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EXPERIMENTAL INVESTIGATION OF DRAG BEHAVIOR FOR PIERS

A THESIS BY

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ABSTRACT

The problem of the obstruction of bridge piers to the flow of water is quite important because of the drag encountered and the back-up of waters in the upstream of piers. . Hence it becomes imperative to determine what shape of piers offer least obstruction to the flow of water and least back-up.

In this field little research and studies have been performed to formulate drag coefficient in terms of relevant variables that govern the flow.

The ultimate purpose of this thesis is to study the drag coefficient behavior with the relevant variables and energy losses .

Five pier shapes were placed in a horizontal flume, 300 flume runs were made to investigate the objectives of this research.

The pier shapes used are :

1) Rectangular nose and tail pier.
2) Rectangular nose and triangular tail pier, with angle 90^0.
3) Triangular nose and tail pier.
4) Circular nose and tail pier.
5) Circular nose and triangular tail pier.

Froude's number range was between 0.2 and 0.8,Reynolds' number range was between $3.55*10^3$ and $1.84*10^4$ and the contraction ratio between 67.0 and 93.4 .

The regression, theoretical and dimensional analysis were used to determine the important hydraulic and geometric variables, that have effect on the drag and on energy loss.

In this research, the drag coefficient was found to be independent of Re and Fr, for the range used. The drag coefficient was found to be a function of contraction ratio.

In conclusion, functional relationships between drag coefficient and contraction ratios were developed for the five pier shapes. Also functional relationships between energy loss and downstream Froude number and contraction ratio were developed for the pier shapes.

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Nizar k. Halasah

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LIST OF SYMBOLS

A	= Area of projected section	L^2
A_s	= Projected area of structure	L^2
A_{so}	= Area of envelope containing projected area	L^2
A_1	= Area of upstream section	L^2
A_2	= Area of downstream section	L^2
A_p	= Projected area of the pier	L
B	= Width of channel	L
b	= Width of channel without the piers	L
b_1	= Width between piers	L
b_p	= Width of the object located in the channel	L
C	= Weisbach coefficient	-
C_A	= d'Aubuission coefficient	-
C_D	= drag coefficient	-
C_L	= Leliavsky coefficient	-
C_N	= Nagler coefficient	-
D	= Diameter of cylinder	L
D_P	= Pressure drag	MLT^{-2}
D_F	= Form drag	MLT^{-2}
d	= Mean depth in the open channel	L
d_A	= Area of elementary surface	L^2
d_o	= Minimum depth between the piers	L
d_{o1}	= Depth of water at the pier nose	L
d_1	= Depth upstream	L
d_2	= Depth downstream	L
E	= Modulus of elasticity	$ML^{-1}T^{-2}$

E_s = Specific energy — L

E_{s1} = Specific energy upstream — L

E_{s2} = Specific energy downstream — L

ΔE = Energy loss due to the presence of piers — L

e = roughness of pier — L

F = Force exerted by the moving fluid on a body — MLT^{-2}

F′ = Force acting by the fluid on a body per unit width — MT^{-2}

F_1 = Upstream force acting on the pier — MLT^{-2}

F_2 = Downstream force acting on the pier — MLT^{-2}

F_1' =Upstream force per unit width — MT^{-2}

F_2' = downstream force per unit width — ML^{-2}

FD = Drag force acting on the object — MLT^{-2}

FL = Uplift force acting on the object — MLT^{-2}

Fr = Froude number — -

Fr_o = Froude number at minimum depth between the piers — -

Fr_1 = Froude number upstream — -

Fr_2 = Froude number downstream — -

Fr_{2L} =The limiting Froude number downstream — -

g = Acceleration of gravity — LT^{-2}

H = Difference between upstream and downstream depths — L

H_1 = Left limb reading of the manometer — L

H_2 = Right limb reading of the manometer — L

h_1 = Upstream velocity head — L

$\bar{h}$ = The vertical distance between the water surface and center of gravity — L

i = Regression coefficient for Froude number downstream -

j = Regression coefficient for contraction ratio -

K = Shape factor -

L = Length of pier L

L_e = Effective width L

m = Subscript for model -

N = Number of opening for the bridge -

n = Ratio of scales between model and prototype -

n_1 = Regression coefficient -

n_2 = Regression coefficient -

p = Subscript for prototype -

$\bar{p}$= Pressure intensity MT^{-2}

Q = Flow rate L^3T^{-1}

q = Flow rate per unit width L^2T^{-1}

Re = Reynolds number -

S = Specific gravity of water -

S_m = Specific gravity of mercury -

U = Uplift force MLT^{-2}

V = Mean velocity of the fluid LT^{-1}

V_1 = Upstream velocity LT^{-1}

V_2 = Downstream velocity LT^{-1}

W = Weight of the pier MLT^{-2}

W' = Weight of sand added at the pier tail MLT^{-2}

W_p : Width of pier L

x = Distance between pier nose and upstream depth L

α = Angle between the tangential to the elementary -

Symbol		Definition	Dimension
		surface and direction of motion of the flow	
α'	=	Coefficient for relation between energy loss, Froude number downstream and contraction ratio	-
ε	=	Percentage of energy recovery	-
κ	=	Reduction coefficient	-
μ	=	Dynamic viscosity	$ML^{-1}T^{-1}$
ρ	=	Mass density of the fluid	ML^{-3}
σ	=	Contraction ratio	-
τ	=	Shear intensity	MT^{-2}
γ	=	specific weight of fluid	$ML^{-2}T^{-2}$

CHAPTER 1

INTRODUCTION

1.1 THE PROBLEM

The problem of the obstruction of bridge piers to the flow of water is quite important because of the drag force acting on the piers, many shapes of piers are used for bridges, and consequently different drag coefficients result.

The "back water" effect of the piers on the flow or the increase in the upstream depth is an important problem and is also worth to be studied, because it brings in many cases legal disputes between farmers and the state as a result of construction of bridges.

1.2 OBJECTIVES

The objectives of this work are:

1) The determination of the drag force on different shapes of piers for different flow discharge at different contraction ratios .

2) The study of the behavior of the drag coefficients for each pier shape with respect to the important dimensionless variables (Reynold number , Froude number , Contraction ratio , etc.).

3) The determination of the energy losses due to bridge pier(s) placed on open channels as a function of downstream Froude number and contraction ratio for different shapes of

piers.

1.3 APPARATUS

a) A horizontal flume of 60.6 cms in width with a point gauge mounted on its rails was used. The flume was provided with a tail gate at the downstream end to regulate the flow depth.

b) An orifice meter was calibrated and then installed along with a differential manometer on a pumped line to measure the flow .

c) Scales were provided to measure the drag force on the pier at each discharge .

d) Piers of five shapes were prepared:

1) Rectangular nose and tail pier.
2) Rectangular nose and triangular tail pier.
3) Triangular nose and tail pier.
4) Circular nose and tail pier.
5) Circular nose and triangular tail pier.

Triangular nose or tail are with angle 90^0, piers dimensions were 4, 2 cms width and constant length 16 cms with enough numbers to have eight contraction ratios with equal spacing for each shape.

The piers were guided by groove engraved in the perspex plate which was placed on the channel bed. Each pier was mounted over almost frictionless rollers projecting about 2 mm from the bottom of the pier.

1.4 PROCEDURE

1) The experiment was started with one pier of a certain

shape in the middle of the flume with halves of piers on both sides of the flume to eliminate the side effect . The pump was operated at low discharge . Discharge was measured by the orifice calibration curve , water profile was recorded upstream and downstream of the piers .

For the same discharge the drag was measured for different contraction ratios of the same shape .

The whole procedure was repeated for several discharges to get enough points for analysis .

2) The same procedure was repeated, until all shapes were investigated.

The details of apparatus and experimental procedure are shown in detail in chapter 3.

CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

When an object is placed within a moving fluid, a force may be inclined to the flow direction, is exerted on the object. This force owes its existence to viscosity of the fluid and the pressure distribution on the body surface. An example of bodies immersed in water is bridge piers and in air is buildings.

2.2 FLOW PAST A SUBMERGED BODY-LIFT AND DRAG

When a body is placed completely submerged in the flowing fluid with velocity V, there is a force exerted by the fluid on the body (F),(fig. 2.1.).In general,the force (F) may be inclined to the direction of motion. The force may be resolved into two components, one in the direction of motion known as drag force FD and another perpendicular to the direction of motion known as lift force, FL.

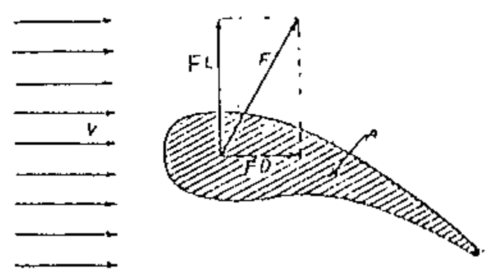


FIG. 2.1. General Forces Acting on a Body by a Moving Fluid

The same force will be exerted when the fluid is at rest and the body moves within it with uniform velocity. In case of symmetrical bodies such as a sphere and a cylinder, when placed in the fluid symmetrically, lift force FL will be equal to zero. and thus total force exerted on the body will be equal to the drag force, FD.

Again, when a symmetrical body is placed in an ideal fluid and is moving with uniform velocity, hydrodynamically it will be balanced i.e. the net resultant force acting on the body will be equal to zero. But when the body is moving through real fluids it experiences some resistance to its motion. The resistance provided by the real fluids is on account of their viscosity i.e. viscosity of the fluids is the factor for the drag on the immersed bodies.

Let there be a body kept stationary in a stream of real fluid,and V be the uniform velocity of the fluid as shown in fig. 2.2. The resultant force F acting on the immersed body is the vector sum of two components, the pressure force and the shear force. In order to find the total force acting on the body, consider an elementary area ab of the body.

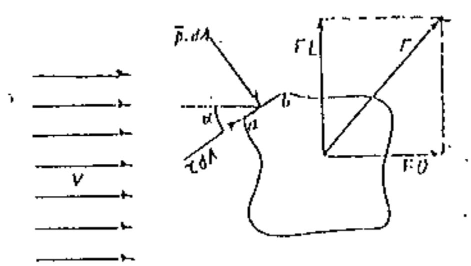


FIG. 2.2. Analysis of Forces Acting on a Body

The two forces acting on the elementary area are :

(i) Pressure force $=\bar{p}.d_A$, acting along the normal direction to the area.

(ii) Shear force $= \tau.d_A$ acting along the tangential direction to the area.

Where

$\bar{p}$ = Pressure intensity

τ = Shear stress.

d_A = Area of the elementary surface ab.

Let

α = The angle between the tangential to the elementary surface and direction of the motion of the fluid.

Then, the component of the pressure force acting on the elementary surface in the direction of motion of the fluid is equal to $\bar{p}.d_A \sin\alpha$. Therefore the total pressure force acting on the whole body in the direction of motion of the fluid is given by.

$$D_p=\int\bar{p}.d_A.\ \sin\alpha \quad \text{.......................(2.1)}$$

Similarly, the component of the shear force acting on the elementary surface in the direction of motion of the fluid is equal to $\tau\ d_A \cos\alpha$. Hence the total shear force acting on the whole body in the direction of motion of the fluid is given by

$$D_f = \int\tau\ .\ d_A \cos\alpha \quad \text{...................(2.2)}$$

The total drag force FD acting on the body will naturally be equal to the sum of D_p and D_f.i.e.

$$FD = D_p + D_f.$$

or $$FD = \int \bar{p} . d_A \sin\alpha + \int \tau . d_A \cos\alpha ....(2.3)$$

Where $\int \bar{p} . d_A \sin\alpha$ is known as pressure drag or form drag and $\int \tau . d_A \cos\alpha$ is called the friction drag or viscous drag.

The shape and the position of the immersed body determines the relative magnitudes of the two components of the total drag force. Let the body be in the form of a thin plate and when it is placed immersed in the moving fluid, such that, fig. 2.3.:

(1) $\alpha = 0$ i.e. the plate is held in the fluid parallel to the direction of flow, then the component

$$\int \bar{p} . d_A \sin\alpha = \text{pressure drag} = 0$$

And the total drag on the plate is given by

$$D_f = \int \tau . d_A \cos\alpha. = \text{friction drag.}$$

(2) When $\alpha = 90^\circ$ i.e. the plate is held immersed in the fluid in a direction perpendicular to the flow direction, then the component

$$\int \tau . d_A \cos\alpha = \text{friction drag} = 0$$

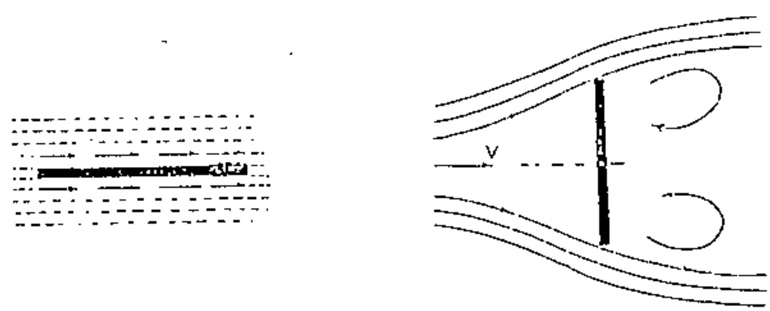
And the total drag on the plate is given by

$$D_f = \int \bar{p} . d_A \sin\alpha = \text{pressure drag.}$$

In between the two extreme positions, there can be any value of α and any shape of the body to determine the relative magnitudes of pressure drag and the friction drag.

By the same process the total lift on the immersed body on account of pressure force and the shear force can be obtained in the form of the following expression.

$$FL = \int \bar{p} \cdot dA \cos \alpha + \int \tau \cdot dA \sin \alpha \quad \ldots(2.4)$$



(a) Thin plate placed parallel to the direction of flow ($\alpha=0^0$)

(b) thin flat plate placed perpendicular to the direction of flow ($\alpha=90^0$)

FIG. 2.3. Thin Plate Immersed in a Moving Fluid with Angles 0,90 to the Direction of Flow

2.3 Classification of Drag

The drag may be classified into the following types :

(i) Skin Friction Drag: This is the tangential force exerted on the immersed body due to the tangential shear caused by the large velocity gradient within the boundary layer at the surface of the body.

(ii) Deformation Drag: The viscosity effect of a flowing fluid past a surface causes the deformation of fluid particles. The deformation occurs when the viscous forces are more significant than the inertial forces, Reynold's number being less than 0.1. The forces responsible for the deformation of fluid particles have two fold effect, one is the horizontal component of these forces, produces an additional resistance to the motion and becomes part of the skin friction drag, second is the lateral component, produces a variation in lateral direction, causes the development of pressure drag. The sum of the two components, the component in the direction of fluid motion known as surface drag and the component in the lateral direction called pressure drag, constitutes the 'deformation drag'. The relative magnitude of the surface drag and the pressure drag depends upon the Reynold's number. When the Reynold's number is very large, the pressure drag becomes negligible and surface drag only constitutes the deformation drag.

(iii) Pressure Drag or Form Drag: When the surface of the immersed body is such that it deviates away from the flow then with the increase of Reynold's number the flowing fluid tends to leave the boundary. The phenomenon is termed 'separation of flow'.This separation of boundary layer affects the flow pattern to a large extent. This causes the change in pressure distribution. In the zone of the separation on the down-stream side, the pressure will be low and equal to the pressure at the point of separation where the velocity is generally highest. This region of low-pressure is known as 'wake'. The pressure difference thus created across the body causes a drag on the body and is known as pressure drag or form drag.

(iv) Total Drag or Profile Drag. The sum of the deformation drag and the form drag constitutes the total drag which is also known as profile drag. At higher values of Reynold's number where the deformation drag is essentially a surface drag only, the total drag is the sum of surface drag and the form drag. The relative magnitudes of the surface drag and the form drag constituting the total drag on an immersed body is the function of, (a) Shape and position of the immersed body,(b) the flow pattern, and (c) the fluid characteristics.

2.4 UNSTREAMLINED (BLUFF) AND STREAMLINED BODIES

We have seen that the magnitude of form drag depends upon the size of separation zone or wake. The separation zone itself is the function of the shape and position of the immersed body. The zone of separation can be determined by establishing the points of separation.

Fig. 2.4. shows three immersed bodies of different shapes. Fig. 2.4-a. shows an aerofoil which is a perfectly streamlined body and the points of separation lie at the rear end. The zone of separation in such cases is therefore very small which results in smaller value of form drag than that of unstreamlined bodies, but on account of more surface area in contact with the flow. The surface drag of streamlined bodies will be higher than that of bluff bodies.

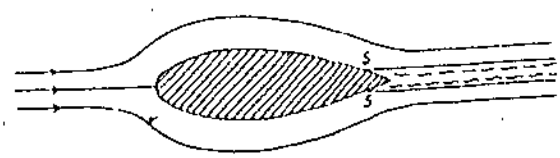
Fig. 2.4-b. shows a bluff body in the shape of a flat plate held normal to the direction of flow. Here the points of separation lie at the sharp corners, because it is impossible

to create the suction of infinite magnitude at the sharp corners of zero curvature to compel the streamlines to adhere to the geometry of the body. A large zone of separation is developed on the downstream side of the plate.

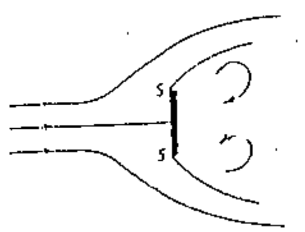
The prevailing pressure in the wake is very small as compared to the stagnation pressure on the upstream side of the plate. The large difference of pressure constitutes a drag on the plate which is wholly a form drag. The total drag is due to form drag as the surface drag is insignificant.

Fig. 2.4-c. shows the third case in which a flow takes place around a smooth cylinder with its axis perpendicular to the flow. A surface of cylinder or sphere may be treated as a case in

(a) Streamlined Body



(b) Bluff Body (Flat Plate)



(C) Smooth Cylinder

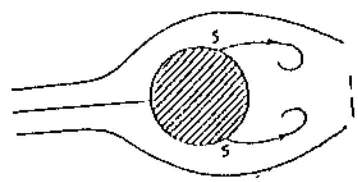


FIG. 2.4. Three Immersed Bodies of Different Shapes

between the flat plate (bluff body) and the aerofoil (perfectly streamlined body). Here the position of points of separation depends upon the Reynold's number. The zone of separation is smaller than that of a flat plate. Hence the pressure drag is smaller than that of a plate, but the surface drag is not negligible because the viscous forces will have components parallel to the direction of flow. The surface drag, of course being very small as compared to the pressure drag, for calculating the total drag of such bodies, the surface drag may be neglected.

2.5 BACKWATER OCCURRENCE

The erection of one or more bridge piers in a stream forces the river to flow through a reduced cross section and hence in passing through this section, the water must acquire a velocity greater than that existing in the unobstructed channel. The increase in velocity can be produced only by elevating the water surface in the reach upstream from the piers which produce the contraction in area, thus, as the stream enters the contracted area, a drop in the water surface is noted accompanying the increase in velocity. However, when the stream expands again into the unobstructed channel downstream from the pier, the water surface fails to rise again to the level of the water surface upstream from the pier. This permanent drop in water level is indicative of energy losses which may originate from three sources, (1) friction of the water on the pier walls, (2) contraction of flow caused by the pier nose, and (3) expansion of the stream as it passes out from between the piers.

The changes in cross section and velocity in the passing bridge piers cause much disturbance in the flow, especially when the pier does not conform in shape to the direction of the contracting filaments of water. The curvature of the stream lines around the upstream nose of a pier induces high and erosive velocities at that point. Eddies may be formed along the sides and below the tail of the pier. These high velocities and resultant eddies often scour out the beds of streams next to the piers to such an extent that the foundations may be endangered and even undermined.

2.6 EARLIER BRIDGE PIER STUDIES

As early as 1862, the obstruction of brigde piers was studied by Weisbach. Weisbach describes two experiments which he performed on small round pier, 0.020 m in diameter in a channel 0.0280 m wide. He considered that discharge through the pier section is equivalent to that through an orifice of a section AB, and under head H,where H is equal to the difference in elevation between gauges NO.1 and NO. 2, as shown in fig. 2.5., and over a weir the length of which is the net stream width at A. The sum of these two discharges should give the discharge past the pier.

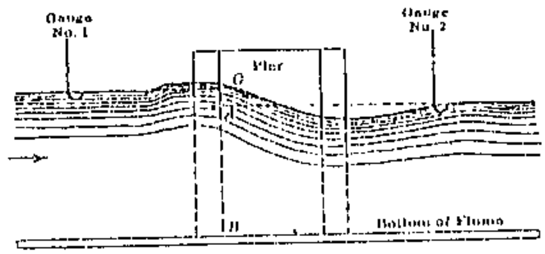


Fig. 2.5. Sketch of Pier Located in Open Channel

$$Q = C\, b_1 \sqrt{2g} \left(\frac{2}{3} H^{3/2} + d_2 H^{1/2}\right) \ldots\ldots\ldots (2.5)$$

Where :

H : Head under the orifice & weir.

b_1 : Width of channel between the piers.

d_2 :Equal to the depth of water downstream.

C : Derived coefficients 0.98 and 0.97 in the two runs which he made.

Merriman (1914), adopted Weisbach's theory with some modifications. He discussed formula considering discharge as consisting of two parts, first passing over a weir of width B under a head H, a second that passing through the submerged orifice of width b and height d_2 under the head H

$$Q = C \sqrt{2g} \left[\frac{2}{3} B \left(H+\frac{V_1^2}{2g}\right)^{3/2} + b\, d_2 \left(H+\frac{V_1^2}{2g}\right)^{1/2}\right] \ldots (2.6)$$

V_1 : Velocity of stream.

B : Equal to the width of approach channel.

b : Width of channel at the pier section.

Nagler (1918), conducted 256 experiments in a flume of Argo Dam, Ann Arbor Mich., during October - December 1914. The experiments were made on 34 different models of bridge piers . The purpose of these experiments was to determine the relative obstruction which different designs of bridge piers offer the flow of water. This involved the derivation of an adequate formula, with reliable coefficients, which would give the amount of back-water caused by the insertion of a pier in the cross-section of the experimental flume.

$$Q = C_N \, B\sqrt{2g}\left[H - 6.3\frac{V_2^2}{2g}\right]\sqrt{H + 1.8\frac{V_1^2}{2g}} \quad \ldots\ldots\ldots(2.7)$$

Where :

C_N : Nagler bridge pier coefficient.

V_1 : Up stream velocity.

V_2 : Down stream velocity.

B : Width of the stream exclusive of the bridge piers.

H : Difference in elevation between upstream & down stream gauges.

The bridge piers coefficient (C_N) was for different shapes.

Yarnell (1934), presented the results of about 2,600 experiments on the obstructive effect of bridge piers to the flow of water. The investigation was undertaken for the purpose of determining :

1- The effect of pier shape on the height of back water caused by the pier.

2- The effect of length of pier upon the height of back water.

3- The effect of magnitude of channel contraction upon the height of back water.

The following are extracted from the results of the investigation on bridge piers of various shapes.

1- The height of the backwater due to bridge piers varies directly with the depth of the unobstructed channel.

2- From his experimental data, Yarnell derived the coefficients for Nagler formula and d'Aubuisson formula. d'Aubuission formula is :

$$Q = C_A B \, d_2 \sqrt{2g \, d_2 + V_1^2} \quad \ldots\ldots\ldots\ldots\ldots (2.8)$$

C_A : d' Aubuission bridge pier coefficient.

B : Width of stream exclusive of the bridge piers

d_2 : Downstream depth .

V_1 : Upstream velocity at section (1),as shown in fig. 2.5.

3- For flow of low velocity and least turbulence, the most efficient shapes are lens-shaped nose and tail, lens-shaped nose and semicircular tail, semicircular nose and lens-shaped tail, convex nose and tail, and semicircular nose and tail. However, the data are not sufficient to differentiate among these shapes for high degree of contraction.

4- Twin-cylinder piers either with or without connecting diaphragms, piers with 90° triangular noses and tails, and piers with recessed webs are less efficient hydraulically than those just mentioned, and piers with square noses and tails are least efficient.

5- Application of batter to the ends of piers slightly increases their hydraulic efficiency, that is raises the C_N and C_A values.

6- Increasing the length of a pier from 4 times the width to 13 times the width has comparatively little effect on its hydraulic efficiency. In some cases the efficiency is thus increased and in other cases decreased. The optimum length-width ratio probably varies with velocity and is generally between 4 and 7. On the average, the values of C_N and C_A will increase about 3 to 5% for the increase ofthe ratio from 4 to 13.

7- Placing the piers at an angle with the current has an insignificant effect on the amount of backwater if the angle is less than 10°. Placing the piers at 20° or more materially increases the amount of backwater; the increase depends upon the quantity of flow, the depth, and the degree of channel contraction. In general, the values of C_N and C_A will decrease about 7% at 20°.

Leliavsky (1955), studied hydraulic calculations for regulators. The most important problem of the hydraulic analysis of regulators is the case when the regulators is fully open.

He presented the theoretical discharge on the assumption that $C_L = 1$ (C_L in practice never equal 1)

$$Q = \frac{2}{3} C_L L_e \sqrt{2g}\left[(H+ha)^{3/2} - ha^{3/2}\right] + C\, L_e H \sqrt{2g(H+ha)} \quad (2.9)$$

C_L : Leliavsky discharge coefficient.

L_e: Effective width of regulator = $N*b_1$.

N : Number of openings.

H : Difference between upstream and downstream level.

ha: $\frac{V_1^2}{2g}$,Upstream velocity head.

V_1: upstream velocity.

b_1: The span of each opening

there are experimental values for C.

He also presented Gauthey formula for heading up with empirical coefficients.

$$H = \frac{V_1^2}{2g}\left[\left(\frac{A_1}{\kappa A}\right)^2 - 1\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.10)$$

H : Difference between upstream and downstream depths

V_1 : Upstream velocity.

A_1 : $d_1 * B$(Area of upstream section).

κA : Effective area.

κ : Reduction coefficient.

Where values of κ were assumed to be dependent on the shape of the pier and the slope of the channel.

Chow (1959), classified the flow through an obstruction to subcritical or supercritical. The energy equation for the reach between the contracted section 0 and section 2 below the contraction fig. 2.6. is

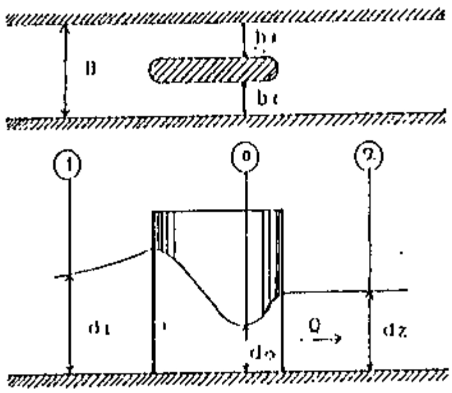


FIG. 2.6.Definition Sketch Showing Flow and Obstruction

$$\varepsilon \left(d_0 + \frac{V_0^2}{2g} \right) = d_2 + \frac{V_2^2}{2g} \quad \text{..............(2.11)}$$

Or

$$\varepsilon d_o (2 + Fr_o^2) = d_2 (2 + Fr_2^2) \quad \text{................(2.12)}$$

Where $Fr_0 = V_0 / \sqrt{gd_0}$, $Fr_2 = V_2 / \sqrt{gd_2}$, and ε represents the percentage of energy recovery, since energy loss will occur between the sections. By the continuity of flow:

$$V_0 b_0 d_0 = V_2 B_2 d_2 \quad \text{...............(2.13)}$$

or $$Fr_0^2 \sigma^2 d_0^3 = Fr_2^2 d_2^3 \quad \text{................(2.14)}$$

Where σ = b/B eliminating do and d_2 from equation (2.12) and (2.13)

$$\sigma^2 = \frac{\varepsilon^3 Fr_2^2 \, (2 + Fr_0^2)^3}{Fr_0^2 \, (2 + Fr_2^2)^3} \quad \text{..........(2.15)}$$

Where the flow at section 0 is critical, $Fr_0 = 1$.

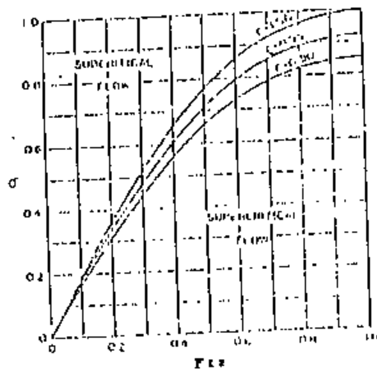


FIG. 2.7. Criterion for Subcritical and Supercritical Flows Through an Obstruction

The value of Fr_2 that satisfies this condition is called the limiting value and is designated by Fr_{2L}. Thus, for $Fr_0 =$ 1, the above equation becomes :

$$\sigma^2 = \frac{27\,\varepsilon^3 Fr_{2L}^2}{(2+Fr_{2L}^2)^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.16)$$

For a given σ, therefore, the flow through the obstruction is critical if $Fr_2 = Fr_{2L}$. Examination of Eq. (2.14) indicates that the flow through the obstruction is subcritical if $Fr_2 < Fr_{2L}$ and supercritical if $Fr_2 > Fr_{2L}$ Equation (2.15) is plotted as shown in fig. 2.7 for $\varepsilon = 1$ (no energy loss), $\varepsilon = 0.95$ (5% energy loss), and $\varepsilon = 0.9$ (10% energy loss). Accordingly, the flow is subcritical if the value of Fr_0 falls on the left side of the plotted curve of an assumed energy loss and supercritical if Fr_2 falls on the right side of the curve.

Apelt and Saccs (1968), measured the forces experienced by models of three different types of bridge piers for angles of inclination between the stream flow and the pier axis in the range 0° to 50°, and the results were presented in the form of drag coefficients and lift coefficients. The types of pier tested were a plate pier, dumb-bell piers, and twin cylinder piers. The values obtained for the lift coefficient for the first two types were large. Their magnitudes were generally falling between one and two for angles of inclination in excess of 10°, where those obtained for the third type were relatively small. The forces measured for all pier types possessed fluctuating components the characteristics of which were described. The fluctuating components experienced by the dumb-bell and twin cylinder piers were generally quite large and complex. The relevance of the model results to prototype conditions was discussed and it was concluded that the force coefficients obtained could be used for preliminary design calculations.

Ball (1974), estimated the drag force on piers by building hydraulic fixed bed model.

In order to specify the hydrodynamic drag required on the model, the drag characteristics of full size structure were needed.

There are two new methods for the simulation of complex structures in hydraulic models. The drag equation may be restated as.

Method(1)

$$FD = \rho \; C_D \frac{A_S}{A_{So}} A_{So} \frac{V^2}{2} \quad . \quad ....(2.17)$$

$$n_D = \frac{(C_D \; As/A_{So})m}{(C_D \; As/A_{So})p} \frac{A_{So}m}{A_{So}p} \frac{V_m^2}{V_p^2} \quad .(2.18)$$

$$n_D = \frac{(C_D \; As/A_{So})m}{(C_D \; As/A_{So})p} n_h^2 \; n_1 \quad ....(2.19)$$

For the drag on the model structure to be correct

$$n_D = n_h^2 \; . \; n_1$$

there fore $(C_D \; As/A_{So})_m$ must equal $(C_D \; As/A_{So})_P$

Method (2)

$$n_D = \frac{(C_D \; A_S V^2)m}{(C_D \; As \; V^2)P} \quad ....(2.20)$$

As $V^2m/V_P^2 = n_h$, and we know that n_D should equal to $n_h^2 \cdot n1$

$$\frac{(CD \; As \;)m}{(CD \; As \;)_P} = n_h^2 \; n_1 \quad ....(2.21)$$

if A_{sm} is larger than the scaled value As_P by a factor, K, so that $A_{sm}=K \; n_h \; n_1 A_{SP}$, then the drag required would be achieved if $(CD)_m = (CD)_P/K$. Summing up these two approaches to the representation of structures on hydraulic models :

1) Scales model $A_{sm} = n_h n_1 A_{SP}$, with condition CDm= CDp.

2) Simulation by method (1) $A_{sm} \leq n_h n_1 Asop$, with condition $(CD \; A_S/A_{SO})_m = (CD \; A_S/A_{SO})_P$.

3) Simulation by method (2) $A_{s\ m} > n_h n_l A_{soP}$, with condition $(CD\ As)_m = n_h n_l (CD\ As)_P$ plus extra care.

Where As: Projected area of structure.

A_{so}: Area of envelope containing projected area.

Ball and Cox (1978), studied the hydrodynamic drag on a rectangular group of 50 flat plates, with steady incident flow normal to the front of the group, and showed it to be a function of five factors :

1) The acceleration of flow between the plates of a row ;
2) The shielding of plates in line with the incident flow;
3) The diversion of flow around the front of group;
4) The rejection of flow through the sides of the group;
5) The formation within the group of an oscillating wake for the whole group.

The drag force on each element of the group was measured for longitudinal and lateral spacing covering the range occurring in existing pier head pile group that the flat plates simulated.

Ball and Hall (1980), studied the hydrodynamic drag on square arrays of model cylindrical piles in the Reynolds number range of 250 to 750 and showed it to be a function of the angle of yaw of the incident flow and is also related to a parameter termed the normalized projected area. The drag coefficient of a pile group increases as the number of piles is reduced and as the pile spacing is increased and may be greater than the measured single-pile value . The data suggest that the replacement of a structure consisting of a large number of small-diameter piles by and equivalent group of fewer larger diameter piles will reduce disturbance of the flow field.

AL- Nassri and McBean (1983), made regression analysis for based models and derived from experimental analysis energy losses due to bridge piers placed in open flow. The models characterize the energy loss as a function of downstream Froude number, contraction ratio, and pier shape. Comparison with existing practice for some results show that existing formula represent conservative values. The five different pier shapes considered are shown in fig. 2.8.

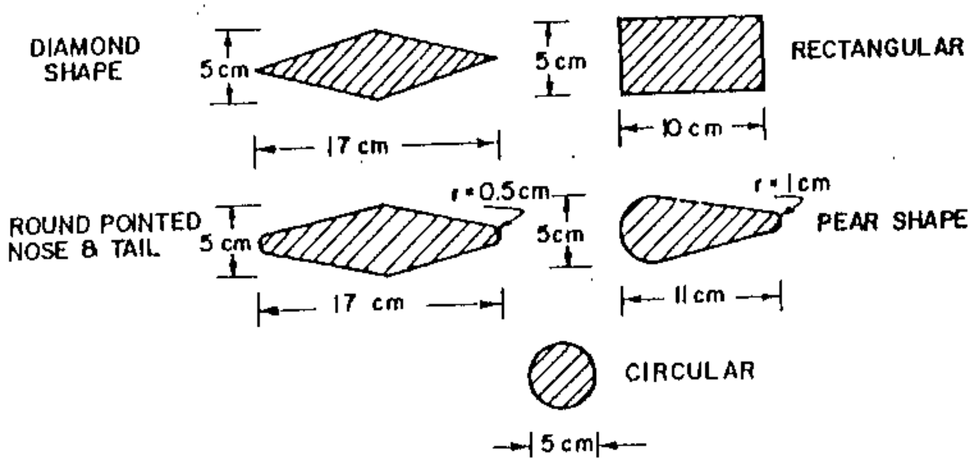


FIG. 2.8. Shapes of Piers Considered

The regression formula is

$$\frac{\Delta E}{E_2} = n_1 \left(\frac{Fr_2}{\sigma} \right)^{n_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.22)$$

Table 2.1. :Values of Constants n_1, n_2 for Different Pier Shapes

Pier Shape	n_1	n_2	Correlation coefficient R
Rectangular	25.83	2.50	0.85
Diamond	8.84	1.67	0.90
Round pointed nose and tail	7.79	1.17	0.87
Pear shape	9.51	1.82	0.86
Circular	11.3	1.84	0.85

The regression coefficient n_2 is not justified, because it is not necessarily that Froude number downstream and contraction ratio have the same regression coefficient. Regression was done by the writerfor rectangular nose and tail pier considering two different powers for Fr and σ. The following equation was obtained with correlation coefficient (R= 0.93), which is higher than 0.85 which was obtained by the aforesaid writer.

$$\frac{\Delta E}{E_2} = 22.4 \frac{Fr_2^{0.37}}{\sigma^{2.17}} \quad \ldots\ldots\ldots\ldots\ldots (2.23)$$

CHAPTER 3

APPARATUS AND EXPERIMENTAL PROCEDURE

3.1 INTRODUCTION

Laboratory equipment used for this study consists of a 3.7 m long, fiberglass sided flume, a glass bed, pier shapes models, a point gauge on a mobile carriage mounted on the side rails of the flume, a scales balance , an orifice meter and a manometer.

They are located in the Hydraulics and Fluid Mechanics laboratory in the Civil Engineering Department, at the University of Jordan.

A general view of the apparatus is shown in fig. 3.1.

3.2 DESCRIPTION OF APPARATUS

3.2.1 The Flume

The experiments were conducted in a flume 60.6 cm wide, 15 cm deep, 370 cm long, of rectangular cross section,and with fiberglass wall sides, water is recirculated by a pump shown in fig. 3.2.

The bed is horizontal, made from glass 1.0 cm thick, and covered by perspex plate 50 cms long in the middle of the flume, The perspex plate was engraved at specified locations to serve as a guide to the piers movement.

In the downstream end of the flume a tail gate was already installed for the purpose of attaining the required

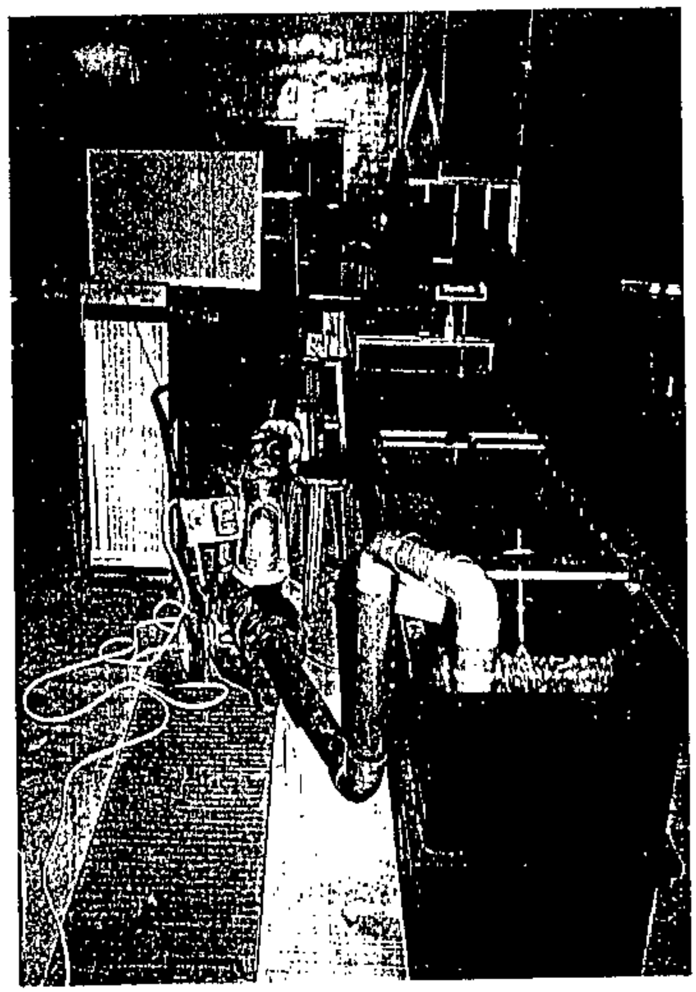


FIG. 3.1. General Veiw of Flume

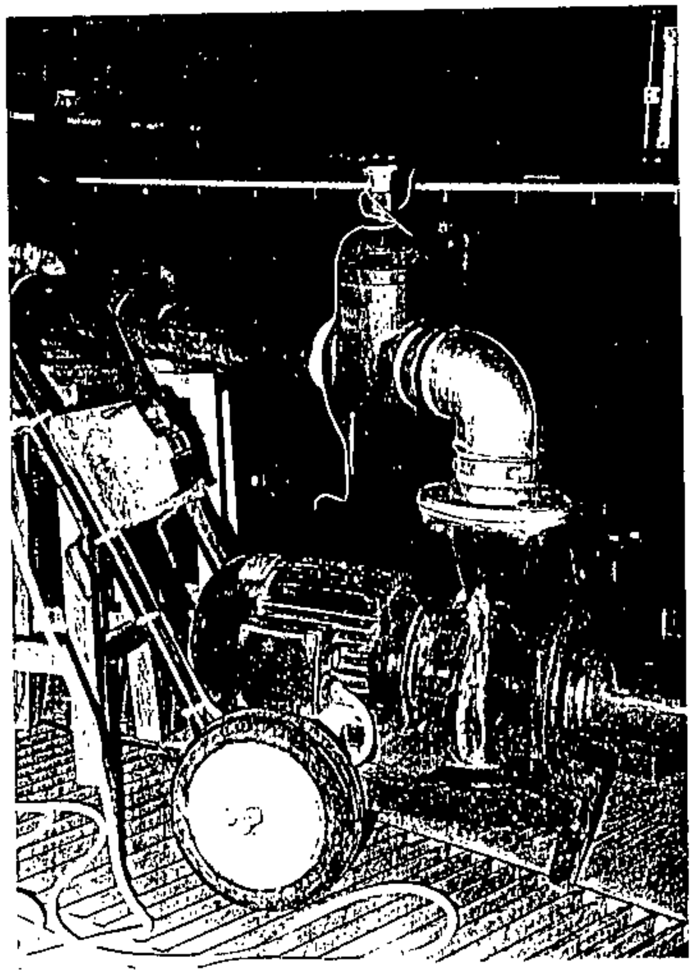


FIG. 3.2. The Pump

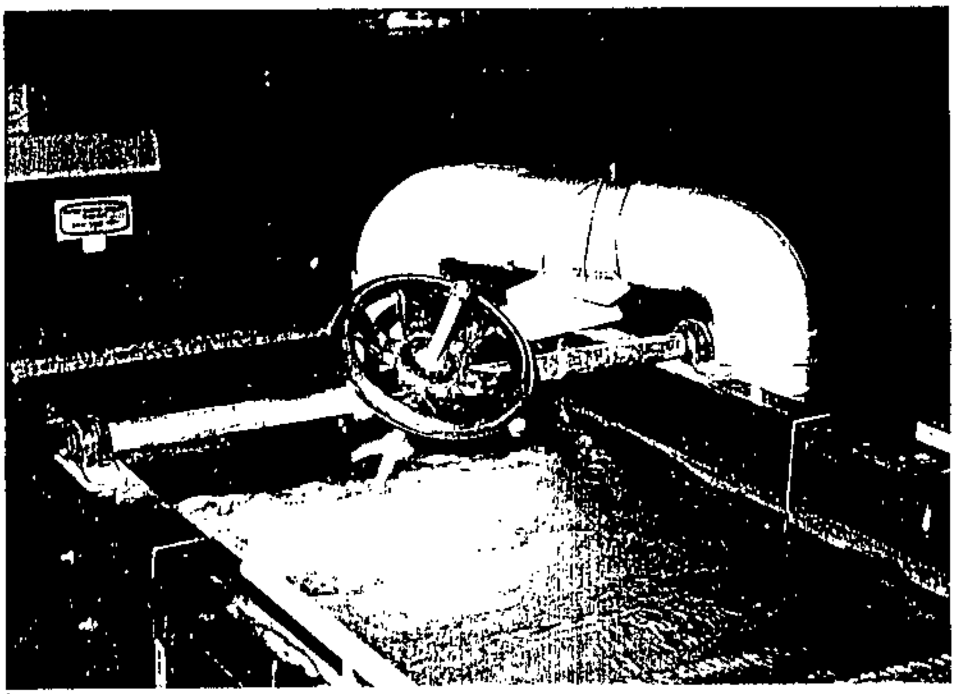


FIG. 3.3. The Tail Gate

depth as shown in fig. 3.3.

3.2.2 Point Gauge and Measuring Carrige

Water surface levels were read by a point gauge mounted on a sliding carriage as shown in fig. 3.4.

The point gauge could be read to the nearest 0.1 mm, the carriage can be moved along the flume length. The carriage has a jockey which can move in the transverse direction.

3.2.3 The Balance

The balance used for measuring the drag force, reads to the nearest 0.01 grams, it is located perpendicular to the direction of flow, plastic pulley was used to transfer the horizontal force into perpendicular direction as shown in fig. 3.5.

3.2.4 The Orifice Meter

The orifice meter is designed to measure the discharge through the pipes. It consists of a circular hole in a thin flat brass plate of 3 mm thickness, the internal diameter of the orifice is 5 cm, and the lip thickness is 8 mm, the brass plate is inserted into a circular groove between the two flanges as shown in fig. 3.6., at a joint in the pipeline, pressure tapings of 2 mm diameterwere connected to the differential mercury manometer through two flexible tubes of 5 mm diameter, located at one pipe diameter upstream, and at half pipe diameter downstream of the plate.

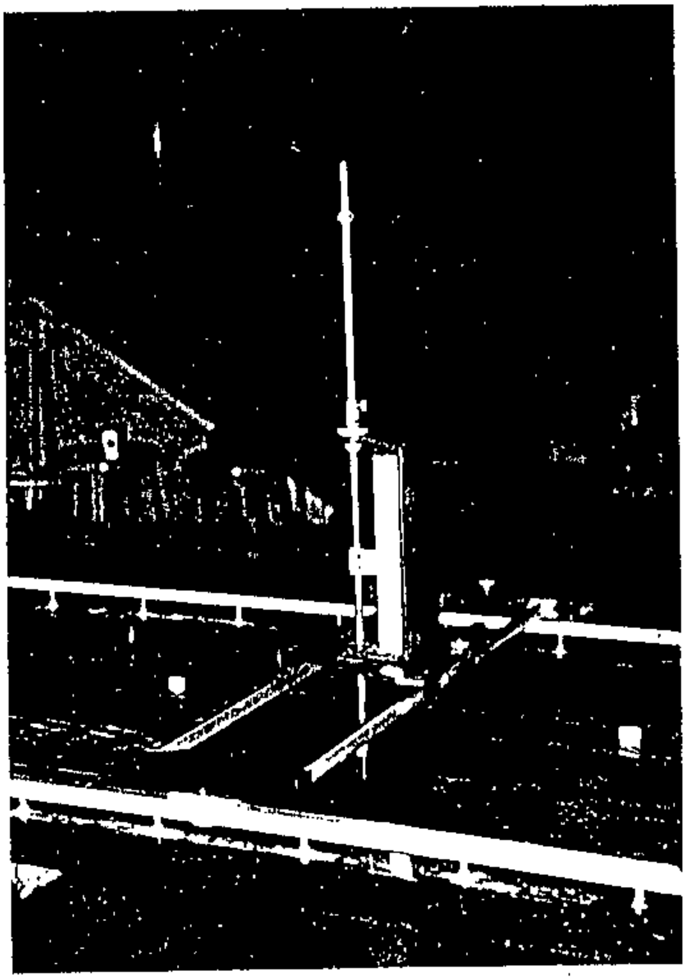


FIG. 3.4. The Depth Point Gauge

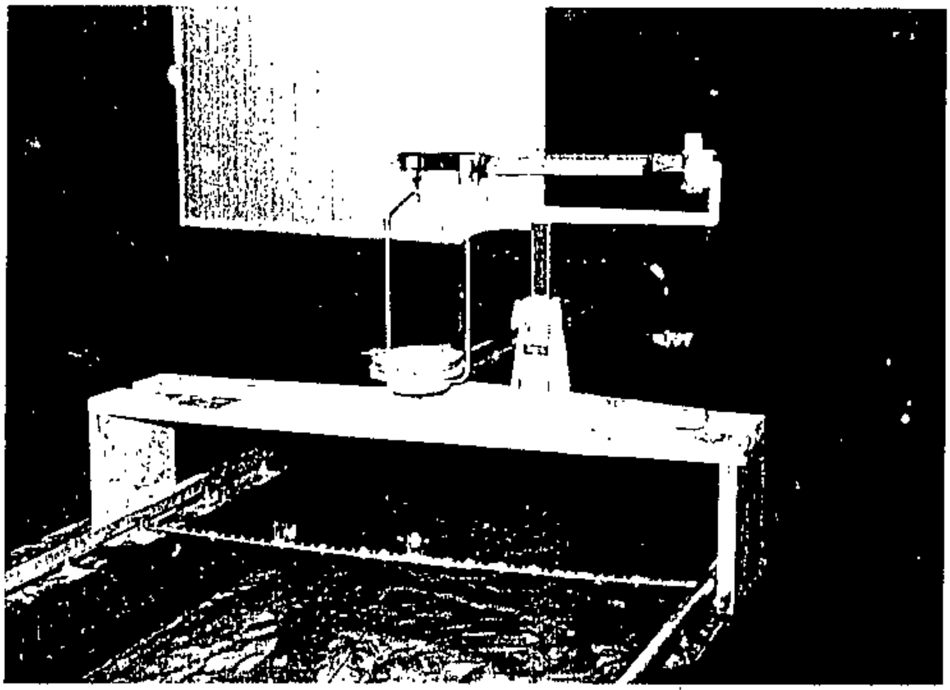


FIG. 3.5. The Balance

FIG. 3.6. The Orifice Meter

The discharge was measured by using a measuring tank, the details of the orifice calibration shown in Appendix A, the relationship between the differential head and discharge is shown in fig. 3.7.

3.2.5 The Manometer

The orifice meter is connected through two flexible tubes 5 mm diameter to the differential U-tube manometer. The internal diameter of the tubes are 8 mm, which are large enough to eliminate the capillary effect, and they are partially filled with mercury. Readings were taken to the nearest 1.0 mm on the vertical position of the manometer as shown in fig. 3.8.

3.2.6 PREPARATION OF THE BED AND THE MODELS

3.2.6.1 The Bed

After the perspex plate, which is 5 mm thick, was cut to 60 cm width to easy fixing in the flume, grooves were engraved in the perspex plate to guide the pier models movement. To overcome the uplifting and moving of the perspex plate, holes were made and sharp wedges were used.

3.2.6.2 The Models

Five pier shapes were investigated in this research, using perspex material to form them , shapes are shown in fig. 3.9. They are:

1) Rectangular nose and tail pier.

