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AN EXPERIMENTAL STUDY & ANALYSIS ON SCOURING AROUND BRIDGE PIER & ABUTMENTS

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ABSTRACT

This paper briefly describes the mechanism of scour process around bridge pier and gives an in-depth review of the various techniques employed for scour control and protection. Many bridges failed around the world because of extreme scour around piers, thus Scouring around bridge piers become a challenging problem for the bridge engineers. Scour is caused by the horseshoe vortex formed due to the presence of the pier obstructing the flow. scour involves the removal of material from around piers, abutments, spurs, and embankments. It is a natural process and is caused by an acceleration of the flow and resulting vortices induced by the flow obstructions Structures built in rivers and estuaries are prone to scour around their foundations. If the depth of scour becomes significant, the foundations' stability may be endangered, with a consequent risk of the structure suffering damage or failure. So in order to prevent a construction(bridges and other Hydraulic structures) from failing The experiments related to this research on scour in rivers and bridge failures were conducted in the Hydraulics Laboratory of the Civil Engineering Department. The most common armouring device is placing of rip rap stones around the pier. Despite the effectiveness of riprap armouring countermeasure, the performance of various flow altering devices is studied. The combination of slot and collar plate can be a suitable solution to prevent the scour if well designed and constructed properly. The combination of permeable sheet piles with riprap can even reduce the scour depth effectively up to 91% in live bed scour conditions. The combination of vanes and collar plate around oblong bridge pier results into less extent of scour and produces a higher degree performance potential of 86.36% as compared with unprotected oblong pier. scour at pier site has been subjected to many investigations throughout the world and only very limited success has been achieved by the attempts. Therefore, more research is needed to analyze the stability of this device on the prototype and field application and enhance their efficiency furthermore.Numerous prediction formulas and design charts have been established as a result of laboratory and field investigations. In this study, a physical model was used to simulate the local scour around piers.

KEYWORDS: Local Scour, bridge pier, Physical model, scour protection, experimental study.

1. INTRODUCTION

scour is a complex phenomenon involving three-dimensional flow, typically developed around piers founded in movable bed rivers. Local scour can lead to partial failure or to collapse of bridge piers because of the high flood velocity. The cost of large bridges, with common and special complex piers, justifies carrying out an accurate prediction of scour depth, for both economic and safety reasons, which in turn leads to the interest of hydraulic engineers in predicting the equilibrium scour depth. Bridge pier scouring is an important issue in the safety evaluation of bridges (Huber 1991). It has been reported that most bridge failures were related to the scour of foundation material. The process of the local scour around bridge piers is fundamentally complex because it depends on many variables (e.g. the flow, pier and bed material characteristics). Accurate prediction of scour depth around bridge piers is essential for their safe and economical design. Numerous studies have investigated flow mechanisms and predictions of scour depth around bridge piers, and some have studied the determination of scour depth under uniform steady flow conditions. As already stated, many parameters influence the scour process and, although many studies have been carried out, a general theory has not been achieved because of the complex structure of the problem.channel bed by erosion below a natural level tending to expose or undermine foundations that would otherwise remain buried. Because the openings of a bridge and specially the distance between the piers are less than the full width of the river, the water accelerates as it approaches and passes through them. Consequently, the velocity is higher than it would otherwise be, and this can cause scouring and undermining of the foundations of the bridge. Scour is a serious problem in bridge piles. Increases in river and stream flows that result in scouring are the principal cause of bridge failures .The ability to protect bridge piers from scouring is critical to bridge safety. Excessive scour can cause high maintenance costs or even bridge collapse. Bridge collapse results in costly repairs, disruption of traffic, and possible death of passengers travelling on the bridge when the collapse occurs The mechanism has the potential to threaten the structural integrity of bridges and hydraulic structures, causing failure when the foundation of the structure is undermined in general and local scour are the major cause of hydraulic factors such as stream instability, long term streambed degradation, while general scour, local scour, and lateral migration were responsible for 60 % highway bridge failures. It has been long established that the basic mechanism causing local scour at bridge piles is the down flow at the upstream face of the piles and subsequent formation of vortices at the base (There are many parameters that affect the flow pattern and the process of scour around bridge piers. These include the size, cohesion, and grading of the bed material, depth of flow, size and shape of the bridge pier, flow velocity, and geometry of the bed. Other factors that influence scour that are the result of significant flood events include floating debris and accumulation and build up of debris. Usually, scour may occur during floods, and it can make bridges collapse.

