scour length for the cases of floor without baffles, L_{sw}, are used to estimate the influence of the suggested system. Fig. 7 shows the relation between L_{sb}/L_{sw} and $1/Fr^2$ for different values of L_b/L_f, and h/s. From this figure it is clear that, for $1/Fr^2 \geq 3$ the suggested system gives a good reduction on scour hole length.

The distance from the end of the floor to the point of maximum scour depth, L_m, is recorded and used to illustrate the variation of L_m/D with $1/Fr^2$ for the considered values of L_b/L_f and h/s as shown in Fig. 8. From this figure it is clear that, the value of L_m/D decreases by increasing the value of $1/Fr^2$ for values of $L_b/L_f = 0.30$, 0.40, 0.50. For $L_b/L_f = 0.60$, and 0.70 the value of L_m/D decreases by increasing the value of $1/Fr^2$ except for h/s = 1.33, at which the value L_m/D reaches its maximum value at $1/Fr^2 = 5$.

Also, the distance from the end of the floor to the point of maximum scour depth for the cases of floor without baffles, L_{mw}, is used to estimate the influence of the suggested system of baffles. Fig. 9 shows the variation L_m/L_{mw} with $1/Fr^2$ for different values of L_b/L_f, and h/s. From this figure, it is clear that, for $1/Fr^2 > 3.5$, the value of L_m/L_{mw} does not exceed 1.0 for all values of L_b/L_f, and h/s.

CONCLUSIONS:

To minimize the deformed scour holes downstream heading-up structures, a system of double lines of angle baffles is suggested. To eliminate the impacts of excessive sever scouring downstream the existed structures, the suggested system is easy to be used as additional elements. From the experimental study, obtained results are analyzed and graphically represented. For the studied parameters within the range of flow conditions, using the suggested system of three lines of angle baffles, generally, reduces the deformed scour hole dimensions. The following points can be mentioned:

- For all positions of baffle lines, the values of h/s = 0.66, and 1.0 gives a minimum values of scour hole dimensions.
- Increasing Froude criteria increases the maximum scour depth.
- Locating the suggested baffle system adjacent to he body of the weir, generally, minimizes the deformed scour depth.
- For L_b/L_f = 0.30, the minimum values of scour hole dimensions occur at h/s = 0.33.
- Decreasing Froude number leads to move the position of maximum scour depth towards he floor end.

REFERENCES

Bhowmik N. G. (1975) " Stilling basin design for low Froude number." J. Hydr. Div., ASCE, 101(7), 901-914.

El Masry A. A. B. (2001), "Minimization of sconr downstream heading-up structures using double lines of angle baffles."

Indian Standard Institution (1969) "Criteria for design of hydraulic jump type stilling basins with horizontal and sloping apron." June.

Peterka, A. J., (1987), "hydraulic design of stilling basin and energy dissipators", U. S. dpt. of the Interior, Bureau of Reclamation, Washington, D. C.

