Study on the Geometry of Bridge Guide Walls by Physical Model

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Abstract

Guide walls are structures constructed upstream of bridges for preventing excessive scour and to make flow distribution more uniform at the bridge section. In the present work 5 types of guide walls were studied in a physical model and were compared considering the distribution of velocity at the bridge section.

For this purpose the main channel as well as the flood plain were built in a flume with non-erodible bed. Measurements were carried out with a micro-propeller at different sections and with different discharges and tail waters. Observations showed that maximum disturbance occurs at the bridge section in long and short wing walls, whereas in other types it is transferred upstream. When Froude Number is less than 0.15 non-uniformity in velocity distribution is low and similar in all types of guide walls. Behavior of long elliptic and circular walls were similar and better than other types in all range of flow tested. Performance of long and short wing walls improve if bridge walls are extended 10% to 20% of bridge length upstream. No relation was found between velocity distribution and the ratio of discharge in the flood plain to the total discharge.

Introduction

To reduce the bridge length , usually a part or whole flood plain is obstructed by road embankments. Owing to constriction in the river course, flow velocity increases in the bridge section and this leads to scouring. In addition, diversion of flow from the obstructed part of the flood plain to bridge section causes local acceleration and scouring adjacent to the bridge abutments. The latter may undermine the abutments and cause the bridge failure. It is reported that 1/3 of bridge failures is due to this type of scouring (Raudkivi,1998). To prevent local scour around bridge abutments, guide walls are used. Guide walls have also the following advantages:

One) Preventing transverse movement of river.
Two) Reducing losses and increasing hydraulic efficiency.
Three) Uniforming flow distribution at bridge section.
Four) Reducing angle of attack to bridge piers.

In this study uniformity in flow distribution has been considered as a criteria for hydraulic behavior of the guide walls.

Types of guide walls

Owing to their plane shape, guide walls could be divided in to 3 types, i) wing wall, ii) Straight with circular head, iii) elliptic. Wing walls usually have 30 to 45° angle with river axis, and are constructed mainly for protection of road embankments. Length of wing walls depends on embankment' s side slope and height.

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Straight guide walls with circular head (Fig.1) have a total length of 0.75 to 1.1 times the bridge length (Indian Standard, 1976; Ranga Raju and Garde,1985). Radius of the curved head is recommended to be 0.4 to 0.5 of the bridge length with a sweep angle from 120° to 145°. No relation between dimensions of this type of wall and flow velocity or proportion of discharge diverted towards the bridge section is given. However a range for flow discharge and river slope is mentioned in application of these type of guide walls (Varma et.al., 1989).

Elliptic guide walls are also recommended in the literature. This type of guide wall is a quarter of an ellipse with a ratio of major to minor axes of about 2.5 to 1 (Fig.2). Various methods are given in references for determining the length of this type of guide wall (i.e. length of major axis). Andreev (see Neil,1973), recommended a length based on the ratio of total discharge to the main channel discharge, with a maximum value of 0.75 time of waterway opening for total length of right and left guide walls. This method gives considerably shorter guide walls than the others. Maza Alvarez(1989), suggested a length of 1.1 times the bridge opening when both banks of river are erodible. Karaki(1961) presented a graph based on physical model studies, from which the length of guide wall is obtained according to acceptable width and depth of scour hole. Bradly(1987) also presented a graph for estimation of guide wall length based on flow velocity at bridge section and proportion of flood plain discharge to the discharge in 30m adjacent to the abutment.

In the present study it was intended to compare the hydraulic behavior of these guide walls considering distribution of velocity in the waterway opening and also observation of flow pattern adjacent to them.

Experimental setup

The experimental flume was 14m long and 2m wide. Due to symmetry only half of channel was modeled and one of the flume walls was assumed as the river axis (Fig.3). 1.4m of the flume width was considered as flood plain and 0.6m of it as half of the main channel (i.e. half of the bridge length) with flood plain constructed 0.15m above the bed of the main channel.