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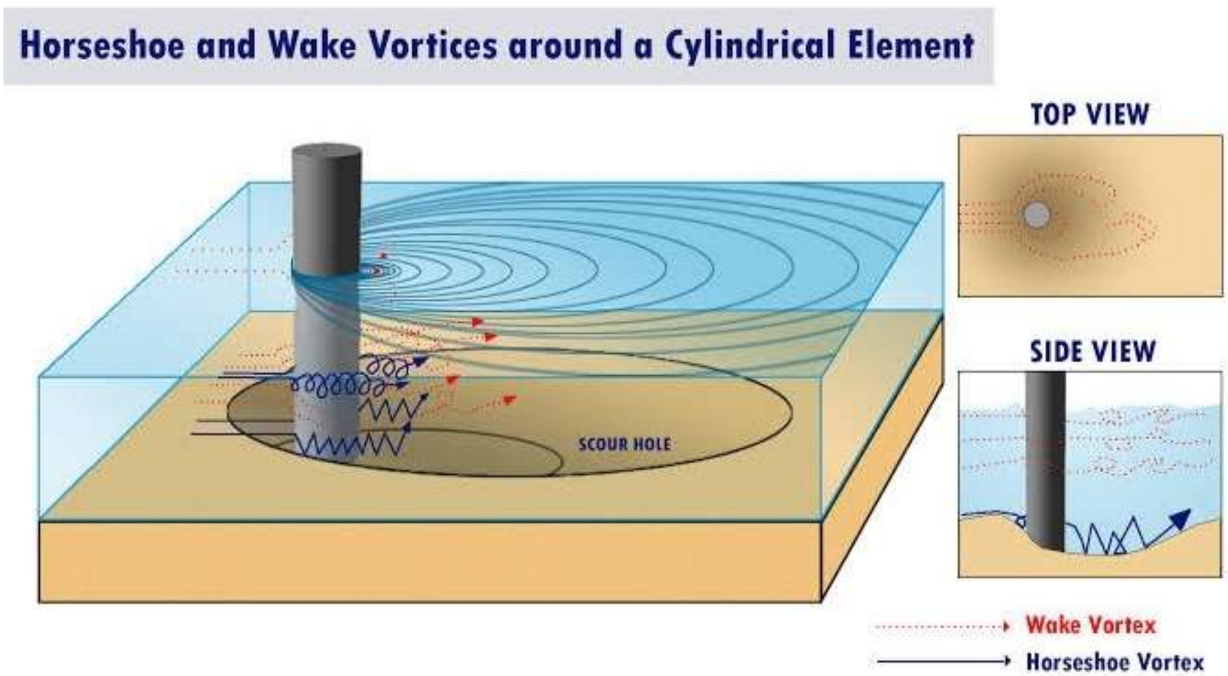
1.1. Scouring Phenomenon around a Bridge Piers

Recent scour related bridge catastrophes throughout the world have received great attention. Scour is local lowering of streambed elevation that takes place around structures that are constructed in flowing water. It means the lowering of the river bed level by water erosions such that there is a tendency to expose the foundations of a bridge. It is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams and from around the piers and abutments of bridges . Such scour around pier can result in structural collapse and loss of life and property. The amount of this reduction below an assumed natured level is termed scour depth.



(Figure 1.1. Showing how Scour hole gets generated around bridge pier by the flowing water)

1.2. Local Scour Importance

Improving the understanding of the local scour phenomena is vital to the engineer responsible for the design of piers and piles foundations. The knowledge of the maximum possible scour around a bridge pier is of paramount importance in safe and economic design of bridge piers. Because complete protection against scour is too expensive, generally, the maximum scour has to be predicted to minimize the risk of failure. Although scour research has become quite extensive, scour related failures still occur, which can be attributed to a lack of knowledge with respect to the process of scour, design criteria, and lack of publicly available results from such research. Because of its prevalence as a cause of bridge failure, scour is highly prioritized by modern bridge engineers. Several national and provincial bridge design codes (including the American Association of State Highway and Transportation Officials

(AASHTO) include provisions for hydraulic design. Such provisions include recommendations for design of bridge piers with respect to scouring, which state that this design is to be done based on one of several code specified "approved methods." These methods refer to empirical equations, which have been derived using experimental and field data over the past half-century. These equations are used to calculate the depth under which foundations must be placed in order to avoid failure due to scour. However, these widely used equations have a tendency to over-predict this depth (referred to as equilibrium scour depth using).