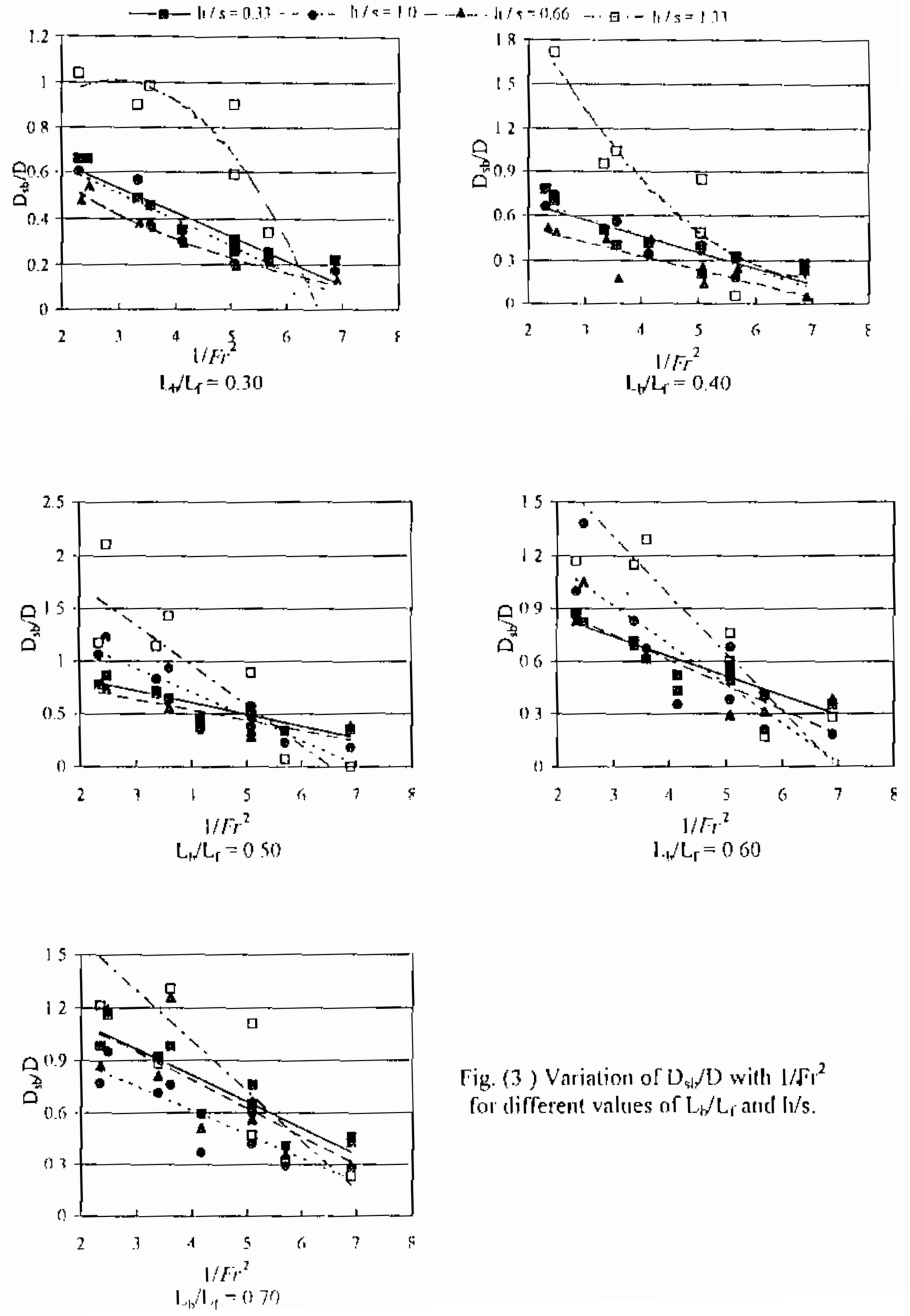
Pillai N. N. (1966) " Stilling basin design for low Froude number. " J. Hydr. Div., ASCE, 1115 (7), 989-994.

Pillai N. N., and et al (1967) "The Drag of Baffle Piers on Hydraulic Jump." Symp. On High Velocity Flow, Indian Institute of Science, Bangalore, India.

Pillai, N. N. (1969) "Stilling basins with wedge shaped baffle blocks." J. Water and Water Engrg., 73(886), 506-509.

Pillai, N. N. (1989) "Hydraulic jump type stilling basin for low Froude number." J. Hydr. Div., ASCE, 1115(7), 989-994.

Vicher, D. L. and Heger, W. H. (1995) " Energy dissipaters." Hydraulic Structures Design Manual. IAHR.