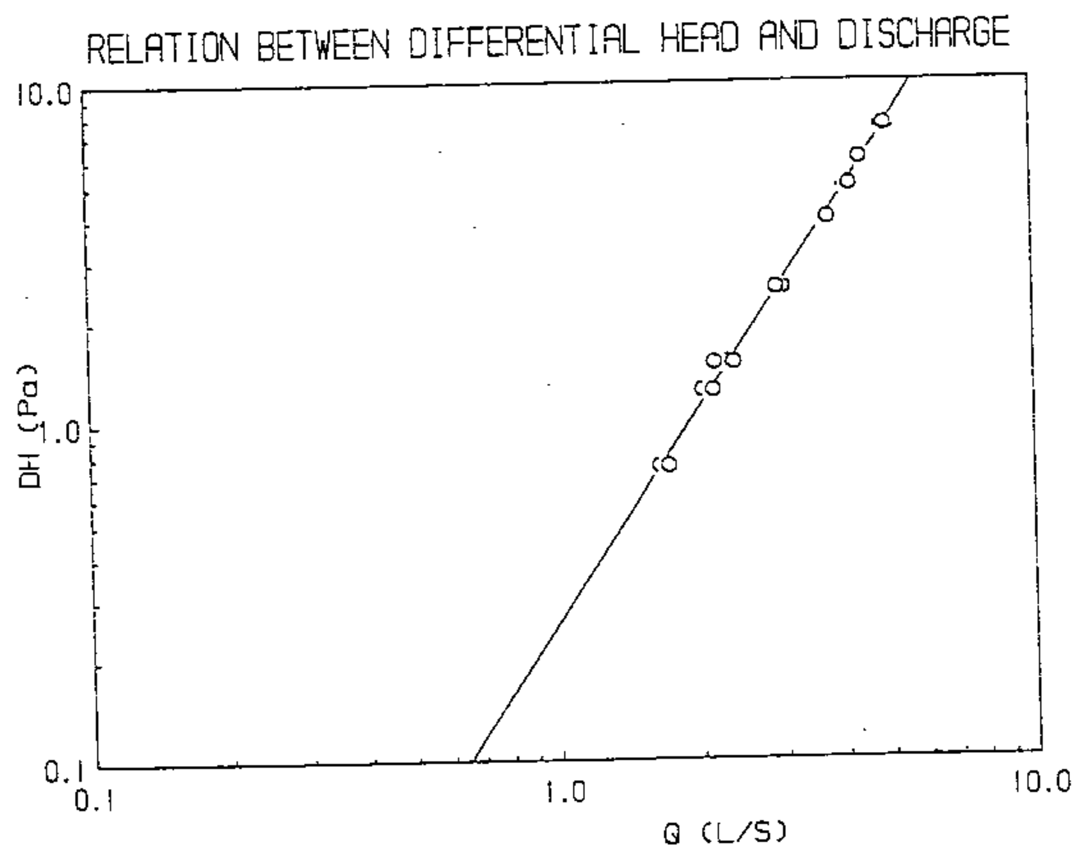


FIG. 3.7. The Calibration Curve

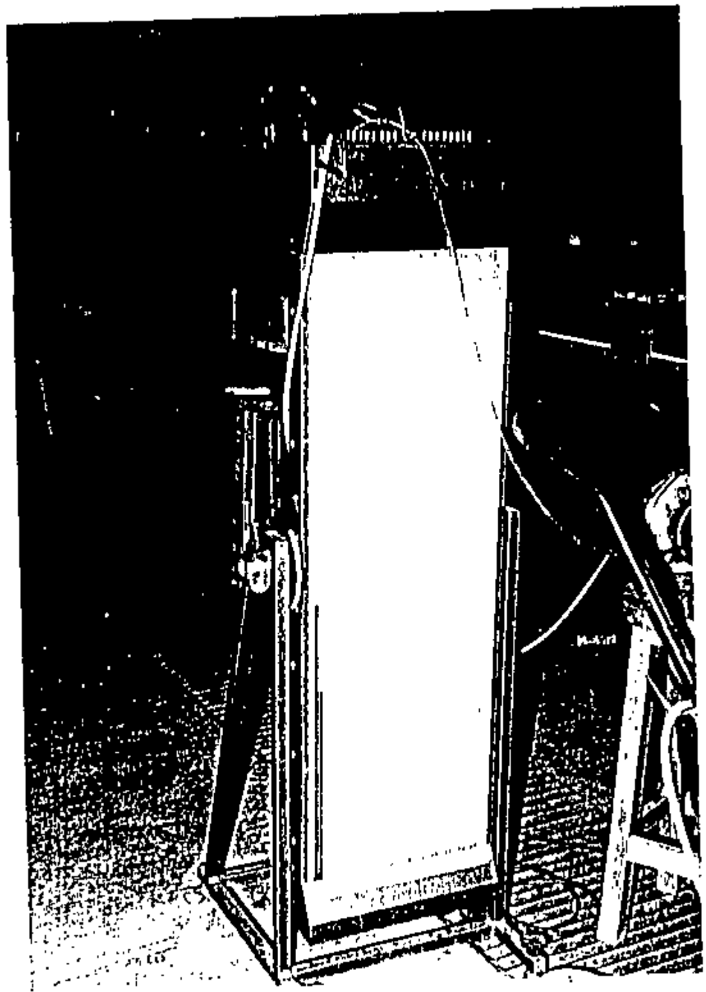


FIG. 3.8. The Manometer

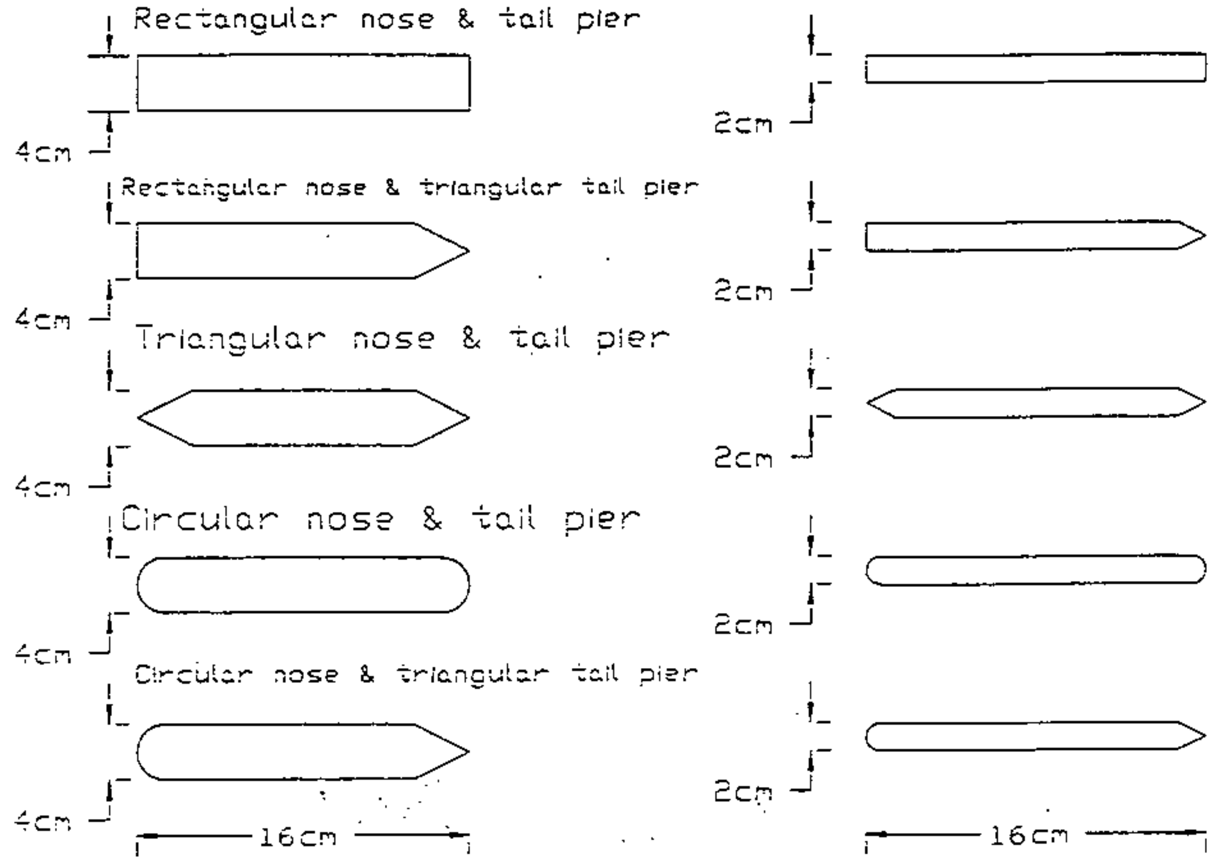


FIG. 3.9. Shapes of Piers Considered

2) Rectangular nose and triangular tail with angle 90 pier.

3) Triangular nose and tail with angle 90 pier.

4) Circular nose and tail pier.

5) Circular nose and triangular tail with angle 90 pier.

Piers dimensions were 4, 2 cm width and constant length 16 cm. The height of each pier was approximately 10 cms to ensure that the top of the pier will never be submerged in water, the piers were set parallel to the flow direction, each pier was installed over almost frictionless rollers projecting about 2 mm from the pier bottom . The location of piers was in the middle third of the flume, to eliminate the effect of entry or exit flow effect.

3.3 PROCEDURE OF MEASUREMENTS

1) The experiment was started with one pier of a certain shape in the middle of the flume with halves of piers on both sides to eliminate side effect.

2) The pump was operated at a certain discharge. Discharge was found by using the calibration curve. Depth of flow is then selected by adjusting the tail gate.

3) Fig. 3.10. shows the way the scales measure the drag, the thread was connected at a point higher than the center of pressure. The couple formed was counter balanced by adding some sand at the pier tail. The uplift pressure force was

almost eliminated by making the pier just floating.

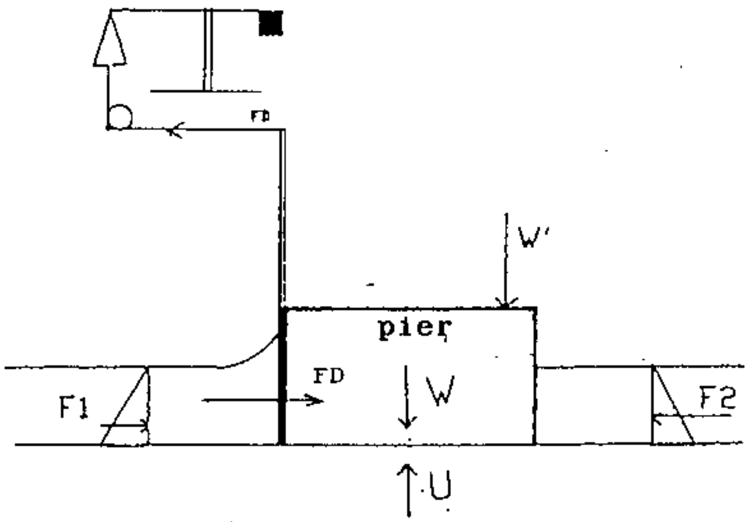


FIG. 3.10. General Forces Acting on the Pier

4) Water profile was recorded upstream and downstream the piers at regular intervals. The readings at each interval were taken in a way such that the point gauge makes number of contacts with the surface equal to the number of departures per second. This was done to avoid the effect of water surface fluctuations.

5) For the same discharge and depth, the drag force was measured for different contraction ratios of the same shape.

6) The whole procedure was repeated for several discharges to get enough points for analysis.

7) The temperature was measured in each run.

8) The procedure was repeated for another shape and so, until all shapes are covered.

CHAPTER 4

ANALYSIS OF THE EXPERIMENTAL RESULTS AND DISCUSSION

4.1 DRAG COEFFICIENT

4.1.1 Introduction

A river flowing past a bridge pier will exert a hydrodynamic force on the pier, the component of which in the direction of flow is known as drag and the component normal to the flow as lift. In a fully turbulent flow, drag force is generated from a combination of the shear stress against the pier face and the pressure differential caused by flow separation at the pier tail.

4.1.2 Dimensional Analysis

The force FD exerted on the pier(of certain length L, width W_P, roughness e, shape factor K) by moving fluid depends upon :

a) Geometric variables : characteristic length L, contraction ratio σ

b) Kinematic variables : flow velocity V

c) Dynamic variables : fluid density ρ, fluid viscosity μ and fluid specific weight γ

The above mentioned variables can be written in the form

$$FD = f(\sigma, L, V, \rho, \mu, \gamma) \quad \ldots\ldots\ldots\ldots\ldots (4.1)$$

choosing L, V and ρ as repeating variables we get the following π terms : Re, Fr, σ, $FD/\rho V^2 A$

Or

$$FD = 1/2\ \rho\ V^2\ A\ \phi\ (\sigma,\ Fr,\ Re) \quad \ldots\ldots\ldots\ldots (4.2)$$

in which A is the submerged frontal area of piers perpendicular to the direction of flow. Fr and Re are Froude's and Reynolds numbers respectively, the quantity ϕ (σ, Fr, Re) is called the drag coefficient CD. Equation (4.2) could be written for certain shape of certain roughness, length and width of a pier

$$FD = \frac{\rho A V^2}{2} \quad CD \quad \ldots\ldots\ldots\ldots (4.3)$$

Or

$$CD = \phi\ (\sigma,\ Fr^2,\ Re) \quad \ldots\ldots\ldots\ldots (4.4)$$

These three parameters correspond to the effect of the contraction, gravity forces and viscous forces.

4.1.3 Computation Of The Drag Coefficient

The equation of the force acting by a moving fluid is the sum of hydrostatic and dynamic forces.

In general

$$F = \rho g A \bar{h} + \rho (Q^2/A) \ldots\ldots\ldots\ldots (4.5)$$

For rectangular cross section channels the force equation

$$F' = \frac{\rho g d^2}{2} + \frac{\rho q^2}{d} \quad \ldots\ldots\ldots\ldots (4.6)$$

Where

F : Force acting by the moving fluid on the pier

F′: Force acting by the moving fluid on the pier per unit width.

ρ : Mass density.

g : Acceleration of gravity.

$\bar{h}$: The vertical distance between the water surface and center of gravity of the flow section.

A : Projected area of section (perpendicular to direction of the flow).

Q : Flow rate.

q : Flow rate per unit width.

d : Depth of water.

The drag force acting on the pier located in a moving fluid is the difference between upstream and downstream forces. Neglecting the very small bed shear force we can write:

$$FD = F_1 - F_2 = CD \frac{\rho V_1^2 A_p}{2} \quad \ldots\ldots\ldots\ldots\ldots (4.7)$$

Where F_1 and F_2 are the forces upstream and downstream of the pier. To determine these forces, the downstream profile was recorded at equal intervals of 1 cm, and at a certain distance downstream of the piers, the depth was found to be constant.

The upstream section at which FD is to be computed was determined by finding the best polynomial regression curve for the upstream profile. FD was computed by trial and error at different sections upstream of the pier and then compared each time with the measured one, until they become equal or almost equal.

Then $$CD = \frac{FD}{1/2\ \rho\ V_1^2 A_p} \quad \ldots\ldots\ldots\ldots\ldots (4.8)$$

Where A_p :Projected area of pier immersed in the moving fluid in the upstream section.

V_1 : Upstream velocity at which measured drag is equal to the computed drag force

The figures below show the relation between the computed drag force and $1/2\ \rho\ V_1^2 A_p$, they have a linear relationship, the slope of which is CD. This relationship is shown in fig. 4.1. through 4.10.

For both piers of width 4 and 2 cm, the distance downstream of the piers, at which the depth of flow was considered constant, was taken equal to 4 cm to avoid completely the effect of pier tail shape.

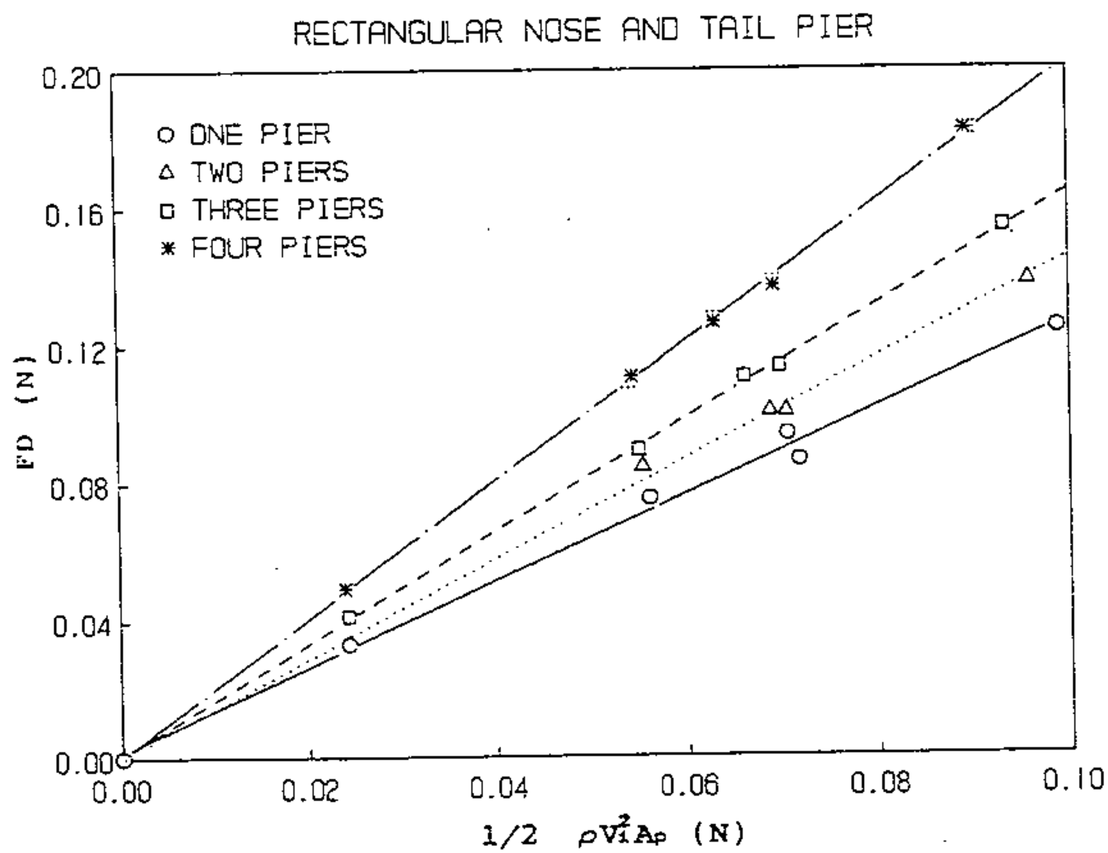


FIG. 4.1. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (4 cm).

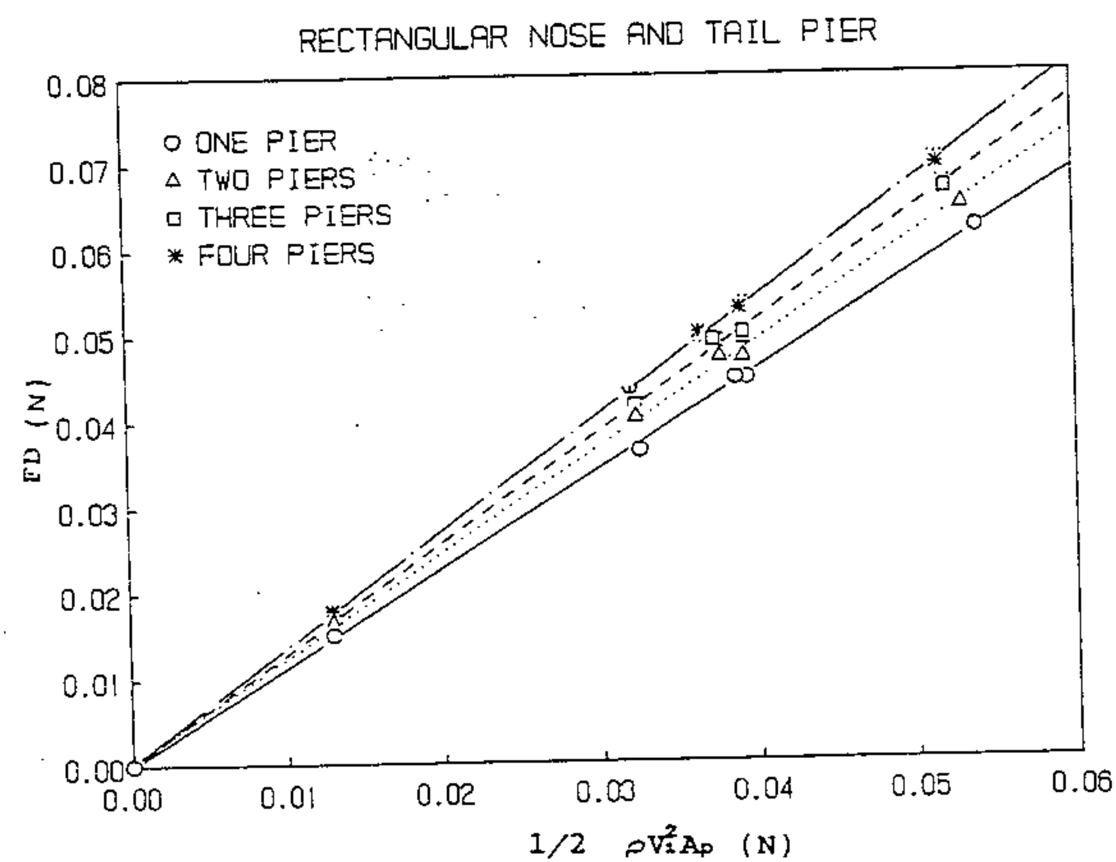


FIG. 4.2. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (2 cm).

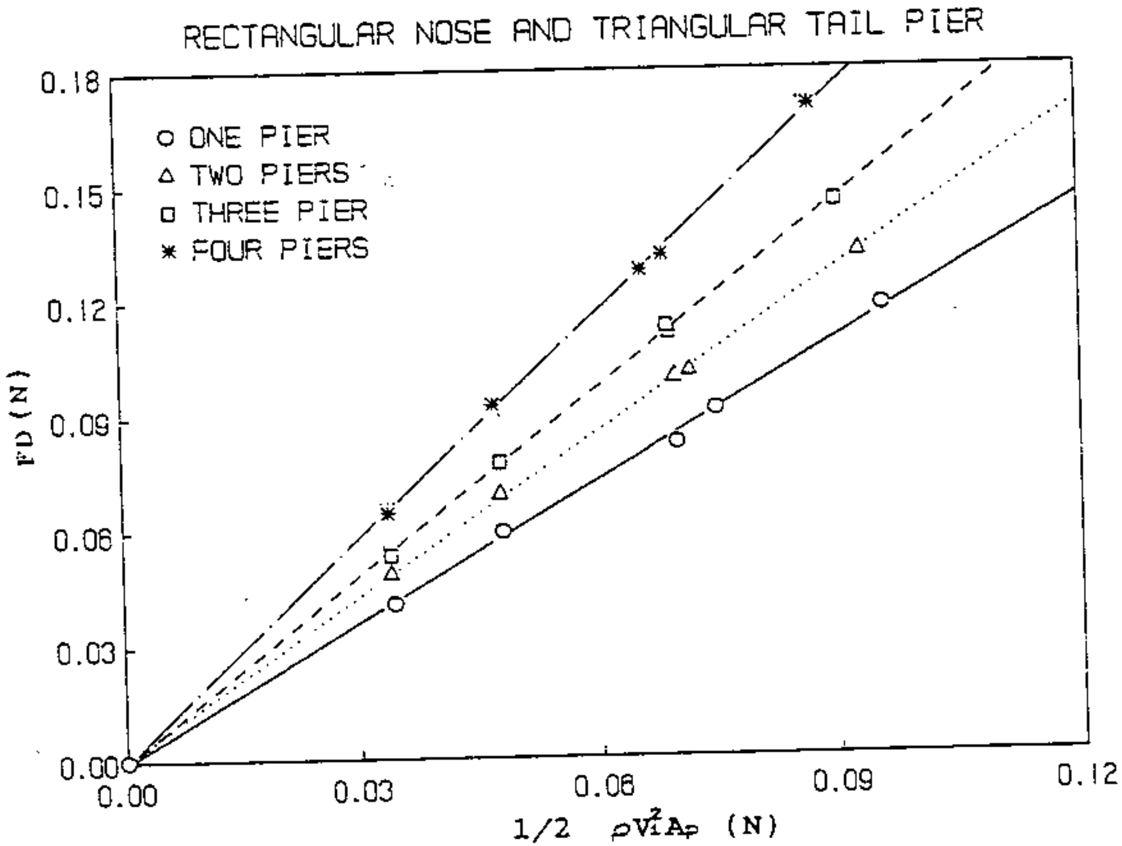


FIG. 4.3. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (4 cm).

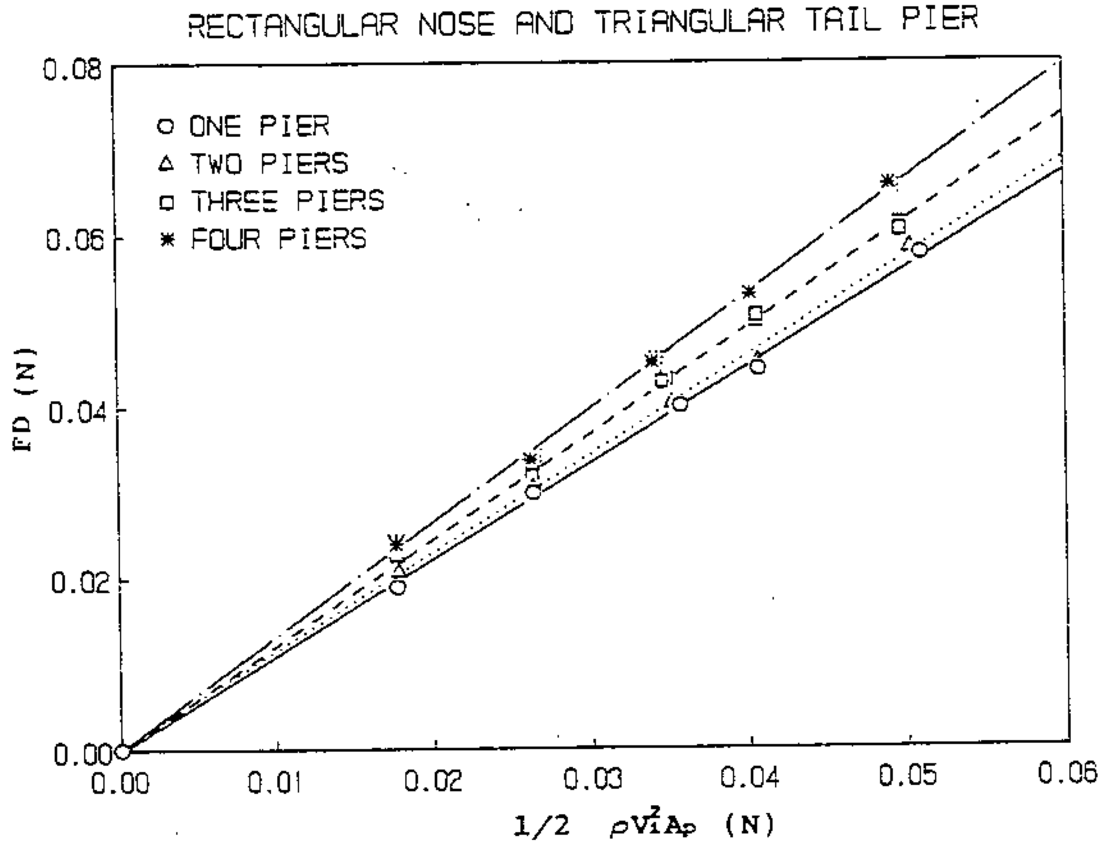


FIG. 4.4. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (2 cm).

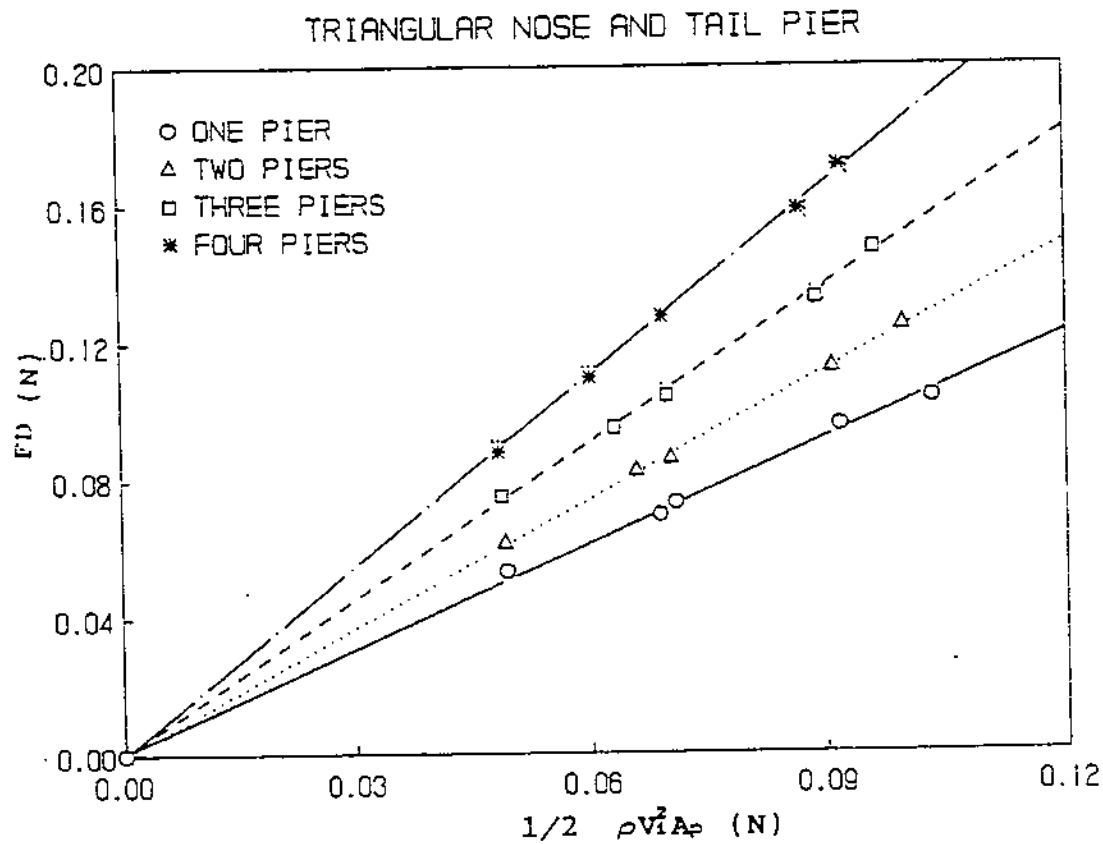


FIG. 4.5. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (4 cm).

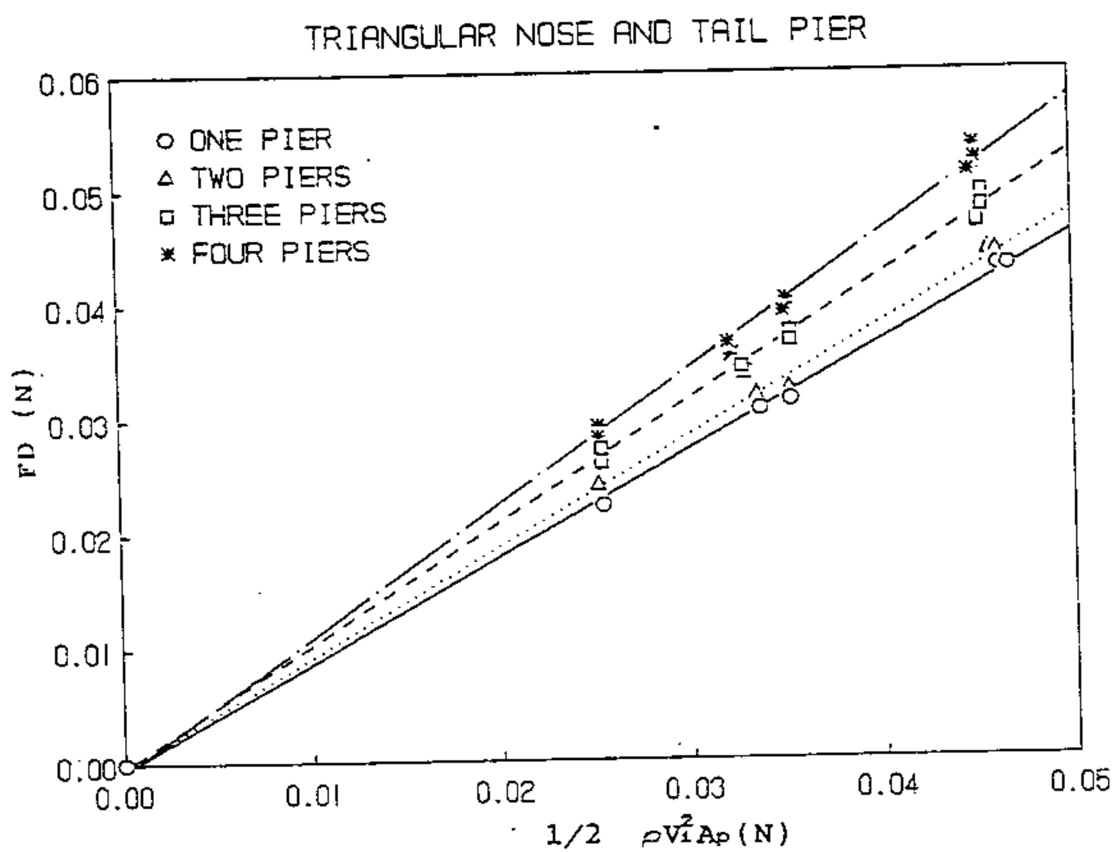


FIG. 4.6. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (2 cm).

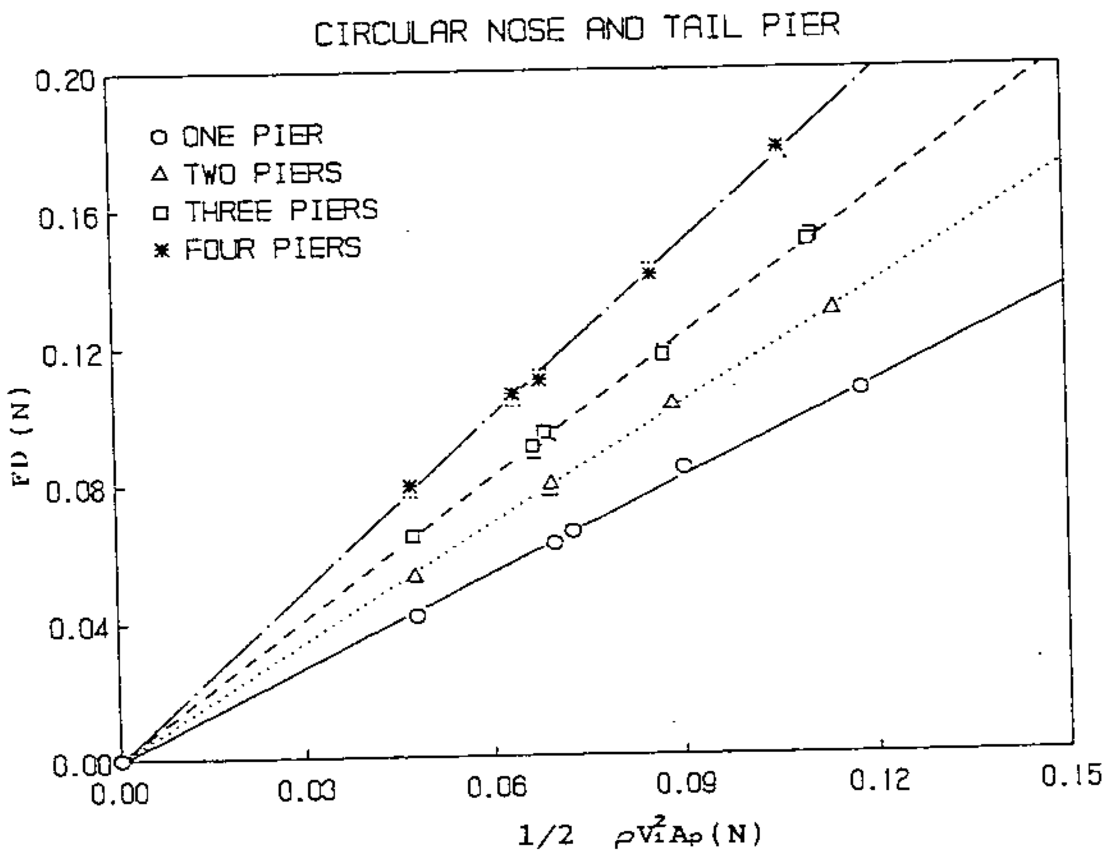


FIG. 4.7. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (4 cm).

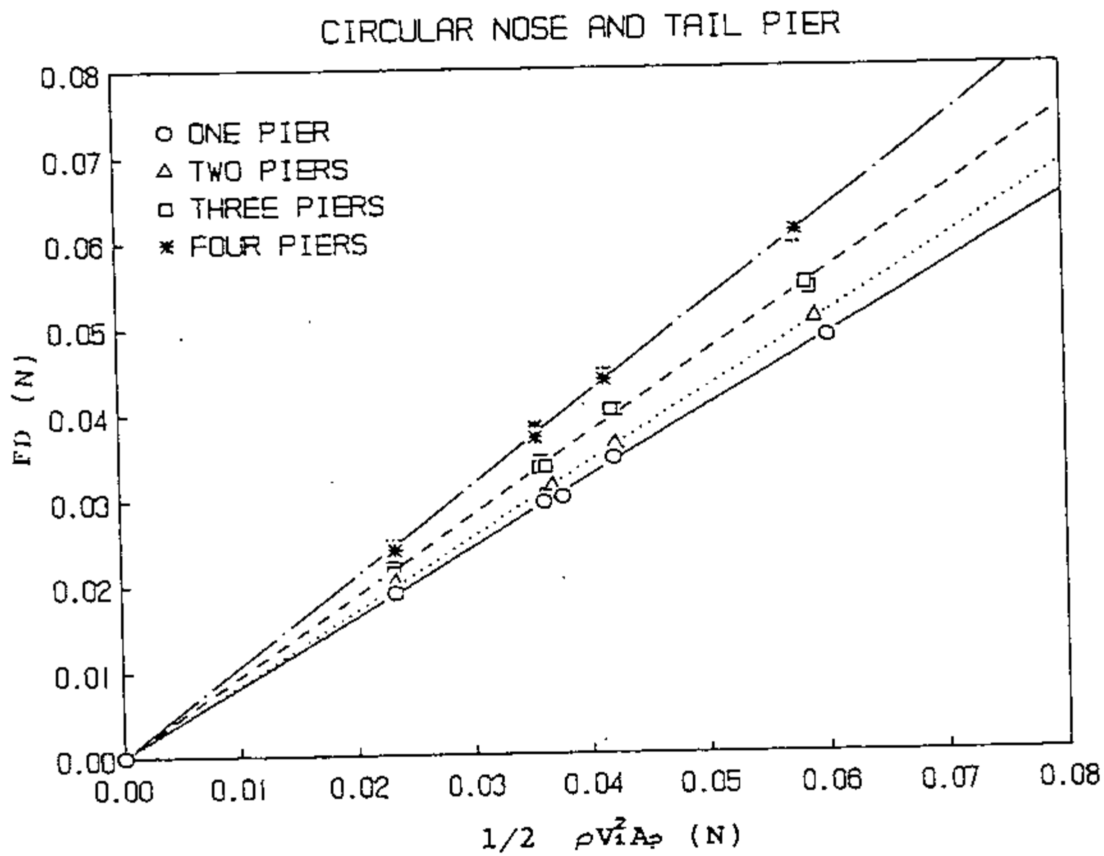


FIG. 4.8. Relationship Between Drag Force and 1/2 $\rho V_1^2 A_p$ for Pier Width (2 cm).

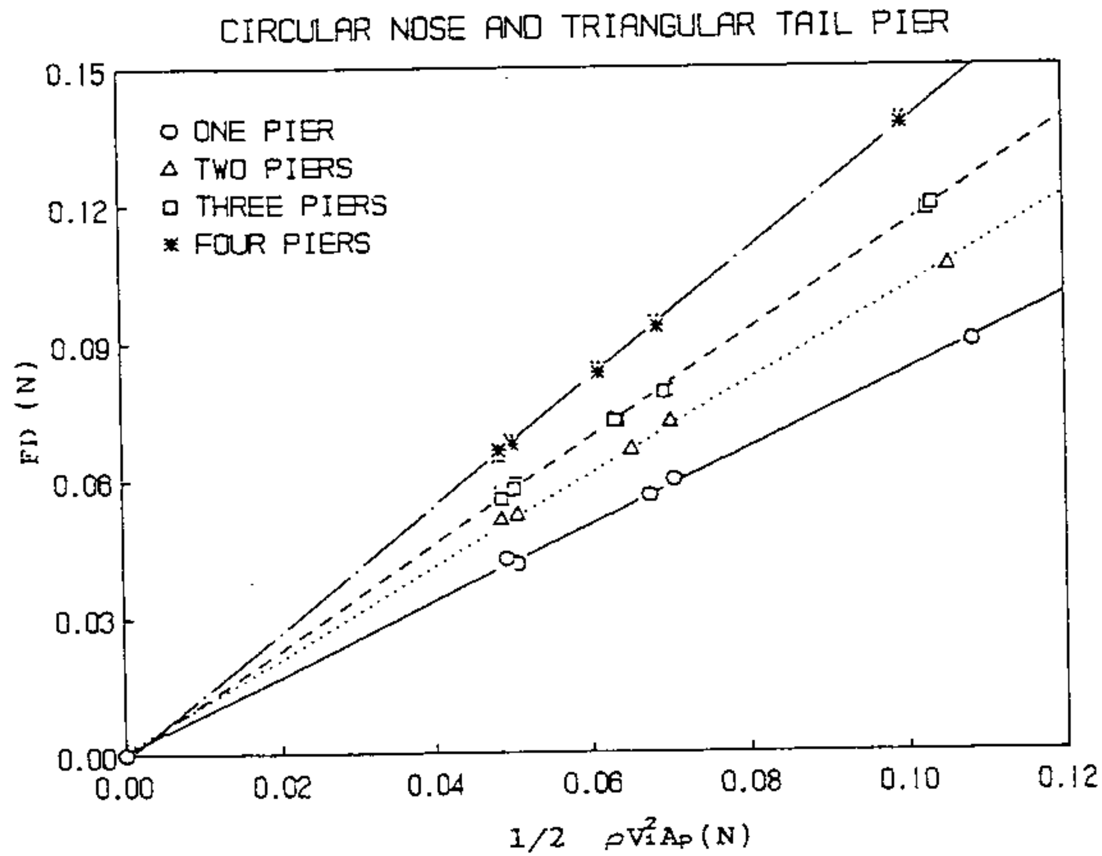


FIG. 4.9. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (4 cm).

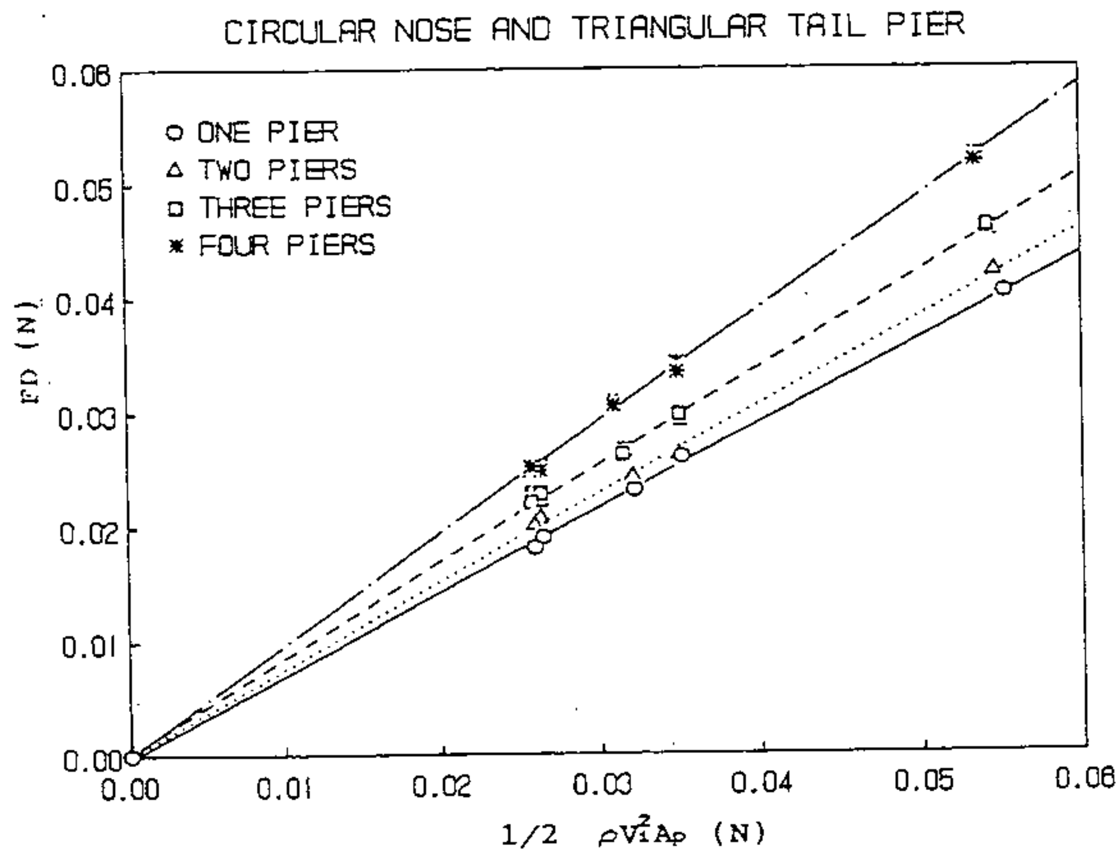


FIG. 4.10. Relationship Between Drag Force and $1/2\ \rho V_1^2 A_p$ for Pier Width (2 cm).

4.1.4 The Effect Of Reynolds Number On Drag Coefficient

The range of Reynolds number using the pier width as the characteristic length is :

$$3.55*10^{3} \le Re \le 1.84*10^{4}$$

In this range of Re, the drag coefficient did not vary with Re, and thus Re is dropped out from the functional relationship of CD and Re, or CD is independent of Re.

Fig. 4.11. and 4.12., show the relationship between drag coefficient and Reynolds number for rectangular nose and tail pier, relationships for the other shapes are shown in Appendix E. Those figures demonstrate that CD is independent of Re.

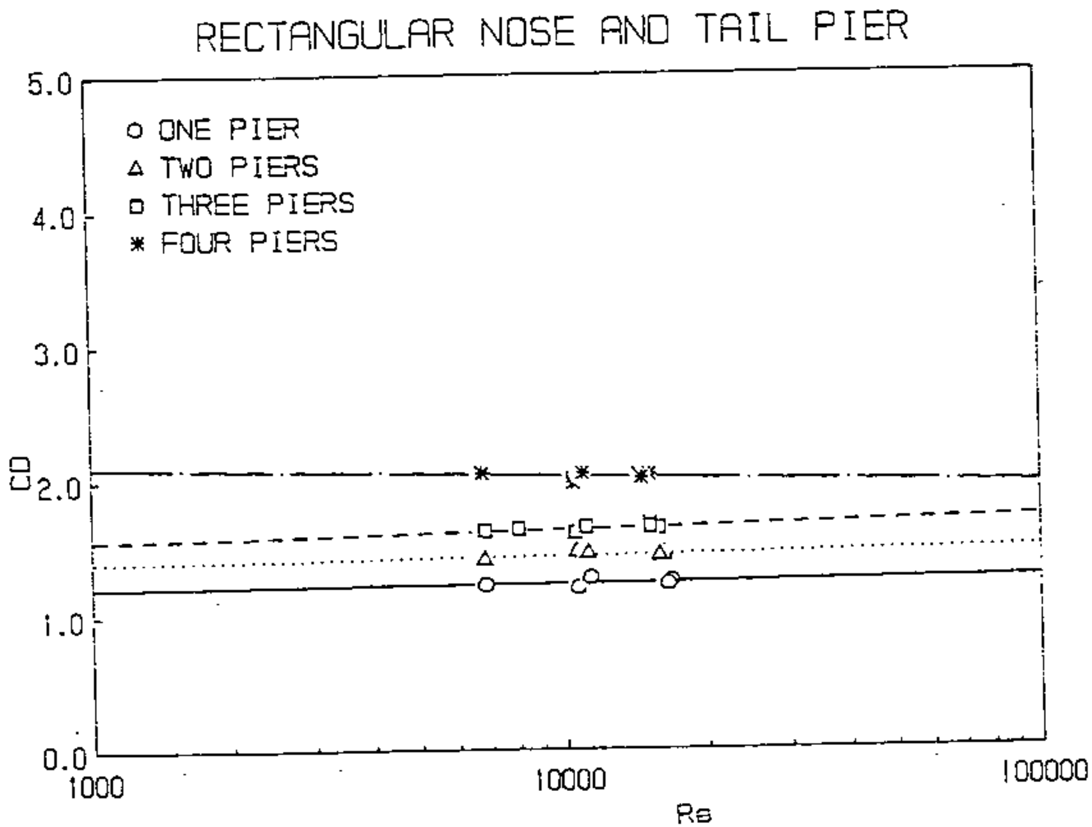


FIG. 4.11. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (4 cm).

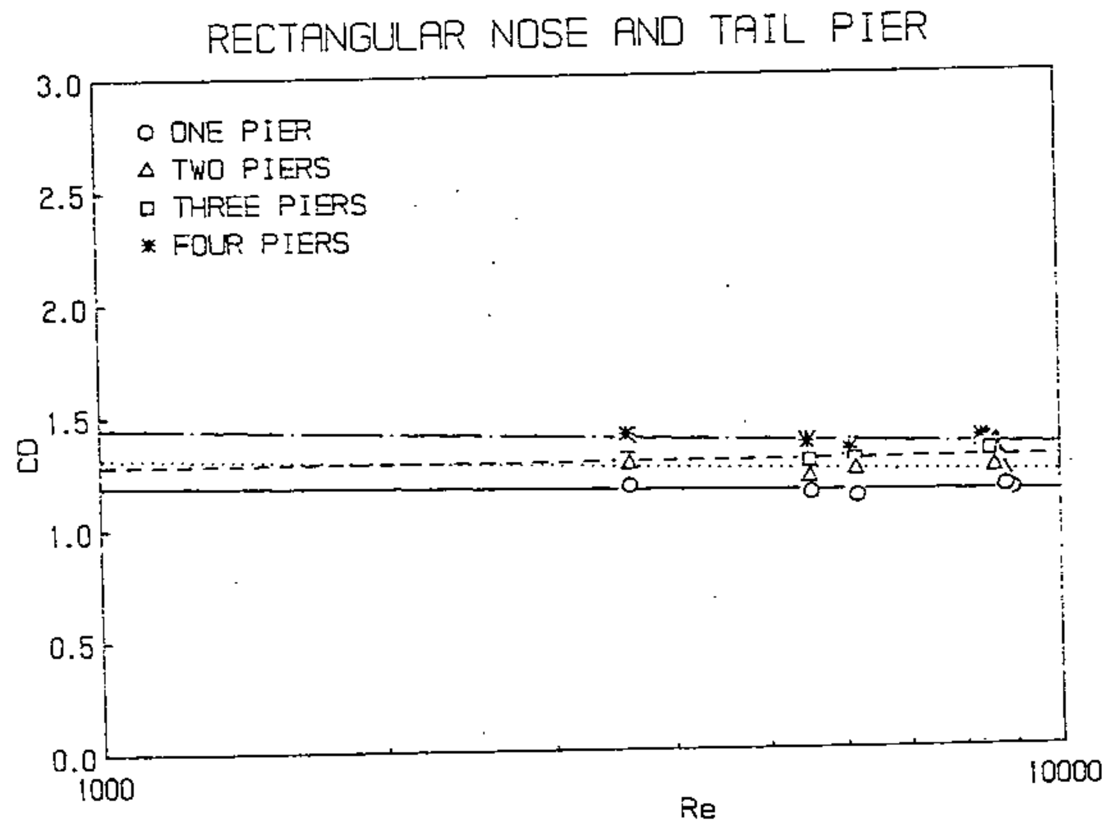


FIG 4.12. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (2 cm).

