STUDY OF THE IMPACT OF INCLINATION ON SCOURING AROUND THE BRIDGE PIER

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ABSTRACT

The scouring has the tendency to affect the structural capacity of the piers, which results in the failure of the bridge due to the undermining action of the water around the foundation of bridge piers. This failure results in the loss of human lives, loss of economical values and loss of money and time. So the safeties of structures, like bridges are a matter of utmost importance. For reducing the scouring, the various researchers have developed various methods. In the present study we have adopted inclination for the reduction of scouring. After collision and overloading, the third main cause for bridge failure is scouring around bridge pier. It is estimated that nearly two-third of bridge failure occurs due to scouring and other flow related causes. Scouring around a bridge pier is a phenomenon that can never be totally ended to zero but can surely be reduced upto a great extent. So the objective of this work is to study the effects of inclination of a bridge pier on local scouring around a bridge pier. In the present research study experimental work was done for the same dimensions with different shapes i.e., circular, octagonal and square. Each pier was founded in a test section inside the hydraulic flume and inclined to desired angle by using a pier inclining model. The experimental work was done for three different discharge values in hydraulic flume. The experimental study reveals that the average scouring got reduced by 15 % for the circular shaped pier, 22% for the octagonal shaped pier and 21% for the circular pier by inclining the piers towards downstream direction. Thus we can conclude that the maximum reduction in scour depth occurs in octagonal shaped pier.

Keywords: *Bridge Piers, Inclined Bridge piers, Open Channel, Scouring, Scour depth Reduction.*

1. INTRODUCTION

The erosion of the bed material around any substance or obstruction is known as scouring. The vertical extent of the soil bed around the structure is called scour depth. When the bed particles get washed away from the bed near the obstruction resulting in the formation of depression is called scour hole. The phenomenon of removal of bed particles from just adjacent to the pier is called local scouring. It occurs due to the obstruction caused by the pier to the direction of flow. This interference of the obstruction to the flow results in the acceleration of the flow. This acceleration of flow results in the formation of the vortex flow around the supporting structure that washes away the bed particles from the pier surrounding area. If flow forms the vortices around the substructure then it results in scouring. If the bed material has cohesive material like clay it requires large force to remove the individual particle. If the flow which is coming towards the pier or abutment, carries any soil particle from the past then it is called live bed scour, and if it does not contain any soil particle from the past then it is called clear water scour. When the flow comes with a certain velocity then there is stagnation of the flow at front face of the pier, when the flow comes in contact with the soil bed, it results in the formation of depression at the front of the pier. Due to this, vortices are created in the area near the piers. The vortex goes downstream the pier and then passes along the sides of pier. This type of vortex flow is called the horseshoe vortex because it resembles with horseshoe. Due to this, the hole which was formed earlier will go on increasing depth wise, till the shear on the bed particles becomes less than the critical shear stress. As we know bridge failures results in the loss of human lives, loss of economical values and loss of money and time. So there safety is our responsibility, for their safety there are generally two ways for checking against scouring, one way is to strengthen the soil around the pier and the other way is to regulate the flow of water around the pier. For strengthening the soil, we can do application of riprap, grout filled bags etc. and for regulating the flow we can control the flow alignment to breath the vortex flow which reduces the velocity of water in the adjoining area of the pier, this can be achieved by the use of sacrificial piles, collars, submerged in the vanes, slot, threading, inclining the pier towards d/s side etc.