$L_b/L_f = 0.30$

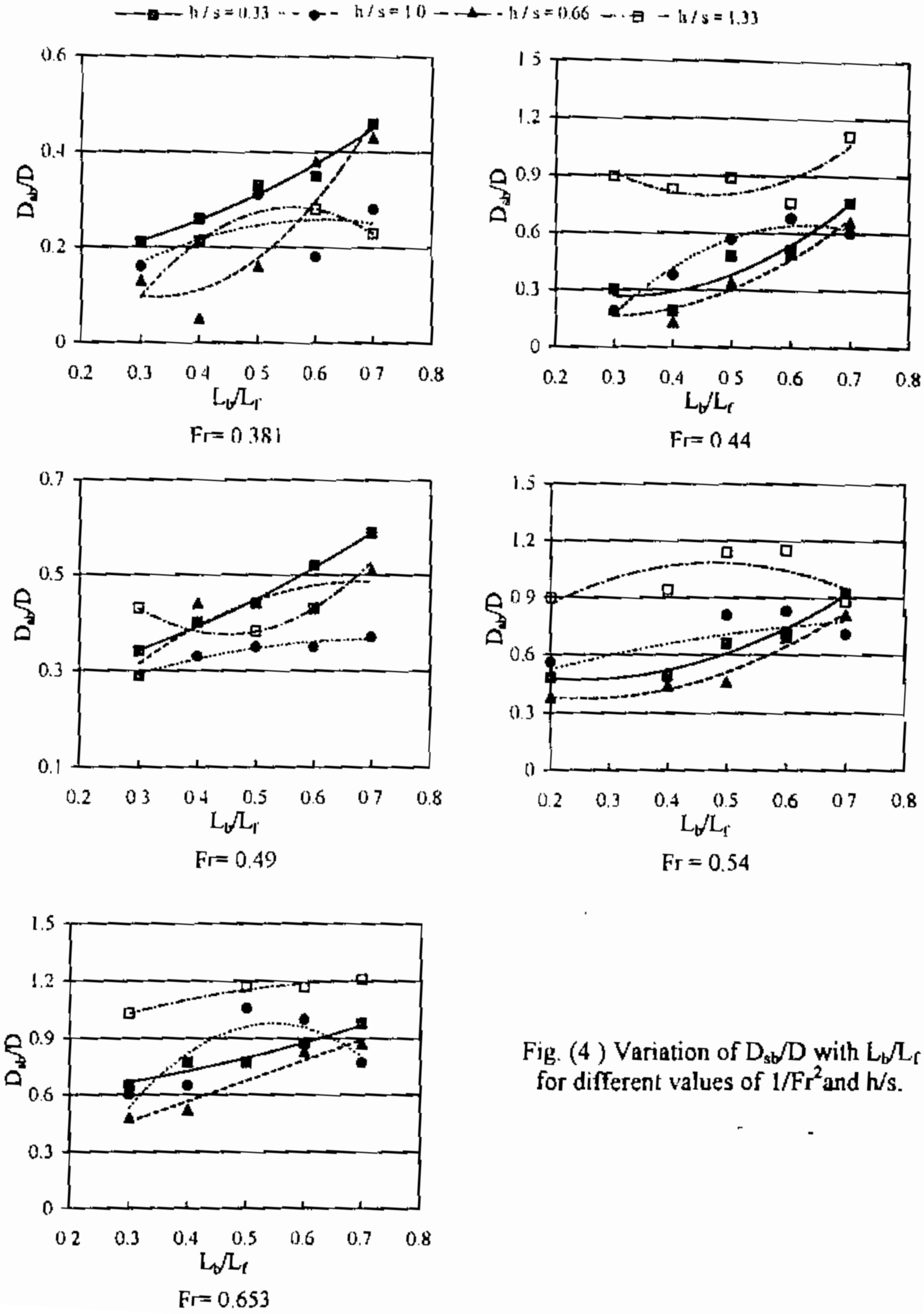
$L_b/L_f = 0.40$

$L_b/L_f = 0.50$

$L_b/L_f = 0.60$

$L_b/L_f = 0.70$

Fig. (3) Variation of D_{sb}/D with $1/Fr^2$ for different values of L_b/L_f and h/s.