1.3. Problem statement

Scour is a major issue causing bridge failure and most of bridge failures in the world have proved it. The ability to protect bridge piers from scouring is critical to bridge safety. Excessive scour can cause high maintenance costs or even bridge collapse. Bridge collapse results in costly repairs, disruption of traffic, and possible death of passengers travelling on the bridge when the collapse occurs. The cost of large bridges, with common and special complex piles and piers, justifies carrying out an accurate prediction of scour depth, for both economic and safety reasons, which in turn leads to the interest of hydraulic engineers in predicting the equilibrium scour depth. Keeping in view the importance of scouring in bridges, it is necessary to analyse possible pier scour reduction. Therefore, in this research the scour reduction measures are analysed experimentally.

1.4. Aim and Scope of this Research

This research examines the scouring for different shaped and different size scaled model bridge piers in a uniform non-cohesive bedding material within a large flume. Through the various experiments conducted and analysis of the data, the reader will be able to assess scour and erosion potential.The main aim of this research is to find an effective way for the Reduction of the scouring around the bridge Piers so that Their will not be any damage to our Hydraulic structures .

1.5. Research questions

Some of questions which we have tried to answer in this research are:

- By changing the flow what will be effect on the scour hole depth of bridge Pier?
- Can scour hole depth depends on the shape of bridge Pier?
- What is the effect of size of bridge pier on scour hole depth?

1.6. Objectives

The main objectives of this research are:

- To reduce local scour around bridge pier by altering of flow technique
- To compare local scour around different shaped and sized piers
- To identify pier shape that responses best in order to minimize scouring effect.
- To find out the relationship of scouring depth with flow velocity, discharge, depth of flow.
- To find out parameters on which scouring depth depends and develop a relationship with scour depth for changes in the parameters.

2. LITERATURE REVIEW

2.1. Previous studies related to scouring around bridge pier & abutments

Chavan et al. **Turbulent Flow Structures and Scour Hole Characteristics around Circular Bridge Piers over Non-Uniform Sand Bed Channels with Downward Seepage**

This paper presents the experimental results of the scour hole characteristics forming around single vertical pier sets on a non-uniform sand bed with and without downward seepage. Empirical equations for the evaluation of the scour hole characteristics such as the length, width, area, and volume, including the downward seepage parameter, are proposed and experimentally tested. Predictions give reasonably good agreement with the experimental data.

Cui et al. **Scour Induced by Single and Twin Propeller Jets**

the authors conduct laboratory experiments to investigate scour induced by single and twin propeller jets Propellers with three and six blades typically used in British ports and harbors are scaled according to the similitude theory and reduced propeller models were created with a printer using biodegradable the polylactic acid filament, PLA, material. A laser rangefinder is used to measure the scour depth during the experiments. Empirical relations for the computation of the scour depth along the propeller axis are provided.

Guan et al**. Scour Evolution Downstream of Submerged Weirs in Clear water Scour Conditions**

The authors propose exponential equations to estimate the temporal variation in the scour depth and scour length downstream of a submerged weir . The study is useful in the development of models capable of estimating scour depth downstream of weirs in rivers or coastal areas, for which the overtopping conditions are very common. The proposed equations for scour hole dimensions, profiles, and sizes will be good tools for hydraulic engineers in the design of scour countermeasures.

Lee et al. **Scouring of Replenished Sediment through Reservoir Flood Discharge Affects Suspended Sediment Concentrations at Downstream River Water Intake**

This paper describes a comprehensive study on the transport of replenished sediment following two methodological approaches, namely numerical modelling and physical scale modelling Valuable field data are used for the models' calibrations and validations. The study makes an important contribution to the use of dredged reservoir sediments focusing on fine (cohesive) sediments for sediment replenishment, which in turn contributes to the morphological stability of the river downstream a dam. In this way, an alternative for the disposal of dredged fine sediments taking advantage of scour is provided.