Whole of the flood plain was assumed to be obstructed by the road embankment. Various guide walls were installed in the model and with each of them velocity distribution was measured at different sections; with each guide wall 3 discharges (40 l/s, 60 l/s and 80 l/s) and with each discharge 3 main channel depths (0.2m, 0.3m and 0.4m) were tested. The range of Froude number in these experiments was between 0.04 to 0.44. Froude number was defined with average velocity and main channel depth at a section far upstream from the constriction where there was no disturbance due to channel constriction or inlet section.

With this arrangement the ratio between total discharge to the main channel discharge could be varied in a wide range of 1.3 to 2.1. Specifications of guide walls used were as follows (Fig.3):

- Type W1: Wing wall with 30° angle to channel axis and 0.52m length.
- Type W2: Similar to type 1 but with 1.2m length (i.e. bridge length).
- Type W3: Straight with circular head. Total length was 1.1 times bridge length. Radius of curvature 0.45 time bridge length with 120° sweep angle.
- Type W4: Elliptical based on Bradly(1987). To be able to use the graphs a 1/30 to 1/50 scale was assumed for the model. For the range of experiment an average value of 0.54m was found for the length of the guide wall.

- Type W5: Elliptical based on Maza Alvarez(1989), with a length 1.1 times bridge length (i.e. 1.32m) and ratio of major to minor axes equal to 2.2.

In each experiment flow pattern was observed with dye injection. Velocity distribution was measured at 6 points in bridge section and at flood plain elevation (Fig.5). To study the effect of adding a straight part to the end of types W1,W2,W4 and W5, velocity distribution was also measured in more 1 or 2 sections 12.5% to 25% of bridge length downstream of section 1 (see Fig.4). In type W3 to evaluate the importance of the straight part, velocity distribution was measured at 3 sections along the wall i) end of circular head (Sec.1) ii and iii) 0.75 time and equal to bridge length downstream of circular head (Sec.2 and Sec.3). Velocity was measured with a micro propeller with 0.1 cm/s accuracy. At each point velocity was measured 5 times and then was averaged.

Experimental Result

Flow pattern observation

In elliptic and circular guide walls which transition from the head to the end of the wall is smooth, disturbance was observed only at the head. In types W1 and W2 water surface drop and flow disturbance occurred at the bridge section. TypeW5 had the best condition with only small disturbance near the head at higher velocities.

Comparison of velocity distribution profiles

The following conclusion could be drawn from velocity distribution profiles:

One) Extension of the elliptic walls 12.5% of bridge length had no significant effect in making the velocity profile more uniform (Fig.6 and Fig.7).

Two) The straight part of the guide wall with circular head (type W3) is effective in reducing non-uniformity in velocity profile (Fig.8).

Three) Non-uniformity in velocity profile is more in the bridge section when wing walls are used. Extension of bridge abutments 10% to 20% of the bridge length upstream and then constructing the wing walls is effective in making the velocity profile more uniform (Fig.9 and Fig.10).

Comparison of uniformity in velocity distribution

Coriolis factor (á) was considered as a criteria for comparison of uniformity in velocity distribution at the bridge section. No relation was found between á and total discharge to main channel discharge ratio. Therefore á was plotted against Froude number. It must be mentioned here that in experiment with 80 l/s flow discharge and 0.2 m depth, due to high disturbance near water surface, velocity was measured at a lower elevation and therefore a lower á is expected comparing with flood plain elevation. The following conclusion were drawn here (see Fig.11):

One) For Froude number less than 0.15 all guide walls have similar á.

Two) In short wing wall (type W1) non-uniformity increases with Froude number, especially for Froude number more than 0.3.

Three) In general, types W2 and W4 have higher á than types W3 and W5.

Four) Type W3 and W5 have similar á in all range of Froude number and lower values than other types. More over increase in Froude number did not increase non-uniformity in velocity distribution (á) in these types.

Summery of conclusion

Guide walls are constructed upstream of bridges to prevent excessive scour and to make velocity distribution more uniform in the bridge section. Reducing losses and angle of attack to bridge piers are other advantages of guide walls. In this study the hydraulic behavior of different types of guide walls recommended in the litrature was compared.