4.1.5 The Effect Of Froude's Number On Drag Coefficient

Most of the measured values of the Froude number downstream lie in the range of :

$$.21 \leq Fr_2 \leq .78$$

Froude's number of this range showed no effect on the drag coefficient as manifested by fig. 4.13. and 4.14., for rectangular nose and tail.

Other shapes relationships are shown in Appendix E.

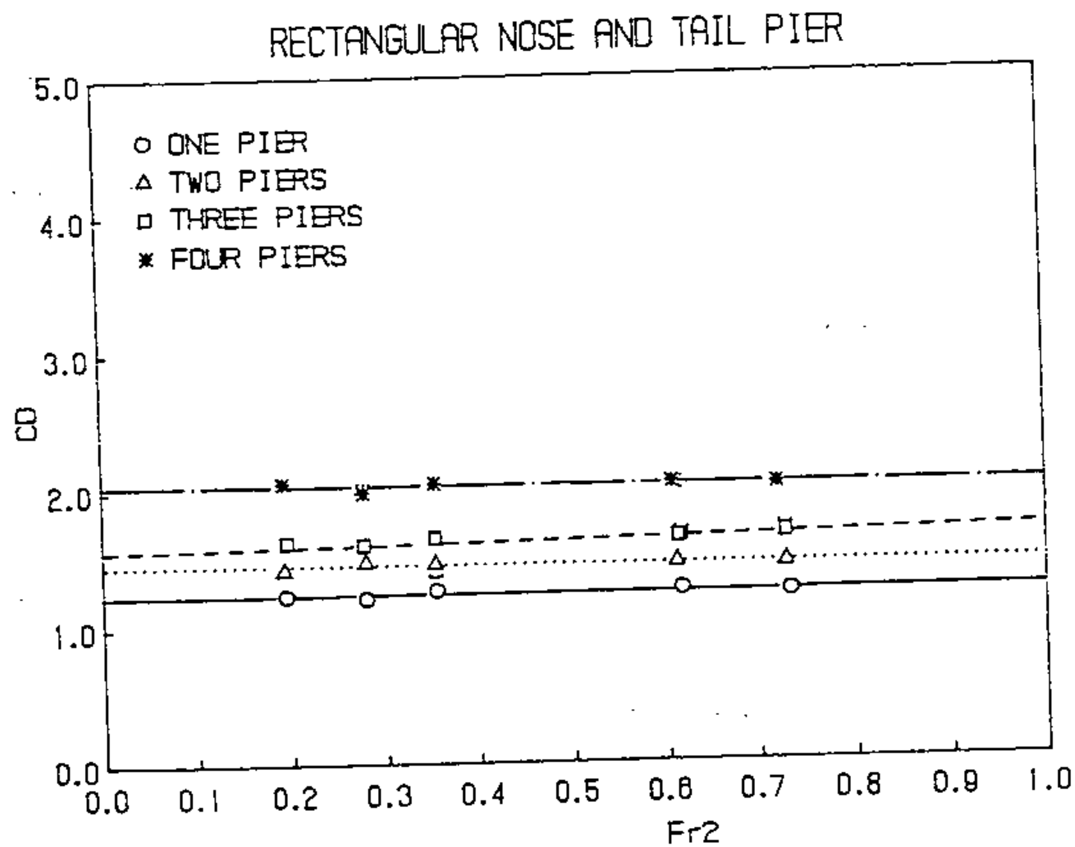


FIG 4.13. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (4 cm).

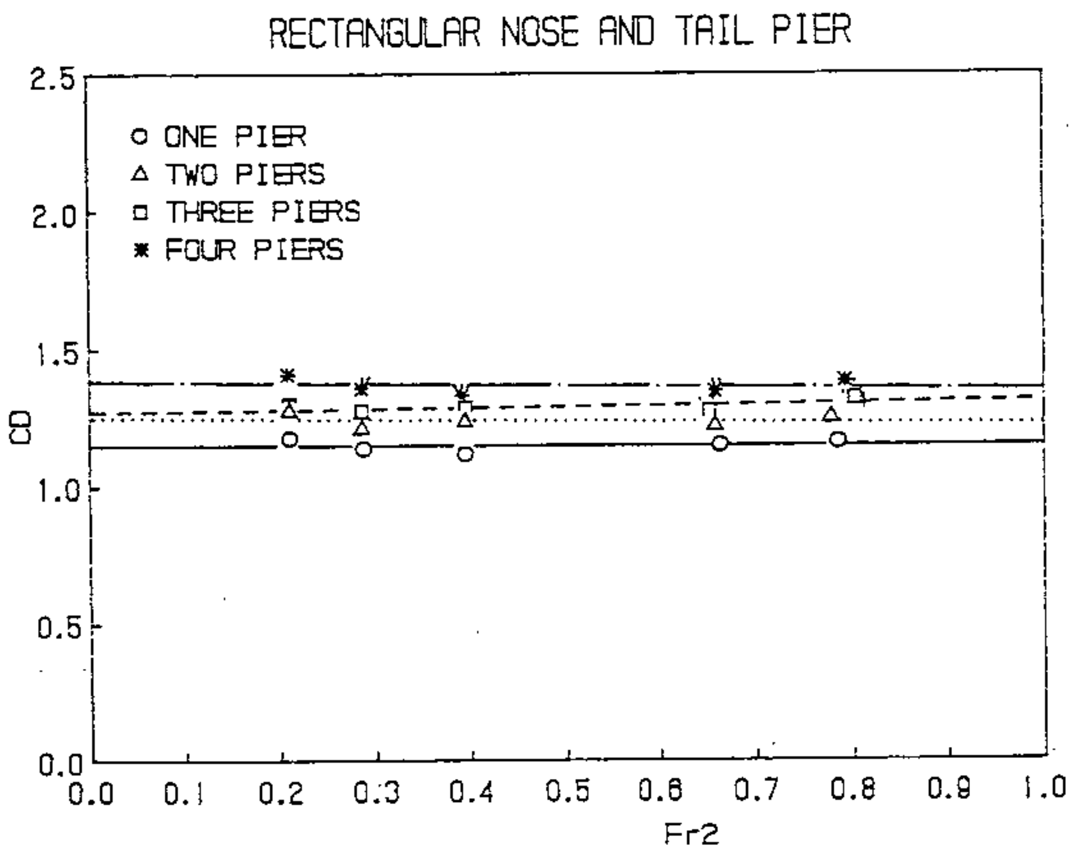


FIG. 4.14. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (2 cm).

4.1.6 The Effect Of The Contraction Ratio On Drag Coefficient

Tests of eight different contraction ratios were carried out for each of the pier shapes. The contraction ratio (σ) is defined as the unobstructed area over the total area at any section as shown in fig. 4.15.

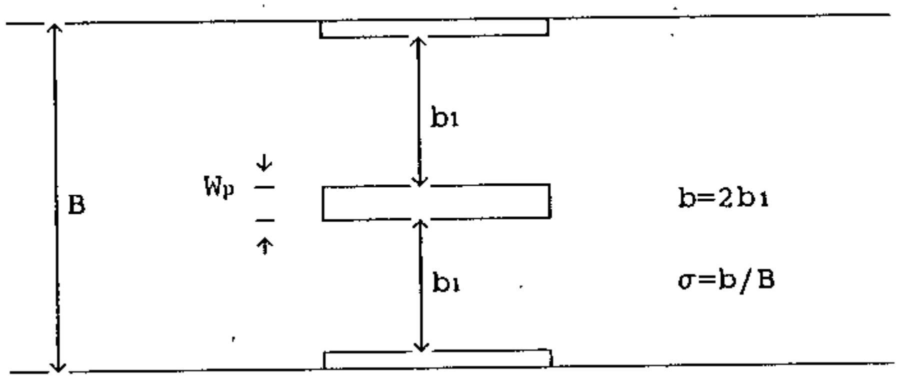


FIG. 4.15. Definition Diagram

The tests of the contraction ratio were conducted for all shapes as per the following dimensions shown in table 4.1.

Table 4.1.: Tests of Contraction Ratios.

Test	Width of pier W_p (cm)	Number of piers	Tolal obstructed width (cm)	$\sigma=b/B$
1	4	1	8	0.868
2	4	2	12	0.802
3	4	3	16	0.736
4	4	4	20	0.670
5	2	1	4	0.934
6	2	2	6	0.901
7	2	3	8	0.868
8	2	4	10	0.835

The contraction ratio range is between

$$67.0\% \leq \sigma \leq 93.4\%$$

The drag coefficient was drawn against σ for each shape as shown in fig. 4.16.

From those figures it is clear that there is a strong relationship between CD and σ.

Regression equation was developed for each shape, and shown in the conclusions.

For the five shapes considered, the drag coefficient decreases respectively as the contraction ratio increases. The highest drag coefficient at the same contraction ratio is for rectangular nose and tail pier, followed by rectangular nose and triangular tail pier, triangular nose and tail pier, circular nose and tail pier, and circular nose and triangular tail pier.

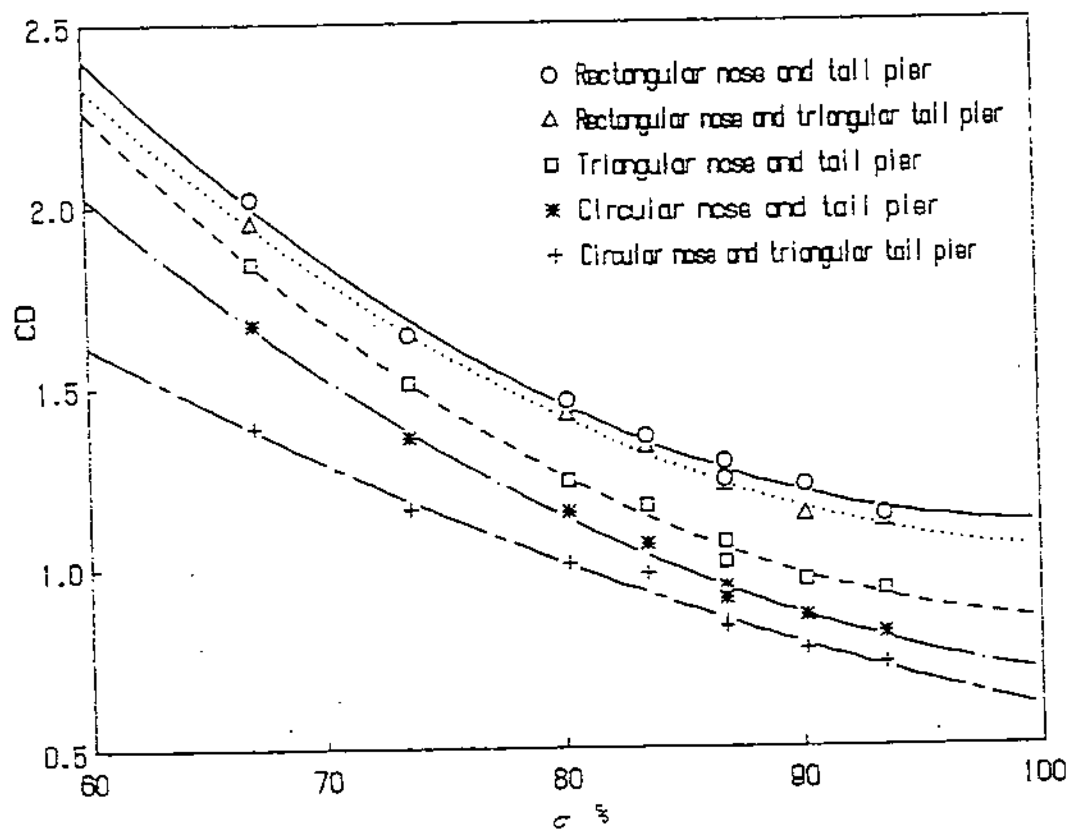


FIG. 4.16. Relationship Between Drag Coefficient and Contraction Ratio .

4.2 THE ENERGY LOSS

4.2.1 Introduction

It is well known that the cross-sectional area of a stream of water cannot be either diminished or increased without causing energy loss, and hence loss in head, in the stream itself.

Therefore, when a bridge pier is constructed in a given stream section, such loss of head will be observed. For, at the nose of the pier, the stream is contracted in width, and, at the tail of pier, it is suddenly enlarged to its original width.

Static head must first be available to accomplish necessary increase in velocity demanded by the decrease in the stream section at the nose of the pier. Hence, there is observed the common phenomenon of 'back-water', or the increase in elevation of the water surface at the nose pier.

The loss, for convenience of these tests, are classified as follows:

1) Loss which may be attributed to the change in section, these are made up of both surface and submerged loss, which are revealed by the turbulence and eddies at the nose and tail pier.

2) Loss due to the friction of the water as it passes the wetted pier surface, these are relatively small when compared with those due to the change in section; they are so small, in fact, in most computations, they are neglected.

4.2.2 Mathematical Model

The specific energy is defined as the vertical distance between the channel bottom and energy line , using the channel bottom as a datum.

The generalized equation of specific energy is

$$Es = d + \frac{1}{2g} * (\frac{Q}{A})^2 \quad \ldots\ldots\ldots\ldots\ldots(4.9)$$

Where A is the area as function of d, and depends on the geometry of the section.

The above equation can be written for a rectangular cross section at upstream and downstream sections respectively as

$$Es_1 = d_1 + \frac{V_1^2}{2g} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.10)$$

$$Es_2 = d_2 + \frac{V_2^2}{2g} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.11)$$

The energy lost due to the presence of the piers, ΔE is written as

$$\Delta E = E_1 - E_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.12)$$

Or rewriting

$$\frac{\Delta E}{E_2} = \frac{E1}{E_2} - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.13)$$

Substituting the values of E_1 and E_2 in equation (4.13)

$$\frac{\Delta E}{E_2} = \frac{V_1^2 + 2gd_1}{V_2^2 + 2gd_2} - 1 \quad \ldots\ldots\ldots\ldots\ldots(4.14)$$

It is desirable to have downstream section as the independent variable, since the downstream profile is uniform and is closed to the mean depth in the channel, so substituting for V_1 by using the continuity equation, we get

$$\frac{\Delta E}{E_2} = \frac{(V_2^2/gd_2)\ (d_2/d_1)^2 + 2(d_1/d_2)}{(V_2^2/gd_2) + 2} - 1 \quad \ldots(4.15)$$

Or

$$\frac{\Delta E}{E_2} = \frac{Fr_2^2\ (d_2/d_1)^2 + 2(d_1/d_2)}{Fr_2^2 + 2} - 1 \quad \ldots(4.16)$$

$$\frac{\Delta E}{E_2} = f\ (Fr_2,\ d_1/d_2) \quad \ldots\ldots\ldots\ldots(4.17)$$

For submerged flow

$$d_1 = f\ (Fr_2, d_2) \quad \ldots\ldots\ldots\ldots(4.18)$$

Or $$\frac{d_1}{d_2} = f\ (Fr_2) \quad \ldots\ldots\ldots\ldots(4.19)$$

So $$\frac{\Delta E}{E_2} = f\ (Fr_2) \quad \ldots\ldots\ldots\ldots(4.20)$$

This equation demonstrates that the percentage of energy loss is a function of the Froude number downstream the piers.

For different contraction ratios σ the general form is:

$$\frac{\Delta E}{E_2} = f\ (Fr_2,\ \sigma) \quad \ldots\ldots\ldots\ldots(4.21)$$

Fig. 4.17. through 4.26. show the relationship between the percentage energy loss and downstream Froude number.

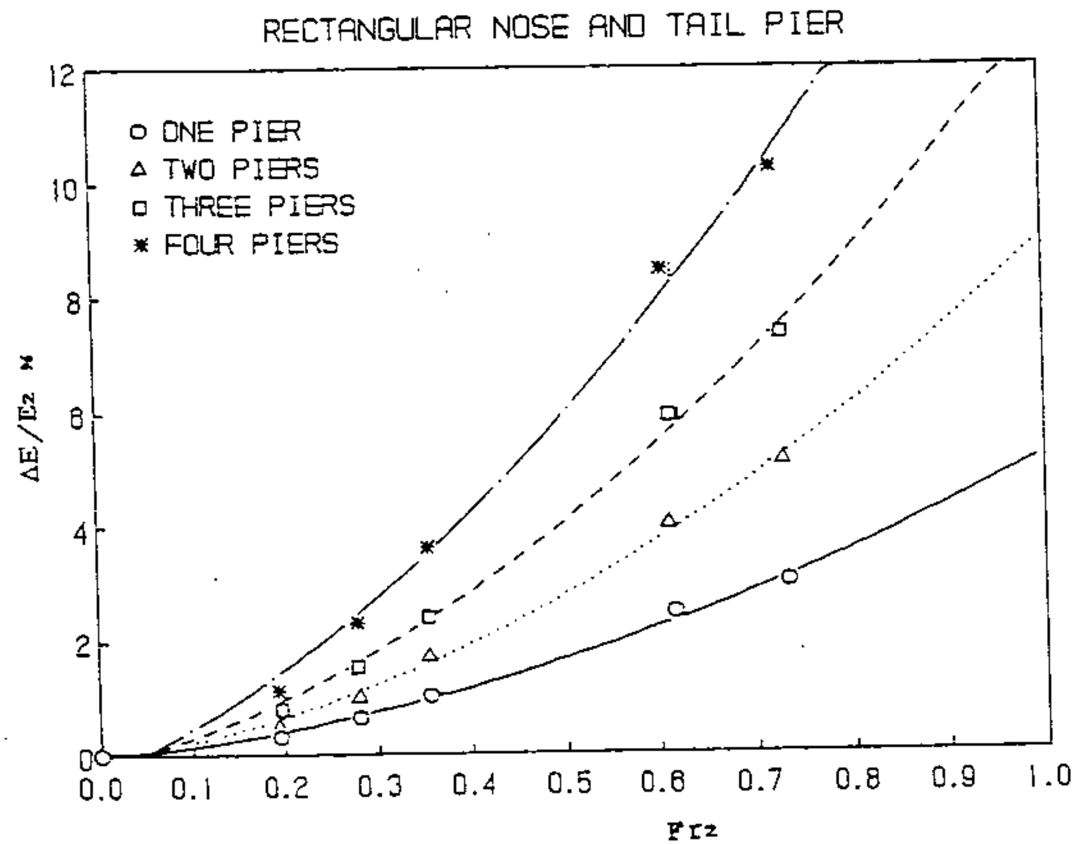


FIG. 4.17. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (4 cm).

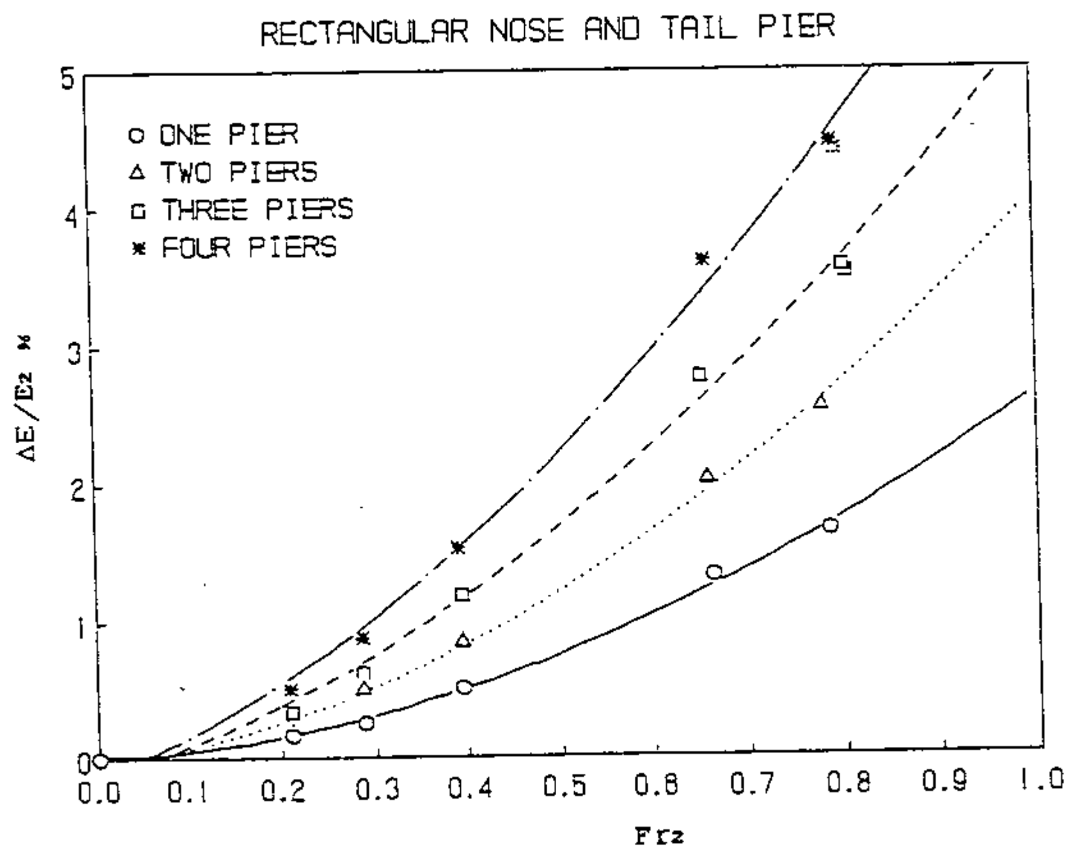


FIG. 4.18. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (2 cm).

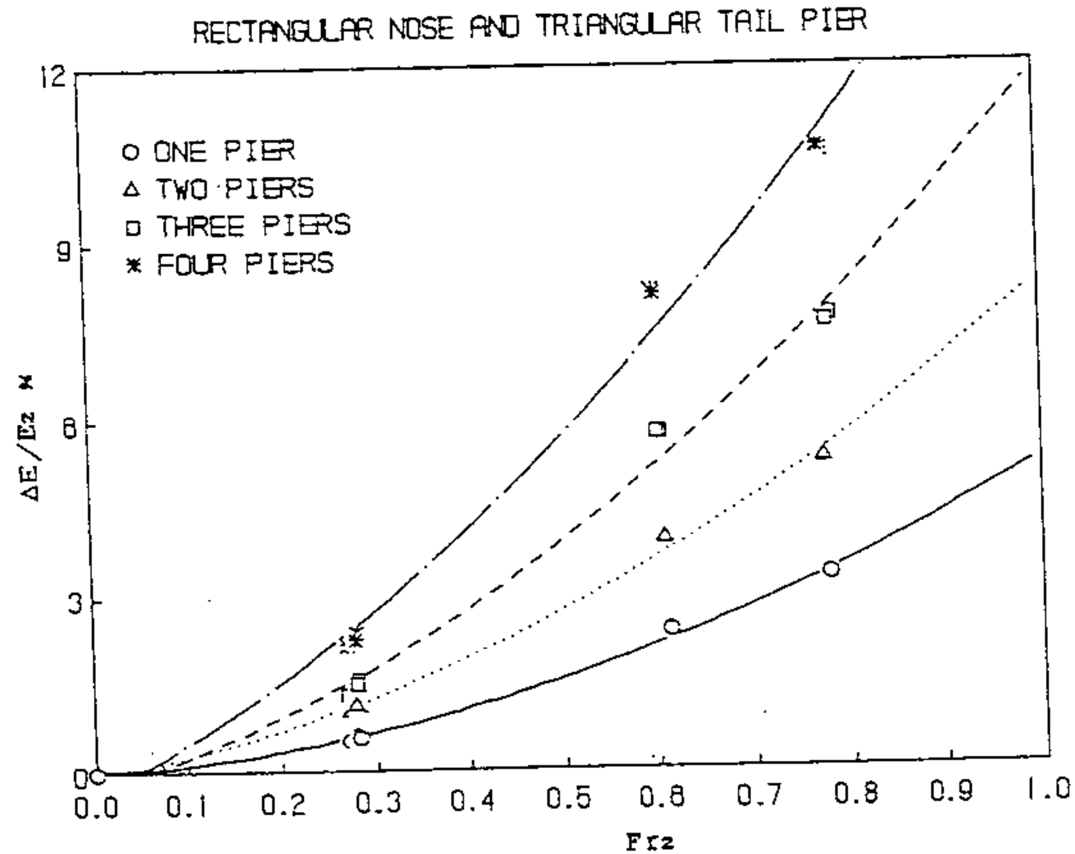


FIG. 4.19. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (4 cm).

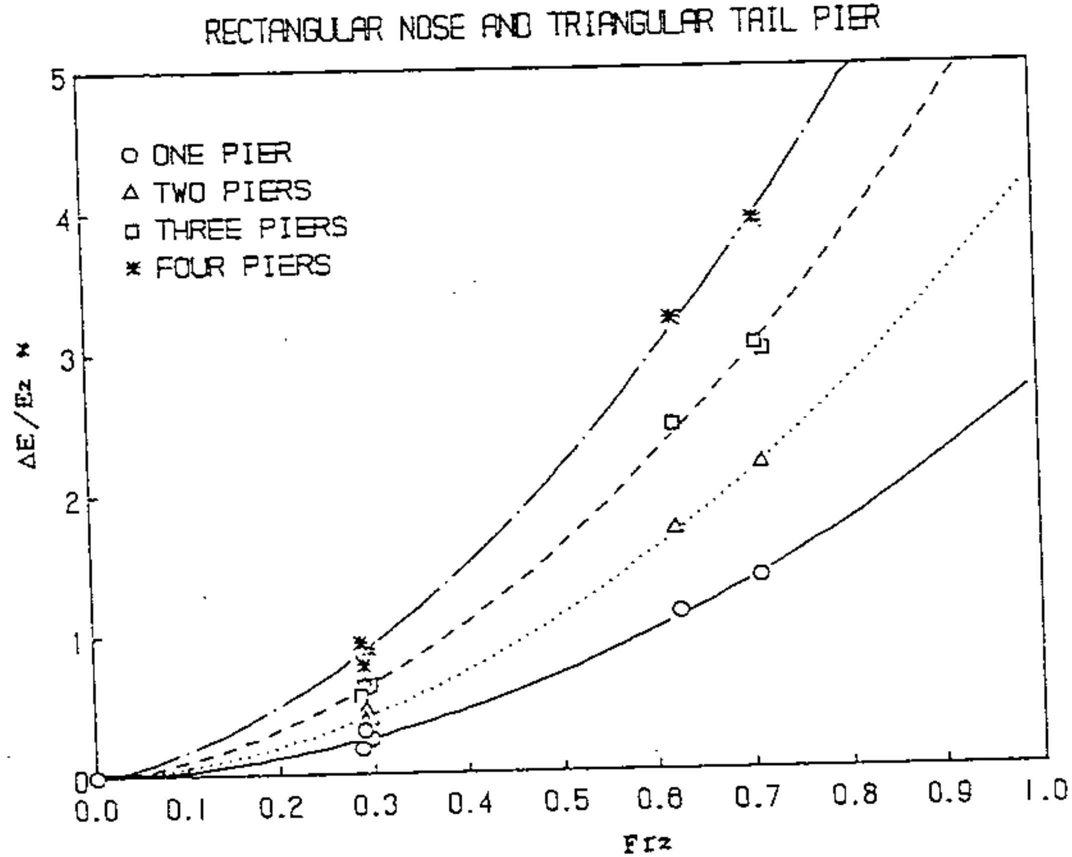


FIG. 4.20. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (2 cm).

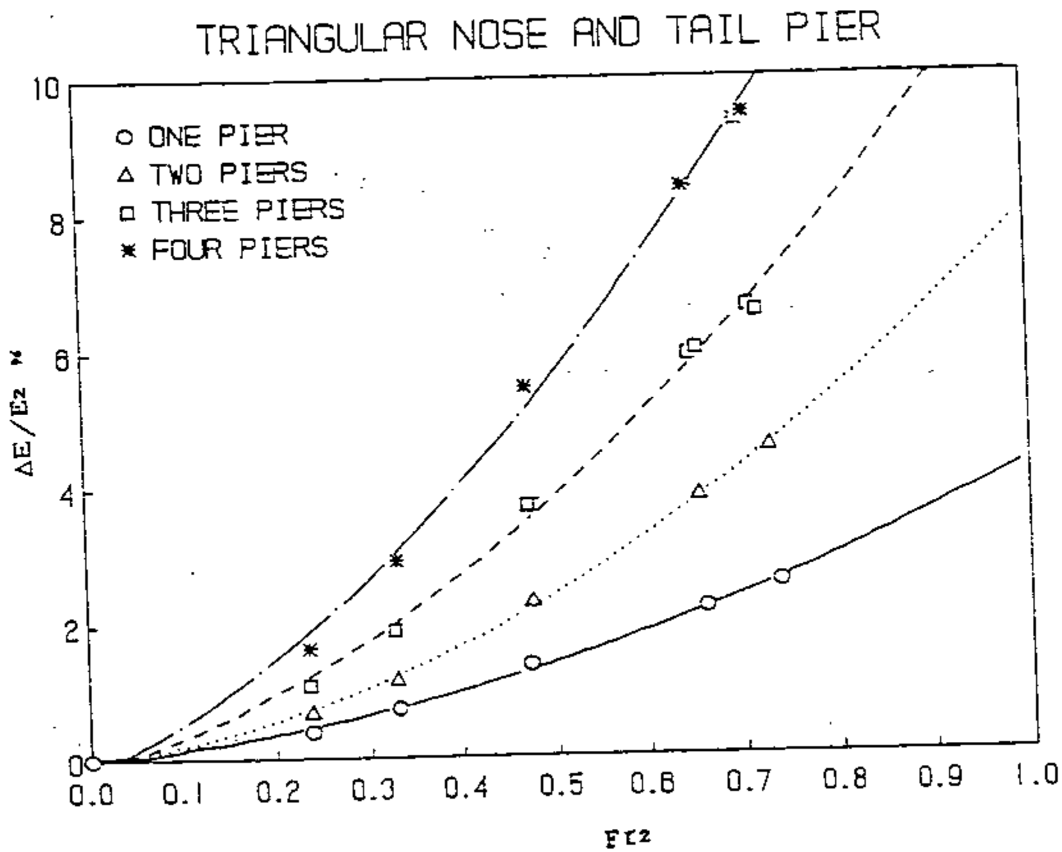


FIG. 4.21. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (4 cm).

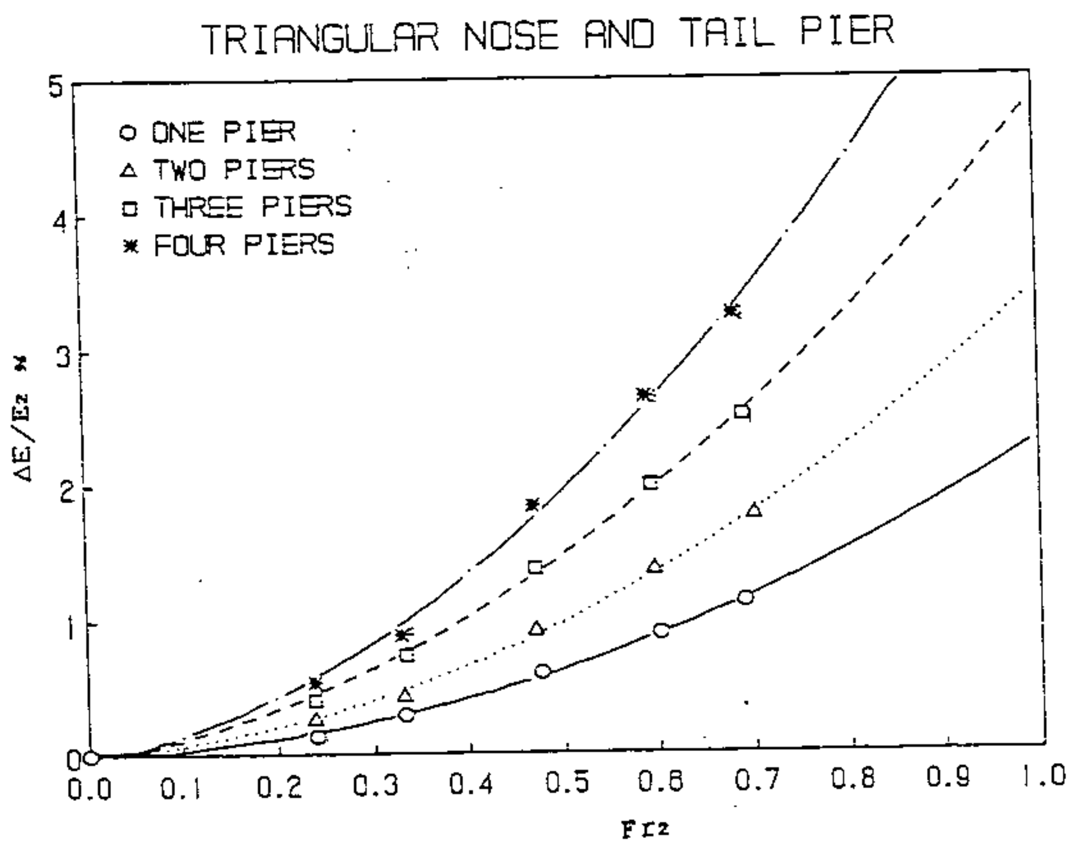


FIG. 4.22. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (2 cm).

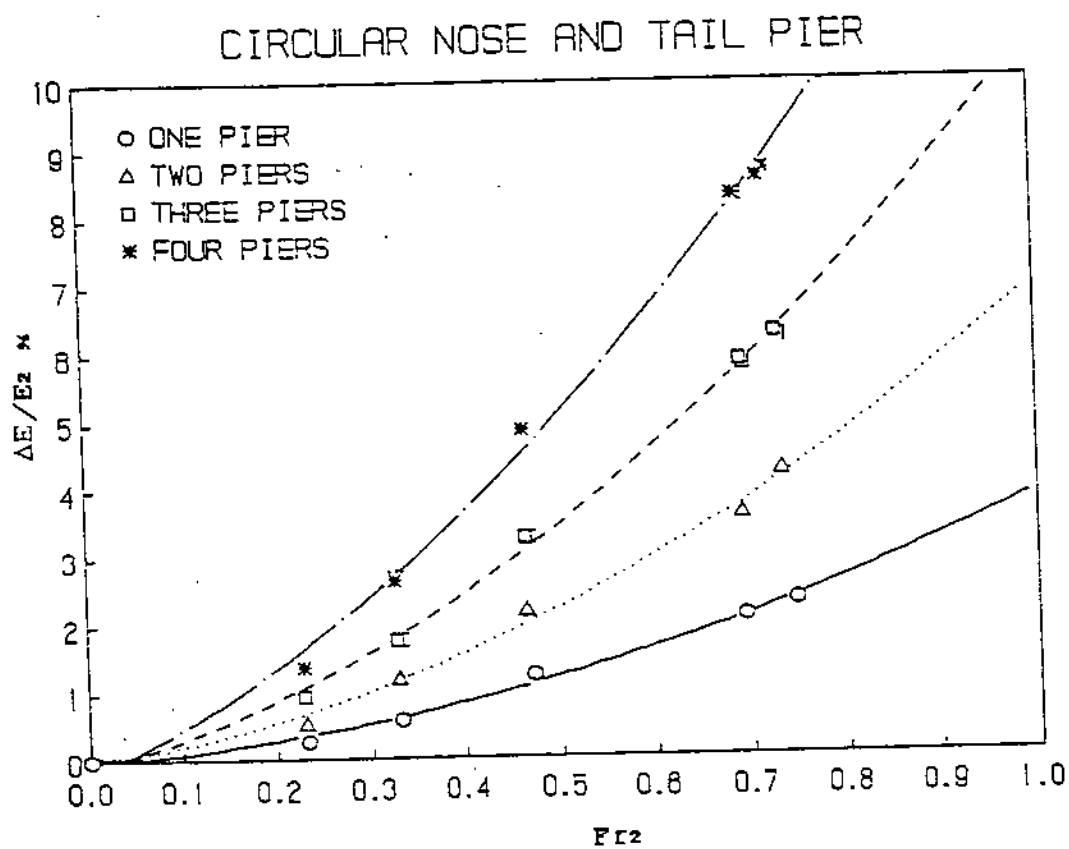


FIG. 4.23. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (4 cm).

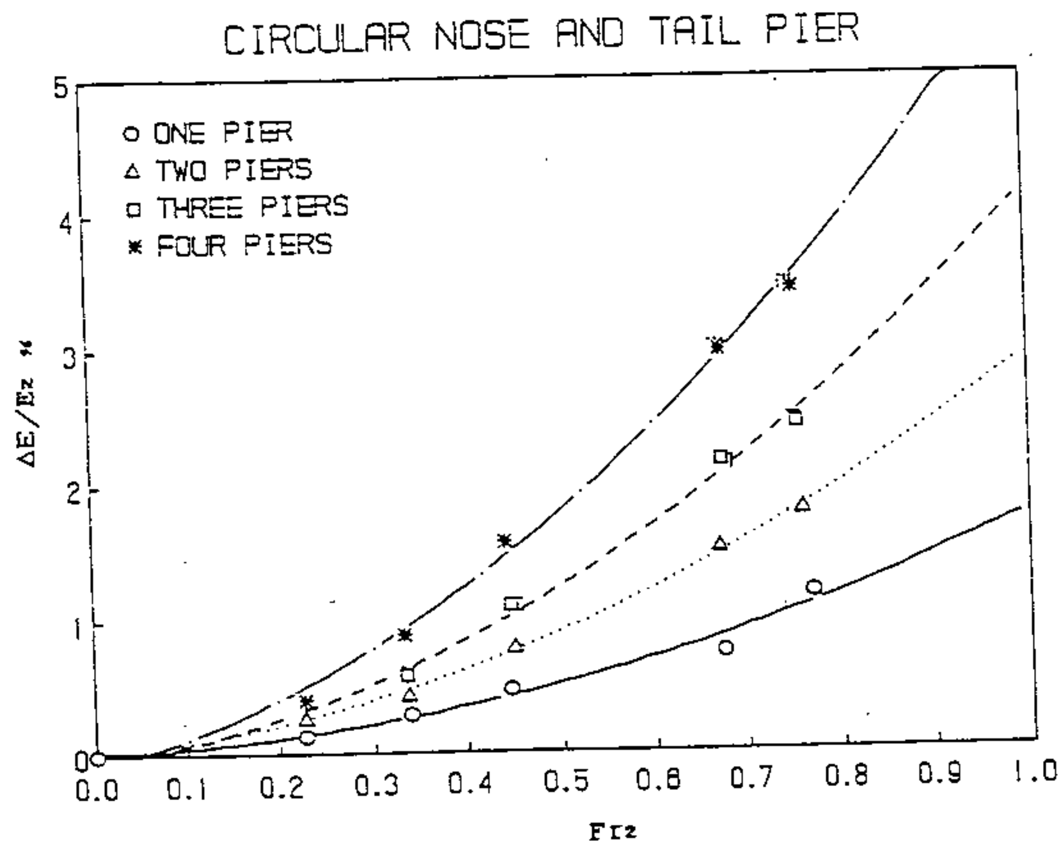


FIG. 4.24. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (2 cm).

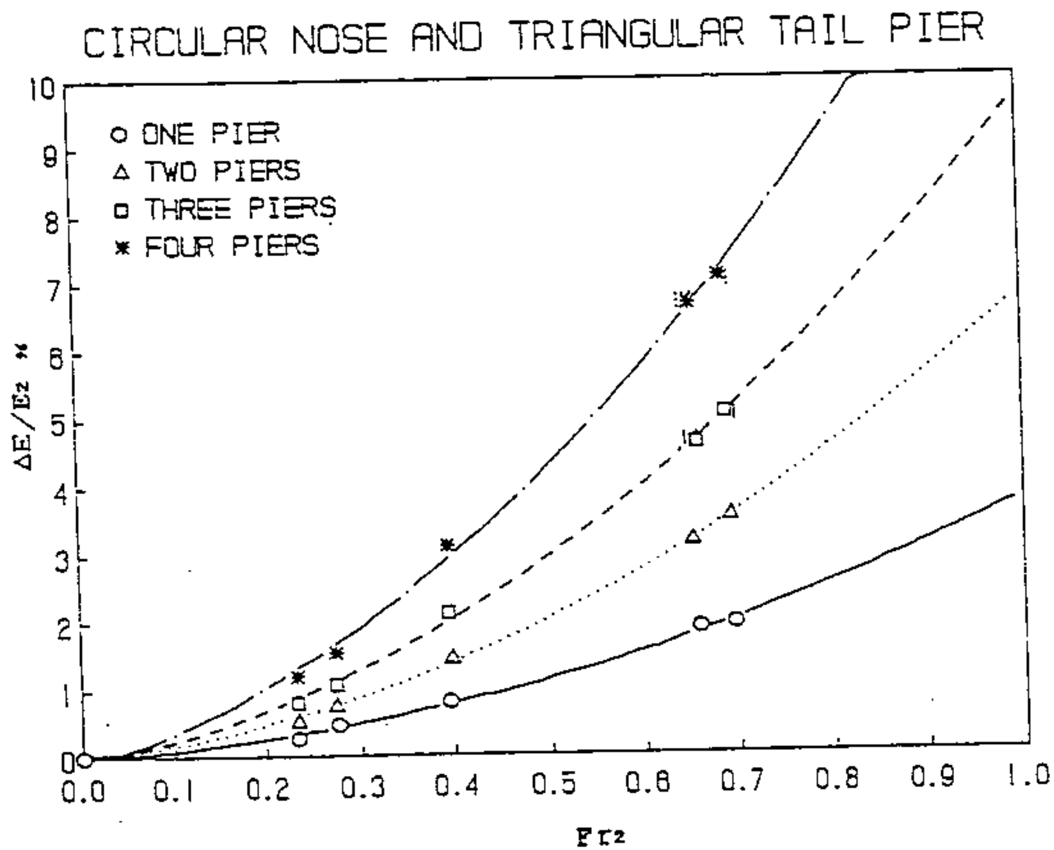


FIG. 4.25. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (4 cm).

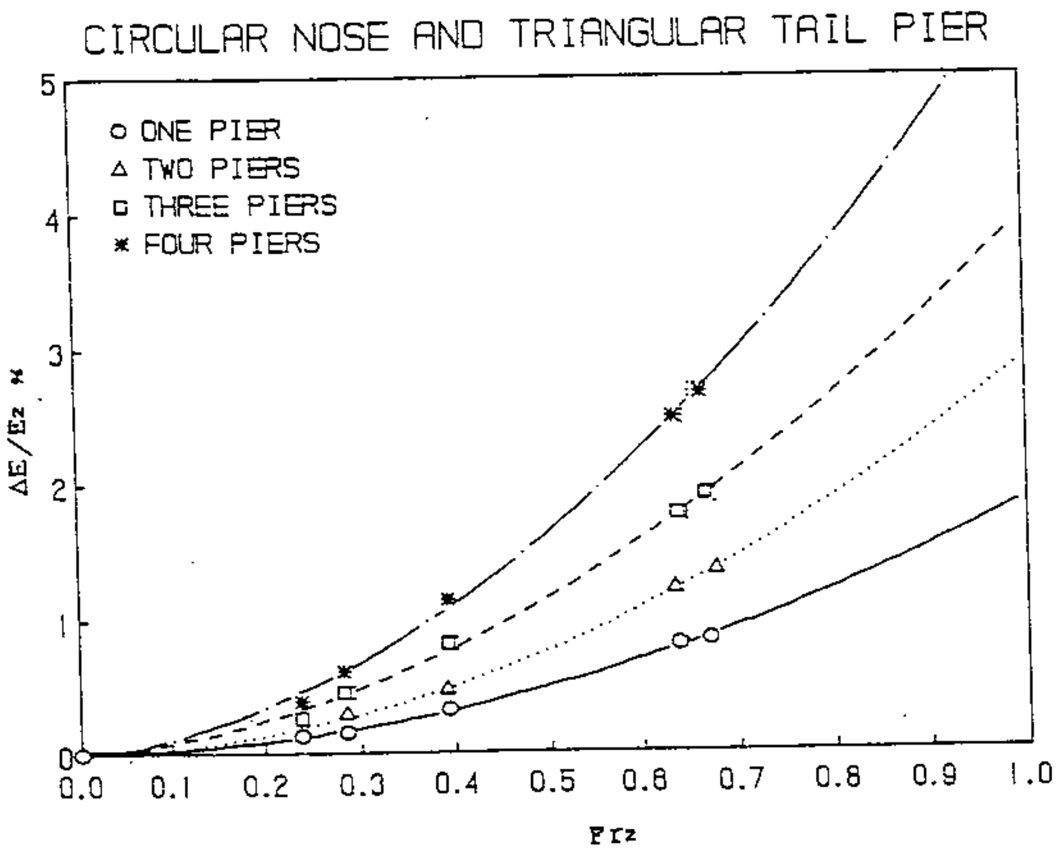


FIG. 4.26. Relationship Between Energy Loss and Downstream Froude Number for Pier Width (2 cm).

4.2.3 Energy Loss

Fig. 4.17. through 4.26. show the variation of energy loss as a function of downstream Froude number and contraction ratio for different pier shapes.

For the five pier shapes with width 4 and 2 cm, all of the curves indicate that the energy loss increases in nonlinear fashion with the downstream Froude number and is proportional inversely to the contraction ratio.

From the previous analysis, the following relationship could be deduced

$$\frac{\Delta E}{E_2} = f\ (Fr_2/\sigma) \quad \ldots\ldots\ldots\ldots\ldots(4.22)$$

The above general relationship does not reflect the shape effect, it can be introduced by assuming the functional form of the relationship to be

$$\frac{\Delta E}{E_2} = \alpha' \frac{Fr_2^{\,i}}{\sigma^{j}} \quad \ldots\ldots\ldots\ldots\ldots(4.23)$$

Using regression with dependent variables Fr_2 and σ, it was found that (i,j) were almost equal for all shapes, so equation (4.23) becomes

$$\frac{\Delta E}{E_2} = \alpha' \frac{Fr_2^{\,1.7}}{\sigma^{6.0}} \quad \ldots\ldots\ldots\ldots\ldots(4.24)$$

Where α' depends on the pier shape, values of α' are shown in the following table below :

Table 4.2. : Values of α'

Shape	α'	Correlation coefficient R^2
Rectangular nose and tail pier	2.12	0.98
Rectangular nose and triangular tail pier	2.03	0.90
Triangular nose and tail pier	1.89	0.94
Circular nose and tail pier	1.67	0.98
Circular nose and triangular tail pier	1.49	0.92

Table 4.2. shows that the values of the correlation coefficient is very high.

From fig. 4.27. through 4.31. upstream specific energy (E_{s1}) can be found, and then by substituting in the general formula :

$$E_{s1} = d_1 + \frac{1}{2g} * \left(\frac{Q}{A_1}\right)^2 \quad \text{.............}(4.25)$$

for $A_1 = B*d_1$. equation (4.25) becomes :

$$d_1^3 - E_{s1}\, d_1^2 + \frac{Q^2}{2gB^2} = 0 \quad \text{...........}(4.26)$$

Solving for d_1, we get d_1 at which the drag could be calculated.

