Scour and Deposition around Causeways and Bed Bars

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Abstract

This paper presents the experimental investigations of effect of bend on scour and deposition patterns around causeways and bed bars. Data have been collected in a re-circulatory open channel flow system on three causeway model slabs for many discharge values ranging from 1.0 l/s and 8.0 l/s. The causeway model slabs were made of cement concrete with 0.75 m length, 0.20 m width and 0.20 m in overall depth. To critically observe the effects of presence of bend on scour and deposition, three locations of causeway slabs and one location of bed bar were used. The first one is provided in a straight reach in the test channel, second one just after the first bend normal to flow and third one was an oblique slab provided between the inner and our curvature of the second bend downstream of the first bend. Data of scour and deposition around causeways and bed bar were recorded after the end of the run. Also photographs were taken. It is concluded that for each discharge, scour and deposition occur in all cases, but at low flow the scour in straight reach is less pronounced. However, scour occur in second and third causeways due to the presence of bends. At still high values of discharges, scour and deposition both are significant in all the causeways. Since first causeway is straight and normal to flow, there is uniform scour and deposition along the edges of the causeways. The scour and successive deposition occur in other two causeways with high magnitudes but the location of maximum scour depth shifted. Also scour holes were observed around the bed bars. Photographs also support the findings in this investigation.
Keyword- Causeway, Channel Bend, Bed Bar, Scour and Deposition

I. INTRODUCTION

Causeways also called Raptas are the low cost submersible structures which are most commonly used in hilly areas where torrential rivers or streams often cross roadways. Causeways save the cost of highways projects as at many places construction of bridges and culverts are replaced by them. The length and width of these structures depends upon the overall width of the streams and the width of the roadways but their overall depth depends upon the maximum depth of scour to be expected at the construction sites. Generally, two types of causeways flushing and vented are in common practice in India and abroad. In flushing type, the crest of the causeway slab is kept at same level of the river bed on which water and traffic both move at low flow condition. In vented causeway, water move through the vents and the traffic move on the road surface well above the river bed level. Scour and deposition are natural phenomena which occur when ever stream or river flow is obstructed due to any obstruction. It is observed in field that many vents of the vented causeways get fully or partially chocked with silt due to heavy silt scour and deposition. This situation generally occurs when ever causeways were located where the streams meander. In this paper an attempt has been made to investigate the effect of bends on the scour around flushing type causeways. Bed bars are simply concrete blocks located at the bed of the newly constructed canals which top surface is flushing with the bed of the canals.

A. Location

The proper location of the causeway is an important issue. In no case the causeway should be located at those places where river has meandering patterns. During flood it may happen that due to secondary currents the water may scour the bed materials of rivers from convex side (outer bend of river) and may deposits on concave side (inner bend) resulting chocking of many ducts (vents of causeway) as shown in Fig.1.

B. Phenomena of Scour and Deposition

Structures built in rivers and channels are subjected to scour around their foundations. If the depth of scour becomes significant, the stability of the foundations endangered, with a consequent risk to the structure of damage or failure. The factors influencing the development of scour are complex and vary according to the type of structure. Scour process is caused by sediment transportation resulted from the flow of the fluid. When the sediment rate transported into a certain area is less than that transported out of this area, a scour hole will be existed. Scoured materials when move downstream with flow of water get deposited. The scour and deposition of sediment upstream and downstream of a vented causeway is shown in Fig.3.