Fr= 0.381

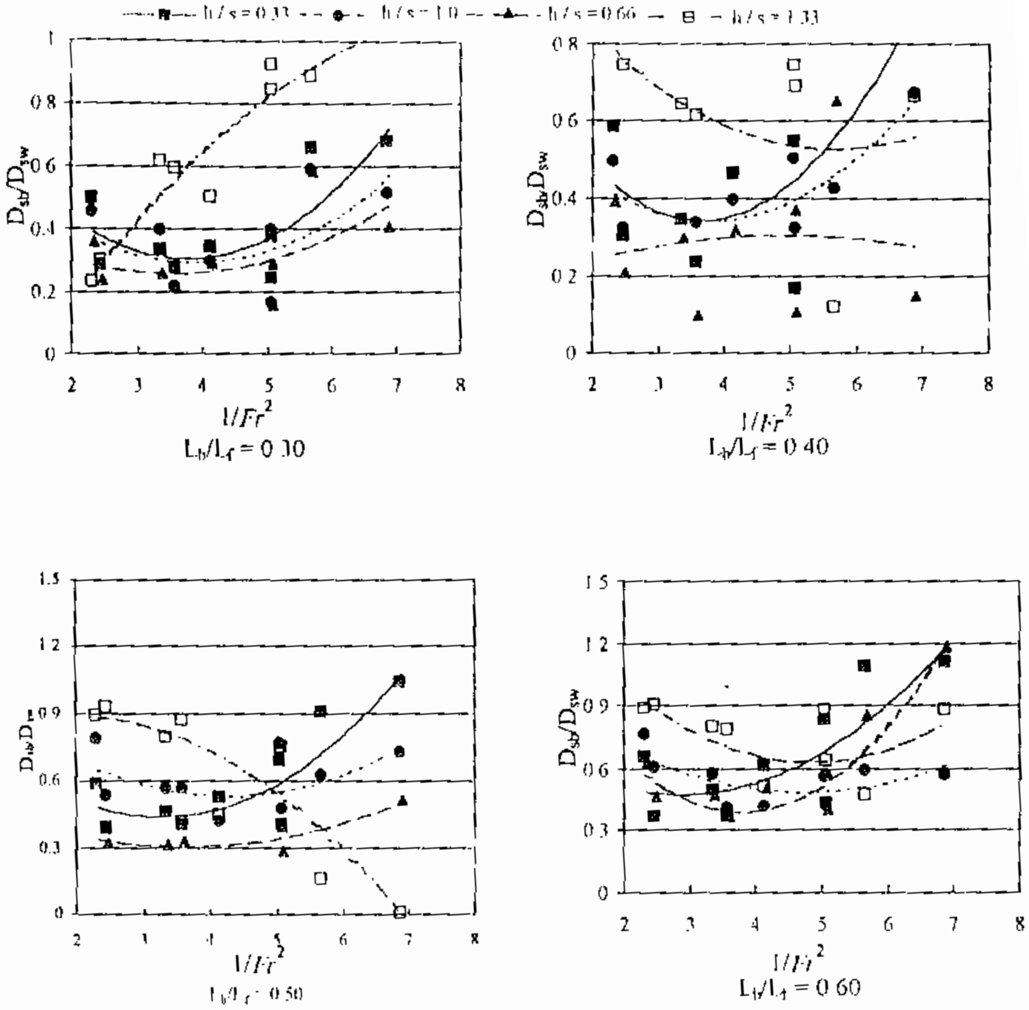
Fr= 0.44

Fr= 0.49

Fr = 0.54

Fr= 0.653

Fig. (4) Variation of D_{sb}/D with L_b/L_f for different values of $1/Fr^2$ and h/s.