Wang et al. **Experimental Investigation of Local Scour Protection for Cylindrical Bridge Piers Using Anti-Scour Collars**

The authors conduct live-bed pier scour experiments to investigate the effects of collars as a scour countermeasure . Three variables, namely the collar installation height, collar external diameter, and collar protection range, are tested. Important design guidelines such as the recommended collar shape, installation height, and collar diameter are provided.

3. RESEARCH METHODOLOGY

3.1. EFFECTS OF PARAMETERS

Experimentation has contributed to determination of the effect of each of these variables on scour depth and geometry, particularly in clear-water scour. Clear-water scour experimentation was more common than live-bed when a sudden influx of results demonstrated that scour depth in live-bed conditions could exceed scour in clear-water conditions. Most variables which affect scour depth and geometry can be categorized into one of five groups, which are generally interdependent

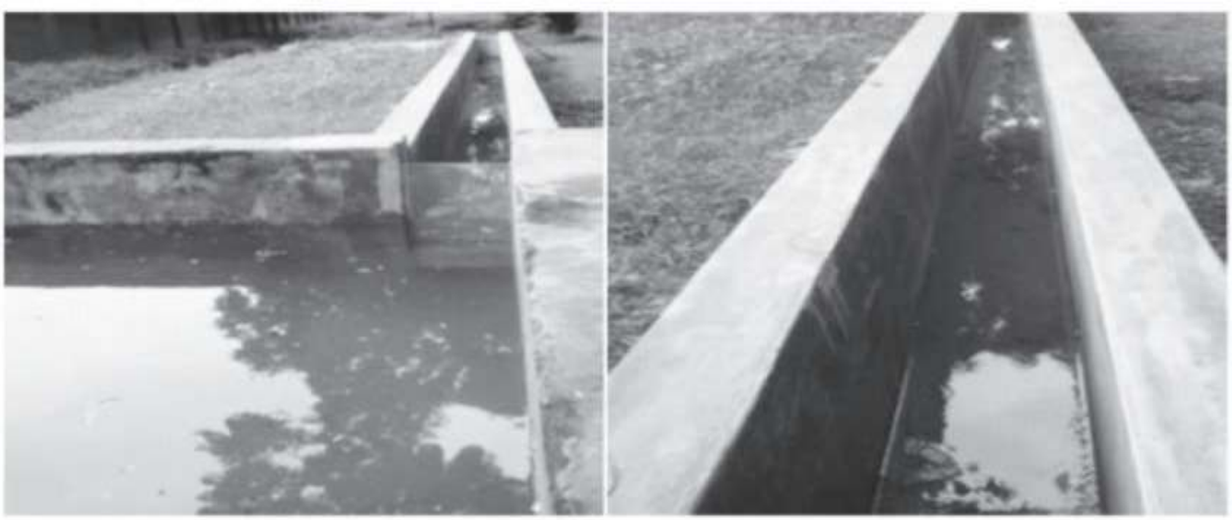
- Flow properties (water depth; energy slope; shear stress in uniform flow; angle of attack; mean flow velocity; and critical velocity of bed material), pier characteristics (pier diameter; shape; surface condition; pier orientation; and debris accumulation)
- Sediment characteristics (sediment density; median sediment size or diameter (d50); uniformity of particle size distribution; cohesiveness; shape factor; angle of repose; and fall velocity)
- It is also stated that pier shape will also alter scour geometry and depth; a more streamlined pier will induce a weaker horseshoe vortex system, lessening intensity of scouring action. The scour depth of a square-nosed

pier can be 1.2 times higher than the scour depth of a sharp-nosed pier, and 1.1 times the depth of scour for a cylindrical or otherwise blunt-nosed pier.