In an experimental flume 14m long and 2m wide, flood plain and main channel were constructed. A constriction was then modeled and different types of guide walls were installed. Velocity distribution at bridge section and different other sections were measured and compared as criteria for hydraulic behavior of guide walls. With each guide wall 3 discharges and with each discharge 3 water depths were tested. Following conclusions were drawn:

One) Higher turbulence and drop in water surface was observed at the end of the wing walls. Extension of bridge abutment 10% to 20% of the bridge length upstream was effective in uniforming velocity distribution at the bridge section.

Two) Adding a straight section to elliptic walls had no significant effect in uniforming velocity distribution.

Three) Straight section of guide wall with circular head is effective in reducing non-uniformity in velocity distribution.

Four) For Froude number less than 0.15, coriolis factor (á) is similar at bridge section for all types of guide walls.

Five) As Froude number increases, á increases for short wing wall (type W1).

Six) With increasing Froude number á remains near 1 for types W3 and W5 guide walls. This shows that the performance of these types is better than the others in higher flow velocities.

For further study on hydraulic performance of different types of guide walls more experiments are underway with erodible bed. In these tests extension and maximum depth of scour for different guide walls will be compared at various flow condition.

Acknowledgement

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References

1. Bradly,J.N.(1987), Hydraulic of Bridge Waterways, Hydraulic Design Series No.1, U.S.Department of Transportation, FHWA
2. Indian Standard (1976), Criteria for River Training Works for Barrages and Weirs in Alluvium, IS:8408-1976
3. Karaki,S.(1961), “Laboratory Study of Spur Dikes for Highway Bridge Protection”, Highway Research Board, Bulletin 286,Washington, D.C.
4. Maza Alvarez,J.A.(1989), “Design of Groins and Spur Dikes”, Proceeding of the 1989 National Conference On Hydraulic Engineers, American Society of Civil Engineering
5. Neill,C.R.(1973), Guide to Bridge Hydraulics, Prepared by project committee on bridge hydraulics, Road and transportation association of Canada, University of Toronto press.

6. Ranga Raju,K.G. & Garde,R.J.(1985), Mechanics of Sediment Transportation and Alluvial Stream Problems, 2nd Edition, Wiley Eastern Limited Pub.
7. Raudkivi,A.J.(1998), Loose Boundary Hydraulics, 4th Edition, Balkema Pub.
8. Richardson,E.V. & Simons,D.B.(1984), “Use of Spur Guide Banks for Highway Crossings”, Transport Research Board, Vol.950, No.20, Transportation Board, Washington,D.C., pp.184-193
9. Varma,C.V.J & Saxena,K.R. & Rao,M.K.(1989), Manual of River Behaviour Management and training, Pub. No.204, Volume 1, Central Board Of Irrigation And Power,India