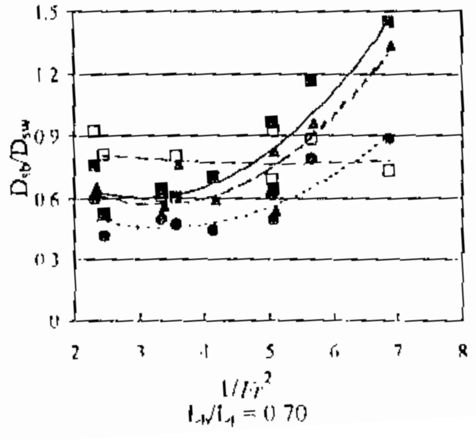


L_b/L_f = 0.30

L_b/L_f = 0.40

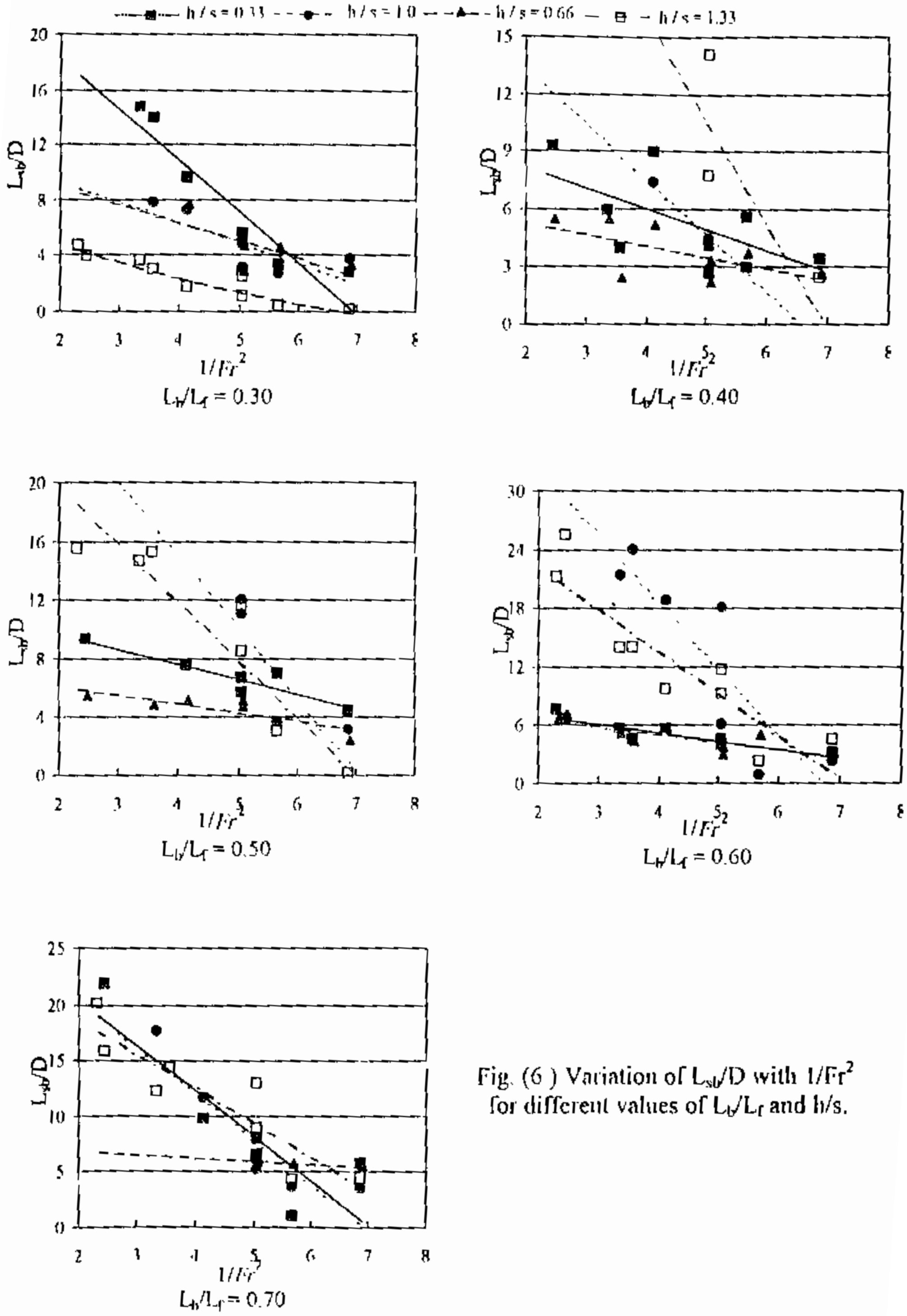
L_b/L_f = 0.50

L_b/L_f = 0.60



L_b/L_f = 0.70

Fig. (5) Variation of D_{sb}/D_{sw} with $1/Fr^2$ for different values of L_b/L_f and h/s.