- There are other scour-influencing factors which are difficult to quantify; for example, inter- particle behaviour in any given sediment will affect scour depth and development. Similarly, the propensity of sediment to develop bed formations (planar beds, ripples, dunes and anti- dunes) under certain flow conditions will also alter the magnitude of scour

3.2. SETUP & METHODOLOGY

All of the experiments were conducted in an experimental flow channel specially built for this research.. The experiment reported herein was conducted in a rectangular flume, 10 m long, 0.3 m wide and 0.6 m deep as shown in Figure below The channel has a working section in the form of a recess that is filled with sediment to a uniform thickness of 0.10 m. The working section of the flume is made up of concrete. The water supply was available from a “water house” that was connected to the channel to facilitate continuous flow A sluice gate made of fibre glass was provided in the upstream to control water flow in the channel in a desired volume. During experiment, water source was maintained to keep hydraulic head of the house constant. The flow velocity was measured manually with the help of Continuity Equation, Q=VA (where, Q is the discharge, V is flow velocity and A is the cross sectional area of the flow channel).



Experimental Setup

Fig.1.1. Experimental setup

The velocity and the discharge of the water flow were measured and calculated using an Acoustic Doppler Velocimeter (ADV) and a Moulinet The pump was turned on and the water flow started. The flow depth, and consequently the

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discharge, for each experiment could be modified by adjusting the pump's pressure. The experiment began when the water reached the desired depth and it was stabilized at that level. The experiment's duration, that is, the period during which scouring would take place, was measured and noted. In the meantime, point velocities were recorded to form the velocity profile. When scouring was practically finished the pump was turned off and the flume was emptied and allowed to drain so that the sand pit dimensions around the piers could be measured. The sand pit extension and scour duration both depended on the flow discharge. In the experiments, piers with four kinds of cross-section shape were used: two were circular-shaped and two had an oval cross-section. The diameter of the larger cylindrical pier was D =4.0 cm and

the smaller one was D = 2.0 cm.

Fig.1.2.Flume in which experiment took place

The E and F parameter dimensions of the oval-shaped piers were E = 9.5 cm and F = 4.0 cm for the bigger one and E = 5.8 cm and F = 2.0 cm for the smaller one . All pier models were made of metal. Two different flow depths were tested. Moreover, for the small piers, experiments were carried out using double piers to study the effects of having more than a single pier. Finally, our search for a solution to the problem of scouring in bridges led us to conduct other experiments, with two piers, one of which was protected. All in all, sixteen experiments were conducted in the course of this research.

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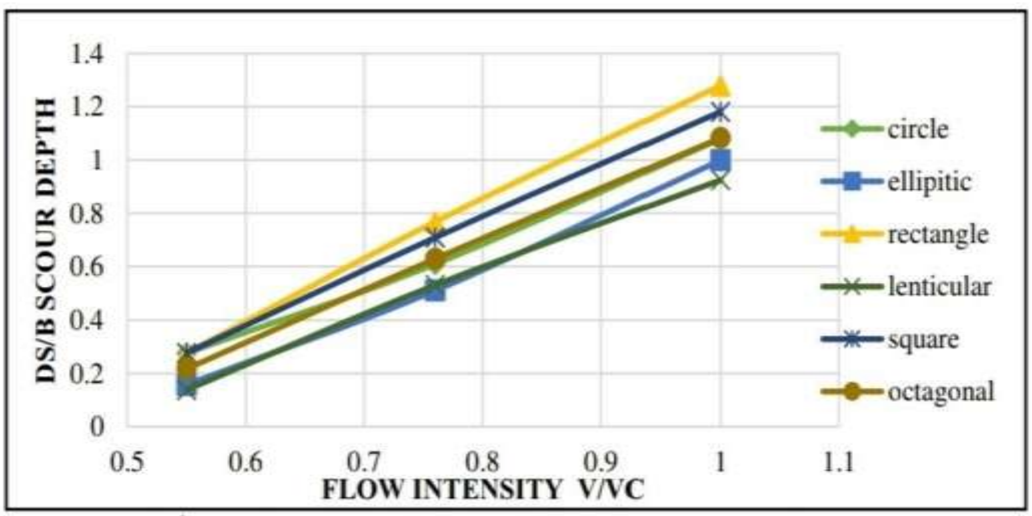
4.1. RESULS & DDISCUSSION