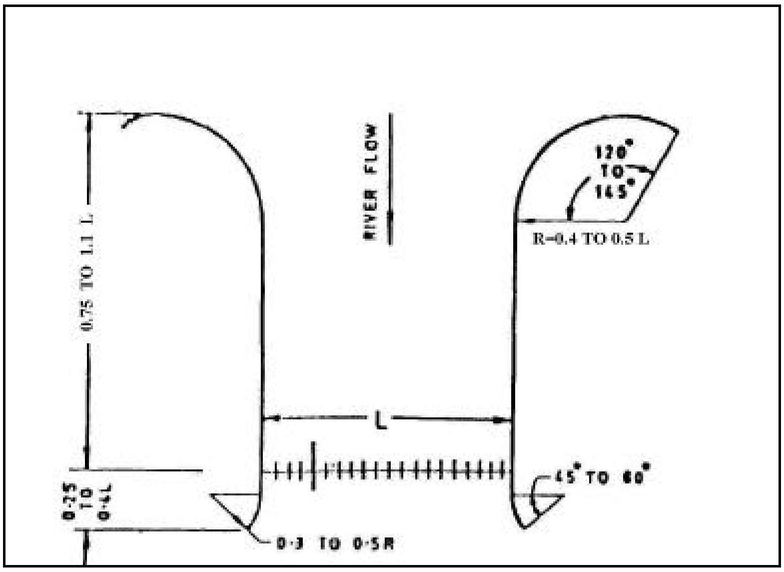

Fig. 1.Circular guide wall

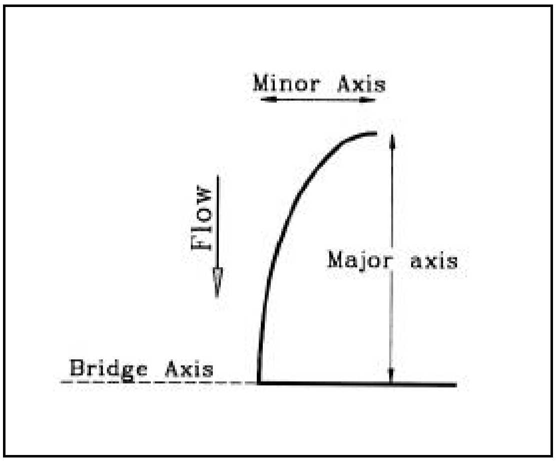

Fig. 2.Elliptic guide wall

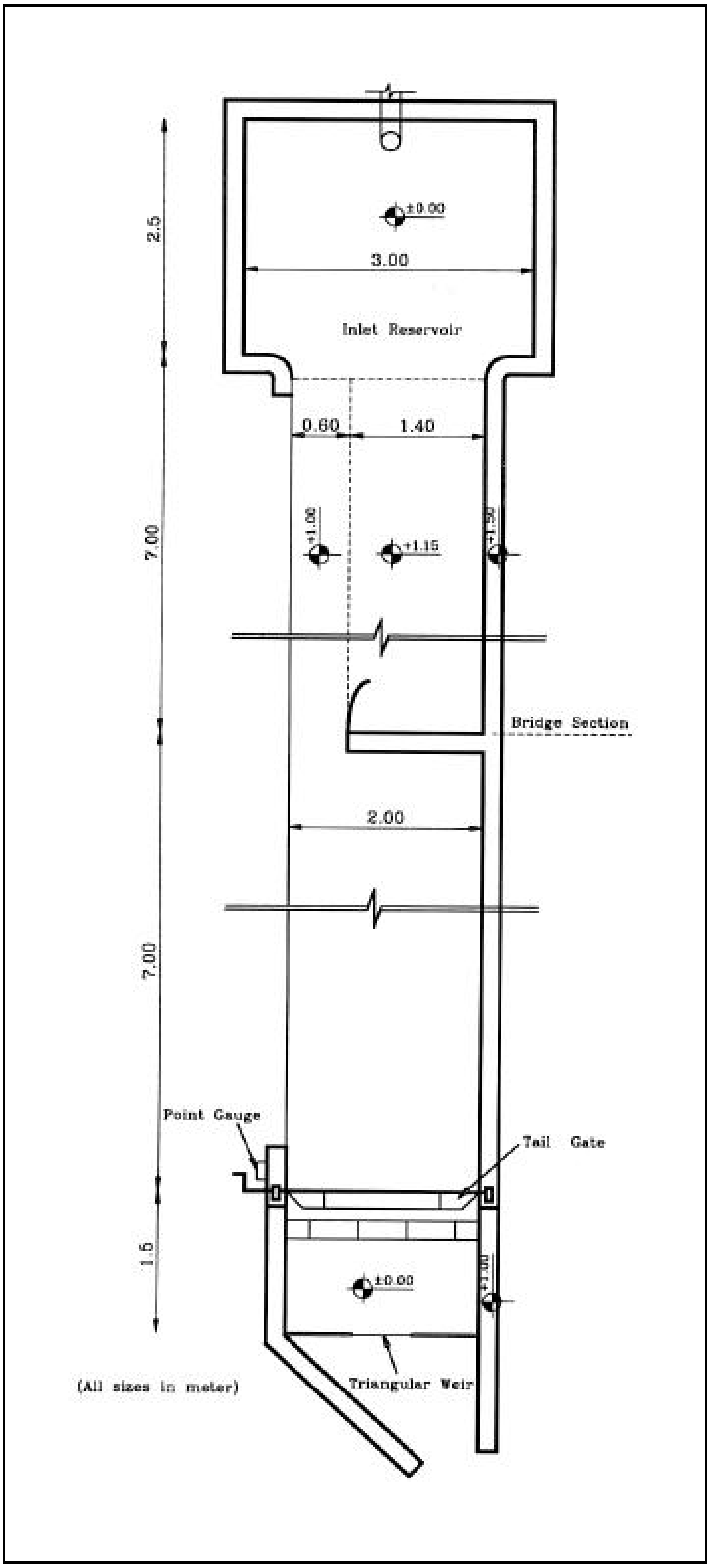

Fig. 3.Plane of the flume