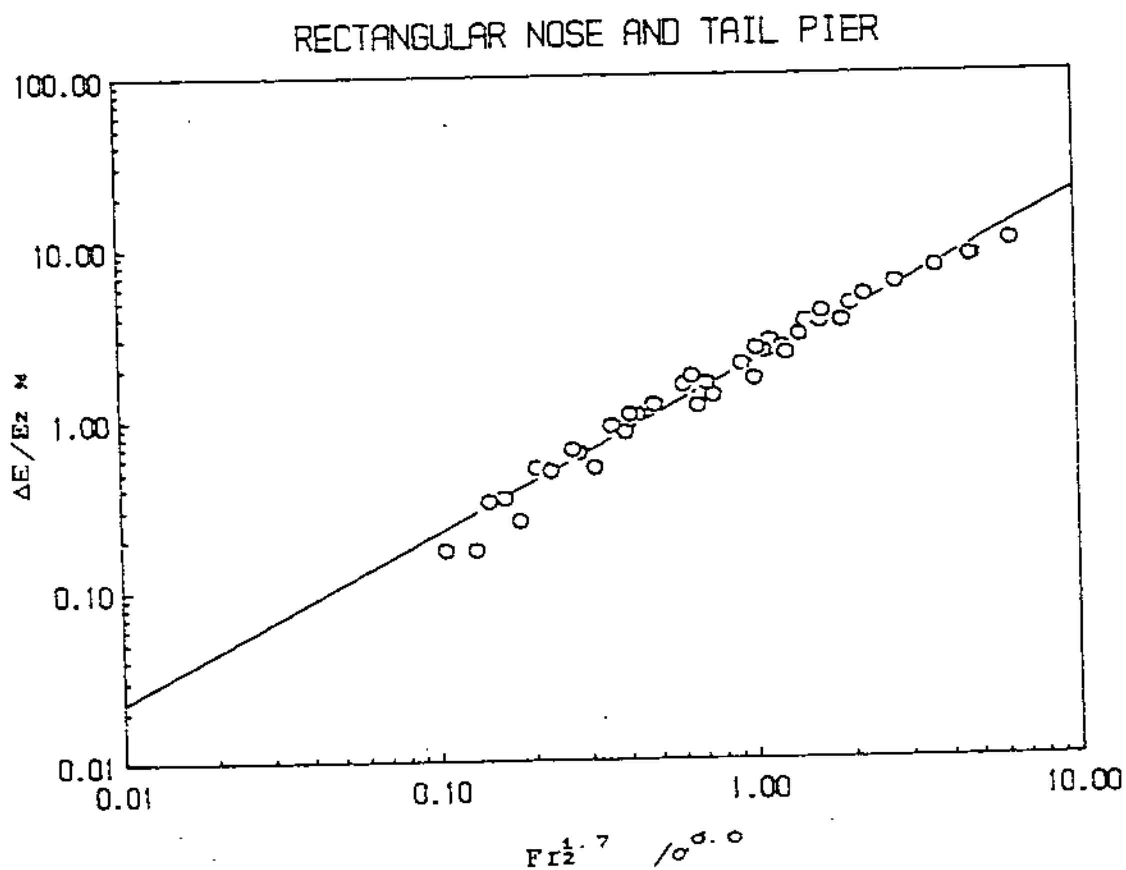


FIG. 4.27. Relationship Between Energy Loss and $Fr_{2}^{1.7}$ $/\sigma^{0.0}$

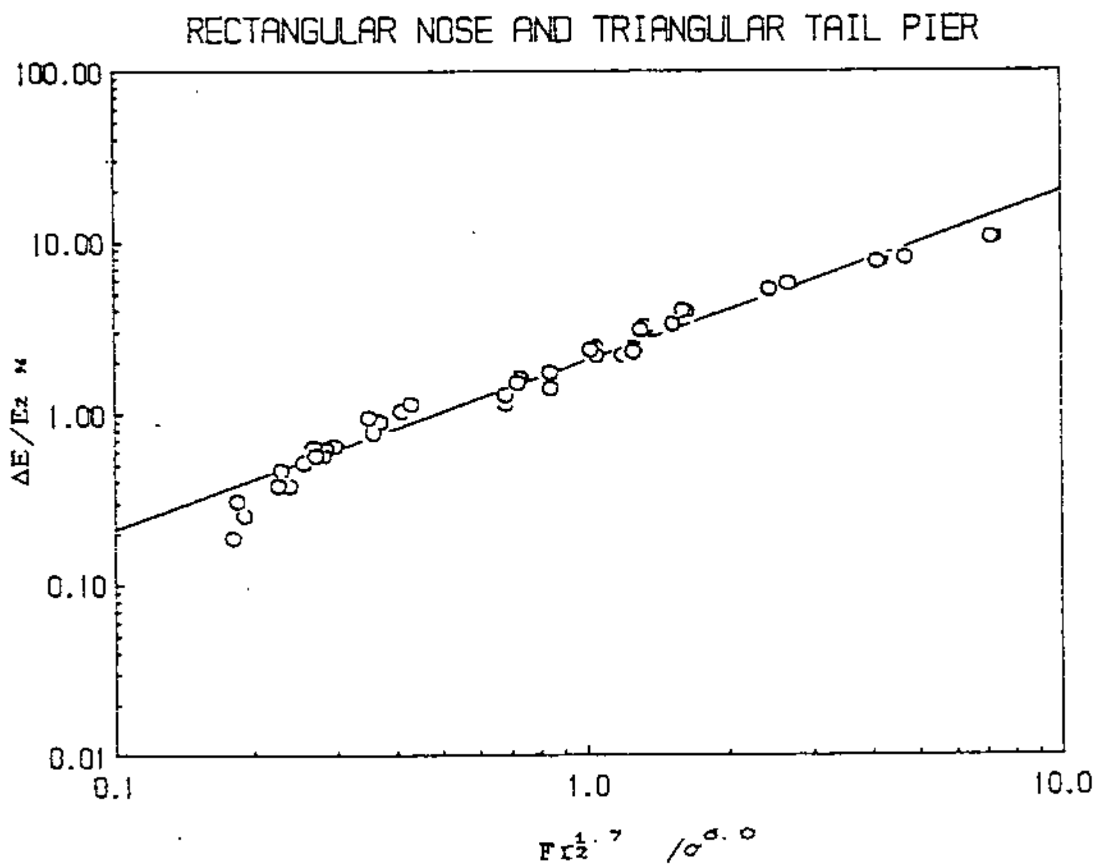


FIG. 4.28. Relationship Between Energy Loss and $Fr_2^{1.7}/\sigma^{0.0}$

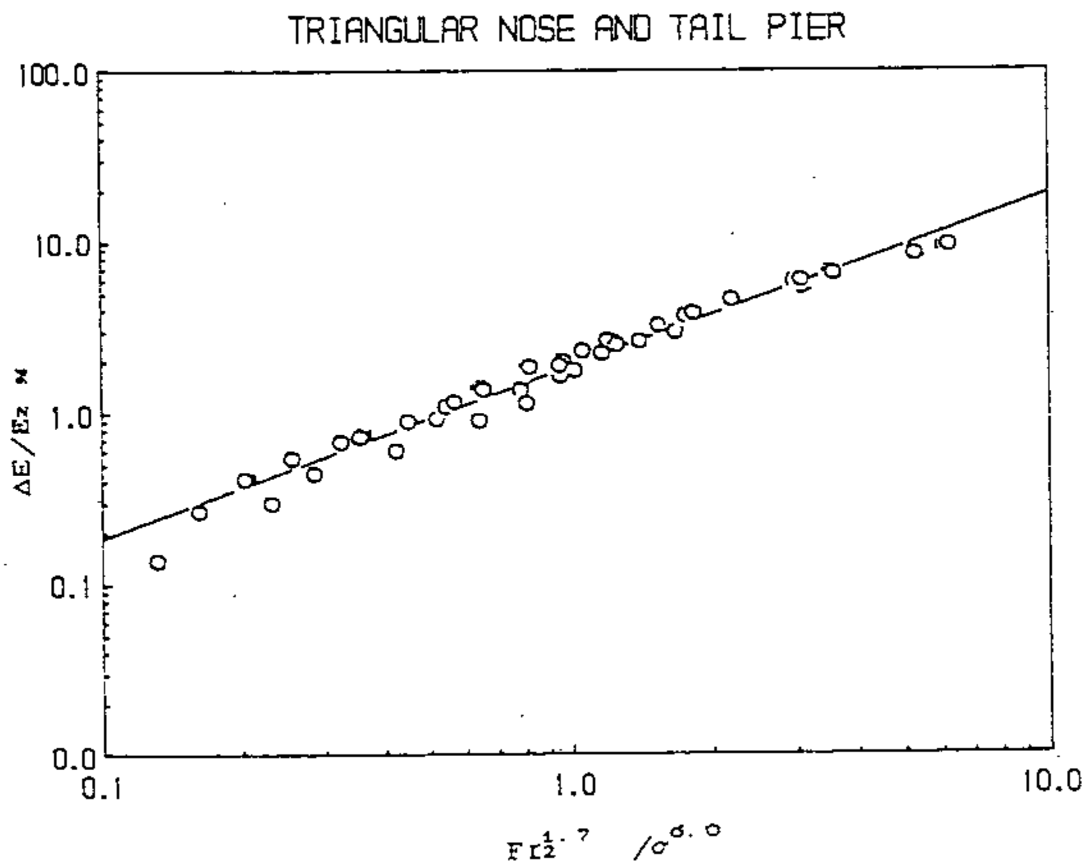


FIG. 4.29. Relationship Between Energy Loss and $Fr_2^{1.7} / \sigma^{0.0}$

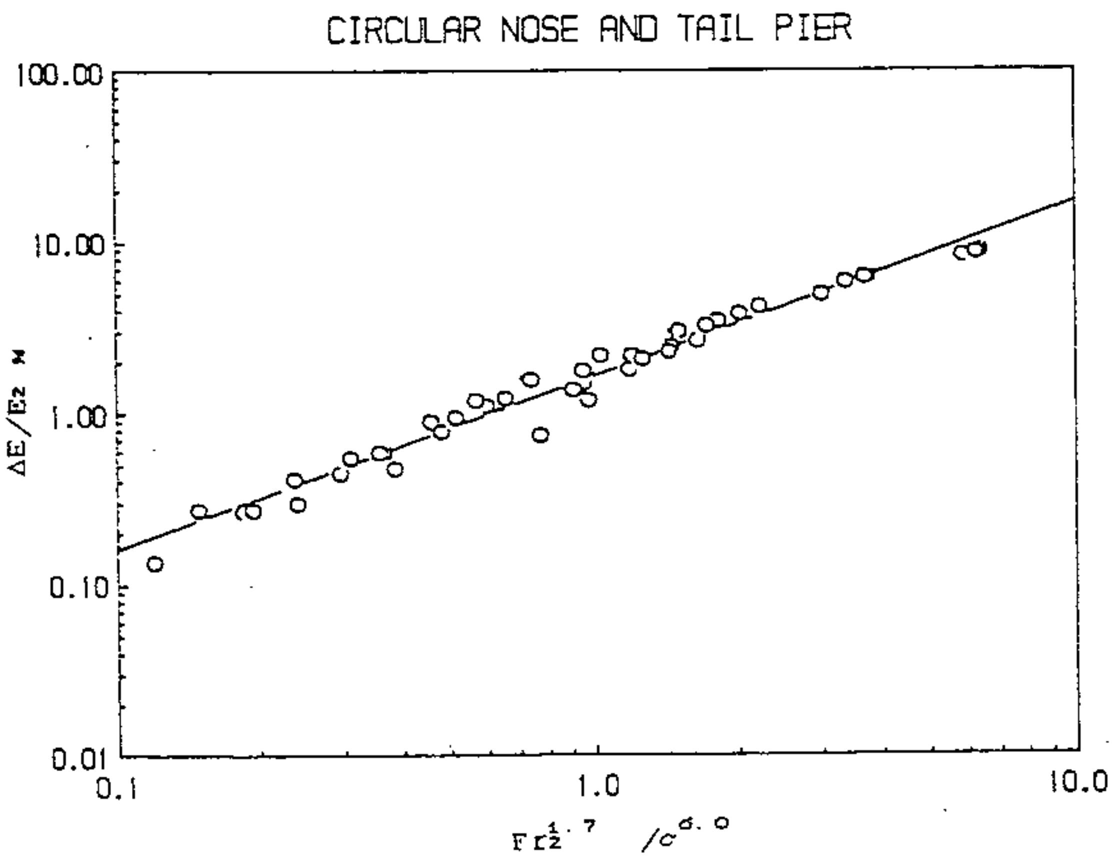


FIG. 4.30. Relationship Between Energy Loss and $Fr_2^{1.7} / \sigma^{0.0}$

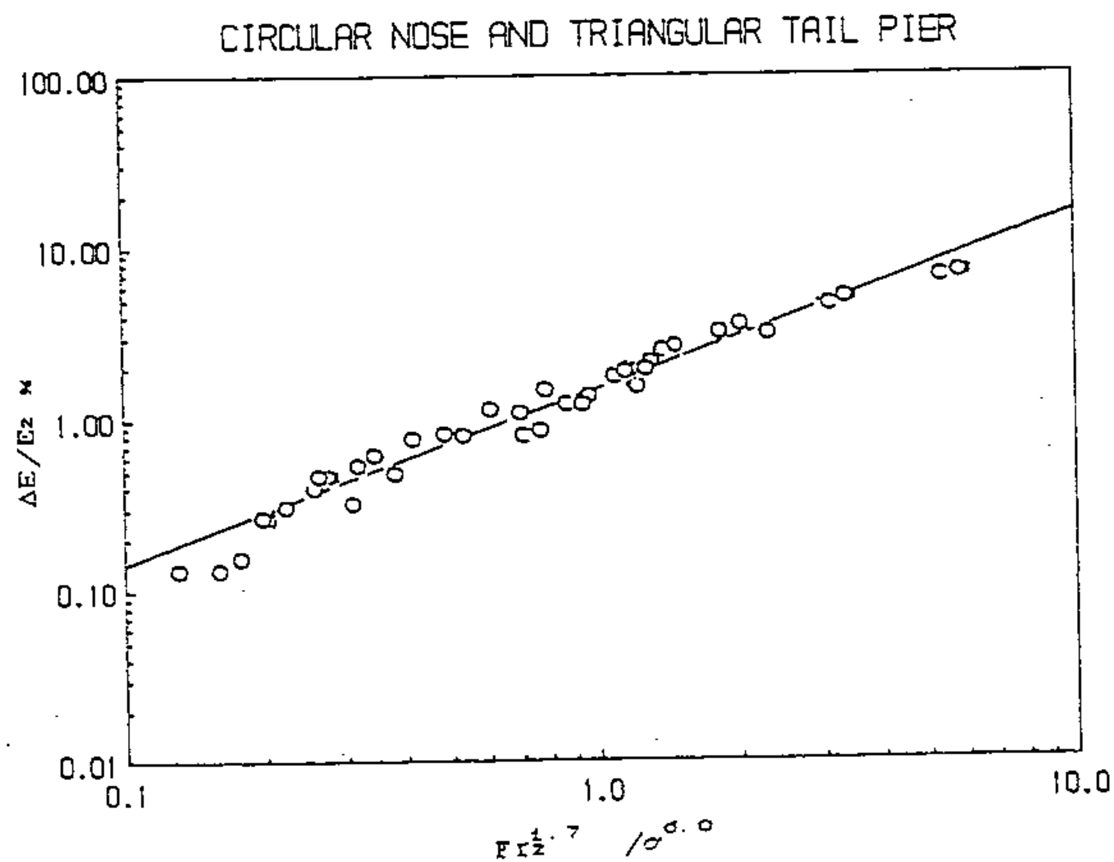


FIG. 4.31. Relationship Between Energy Loss and $Fr_2^{1.7} / \sigma^{0.0}$

CHAPTER 5

CONCLUSIONS

Analysis of the experimental data leads to the following conclusions

1) The drag coefficient was found to be independent of Re and Fr, for their range used in this research.

The drag coefficient is dependent solely on the contraction ratio for the range of Re and Fr used in this research. Five functional relationships were developed relating CD with σ. Those relationships are :

a) For rectangular nose and tail pier

$$CD = 1.25*((\sigma-60)/40)^2-2.54*((\sigma-60)/40)+2.41$$

b) For rectangular nose and triangular tail pier

$$CD = 1.08*((\sigma-60)/40)^2-2.34*((\sigma-60)/40)+2.32$$

c) For triangular nose and tail pier

$$CD = 1.21*((\sigma-60)/40)^2-2.62*((\sigma-60)/40)+2.26$$

d) For circular nose and tail pier

$$CD = 0.90*((\sigma-60)/40)^2-2.22*((\sigma-60)/40)+2.03$$

e) For circular nose and triangular tail pier

$$CD = 0.39*((\sigma-60)/40)^2-1.40*((\sigma-60)/40)+1.61$$

For the five shapes considered, the drag coefficient decreases respectively as the contraction ratio increases.

The highest drag coefficient at the same contraction ratio is for rectangular nose and tail pier, followed by rectangular nose and triangular tail pier, triangular nose and tail pier, circular nose and tail pier, and circular nose and triangular tail pier.

2) The energy lost due to the presence of piers in open channel flow is dependent on the downstream Froude number and the contraction ratio for each pier shape. The relationship between the above parameters is given by

$$\frac{\Delta E}{E_2} = \alpha' \frac{Fr^{1.7}}{\sigma^{6.0}}$$

Where α' is a shape factor and is equal to (2.12) for rectangular nose and tail pier, (2.03) for rectangular nose and triangular tail pier, and (1.89) for triangular nose and tail pier, (1.67) for circular nose and tail pier , and (1.49) for circular nose and triangular tail pier.

Among the five shapes of piers considered, it was found that the maximum energy loss occurs for rectangular nose and tail pier, followed by rectangular nose and triangular tail pier,triangular nose and tail pier, circular nose and tail pier, and circular nose and triangular tail pier..

The regression formulas derived above are useful to find the total specific energy upstream.

3) The upstream and downstream depths 'for estimating the drag force', can be determined by the following procedure:

a) Find the uniform downstream depth after installing the pier(s), from any open channel flow formula like Chezy or Manning.

b) Compute downstream Froude's number.

c) Use the relevant figures for 4.27. to 4.31., to find E_{s1} or use the formula of $\Delta E/E_2$

d) Using the general specific energy equation

$$E_{s1} = d_1 + \frac{1}{2g}\left(\frac{Q}{A}\right)^2$$

Which could be put in the following form for rectangular channels.

$$d_1^3 - E_{s1}\, d_1^2 + \frac{Q^2}{2gB^2} = 0$$

Where d_1 is the positive root of the above equation. Thus the depth at which the drag force is computed could be found easily.

e) Using the following equation, the drag force can be found

$$FD = F_1 - F_2$$

Or

$$FD = \left(Q\,\rho\, V_1 + 1/2\, \rho g\, d_1^2 \right) - \left(Q\,\rho\, V_2 + 1/2\, \rho\, g\, d_2^2 \right)$$

f) Using the following equation, drag coefficient could be found

$$CD = \frac{FD}{1/2\, \rho\, V_1^2 A_p}$$

Where A_p is the projected area at d_1 and V_1 is the velocity at d_1.

4) The results are only applicable to the nose and tail shapes used in this research.

5) Further studies are needed to check the effect of roughness on the drag force.

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11) AL-Nassri,Sabah A.,and McBean ,Edward A. , "Bridge Pier Shape and Contraction Ratios ",Journal of Engineering and Applied Sciences,1983 ,Vol. No.2,pp.115-129,1983.

TABLE A1

Calibration data for the orifice meter

Diameter of pipe line 0.1016 m; Area of cross-section of pipe line 8.107×10^{-3} m^2;
Diameter of orifice in orifice plate = 0.0508 m; Area of cross-section of orifice = 2.027×10^{-3} m^2
Area of measuring tank = 1.53 m^2; Kinematic viscosity of water = 0.836×10^{-6} m^2/s
Temperature of water = 28 °C

		1	2	3	4	5	6	7	8
Discharge Measurement	Initial level (cm)	20	31	42	24	38	52	35	23
	Final level (cm)	30	41	51.6	36.5	50.5	60	47.5	36.8
	Time in secs (cm)	90.2	90.2	90.15	90.2	90.2	60.5	90	89.8
	Volume (m3)	0.153	0.153	0.147	0.191	0.191	0.123	0.191	0.211
	Q (L / S)	1.7	1. 7	1.63	2.12	2.12	2.02	2.13	2.35
Manometer Reading	Left limb reading H1 (cm)	52.9	52.9	52.9	53.1	53.1	53.1	53.2	53.2
	Right limb reading H2 (cm)	52.3	52.3	52.3	52.1	52.1	52.1	52.0	52.0
	Difference of head of fluid in orifice meter $H = (H_1 - H_2) (\frac{Sm}{S} - 1) \times 9.81$ (Pa)	0.74	0.74	0.74	1.23	1.23	1.23	1.48	1.48

9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
39	9	29	48	8	32	39	15	34	51	35	26	45	8	10	30	30
52.4	25	46.5	59.3	25	46.5	55.2	32	49.8	61	52	43	59.5	27.2	29	49.3	49.2
90.15	90.36	90	60.2	90	60	60.15	60	60	38.3	60	59.35	52	60.2	60.3	60	59.85
.205	.260	.258	.173	.260	.222	.248	.245	.242	.153	.260	0.25	. 222	.294	.291	.296	.294
2.28	2.88	2.98	2.87	2.89	3.70	4.12	4.08	4.03	4.0	4.34	4.35	4.3	4.38	4.82	4.93	4.91
53.2	53.6	53.6	53.5	53.6	54.2	54.5	54.6	54.5	54.5	55	55	55	55.6	55.6	55.6	55.6
52.0	51.5	51.6	51.6	51.5	51.0	50 .0	50.6	50.6	50.6	50.2	50.2	50.2	49.5	49.5	49.6	49.6
1.48	2.46	2.46	2.46	2.46	3.94	4.92	4.92	4.92	4.92	5.91	5.91	5.91	7.39	7.39	7.39	7.39

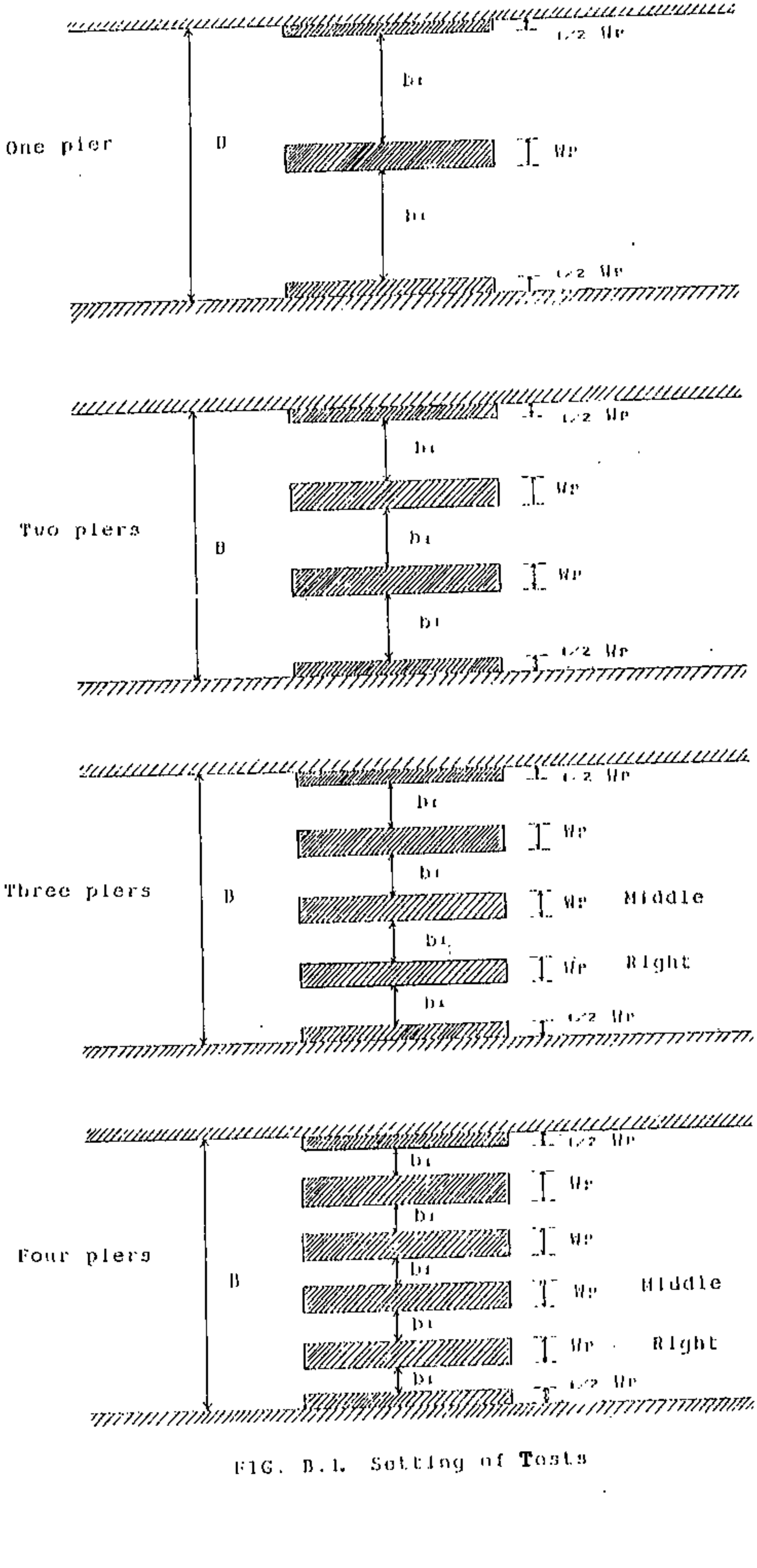

FIG. B.1. Setting of Tests

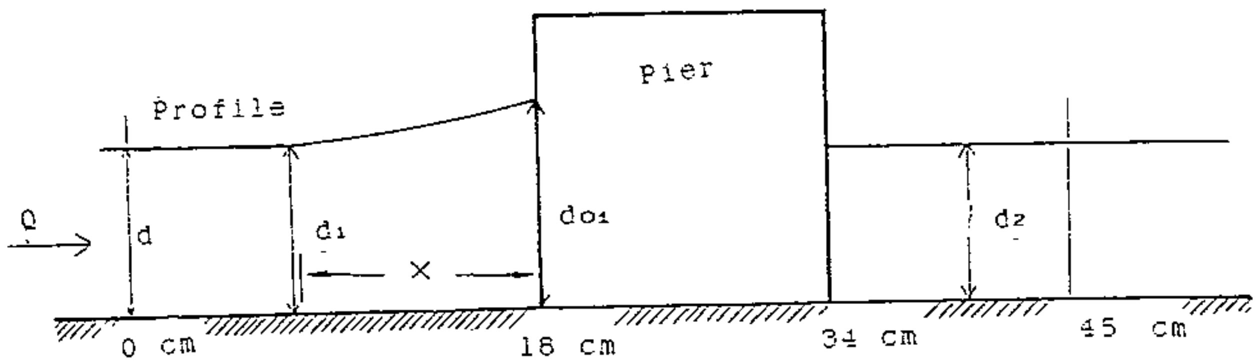

FIG. B.2. Definition Sketch of Pier Located in Open Channel

Shape : Rectangular nose and tail pier

Number of pier(s) : One Width of pier : 4 cm

Drag: (K)	8.99		12.59		7.23		3.04		8.41	
Station (cm)	mean* depth (cm)	profile (cm)	mean* depth (cm)	profile (cm)	mean* depth (cm)	profile (cm)	mean* depth (cm)	profile (cm)	mean* depth (cm)	profile (cm)
0	2.68	2.74	3.77	3.80	4.82	4.84	5.75	5.76	6.85	6.84
2	2.69	2.72	3.74	3.76	4.80	4.86	5.76	5.78	6.85	6.86
4	2.71	2.76	3.75	3.79	4.83	4.85	5.76	5.74	6.86	6.83
6	2.68	2.78	3.76	3.81	4.81	4.83	5.79	5.78	6.84	6.85
8	2.73	2.77	3.78	3.84	4.79	4.86	5.81	5.80	6.85	6.87
10	2.72	2.80	3.77	3.86	4.78	4.90	5.80	5.84	6.85	6.90
11	2.75	2.84	3.79	3.90	4.82	4.91	5.78	5.88	6.86	6.97
12	2.72	2.86	3.77	3.94	4.83	4.93	5.77	5.90	6.87	6.95
13	2.74	2.90	3.75	3.97	4.78	4.96	5.77	5.94	6.85	6.96
14	2.71	2.92	3.77	4.02	4.83	5.07	5.78	5.95	6.84	6.99
15	2.68	2.98	3.75	4.12	4.82	5.12	5.80	6.04	6.83	7.05
16	2.70	3.08	3.73	4.18	4.81	5.14	5.81	6.09	6.85	7.14
17	2.72	3.12	3.74	4.21	4.83	5.16	5.79	6.11	6.84	7.24
18	2.73	3.19	3.76	4.32	4.82	5.21	5.80	6.14	6.86	7.38
34	2.71	2.51	3.77	3.48	4.80	4.61	5.79	5.58	6.87	6.68
35	2.70	2.55	3.76	3.54	4.78	4.64	5.78	5.63	6.82	6.72
36	2.74	2.60	3.78	3.62	4.79	4.68	5.77	5.68	6.83	6.74
37	2.72	2.63	3.77	3.69	4.82	4.74	5.76	5.72	6.84	6.78
38	2.73	2.70	3.74	3.74	4.81	4.79	5.76	5.77	6.86	6.84
39	2.71	2.74	3.76	3.76	4.83	4.81	5.78	5.79	6.85	6.86
40	2.72	2.72	3.74	3.73	4.80	4.80	5.78	5.76	6.85	6.82
41	2.74	2.73	3.75	3.76	4.82	4.82	5.80	5.80	6.84	6.85
42	2.75	2.71	3.74	3.72	4.83	4.78	5.79	5.78	6.83	6.83
43	2.73	2.72	3.75	3.74	4.81	4.80	5.81	5.80	6.85	6.84
44	2.70	2.74	3.76	3.75	4.79	4.81	5.78	5.76	6.84	6.87
45	2.72	2.73	3.77	3.73	4.80	4.79	5.77	5.78	6.83	6.81

* Without obstruction

Shape : Rectangular nose and tail pier

Number of piers(n): (Two) Width of pier: 4 cm

Drag(g)	10.07	14.17	8.21	3.49	10.60
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.78	4.86	5.78	6.82
2	2.72	3.79	4.82	3.76	6.84
4	2.78	3.82	4.85	5.81	6.86
6	2.80	3.80	4.87	5.79	6.82
8	2.86	3.84	4.88	5.80	6.87
10	2.89	3.88	4.91	5.81	6.88
11	2.92	3.93	4.93	5.82	6.90
12	2.96	3.99	4.96	5.83	6.92
13	3.01	4.03	4.97	5.88	6.97
14	3.04	4.13	5.08	5.93	7.08
15	3.08	4.17	5.14	6.09	7.16
16	3.14	4.26	5.17	6.14	7.22
17	3.18	4.33	5.22	6.18	7.32
18	3.28	4.43	5.29	6.23	7.42
34	2.55	3.51	4.60	5.51	6.61
35	2.54	3.56	4.67	5.58	6.69
36	2.58	3.54	4.69	5.61	6.76
37	2.64	3.67	4.73	5.69	6.81
38	2.72	3.78	4.80	5.74	6.84
39	2.74	3.74	4.82	5.78	6.85
40	2.70	3.77	4.84	5.80	6.83
41	2.73	3.75	4.82	5.84	6.85
42	2.71	3.76	4.78	5.79	6.86
43	2.72	3.77	4.84	5.81	6.88
44	2.74	3.77	4.84	5.79	6.86
45	2.70	3.75	4.78	5.84	6.84

Shape : Rectangular nose and tail pier

Number of piers(s): Three (Middle)   Width of pier: 4cm

Drag(g)	11.17	15.60	9.20	4.02	11.46
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.76	3.74	4.81	5.74	6.81
2	2.74	3.78	4.86	5.71	6.86
4.	2.75	3.76	4.83	5.73	6.83
6.	2.78	3.79	4.85	5.76	6.85
8	2.81	3.84	4.91	5.80	6.88
10	2.86	3.87	4.96	5.82	6.94
11.	2.94	3.91	4.99	5.83	6.98
12	2.99	3.99	5.04	5.86	7.04
13	3.08	4.06	5.14	5.91	7.07
14	3.12	4.12	5.16	5.98	7.12
15	3.16	4.18	5.18	6.08	7.16
16	3.21	4.26	5.26	6.14	7.19
17	3.29	4.32	5.29	6.19	7.28
18	3.39	4.48	5.35	6.28	7.46
34	2.48	3.54	4.58	5.54	6.61
35	2.54	3.58	4.63	5.52	6.66
36	2.59	3.64	4.67	5.56	6.71
37	2.68	3.68	4.74	5.64	6.73
38	2.71	3.74	4.78	5.74	6.79
39	2.73	3.76	4.80	5.76	6.86
40	2.72	3.74	4.81	5.77	6.85
41	2.74	3.75	4.82	5.75	6.86
42	2.70	3.77	4.83	5.76	6.86
43	2.72	3.73	4.84	5.77	6.85
44	2.74	3.77	4.82	5.75	6.84
45	2.70	3.75	4.84	5.74	6.86

Shape : Rectangular nose and tail pier

Number of piers(s): Three (right)   Width of pier: 4cm

Drag(g)	11.23	15.72	9.16	3.98	11.44
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.76	4.84	5.79	6.84
2	2.75	3.74	4.82	5.78	6.83
4	2.77	3.75	4.85	5.76	6.85
6	2.85	3.78	4.87	5.79	6.87
8	2.84	3.83	4.90	5.81	6.89
10	2.91	3.85	4.94	5.83	6.93
11	2.97	3.93	4.96	5.85	6.99
12	3.04	4.01	5.02	5.87	7.04
13	3.11	4.08	5.03	5.93	7.09
14	3.17	4.13	5.16	5.97	7.14
15	3.22	4.17	5.19	6.10	7.17
16	3.28	4.25	5.25	6.16	7.21
17	3.35	4.29	5.31	6.21	7.26
18	3.44	4.42	5.39	6.32	7.42
34	2.44	3.58	4.51	5.56	6.64
35	2.49	3.61	4.58	5.55	6.68
36	2.57	3.64	4.65	5.61	6.74
37	2.64	3.67	4.68	5.66	6.79
38	2.70	3.72	4.74	5.73	6.85
39	2.74	3.74	4.76	5.78	6.87
40	2.72	3.75	4.80	5.77	6.86
41	2.74	3.76	4.84	5.81	6.87
42	2.73	3.73	4.83	5.77	6.88
43	2.71	3.75	4.81	5.80	6.84
44	2.73	3.76	4.82	5.76	6.86
45	2.71	3.74	4.84	5.78	6.88

Shape : Rectangular nose and tail pier
Number of piers(s): Four (Middle)   Width of pier: 4 cm

Drag(g)	12.87	18.59	11.27	5.03	13.94
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.76	4.84	5.74	6.83
2	2.78	3.74	4.86	5.78	6.86
4	2.76	3.79	4.83	5.75	6.85
6	2.84	3.82	4.85	5.74	6.87
8	2.89	3.89	4.87	5.79	6.91
10	2.94	3.96	4.93	5.84	6.93
11	2.97	4.07	4.97	5.86	6.97
12	3.06	4.13	5.03	5.87	7.04
13	3.12	4.21	5.12	5.93	7.09
14	3.24	4.29	5.18	5.96	7.14
15	3.29	4.31	5.24	6.05	7.19
16	3.33	4.37	5.28	6.16	7.27
17	3.38	4.44	5.36	6.22	7.34
18	3.48	4.54	5.47	6.36	7.54
34	2.46	3.59	4.63	5.56	6.64
35	2.52	3.61	4.65	5.58	6.68
36	2.58	3.66	4.66	5.66	6.74
37	2.68	3.69	4.68	5.69	6.75
38	2.72	3.74	4.76	5.74	6.82
39	2.74	3.75	4.82	5.76	6.86
40	2.76	3.78	4.83	5.82	6.85
41	2.75	3.77	4.84	5.80	6.84
42	2.73	3.76	4.83	5.84	6.88
43	2.76	3.80	4.85	5.81	6.86
44	2.75	3.78	4.79	5.82	6.85
45	2.74	3.82	4.83	5.84	6.87

Shape : Rectangular nose and tail pier
Number of piers(s): Four (right) Width of pier: 4 cm

Drag(g)	12.96	18.58	11.12	4.98	14.09
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.76	3.74	4.79	5.76	6.86
2	2.75	3.75	4.82	5.75	6.84
4	2.77	3.78	4.86	5.78	6.85
6	2.82	3.83	4.84	5.81	6.88
8	2.87	3.88	4.89	5.83	6.93
10	2.93	3.98	4.92	5.85	6.95
11	2.99	4.05	4.98	5.89	6.99
12	3.05	4.11	5.06	5.92	7.01
13	3.14	4.22	5.14	5.96	7.05
14	3.26	4.32	5.17	6.03	7.11
15	3.31	4.38	5.27	6.09	7.18
16	3.34	4.48	5.32	6.16	7.28
17	3.40	4.56	5.38	6.26	7.38
18	3.51	4.61	5.51	6.41	7.51
34	2.51	3.55	4.62	5.53	6.61
35	2.56	3.58	4.67	5.57	6.66
36	2.61	3.64	4.69	5.62	6.72
37	2.68	3.70	4.72	5.71	6.74
38	2.74	3.75	4.79	5.76	6.84
39	2.72	3.74	4.81	5.79	6.84
40	2.75	3.77	4.83	5.82	6.85
41	2.76	3.78	4.84	5.84	6.86
42	2.73	3.76	4.87	5.83	6.88
43	2.75	3.74	4.83	5.81	6.87
44	2.76	3.80	4.85	5.84	6.85
45	2.74	3.77	4.86	5.83	6.86

Shape : Rectangular nose and tail pier

Number of pier(s) : One   Width of pier : 2cm

Drage(g)	4.56		6.33		3.70		1.55		4.57	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.58	2.56	3.60	3.58	4.63	4.61	5.48	5.50	6.98	6.96
2	2.56	2.58	3.58	3.62	4.65	4.63	5.50	5.53	6.99	6.99
4	2.59	2.61	3.61	3.64	4.64	4.62	5.56	5.52	7.01	6.98
6	2.60	2.63	3.62	3.63	4.67	4.66	5.52	5.54	6.99	6.01
8	2.58	2.62	3.64	3.61	4.66	4.65	5.54	5.52	7.00	7.00
10	2.61	2.65	3.62	3.64	4.64	4.67	5.53	5.51	7.00	6.97
11	2.59	2.67	3.61	3.63	4.65	4.68	5.52	5.54	6.99	7.00
12	2.56	2.66	3.59	3.65	4.67	4.72	5.55	5.51	7.03	7.01
13	2.57	2.69	3.64	3.67	4.66	4.73	5.53	5.52	7.02	6.99
14	2.58	2.71	3.62	3.70	4.64	4.75	5.49	5.53	7.01	7.03
15	2.55	2.74	3.63	3.75	4.63	4.74	5.55	5.56	7.03	7.06
16	2.56	2.78	3.62	3.77	4.65	4.78	5.52	5.57	7.00	7.08
17	2.58	2.81	3.64	3.86	4.63	4.83	5.54	5.61	7.02	7.14
18	2.60	2.86	3.62	3.99	4.65	4.94	5.56	5.64	7.00	7.19
34	2.61	2.56	3.61	3.61	4.63	4.63	5.55	5.49	6.99	6.98
35	2.60	2.59	3.62	3.60	4.66	4.65	5.53	5.51	7.00	6.96
36	2.59	2.57	3.60	3.58	4.64	4.61	5.57	5.52	6.98	6.99
37	2.58	2.58	3.58	3.62	4.65	4.63	5.49	5.50	7.00	6.97
38	2.57	2.60	3.61	3.60	4.63	4.62	5.50	5.52	7.01	6.99
39	2.59	2.62	3.62	3.58	4.64	4.64	5.52	5.51	7.02	7.01
40	2.60	2.58	3.60	3.62	4.65	4.63	5.56	5.53	7.02	7.00
41	2.56	2.61	3.59	3.60	4.63	4.66	5.52	5.50	7.03	7.02
42	2.57	2.59	3.60	3.58	4.64	4.65	5.51	5.54	7.01	7.00
43	2.58	2.61	3.61	3.60	4.66	4.64	5.54	5.51	6.99	6.98
44	2.60	2.60	3.62	3.59	4.65	4.66	5.49	5.53	7.00	7.01
45	2.61	2.59	3.60	3.59	4.63	4.65	5.52	5.54	7.00	7.00

Shape : Rectangular nose and tail pier

Number of piers(s): Two   Width of pier: 2cm

Drag(g)	4.79	6.60	4.09	1.68	4.82
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.61	3.61	4.66	5.52	6.99
2	2.63	3.60	4.64	5.51	6.97
4	2.60	3.59	4.67	5.54	6.98
6	2.62	3.62	4.65	5.55	7.01
8	2.65	3.63	4.66	5.54	6.99
10	2.64	3.65	4.69	5.53	7.02
11	2.66	3.66	4.68	5.52	7.03
12	2.69	3.64	4.70	5.54	7.01
13	2.72	3.67	4.71	5.55	7.03
14	2.73	3.70	4.75	5.56	7.05
15	2.78	3.78	4.76	5.57	7.06
16	2.80	3.85	4.79	5.58	7.09
17	2.89	3.97	4.86	5.62	7.13
18	2.94	4.11	4.96	5.64	7.18
34	2.58	3.59	4.63	5.51	6.97
35	2.61	3.62	4.65	5.50	7.00
36	2.60	3.63	4.62	5.53	7.01
37	2.62	3.61	4.63	5.51	6.98
38	2.59	3.62	4.64	5.52	7.01
39	2.61	3.61	4.63	5.53	7.02
40	2.62	3.60	4.65	5.50	7.00
41	2.63	3.63	4.66	5.51	7.03
42	2.61	3.64	4.64	5.53	7.04
43	2.62	3.61	4.63	5.54	7.00
44	2.59	3.60	4.62	5.51	7.01
45	2.61	3.62	4.65	5.54	7.04

Shape : Rectangular nose and tail pier

Number of piers(n): Three(middle)   Width of pier: 2 cm

Drag(g)	5.01	6.79	4.23	1.70	5.10
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.56	3.62	4.64	5.48	7.01
2	2.61	3.63	4.65	5.51	6.99
4	2.58	3.61	4.66	5.53	7.02
6	2.63	3.64	4.67	5.50	6.97
8	2.62	3.65	4.65	5.52	6.99
10	2.65	3.66	4.68	5.54	7.02
11	2.66	3.64	4.71	5.53	7.03
12	2.65	3.65	4.70	5.55	7.04
13	2.67	3.68	4.73	5.56	7.02
14	2.70	3.74	4.76	5.54	7.06
15	2.75	3.76	4.83	5.57	7.08
16	2.83	3.85	4.88	5.59	7.14
17	2.90	3.96	4.94	5.65	7.17
18	2.99	4.16	5.08	5.71	7.24
34	2.56	3.61	4.65	5.49	6.99
35	2.54	3.62	4.63	5.52	7.01
36	2.55	3.59	4.64	5.53	7.00
37	2.60	3.63	4.62	5.51	7.02
38	2.58	3.64	4.65	5.50	7.01
39	2.56	3.63	4.66	5.52	7.00
40	2.54	3.66	4.63	5.54	7.02
41	2.56	3.65	4.62	5.53	6.99
42	2.54	3.67	4.64	5.52	7.02
43	2.53	3.66	4.65	5.51	7.03
44	2.56	3.65	4.66	5.54	7.02
45	2.58	3.67	4.63	5.53	7.00

Shape : Rectangular nose and tail pier

Number of piers(s): Three (right) Width of pier: 2 cm

Drag (g)	4.98	6.83	4.20	1.70	5.03
Stations (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.58	3.60	4.63	5.51	6.98
2	2.60	3.62	4.66	5.53	6.99
4	2.62	3.63	4.64	5.52	6.97
6	2.63	3.61	4.66	5.54	7.00
8	2.61	3.64	4.66	5.50	7.03
10	2.63	3.65	4.68	5.52	7.02
11	2.64	3.66	4.70	5.54	7.04
12	2.66	3.68	4.72	5.53	6.99
13	2.68	3.70	4.74	5.56	7.01
14	2.72	3.74	4.73	5.57	7.03
15	2.76	3.77	4.78	5.57	7.09
16	2.85	3.86	4.85	5.58	7.16
17	2.92	3.95	4.92	5.66	7.19
18	2.98	4.19	5.06	5.94	7.27
34	2.57	3.63	4.64	5.51	7.00
35	2.56	3.65	4.65	5.53	6.99
36	2.55	3.62	4.63	5.52	6.98
37	2.57	3.64	4.62	5.53	6.99
38	2.56	3.65	4.63	5.54	7.00
39	2.55	3.66	4.64	5.53	7.01
40	2.58	3.67	4.65	5.52	7.02
41	2.56	3.64	4.66	5.50	6.99
42	2.54	3.63	4.65	5.51	6.98
43	2.56	3.65	4.63	5.52	7.01
44	2.54	3.67	4.62	5.54	7.02
45	2.53	3.66	4.66	5.53	6.98

Shape : Rectangular nose and tail pier
Number of piers(s): Four (Middle)   Width of pier: 2cm

Drag(g)	5.11	7.08	4.32	1.83	5.39
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.56	3.63	4.62	5.53	6.99
2	2.58	3.61	4.65	5.52	7.01
4	2.57	3.65	4.66	5.54	7.02
6	2.61	3.63	4.64	5.53	7.01
8	2.62	3.62	4.65	5.55	7.01
10	2.64	3.64	4.66	5.56	7.02
11	2.61	3.66	4.72	5.54	7.00
12	2.63	3.67	4.71	5.55	7.03
13	2.65	3.71	4.73	5.57	7.04
14	2.69	3.75	4.75	5.58	7.03
15	2.75	3.79	4.82	5.61	7.06
16	2.78	3.89	4.88	5.66	7.18
17	2.89	3.98	4.97	5.82	7.28
18	3.03	4.28	5.13	5.98	7.39
34	2.56	3.59	4.63	5.53	6.99
35	2.58	3.61	4.65	5.51	7.01
36	2.57	3.60	4.64	5.53	7.02
37	2.59	3.62	4.63	5.52	7.00
38	2.58	3.61	4.65	5.53	7.01
39	2.59	3.62	4.66	5.52	7.04
40	2.58	3.63	4.67	5.55	7.03
41	2.57	3.62	4.68	5.56	7.02
42	2.60	3.64	4.66	5.54	7.00
43	2.58	3.61	4.64	5.53	7.03
44	2.56	3.60	4.65	5.55	7.02
45	2.57	3.62	4.67	5.56	7.04

Shape : Rectangular nose and tail pier

Number of piers(s): Four (right)   Width of pier: 2cm

Drag(g)	5.05	7.13	4.35	1.83	5.43
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.58	3.60	4.63	5.54	7.01
2	2.56	3.62	4.65	5.53	7.00
4	2.57	3.63	4.64	5.54	7.02
6	2.59	3.62	4.63	5.55	6.99
8	2.62	3.64	4.65	5.56	7.01
10	2.61	3.65	4.66	5.55	7.02
11	2.64	3.67	4.71	5.57	7.03
12	2.65	3.69	4.73	5.57	7.03
13	2.65	3.72	4.75	5.58	7.04
14	2.71	3.76	4.79	5.60	7.06
15	2.73	3.78	4.87	5.62	7.19
16	2.77	3.92	4.96	5.65	7.26
17	2.86	3.99	5.08	5.80	7.36
18	3.01	4.26	5.16	5.96	7.42
34	2.56	3.60	4.63	5.50	7.00
35	2.55	3.62	4.64	5.51	7.01
36	2.57	3.61	4.63	5.52	7.02
37	2.58	3.63	4.65	5.53	7.00
38	2.57	3.63	4.66	5.52	7.01
39	2.58	3.64	4.68	5.53	7.02
40.	2.56	3.65	4.67	5.54	7.03
41	2.59	3.62	4.65	5.51	7.04
42	2.57	3.61	4.64	5.50	7.03
43	2.55	3.64	4.66	5.53	7.02
44	2.56	3.65	4.67	5.54	7.00
45	2.58	3.63	4.68	5.52	7.02

Shape : Rectangular nose and triangular tail pier

Number of pier(s) : One   Width of pier : 4 cm

Drac (g)	9.31		12.01		4.15		6.06		8.42	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.58	2.59	3.73	3.74	4.73	4.74	5.61	5.64	7.00	7.02
2	2.59	2.61	3.72	3.75	4.74	4.76	5.59	5.66	7.01	7.04
4	2.61	2.60	3.71	3.73	4.73	4.75	5.58	5.67	7.02	7.05
6	2.63	2.63	3.69	3.75	4.75	4.77	5.61	5.68	7.03	7.04
8	2.65	2.65	3.71	3.77	4.76	4.76	5.63	5.67	7.04	7.05
10	2.66	2.64	3.72	3.81	4.76	4.78	5.62	5.69	7.03	7.06
11	2.64	2.72	3.73	3.85	4.77	4.77	5.63	5.68	7.02	7.08
12	2.63	2.78	3.74	3.88	4.75	4.79	5.64	5.72	7.01	7.09
13	2.62	2.83	3.76	3.89	4.76	4.82	5.60	5.74	7.03	7.07
14	2.61	2.89	3.75	3.94	4.74	4.83	5.62	5.78	7.02	7.09
15	2.59	2.94	3.73	3.99	4.75	4.85	5.63	5.82	7.02	7.14
16	2.61	2.98	3.71	4.09	4.73	4.89	5.62	5.87	7.03	7.17
17	2.62	3.04	3.69	4.11	4.74	4.94	5.62	5.92	7.02	7.26
18	2.63	3.11	6.68	4.24	4.75	4.97	5.64	6.06	7.01	7.33
34	2.64	2.59	3.72	3.69	4.76	4.72	5.63	5.62	7.02	6.99
35	2.62	2.61	3.74	3.70	4.74	4.73	5.62	5.61	7.02	6.98
36	2.64	2.62	3.73	3.72	4.77	4.75	5.64	5.63	7.03	7.00
37	2.65	2.64	3.71	3.71	4.75	4.74	5.63	5.63	7.00	7.02
38	2.61	2.63	3.72	3.70	4.76	4.74	5.64	5.64	7.02	7.01
39	2.63	2.62	3.69	3.71	4.74	4.75	5.61	5.65	7.03	7.02
40	2.64	2.63	3.71	3.72	4.75	4.73	5.63	5.64	7.03	7.01
41	2.65	2.64	3.69	3.71	4.73	4.74	5.62	5.63	7.02	7.00
42	2.63	2.65	3.73	3.69	4.76	4.76	5.64	5.62	7.01	7.03
43	2.62	2.63	3.72	3.70	4.75	4.74	5.62	5.64	7.00	7.02
44	2.64	2.61	3.74	3.71	4.74	4.72	5.63	5.66	7.02	6.99
45	2.65	2.61	3.73	3.70	4.77	4.73	5.64	5.65	7.03	7.00

Shape : Rectangular nose and triangular tail pier

Number of piers(s) : Two

Width of pier: 4 cm

Drag(g)	10.30	13.45	4.96	7.05	10.15
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.64	3.67	4.77	5.64	7.04
2	2.66	3.74	4.76	5.63	7.03
4	2.65	3.77	4.75	5.65	7.05
6	2.67	3.79	4.78	5.64	7.05
8	2.68	3.81	4.78	5.66	7.06
10	2.72	3.83	4.77	5.68	7.04
11	2.74	3.84	4.79	5.72	7.05
12	2.78	3.89	4.80	5.74	7.08
13	2.85	3.94	4.82	5.77	7.10
14	2.88	3.99	4.84	5.78	7.12
15	2.96	4.04	4.86	5.81	7.14
16	3.06	4.11	4.92	5.89	7.19
17	2.16	4.18	4.96	5.98	7.31
18	3.23	4.37	5.06	6.15	7.42
34	2.61	3.70	4.74	5.60	6.99
35	2.63	3.71	4.75	5.62	7.01
36	2.64	3.74	4.76	5.61	7.00
37	2.65	3.73	4.75	5.63	7.02
38	2.64	3.72	4.76	5.62	7.00
39	2.65	3.73	4.74	5.63	7.01
40	2.63	3.71	4.75	5.64	7.00
41	2.64	3.70	4.77	5.65	7.02
42	2.66	3.72	4.78	5.63	6.68
43	2.64	3.74	4.76	5.61	7.01
44	2.62	3.73	4.75	5.62	7.01
45	2.65	3.72	4.77	5.64	7.02

Shape :Rectangular nose and tail pier

Number of piers(s): Three (Middle) Width of pier: 4 cm

Drag(g)	11.51	14.85	5.47	7.92	11.36
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.64	3.75	4.74	5.65	7.02
2	2.66	3.77	4.76	5.63	7.00
4	2.67	3.78	4.78	5.66	7.03
6	2.66	3.78	4.81	5.65	7.04
8	2.72	3.82	4.83	5.67	7.04
10	2.74	3.84	4.85	5.70	7.04
11	2.79	3.85	4.84	5.71	7.05
12	2.84	3.91	4.86	5.73	7.08
13	2.92	3.96	4.88	5.76	7.11
14	2.96	4.00	4.91	5.79	7.14
15	3.08	4.09	4.93	5.85	7.18
16	3.13	4.16	5.01	5.93	7.28
17	3.21	4.24	5.06	6.02	7.38
18	3.39	4.48	5.18	6.25	7.53
34	2.60	3.71	4.73	5.59	7.00
35	2.64	3.72	4.72	5.61	7.01
36	2.61	3.71	4.75	5.62	7.02
37	2.63	3.73	4.74	5.61	7.00
38	2.62	3.74	4.75	5.62	7.02
39	2.63	3.75	4.74	5.61	7.01
40	2.62	4.74	4.75	5.60	7.02
41	2.63	3.73	4.76	5.61	7.03
42	2.64	3.76	4.75	5.59	7.02
43	2.63	3.74	4.76	5.61	7.03
44	2.61	3.72	4.75	5.62	7.02
45	2.63	3.73	4.74	5.60	7.01

Shape : Rectangular nose and triangular tail pier

Number of piers(s) : Three (right) Width of pier : 4 cm

Drag(g)	11.52	14.89	5.49	7.86	11.34
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.66	3.74	4.76	5.63	7.00
2	2.65	3.76	4.75	5.64	7.01
4	2.66	3.79	4.77	5.65	7.00
6	2.68	3.78	4.78	5.64	7.00
8	2.70	3.84	4.82	5.66	7.02
10	2.73	3.85	4.86	5.66	7.03
11	2.77	3.89	4.86	5.67	7.01
12	2.81	3.95	4.88	5.72	7.04
13	2.89	4.02	4.91	5.76	7.09
14	2.95	4.05	4.94	5.81	7.12
15	3.08	4.12	5.02	5.88	7.15
16	3.15	4.17	5.09	5.96	7.24
17	3.24	4.28	5.14	6.03	7.33
18	3.41	4.46	5.21	6.21	7.51
34	2.60	3.70	4.73	5.58	7.00
35	2.62	3.73	4.75	5.60	7.01
36	2.64	3.72	4.74	5.61	7.00
37	2.63	3.72	4.75	5.62	7.00
38	2.63	3.73	4.74	5.63	7.01
39	2.62	3.74	4.76	5.62	7.02
40	2.61	3.73	4.75	5.61	7.03
41	2.60	3.72	4.78	5.63	7.02
42	2.63	3.74	4.77	5.64	7.01
43	2.64	3.75	4.76	5.62	7.03
44	2.62	3.73	4.75	5.60	7.02
45	2.63	3.71	4.77	5.62	7.01