4.1. Effect of Flow Intensity on Scour for Different Pier Shapes.

Flow intensity is defined as the ratio of the approach mean velocity (v) to the critical mean velocity (vc). Flow velocity regarded as an important factor affecting scour depth development because it has a direct influence on the kinetic energy of running water. Simulations were performed for different pier shape models (circular, rectangular, square, octagonal, elliptical, and lenticular) under different flow intensity ratios (0.55, 0.76, 1.0). The boundary conditions, flow depth, and other parameters were held same with the exception of flow intensity, which was varied to investigate its influence on the scour. According to the results seen in Figure (8), scour depth around each pier increased linearly with flow intensity and reached a maximum value at a flow intensity equal to 1.0. These results also revealed that a rectangular pier with a blunt nose upstream pier shape developed maximum scour depth due to the upstream pier shape and corners, where a strong horseshoe vortex system occurs. Both square and octagonal shapes have less scour depth compared with a rectangle shape, and both circular and elliptic shapes have round nose pier shapes, which generate less scour depth at the upstream face but increase scour depth at the middle due to the increase in velocity. The lenticular pier with a sharp nose pier shape developed less scour depth as compared with other shapes due to having an upstream shape that encourages only a very weak vortex system. The lenticular shape reduced the scour depth by about 40% compared to the rectangular shape at v/vc equal to 1.



Influence of flow intensity on scour depth for different pier shapes.

Fig.1.3. scour depth Vs pier shape

4.2. Effect of Flow Depth on Scour for Different Pier Shapes

Flow depth is another important factor affecting the development of local scour depth; it is usually referred to as flow shallowness and is examined by relating flow depth (y) to pier width (b). Flow shallowness is classified relative to the local scour at bridge piers of three classes: 1) narrow pier; 2) intermediate width pier; and 3) wide pier. The ratios chosen in this study were based on this classification, and six piers with different shapes were simulated with different flow shallowness ratios (0.197, 0.984, 2.953) to examine the variation of the maximum scour depth against flow depth. According to the results shown in Figure below at a shallow flow depth (wide pier) ratio (0.197), scour depth reduced to a minimum value. For deep flows compared to pier width, for a narrow pier at ratio (2.953), scour depth increased and reached a maximum value dependent on pier diameter (b). According to the results, scour depth increases with increasing flow depth, though rectangular piers develop the maximum scour depth compared with other shapes.

4.3. Effect of Pier Width on Local Scour Depth at Different Pier Shapes :

The width of a pier has a direct effect on the depth of scour: the wider the pier, the deeper the scour. The ratio of pier width to channel width is thus probably a better measure of scour potential than pier width alone. In this study, six pier shapes with varied diameter cross sections were simulated, with this variation represented as a ratio b/B, (0.111, 0.15, 0.20). Figure (10) shows the relationship between the simulated maximum scour depth at 30 minutes and the pier width ratio for different flow intensity ratios. It can be observed that the scour depth steadily increases with the increase in pier width ratio, reaching a maximum scour depth at a ratio of 0.20; the lenticular pier still has the minimum scour depth, however.