$L_b/L_f = 0.30$

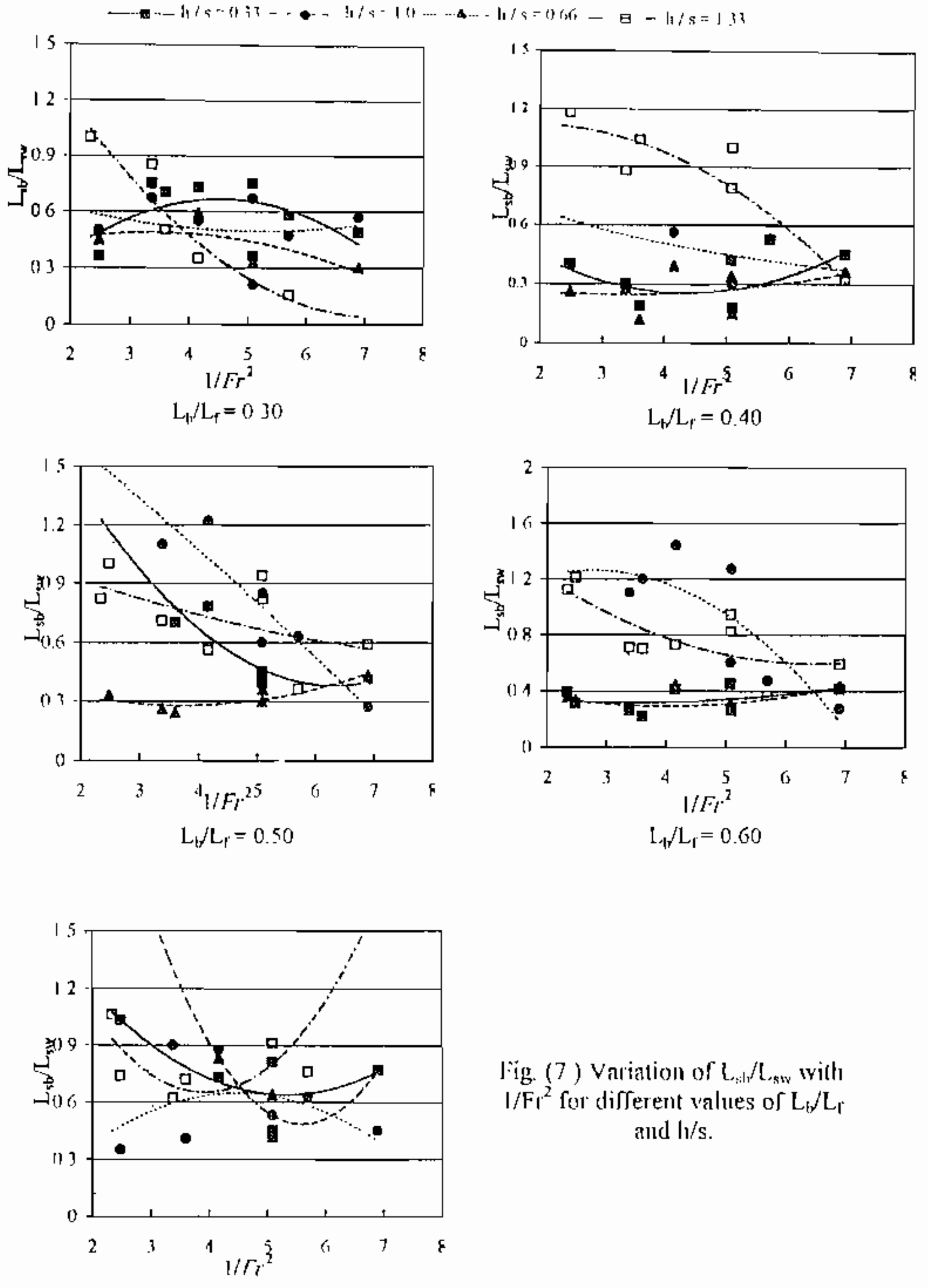
$L_b/L_f = 0.40$

$L_b/L_f = 0.50$

$L_b/L_f = 0.60$

$L_b/L_f = 0.70$

Fig. (6) Variation of L_{sb}/D with $1/Fr^2$ for different values of L_b/L_f and h/s.