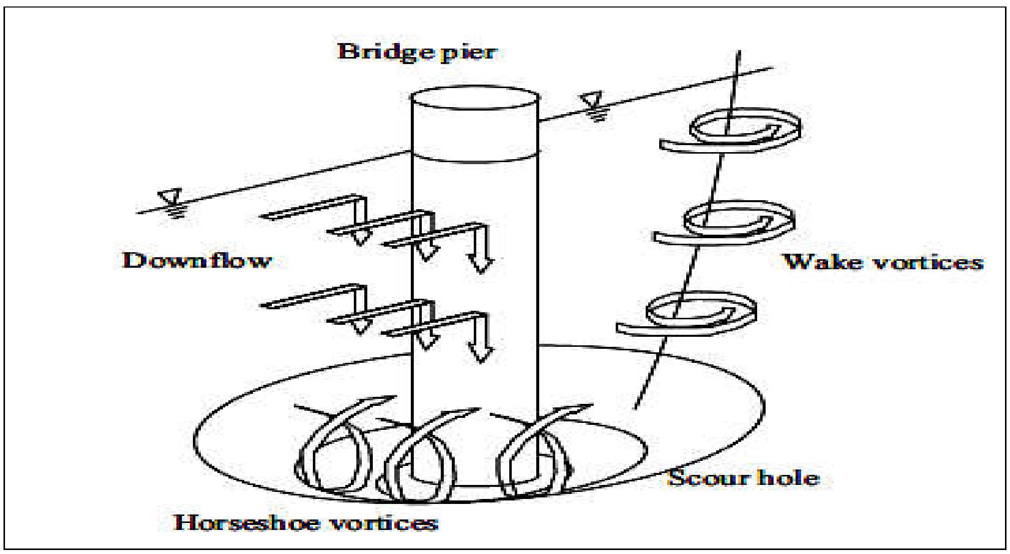


Fig. 1. Schematic view of scour process

TYPES OF SEDIMENTS AND THEIR BEHAVIOUR

Generally the material present in the bed is more important for knowing the scouring process.

1. Non- cohesive Material: These materials are composed of the granular structure, with the possibility of individual particles getting washed away when its stabilizing force is overcome by the force of approach flow. The capability of the individual to get washed away depends upon its shape, density and its packing on the bed.
2. Cohesive Material: These particles generally consist of clay. These materials require large velocity of flowing water to overcome the stabilizing force of individual particle but when it is achieved, it can be easily transported by flowing water.
3. Armoring: The process of preserving a large particle and let the washing away of the small particle in well graded channel is called Armoring. This controls the scouring up to some extent. This includes the laying of elongated shape materials on the bed.

FACTORS AFFECTING THE SCOUR

1. Type of flow: Type of flow is responsible for the scouring. If the flow forms vortices then there will be more scouring around the pier and if the flow is turbulent it also leads to scouring as the velocity of the flow is high. High flood flows also causes scouring.
2. Type of Fluid: Type of the fluid is also another factor on which the scouring depends. The fluid may be considered as erosive fluid or non –erosive fluid. In the erosive fluid, velocity is more if it contains any debris or any other material on the other hand, the non-erosive fluid does not erode the particles and hence scouring does not take place.
3. Shape of Substructure: This is also an important factor on which the scouring depends. Shape of substructure may be circular, square, etc. and extent of scouring is different for different shapes.
4. River bed Material: Extent of scouring also depends on the material which is present in the river bed. The river bed may contain non-cohesive or cohesive material. If the river bed contains non- cohesive material then there is a possibility of individual particle getting washed away if the stabilizing force of the particle is overcome by the force of approaching water. On the other hand, if the river bed contains cohesive material like clay then the possibility of individual particle getting washed away is less because of the large force requirement or high velocity water to overcome the stabilizing force of the individual particle.

LITERATURE REVIEW

SCOURING MEASUREMENT IMPORTANCE

Scour is a topical issue in the marine environment due to the recent development of offshore wind farms in coastal waters. This is an active area of research because it is currently difficult to accurately predict the scour depth that will occur at a structure's foundations in the field. Simplified scale modeling in laboratory flumes can help to advance understanding of the mechanisms for scour and the interactions between the fluid, structure, and sediment. A suitable measurement technique needs to be implemented to monitor the scour depth detesting. In practice this is difficult because of the need for the method to be non-intrusive but still operate at the required time and spatial resolutions at the small scale. Consequently, a wide range of measurement systems have been presented in the scour [1]. Earlier the equation and models that were used to predict the pier scour provided a single maximum value of scour depth rather than scour depth as a function of time. Therefore the number of years in which the scour depth will be reached cannot be estimated. So in this research, a time dependent model and subsequent risk of failure analysis has been used and this has enabled the design engineering to base a bridge pier design on an estimated probability of failure rather than on the basis of experience, thus providing it to be a method of safer design of bridges [2].