Fig. 1: Vented and Flushing causeways

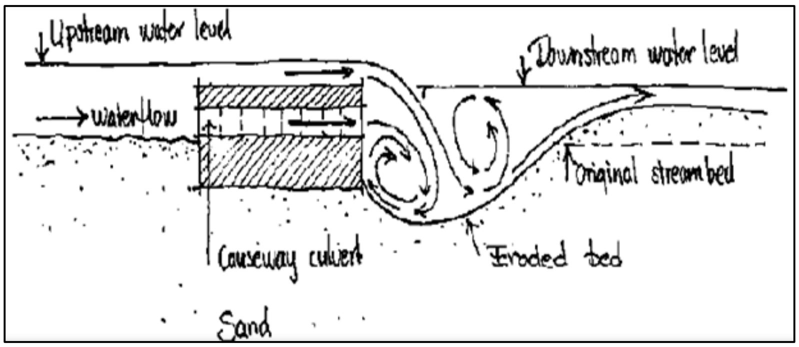

Fig. 3: Scour and deposition d/s of a vented causeway

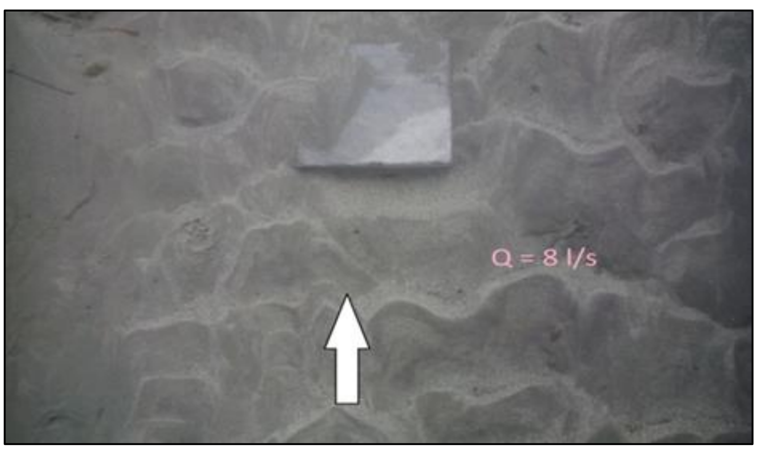

Fig. 4: Scour and deposition around bed bar

II. EXPERIMENTAL SETUP AND PROCEDURE

The experimental set-up used in the present study consisted of a 60 m long, 0.75 m wide and 0.60 m deep rectangular open channel having two successive bends. It was a re-circulatory flow system. The experimental set-up is shown in Fig.5. Experiments have been carried out on three model causeway slabs and one bed bar slab. These slabs have been constructed with cement concrete. The lengths of the two slabs are kept equal to the width of the channel while length of third slab is kept equals to the perpendicular distance between inner and outer curvatures of the bend. The width and over all depths of each slabs are kept as 0.20 m and 0.20 m respectively. The bed bar is a cube of 15 cm.

A. Installation or Location of Causeway Slabs and Bed Bar

The first slab is located in the straight reach of the channel, normal to flow and flushing with the channel bed. The second one is kept just downstream of the first bend normal to flow, third one is placed in second bend oblique to flow between inner and outer curvatures and the bed bar is located downstream of the third causeway in a straight portion of the channel as shown in Fig.5.

Uniform size of the sand d=0.22 mm was used to form the channel bed. Flow in the channel has been diverted from an overhead tank through a re-circulatory flow system. To measure flow rate a pre-calibrated sharp crested rectangular weir has been used at the downstream end of the channel.