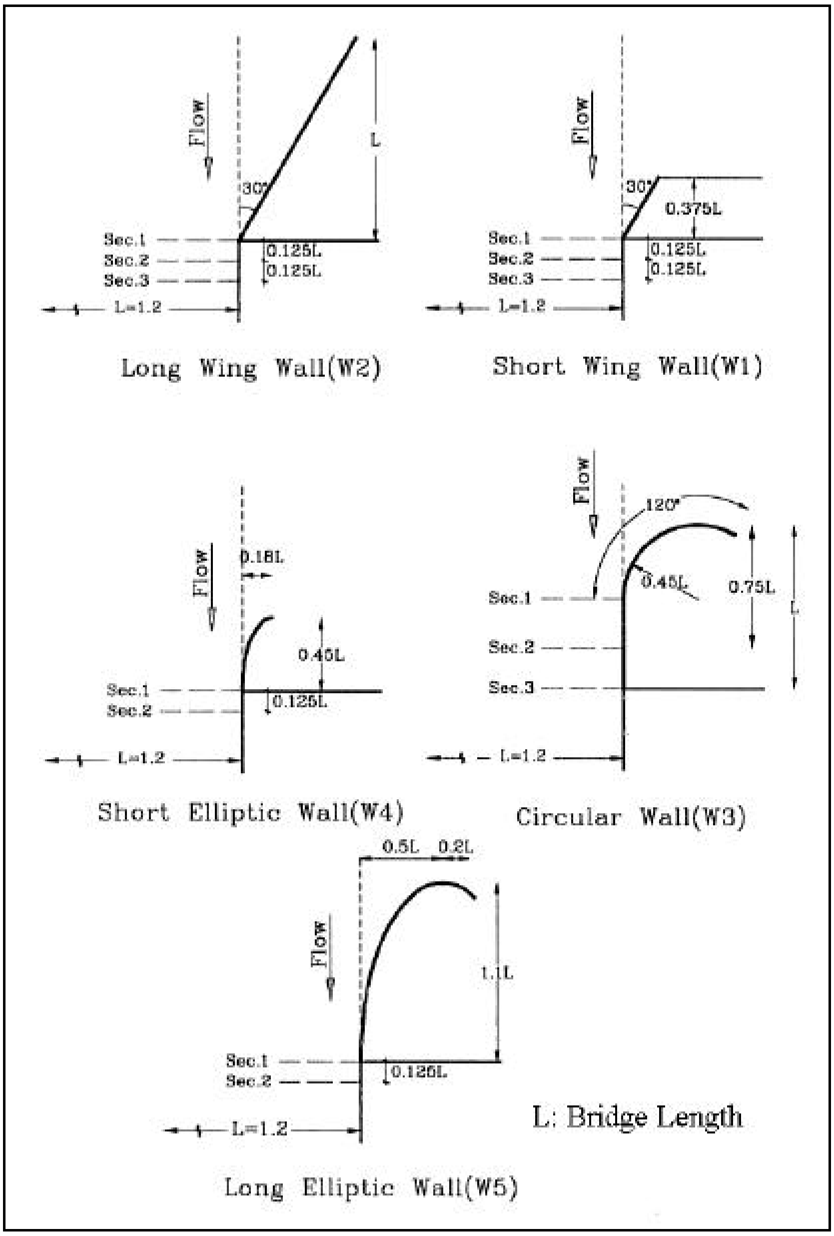

Fig. 4.Various types of guide walls and measurement sections in the model

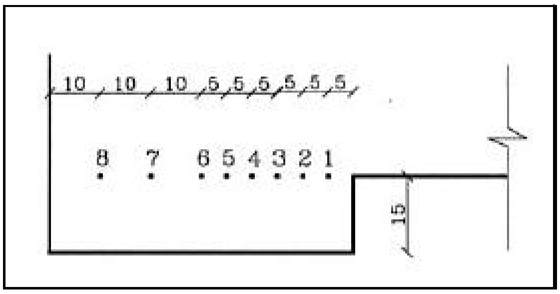