METHODS FOR THE PROTECTION OF BRIDGE PIERS

Some research work on the protection of bridge pier is briefly described below:

1. Use of combination of riprap and collar they used an application of riprap alone and a combination of riprap and a collar to control the scour around rectangular bridge piers. A collar three times wider than the pier's width was installed around the pier at the streamed level. The results of the experiments showed that with increase in both the skew angle and the aspect ratio of the piers, the stable riprap size and extent also got increased [3]. Researchers used independent and continuous pier collar in combination with riprap for reducing local scour around bridge pier group. The effectiveness of collar was evaluated experimentally. The results showed that in the case of two piers in line, combination of continuous collar sand riprap results in the most significant scour reduction of about 50 and 60 for the front and rear piers respectively [4].

2. Replacement of solid pier by Group of piers in their research, they have replaced the solid pier by a group of three smaller piers. The extent of pier scouring in the pier group in its best orientation is compared with that due to a solid pier of diameter of the pier group. The results showed that scour reduction is about 40% in the pier group [5].
3. Use of slot and combination of slot and collar a researcher used a slot alone and a combination of slot and collar as devices for controlling the depth of scour. The results showed that scour got reduced by as much as 20% on using a slot alone. The combination of slot and collar further reduced the scour hole [6]. Another researcher used a slot alone and a combination of bedsill as a countermeasure against local scouring at a smooth circular bridge pier. The effectiveness of the slot was evaluated by changing its sinking depth into a sand bed. The results showed that maximum scour depth reduction was about 30% in the best configurations. And the scour reduction when using the combination system of slot and bedsill was about 45% on average [7].
4. Use of Bed sill as scour reduction device in a research work researchers used a bedsill located at downstream side of the circular piers as a scour reduction device. The effectiveness with the distance between the pier and sill was evaluated. The results showed that a bedsill placed at a small distance downstream of the pier reduces the scour depth upto a great extent [8].
5. By inclining the bridge piers researcher used the effects of inclination of a bridge pier on local scour depths around bridge pier experimentally. Single circular pier inclined towards the downstream direction was founded in a uniform bed material. The results showed that the scour depth decreased as they increased the inclination angle of the pier [9]. In this research work scour around circular shaped bridge piers with two different diameters and different inclination angles towards downstream side has been investigated experimentally under clear water condition and different discharges. The results showed that an increase in the inclination angle leads to a significant decrease in the scour depth [10].