Shape : Rectangular nose and triangular tail pier

Number of piers(s): Four (Middle)   Width of pier: 4 cm

Drag(g)	13.02	17.38	6.61	9.44	13.40
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.66	3.78	4.77	5.66	7.01
2	2.65	3.82	4.76	5.68	7.00
4	2.67	3.84	4.78	5.69	7.01
6	2.69	3.87	4.82	5.69	7.01
8	2.74	3.92	4.84	5.72	7.02
10	2.75	3.96	4.85	5.74	7.03
11	2.79	4.06	4.86	5.77	7.02
12	2.85	4.12	4.88	5.80	7.04
13	2.96	4.25	4.93	5.84	7.15
14	3.08	4.32	4.96	5.88	7.22
15	3.14	4.42	5.08	5.94	7.28
16	3.28	4.52	5.14	6.01	7.33
17	3.36	4.58	5.19	6.16	7.58
18	3.48	4.69	5.29	6.37	7.63
34	2.62	3.71	4.72	5.61	6.99
35	2.61	3.72	4.74	5.62	7.00
36	2.63	3.73	4.75	5.64	7.01
37	2.62	3.72	4.74	5.63	7.02
38	2.63	3.73	4.75	5.64	7.03
39	2.64	3.72	4.76	5.63	7.02
40	2.65	3.75	4.75	5.64	7.03
41	2.66	3.76	4.77	5.65	7.04
42	2.65	3.74	4.78	5.62	7.03
43	2.63	3.75	4.75	5.64	7.04
44	2.62	3.74	4.74	5.66	7.03
45	2.64	3.73	4.76	5.65	7.03

Shape : Rectangular nose and triangular tail pier

Number of piers(s): Four (right) Width of pier: 4 cm

Drag(g)	13.00	17.34	6.66	9.39	19.43
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.66	3.79	4.79	5.64	7.02
2	2.68	3.81	4.78	5.66	7.01
4	2.67	3.83	4.77	5.69	7.03
6	2.69	8.86	4.79	5.68	7.02
8	2.72	3.89	4.81	5.74	7.04
10	2.76	3.94	4.86	5.76	7.03
11	2.81	4.04	4.88	5.79	7.06
12	2.87	4.13	4.91	5.82	7.11
13	2.99	4.25	4.95	5.85	7.26
14	3.12	4.34	4.97	5.89	7.29
15	3.16	4.44	5.06	3.97	7.36
16	3.26	4.53	5.15	6.05	7.42
17	3.38	4.61	5.22	6.15	7.58
18	3.46	4.71	5.30	6.32	7.66
34	2.60	3.72	4.73	5.61	7.01
35	2.61	3.72	4.72	5.63	7.01
36	2.62	3.73	4.73	5.62	7.02
37	2.61	3.74	4.72	5.64	7.00
38	2.62	3.73	4.74	5.64	7.01
39	2.63	3.74	4.75	5.63	7.01
40	2.65	3.75	4.75	5.64	7.03
41	2.64	3.76	4.76	5.63	7.02
42	2.63	3.77	4.74	5.65	7.02
43	2.63	3.76	4.73	5.63	7.03
44	2.61	3.75	4.75	5.64	7.01
45	2.61	3.74	4.77	5.64	7.02

Shape : Rectangular nose and triangular tail pier

Number of pier(s) : One   Width of pier : 2 cm

Drag (g)	4.08		5.87		1.94		3.05		4.52	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.70	2.76	3.68	3.66	4.69	4.70	5.64	5.68	6.90	6.91
2	2.72	2.75	3.66	3.68	4.70	4.71	5.65	5.70	6.88	6.92
4	2.74	2.78	3.67	3.71	4.72	4.72	5.66	5.71	6.92	6.90
6	2.73	2.77	3.68	3.69	4.71	4.73	5.66	5.69	6.91	6.91
8	2.75	2.80	3.69	3.72	4.73	4.72	5.65	5.72	6.90	6.92
10	2.74	2.81	3.70	3.74	4.72	4.74	5.66	5.70	6.89	6.94
11	2.73	2.82	3.69	3.75	4.69	4.75	5.67	5.73	6.87	6.95
12	2.71	2.83	3.68	3.77	4.70	4.75	5.68	5.76	6.88	6.97
13	2.70	284	3.70	3.84	4.72	4.76	5.66	5.77	6.90	7.04
14	2.72	2.86	3.69	3.86	4.71	4.79	5.65	5.81	6.89	7.07
15	2.73	2.92	3.67	3.89	4.69	4.81	5.64	5.85	6.88	7.11
16	2.75	2.97	3.66	3.92	4.70	4.83	5.66	5:89	6.90	7.13
17	2.74	3.04	3.68	3.98	4.72	4.86	5.67	5.94	6.89	7.24
18	2.72	3.12	3.69	4.09	4.69	4.94	5.68	6.06	6.88	7.33
34	2.74	2.72	3.66	3.64	4.69	4.68	5.66	5.65	6.89	6.87
35	2.75	2.74	3.67	3.66	4.70	4.70	5.65	5.66	6.90	6.86
36	2.72	2.73	3.66	3.67	4.73	4.69	5.67	5.64	6.88	6.88
37	2.70	2.74	3.67	3.65	4.71	4.72	5.68	5.66	6.90	6.87
38	2.73	2.75	3.68	3.67	4.72	4.71	5.66	5.67	6.89	6.88
39	2.74	2.73	3.70	3.68	4.72	4.70	5.65	5.66	6.91	6.90
40	2.75	2.74	3.69	3.67	4.70	4.71	5.67	5.65	6.90	6.89
41	2.72	2.75	3.66	3.69	4.71	4.72	5.68	5.66	6.90	6.90
42	2.73	2.77	3.68	3.66	4.73	4.70	5.66	5.68	6.91	6.91
43	2.75	2.76	3.69	3.68	4.72	4.71	5.65	5.66	6.89	6.88
44	2.74	2.75	3.70	3.70	4.69	4.72	5.67	5.64	6.90	6.87
45	2.73	2.76	1.67	3.69	4.70	3.71	5.66	5.65	6.88	6.89

Shape : Rectangular nose and triangular tail pier

Number of piers(n): Two Width of piers: 2 cm

Drag(g)	4.11	5.95	2.12	3.11	4.60
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.75	3.72	4.68	5.70	6.90
2	2.76	3.74	4.69	5.69	6.91
4	2.74	3.75	4.70	5.71	6.92
6	2.77	3.73	4.71	5.70	6.90
8	2.78	3.75	4.72	5.72	6.92
10	2.76	3.77	4.73	5.70	6.93
11	2.80	3.81	4.75	5.72	6.95
12	2.84	3.84	4.77	5.77	6.98
13	2.86	3.87	4.76	5.79	7.06
14	2.89	3.93	4.80	5.85	7.10
15	2.96	3.97	4.84	5.88	7.14
16	3.02	4.05	4.86	5.95	7.16
17	3.08	4.11	4.92	6.07	7.24
18	3.21	4.24	4.99	6.19	7.42
34	2.72	3.66	4.68	5.64	6.87
35	2.73	3.68	4.69	5.66	6.88
36	2.72	3.68	4.70	5.67	6.87
37	2.74	3.67	4.71	5.66	6.89
38	2.73	3.68	4.70	5.68	6.87
39	2.74	3.70	4.71	5.67	6.89
40	2.73	3.72	4.70	5.65	6.90
41	2.75	3.74	4.69	5.66	6.91
42	2.73	3.71	4.68	5.67	6.89
43	2.74	3.72	4.70	5.69	6.87
44	2.75	3.70	4.72	5.68	6.88
45	2.73	3.72	4.71	5.67	6.89

Shape : Rectangular nose and triangular tail pier

Number of piers(s): Three (middle) Width of pier: 2 cm

Drag(g)	4.36	6.17	2.18	3.25	5.15
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.76	3.70	4.69	5.68	6.92
2	2.75	3.74	4.70	5.67	6.91
4	2.78	3.75	4.72	5.69	6.93
6	2.79	3.74	4.74	5.71	6.92
8	2.81	3.73	4.74	5.74	6.93
10	2.82	3.76	4.75	5.75	6.94
11	2.84	3.82	4.73	5.77	6.96
12	2.88	3.87	4.76	5.82	6.99
13	2.91	3.93	4.78	5.85	7.07
14	2.92	3.98	4.82	5.89	7.16
15	2.99	4.06	4.87	5.96	7.22
16	3.07	4.15	4.91	6.09	7.29
17	3.17	4.27	4.98	6.17	7.38
18	3.37	4.46	5.08	6.29	7.54
34	2.70	3.68	4.69	5.66	6.88
35	2.72	3.69	4.71	5.67	6.87
36	2.74	3.70	4.72	5.67	6.89
37	2.73	3.71	4.70	5.68	6.91
38	2.74	3.70	4.71	5.69	6.90
39	2.75	3.71	4.72	5.70	6.91
40	2.74	3.72	4.73	5.68	6.92
41	2.76	3.73	4.72	5.67	6.90
42	2.77	3.71	4.73	5.66	6.89
43	2.75	3.70	4.71	5.67	6.88
44	2.73	3.69	4.72	5.69	6.94
45	2.75	3.72	4.72	5.69	6.90

Shape : Rectangular nose and triangular tail pier

Number of piers(s): Three(right)   Width of pier: 2 cm

Drag(g)	4.40	6.23	2.19	3.26	5.11
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.78	3.71	4.72	5.66	6.90
2	2.76	3.72	4.70	5.68	6.92
4	2.79	3.74	4.71	5.69	6.91
6	2.78	3.76	4.72	5.68	6.93
8	2.82	3.77	4.73	5.72	6.92
10	2.84	3.79	4.74	5.73	6.93
11	2.85	3.83	4.77	5.75	6.95
12	2.87	3.88	4.76	5.81	6.97
13	2.92	3.95	4.79	5.86	7.04
14	2.94	4.01	4.81	5.90	7.15
15	3.02	4.08	4.85	5.95	7.24
16	3.09	4.14	4.92	6.04	7.28
17	3.18	4.24	4.97	6.15	7.35
18	3.32	4.45	5.07	6.26	7.49
34	2.70	3.67	4.70	5.65	6.87
35	2.72	3.68	4.72	5.66	6.88
36	2.71	3.70	4.71	5.67	6.88
37	2.73	3.72	4.70	5.67	6.90
38	2.74	3.71	4.71	5.68	6.91
39	2.75	3.68	4.72	5.69	6.90
40	2.73	3.70	4.74	5.68	6.88
41	2.72	3.72	4.75	5.66	6.89
42	2.73	3.74	4.73	5.65	6.90
43	2.71	3.73	4.74	5.66	6.92
44	2.74	3.71	4.72	5.67	6.91
45	2.75	3.69	4.75	5.68	6.90

Shape : Rectangular nose and triangular tail pier

Number of piers(s) : Four (Middle)　　　Width of pier : 2 cm

Drag(g)	4.60	6.70	2.44	3.46	5.41
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.76	3.72	4.74	5.70	6.94
2	2.78	3.74	4.75	5.71	6.95
5	2.79	3.75	4.73	5.69	6.93
6	2.82	3.73	4.75	5.72	6.95
8	2.84	3.76	4.73	5.71	6.97
10	2.86	3.78	4.75	5.73	6.98
11	2.87	3.83	4.78	5.74	6.99
12	2.95	3.89	4.80	5.77	7.03
13	2.99	3.97	4.82	5.83	7.07
14	3.02	4.06	4.85	5.94	7.18
15	3.10	4.15	4.87	5.99	7.29
16	3.17	4.23	4.96	6.11	7.36
17	3.26	4.38	5.04	6.20	7.44
18	3.48	4.59	5.12	6.37	7.56
34	2.71	3.66	4.70	5.66	6.88
35	2.72	3.67	4.69	5.68	6.90
36	2.73	3.66	4.71	5.69	6.91
37	2.72	3.68	4.72	5.70	6.92
38	2.73	3.69	4.73	5.69	6.90
39	2.74	3.70	4.72	5.68	6.92
40	2.76	3.72	4.73	5.69	6.94
41	2.77	3.73	4.75	5.70	6.93
42	2.76	3.72	4.74	5.71	6.94
43	2.75	3.71	4.73	4.69	6.92
44	2.77	3.72	4.71	5.67	6.91
45	2.76	3.70	4.72	5.68	6.93

Shape : Rectangular nose and triangular tail pier

Number of piers(s): Four (right) Width of pier: 2 cm

Drag(g)	4.63	6.66	2.46	3.49	5.39
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.74	4.72	5.69	6.93
2	2.76	3.73	4.73	5.72	6.94
4	2.78	3.76	4.75	5.70	6.95
6	2.80	3.77	4.74	5.71	6.94
8	2.82	3.78	4.75	5.73	6.96
10	2.85	3.79	4.77	5.75	6.99
11	2.88	3.85	4.79	5.76	6.98
12	2.93	3.88	4.83	5.78	7.02
13	2.97	3.95	4.84	5.85	7.04
14	3.04	4.05	4.86	5.92	7.16
15	3.12	4.13	4.88	5.97	7.27
16	3.18	4.22	4.95	6.07	7.35
17	3.28	4.36	5.02	618	741
18	3.46	4.55	5.14	6.34	7.55
34	2.71	3.68	4.69	5.68	6.87
35	2.70	3.66	4.71	5.66	6.89
36	2.71	3.68	4.71	5.67	6.90
37	2.73	3.67	4.72	5.66	6.91
38	2.74	3.69	4.73	5.67	6.92
39	2.73	3.70	4.74	5.68	6.93
40	2.74	3.71	4.75	5.69	6.91
41	2.75	3.70	4.74	5.70	6.93
42	2.76	3.72	4.72	5.68	6.94
43	2.74	3.71	4.71	5.67	6.92
44	2.72	3.68	4.73	5.66	6.94
45	2.74	3.70	4.74	5.68	6.90

Shape : Triangular nose and tail pier

Number of pier(s) : One Width of pier : 4 cm

Drag (g)	7.09		10.57		9.72		7.45		5.42	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.67	2.65	3.62	3.60	4.64	4.67	5.81	5.83	6.74	6.72
2	2.65	2.67	3.61	3.62	4.65	4.69	5.83	5.86	6.73	6.74
4	2.68	2.66	3.60	3.61	4.62	4.70	5.84	5.85	6.74	6.73
6	2.64	2.69	3.58	3.63	4.60	4.68	5.85	5.86	6.75	6.75
8	2.65	2.72	3.56	3.65	4.61	4.72	5.83	5.92	6.74	6.76
10	2.66	2.73	3.55	3.68	4.63	4.74	5.82	5.93	6.76	6.81
11	2.68	2.75	3.58	3.71	4.65	4.77	5.84	5.97	6.75	6.82
12	2.69	2.78	3.57	3.74	4.62	4.83	5.82	6.06	6.76	6.86
13	2.68	2.79	3.55	3.76	4.64	4.89	5.83	6.12	6.75	6.92
14	2.65	2.82	3.58	3.83	4.61	4.94	5.84	6.21	6.74	6.96
15	2.66	2.85	3.60	3.87	4.63	4.99	5.85	6.29	6.73	7.09
16	2.64	2.88	3.62	3.96	4.62	5.08	5.84	6.33	6.74	7.12
17	2.66	2.94	3.59	4.05	4.60	5.14	5.83	6.42	6.75	7.19
18	2.68	3.02	3.57	4.16	4.64	5.32	5.82	6.53	6.75	7.27
34	2.65	2.61	3.56	3.54	4.65	4.61	5.81	5.79	6.73	6.70
35	2.64	2.62	3.58	3.55	4.62	4.60	5.82	5.80	6.75	6.72
36	2.66	2.64	3.54	3.56	4.60	4.61	5.83	5.81	6.74	6.73
37	2.65	2.63	3.58	3.56	4.62	4.62	5.84	5.82	6.75	6.74
38	2.64	2.62	3.60	3.57	4.64	4.63	5.81	5.82	6.74	6.76
39	2.66	2.63	3.57	3.58	4.61	4.64	5.84	5.83	6.73	6.75
40	2.67	2.64	3.58	3.56	4.62	4.65	5.83	5.81	6.74	6.76
41	2.68	2.65	3.61	3.55	4.60	4.64	5.82	5.84	6.75	6.74
42	2.65	2.63	3.60	3.54	4.62	4.63	5.83	5.82	6.73	6.75
43	2.64	2.62	3.58	3.56	4.63	4.65	5.84	5.80	6.73	6.73
44	2.66	2.61	3.56	3.57	4.64	4.63	5.82	5.83	6.74	6.75
45	2.65	2.62	3.58	3.55	4.62	4.64	5.81	5.82	6.73	6.77

Shape :Triangular nose and tail pier

Number of piers(n): Two   Width of pier: 4 cm

Drag(g)	8.40	12.70	11.47	8.76	6.29
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.68	3.62	4.65	5.85	6.74
2	2.70	3.64	4.67	5.87	6.72
4	2.72	3.63	4.69	4.86	6.73
6	2.73	3.65	4.68	5.88	6.74
8	2.75	3.66	4.71	5.93	6.75
10	2.74	3.67	4.75	4.95	6.78
11	2.76	3.73	4.79	5.99	6.85
12	2.81	3.75	4.84	6.05	6.88
13	2.84	3.79	4.88	6.15	6.91
14	2.87	3.86	4.96	6.22	6.95
15	2.93	3.89	5.02	6.31	7.00
16	2.95	3.99	5.12	6.39	7.13
17	2.99	4.12	5.25	6.47	7.26
18	3.09	4.28	5.42	6.61	7.38
34	2.60	3.54	4.59	5.78	6.70
35	2.62	3.56	4.60	5.81	6.71
36	2.63	3.57	4.61	5.82	6.72
37	2.64	3.55	4.62	5.80	6.74
38	2.65	3.56	4.63	5.82	6.73
39	2.66	3.57	4.64	5.83	6.74
40	2.65	3.58	4.65	5.84	6.75
41	2.64	3.60	4.63	5.85	6.76
42	2.63	3.59	4.62	5.86	6.74
43	2.65	3.57	4.61	5.84	6.72
44	2.67	3.58	4.63	5.85	6.75
45	2.66	5.57	4.64	5.86	6.74

Shape : Triangular nose and tail pier

Number of piers(s): Three (middle) Width of pier: 4. cm

Drag(g)	9.71	15.01	13.51	10.65	7.70
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.70	3.64	4.62	5.86	6.75
2	2.68	3.66	4.64	5.85	6.74
4	2.71	3.67	4.66	5.88	6.73
6	2.72	3.67	4.65	5.91	6.76
8	2.74	3.69	4.74	5.94	6.78
10	2.75	3.72	4.78	5.97	6.80
11	2.82	3.76	4.85	6.03	6.87
12	2.86	3.81	4.86	6.11	6.92
13	2.92	3.87	4.89	6.18	6.97
14	2.98	3.93	4.99	6.25	7.05
15	3.03	3.98	5.07	6.37	7.18
16	3.07	4.06	5.19	6.44	7.24
17	3.14	4.16	5.28	6.56	7.32
18	3.21	4.38	5.54	6.74	7.51
34	2.62	3.55	4.58	5.80	6.72
35	2.64	3.57	4.60	5.81	6.71
36	2.63	3.56	4.62	5.83	6.70
37	2.65	3.56	4.61	5.82	6.72
38	2.66	3.57	4.63	5.84	6.74
39	2.68	3.58	4.64	5.83	6.75
40	2.69	3.59	4.66	5.84	6.74
41	2.67	3.58	4.65	5.86	6.76
42	2.70	3.57	4.63	5.87	6.77
43	2.68	3.58	4.62	5.85	6.75
44	2.67	3.58	4.64	5.84	6.73
45	2.68	3.59	4.63	5.86	6.74

Shape : Triangular nose and tail pier

Number of piers(n): Three (right)   Width of pier: 4 cm

Drag(g)	9.69	14.93	13.61	10.72	7.60
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.68	3.65	4.64	5.85	6.76
2	2.70	3.67	4.66	5.87	6.78
4	2.72	3.69	4.65	5.86	6.76
6	2.74	3.70	4.67	5.90	6.77
8	2.77	3.68	4.72	5.95	6.80
10	2.79	3.74	4.76	5.99	6.82
11	2.85	3.77	4.83	6.03	6.86
12	2.89	3.82	4.88	6.13	6.95
13	2.94	3.86	4.92	6.20	6.98
14	2.97	3.95	4.97	6.27	7.04
15	3.07	3.99	5.05	6.35	7.16
16	3.13	4.07	5.18	6.42	7.25
17	3.17	4.18	5.26	6.52	7.33
18	3.25	4.40	5.51	6.72	7.49
34	2.62	3.56	4.59	5.81	6.70
35	2.64	3.58	4.60	5.82	6.72
36	2.63	3.57	4.61	5.83	6.74
37	2.65	3.59	4.58	5.84	6.73
38	2.66	3.60	4.60	5.85	6.74
39	2.68	3.62	4.62	5.86	6.75
40	2.70	3.63	4.63	5.87	6.74
41	2.72	3.62	4.64	5.85	6.76
42	2.74	3.60	4.66	5.84	6.77
43	2.73	3.61	4.64	5.83	6.78
44	2.72	3.59	4.63	5.85	6.76
45	2.71	3.62	4.63	5.86	6.75

Shape : Triangular nose and tail piers

Number of piers(n): Four (middle) Width of pier: 4 cm

Drag(g)	11.20	17.45	16.19	12.98	8.98
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.70	3.63	4.66	5.88	6.78
2	2.74	3.68	4.68	5.87	6.80
4	2.72	3.70	4.70	5.89	6.81
6	2.75	3.73	4.69	5.92	6.82
8	2.79	3.75	4.74	5.97	6.79
10	2.84	3.78	4.77	6.01	6.83
11	2.92	3.85	4.86	6.08	6.87
12	2.96	3.87	4.95	6.17	6.92
13	2.03	3.94	5.03	6.24	7.01
14	3.14	4.05	5.14	6.35	7.14
15	3.19	4.12	5.23	6.46	7.22
16	3.28	4.21	5.31	6.55	7.31
17	3.32	4.36	5.44	6.67	7.43
18	3.41	4.55	5.61	6.81	7.58
34	2.62	3.55	4.60	5.79	2.72
35	2.63	3.56	4.62	5.80	2.73
36	2.65	3.57	4.63	5.82	2.72
37	2.67	3.58	4.62	5.83	2.74
38	2.69	3.59	4.64	5.82	2.75
39	2.68	3.62	4.63	5.81	2.76
40	2.70	3.60	4.65	5.82	2.77
41	2.71	3.63	4.66	5.83	2.78
42	2.72	3.65	4.67	5.84	2.76
43	2.71	3.64	4.65	5.82	2.75
44	2.70	3.63	4.63	5.80	2.74
45	2.72	3.61	4.64	5.82	2.76

Shape : Triangular nose and tail pier

Number of piers(n): Four (right) Width of pier: 4 cm

Drag(g)	11.34	17.37	16.09	13.03	9.13
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.66	4.64	5.86	6.80
2	2.72	3.64	4.66	5.88	6.77
4	2.76	3.68	4.71	5.90	6.79
6	2.74	3.71	4.72	5.91	6.80
8	2.77	3.74	4.75	5.95	6.81
10	2.82	3.79	4.77	5.99	6.84
11	2.90	3.83	4.85	6.06	6.87
12	2.95	3.88	4.93	6.15	6.91
13	3.05	3.96	5.02	6.21	6.99
14	3.15	4.04	5.12	6.32	7.07
15	3.21	4.11	5.20	6.45	7.19
16	3.25	4.19	5.32	6.53	7.28
17	3.32	4.31	5.41	6.63	7.41
18	3.44	4.51	5.59	6.77	7.55
34	2.64	3.58	4.61	5.80	2.71
35	2.65	3.59	4.62	5.81	2.73
36	2.66	3.57	4.63	5.83	2.74
37	2.67	3.56	4.64	5.84	2.72
38	2.69	3.58	4.64	5.85	2.74
39	2.71	3.60	4.65	5.86	2.76
40	2.73	3.61	4.66	5.84	2.78
41	2.74	3.62	4.64	5.83	2.77
42	2.74	3.60	4.63	5.82	2.75
43	2.73	3.62	4.62	5.84	2.74
44	2.72	3.64	4.64	5.83	2.76
45	2.73	3.61	3.65	5.85	2.75

Shape : Triangular nose and tail pier

Number of pier(s) : One Width of pier : 2 cm

D.sge(Q)	3.12		4.37		4.37		3.20		2.27	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.70	2.74	3.68	3.66	4.62	4.63	5.77	5.74	6.77	6.76
2	2.72	2.75	3.70	3.68	4.63	4.62	5.74	5.75	6.78	6.77
4	2.74	2.76	3.71	3.70	4.62	4.65	5.76	5.76	6.78	6.75
6	2.73	2.74	3.69	3.71	4.65	4.66	5.75	5.75	6.79	6.76
8	2.70	2.77	3.66	3.72	4.64	4.72	5.75	5.76	6.77	6.78
10	2.68	2.79	3.68	3.74	4.64	4.77	5.74	5.81	6.78	6.79
11	2.71	2.81	3.67	3.77	4.63	4.79	5.73	5.82	6.78	6.78
12	2.73	2.86	3.70	3.83	4.61	4.85	5.75	5.85	6.78	6.82
13	2.69	2.88	3.69	3.89	4.65	4.91	5.73	5.93	6.79	6.85
14	2.70	2.91	3.67	3.93	4.64	4.96	5.76	5.98	6.77	6.90
15	2.72	2.94	3.65	3.99	4.62	5.03	5.74	6.05	6.78	6.96
16	2.74	2.99	3.67	4.02	4.65	5.06	5.75	6.08	6.79	7.02
17	2.73	3.03	3.69	4.04	4.63	5.09	5.76	6.11	6.77	7.08
18	2.72	3.08	3.71	4.10	4.61	5.14	5.74	6.16	6.77	7.12
34	2.70	2.68	3.65	3.62	4.60	4.56	5.73	5.72	6.77	6.75
35	2.68	2.69	3.67	3.63	4.62	4.58	5.74	5.73	6.76	6.77
36	2.71	2.70	3.69	3.64	4.61	4.59	5.75	5.74	6.79	6.76
37	2.73	2.71	3.68	3.63	4.63	4.60	5.76	5.74	6.76	6.77
38.	2.74	2.72	3.66	3.65	4.62	4.61	5.74	5.75	6.79	6.75
39	2.73	2.73	3.68	3.66	4.64	4.62	5.75	5.76	6.78	6.77
40	2.72	2.74	3.67	3.68	4.65	4.60	5.73	5.77	6.78	6.76
41	2.70	2.75	3.69	3.65	4.63	4.61	5.74	5.78	6.79	6.78
42	2.74	2.73	3.70	3.66	4.65	4.62	5.75	5.75	6.77	6.79
43	2.72	2.73	3.68	3.67	4.63	4.61	5.76	5.76	6.78	6.77
44	2.75	2.74	3.66	3.65	4.62	4.60	5.75	5.74	6.77	6.76
45	2.73	2.75	3.71	3.64	4.61	4.62	5.73	5.75	6.78	6.77

Shape : Triangular nose and tail pier

Number of piers(s): Two — Width of pier: 2 cm

Drag(g)	3.24	4.50	4.51	3.29	2.46
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.73	3.67	4.65	5.73	6.75
2	2.72	3.66	4.66	5.75	6.76
4	2.75	3.68	4.64	5.74	6.77
6	2.74	3.72	4.65	5.67	6.75
8	2.76	3.75	4.70	5.78	6.78
10	2.79	3.80	4.75	5.83	6.80
11	2.82	3.85	4.81	5.84	6.81
12	2.85	3.86	4.87	5.89	6.86
13	2.91	3.91	4.93	5.95	6.91
14	2.93	3.97	4.98	6.03	6.95
15	2.96	4.05	5.05	6.09	6.99
16	2.98	4.11	5.11	6.12	7.05
17	3.06	9.15	5.13	6.14	7.13
18	3.14	4.18	5.19	6.20	7.18
34	2.67	3.64	4.58	5.72	6.76
35	2.68	3.66	4.59	5.74	6.75
36	2.66	3.67	4.60	5.75	6.77
37	2.69	3.65	4.62	5.76	6.78
38	2.70	3.67	4.61	5.77	6.80
39	2.71	3.66	4.63	5.78	6.79
40	2.70	3.68	4.64	5.77	6.81
41	2.69	3.69	4.65	5.79	6.78
42	2.68	3.70	4.67	5.76	6.80
43	2.70	3.68	4.65	5.75	6.82
44	2.72	3.69	3.64	5.78	6.80
45	2.71	3.66	4.63	5.76	6.81

Shape : Triangular nose and tail piers
Number of piers(s): Three (middle)
Width of pier: 2 cm

Drag(g)	3.50	4.90	5.04	3.73	2.77
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.68	4.67	5.75	6.77
2	2.75	3.70	4.68	5.77	6.75
4	2.76	3.71	4.66	5.76	6.76
6	2.77	3.69	4.67	5.78	6.77
8	2.76	3.72	4.69	5.79	6.78
10	2.81	3.77	4.74	5.84	6.81
11	2.85	3.82	4.79	5.87	6.82
12	2.89	3.89	4.85	5.90	6.85
13	2.94	3.96	4.94	5.96	6.94
14	2.97	4.02	5.02	6.02	6.98
15	3.00	4.09	5.07	6.08	7.03
16	3.04	4.14	5.16	6.14	7.10
17	3.10	4.18	5.20	6.18	7.17
18	3.21	4.29	5.31	6.34	7.35
34	2.66	3.65	4.60	5.71	6.77
35	2.68	3.66	4.58	5.73	6.76
36	2.70	3.68	4.61	5.74	6.77
37	2.71	3.70	4.60	5.75	6.78
38	2.72	3.68	4.62	5.73	6.77
39	2.74	3.69	4.64	5.74	6.78
40	2.73	3.70	4.63	5.75	6.79
41	2.75	3.71	4.65	5.76	6.78
42	2.74	3.72	4.66	5.77	6.78
43	2.72	3.70	4.64	5.75	6.79
44	2.71	3.69	4.63	5.76	6.77
45	2.73	3.70	4.65	5.75	6.78

Shape : Triangular nose and tail pier

Number of piers(s): Three (right)   Width of pier: 2 cm

Drag(g)	3.45	4.77	4.91	3.81	2.66
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.76	3.70	4.66	5.76	6.76
2	2.75	3.71	4.67	5.79	6.75
4	2.74	3.69	4.68	5.77	6.75
6	2.76	3.72	4.70	5.78	6.76
8	2.78	3.74	4.69	5.81	6.77
10	2.82	3.78	4.75	5.85	6.79
11	2.86	3.84	4.81	5.89	6.82
12	2.91	3.88	4.86	5.92	6.86
13	2.95	3.95	4.92	5.97	6.93
14	2.99	4.04	4.99	6.04	6.99
15	3.02	4.11	5.05	6.09	7.05
16	3.07	4.16	5.16	6.17	7.13
17	3.12	4.21	5.22	6.21	7.20
18	3.22	4.31	5.33	6.32	7.37
34	2.68	3.64	4.62	5.70	6.74
35	2.67	3.65	4.60	5.72	6.75
36	2.69	3.66	4.58	5.73	6.76
37	2.70	3.69	4.60	5.74	6.75
38	2.71	3.70	4.63	5.75	6.76
39	2.72	3.69	4.64	5.73	6.75
40	2.70	3.71	4.65	5.74	6.77
41	2.72	3.72	4.66	5.75	6.77
42	2.73	3.73	4.67	5.75	6.76
43	2.74	3.71	4.66	5.74	6.75
44	2.73	3.72	4.65	5.73	6.76
45	2.72	3.73	4.67	5.74	6.77

Shape : Triangular nose and tail pier

Number of piers(n): Four (middle)   Width of pier: 2 cm

Drag(g)	3.72	5.22	5.32	3.99	2.88
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.77	3.72	4.65	5.74	6.76
2	2.75	3.70	4.66	5.75	6.77
4	2.76	3.71	4.67	5.76	6.78
6	2.77	3.73	4.68	5.76	6.77
8	2.79	3.72	4.66	5.77	6.76
10	2.81	3.74	4.70	5.83	6.78
11	2.85	3.79	4.78	5.90	6.83
12	2.93	3.86	4.85	5.95	6.85
13	2.96	3.96	4.95	6.07	6.93
14	3.01	4.08	5.02	6.13	7.00
15	3.06	4.15	5.08	6.19	7.07
16	3.14	4.23	5.19	6.26	7.16
17	3.18	4.29	5.26	6.35	7.25
18	3.34	4.46	5.42	6.49	7.32
34	2.70	3.65	4.60	5.73	6.74
35	2.71	3.66	4.62	5.74	6.76
36	2.72	3.68	4.61	5.75	6.75
37	2.73	3.70	4.63	5.77	6.77
38	2.74	3.69	4.64	5.76	6.78
39	2.75	3.70	4.65	5.77	6.80
40	2.73	3.71	4.66	5.78	6.81
41	2.75	3.72	4.65	5.79	6.79
42	2.76	3.74	4.66	5.80	6.82
43	2.77	3.73	4.64	5.78	6.80
44	2.75	3.75	4.66	5.76	6.80
45	2.76	3.72	4.65	5.77	6.81

Shape : Triangular nose and tail pier

Number of piers(n): Four (right) Width of pier: 2 cm

Drag(g)	3.60	5.28	5.45	4.10	2.98
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.70	4.64	5.73	6.78
2	2.76	3.68	4.65	5.76	6.77
4	2.77	3.71	4.66	5.75	6.79
6	2.75	3.72	4.67	5.74	6.78
8	2.78	3.74	4.68	5.76	6.77
10	2.82	3.76	4.71	5.82	6.79
11	2.85	3.78	4.76	5.89	6.81
12	2.91	3.84	4.83	5.96	6.84
13	2.95	3.95	4.91	6.05	6.93
14	3.03	4.05	4.98	6.11	7.02
15	3.09	4.13	5.06	6.18	7.09
16	3.16	4.21	5.15	6.25	7.15
17	3.20	4.26	5.24	6.33	6.27
18	3.36	4.43	5.39	6.46	7.36
34	2.71	3.66	4.62	5.74	6.76
35	2.72	3.68	4.61	5.75	6.77
36	2.71	3.69	4.60	5.76	6.78
37	2.73	3.70	4.62	5.77	6.79
38	2.74	3.71	4.63	5.78	6.80
39	2.75	3.69	4.65	5.77	6.79
40	2.73	3.70	4.66	5.79	6.80
41	2.75	3.72	4.65	5.80	6.81
42	2.74	3.71	4.69	5.78	6.80
43	2.75	3.68	4.67	5.76	6.80
44	2.74	3.71	4.66	5.78	6.79
45	2.73	3.70	4.65	5.79	6.81

Shape : Circular nose and tail pier

Number of pier(s) : One   Width of pier : 4 cm

Drag (g)	6.71		10.02		8.54		6.33		4.22	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.67	2.70	3.60	3.64	4.63	4.65	5.75	5.76	6.79	6.80
2	2.70	2.72	3.62	3.65	4.65	4.67	5.78	5.77	6.80	6.79
4	2.66	2.69	3.61	3.62	4.64	4.66	5.79	5.78	6.82	6.80
6	2.69	2.71	3.63	3.63	4.66	4.68	5.76	5.79	6.81	6.80
8	2.70	2.73	3.64	3.65	4.65	4.69	5.79	5.80	6.83	6.81
10	2.68	2.75	3.62	3.68	4.63	4.72	5.76	5.78	6.81	6.82
11	2.71	2.78	3.61	3.72	4.62	4.74	5.78	5.82	6.82	6.84
12	2.69	2.83	3.63	3.79	4.64	4.77	5.77	5.84	6.83	6.86
13	2.66	2.89	3.60	3.86	4.66	4.82	5.75	5.89	6.81	6.92
14	2.68	2.95	3.62	3.93	4.62	4.90	5.78	5.95	6.83	6.95
15	2.69	3.03	3.64	4.00	4.64	4.96	5.76	6.02	6.82	7.02
16	2.70	3.08	3.63	4.07	4.63	5.04	5.77	6.10	6.86	7.08
17	2.67	3.11	3.62	4.15	4.65	5.11	5.79	6.14	6.79	7.14
18	2.68	3.39	3.61	4.28	4.64	5.22	5.75	6.19	6.82	7.24
34		2.63		3.60		4.58		5.72		6.78
35		2.64		3.61		4.59		5.73		6.79
36		2.65		3.62		4.60		5.74		6.80
37		2.64		3.62		4.62		5.76		6.81
38		2.65		3.63		4.61		5.74		6.80
39		2.66		3.62		4.59		5.75		6.79
40		2.67		3.61		4.60		5.76		6.00
41		2.66		3.63		4.62		5.75		6.81
42		2.68		3.64		4.63		5.76		6.80
43		2.66		3.65		4.62		5.74		6.00
44		2.64		3.63		4.63		5.75		6.81
45		2.65		3.64		4.61		5.75		6.80

Shape : Circular nose and tail pier

Number of piers(n): Two   Width of pier: 4 cm

Drag(g)	8.10	13.20	10.44	7.92	5.39
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.72	3.63	4.67	5.78	6.78
2	2.71	3.65	4.66	5.79	6.81
4	2.70	3.64	4.68	5.76	6.80
6	2.71	3.66	4.70	5.78	6.82
8	2.73	3.67	4.73	5.79	6.81
10	2.74	3.70	4.75	5.80	6.83
11	2.79	3.73	4.79	5.83	6.82
12	2.84	3.78	4.85	5.86	6.85
13	2.92	3.89	4.91	5.91	6.93
14	2.97	3.96	4.96	5.98	6.98
15	3.07	4.03	5.03	6.05	7.06
16	3.12	4.14	5.13	6.14	7.15
17	3.18	4.21	5.18	6.21	7.23
18	3.29	4.37	5.30	6.32	7.38
34	2.65	3.61	4.60	5.74	6.78
35	2.64	3.62	4.59	5.75	6.79
36	2.63	3.63	4.58	5.76	6.80
37	2.65	3.64	4.60	5.75	6.81
38	2.66	3.62	4.62	5.76	6.82
39	2.68	3.63	4.63	5.77	6.83
40	2.69	3.64	4.64	5.78	6.82
41	2.67	3.63	4.66	5.79	6.81
42	2.69	3.65	4.65	5.80	6.82
43	2.70	3.64	4.66	5.78	6.80
44	2.71	3.66	4.64	5.79	6.81
45	2.72	3.65	4.64	5.80	6.82

Shape :Circular nose and tail pier

Number of piers(s): Three (Middle) Width of pier: 4 cm

Drag(g)	9.20	15.32	11.89	9.66	6.61
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.73	3.65	4.68	5.80	6.82
2	2.72	3.64	4.67	5.78	6.81
4	2.73	3.66	4.69	5.81	6.82
6	2.74	3.65	4.68	5.82	6.80
8	2.75	3.68	4.71	5.84	6.83
10	2.77	3.72	4.76	5.83	6.82
11	2.82	3.75	4.82	5.86	6.83
12	2.87	3.80	4.87	5.91	6.87
13	2.93	3.87	4.96	5.95	6.92
14	2.98	3.95	5.05	6.06	6.97
15	3.08	4.08	5.12	6.15	7.12
16	3.16	4.16	5.17	6.21	7.19
17	3.25	4.28	5.26	6.29	7.28
18	3.38	4.49	5.42	6.45	7.51
34	2.66	3.62	4.61	5.75	6.80
35	2.67	3.60	4.62	5.76	6.81
36	2.69	3.63	4.63	5.74	6.82
37	2.70	2.62	4.62	5.75	6.82
38	2.70	3.63	4.63	5.76	6.83
39	2.68	3.62	4.64	5.77	6.84
40	2.69	3.64	4.63	5.78	6.83
41	2.71	3.65	4.65	5.79	6.84
42	2.72	3.64	4.66	5.80	6.83
43	2.70	3.63	4.65	5.82	6.83
44	2.69	3.65	4.67	5.81	6.83
45	2.68	3.64	4.65	5.79	6.84

Shape : Circular nose and tail pier

Number of piers(n): Three (right) Width of pier: 4 cm

Drag(g)	9.08	15.43	11.97	9.55	6.66
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.71	3.63	4.66	5.81	6.83
2	2.73	3.65	4.68	5.80	6.82
4	2.74	3.64	4.67	5.81	6.83
6	2.75	3.66	4.69	5.82	6.83
8	2.74	3.67	4.68	5.83	6.84
10	2.76	3.71	4.74	5.85	6.82
11	2.83	3.73	4.77	5.87	6.85
12	2.89	3.78	4.85	5.92	6.88
13	2.95	3.85	4.93	5.97	6.94
14	3.00	3.93	4.99	6.04	6.99
15	3.15	4.05	5.09	6.13	7.09
16	3.19	4.13	5.15	6.22	7.18
17	3.27	4.26	5.23	6.31	7.26
18	3.40	4.51	5.40	6.48	7.55
34	2.67	3.60	4.60	5.74	6.80
35	2.65	3.59	4.61	5.75	6.79
36	2.68	3.58	4.62	5.74	6.81
37	2.67	3.60	4.63	5.75	6.80
38	2.68	3.61	4.64	5.76	6.80
39	2.70	3.59	4.63	5.75	6.79
40	2.69	3.62	4.65	5.76	6.80
41	2.68	3.60	4.66	5.77	6.81
42	2.69	3.63	4.64	5.76	6.81
43	2.70	3.65	4.65	5.76	6.82
44	2.69	3.63	4.63	5.75	6.83
45	2.68	3.62	4.64	5.77	6.81

Shape : Circular nose and tail pier

Number of piers(n): Four (MIDDLE) Width of pier: 4 cm

Drag(g)	10.77	18.05	14.30	11.20	8.06
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.73	3.70	4.68	5.82	6.85
2	2.74	3.68	4.70	5.84	6.86
4	2.76	3.69	4.72	5.86	6.85
6	2.75	3.71	4.71	5.85	6.85
8	2.77	3.72	4.72	5.87	6.87
10	2.78	3.75	4.75	5.86	6.86
11	2.84	3.81	4.82	5.88	6.88
12	2.88	3.87	4.89	5.90	6.91
13	2.96	3.92	4.94	5.94	6.95
14	3.07	4.03	5.01	5.98	6.98
15	3.17	4.12	5.14	6.11	7.12
16	3.24	4.24	5.25	6.28	7.22
17	3.32	4.35	5.37	6.40	7.32
18	3.54	4.63	5.51	6.61	7.67
34	2.70	3.61	4.62	5.78	6.80
35	2.71	3.62	4.64	5.77	6.81
36	2.69	3.63	4.65	5.76	6.82
37	2.71	3.64	4.65	5.79	6.83
38	2.72	3.65	4.66	5.80	6.83
39	2.73	3.64	4.65	5.78	7.82
40	2.74	3.65	4.65	5.80	6.83
41	2.75	3.66	4.67	5.79	6.84
42	2.74	3.63	4.66	5.81	6.83
43	2.76	3.65	4.67	5.82	6.84
44	2.75	3.67	4.65	5.80	6.83
45	2.74	3.65	4.65	2.80	6.83

Shape : Circular nose and tail pier

Number of piers(n): Four (right) Width of pier: 4cm

Drag(g)	10.66	17.97	14.39	11.26	7.94
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.72	3.69	4.66	5.80	6.84
2	2.73	3.70	4.68	5.83	6.85
4	2.75	3.71	4.72	5.84	6.87
6	2.76	3.72	4.70	5.86	6.86
8	2.78	3.73	4.71	5.87	6.87
10	2.80	3.77	4.74	5.88	6.88
11	2.85	3.83	4.81	5.90	6.90
12	2.90	3.89	4.87	5.92	6.92
13	2.98	3.94	4.93	5.94	6.94
14	3.08	4.05	5.02	6.00	6.99
15	3.15	4.13	5.11	6.13	7.15
16	3.26	4.26	5.23	6.26	7.25
17	3.35	4.36	5.35	6.38	7.34
18	3.51	4.61	5.49	6.58	7.63
34	2.70	3.62	4.61	5.77	6.82
35	2.71	3.63	4.62	5.78	6.83
36	2.72	3.62	4.64	5.76	6.82
37	2.70	3.64	4.65	5.78	6.84
38	2.69	3.65	4.65	5.77	6.84
39	2.68	3.63	4.65	5.78	6.84
40	2.70	3.64	4.67	5.79	6.85
41	2.71	3.63	4.66	5.80	6.84
42	2.72	3.65	4.67	5.79	6.83
43	2.70	3.66	4.65	5.81	6.85
44	2.71	3.64	4.66	5.79	6.84
45	2.72	3.65	4.66	5.80	6.84

Shape : Circular nose and tail pier

Number of pier(s) : One   Width of pier : 2 cm

Discharge (Q)	3.07		4.95		3.52		3.01		1.95	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
07	2.61	2.60	3.73	3.72	4.70	4.69	5.72	5.70	6.84	6.83
2	2.63	2.62	3.72	3.74	4.68	4.70	5.73	5.71	6.85	6.83
4	2.65	2.61	3.70	3.76	4.66	4.71	5.72	5.71	6.84	6.84
6	2.62	2.62	3.71	3.73	4.69	4.72	5.74	5.72	6.85	6.85
8	2.60	2.63	3.72	3.75	4.67	4.74	5.73	5.73	6.85	6.85
10	2.59	2.65	3.69	3.77	4.69	4.76	5.75	5.74	6.86	6.85
11	2.62	2.67	3.72	3.79	4.68	4.79	5.73	5.77	6.84	6.87
12	2.64	2.68	3.70	3.81	4.70	4.80	5.76	5.78	6.86	6.89
13	2.65	2.71	3.69	3.85	4.69	4.82	5.74	5.79	6.85	6.91
14	2.63	2.73	3.72	3.88	4.68	4.85	5.76	5.81	6.86	6.92
15	2.60	2.75	3.73	3.92	4.66	4.88	5.74	5.83	6.85	6.95
16	2.61	2.76	3.72	3.97	4.69	4.94	5.72	5.86	6.84	6.96
17	2.59	2.78	3.71	4.02	4.66	4.99	5.73	5.91	6.85	6.99
18	2.62	2.81	3.73	4.07	4.68	5.04	5.74	5.99	6.85	7.03
34		2.58		3.68		4.66		5.69		6.82
35		2.59		3.69		4.67		5.70		6.83
36		2.61		3.68		4.68		5.71		6.84
37		2.60		3.70		4.67		5.70		6.85
38		2.61		3.71		4.66		5.70		6.84
39		2.59		3.72		4.67		5.69		6.83
40		2.60		3.69		4.68		5.71		6.85
41		2.62		3.71		4.69		5.70		6.83
42		2.60		3.70		4.70		5.70		6.84
43		2.58		3.72		4.71		5.71		6.84
44		2.61		3.73		4.72		5.69		6.84
45		2.60		3.74		4.70		5.70		6.84

Shape : Circular nose and tail pier

Number of piers(s): Two

Width of pier: 2 cm

Drag(g)	3.19	5.17	3.69	3.07	2.07
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.62	3.72	4.69	5.72	6.84
2	2.64	3.73	4.70	5.71	6.85
4	2.63	3.75	4.71	5.72	6.84
6.	2.69	3.74	4.72	5.72	6.83
8	2.65	3.76	4.74	5.74	6.85
10	2.67	3.77	4.73	5.75	6.85
11	2.69	3.78	4.75	5.75	6.88
12	2.72	3.81	4.79	5.76	6.90
13	2.74	3.85	4.83	5.78	6.93
14	2.79	3.88	4.86	5.82	6.94
15	2.81	3.94	4.90	5.85	6.96
16	2.83	3.98	4.96	5.87	7.02
17	2.86	4.06	5.02	5.94	7.05
18	2.91	4.12	5.11	6.05	7.12
34	2.59	3.69	4.65	5.70	6.83
35	2.60	3.68	4.66	5.71	6.83
36	2.61	3.69	4.67	5.69	6.85
37	2.58	3.70	4.68	5.70	6.84
38	2.59	3.71	4.66	5.71	6.84
39	2.60	3.72	4.67	5.70	6.84
40	2.62	3.74	4.66	5.72	6.85
41	2.61	3.73	4.68	5.73	6.83
42	2.63	3.65	4.66	5.74	6.85
43	2.64	3.74	4.65	5.73	6.84
44	2.63	3.73	4.64	5.72	6.85
45	2.65	3.72	4.66	5.73	6.84

Shape Circular nose and tail pier
Number of piers(s): Three (Middle)   Width of piers: 2 cm

Drag(g)	3.43	3.89	4.09	3.41	2.18
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.63	3.74	4.70	5.73	6.85
2	2.63	3.75	4.71	5.74	6.85
4	2.65	3.73	4.72	5.73	6.86
6	2.65	3.75	4.73	5.74	6.84
8	2.64	3.77	4.72	5.75	6.85
10	2.66	3.79	4.74	5.76	6.86
11	2.68	3.83	4.76	5.77	6.87
12	2.73	3.85	4.78	5.78	6.89
13	2.76	3.90	4.82	5.81	6.92
14	2.81	3.92	4.87	5.84	6.95
15	2.83	3.96	4.92	5.89	6.98
16	2.86	4.04	4.99	5.93	7.06
17	2.90	4.09	5.06	5.98	7.11
18	2.96	4.16	5.19	6.13	7.19
34	2.58	3.68	4.66	5.71	6.84
35	2.59	3.69	4.67	5.72	6.83
36	2.60	3.71	4.65	5.73	6.85
37	2.60	3.70	4.67	5.73	6.84
38	2.61	3.71	4.68	5.74	6.86
39	2.62	3.70	4.66	5.73	6.85
40	2.63	3.72	4.67	5.74	6.84
41	2.62	3.73	4.69	5.75	6.86
42	2.64	3.74	4.70	5.76	6.87
43	2.65	3.72	4.70	5.75	6.88
44	2.63	3.73	4.69	5.74	6.86
45	2.64	3.72	4.68	5.72	6.85

Shape : Circular nose and tail pier
Number of piers(s): Three(right)   Width of pier: 2 cm