$L_b/L_f = 0.30$

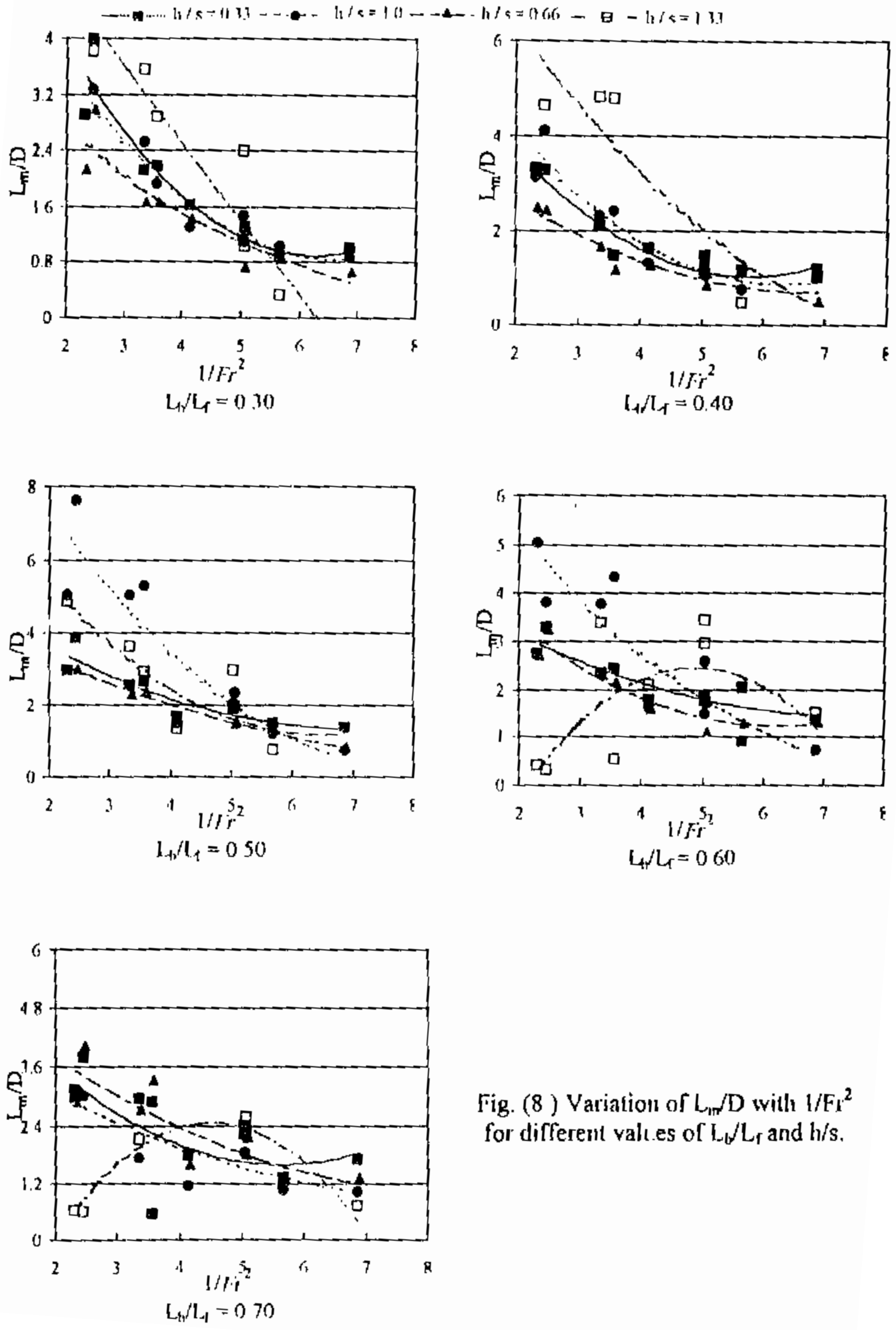
$L_b/L_f = 0.40$

$L_b/L_f = 0.50$

$L_b/L_f = 0.60$

$L_b/L_f = 0.70$

Fig. (7) Variation of L_{sb}/L_{sw} with $1/Fr^2$ for different values of L_b/L_f and h/s.