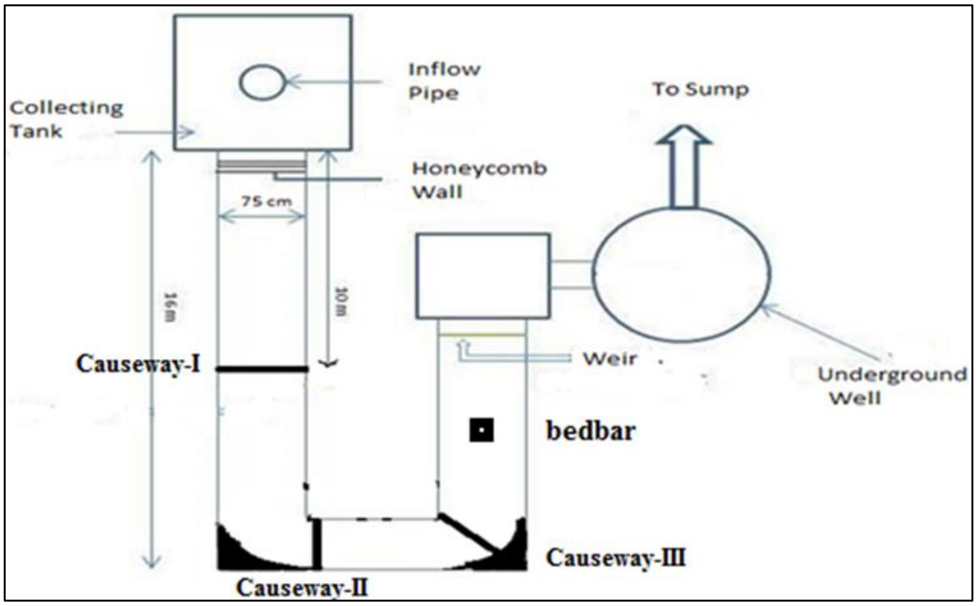

Fig. 5: Schematic diagram of experimental setup

B. Procedure

Initially very small quantity of water approximately 1 l/s from the overhead tank was diverted into the test channel at the constant head to maintain the steady uniform flow. Gradually the gate opening is increased till the required flow is maintained in the channel. This was done with the help of pre-calibrated sharp crested weir provided at the end of the test sections. After steady state condition is maintained, the visual observation regarding flow pattern and scour & deposition have been started. Visual observations were taken time to time at each test section and photographs were also been taken at the end of the run. The data for scour and deposition were collected for four discharge values for all three causeways and Bed bar. Visual observations were first made using coloured balls to see the flow patterns across each causeway slabs. Also, the depths of scour around the upstream faces of each causeway and bed bars have been measured accurately.

III. DATA ANALYSIS AND RESULTS PRESENTATION

The data for scour depth Sc collected in the lab for all three causeways are first normalised by dividing them with the sediment size d50. Similarly, the transverse distance ‘x’ along the causeways measured from left side to right side, has also been normalized by dividing it with channel width W. These data have been plotted as shown in Figs.6, 8 10 and 12.

A. Scour and deposition around causeway I

The photogrammetric view of the scour at causeway-I is shown in Fig.6 and graphical representation in Fig.7. It is clear from this figure that at all discharge values, the scour around the edge of the first causeway placed in straight channel and normal to flow is almost uniform and with low magnitudes. This may be attributed to uniform velocity and pressure distribution near and upstream of the causeway. Very small ripples were seen at low value of discharge and moderate dunes at high value of Flow. The flow being subcritical and shear velocity is also less than critical shear velocity.

B. Scour and deposition around second causeway II

Second causeway was located just downstream of the first bend to see the effect of the presence of bend on scour pattern. Since flow is not uniform at upstream of the causeways due to the presence of the bends, the scour and successive deposition which occur along the edges of the causeways is also not uniform. The scour starts to occur after one fourth length of the causeway and extends gradually towards the centre from left to right. At centre depth of scour is maximum. The scour hole and its extent can easily be seen in Fig.8 and Fig.9.

C. Scour and deposition around third causeway III

In third causeway which is provided in second bend of the channel (Fig.10 & Fig.11) the scour and deposition is also not uniform due to non-uniformity of the flow condition upstream of the causeway. When flow was started, the scour holes were developed at many places of the causeway but since upstream of this causeway; dunes were developed as the flow velocity in the straight channel upstream of the causeway is not uniform. After the elapse of the time, the scour holes were filled up and other holes were developed. This phenomenon was continued till the end of the run.