Drag(g)	3.38	5.52	4.10	3.48	2.22
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.64	3.72	4.72	5.74	6.85
2	2.65	3.74	4.70	5.75	6.84
4	2.63	3.75	4.71	5.73	6.85
6	2.64	3.74	4.72	5.74	6.85
8	2.65	3.76	4.74	5.75	6.85
10	2.67	3.79	4.75	5.77	6.87
11	2.68	3.84	4.77	5.79	6.86
12	2.72	3.87	3.80	5.78	6.89
13	2.75	3.91	4.84	5.80	6.93
14	2.80	3.94	4.88	5.83	6.95
15	2.84	3.97	4.91	5.87	6.98
16	2.88	4.02	4.98	5.92	7.05
17	2.91	4.08	5.08	599	7.09
18	2.98	4.15	5.20	6.12	7.18
34	2.59	3.67	4.65	5.72	6.83
35	2.58	3.68	4.67	5.73	6.85
36	2.60	3.69	4.66	5.71	6.84
37	2.61	3.70	4.67	5.74	6.85
38	2.62	3.71	4.66	5.73	6.85
39	2.63	3.69	4.67	5.72	6.86
40	2.62	3.70	4.65	5.74	6.88
41	2.64	3.68	4.66	5.73	6.87
42	2.65	3.71	4.68	5.74	6.86
43	2.66	3.72	4.66	5.75	6.84
44	2.64	3.70	4.65	5.73	6.85
45	2.63	3.69	4.64	5.74	6.86

Shape : Circular nose and tail pier

Number of piers(s): Four (Middle)   Width of pier: 2 cm

Drag(g)	3.77	6.21	4.45	3.89	2.45
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.63	3.74	4.70	5.75	6.84
2	2.64	3.76	4.71	5.76	6.86
4	2.65	3.75	4.72	5.74	6.85
6	2.66	3.75	4.73	5.76	6.86
8	2.67	3.74	4.75	5.76	6.86
10	2.69	3.76	4.76	5.78	6.87
11	2.70	3.80	4.78	5.81	6.88
12	2.73	3.85	4.82	5.82	6.92
13	2.75	3.93	4.86	5.84	6.94
14	2.81	3.97	4.93	5.87	6.95
15	2.85	4.03	4.97	5.90	6.99
16	2.89	4.06	5.05	5.94	7.08
17	2.94	4.13	5.14	6.02	7.13
18	3.02	4.22	5.26	6.17	7.25
34	2.58	3.69	4.66	5.74	6.82
35	2.59	3.69	4.68	5.73	6.84
36	2.60	3.70	4.70	5.75	6.84
37	2.62	3.73	4.69	5.74	6.83
38	2.63	3.71	4.68	5.75	6.84
39	2.64	3.72	4.69	5.76	6.85
40	2.66	3.71	4.70	5.77	6.84
41	2.65	369	4.71	5.77	6.83
42	2.64	3.70	4.69	5.77	6.85
43	2.62	3.74	4.72	5.76	6.84
44	2.63	3.73	4.73	5.75	6.84
45	2.62	3.72	4.74	5.76	6.83

Shape: Circular nose and tail pier

Number of piers(n): Four (right)   Width of pier: 2 cm

Drag(g)	3.85	6.13	4.52	3.85	2.50
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.65	3.73	4.69	5.76	6.85
2	2.63	3.75	4.72	5.74	6.84
4	2.66	3.76	4.71	5.75	6.85
6	2.65	3.74	4.73	5.76	6.85
8	2.68	3.75	4.74	5.77	6.87
10	2.72	3.78	4.77	5.79	6.88
11	2.74	3.81	4.79	5.82	6.90
12	2.75	3.83	4.84	5.83	6.93
13	2.77	3.88	4.87	5.85	6.95
14	2.82	3.93	4.92	5.89	6.97
15	2.87	4.00	4.99	5.92	7.05
16	2.90	4.05	5.07	5.97	7.12
17	2.95	4.15	5.15	6.03	7.18
18	3.04	4.24	5.24	6.16	7.27
34	2.59	3.70	4.68	5.73	6.83
35	2.60	3.68	4.69	5.72	6.84
36	2.61	3.69	4.70	5.73	6.85
37	2.62	3.70	4.69	5.75	6.85
38	2.63	3.71	4.70	5.74	6.86
39	2.65	3.73	4.71	5.73	6.85
40	2.64	3.72	4.73	5.75	6.86
41	2.66	3.74	4.72	5.74	6.84
42	2.65	3.73	4.74	5.76	6.86
43	2.67	3.75	4.73	5.75	6.88
44	2.65	3.73	4.72	5.77	6.87
45	2.66	3.74	4.72	5.75	6.86

Shape : Circular nose and triangular tail pier

Number of pier(s) : One Width of pier : 4 cm

Drag (g)	5.76		9.16		6.11		4.34		4.23	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.71	2.73	3.65	3.66	4.80	4.82	5.76	5.80	6.91	6.92
2	2.73	2.72	3.64	3.68	4.81	4.84	5.79	5.81	6.92	6.93
4	2.70	2.74	3.53	3.65	4.82	4.85	5.80	5.78	6.92	6.94
6	2.69	2.75	3.66	3.67	4.79	4.86	5.78	5.82	6.91	6.94
8	2.72	2.76	3.65	3.69	4.80	4.88	5.77	5.84	6.93	6.95
10	2.68	2.76	3.64	3.70	4.83	4.90	5.76	5.86	6.93	6.94
11	2.70	3.78	3.63	3.72	4.82	4.91	5.78	5.89	6.92	6.97
12	2.73	2.81	3.64	3.76	4.79	4.92	5.79	5.93	6.92	6.96
13	2.72	2.85	3.66	3.83	4.80	4.95	5.77	5.97	6.93	7.02
14	2.70	2.89	3.64	3.87	4.81	5.00	5.78	6.03	6.91	7.05
15	2.71	2.94	3.63	3.95	4.82	5.02	5.80	6.07	6.92	7.08
16	2.73	3.00	3.65	4.01	4.80	5.11	5.81	6.13	6.93	7.12
17	2.70	3.05	3.63	4.07	4.79	5.16	5.80	6.18	6.91	7.19
18	2.69	3.12	3.64	4.18	4.82	5.21	5.77	6.25	6.92	7.28
34		2.68		3.63		4.80		5.77		6.93
35		2.69		3.62		4.81		5.78		6.92
36		2.70		3.63		4.82		5.78		6.93
37		2.71		3.64		4.84		5.80		6.93
38		2.72		3.63		4.84		5.80		6.94
39		2.73		3.65		4.83		5.81		6.94
40		2.72		3.66		4.82		5.80		6.94
41		2.74		3.64		4.83		5.78		6.93
42		2.71		3.67		4.85		5.79		6.95
43		2.73		3.68		3.86		5.81		6.94
44		2.75		3.69		4.84		5.82		6.95
45		2.74		3.67		4.85		5.80		6.94

Shape : Circular nose and triangular tail pier

Number of piers(n): Two | Width of pier: 4 cm

Drag(c)	6.76	10.85	7.36	5.21	5.31
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.71	3.64	4.84	5.78	6.94
2	2.74	3.66	4.86	5.81	6.95
4	2.73	3.67	4.85	5.82	6.93
6	2.75	3.65	4.86	5.83	6.94
8	2.77	3.68	4.87	5.82	6.94
10	2.76	3.71	4.89	5.84	6.95
11	2.80	3.73	4.93	5.88	6.95
12	2.83	3.75	4.95	5.95	6.97
13	2.86	3.81	5.03	6.00	7.05
14	2.88	3.85	5.06	6.05	7.10
15	2.93	3.93	5.11	6.11	7.13
16	3.02	4.08	5.16	6.17	7.18
17	3.10	4.15	5.22	6.25	7.25
18	3.18	4.22	5.29	6.37	6.41
34	2.70	3.64	4.82	5.78	6.90
35	2.69	3.66	4.80	5.79	6.92
36	2.70	3.65	4.83	5.80	6.91
37	2.71	3.67	4.81	5.81	6.90
38	2.72	3.68	4.82	5.80	6.91
39	2.73	3.66	4.83	5.81	6.92
40	2.75	3.67	4.85	5.80	6.92
41	2.74	3.68	4.84	5.82	6.91
42	2.76	3.69	4.83	5.83	6.93
43	2.75	3.70	4.81	5.84	6.93
44	2.74	3.68	4.83	5.82	6.92
45	2.73	3.70	4.82	5.83	6.91

Shape :Circular nose and triangular tail pier
Number of piers(s): Three (Middle) Width of pier: 4 cm

Drag(g)	7.40	12.21	8.04	5.70	5.94
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.72	3.65	4.82	5.82	6.93
2	2.73	3.67	4.83	5.82	6.95
4	2.75	3.67	4.84	5.83	6.94
6	2.74	3.68	4.85	5.84	6.93
8	2.75	3.66	4.86	5.83	6.95
10	2.78	3.68	4.88	5.85	6.94
11	2.81	3.71	4.91	5.87	6.96
12	2.85	3.75	4.95	5.90	6.98
13	2.88	3.83	4.99	5.98	7.06
14	2.92	3.38	5.06	6.09	7.12
15	2.95	3.95	5.14	6.16	7.15
16	3.06	4.12	5.18	6.23	7.22
17	3.13	4.17	5.28	6.32	7.35
18	3.27	4.30	5.35	6.43	7.46
34	2.73	3.63	4.81	5.78	6.92
35	2.72	3.64	4.82	5.80	6.93
36	2.70	3.65	4.83	5.81	6.91
37	2.73	3.66	4.81	5.79	6.92
38	2.75	3.66	4.82	5.81	6.93
39	2.73	3.65	4.83	5.80	6.94
40	2.76	3.64	4.84	5.79	6.92
41	2.74	3.66	4.86	5.82	6.94
42	2.75	3.67	4.85	5.81	6.94
43	2.76	3.66	4.84	5.83	6.95
44	2.75	3.68	4.86	5.82	6.96
45	2.73	3.67	4.87	5.81	6.95

Shape : Circular nose and triangular tail pier

Number of piers(s): Three (right) Width of pier: 4 cm

Drag(g)	7.45	12.12	8.09	5.75	6.03
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.66	4.85	5.81	6.93
2	2.73	3.64	4.84	5.83	6.93
4	2,72	3,65	4,86	5,82	6,94
6	2,75	3,67	4,85	5.84	6.95
8	2,76	3.67	4.87	5.85	6.94
10	2.77	3.69	4.89	5.84	6.96
11	2.81	3.72	4.93	5.88	6.97
12	2.86	3.76	4.96	5.92	6.99
13	2.88	3.85	5.01	5.96	7.05
14	2.94	3.90	5.09	6.06	7.14
15	2.96	3.96	5.15	6.15	7.17
16	3.04	4.14	5.20	6.22	7.22
17	3.15	4.18	5.31	6.34	7.31
18	3.25	4.35	5.39	6.42	7.48
34	2.70	3.64	4.83	5.80	6.91
35	2.71	3.65	4.82	5.81	6.92
36	2.73	3.63	4.81	5.79	6.93
37	2.72	3.64	4.83	5.78	6.92
38	2.73	3.65	4.84	5.79	6.93
39	2.72	3.66	4.85	5.80	6.92
40	2.74	3.68	4.82	5.82	6.92
41	2.73	3.67	4.83	5.81	6.93
42	2.75	3.69	4.85	5.83	6.92
43	2.76	3.70	4.86	5.84	6.91
44	2.74	3.71	4.84	5.83	6.92
45	2.75	3.68	4.85	5.85	6.93

Shape : Circular nose and triangular tail pier
Number of piers(s): Four (Middle) Width of pier: 4 cm

Drag (g)	8.50	14.00	9.50	6.78	6.89
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.64	4.83	5.83	6.95
2	2.75	3.66	4.86	5.80	6.93
4	2.74	3.67	4.84	5.81	6.95
6	2.76	3.65	3.86	5.85	6.94
8	2.75	3.68	4.87	5.87	6.93
10	2.78	3.71	4.91	5.86	6.95
11	2.83	3.73	4.96	5.90	6.98
12	2.88	3.77	5.02	5.94	7.02
13	2.92	3.85	5.05	5.98	7.07
14	2.97	3.93	5.11	6.10	6.16
15	3.03	3.99	5.16	6.18	7.24
16	3.11	4.16	5.23	6.25	6.35
17	3.19	4.22	5.32	6.39	7.43
18	3.33	4.48	5.42	6.55	7.53
34	2.72	3.63	4.80	5.77	6.91
35	2.73	3.65	4.82	5.78	6.92
36	2.74	3.64	4.83	5.80	6.93
37	2.72	3.65	4.81	5.81	6.93
38	2.74	3.66	4.82	5.82	6.94
39	2.76	3.67	4.83	5.81	6.94
40	2.77	3.66	4.84	5.82	6.93
41	2.75	3.68	4.85	5.83	6.94
42	2.78	3.66	4.84	5.84	6.95
43	2.77	3.68	4.86	5.82	6.95
44	2.76	3.67	4.85	5.80	6.94
45	2.77	3.67	4.83	5.83	6.93

Shape : Circular nose and triangular tail pier

Number of piers(s): Four (right) Width of pier: 4cm

Drag(g)	8.54	14.08	9.56	6.65	6.95
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.73	3.67	4.85	5.80	6.94
2	2.76	3.68	4.86	5.81	6.94
4	2.75	3.66	4.84	5.82	6.95
6	2.78	3.65	4.83	5.83	6.94
8	2.77	3.67	4.85	5.84	6.95
10	2.78	3.70	4.88	5.83	6.93
11	2.85	3.75	4.94	5.85	6.96
12	2.88	3.81	5.00	5.92	7.00
13	2.94	3.86	5.06	5.96	7.06
14	2.95	3.92	5.12	6.06	7.14
15	3.05	4.01	5.19	6.16	7.22
16	3.12	4.17	5.24	6.23	7.31
17	3.22	4.24	5.30	6.35	7.40
18	3.42	4.45	5.49	6.52	7.55
34	2.73	3.64	4.82	5.78	6.92
35	2.74	3.65	4.83	5.80	6.93
36	2.72	3.66	4.80	5.82	6.92
37	2.73	3.67	4.82	5.81	6.92
38	2.74	3.68	4.84	5.83	6.93
39	2.75	3.69	4.85	5.84	6.94
40	2.73	3.70	4.83	5.85	6.94
41	2.76	3.71	4.86	5.84	6.95
42	2.77	3.72	4.85	5.83	6.95
43	2.75	3.68	4.87	5.85	6.94
44	2.74	3.69	4.85	5.84	6.93
45	2.76	3.68	4.84	5.84	6.94

Shape : Circular nose and triangular tail pier

Number of pier(s) : One Width of pier : 2 cm

Drage(s)	2.35		4.11		2.66		1.85		1.94	
Station (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)	mean depth (cm)	profile (cm)
0	2.70	2.71	3.75	3.72	4.82	4.84	5.78	5.76	6.94	6.93
2	2.72	2.74	3.73	3.74	4.84	4.86	5.79	5.77	6.94	6.93
4	2.73	2.72	3.76	3.75	4.85	4.83	5.77	5.76	6.93	6.94
6	2.75	2.73	3.75	3.73	4.83	4.85	5.76	5.78	6.94	6.94
8	2.74	2.75	3.72	3.76	4.81	4.86	5.75	5.75	6.94	6.96
10	2.72	2.76	3.74	3.78	4.82	4.88	5.77	5.77	6.93	6.95
11	2.71	2.77	3.75	3.82	4.83	4.87	5.76	5.78	6.95	6.97
12	2.73	2.76	3.76	3.85	4.85	4.91	5.78	5.76	6.95	6.99
13	2.72	2.79	3.74	3.84	4.82	4.93	5.76	5.79	6.94	7.02
14	2.73	2.81	2.73	4.87	4.83	4.92	5.75	5.81	6.93	7.06
15	2.75	2.83	3.75	3.93	4.82	4.95	5.79	5.84	6.92	7.05
16	2.72	2.85	3.72	3.96	4.84	4.97	5.78	5.86	6.94	7.10
17	2.71	2.91	3.74	4.02	4.83	5.05	5.75	5.91	6.94	7.12
18	2.73	2.96	3.73	4.08	4.85	5.12	5.77	5.96	6.93	7.14
·34		2.70		3.74		4.82		5.74		6.93
35		2.71		3.73		4.83		5.76		6.92
36		2.72		3.72		4.85		5.75		6.94
37		2.74		3.74		4.86		5.78		6.93
38		2.72		3.75		4.84		5.76		6.94
39		2.74		3.74		4.85		5.75		6.93
40		2.73		3.76		4.83		5.78		6.94
41		2.75		3.78		4.86		5.77		6.95
42		2.76		3.76		4.85		5.75		6.94
43		2.74		3.77		4.87		5.74		6.95
44		2.75		3.75		4.84		5.76		6.95
45		2.73		3.76		4.85		5.75		6.93

Shape : Circular nose and triangular tail pier

Number of piers(s): Two Width of pier: 2 cm

Drag(g)	2.48	4.29	2.68	2.05	2.11
Station (km)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.73	3.74	4.82	5.75	6.95
2	2.71	3.76	4.84	5.77	6.95
4	2.73	3.77	4.85	5.76	6.96
6	2.75	3.75	4.83	5.78	6.95
8	2.72	3.76	4.86	5.80	6.94
10	2.74	3.78	4.85	5.77	6.96
11	2.77	3.83	4.88	5.79	6.98
12	2.78	3.85	4.90	5.78	6.97
13	2.81	3.87	4.94	5.83	7.01
14	2.82	3.88	4.95	5.85	7.04
15	2.84	3.93	4.97	5.84	7.07
16	2.87	3.97	5.00	5.87	7.13
17	2.93	4.04	5.07	5.94	7.15
18	2.99	4.12	5.16	5.98	7.18
34	2.70	3.73	4.84	5.76	6.94
35	2.72	3.72	4.83	5.74	6.96
36	2.71	3.75	4.85	5.75	6.95
37	2.73	3.73	4.86	5.78	6.93
38	2.70	3.75	4.85	5.75	6.95
39	2.71	3.76	4.87	5.76	6.97
40	2.73	3.77	4.86	5.74	6.98
41	2.74	3.78	4.88	5.75	6.96
42	2.73	3.76	4.89	5.77	6.97
43	2.74	3.79	4.87	5.78	6.97
44	2.73	3.78	4.88	5.75	6.99
45	2.74	3.77	4.86	5.76	6.98

Shape : Circular nose and triangular tail pier

Number of piers(n): Three (Middle) Width of pier: 2 cm

Drag(g)	2.68	4.70	3.64	2.25	2.32
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.74	3.75	4.85	5.78	6.95
2	2.75	3.77	4.83	5.77	6.94
4	2.76	3.78	4.86	5.76	6.93
6	2.74	3.76	4.87	5.75	6.95
8	2.73	3.75	4.84	5.77	6.96
10	2.75	3.75	4.86	5.78	6.95
11	2.77	3.78	4.88	5.80	695
12	2.76	3.84	4.91	5.81	6.97
13	2.79	3.88	4.92	5.79	7.03
14	2.84	3.91	4.94	5.83	7.05
15	2.86	3.95	4.96	5.86	6.07
16	2.90	3.99	4.99	5.85	7.12
17	2.94	4.05	5.07	5.92	6.14
18	3.05	4.16	5.18	6.00	7.17
34	2.72	3.72	4.84	5.75	6.95
35	2.74	3.74	4.83	5.76	6.94
36	2.73	3.73	4.85	5.74	6.93
37	2.75	3.74	4.82	5.75	6.96
38	2.74	3.76	4.84	5.77	6.96
39	2.73	3.75	4.83	5.76	6.95
40	2.75	3.77	4.85	5.78	6.97
41	2.76	3.76	4.85	5.80	6.96
42	2.74	3.78	4.86	5.77	6.96
43	2.77	3.76	4.87	5.79	6.97
44	2.75	3.75	4.85	5.80	6.96
45	2.76	3.74	4.84	5.78	6.97

Shape : Circular nose and triangular tail pier

Number of piers(n): Three (right) Width of pier: 2 cm

Drag(g)	2.72	4.67	3.00	2.33	2.27
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.76	3.72	4.84	5.76	6.94
2	2.75	3.74	4.86	5.77	6.95
4	2.74	3.73	4.83	5.78	6.95
6	2.76	3.75	4.85	5.79	6.94
8	2.75	3.76	4.87	5.77	6.95
10	2.74	3.74	4.86	5.82	6.94
11	2.76	3.77	4.89	5.84	6.96
12	2.78	3.80	4.93	5.80	6.98
13	2.81	3.84	4.92	5.83	7.00
14	2.82	3.88	4.95	5.85	7.04
15	2.85	3.93	4.97	5.87	7.06
16	2.89	3.97	5.00	5.88	7.11
17	2.95	4.02	5.03	5.94	7.14
18	3.06	4.14	5.17	6.03	7.16
34	2.74	3.73	4.82	5.75	6.93
35	2.72	3.72	4.83	5.74	6.95
36	2.73	3.74	4.84	5.75	6.94
37	2.74	3.75	4.85	5.76	6.94
38	2.76	3.73	4.86	5.75	6.95
39	2.74	3.75	4.85	5.76	6.94
40	2.75	3.74	4.84	5.74	6.95
41	2.73	3.76	4.85	5.75	6.96
42	2.74	3.77	4.83	5.78	6.95
43	2.72	3.75	4.82	5.77	6.95
44	2.75	3.76	4.84	5.76	6.94
45	2.76	3.74	4.85	5.74	6.96

Shape : Circular nose and triangular tail pier

Number of piers(s): Four (middle) Width of pier: 2cm

Drag(g)	3.11	5.28	3.41	2.57	2.54
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.73	3.75	4.85	5.78	6.96
2	2.76	3.77	4.83	5.76	6.95
4	2.78	3.78	4.86	5.80	6.94
6	2.77	3.75	4.85	5.79	6.95
8	2.76	3.76	4.84	5.81	6.97
10	2.79	3.78	4.87	5.78	6.96
11	2.81	3.80	4.89	5.77	6.95
12	2.83	3.78	4.93	5.79	6.97
13	2.82	3.83	4.95	5.81	6.99
14	2.84	3.87	4.98	5.82	7.03
15	2.87	3.95	5.02	5.84	6.09
16	2.92	3.99	5.06	5.85	7.15
17	2.97	4.05	5.09	5.96	7.18
18	3.13	4.19	5.21	6.11	7.23
34	2.73	3.75	4.83	5.74	6.93
35	2.74	3.73	4.84	5.75	6.94
36	2.75	3.72	4.83	5.76	6.95
37	2.77	3.74	4.85	5.77	6.94
38	2.76	3.76	4.83	5.78	6.96
39	2.75	3.78	4.84	5.80	6.97
40	2.78	3.77	4.85	5.77	6.95
41	2.77	3.79	4.85	5.79	6.96
42	2.75	3.78	4.86	5.80	6.96
43	2.74	3.77	4.85	5.78	6.97
44	2.76	3.75	4.87	5.76	6.96
45	2.75	3.76	4.85	5.77	6.96

Shape : Circular nose and triangular tail pier

Number of piers(s): Four (right) Width of pier: 2 cm

Drop(cm)	3.14	5.33	3.49	2.53	2.57
Station (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)	profile (cm)
0	2.77	3.77	4.84	5.80	6.96
2	2.75	3.78	4.86	5.79	6.95
4	2.76	3.76	4.87	5.78	6.95
6	2.74	3.77	4.85	5.81	6.95
8	2.75	3.75	4.87	5.77	6.97
10	2.78	3.78	4.88	5.76	6.95
11	2.76	3.82	4.87	5.79	6.97
12	2.79	3.83	4.89	5.80	6.98
13	2.81	3.85	4.92	5.82	7.00
14	2.85	3.84	4.96	5.85	7.02
15	2.89	3.89	5.01	5.87	7.08
16	2.94	3.96	5.05	5.86	7.14
17	2.98	4.03	5.10	5.95	7.16
18	3.15	4.18	5.18	6.10	7.21
34	2.75	3.74	4.84	5.75	6.94
35	2.73	3.75	4.85	5.77	6.93
36	2.74	3.73	4.86	5.76	6.94
37	2.76	3.76	4.84	5.75	6.95
38	2.75	3.74	4.85	5.76	6.96
39	2.76	3.75	4.83	5.77	6.94
40	2.77	3.76	4.84	5.78	6.95
41	2.78	3.76	4.86	5.77	6.96
42	2.76	3.78	4.85	5.77	6.95
43	2.79	3.77	4.87	5.78	6.94
44	2.77	3.76	4.85	5.76	6.95
45	2.76	3.75	4.86	5.78	6.95

Shape : Rectangualr nose and tail pier

Width of pier : 4 cm

No. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2 \rho V_1^2 A_1$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1' (N/m)	F2' (N/m)	FD (N)	CD
One pier	57.6	47.6	2.72	6.201	0.352	0.0717	10.233	2.91	2.71	7.725	7.440	0.0882	1.23
	62.2	43.0	3.76	8.436	0.356	0.0988	13.921	3.91	3.74	12.411	12.000	0.1235	1.25
	59.5	46.00	4.81	7.072	0.240	0.0558	11.670	4.86	4.80	14.337	14.089	0.0709	1.27
	55.8	49.3	5.78	5.070	0.144	0.0242	8.393	5.90	5.75	17.653	17.544	0.0298	1.23
	64.8	40.3	6.83	9.468	0.227	0.0706	15.624	6.89	6.84	26.733	26.424	0.0654	1.21
Two piers	57.6	47.6	2.72	6.201	0.337	0.0686	10.233	3.04	2.72	7.949	7.452	0.0988	1.44
	62.2	43.0	3.76	8.436	0.345	0.0958	13.921	4.03	3.76	12.730	12.046	0.1390	1.45
	59.2	46.00	4.81	7.072	0.237	0.0552	11.670	4.92	4.82	14.590	14.171	0.0805	1.46
	55.8	49.3	5.78	5.144	0.144	0.0241	8.393	5.83	5.80	17.817	17.653	0.0342	1.48
	64.8	40.3	6.85	9.468	0.225	0.0703	15.624	6.92	6.84	26.921	26.424	0.1040	1.48

Shape : Rectangular nose and tail pier

Width of pier : 4 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1' (N/m)	F2' (N/m)	FD (N)	CD
Three Piers (middle)	57.6	47.6	2.72	6.201	0.324	0.0660	10.233	3.16	2.72	8.183	7.452	0.1096	1.66
	62.2	43.0	3.76	8.436	0.336	0.0933	13.921	4.14	3.73	13.042	12.023	0.1530	1.64
	59.2	46.00	4.81	7.072	0.235	0.0547	11.670	4.96	4.82	14.761	14.171	0.0903	1.65
	55.8	49.3	5.78	5.086	0.144	0.0242	8.393	5.81	5.76	17.707	17.435	0.0394	1.63
	64.8	40.3	6.85	9.468	0.224	0.0698	15.624	6.97	6.85	27.235	26.463	0.1124	1.61
Three Piers (right)	57.6	47.6	2.72	6.201	0.324	0.0660	10.233	3.16	2.72	8.183	7.452	0.1102	1.67
	62.2	43.0	3.76	8.436	0.337	0.0935	13.921	4.13	3.74	13.013	12.000	0.1542	1.65
	59.2	46.00	4.81	7.072	0.236	0.0548	11.670	4.95	4.51	14.718	14.130	0.0899	1.64
	55.8	49.3	5.78	5.070	0.144	0.0241	8.393	5.83	5.78	17.817	17.544	0.0390	1.62
	64.8	40.3	6.85	9.468	0.224	0.0697	15.624	6.98	6.86	27.298	26.547	0.1122	1.61

Shape : Rectangular nose and tail pier

Width of pier : 4 cm

No. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2 \rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four Piers (middle)	57.6	47.6	2.72	6.201	0.308	0.0629	10.233	3.32	2.74	8.530	7.478	0.1263	2.01
	62.2	43.0	3.76	8.436	0.322	0.0894	13.921	4.23	3.78	13.592	12.092	0.1324	2.04
	59.2	45.00	4.81	7.072	0.232	0.0540	11.570	5.03	4.82	15.064	14.171	0.1106	2.05
	55.8	49.3	5.78	5.086	0.143	0.0239	8.393	5.87	5.80	18.037	17.653	0.0493	2.06
	64.8	40.3	6.85	9.468	0.222	0.0691	15.624	7.04	6.86	27.680	26.547	0.1368	1.98
Four Piers (right)	57.6	47.6	2.72	6.201	0.308	0.0629	10.233	3.32	2.74	8.530	7.478	0.1271	2.02
	62.2	43.0	3.76	8.436	0.324	0.0898	13.921	4.30	3.76	13.582	12.046	0.1823	2.03
	59.2	45.00	4.81	7.072	0.231	0.0537	11.570	5.05	4.84	15.152	14.254	0.1091	2.03
	55.8	49.3	5.78	5.070	0.142	0.0238	8.393	5.89	5.82	18.148	17.762	0.0489	2.05
	64.8	40.3	6.85	9.468	0.222	0.0691	15.624	7.04	6.86	27.680	26.547	0.1382	2.00

Shape : Rectangular nose and tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1' (N/m)	F2' (N/m)	FD (N)	CD
One piers	57.6	47.5	2.58	5.229	0.376	0.0386	10.277	2.73	2.60	7.498	7.352	0.0447	1.16
	62.5	42.5	3.61	8.582	0.383	0.0540	14.162	3.70	3.60	12.093	11.889	0.0621	1.15
	60.0	45.2	4.65	7.472	0.264	0.0324	12.330	4.67	4.64	13.904	13.768	0.0363	1.12
	55.9	49.3	5.52	5.126	0.153	0.0129	8.459	5.53	5.52	16.236	16.185	0.0152	1.15
	56.6	38.6	7.01	10.082	0.237	0.0393	16.637	7.02	7.00	28.016	27.890	0.0448	1.14
Two piers	57.5	47.5	5.228	0.228	0.367	0.0376	10.277	2.80	2.61	7.591	7.362	0.0470	1.25
	62.5	42.5	3.61	8.582	0.376	0.0530	14.162	3.77	3.62	12.248	11.926	0.0647	1.22
	60.0	45.2	4.65	7.472	0.263	0.0323	12.330	4.69	4.64	13.981	13.788	0.0401	1.24
	55.9	5.52	5.126	0.153	0.153	0.0129	8.459	5.53	5.52	16.236	16.185	0.0165	1.28
	56.6	38.6	7.01	0.237	0.236	0.0391	16.637	7.06	7.02	28.259	28.016	0.0473	1.21

Shape : Rectangular nose and tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2 \rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1' (N/m)	F2' (N/m)	FD (N)	CD
Three piers (middle)	57.6	47.5	2.55	6.228	0.363	0.0372	10.277	2.53	2.56	7.634	7.315	0.0491	1.32
	62.5	42.6	3.61	8.582	0.369	0.0520	14.162	3.84	3.64	12.412	11.966	0.0666	1.28
	60.0	45.2	4.65	7.472	0.262	0.0322	12.330	4.71	4.64	14.059	13.788	0.0415	1.29
	55.9	49.3	5.52	5.125	0.153	0.0129	8.459	5.54	5.52	16.238	16.155	0.0167	1.30
	66.5	38.6	7.01	10.082	0.236	0.0391	16.637	7.06	7.01	28.269	27.933	0.0500	1.28
Three piers (right)	57.6	47.5	2.55	6.228	0.364	0.0373	10.277	2.82	2.55	7.619	7.306	0.0489	1.31
	62.5	42.6	3.61	8.582	0.368	0.0519	14.162	3.85	3.65	12.436	11.987	0.0670	1.29
	60.0	45.2	4.65	7.472	0.262	0.0322	12.330	4.71	4.64	14.059	13.788	0.0412	1.28
	55.9	49.3	5.52	5.125	0.153	0.0129	8.459	5.54	5.52	16.238	16.155	0.0167	1.30
	66.6	38.6	7.01	10.082	0.236	0.0391	16.637	7.05	7.00	28.206	27.890	0.0493	1.26

Shape : Rectangular nose and tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four Piers (middle)	57.6	47.5	2.58	6.228	0.354	0.0363	10.277	2.90	2.58	7.740	7.333	0.0501	1.38
	62.5	42.6	3.61	8.582	0.365	0.0515	14.162	3.86	3.62	12.509	11.926	0.0695	1.35
	60.0	45.2	4.75	7.472	0.260	0.0319	12.330	4.75	4.66	14.217	13.865	0.0424	1.33
	55.9	49.3	5.52	5.126	0.152	0.0128	8.459	5.57	5.54	16.444	16.288	0.0180	1.41
	66.6	38.6	7.01	10.082	0.235	0.0389	16.637	7.09	7.02	28.460	28.016	0.0529	1.36
Four Piers (right)	57.6	47.5	2.58	6.228	0.356	0.0364	10.277	2.89	2.57	7.724	7.324	0.0495	1.36
	62.5	42.6	3.61	8.582	0.364	0.0514	14.162	3.89	3.63	12.334	11.948	0.0699	1.36
	60.0	45.2	4.65	7.472	0.260	0.0319	12.330	4.75	4.66	14.217	13.665	0.0427	1.34
	55.9	49.3	5.52	5.126	0.152	0.0128	8.459	5.55	5.52	16.340	16.135	0.180	1.40
	66.6	38.6	7.01	10.082	0.235	0.0389	16.637	7.09	7.02	28.460	28.016	0.0533	1.37

Shape Rectangularnose and triangular tail pier

Width of pier : 4 cm

NO. of piers	E1 (cm)	E2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	[illegible] (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
One pier	57.7	47.4	2.62	6.292	0.362	0.0749	10.383	2.57	2.63	7.769	7.465	0.0913	1.22
	61.7	43.4	3.72	8.254	0.353	0.0958	13.620	3.86	3.70	12.072	11.668	0.1178	1.23
	56.4	48.7	4.75	5.482	0.190	0.0342	9.046	4.77	4.74	12.831	12.702	0.0407	1.19
	59.2	45.9	5.62	7.082	0.206	0.0479	11.686	5.58	5.64	18.165	17.961	0.0594	1.24
	65.0	40.1	7.02	9.534	0.223	0.0700	15.733	7.05	7.01	27.792	27.537	0.0825	1.18
Two piers	57.7	47.4	2.62	6.292	0.346	0.0716	10.383	3.00	2.64	7.930	7.476	0.1010	1.41
	61.7	43.4	3.72	8.254	0.342	0.0929	13.620	3.98	3.72	12.387	11.733	0.1319	1.42
	56.4	48.7	4.75	5.482	0.188	0.0338	9.046	4.82	4.76	13.047	12.788	0.0487	1.44
	59.2	45.9	5.62	7.082	0.205	0.0478	11.686	5.76	5.63	18.266	17.910	0.0692	1.45
	65.0	40.1	7.02	9.534	0.222	0.0697	15.733	7.08	7.00	27.984	27.473	0.0996	1.43

Shape : Rectangular nose and triangular tail pier

Width of pier : 4 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2 \rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Three piers (middle)	57.7	47.4	2.62	6.292	0.333	0.0689	10.383	3.12	2.63	8.201	7.465	0.1129	1.64
	61.7	43.4	3.72	8.254	0.331	0.0900	13.620	4.11	3.74	12.754	11.780	0.1457	1.62
	56.4	48.7	4.75	5.482	0.187	0.0338	9.046	4.83	4.75	13.091	12.745	0.0537	1.59
	59.2	45.9	5.62	7.082	0.205	0.0477	11.686	5.71	5.61	18.319	17.809	0.0777	1.63
	65.0	40.1	7.02	9.534	0.221	0.0692	15.733	7.12	7.02	23.307	27.600	0.1114	1.61
Three piers (right)	57.7	47.4	2.62	0.362	0.333	0.0689	10.383	3.12	2.62	8.201	7.455	0.1130	1.64
	61.7	43.4	3.72	8.254	0.332	0.0902	13.620	4.10	3.73	12.725	11.756	0.1461	1.62
	56.4	48.7	4.75	5.482	0.187	0.0337	9.046	4.84	4.76	13.135	12.788	0.0539	1.60
	59.2	45.9	5.62	7.082	0.204	0.0476	11.686	5.72	5.62	18.371	17.859	0.0771	1.62
	65.0	40.1	7.02	9.534	0.221	0.0692	15.733	7.12	7.02	28.307	27.600	0.1112	1.61

Shape : Rectangular nose and triangular tail pier

Width of pier : 4 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four piers (middle)	57.7	47.4	2.62	6.292	0.317	0.0655	10.383	3.23	2.64	8.534	7.476	0.1277	1.95
	61.7	43.4	3.72	8.254	0.320	0.0870	13.620	4.25	3.74	13.178	11.780	0.1705	1.96
	56.4	48.7	4.75	5.482	0.185	0.0334	9.046	4.88	4.76	13.311	12.788	0.0648	1.94
	59.2	45.9	5.62	7.082	0.202	0.0470	11.686	5.79	5.64	18.736	17.961	0.0926	1.97
	65.0	40.1	7.02	9.534	0.219	0.0685	15.733	7.20	7.03	28.754	27.664	0.1315	1.92
Four piers (right)	57.7	47.4	2.62	0.362	0.315	0.0657	10.383	3.27	2.63	8.512	7.465	0.1275	1.94
	61.7	43.4	3.72	8.254	0.320	0.0868	13.620	4.26	3.75	13.210	11.803	0.1701	1.96
	56.4	48.7	4.75	5.482	0.186	0.0335	9.045	4.87	4.75	13.267	12.745	0.0653	1.95
	59.2	45.9	5.62	7.082	0.202	0.0470	11.686	5.79	5.64	18.736	17.961	0.0921	1.96
	65.0	40.1	7.02	9.534	0.219	0.0686	15.733	7.19	7.02	28.698	27.600	0.1317	1.92

Shape : Rectangular nose and triangular tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1′ (N/m)	F2′ (N/m)	FD (N)	CD
One pier	57.5	47.8	2.73	6.116	0.355	0.0357	10.092	2.84	2.75	7.516	7.387	0.0400	1.12
	62.2	43.0	3.68	8.427	0.368	0.0510	13.906	3.78	3.70	12.082	11.899	0.0576	1.13
	56.5	48.6	4.71	5.561	0.194	0.0177	9.177	4.73	4.72	12.709	12.667	0.0190	1.07
	59.9	45.3	5.66	7.427	0.215	0.0263	12.256	5.70	5.65	13.506	13.404	0.0299	1.14
	66.9	38.3	6.89	10.181	0.243	0.0406	16.800	6.92	6.90	27.470	27.347	0.0443	1.09
Two piers	57.7	47.8	2.73	6.116	0.350	0.0352	10.092	2.88	2.74	7.578	7.374	0.0403	1.15
	52.2	43.0	3.68	8.427	0.363	0.0503	13.906	3.83	3.71	12.201	11.921	0.0584	1.16
	56.5	48.6	4.71	5.561	0.194	0.0178	9.177	4.72	4.70	12.667	12.582	0.0208	1.17
	59.9	45.3	5.66	7.427	0.215	0.0263	12.256	5.70	5.67	13.506	13.353	0.0305	1.16
	66.9	38.3	6.89	10.181	0.243	0.0406	16.800	6.92	6.89	27.470	27.285	0.0451	1.11

Shape Rectangualr nose and triangular tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Three piers (middle)	57.5	47.8	2.73	6.116	0.343	0.0345		2.94	2.75	7.677	7.387	0.0428	1.24
	62.2	43.0	3.68	8.427	0.358	0.0497		3.88	3.71	12.325	11.921	0.0605	1.22
	56.5	48.6	4.71	5.561	0.193	0.0177		4.75	4.72	12.795	12.567	0.0214	1.21
	59.9	45.3	5.66	7.427	0.214	0.0262		5.72	5.68	18.609	18.404	0.0319	1.22
	66.9	38.3	6.89	10.181	0.242	0.0405		6.95	6.90	27.656	27.347	0.0505	1.25
Three piers (right)	57.5	47.8	2.73	6.116	0.346	0.0348		2.92	2.73	7.643	7.361	0.0432	1.24
	62.2	43.0	3.68	8.427	0.358	0.0497		3.88	3.71	12.235	11.922	0.0611	1.22
	56.5	48.6	4.71	5.561	0.193	0.0176		4.76	4.73	12.937	12.709	0.0215	1.22
	59.9	45.3	5.66	7.427	0.215	0.0262		5.71	5.67	18.557	18.353	0.0320	1.22
	66.9	38.3	6.89	10.181	0.242	0.0405		6.95	6.90	27.656	27.347	0.0501	1.24

Shape Rectangular nose and triangular tail pier

Width of pier : 2 cm

No.of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	W.avrag (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four piers (middle)	57.5	47.8	2.73	6.116	0.336	0.0339		2.99	2.75	7.764	7.387	0.0451	1.33
	62.2	45.0	3.68	8.427	0.354	0.0490		3.93	3.71	12.452	11.921	0.065	1.34
	56.5	45.6	4.71	5.561	0.192	0.0176		4.78	4.73	12.923	12.709	0.0239	1.36
	59.9	45.3	5.66	7.427	0.214	0.0261		5.74	5.69	18.711	18.455	0.0339	1.30
	66.9	38.3	6.89	10.131	0.240	0.0402		6.99	6.92	27.905	27.470	0.0531	1.32
Four piers (right)	57.5	47.8	2.73	6.116	0.339	0.0341		2.98	2.74	7.746	7.374	0.0452	1.33
	62.2	43.0	3.68	0.368	0.355	0.0492		3.92	3.70	12.426	11.899	0.0653	1.33
	56.5	48.6	4.71	5.561	0.192	0.0175		4.78	4.73	12.923	12.709	0.0241	1.37
	59.9	45.3	5.66	7.427	0.215	0.0264		5.73	5.68	15.692	15.436	0.0342	1.29
	66.9	38.3	6.89		0.240	0.0402		6.99	6.92	27.905	27.470	0.0529	1.32

Shape : Triangular nose and tail piers

Width of pier : 4 cm

No. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1′ (N/m)	F2′ (N/m)	FD (N)	CD
One Pier	57.2	43.0	2.66	5.964	0.351	0.0689	9.842	2.80	2.63	7.279	7.051	0.0696	1.01
	62.1	43.1	3.58	8.409	0.373	0.1032	13.875	3.72	3.56	11.922	11.584	0.1037	1.00
	63.4	41.7	4.62	8.941	0.312	0.0917	14.754	4.73	4.64	15.521	15.193	0.0954	1.04
	63.0	42.2	5.83	8.762	0.246	0.0710	14.459	5.87	5.82	20.391	20.135	0.0731	1.03
	60.7	44.4	6.74	7.829	0.191	0.0493	12.919	6.75	6.72	24.734	24.547	0.0532	1.08
Two Piers	57.2	43.0	2.66	5.964	0.336	0.0659	9.842	2.93	2.65	7.490	7.075	0.0824	1.26
	62.1	43.1	3.58	8.409	0.360	0.0997	13.876	3.85	3.58	12.229	11.624	0.1246	1.25
	63.4	41.7	4.62	8.941	0.309	0.0908	14.754	4.75	4.63	15.706	15.163	0.1125	1.24
	63.0	42.2	5.83	8.762	0.244	0.0704	14.459	5.92	5.84	20.649	20.237	0.0859	1.22
	60.7	44.4	6.74	7.829	0.190	0.0490	12.919	6.79	6.74	24.984	24.671	0.0617	1.26

Shape : Triangular nose and tail pier

Width of pier : 4 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2\ \rho V_1^2 A_f$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1′ (N/m)	F2′ (N/m)	FD (N)	CD
Three Pier (middle)	57.2	48.0	2.66	5.954	0.322	0.0631	9.842	3.06	2.68	7.731	7.112	0.0953	1.51
	62.1	43.1	3.58	8.409	0.348	0.0962	13.876	3.99	3.58	12.590	11.624	0.1472	1.53
	63.4	41.7	4.62	8.941	0.302	0.0889	14.754	4.88	4.64	16.085	15.198	0.1325	1.49
	63.0	42.2	5.83	8.752	0.242	0.0697	14.459	5.98	5.85	20.962	20.258	0.1045	1.50
	60.7	44.4	6.74	7.829	0.189	0.0487	12.919	6.83	6.75	25.236	24.734	0.0755	1.55
Three Pier (right)	57.2	48.0	2.66	5.954	0.320	0.0627	9.842	3.08	2.70	7.770	7.138	0.0951	1.52
	62.1	43.1	3.58	8.409	0.345	0.0957	13.876	4.01	3.61	12.644	11.685	0.1465	1.53
	63.4	41.7	4.62	8.941	0.303	0.0891	14.754	4.87	4.63	16.046	15.163	0.1335	1.50
	63.0	42.2	5.83	8.762	0.242	0.0697	14.459	5.98	5.85	20.962	20.258	0.1052	1.51
	60.7	44.4	6.74	7.829	0.189	0.0486	12.919	6.84	6.76	25.299	24.796	0.0746	1.53

Shape : Triangular nose and tail pier

Width of pier : 4 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four Piers (middle)	57.2	43.0	2.66	5.964	0.306	0.0599	9.542	3.22	2.70	8.065	7.138	0.1099	1.85
	52.1	43.1	3.58	8.409	0.333	0.0920	13.876	4.17	3.52	13.100	11.705	0.1712	1.86
	63.4	41.7	4.62	8.941	0.0868	0.0868	14.754	5.00	4.65	16.558	15.233	0.1588	1.83
	63.0	42.2	5.83	8.762	0.240	0.0692	14.459	6.02	5.82	21.174	20.135	0.1273	1.84
	60.7	44.4	6.74	7.829	0.188	0.0483	12.919	6.88	6.76	25.353	24.796	0.0881	1.82
Four Piers (right)	57.2	43.0	2.66	5.964	0.305	0.0598	9.842	3.23	2.72	8.087	7.165	0.1112	1.86
	52.1	43.1	3.58	8.409	0.334	0.0922	13.876	4.16	3.51	13.071	11.685	0.1704	1.85
	63.4	41.7	4.62	8.941	0.296	0.0869	14.754	4.99	4.64	16.317	15.198	0.1578	1.82
	63.0	42.2	5.83	8.762	0.239	0.0690	14.459	6.04	5.84	21.280	20.237	0.1278	1.85
	60.7	44.4	6.74	7.829	0.186	0.0483	12.919	6.88	6.76	25.353	24.796	0.0896	1.86

Shape : Triangular nose and tail pier

Width of pier : 2 cm

No. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
One pier	57.1	43.1	2.71	5.889	0.347	0.0336	9.718	2.80	2.73	7.193	7.090	0.0306	0.91
	61.1	44.0	3.66	7.992	0.335	0.0456	13.188	3.72	3.66	11.423	11.283	0.0429	0.92
	63.3	41.9	4.63	8.891	0.316	0.0461	14.672	4.65	4.61	15.151	15.040	0.0429	0.93
	62.7	42.4	5.75	8.663	0.247	0.0352	14.295	5.78	5.76	19.852	19.752	0.0314	0.89
	61.0	44.1	6.75	7.947	0.193	0.0253	13.114	6.78	6.77	24.996	24.933	0.0223	0.88
Two piers	57.1	43.1	2.71	5.889	0.346	0.0335	9.718	2.81	2.70	7.208	7.048	0.0318	0.95
	61.1	44.0	3.68	7.992	0.350	0.0460	13.188	3.77	3.68	11.544	11.329	0.0441	0.96
	63.3	41.9	4.63	8.891	0.312	0.0456	14.672	4.70	4.64	15.361	15.146	0.0442	0.97
	62.7	42.4	5.75	8.563	0.246	0.0351	14.295	5.80	5.77	19.953	19.802	0.0323	0.95
	61.0	44.1	6.78	7.947	0.192	0.0251	13.114	6.82	6.80	25.247	25.121	0.0241	0.96

Shape : Triangular nose and tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Three piers (middle)	57.1	45.1	2.71	5.809	0.337	0.0327		2.88	2.73	7.322	7.090	0.0343	1.05
	61.1	44.0	3.68	7.992	0.344	0.0453		3.83	3.70	11.695	11.375	0.0481	1.06
	63.3	41.9	4.63	8.891	0.310	0.0453		4.73	4.64	15.470	15.146	0.0494	1.09
	62.7	42.4	5.75	8.663	0.247	0.0352		5.79	5.74	19.903	19.652	0.0366	1.04
	61.0	44.1	6.78	7.947	0.193	0.0252		6.91	6.78	25.184	24.996	0.0272	1.08
Three piers (right)	57.1	48.1	2.71	5.889	0.339	0.0328		2.87	2.72	7.305	7.076	0.0336	1.03
	61.1	44.0	3.68	7.992	0.343	0.0451		3.84	3.71	11.721	11.399	0.0468	1.04
	63.3	41.9	4.63	8.891	0.310	0.0452		4.74	4.65	15.507	15.181	0.0482	1.07
	62.7	42.4	5.75	8.663	0.247	0.0352		5.79	5.74	19.903	19.652	0.0374	1.06
	61.0	44.1	6.78	7.947	0.193	0.0252		6.79	6.76	25.038	24.871	0.0261	1.03

Shape : Triangular nose and tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2\,\rho V_1^2 A_f$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four piers (middle)	57.1	43.1	2.71	5.889	0.331	0.0320		2.94	2.75	7.426	7.118	0.0365	1.14
	61.1	44.0	3.68	7.992	0.339	0.0446		3.89	3.72	11.852	11.423	0.0512	1.15
	63.3	41.9	4.63	8.891	0.308	0.0450		4.77	4.65	15.618	15.131	0.0522	1.16
	62.7	42.4	5.75	8.663	0.245	0.0349		5.84	5.78	20.157	19.852	0.0391	1.12
	61.0	44.1	6.78	7.947	0.192	0.0231		6.84	6.80	25.373	25.121	0.0253	1.13
Four piers (sight)	57.1	43.1	2.71	5.889	0.332	0.0321		2.93	2.74	7.408	7.104	0.0353	1.10
	61.1	44.0	3.68	7.992	0.341	0.0448		3.87	3.70	11.799	11.375	0.0518	1.16
	63.3	41.9	4.63	8.891	0.307	0.0449		4.78	4.66	15.655	15.217	0.0535	1.19
	62.7	42.4	5.75	8.663	0.246	0.0350		5.82	5.76	20.055	19.752	0.0402	1.15
	61.0	44.1	6.78	7.947	0.192	0.0231		6.84	6.80	25.373	25.121	0.0292	1.26

Shape : Circular nose and tail pier

Width of pier : 4 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2 \rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F_1' (N/m)	F_2' (N/m)	FD (N)	CD
One pier	57.5	47.7	2.68	6.139	0.359	0.0725	10.130	2.82	2.66	7.513	7.303	0.0658	0.91
	63.8	41.3	3.62	9.083	0.394	0.1178	14.988	3.80	3.63	12.949	12.508	0.1061	0.90
	63.1	42.0	4.64	8.826	0.311	0.0901	14.364	4.69	4.61	15.258	14.973	0.0838	0.93
	62.6	42.5	5.77	8.621	0.246	0.0697	14.226	5.79	5.75	19.869	19.667	0.0621	0.89
	60.5	44.6	6.81	7.729	0.157	0.0475	12.754	6.82	6.80	25.111	24.985	0.0414	0.87
Two piers	57.5	47.7	2.68	6.139	0.342	0.0691	10.130	2.96	2.69	7.737	7.338	0.0795	1.15
	63.8	41.3	3.62	9.083	0.380	0.1136	14.988	3.94	3.64	13.269	12.626	0.1295	1.14
	63.1	42.0	4.64	8.826	0.304	0.0883	14.364	4.79	4.65	15.627	15.114	0.1024	1.16
	62.6	42.5	5.77	8.621	0.243	0.0688	14.226	5.86	5.78	20.226	19.818	0.0777	1.13
	60.5	44.6	6.81	7.729	0.243	0.0473	12.754	6.86	6.82	25.364	25.111	0.0529	1.12