Fig. 5. Position of the measurement points (distances in cm)

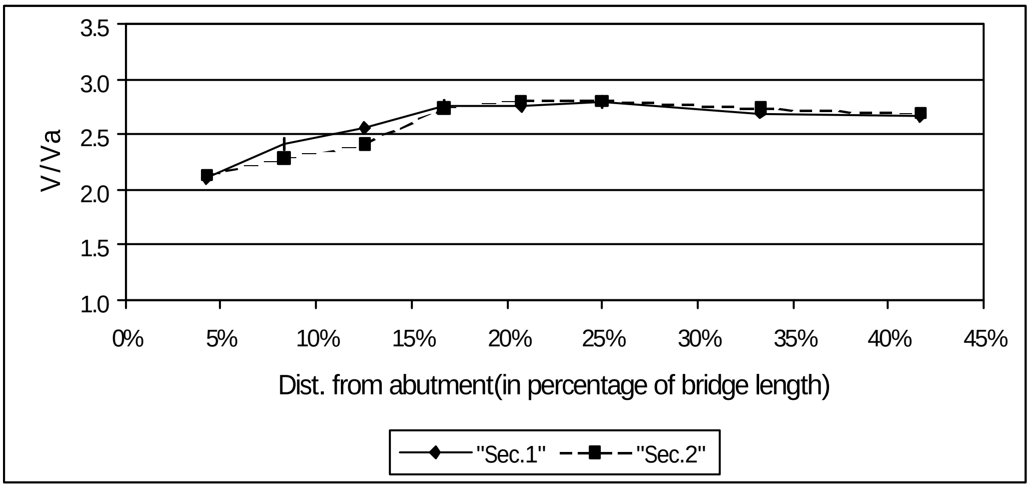

Fig. 6.Velocity distribution for wall type W4 ,Q=80l/s , Flow depth=0.3m(Va: average velocity in an upstream section)