Fig. 6: Photogrammetric view of scour around Causeway I

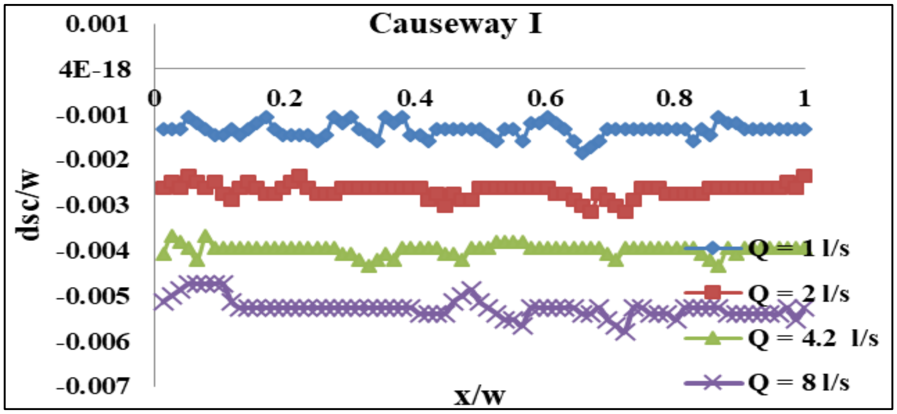

Fig. 7: Variation of scour along a Causeway– I

Fig. 8: Photogrammetric view of Scour around Causeway – II

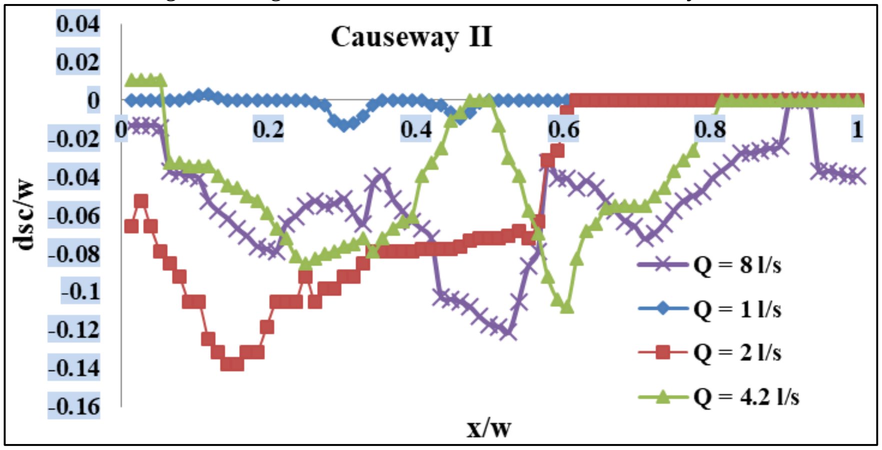

Fig. 9: Variation of scour along Causeway II

D. Scour and Deposition around Bed Bar

For all four discharge values the scour depths were also measured around the bed bars and plotted as shown in Fig.12 and Fig.13.