Shape : Circular nose and tail pier

Width of pier : 4 cm

No. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	Hz Pw Fe (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1' (N/m)	F2' (N/m)	FD (N)	CD
Three piers(middle)	57.5	47.7	2.68	6.139	0.329	0.0664	10.132	3.08	2.70	7.957	7.351	0.0903	1.36
	63.8	41.3	3.62	9.083	0.367	0.1097	14.983	4.08	3.64	13.623	12.526	0.1503	1.37
	63.1	42.0	4.64	8.826	0.300	0.0870	14.564	4.86	4.65	15.894	15.114	0.1166	1.34
	62.6	42.5	5.77	8.621	0.241	0.0682	14.226	5.91	5.79	20.484	19.869	0.0943	1.39
	60.5	44.6	6.81	7.729	0.185	0.0470	12.754	6.90	6.83	25.620	25.174	0.0648	1.38
Three piers(right)	57.5	47.7	2.68	6.139	0.330	0.0666	10.130	3.07	2.69	7.938	7.338	0.0891	1.34
	63.3	41.3	3.62	9.394	0.369	0.1103	14.988	4.06	3.62	13.371	12.589	0.1514	1.37
	63.1	42.0	4.64	8.826	0.300	0.0872	14.564	4.85	4.64	15.855	15.079	0.1174	1.35
	62.6	42.5	5.77	8.621	0.242	0.0686	14.225	5.88	5.76	20.329	19.718	0.0937	1.37
	60.5	44.6	6.81	7.729	0.185	0.0471	12.754	6.88	5.81	25.492	25.048	0.0653	1.39

Shape : Circular nose and tail pier

Width of pier : 4 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_F$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1' (N/m)	F2' (N/m)	FD (N)	CD
Four piers (middle)	57.5	47.7	2.68	6.139	0.314	0.0633	10.130	3.23	2.74	8.265	7.402	0.1057	1.67
	63.5	41.3	3.62	9.083	0.353	0.1053	14.988	4.25	3.65	14.096	12.645	0.1771	1.68
	63.1	42.0	4.64	8.526	0.293	0.0851	14.564	4.97	4.66	16.326	15.150	0.1403	1.65
	62.6	42.5	5.77	8.621	0.238	0.0674	14.226	5.98	5.80	20.851	19.919	0.1099	1.63
	60.5	44.5	6.81	7.729	0.184	0.0468	12.754	6.93	6.83	25.812	25.274	0.0791	1.69
Four piers (right)	57.5	47.7	2.68	6.139	0.315	0.0635	10.130	3.22	2.72	8.244	7.376	0.1046	1.65
	63.8	41.3	3.62	9.083	0.354	0.1056	14.988	4.24	3.64	14.067	12.626	0.1753	1.67
	63.1	42.0	4.64	8.626	0.293	0.0851	14.564	4.97	4.66	16.326	15.150	0.1412	1.66
	62.6	42.5	5.77	8.621	0.238	0.0676	14.226	5.97	5.79	20.798	19.869	0.1105	1.64
	60.5	44.6	6.81	7.729	0.184	0.0467	12.754	6.94	6.84	25.877	25.237	0.0779	1.67

Shape : Circular nose and tail pier

Width of pier : 2 cm

No. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (M/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F_1' (N/m)	F_2' (N/m)	FD (N)	CD
One pier	57.4	47.8	2.52	6.108	0.375	0.0376	10.079	2.59	2.50	7.300	7.198	0.0301	0.80
	64.0	41.2	3.71	9.146	0.399	0.0600	15.092	3.73	3.72	12.989	12.826	0.0486	0.81
	62.4	42.7	4.68	8.552	0.299	0.0420	14.112	4.72	4.59	15.094	14.953	0.0345	0.82
	62.8	42.3	5.74	8.711	0.251	0.0360	14.375	5.72	5.70	19.592	19.493	0.0295	0.82
	60.4	44.3	6.85	7.643	0.154	0.0231	12.612	6.85	6.84	25.248	25.185	0.0191	0.83
Two piers	57.4	47.8	2.52	6.108	0.367	0.0368	10.079	2.75	2.62	7.378	7.219	0.0313	0.85
	64.0	41.2	3.71	9.146	0.392	0.0590	15.092	3.85	3.73	13.140	12.885	0.0507	0.86
	62.4	42.7	4.68	8.552	0.300	0.0421	14.112	4.71	4.66	15.056	14.873	0.0362	0.86
	62.8	42.3	5.74	8.711	0.250	0.0358	14.375	5.75	5.72	19.741	19.592	0.0301	0.84
	60.4	44.8	6.85	7.643	0.184	0.0231	12.612	6.86	6.84	25.312	25.185	0.0203	0.88

Shape : Circular nose and tail pier

Width of pier : 2 cm

No.of piers	H1 (cm)	H2 (cm)	d_1 (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	P'_1 (N/m)	P'_2 (N/m)	FD (N)	CD
Three piers(Middle)	57.4	47.3	2.62	6.108	0.360	0.0362	10.079	2.80	2.63	7.447	7.230	0.0336	0.93
	64.0	41.2	3.71	9.146	0.388	0.0583	15.092	3.69	3.72	13.231	12.865	0.0548	0.94
	62.4	4.63	4.68	8.552	0.297	0.0418	14.112	4.75	4.68	15.206	14.946	0.0401	0.96
	62.8	42.3	5.74	8.711	0.249	0.0356	14.375	5.78	5.74	19.391	19.691	0.0335	0.94
	60.4	44.5	6.35	7.643	0.183	0.0230	12.612	6.58	6.56	23.440	23.312	0.0214	0.93
Three piers(right)	57.4	47.3	2.62	6.108	0.359	0.0360	10.079	2.81	2.64	7.452	7.241	0.0332	0.92
	64.0	41.2	3.71	9.146	0.390	0.0587	15.092	3.87	3.70	13.135	12.828	0.0542	0.92
	62.4	42.7	4.68	8.552	0.298	0.0420	14.112	4.73	4.66	15.131	14.873	0.0402	0.96
	62.8	42.3	5.74	8.711	0.249	0.0337	14.375	5.77	5.73	19.641	19.641	0.0341	0.96
	60.4	44.6	7.643	0.184	0.183	0.0230	12.612	6.88	6.36	23.440	23.312	0.0218	0.95

Shape : Circular nose and tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (M/s)	1/2 ρ $V_1^2 A_f$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four piers (middle)	57.4	2.62	2.62	6.108	0.351	0.0353	10.079	2.37	2.64	7.553	7.241	0.0370	1.05
	54.0	41.2	3.71	9.145	0.382	0.0575	15.092	3.95	3.72	13.372	12.865	0.0609	1.06
	62.4	42.7	4.58	8.532	0.293	0.0413	14.112	4.81	4.71	15.434	15.056	0.0437	1.06
	62.5	42.3	5.74	8.711	0.247	0.0354	14.373	5.82	5.76	20.094	19.791	0.0382	1.08
	60.4	44.8	6.85	7.643	0.184	0.0231	12.612	6.87	6.84	25.375	25.135	0.0240	1.04
Four pier (right)	57.5	47.8	2.62	6.108	0.350	0.0352	10.079	2.58	2.65	7.569	7.253	0.0378	1.08
	64.0	41.2	3.71	9.146	0.381	0.0573	15.092	3.96	3.73	13.397	12.885	0.0601	1.05
	62.4	42.7	4.68	8.532	0.293	0.0412	14.112	4.82	4.72	15.473	15.094	0.0443	1.08
	62.8	42.3	5.74	8.711	0.247	0.0354	14.373	5.81	5.75	20.043	19.741	0.0378	1.07
	50.4	44.8	6.85	7.643	0.183	0.0230	12.612	5.89	6.86	25.504	25.312	0.0245	1.06

Shape : Circular nose and triangular tail pier

Width of pier : 4 cm

No. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\rho/2\, V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
One pier	57.1	48.0	2.71	5.945	0.344	0.0573	9.810	2.85	2.73	7.335	7.156	0.0565	0.84
	62.9	42.3	3.64	8.713	0.378	0.1084	14.378	3.80	3.66	12.479	12.176	0.0899	0.83
	61.1	44.1	4.81	7.970	0.269	0.0705	13.152	4.89	4.84	15.212	15.011	0.0599	0.85
	5.95	45.6	5.78	7.254	0.0205	0.0490	11.970	5.83	5.80	19.062	18.904	0.0426	0.87
	61.3	43.9	6.92	8.052	0.191	0.0506	13.287	6.95	6.94	26.205	26.076	0.0415	0.82
Two piers	57.1	48.0	2.71	5.945	0.333	0.0550	9.810	2.95	2.74	7.504	7.170	0.0663	1.02
	62.9	42.3	3.64	8.713	0.368	0.1054	14.378	3.91	3.68	12.741	12.217	0.1064	1.01
	61.1	44.1	4.81	7.970	0.257	0.0701	13.152	4.92	4.83	15.335	14.971	0.0722	1.03
	5.95	45.6	5.78	7.254	0.204	0.0486	11.970	5.87	5.82	19.274	19.009	0.0511	1.05
	61.3	43.9	6.92	8.052	0.191	0.0306	13.287	6.96	6.92	26.205	25.948	0.0521	1.03

Shape : Circular nose and triangular tail pier

Width of pier 4 cm

No. of piers	H1 (cm)	$\overline{H2}$ (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F_1' (N/m)	F_2' (N/m)	FD (N)	CD
Three Piers (middle)	57.1	48.0	2.71	5.945	0.323	0.0631	9.810	3.04	2.75	7.672	7.184	0.0726	1.15
	62.9	42.3	3.64	8.713	0.360	0.1033	14.378	3.99	3.66	12.944	12.176	0.1198	1.16
	61.1	44.1	4.81	7.970	0.264	0.0692	13.152	4.98	4.85	15.563	15.031	0.0789	1.14
	59.5	45.6	5.78	7.254	0.204	0.0486	11.970	5.88	5.81	19.327	18.957	0.0559	1.15
	61.3	43.9	6.92	8.052	0.190	0.0503	13.287	7.00	6.94	26.463	26.075	0.0583	1.16
Three Piers (right)	57.1	48.0	2.71	5.945	0.324	0.0633	9.810	3.03	2.74	7.652	7.170	0.0731	1.15
	62.9	42.3	3.64	8.713	0.359	0.1027	14.378	4.01	3.68	12.997	12.217	0.1169	1.16
	61.1	44.1	4.81	7.970	0.265	0.0694	13.152	4.97	4.84	15.541	15.011	0.0794	1.14
	59.5	45.5	5.78	7.254	0.203	0.0483	11.970	5.89	5.82	19.381	19.009	0.0564	1.16
	61.3	43.9	6.92	8.052	0.190	0.0504	13.287	6.98	6.92	26.334	25.948	0.0592	1.17

Shape : Circular nose and triangular tail pier

Width of pier : 4 cm

No. of piers	E1 (cm)	E2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$1/2 \rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four piers (middle)	57.1	43.0	2.71	5.945	0.311	0.0609	9.810	3.15	2.76	7.594	7.198	0.0834	1.37
	62.9	42.3	3.64	8.713	0.347	0.0995	14.378	4.14	3.68	13.353	12.217	0.1373	1.38
	61.1	44.1	4.81	7.970	0.261	0.0685	13.152	5.03	4.84	15.793	15.011	0.0932	1.36
	59.5	45.6	5.78	7.254	0.202	0.0482	11.970	5.92	5.82	19.542	19.009	0.0665	1.38
	61.3	43.9	6.92	8.052	0.189	0.0501	13.287	7.03	6.94	26.658	26.073	0.0676	1.35
Four piers (right)	57.1	43.0	3.845	0.344	0.312	0.0611	9.810	3.14	2.75	7.873	7.184	0.0838	1.37
	62.9	42.3	3.64	8.713	0.346	0.0990	14.378	4.16	3.70	13.410	12.259	0.1381	1.39
	61.1	44.1	4.81	7.970	0.261	0.0684	13.152	5.04	4.85	15.835	15.051	0.0938	1.37
	59.5	45.6	5.78	7.254	0.0202	0.0481	11.970	5.94	5.84	19.649	19.113	0.0652	1.36
	61.3	43.9	6.92	8.052	0.189	0.0501	13.287	7.03	6.94	26.658	26.076	0.0682	1.36

Shape : Circular nose and triangular tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
One pier	56.8	48.3	2.73	5.749	0.340	0.0321	9.457	2.79	2.74	7.019	6.943	0.0231	0.72
	63.1	42.1	3.74	8.814	0.381	0.0552	14.545	3.82	3.75	12.651	12.515	0.0403	0.73
	61.0	44.1	4.83	7.952	0.269	0.0352	13.122	4.87	4.85	15.115	15.035	0.0261	0.74
	59.9	45.3	5.77	7.421	0.212	0.0259	12.246	5.77	5.76	18.863	18.811	0.0181	0.70
	61.6	43.5	6.94	8.217	0.195	0.0254	13.559	6.95	6.94	26.245	26.131	0.0190	0.72
Two piers	56.8	48.3	2.73	5.749	0.339	0.0320	9.487	2.80	2.72	7.035	6.913	0.0243	0.76
	63.1	42.1	3.74	8.814	0.377	0.0546	14.545	3.86	3.77	12.744	12.538	0.0421	0.77
	61.0	44.1	4.83	7.952	0.265	0.0350	13.122	4.90	4.87	15.237	15.115	0.0263	0.75
	59.9	45.3	5.77	7.421	0.212	0.0259	12.246	5.78	5.76	18.914	18.811	0.0201	0.78
	61.6	43.5	6.94	8.217	0.194	0.0252	13.559	6.98	6.97	26.436	26.374	0.0207	0.79

Shape : Circular nose and triangular tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_1$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Three Piers (middle)	56.8	48.3	2.73	5.749	0.332	0.0314	9.487	2.86	2.73	7.134	5.958	0.0263	0.84
	36.1	42.1	3.74	8.814	0.374	0.0342	14.545	3.89	3.75	12.815	12.516	0.0461	0.85
	61.0	44.1	4.83	7.952	0.256	0.0350	13.122	4.90	4.85	15.237	15.085	0.0298	0.85
	59.9	45.3	5.77	7.421	0.211	0.0257	12.246	5.81	5.76	19.071	18.914	0.0231	0.86
	61.5	43.5	6.94	8.217	0.194	0.0262	13.559	6.98	6.96	26.438	26.309	0.0228	0.87
Three Piers (right)	56.8	48.3	2.73	5.749	0.333	0.0315	9.487	2.85	2.74	7.117	6.943	0.0267	0.85
	63.1	42.1	3.74	8.814	0.375	0.0343	14.545	3.88	3.75	12.971	12.495	0.0458	0.84
	61.0	44.1	4.83	7.952	0.268	0.0351	13.122	4.89	4.84	15.196	14.995	0.0294	0.84
	59.9	45.3	5.77	7.421	0.212	0.0258	12.245	5.79	5.76	18.967	18.311	0.0229	0.89
	61.6	43.5	6.94	8.217	0.195	0.0263	13.559	6.97	6.95	26.374	26.245	0.0223	0.85

Shape :Circular nose and triangular tail pier

Width of pier : 2 cm

NO. of piers	H1 (cm)	H2 (cm)	d (cm)	Q (L/s)	V1 (m/s)	$\frac{1}{2}\rho V_1^2 A_p$ (N)	q (L/s/m)	d1 (cm)	d2 (cm)	F1 (N/m)	F2 (N/m)	FD (N)	CD
Four piers (middle)	56.3	48.3	2.73	5.749	0.326	0.0308	9.487	2.91	2.75	7.221	6.973	0.0303	0.99
	53.1	42.1	3.74	8.814	0.368	0.0534	14.545	3.95	3.77	12.963	12.538	0.0518	0.97
	61.0	44.1	4.83	7.952	0.267	0.0349	13.122	4.92	4.85	15.319	15.035	0.0335	0.96
	59.9	45.3	5.77	7.421	0.210	0.0257	12.246	5.82	5.76	19.124	19.914	0.0252	0.98
	61.5	43.5	6.94	8.217	0.194	0.0262	13.559	6.99	6.96	26.503	26.309	0.0249	0.95
Four piers (right)	56.8	48.3	2.73	5.749	0.325	0.0307	9.487	2.92	2.77	7.239	6.985	0.0308	1.00
	53.1	42.1	3.74	8.814	0.369	0.0535	14.545	3.94	3.76	12.938	12.516	0.0523	0.98
	61.0	44.1	4.83	7.952	0.267	0.0349	13.122	4.92	4.85	15.319	15.035	0.0342	0.98
	59.9	45.3	5.77	7.421	0.211	0.0257	12.246	5.81	5.77	19.071	18.863	0.0248	0.96
	51.6	43.5	8.217	0.195	0.194	0.0252	13.559	6.98	6.95	26.438	26.245	0.0252	0.96

Shape: Rectangular nose and tail pier

Width of pier : 4 cm | Width of pier : 2 cm

		Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier		6.201	4.65	2.91	3.20	6.228	3.32	2.73	2.86
		8.436	6.82	3.91	4.32	8.582	3.82	3.70	3.97
		7.072	15.24	4.86	5.21	7.472	9.60	4.67	4.92
		5.086	9.70	5.80	6.15	5.126	14.79	5.53	5.64
		9.468	9.62	6.89	7.38	10.082	4.30	7.02	7.19
Two pier		6.201	3.89	3.04	3.27	6.228	2.41	2.80	2.94
		8.436	5.14	4.03	4.42	8.582	2.96	3.77	4.12
		7.072	7.61	4.92	5.29	7.472	6.59	4.69	4.95
		5.086	6.86	5.83	6.25	5.126	12.47	5.53	5.64
		9.468	6.55	6.92	7.42	10.082	3.09	7.06	7.18
Three piers	Middle	6.201	3.13	3.16	3.37	6.228	2.14	2.83	3.01
		8.436	3.35	4.14	4.46	8.582	2.34	3.84	4.15
		7.072	8.04	4.96	5.34	7.472	5.83	4.71	5.07
		5.086	8.21	5.81	6.29	5.126	5.25	5.54	5.70
		9.468	7.24	6.97	7.42	10.082	4.06	7.06	7.24
	Right	6.201	3.93	3.16	3.43	6.228	2.20	2.82	2.99
		8.436	3.76	4.13	4.40	8.582	2.18	3.85	4.16
		7.072	7.73	4.95	5.39	7.472	5.48	4.71	5.05
		5.086	7.85	5.83	6.32	5.126	3.74	5.54	5.88
		9.468	7.08	6.98	7.38	10.082	3.71	7.05	7.28
Four piers	Middle	6.201	2.32	3.32	3.47	6.228	0.95	2.90	3.03
		8.436	3.09	4.32	4.52	8.582	2.14	3.88	4.24
		7.072	6.02	5.03	5.45	7.472	4.30	4.75	5.11
		5.086	6.32	5.87	6.36	5.126	4.10	5.57	5.97
		9.468	5.45	7.04	7.50	10.082	3.09	7.09	7.40
	Right	6.201	2.58	3.32	3.49	6.228	0.86	2.89	3.00
		8.436	4.02	4.30	4.62	8.582	2.14	3.89	4.23
		7.072	5.93	5.05	5.49	7.472	5.20	4.75	5.17
		5.086	7.00	5.89	6.40	5.126	12.82	5.55	5.95
		9.468	5.45	7.04	7.49	10.082	4.39	7.09	7.45

Shape: Rectangular nose and triangular tail pier

Width of pier : 4 cm — Width of pier : 2 cm

	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	6.292	4.10	2.87	3.10	6.116	5.35	2.84	3.13
	8.254	6.93	3.86	4.23	8.427	6.08	3.78	4.07
	5.482	8.28	4.77	4.98	5.561	10.65	4.73	4.93
	7.082	9.15	5.68	6.04	7.427	15.14	5.70	6.04
	9.534	12.95	7.05	7.33	10.181	9.77	6.92	7.32
Two pier	6.292	2.59	3.00	3.24	6.116	4.39	2.88	3.20
	8.254	3.84	3.98	4.35	8.427	5.98	3.87	4.23
	5.482	4.65	4.82	5.05	5.561	10.32	4.72	4.99
	7.082	7.56	5.70	6.13	7.427	15.24	5.70	6.19
	9.534	5.13	7.08	7.42	10.181	9.95	6.92	7.38
Three piers, Middle	6.292	2.23	3.12	3.37	6.116	3.78	2.94	3.35
	8.254	2.57	4.11	4.45	8.427	5.46	3.88	4.44
	5.482	9.19	4.83	5.18	5.561	7.03	4.75	5.08
	7.082	6.84	5.71	6.23	7.427	10.50	5.72	6.30
	9.534	4.38	7.12	7.53	10.181	7.87	6.95	7.53
Three piers, Right	6.292	2.26	3.12	3.40	6.116	4.71	2.92	3.32
	8.254	3.37	4.10	4.43	8.427	5.96	3.88	4.42
	5.482	8.14	4.84	5.22	5.561	6.62	4.76	5.07
	7.082	5.84	5.72	6.19	7.427	9.71	5.71	6.26
	9.534	3.71	7.12	7.20	10.181	7.35	6.95	7.48
Four piers, Middle	6.292	1.78	3.28	3.49	6.116	4.50	2.99	3.45
	8.254	4.71	4.25	4.68	8.427	5.34	3.93	4.57
	5.482	6.68	4.88	5.30	5.561	6.41	4.78	5.12
	7.082	5.91	5.79	6.35	7.427	7.43	5.74	6.37
	9.534	3.93	7.20	7.66	10.181	7.45	6.99	7.57
Four piers, Right	6.292	2.03	3.27	3.46	6.116	4.80	2.98	3.44
	8.254	4.68	4.26	4.70	8.427	5.48	3.92	4.54
	5.482	7.24	4.87	5.31	5.561	7.85	4.72	5.13
	7.082	6.77	5.79	6.31	7.427	8.94	5.73	6.33
	9.534	5.18	7.19	7.67	10.181	7.17	6.99	7.55

Shape: Rectangular nose and triangular tail pier

		Width of pier : 4 cm				Width of pier : 2 cm			
		Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier		6.292	4.10	2.87	3.10	6.116	5.35	2.84	3.13
		8.254	6.93	3.86	4.23	8.427	6.08	3.78	4.07
		5.482	8.28	4.77	4.98	5.561	10.65	4.73	4.93
		7.082	9.15	5.68	6.04	7.427	15.14	5.70	6.04
		9.534	12.95	7.05	7.33	10.181	9.77	6.92	7.32
Two pier		6.292	2.59	3.00	3.24	6.116	4.39	2.88	3.20
		8.254	3.84	3.98	4.35	8.427	5.98	3.83	4.23
		5.482	4.65	4.82	5.05	5.561	10.32	4.72	4.99
		7.082	7.56	5.70	6.13	7.427	15.24	5.70	6.19
		9.534	5.13	7.08	7.42	10.181	9.95	6.92	7.38
Three piers	middle	6.292	2.23	3.12	3.37	6.136	3.78	2.94	3.35
		8.254	2.57	4.11	4.45	8.427	5.46	3.88	4.44
		5.482	9.19	4.83	5.18	5.561	7.03	4.75	5.08
		7.082	6.84	5.71	6.23	7.427	10.50	5.72	6.30
		9.534	4.38	7.12	7.53	10.181	7.87	6.95	7.53
	right	6.292	2.26	3.12	3.40	6.116	4.71	2.92	3.32
		8.254	3.17	4.10	4.43	8.427	5.96	3.88	4.42
		5.482	8.14	4.84	5.22	5.561	6.62	4.76	5.07
		7.082	5.84	5.72	6.19	7.427	9.71	5.71	6.26
		9.534	3.71	7.12	7.20	10.181	7.35	6.95	7.48
Four piers	middle	6.292	1.78	3.28	3.49	6.116	4.50	2.99	3.45
		8.254	4.71	4.25	4.68	8.427	5.34	3.93	4.57
		5.482	6.68	4.88	5.30	5.561	6.41	4.78	5.12
		7.082	5.93	5.79	6.35	7.427	7.43	5.74	6.37
		9.534	3.93	7.20	7.66	10.181	7.45	6.99	7.57
	right	6.292	2.03	3.27	3.46	6.116	4.80	2.98	3.44
		8.254	4.68	4.26	4.70	8.427	5.48	3.92	4.54
		5.482	7.24	4.87	5.33	5.561	7.85	4.72	5.13
		7.082	6.77	5.79	6.31	7.427	8.94	5.73	6.33
		9.534	5.18	7.19	7.67	10.181	7.17	6.99	7.55

Shape: Rectangular nose and triangular tail pier

		Width of pier : 4 cm				Width of pier : 2 cm		
		Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier		6.292	4.10	2.87	3.10	6.116	5.35	2.84	3.13
		8.254	6.93	3.86	4.23	8.427	6.08	3.78	4.07
		5.482	8.28	4.77	4.98	5.561	10.65	4.73	4.93
		7.082	9.15	5.68	6.04	7.427	15.14	5.70	6.04
		9.534	12.95	7.05	7.33	10.181	9.77	6.92	7.32
Two pier		6.292	2.59	3.00	3.24	6.116	4.39	2.88	3.20
		8.254	3.84	3.98	4.35	8.427	5.98	3.83	4.23
		5.482	4.65	4.82	5.05	5.561	10.32	4.72	4.99
		7.082	7.56	5.70	6.13	7.427	15.24	5.70	6.19
		9.534	5.13	7.08	7.42	10.181	9.95	6.92	7.38
Three piers	Middle	6.292	2.23	3.12	3.37	6.116	3.78	2.94	3.35
		8.254	2.57	4.11	4.45	8.427	5.46	3.88	4.44
		5.482	9.19	4.83	5.18	5.561	7.03	4.75	5.08
		7.082	6.84	5.71	6.23	7.427	10.50	5.72	6.30
		9.534	4.38	7.12	7.53	10.181	7.87	6.95	7.53
	Right	6.292	2.26	3.32	3.40	6.116	4.71	2.92	3.32
		8.254	3.17	4.10	4.43	8.427	5.96	3.88	4.42
		5.482	8.14	4.84	5.22	5.561	6.62	4.76	5.07
		7.082	5.84	5.72	6.19	7.427	9.71	5.71	6.26
		9.534	3.71	7.12	7.20	10.181	7.35	6.95	7.48
Four piers	Middle	6.292	1.78	3.28	3.49	6.116	4.50	2.99	3.45
		8.254	4.71	4.25	4.68	8.427	5.34	3.93	4.57
		5.482	6.68	4.88	5.30	5.561	6.41	4.78	5.12
		7.082	5.93	5.79	6.35	7.427	7.43	5.74	6.37
		9.534	3.93	7.20	7.66	10.181	7.45	6.99	7.57
	Right	6.292	2.03	3.27	3.46	6.116	4.80	2.98	3.44
		8.254	4.68	4.26	4.70	8.427	5.48	3.92	4.54
		5.482	7.24	4.87	5.33	5.561	7.85	4.72	5.13
		7.082	6.77	5.79	6.31	7.427	8.94	5.73	6.33
		9.534	5.18	7.19	7.67	10.181	7.17	6.99	7.55

TABLE D3

The results of computer program for triangular nose and tail pier

Shape: Triangular nose and tail pier

Width of pier : 4 cm — Width of pier : 2 cm

	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	5.964	4.56	2.80	3.01	5.889	7.77	2.80	3.08
	8.409	6.43	3.72	4.16	7.992	9.47	3.72	4.09
	8.941	9.02	4.73	5.29	8.891	12.97	4.65	5.14
	8.762	11.12	5.87	6.52	8.663	8.67	5.78	6.16
	7.829	10.32	6.75	7.27	7.947	7.96	6.78	7.13
Two pier	5.964	2.57	2.93	3.08	5.889	7.59	2.83	3.13
	8.409	3.82	3.85	4.27	7.992	8.93	3.77	4.19
	8.941	7.19	4.78	5.41	8.891	9.65	4.70	5.18
	8.762	9.29	5.92	6.60	8.663	8.67	5.80	6.19
	7.829	8.48	6.79	7.39	7.947	7.20	6.82	7.18
Three piers — middle	5.964	2.39	3.06	3.21	5.889	5.97	2.88	3.19
	8.409	2.93	3.99	4.35	7.992	6.96	3.83	4.27
	8.941	5.56	4.88	5.53	8.891	8.51	4.73	5.29
	8.762	8.45	5.94	6.73	8.663	10.57	5.79	6.32
	7.829	7.88	6.83	7.49	7.947	8.15	6.81	7.33
Three piers — right	5.964	2.57	3.08	3.25	5.839	6.80	2.87	3.20
	8.409	2.82	4.01	4.37	7.992	6.99	3.84	4.30
	8.941	5.70	4.87	5.48	8.891	8.63	4.74	5.32
	8.762	8.79	5.98	6.69	8.663	11.22	5.79	6.31
	7.829	7.85	6.86	7.48	7.947	8.53	6.79	7.35
Four piers — middle	5.964	2.66	3.22	3.40	5.889	5.16	2.94	3.32
	8.409	2.52	4.17	4.54	7.992	6.09	3.89	4.43
	8.941	5.22	5.00	5.59	8.891	7.24	4.77	5.40
	8.762	8.29	6.02	6.81	8.663	8.23	5.84	6.47
	7.829	7.02	6.88	7.57	7.947	6.62	6.84	7.33
Four piers — right	5.964	2.58	3.23	3.42	5.889	5.41	2.93	3.33
	8.409	2.42	4.16	4.49	7.992	6.02	3.87	4.41
	8.941	5.18	4.99	5.57	8.891	6.85	4.78	5.38
	8.762	7.47	6.04	6.76	8.663	8.43	5.82	6.44
	7.829	7.00	6.88	7.56	7.947	6.63	6.84	7.37

Shape: Triangular nose and tail pier

	Width of pier : 4 cm				Width of pier : 2 cm			
	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	5.964	4.56	2.80	3.01	5.889	7.77	2.80	3.08
	8.409	6.43	3.72	4.16	7.992	9.47	3.72	4.09
	8.941	9.02	4.73	5.29	8.891	12.97	4.65	5.14
	8.762	11.12	5.87	6.52	8.663	8.67	5.78	6.16
	7.829	10.32	6.75	7.27	7.947	7.96	6.78	7.13
Two pier	5.964	2.57	2.93	3.08	5.889	7.59	2.81	3.13
	8.409	3.82	3.85	4.27	7.992	8.93	3.77	4.19
	8.941	7.19	4.78	5.41	8.891	9.65	4.70	5.18
	8.762	9.29	5.92	6.60	8.663	8.67	5.80	6.19
	7.829	8.48	6.79	7.39	7.947	7.20	6.82	7.18
Three piers, middle	5.964	2.39	3.06	3.21	5.889	5.97	2.88	3.19
	8.409	2.93	3.99	4.35	7.992	6.96	3.83	4.27
	8.941	5.56	4.88	5.53	8.891	8.51	4.73	5.29
	8.762	8.45	5.94	6.73	8.663	10.57	5.79	6.32
	7.829	7.88	6.83	7.49	7.947	8.15	6.81	7.33
Three piers, right	5.964	2.57	3.08	3.25	5.839	6.80	2.87	3.20
	8.409	2.82	4.01	4.37	7.992	6.99	3.84	4.30
	8.941	5.70	4.87	5.48	8.891	8.63	4.74	5.32
	8.762	8.79	5.98	6.69	8.663	11.22	5.79	6.31
	7.829	7.85	6.84	7.48	7.947	8.53	6.79	7.35
Four piers, middle	5.964	2.66	3.22	3.40	5.889	5.16	2.94	3.32
	8.409	2.52	4.17	4.54	7.992	6.09	3.89	4.43
	8.941	5.22	5.00	5.59	8.891	7.24	4.77	5.40
	8.762	8.29	6.02	6.81	8.663	8.23	5.64	6.47
	7.829	7.02	6.88	7.57	7.947	6.62	6.84	7.33
Four piers, right	5.964	2.58	3.23	3.42	5.889	5.41	2.93	3.33
	8.409	2.42	4.16	4.49	7.992	6.02	3.87	4.41
	8.941	5.18	4.99	5.57	8.891	6.85	4.78	5.38
	8.762	7.47	6.04	6.76	8.663	8.43	5.82	6.44
	7.829	7.00	6.88	7.56	7.947	6.69	6.84	7.37

Shape: Triangular nose and tail pier

Width of pier : 4 cm Width of pier : 2 cm

	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	5.964	4.56	2.80	3.01	5.889	7.77	2.80	3.08
	8.409	6.43	3.72	4.16	7.992	9.47	3.72	4.09
	8.941	9.02	4.73	5.29	8.891	12.97	4.65	5.14
	8.762	11.12	5.87	6.52	8.663	8.67	5.78	6.16
	7.829	10.32	6.75	7.27	7.947	7.96	6.78	7.13
Two pier	5.964	2.57	2.93	3.08	5.889	7.59	2.83	3.13
	8.409	3.82	3.85	4.27	7.992	8.93	3.77	4.19
	8.941	7.19	4.78	5.41	8.891	9.65	4.70	5.18
	8.762	9.29	5.92	6.60	8.663	8.67	5.80	6.19
	7.829	8.48	6.79	7.39	7.947	7.20	6.82	7.18
Three piers Middle	5.964	2.39	3.06	3.21	5.889	5.97	2.88	3.19
	8.409	2.93	3.99	4.35	7.992	6.96	3.83	4.27
	8.941	5.56	4.88	5.51	8.891	8.51	4.73	5.29
	8.762	8.45	5.94	6.73	8.663	10.57	5.79	6.32
	7.829	7.88	6.83	7.49	7.947	8.15	6.81	7.33
Three piers Right	5.964	2.57	3.08	3.25	5.839	6.80	2.87	3.20
	8.409	2.82	4.01	4.37	7.992	6.99	3.84	4.30
	8.941	5.70	4.87	5.48	8.891	8.63	4.74	5.32
	8.762	8.79	5.98	6.69	8.663	11.22	5.79	6.31
	7.829	7.85	6.84	7.48	7.947	8.53	6.79	7.35
Four piers Middle	5.964	2.66	3.22	3.40	5.889	5.16	2.94	3.32
	8.409	2.52	4.17	4.54	7.992	6.09	3.89	4.43
	8.941	5.22	5.00	5.59	8.891	7.24	4.77	5.40
	8.762	8.29	6.02	6.81	8.663	8.23	5.84	6.47
	7.829	7.02	6.88	7.57	7.947	6.62	6.84	7.33
Four piers Right	5.964	2.58	3.23	3.42	5.889	5.41	2.93	3.33
	8.409	2.42	4.16	4.49	7.992	6.02	3.87	4.41
	8.941	5.18	4.99	5.57	8.891	6.85	4.78	5.38
	8.762	7.47	6.04	6.76	8.663	8.43	5.82	6.44
	7.829	7.00	6.88	7.56	7.947	6.63	6.84	7.37

Shape: Circular nose and tail pier

Width of pier : 4 cm — Width of pier : 2 cm

	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	6,139	6,34	2,82	3.18	6,108	5.73	2.79	2,80
	9.083	5.75	3,80	4,27	9.146	7.38	3.78	4.07
	8,826	9.38	4.69	5.22	8.552	12.36	4.72	5.04
	8,621	14.46	5.79	6.20	8.711	12.48	5.72	5.98
	7.729	8.29	6.82	7.24	7.643	9.79	6.85	7.03
Two pier	6.139	4.18	2.96	3.28	6.108	4.97	2.75	2.86
	9.083	4.03	3.94	4.36	9.146	4.86	3.85	4.12
	8,826	7.37	4.79	5.30	8.552	14.69	4.71	5.11
	8,621	6,25	5.86	6.32	8.711	7.66	5.75	6.04
	7.729	6.36	6.86	7.38	7.643	8,21	6.86	7.11
Three piers middle	6.139	2.85	3.08	3.38	6.108	3.76	2.80	2.94
	9.083	2.71	4.08	4.48	9.146	4.91	3.89	4.16
	8,826	6.83	4.86	5.40	8.552	7.56	4.75	5.18
	8,621	6,21	5.91	6.44	8.711	6.25	5.78	6.11
	7.729	5.45	6.90	7.49	7.643	6.51	6.88	7.19
Three piers right	6.139	3.42	3.07	3.39	6.108	3.54	2.81	2.97
	9.083	2.66	4.06	4.49	9.146	5.70	3.87	4.14
	8,826	5.89	4.85	5.38	8.552	10.76	4.73	5.20
	8,621	7.11	5.88	6,47	8.711	7.45	5.77	6,11
	7.729	6,11	6,88	7.52	7.643	6.75	6,88	7,18
Four piers middle	6,139	2,16	3.23	3.51	6.108	2,40	2,87	3,02
	9.083	1,93	4.25	4,60	9.146	4.15	3.95	4.20
	8,826	4,67	4.97	5.51	8.552	6,32	4,81	5.26
	8,621	4,46	5.98	6.62	8,711	5.48	5.82	6.15
	7.729	5.15	6.93	7.63	7.643	8.69	6.87	7.24
Four piers right	6,139	2.31	3.22	3.50	6,108	2.46	2.88	3.03
	9,083	2.11	4,24	4.58	9.146	3.49	3.96	4.24
	8,826	4.52	4.97	5.49	8.552	6.29	4.82	5.24
	8.621	4.86	5.97	6.59	8.711	7.09	5.83	6.15
	7.729	5.34	6.94	7.63	7.643	7.57	6.89	7.28

Shape: Circular nose and tail pier

	Width of pier : 4 cm				Width of pier : 2 cm			
	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	6.139	6.34	2.82	3.18	6.108	5.73	2.79	2.80
	9.083	5.75	3.80	4.27	9.146	7.38	3.78	4.07
	8.826	9.38	4.69	5.22	8.552	12.36	4.72	5.04
	8.621	14.46	5.79	6.20	8.711	12.48	5.72	5.98
	7.729	8.29	6.82	7.24	7.643	9.79	6.85	7.03
Two pier	6.139	4.18	2.96	3.28	6.108	4.97	2.75	2.86
	9.083	4.03	3.94	4.36	9.146	4.86	3.85	4.12
	8.826	7.37	4.79	5.30	8.552	14.69	4.71	5.11
	8.621	6.25	5.86	6.32	8.711	7.66	5.75	6.04
	7.729	6.36	6.86	7.38	7.643	8.21	6.86	7.11
Three piers, middle	6.139	2.85	3.08	3.38	6.108	3.76	2.80	2.94
	9.083	2.71	4.08	4.48	9.146	4.91	3.89	4.16
	8.826	6.33	4.86	5.40	8.552	7.56	4.75	5.18
	8.621	6.21	5.91	6.44	8.711	6.25	5.78	6.11
	7.729	5.45	6.90	7.49	7.643	6.51	6.88	7.19
Three piers, right	6.139	3.42	3.07	3.39	6.108	3.54	2.81	2.97
	9.083	2.66	4.06	4.49	9.146	5.70	3.87	4.18
	8.826	5.89	4.85	5.38	8.552	10.76	4.73	5.20
	8.621	7.11	5.88	6.47	8.711	7.45	5.77	6.11
	7.729	6.11	6.88	7.52	7.643	6.75	6.88	7.18
Four piers, middle	6.139	2.16	3.23	3.51	6.108	2.40	2.87	3.02
	9.083	1.93	4.25	4.60	9.146	4.15	3.95	4.20
	8.826	4.67	4.97	5.51	8.552	6.32	4.81	5.26
	8.621	4.46	5.98	6.62	8.711	5.48	5.82	6.15
	7.729	5.15	6.93	7.63	7.643	8.69	6.87	7.24
Four piers, right	6.139	2.31	3.22	3.50	6.108	2.46	2.88	3.03
	9.083	2.11	4.24	4.58	9.146	3.49	3.96	4.24
	8.826	4.52	4.97	5.49	8.552	6.29	4.82	5.24
	8.621	4.86	5.97	6.59	8.711	7.09	5.81	6.35
	7.729	5.34	6.94	7.61	7.643	7.57	6.89	7.28

Shape: Circular nose and tail pier

Width of pier : 4 cm — Width of pier : 2 cm

	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	6.139	6.34	2.82	3.18	6.108	5.73	2.79	2.80
	9.083	5.75	3.80	4.27	9.146	7.38	3.78	4.07
	8.826	9.38	4.69	5.22	8.552	12.36	4.72	5.04
	8.621	14.46	5.79	6.20	8.711	12.48	5.72	5.98
	7.729	8.29	6.82	7.24	7.643	9.79	6.85	7.03
Two pier	6.139	4.18	2.96	3.28	6.108	4.97	2.75	2.86
	9.083	4.03	3.94	4.36	9.146	4.86	3.85	4.12
	8.826	7.37	4.79	5.30	8.552	14.69	4.71	5.11
	8.621	6.25	5.86	6.32	8.711	7.66	5.75	6.04
	7.729	6.36	6.86	7.38	7.643	8.21	6.86	7.11
Three piers — Middle	6.139	2.85	3.08	3.38	6.108	3.76	2.80	2.94
	9.083	2.71	4.08	4.48	9.146	4.91	3.89	4.16
	8.826	6.03	4.86	5.40	8.552	7.56	4.75	5.18
	8.621	6.21	5.91	6.44	8.711	6.25	5.78	6.11
	7.729	5.45	6.90	7.49	7.643	6.51	6.88	7.19
Three piers — Right	6.139	3.42	3.07	3.39	6.108	3.54	2.81	2.97
	9.083	2.66	4.06	4.49	9.146	5.70	3.87	4.14
	8.826	5.89	4.85	5.38	8.552	10.76	4.73	5.20
	8.621	7.11	5.88	6.47	8.711	7.45	5.77	6.11
	7.729	6.11	6.88	7.52	7.643	6.75	6.88	7.18
Four piers — Middle	6.139	2.16	3.23	3.51	6.108	2.40	2.87	3.02
	9.083	1.93	4.25	4.60	9.146	4.15	3.25	4.20
	8.826	4.67	4.97	5.51	8.552	6.32	4.81	5.26
	8.621	4.46	5.98	6.62	8.711	5.48	5.82	6.15
	7.729	5.15	6.93	7.63	7.643	8.69	6.87	7.24
Four piers — Right	6.139	2.31	3.22	3.50	6.108	2.46	2.88	3.03
	9.083	2.11	4.24	4.58	9.146	3.49	3.96	4.24
	8.826	4.52	4.97	5.49	8.552	6.29	4.82	5.24
	8.621	4.86	5.97	6.59	8.711	7.09	5.81	6.15
	7.729	5.34	6.94	7.61	7.643	7.57	6.89	7.28

TABLE D5

The results of computer program for circular nose and triangular tail pier

Shape: Circular nose and triangular tail pier

	Width of pier: 4 cm				Width of pier: 2 cm			
	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	5.945	4.46	2.85	3.12	5.749	3.57	2.79	2.96
	8.713	5.35	3.80	4.17	8.814	6.27	3.82	4.08
	7.970	8.18	4.89	5.22	7.952	9.14	4.87	5.11
	7.254	9.60	5.83	6.24	7.421	6.81	5.77	5.96
	8.052	7.31	6.96	7.27	8.217	9.19	6.95	7.14
Two pier	5.945	2.91	2.95	3.19	5.749	4.71	2.80	2.99
	8.713	3.51	3.91	4.24	8.814	4.96	3.86	4.11
	7.970	7.33	4.92	5.28	7.952	5.69	4.90	5.15
	7.254	7.70	5.87	6.36	7.421	10.65	5.78	5.98
	8.052	7.49	6.96	7.39	8.217	6.42	6.98	7.19
Three piers – Middle	5.945	2.13	3.04	3.26	5.749	2.95	2.86	3.03
	8.713	2.82	3.99	4.31	8.814	4.21	3.89	4.14
	7.970	5.42	4.98	5.36	7.952	5.34	4.90	5.17
	7.254	7.34	5.88	6.43	7.421	4.68	5.81	5.99
	8.052	5.97	7.00	7.46	8.217	6.51	6.98	7.18
Three piers – Right	5.945	2.28	3.03	3.25	5.749	3.01	2.85	3.05
	8.713	2.74	4.01	4.35	8.814	3.76	3.88	4.13
	7.970	5.97	4.97	5.39	7.952	7.08	4.89	5.14
	7.254	6.88	5.89	6.43	7.421	12.04	5.72	6.02
	8.052	7.07	6.98	7.46	8.217	6.58	6.97	7.17
Four piers – Middle	5.945	3.41	3.15	3.26	5.749	2.30	2.91	3.10
	8.713	1.86	4.14	4.45	8.814	2.60	3.95	4.18
	7.970	5.33	5.03	5.41	7.952	5.82	4.92	5.19
	7.254	6.75	5.92	6.55	7.421	3.31	5.82	6.09
	8.052	6.00	7.03	7.54	8.217	5.69	6.99	7.24
Four piers – Right	5.945	1.95	3.14	3.40	5.749	2.30	2.92	3.13
	8.713	1.83	4.16	4.44	8.814	2.43	3.94	4.16
	7.970	5.01	5.04	5.45	7.952	5.15	4.92	5.18
	7.254	5.54	5.94	6.51	7.421	4.56	5.81	6.07
	8.052	5.59	7.03	7.55	8.217	6.36	6.98	7.22

Shape: Circular nose and triangular tail pier

	Width of pier : 4 cm				Width of pier : 2 cm			
	Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier	5.945	4.46	2.85	3.12	5.749	3.57	2.79	2.96
	8.713	5.35	3.80	4.17	8.814	6.27	3.82	4.08
	7.970	8.18	4.89	5.22	7.952	9.14	4.87	5.11
	7.254	9.60	5.83	6.24	7.421	6.81	5.77	5.96
	8.052	7.31	6.96	7.27	8.217	2.19	6.95	7.14
Two pier	5.945	2.91	2.95	3.19	5.749	4.71	2.80	2.99
	8.713	3.51	3.91	4.24	8.814	4.96	3.86	4.11
	7.970	7.31	4.92	5.28	7.952	5.69	4.90	5.15
	7.254	7.70	5.87	6.36	7.421	10.65	5.78	5.98
	8.052	7.43	6.96	7.39	8.217	6.42	6.98	7.19
Three piers Middle	5.945	2.13	3.04	3.26	5.749	2.95	2.86	3.03
	8.713	2.82	3.99	4.31	8.814	4.21	3.89	4.14
	7.970	5.42	4.98	5.36	7.952	5.34	4.90	5.17
	7.254	7.14	5.88	6.43	7.421	4.68	5.81	5.99
	8.052	5.97	7.00	7.46	8.217	6.53	6.98	7.18
Three piers Right	5.945	2.78	3.03	3.25	5.749	3.01	2.85	3.05
	8.713	2.74	4.01	4.35	8.814	3.76	3.88	4.13
	7.970	5.97	4.97	5.39	7.952	7.08	4.89	5.14
	7.254	6.88	5.89	6.43	7.421	12.04	5.79	6.02
	8.052	7.07	6.98	7.46	8.217	6.58	6.97	7.17
Four piers Middle	5.945	1.41	3.15	3.26	5.749	2.30	2.91	3.10
	8.713	1.86	4.14	4.45	8.814	2.60	3.95	4.18
	7.970	5.33	5.03	5.41	7.952	5.82	4.92	5.19
	7.254	6.75	5.92	6.55	7.421	3.31	5.82	6.09
	8.052	6.00	7.03	7.54	8.217	5.69	6.99	7.24
Four piers Right	5.945	1.95	3.14	3.40	5.749	2.30	2.92	3.13
	8.713	1.83	4.16	4.44	8.814	2.43	3.94	4.16
	7.970	5.01	5.04	5.45	7.952	5.15	4.92	5.18
	7.254	5.54	5.94	6.51	7.421	4.56	5.81	6.07
	8.052	5.59	7.03	7.55	8.217	6.36	6.98	7.22

Shape: Circular nose and triangular tail pier

Width of pier : 4 cm — Width of pier : 2 cm

		Q m3/s	X cm	d1 cm	d01 cm	Q	x	d1	d01
One pier		5.945	4.46	2.85	3.12	5.749	3.57	2.79	2.96
		8.713	5.35	3.80	4.17	8.814	6.27	3.82	4.08
		7.970	8.18	4.89	5.22	7.952	9.14	4.87	5.11
		7.254	9.60	5.83	6.24	7.421	6.81	5.77	5.96
		8.052	7.31	6.96	7.27	8.217	9.19	6.95	7.14
Two pier		5.945	2.91	2.95	3.19	5.749	4.71	2.80	2.99
		8.713	3.51	3.91	4.24	8.814	4.96	3.86	4.11
		7.970	7.31	4.92	5.28	7.952	5.69	4.90	5.15
		7.254	7.70	5.87	6.36	7.421	10.65	5.78	5.98
		8.052	7.43	6.96	7.39	8.217	6.42	6.98	7.19
Three piers	middle	5.945	2.13	3.04	3.26	5.749	2.95	2.86	3.03
		8.713	2.82	3.99	4.31	8.814	4.21	3.89	4.14
		7.970	5.42	4.98	5.36	7.952	5.34	4.90	5.17
		7.254	9.14	5.88	6.43	7.421	4.68	5.81	5.99
		8.052	5.97	7.00	7.46	8.217	6.53	6.98	7.18
	right	5.945	2.28	3.03	3.25	5.749	3.01	2.85	3.05
		8.713	2.74	4.01	4.35	8.814	3.76	3.88	4.13
		7.970	5.97	4.97	5.39	7.952	7.08	4.89	5.14
		7.254	6.88	5.89	6.43	7.421	12.04	5.79	6.02
		8.052	7.07	6.98	7.46	8.217	6.58	6.97	7.17
Four piers	middle	5.945	1.41	3.15	3.26	5.749	2.30	2.91	3.10
		8.713	1.86	4.14	4.45	8.814	2.60	3.95	4.18
		7.970	5.33	5.03	5.43	7.952	5.82	4.92	5.19
		7.254	6.75	5.92	6.55	7.421	3.31	5.82	6.09
		8.052	6.00	7.03	7.54	8.217	5.69	6.99	7.24
	right	5.945	1.95	3.14	3.40	5.749	2.30	2.92	3.13
		8.713	1.83	4.16	4.44	8.814	2.43	3.94	4.16
		7.970	5.01	5.04	5.45	7.952	5.15	4.92	5.18
		7.254	5.54	5.94	6.51	7.421	4.56	5.81	6.07
		8.052	5.59	7.03	7.55	8.217	6.36	6.98	7.22

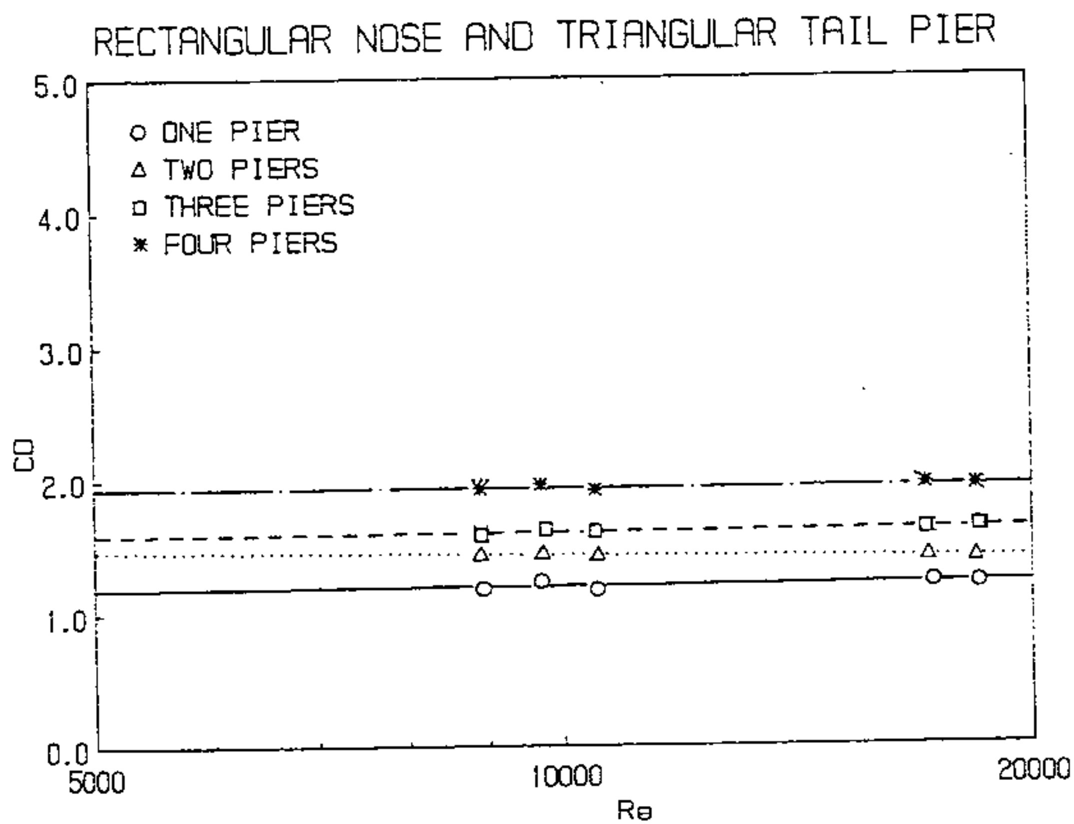

FIG. E.1. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (4 cm).