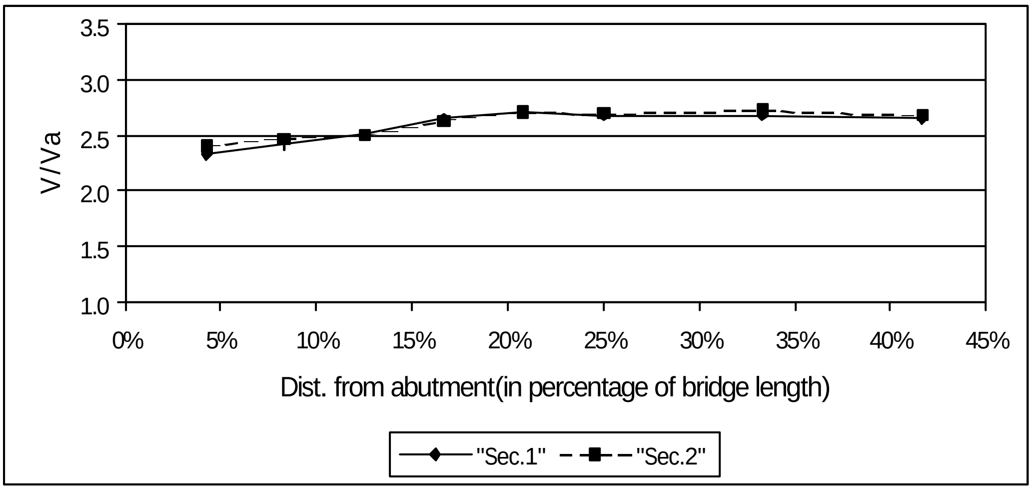

Fig. 7.Velocity distribution for wall type W5,Q=80l/s , Flow depth=0.3m(Va: average velocity in an upstream section)

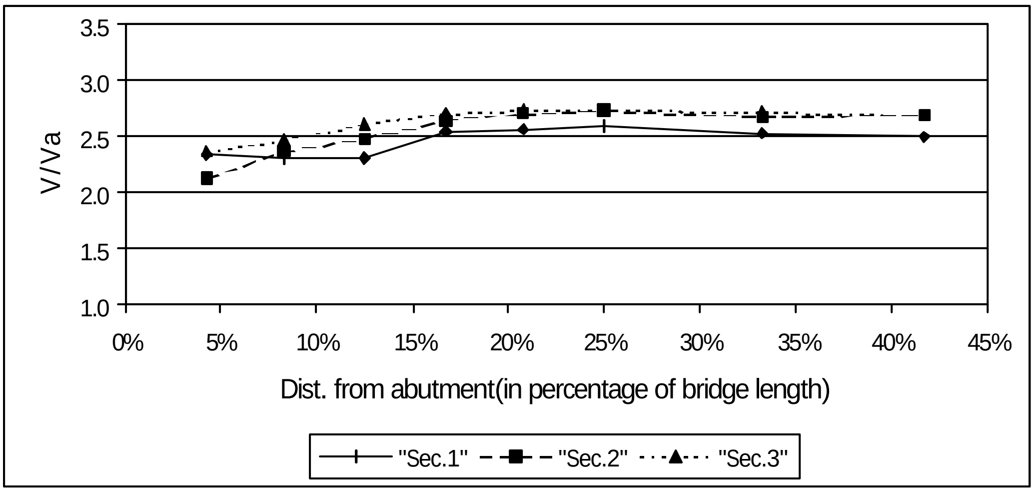

Fig. 8.Velocity distribution for wall type W3, Q=80l/s , Flow depth=0.3m(Va: average velocity in an upstream section)

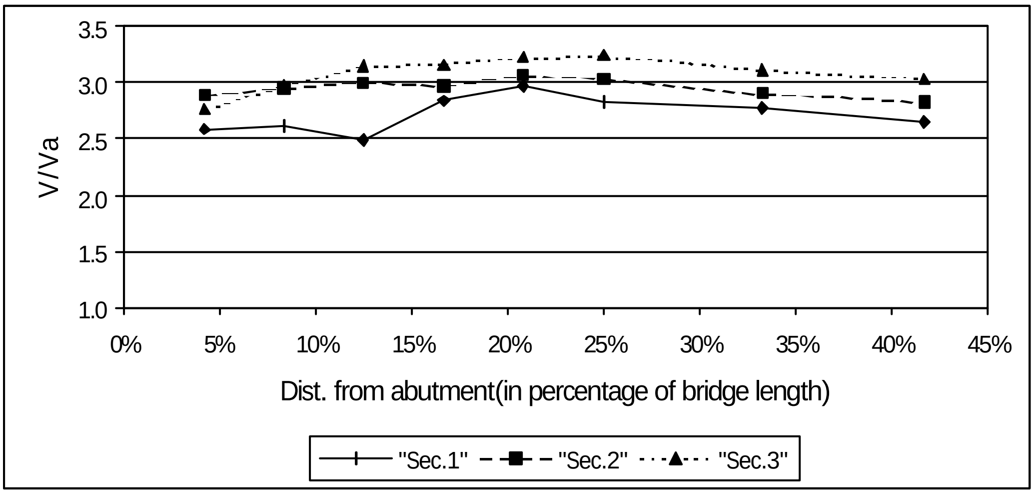

Fig. 9.Velocity distribution for wall type W1, Q=60l/s , Flow depth=40cm(Va: average velocity in an upstream section)