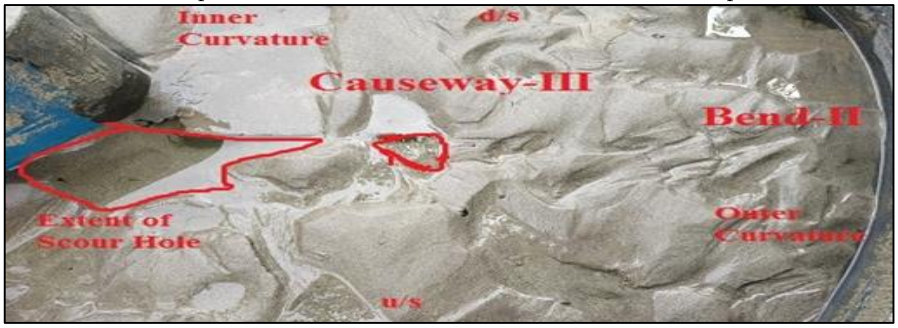

Fig. 10: Photogrammetric view of scour around causeway–III

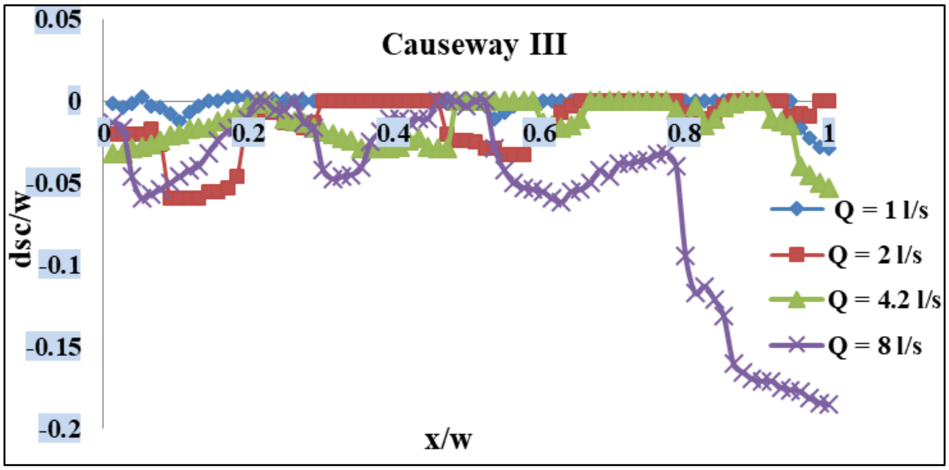

Fig. 11: Variation of Scour along Causeway – III

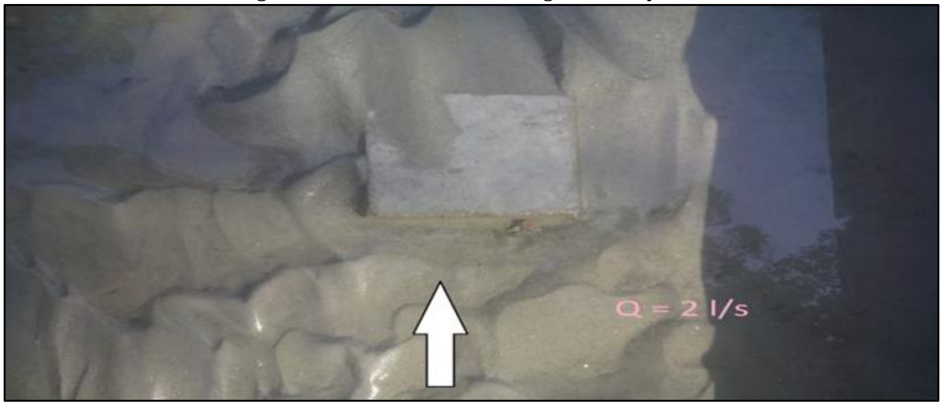

Fig. 12: Photogrammatic view of the Bed bar

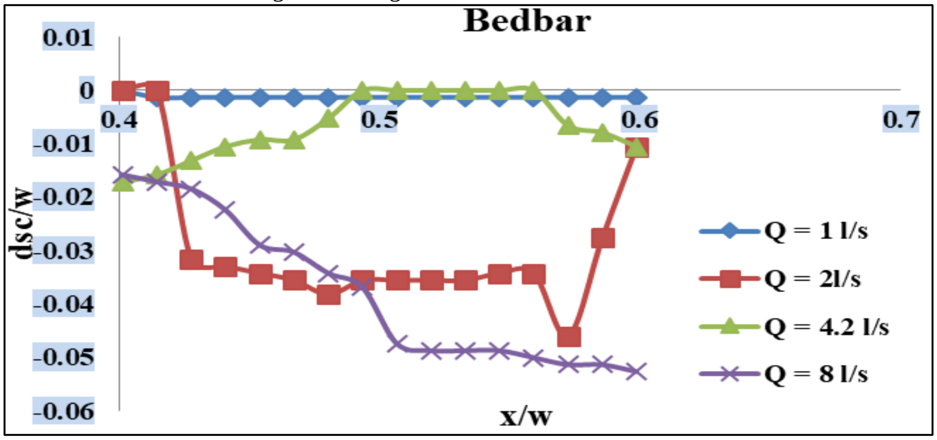

Fig. 13: Variation of scour around Bed bar

IV. CONCLUSIONS

1) The scour around the edge of the first causeway for all the discharges are almost uniform and comparatively small but scour depths increase with increase of discharge.
2) The scour is more pronounced in second causeway mostly at the centre. The deposition of sediment occurs only at the downstream side of the causeway at inner bend at about 20% of the causeway length. Similar condition was found for the high value of discharge also.
3) In third causeway the scour holes were developed at many places of the causeway. No uniform scour was seen as the bed was mobile and there was continuous movement of sand towards the causeway. If the discharge increases, the scour depths also increases.
4) It is recommended that in no case, causeways should be located at the meandering of streams or where there are bends.

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