$L_b/L_f = 0.30$

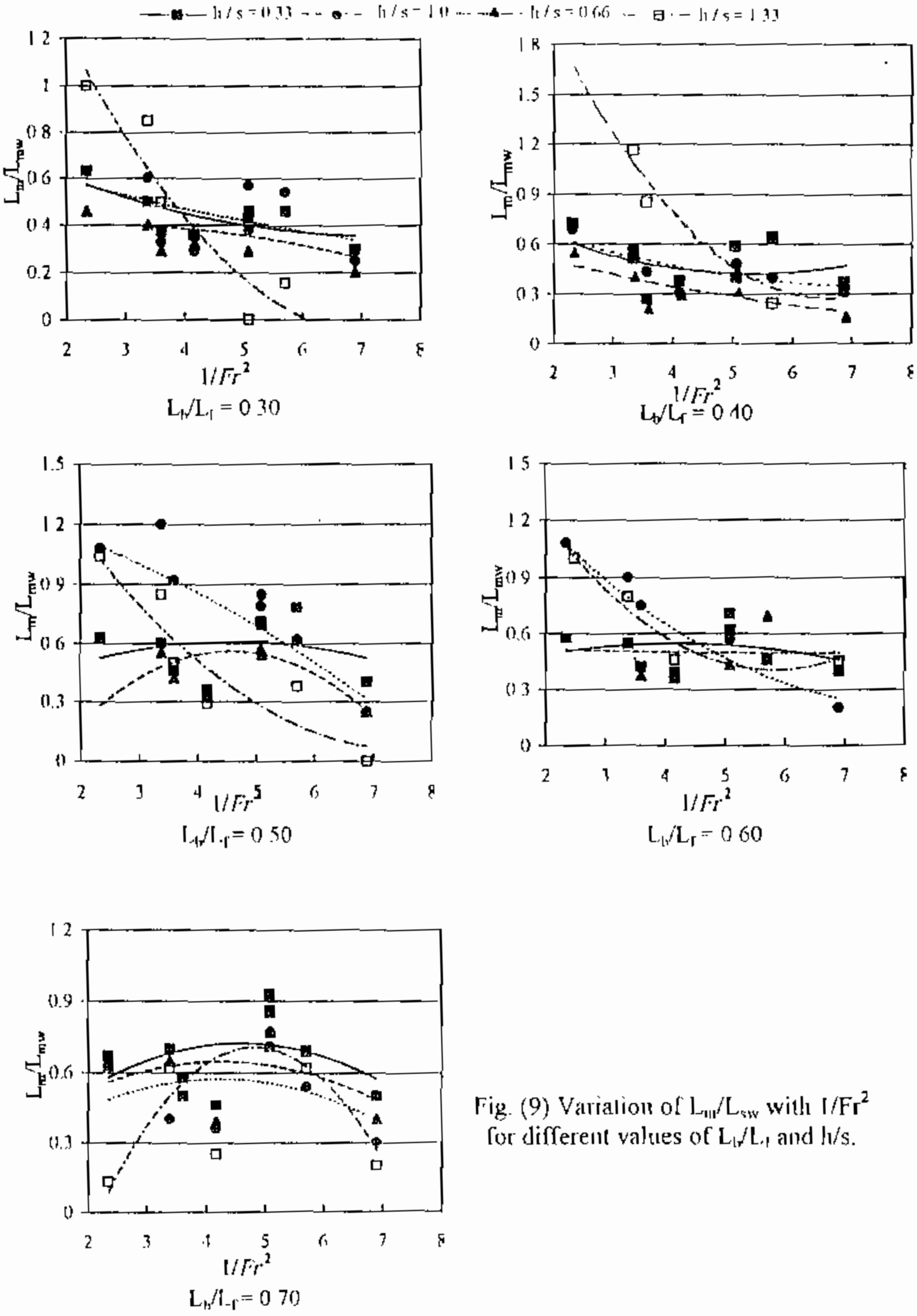
$L_b/L_f = 0.40$

$L_b/L_f = 0.50$

$L_b/L_f = 0.60$

$L_b/L_f = 0.70$

Fig. (8) Variation of L_m/D with $1/Fr^2$ for different values of L_b/L_f and h/s.



$L_b/L_f = 0.30$

$L_b/L_f = 0.40$

$L_b/L_f = 0.50$

$L_b/L_f = 0.60$

$L_b/L_f = 0.70$

Fig. (9) Variation of L_{rr}/L_{sw} with $1/Fr^2$ for different values of L_b/L_f and h/s.