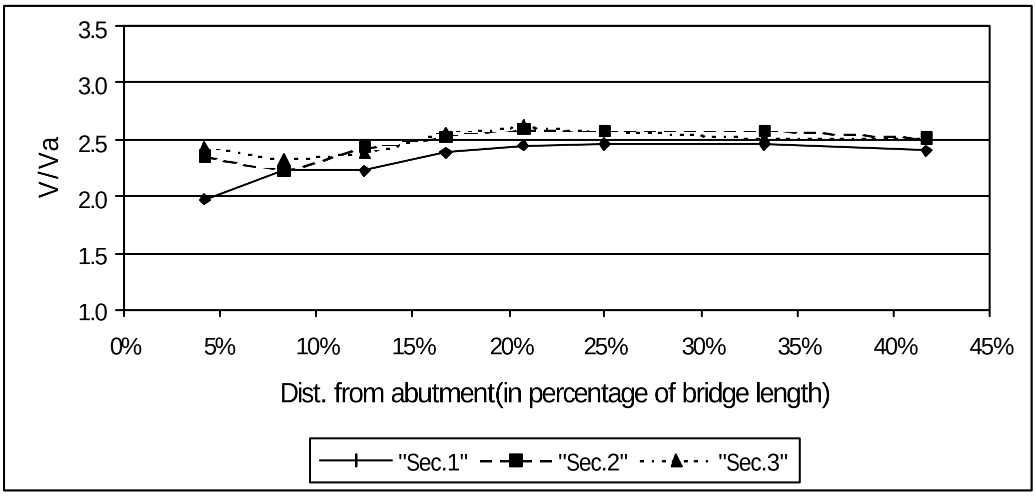

Fig. 10.Velocity distribution for wall type W2,Q=80l/s , Flow depth=30cm(Va: average velocity in an upstream section)

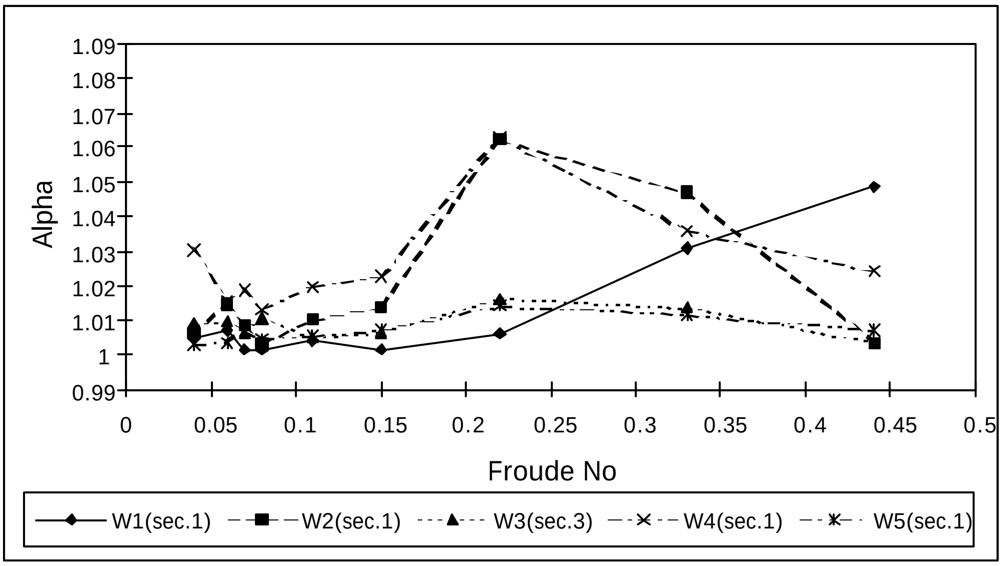

Fig. 11 .Coriolis factor(á) vs. Froude No.