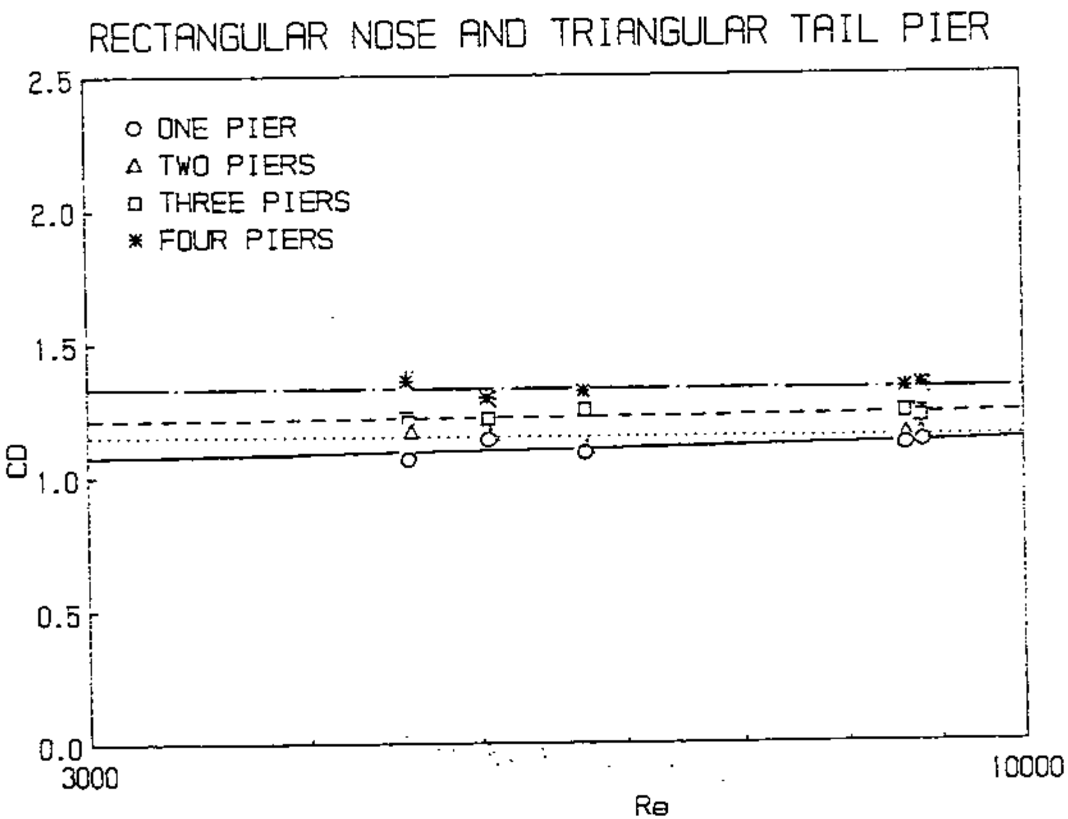

FIG. E.2. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (2 cm).

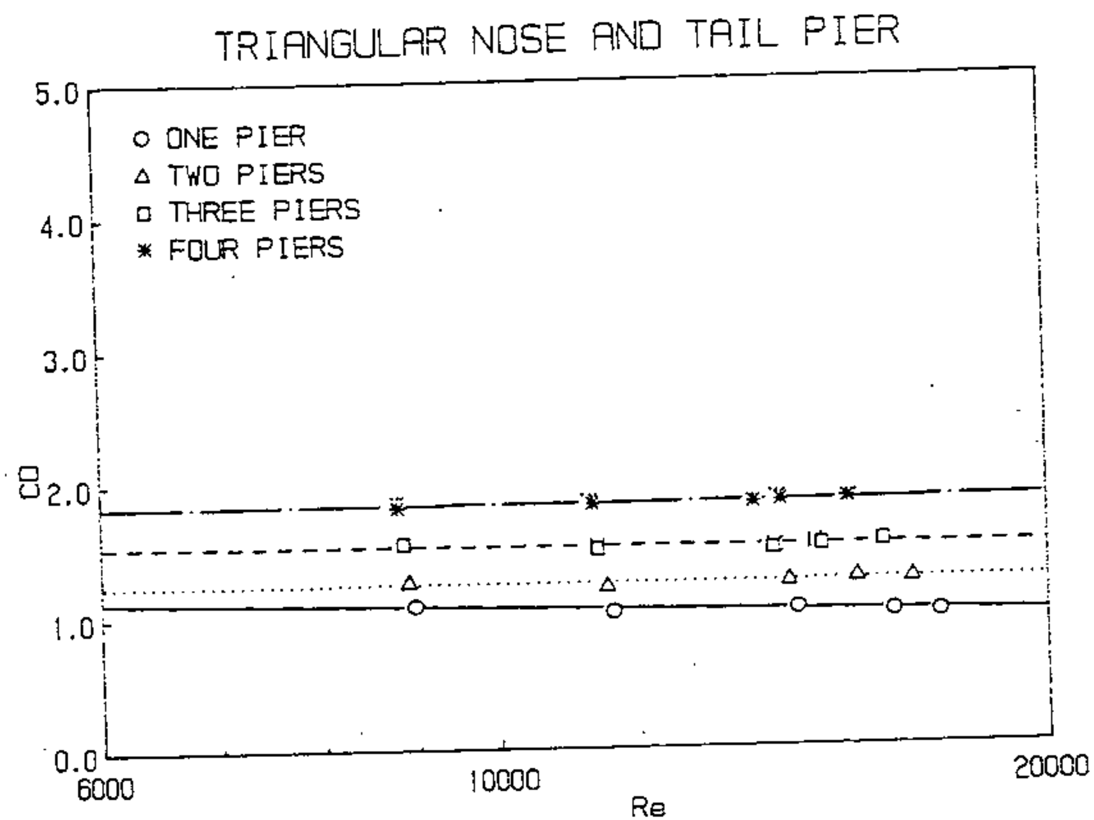

FIG. E.3. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (4 cm).

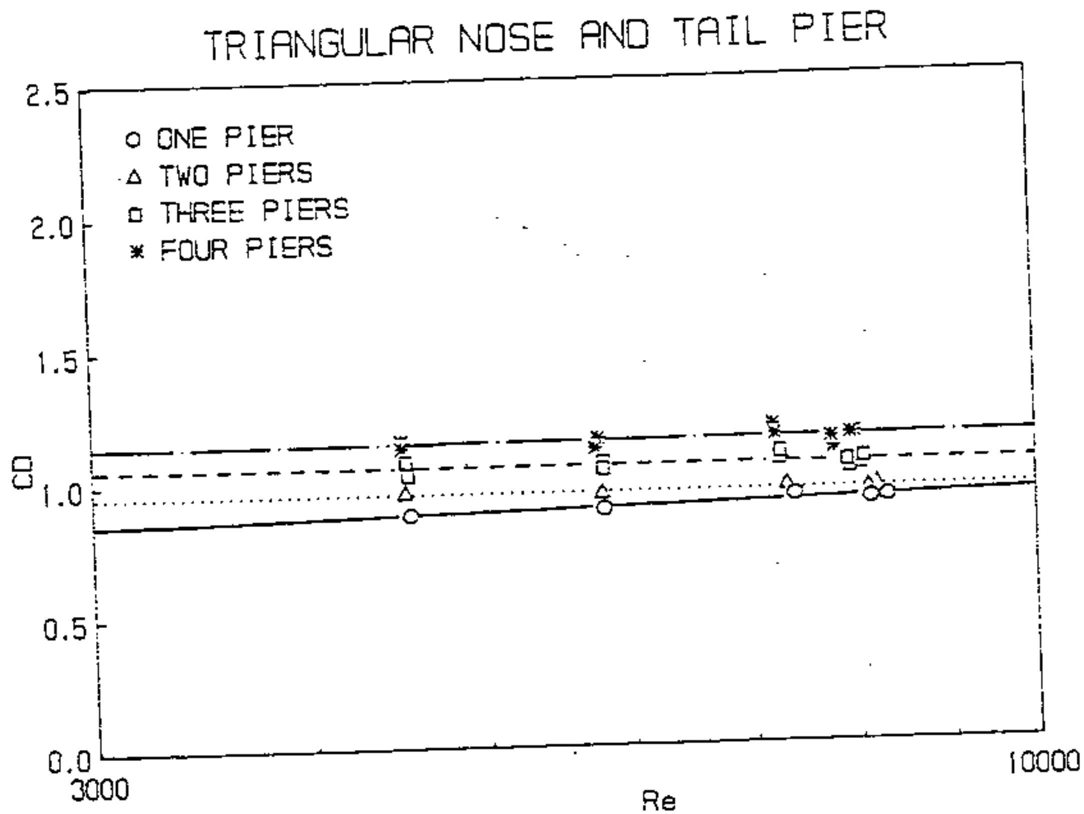

FIG. E.4. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (2 cm).

CIRCULAR NOSE AND TAIL PIER

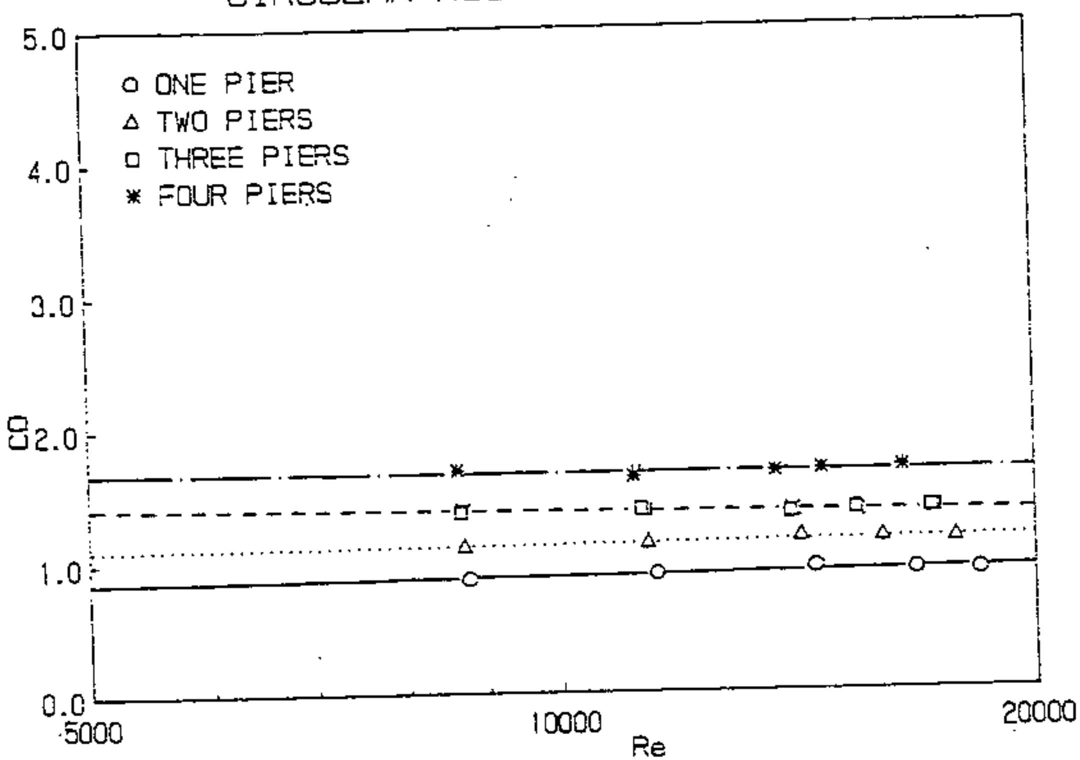

FIG. E.5. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (4 cm).

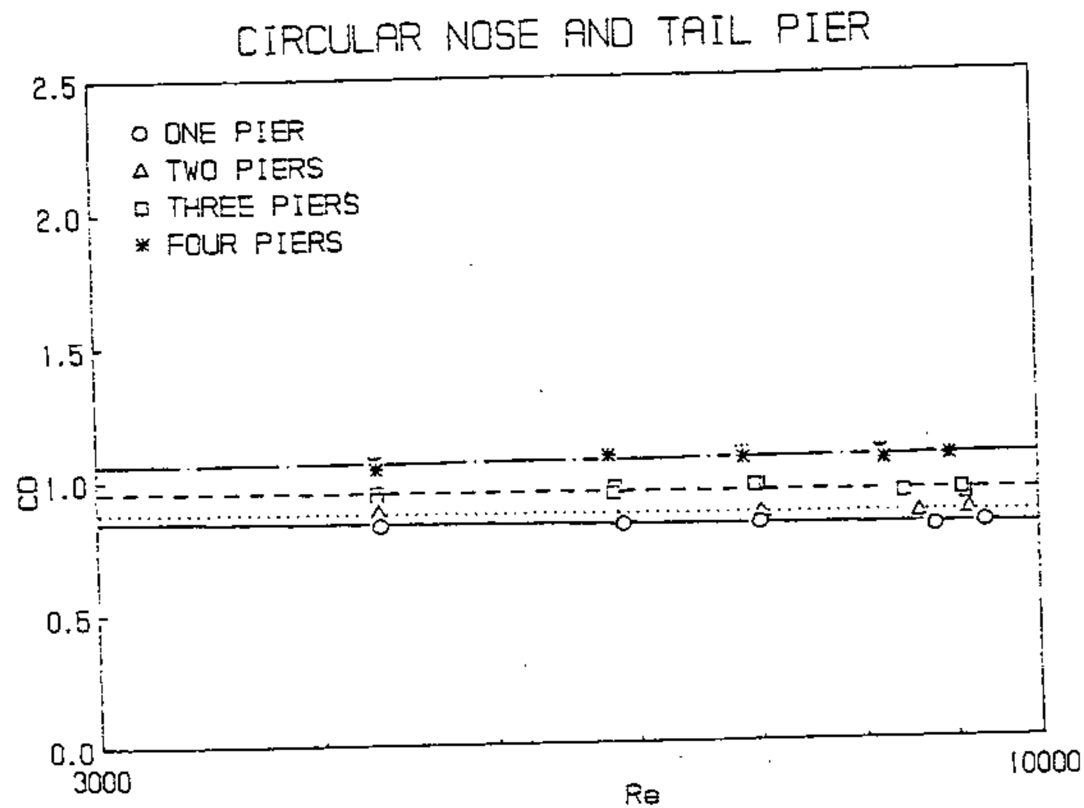

FIG E.6. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (2 cm).

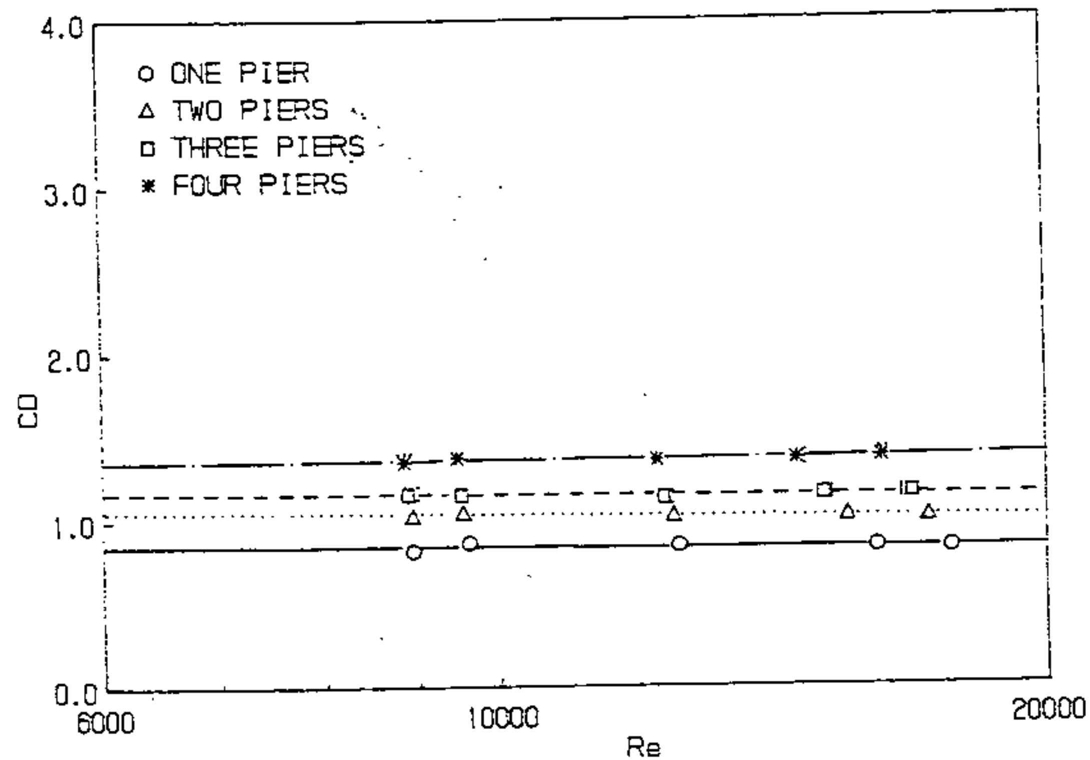

FIG E.7. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (4 cm).

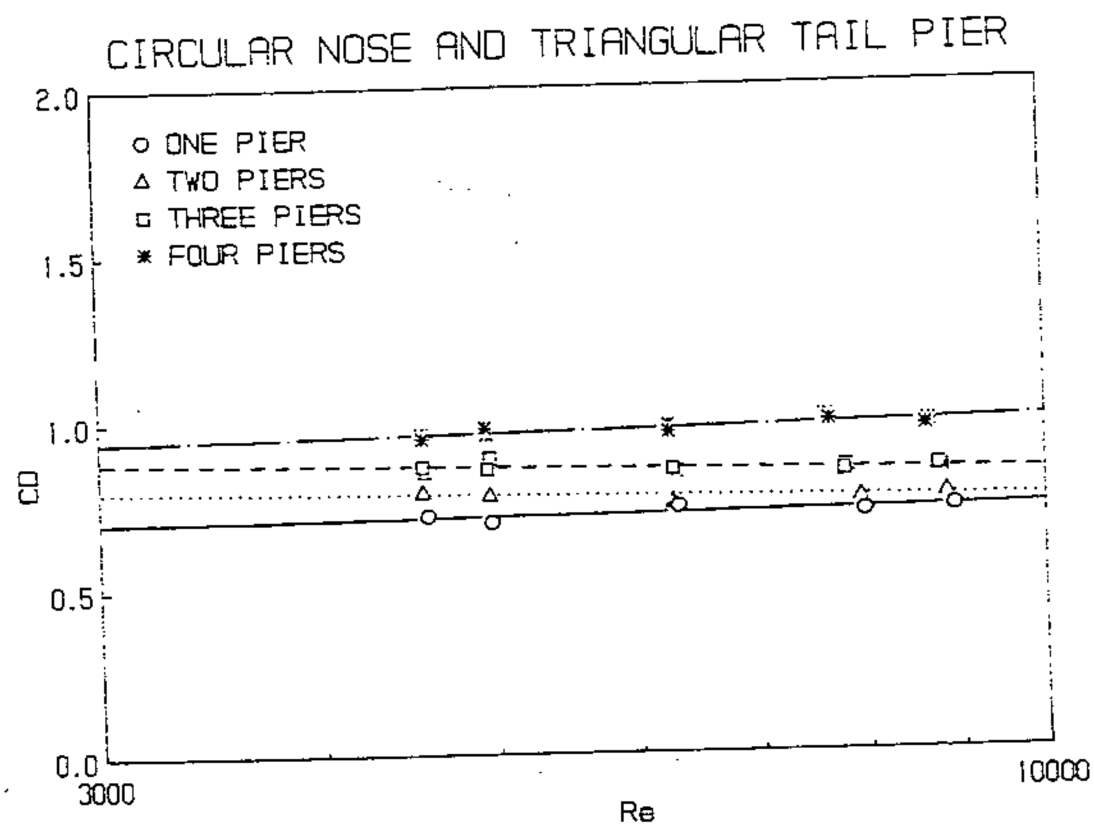

FIG E.8. Relationship Between Drag Coefficient and Reynolds Number for Pier Width (2 cm).

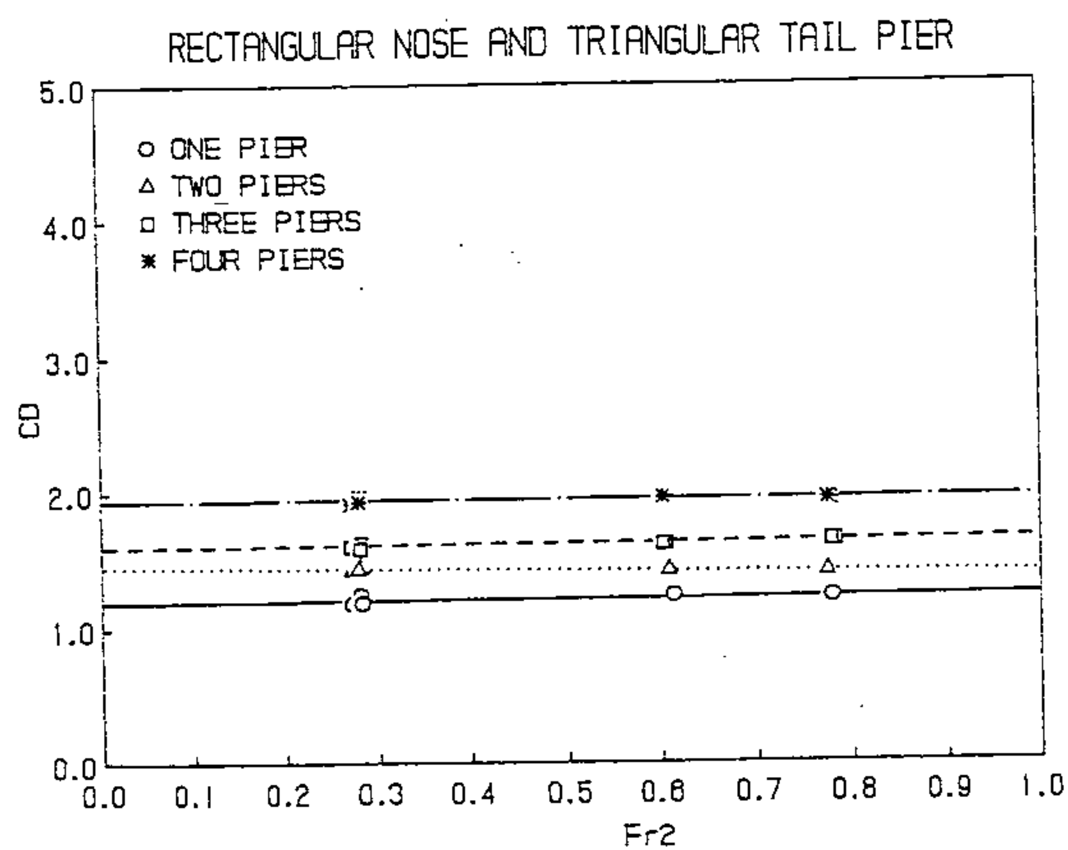

FIG. E.9. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (4 cm).

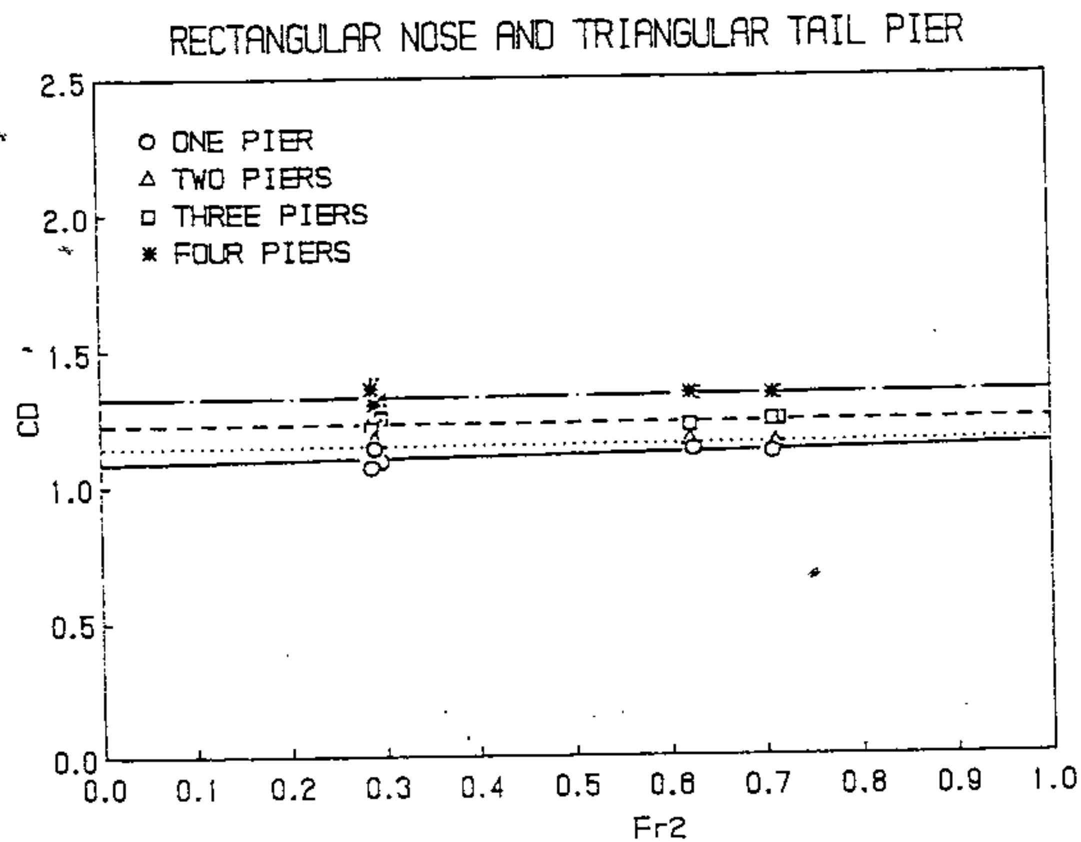

FIG. E.10. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (2 cm).

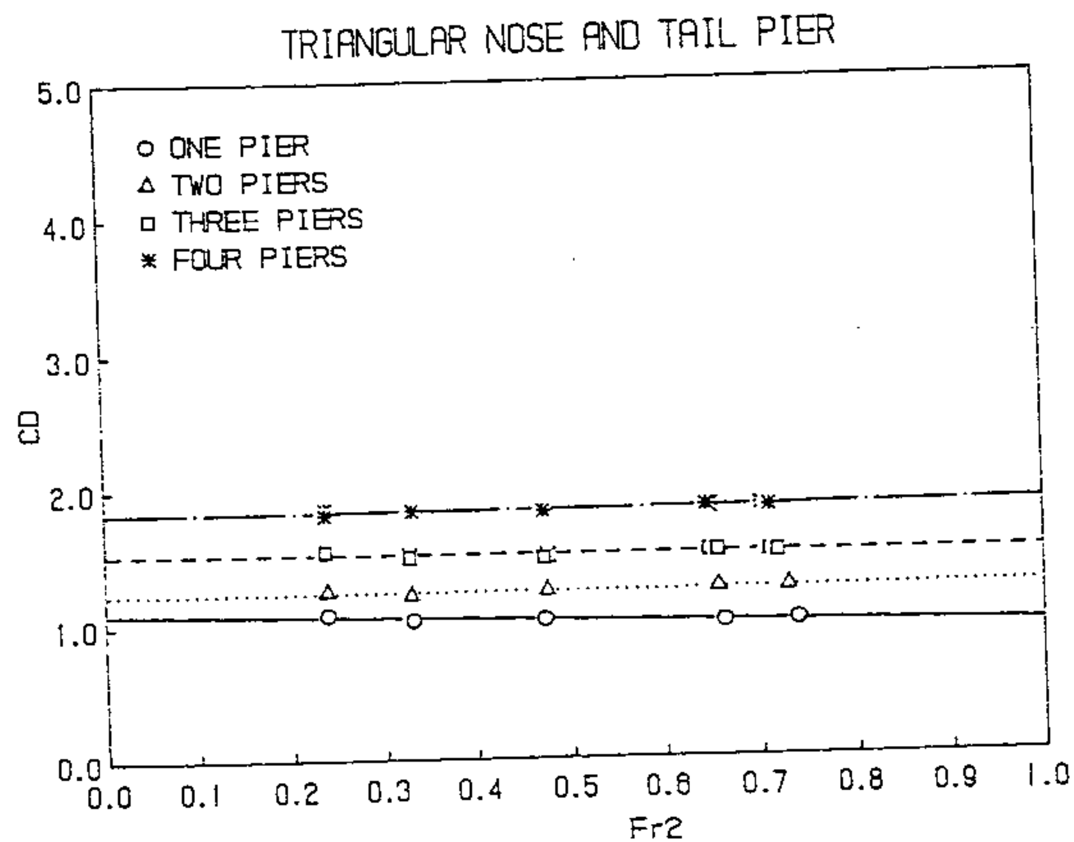

FIG. E.11. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (4 cm).

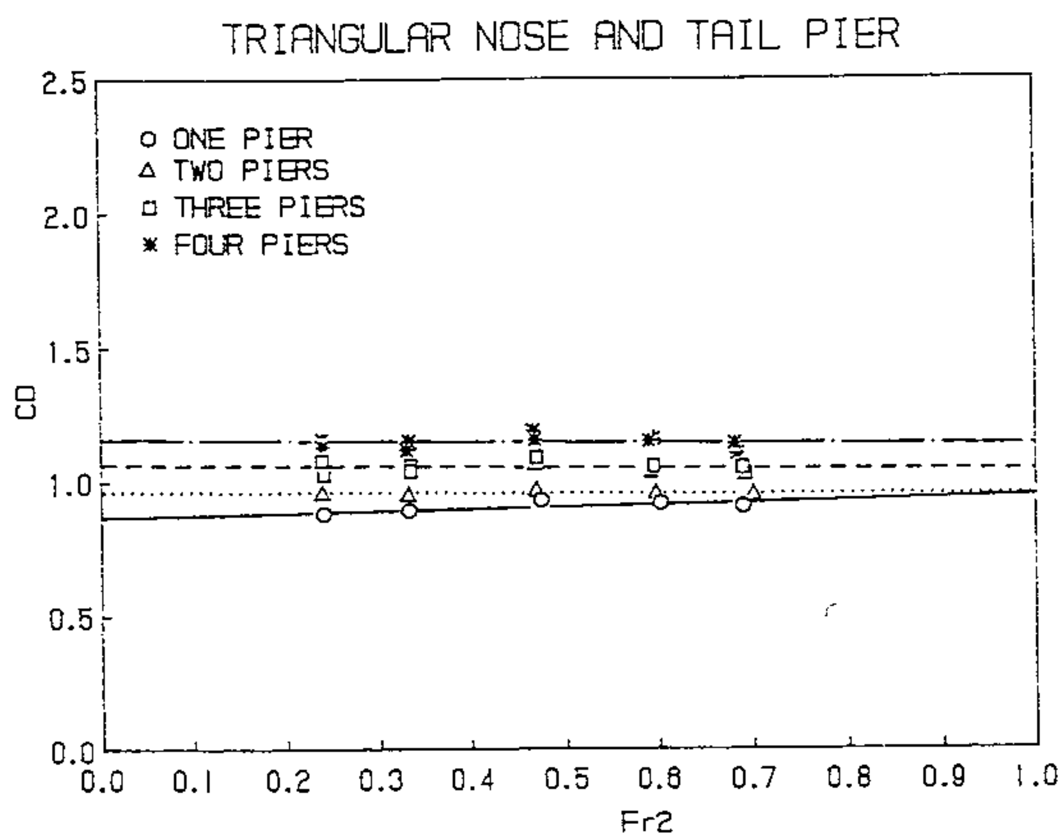

FIG. E.12. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (2 cm).

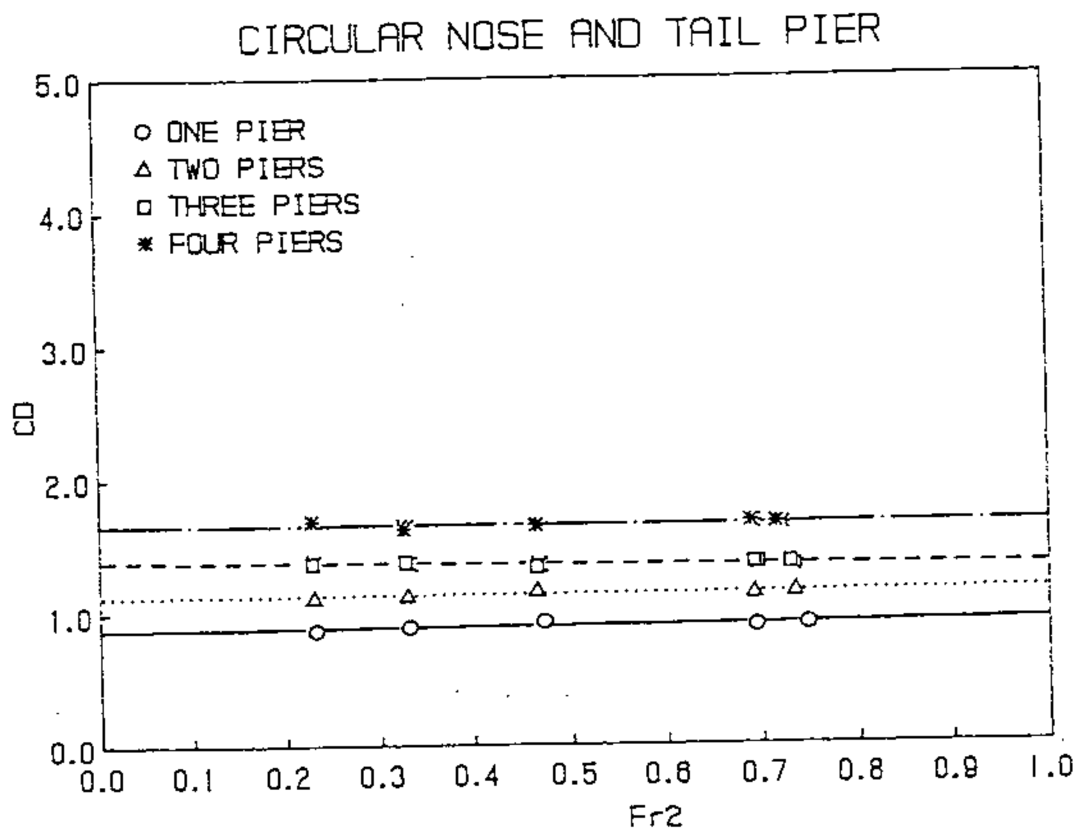

FIG. E.13. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (4 cm).

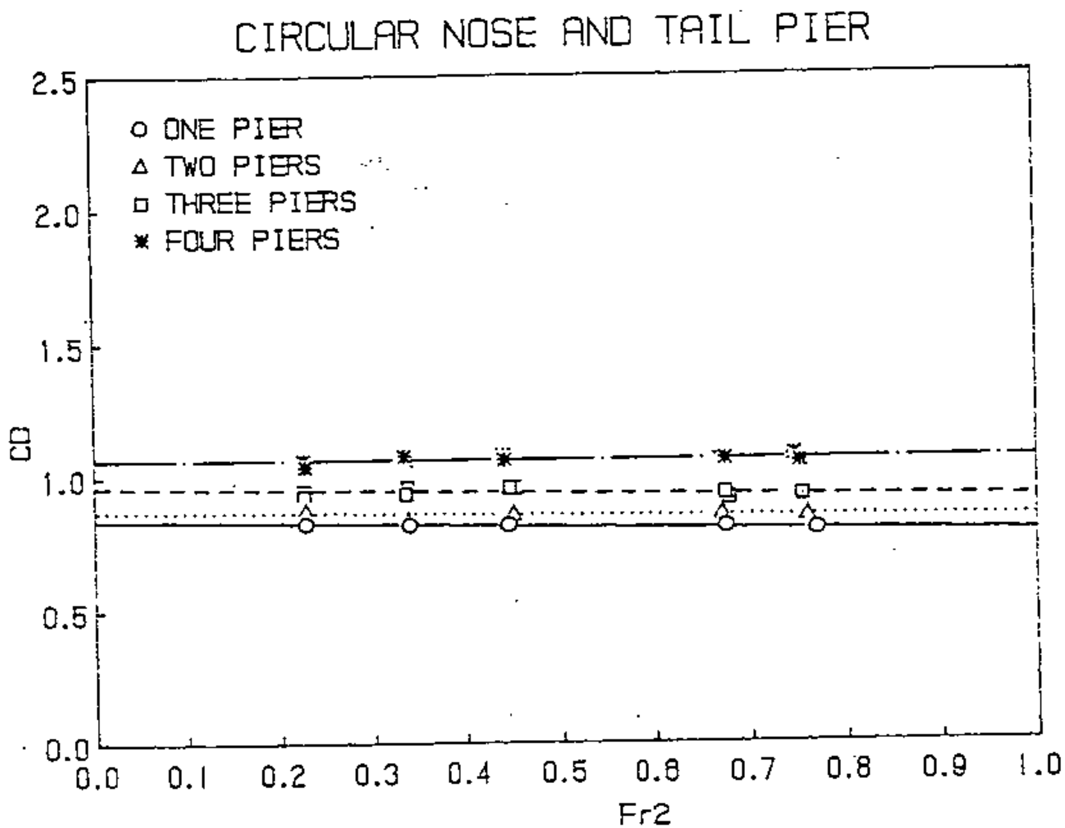

FIG. E.14. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (2 cm).

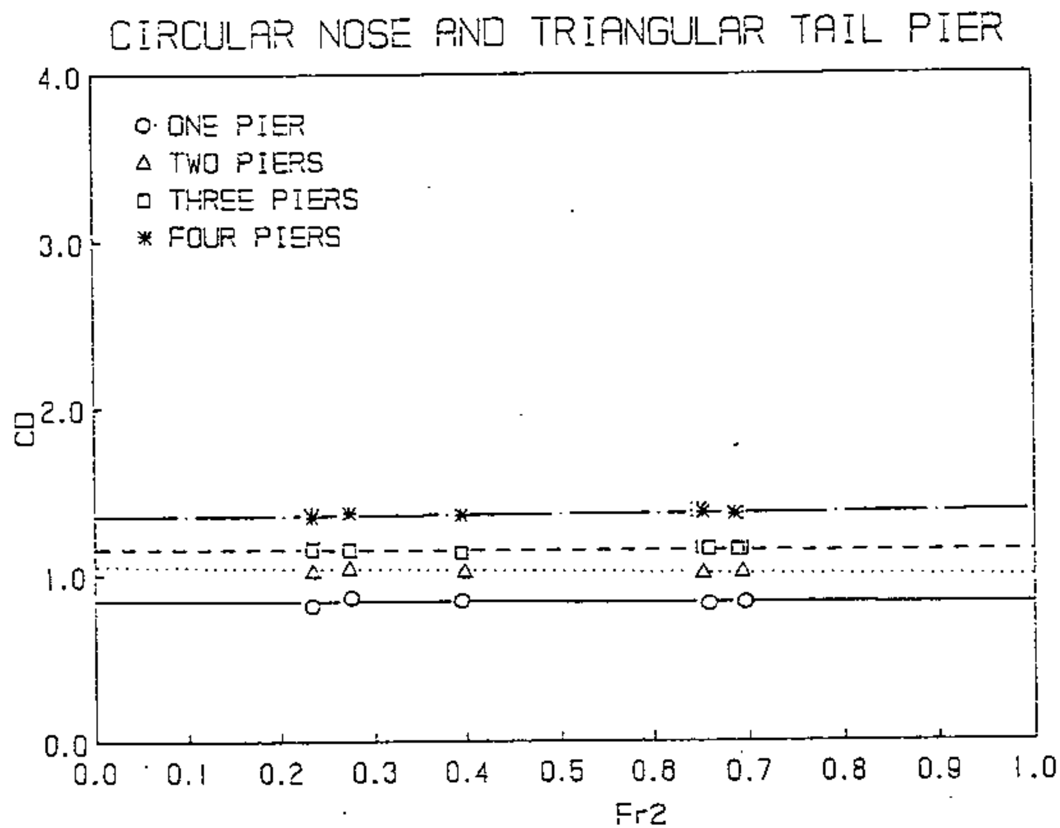

FIG. E.15. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (4 cm).

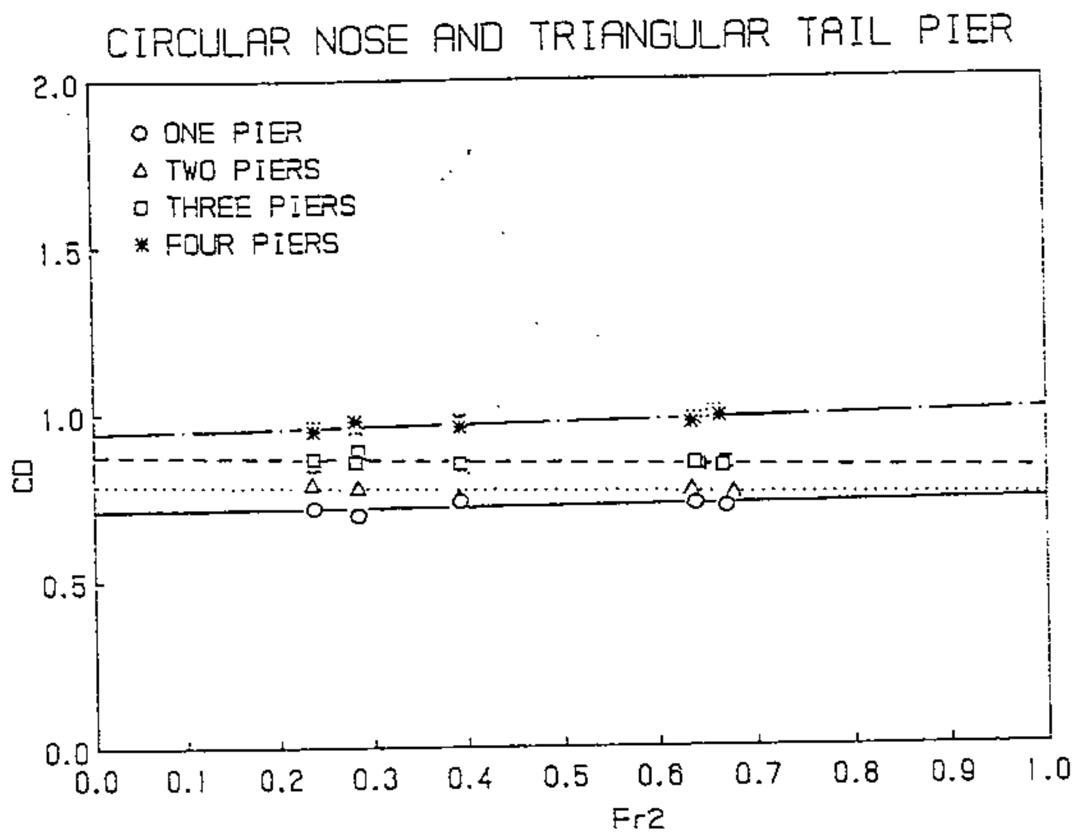

FIG E.16. Relationship Between Drag Coefficient and Downstream Froude Number for Pier Width (2 cm).

التحري التجريبي لسلوك الدفع لركائز الجسور

رسالة ماجستير

مقدمة من الباحث

المهندس نزار خليل صالح الهلسة

اشراف الدكتور

سليمان عفيف الصمادي

كلية الدراسات العليا للعلوم
الهندسية والرياضية والفيزيائية
كلية الدراسات العليا
الجامعة الاردنية / عمان

٤ آب ١٩٩١

التحري التجريبي لسلوك الدفع لركائز الجسور

Experimental investigation of drag behavior for piers

ان قوة دفع المياه لركائز الجسور بالرغم انها قليلة مقارنة مع الحمل الموضوع على هذه الركائز، الا أنه يجب اخذها في الاعتبار بالنسبة للتصميم الهيدروليكي نظرا لاختلاف معامل الدفع.

ان الهدف الرئيسي من هذا البحث هو:-

١- قياس قوة الدفع لعدة أشكال من ركائز الجسور بتدفق ونسب تضيق مختلفة.

٢- درسات تاثير عدد رينولد وعدد فرويد ونسبة التضيق على معامل الدفع لاشكال متعددة من ركائز الجسور.

٣- تقدير الطاقة المستهلكة نتيجة وضع الركائز في المجرى المائي.

ولتحقيق هذا الغرض فقد اجريت الدراسة على خمسة اشكال من ركائز الجسور وهي:

١- مقدمة ونهاية مستطيلة.

٢- مقدمة مستطيلة ونهاية مثلثية بزاوية ٩٠ .

٣- مقدمة ونهاية مثلثية بزاوية ٩٠ .

٤- مقدمة ونهاية دائرية.

٥- مقدمة دائرية ونهاية مثلثية بزاوية ٩٠ .

ولعدد فرويد يتراوح من ٢ر٠ - ٨ر٠ ولعدد رينولد يتراوح من ٥٥ر٣ × $١٠^{٣}$ - ٨٤ر١ × $١٠^{٤}$ ونسبة تضيق من ٦٧% - ٤ر٩٢%.

تحتوي هذه الرسالة على خمسة فصول بالاضافة الى الملخص والمراجع والملاحق:

١- الفصل الاول - مقدمة.

٢- الفصل الثاني - ويشتمل على عرض موجز لأهم النظريات والابحاث والاختبارات الميدانية والمخبرية.

٣- الفصل الثالث - وهو خاص ببرنامج التجارب العملية التي أجريت في هذا البحث شاملا شرحا وافيا للاجهزة والادوات المستخدمة وطريقة العمل وكلها مدعمة بالرسومات والصور التوضيحية.

٤- الفصل الرابع - ويحتوي على المداخل النظرية والبعدية للمشكلة، وكذلك يشتمل على عرض شامل لنتائج التجارب وتحليلها ومناقشتها ضمن تلك المداخل مدعمة بالرسومات البيانية المفصلة للعلاقات المختلفة التي تم التوصل اليها.

٥- الفصل الخامس - ويحتوي على ملخص النتائج التي تم التوصل اليها استنادا الى القياسات المخبرية.

ويمكن تلخيص أهم النتائج بما يلي:

أ- معامل الدفع لا يعتمد على عدد رينولد وعدد فرويد ضمن مجال البحث ولكنها تعتمد بشكل خاص على نسبة التضيق.

وقد استنتجت العلاقات التالية لكل ركيزة:

١- مقدمة ونهاية مستطيلة.

$$CD= 1.25*((\sigma-60)/40)^2-2.54*((\sigma-60)/40)+2.41$$

٢- مقدمة مستطيلة ونهاية مثلثية بزاوية ٩٠ .

$$CD= 1.08*((\sigma-60)/40)^2-2.34*((\sigma-60)/40)+2.32$$

٣- مقدمة ونهاية مثلثية بزاوية ٩٠ .

$$CD= 1.21*((\sigma-60)/40)^2-2.62*((\sigma-60)/40)+2.26$$

٤- مقدمة ونهاية دائرية

$$CD= 0.90*((\sigma-60)/40)^2-2.22*((\sigma-60)/40)+2.03$$

٥- مقدمة دائرية ونهاية مثلثية.

$$CD= 0.39*((\sigma-60)/40)^2-1.40*((\sigma-60)/40)+1.61$$

وفي جميع الاشكال فان معامل الدفع يتناقص تدريجيا كلما زادت نسبة التضيق.

ب-ان الطاقة المستهلكة نتيجة وضع الركائز في القنوات المائية تعتمد على عدد فرويد باتجاه جريان الماء ونسبة التضيق.

$$\frac{\Delta E}{Ez} = \alpha' \frac{Fr^{1.7}}{\sigma^{6.0}}$$

α' : معامل الشكل كما هو مبين في الجدول التالي:

الشكل	α'
١- مقدمة ونهاية مستطيلة	٢ر١٢
٢- مقدمة مستطيلة ونهاية مثلثية بزاوية ٩٠	٢ر٠٣
٣- مقدمة ونهاية مثلثية بزاوية ٩٠ .	١ر٨٩
٤- مقدمة ونهاية دائرية.	١ر٦٧
٥- مقدمة دائرية ونهاية مثلثية بزاوية ٩٠ .	١ر٤٩

ج-ان تحديد جريان المياه بالنسبة لمعامل الدفع يمكن ايجاده بالطريقة التالية:

١- ايجاد العمق باتجاه جريان المياه المنتظم بعد تثبيت الركيزة.

٢- حساب عدد فرويد باتجاه جريان المياه.

٣- استعمال العلاقات (4.31 - 4.27) لايجاد ES1 او استعمال المعادلات:

$$\frac{\Delta E}{E_2} = \alpha' \frac{Fr^{1.7}}{\sigma^{6.0}}$$

٤- باستعمال معادلة الطاقة العامة.

$$E_{s1} = d_1 + \frac{1}{2g} \left(\frac{Q}{A}\right)^2$$

يمكن ايجاد العمق عكس اتجاه جريان المياه..

٥- قوة الدفع يمكن ايجادها من المعادلة التالية:

$$FD = \left(Q\,\rho\,V_1 + 1/2\,\rho g\,d_1^2 \right) - \left(Q\,\rho\,V_2 + 1/2\,\rho\,g\,d_2^2 \right)$$

٦- معامل الدفع يمكن ايجاده من المعادلة التالية:

$$CD = \frac{FD}{1/2\,\rho\,V_1^2 A_p}$$

د- النتائج السابقة يمكن تطبيقها على الاشكال المستعملة في هذا البحث.