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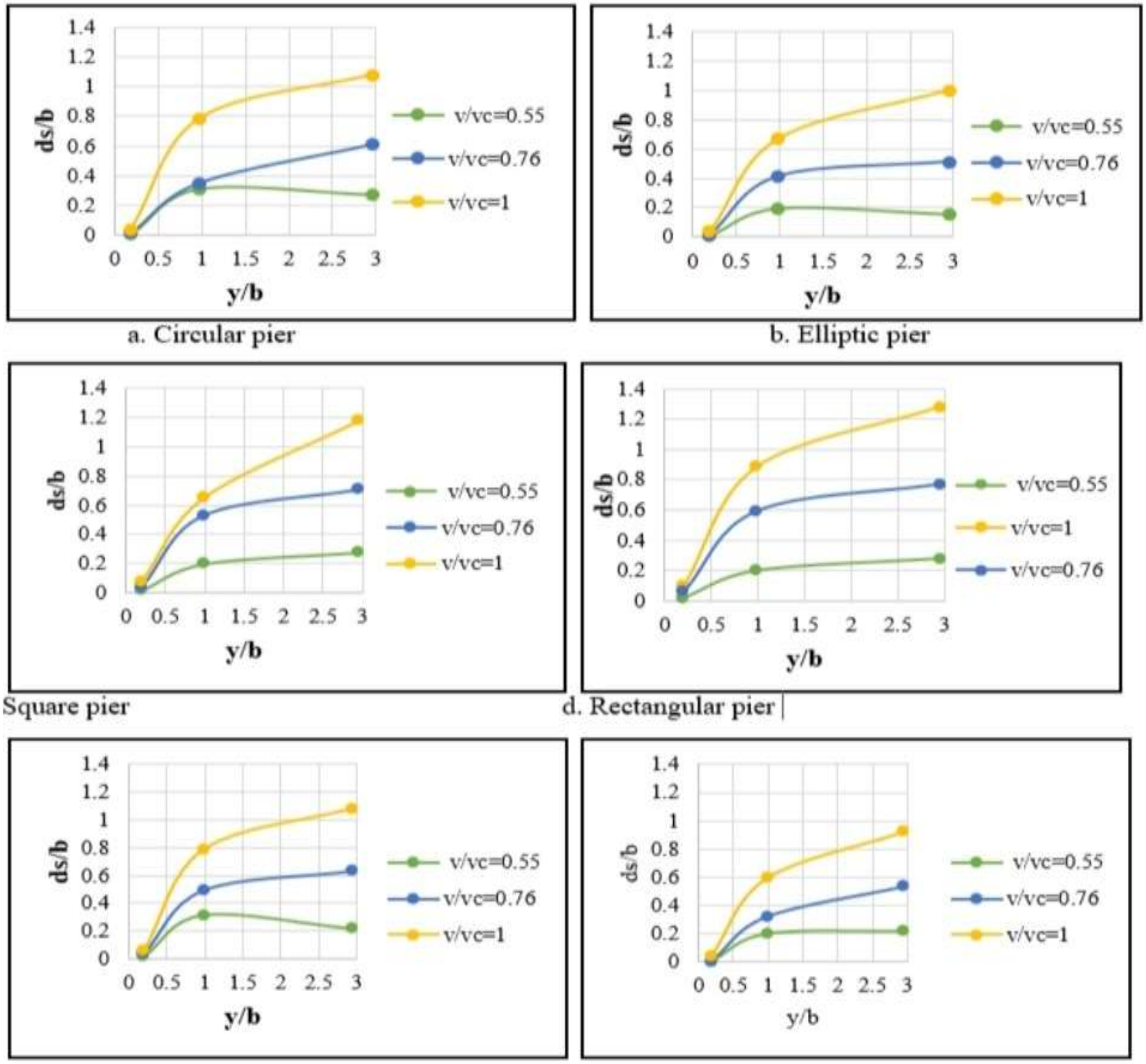

a. Circular pier b. Elliptic pier

Square pier d. Rectangular pier

e. Octagonal pier f. Lenticular pier

Scour depth versus flow depth for different pier shapes for different flow intensity.

Fig.1.4. Scour depth Vs shape of different types of piers.

5. RESULTS & RECOMMENDATIONS

Following are the main conclusions & few recommendations which were extracted from this search. ➢ Scour monitoring is very important to avoid major damages.

- Since by the experiments it was found the local scour of 4.6m during last 10 years & the bridge pier can tolerate this. So it is recommended that to continue local scour monitoring every 5 years minimum ➢ Scour depth increases with increase in pier diameter.
- The obtained results suggest that scour depth rate depends on the pier shape & by this experimental study and analysis it was found that rectangular pier can have maximum scour depth much higher then that of other shapes and it was experimentally found that lenticular pier have minimum scour depth as that of other piers due to Their minimum exposed area without side corners.
- The experimental study of our research also indicate that scour depth also reaches maximum value with the increase in width of pier. Rectangular pier have maximum value of scour depth ratio of 1.7 at a maximum pier width of ratio 0.2.while as scour depth ratio of lenticular pier was 1.01 at a pier width ratio 0.2
- Overall From this search it was experimentally found that lenticular piers are suitable for the Reduction of the scouring around bridge and they reduces about 60% of scour as compared to other types of pier.
- As the Rip-Rap Method of Reduction of scour is an old Method and very expensive it was replaced by Collar and slot Method it was experimentally found that Collars and vanes blades which proves every effective in the Reduction of the scour

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