METHODOLOGY

EXPERIMENTAL SETUP

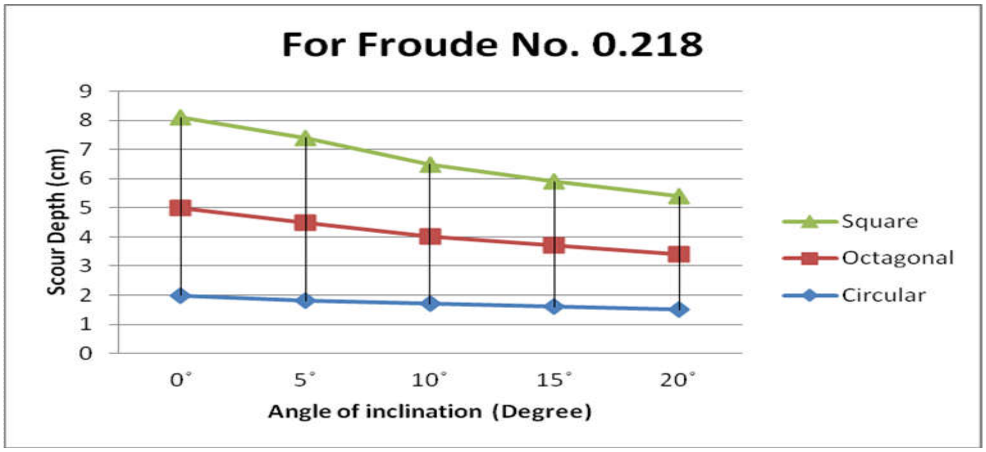
The experimental setup consists of:-

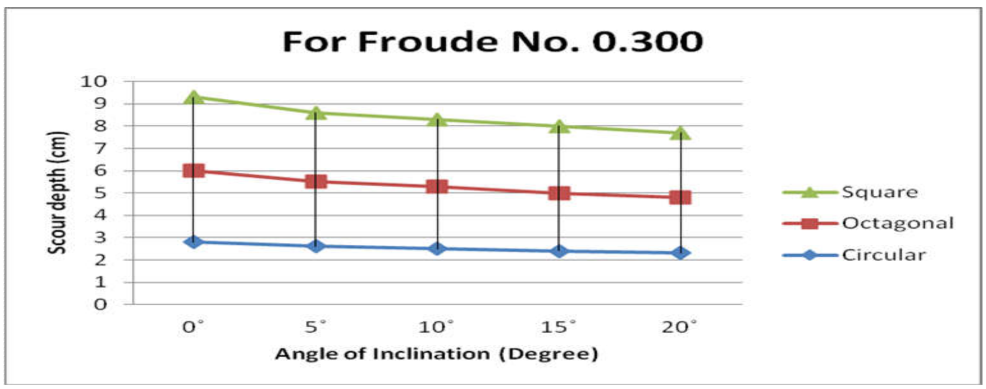
- Tilting hydraulic flume
- Pier inclining model
- Circular pier
- Octagonal pier
- Square pier
- Trowel

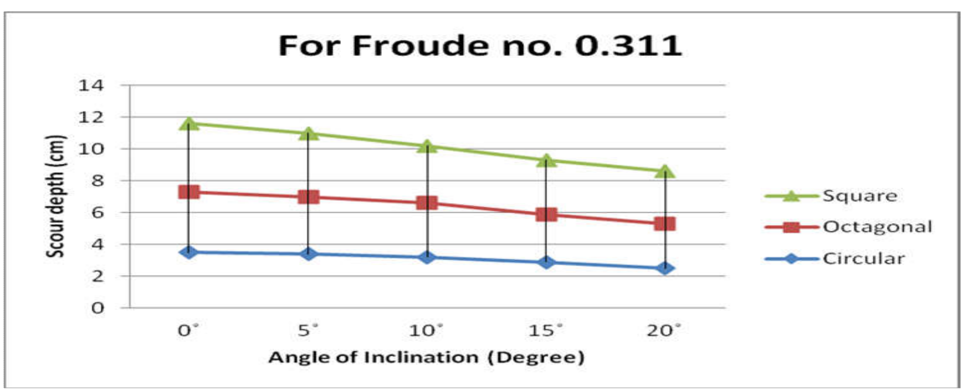
For performing the experimental runs we take three different shapes of the pier i.e., circular, octagonal and square. The experimental runs are first performed for circular shaped pier of diameter 4 cm and length 50 cm. The flume is first cleaned off dust by allowing free discharge through it. After this a test section of 1.1 m length and 14 cm height is set inside the flume. The circular pier is then placed in the test section and inclined at an angle of 0˚ with respect to vertical axis with the help of pier inclining model. Sand is then laid in the test section and flattened perfectly with the help of trowel. Water is allowed to flow in the flume for 4 hours. After 4 hours water is allowed to drain out of the flume and readings are taken for the scour hole so formed. The same procedure is then again repeated for circular pier after changing the inclination angle to 5˚, 10˚, 15˚, 20˚. Similarly same procedure is then repeated for the other shapes of pier.

RESULTS AND CONCLUSIONS

In this research work, we have taken 45 different experimental runs to observe the trend of scouring. Three different shapes of the pier were used. Five different inclination angles were set for each of the pier i.e., 0˚, 5˚,10˚,15˚, 20˚ and the experimental runs were taken on three different discharge values i.e., Froude no. 0.281, 0.300 and 0.311. Results obtained from these three Froude no's are represented in graphical manner below.







CONCLUSIONS

In our experimental study, we found that the effect inclination of a bridge pier on local scouring around bridge pier. The results revealed as follows:

- As we increased the angle of inclination of a bridge pier towards the downstream direction from 0˚ to 20˚ w.r.t the vertical axis, the local scouring around a bridge pier got reduced accordingly.
- The scouring depends on the shape of a bridge pier i.e., scouring is minimum for a circular pier, intermediate for an octagonal pier and maximum for a square pier of same dimensions.
- Dimension of a pier is also a function of scouring greater the obstruction to the flow, greater is the scouring around it.
- The scouring also depends on the Froude number i.e., as we increased the Froude number, the scouring also got increased.

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