Experimental Study on Scour Around Bridge Piers having different Geometry and width on Sandy bed

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Abstract

In this study, the scour depth and dimensions of the scour depth around different shaped piers were compare. Maximum and Minimum scour depth were find out. The experiments were carried out by using sharp nose, elliptical, Oblong rectangular piers to compare the various scour hole geometries at the same flow conditions. Numerous experiments were conducted in a rectangular flume (25.0 m long, 0.95 m wide and 1.00 m deep) with bridge pier having length and breadth ratio were 2 and 4. The flume bed of 20 cm thickness consists of non uniform graded material with d_{50}=0.65 mm. The experiments were carried out in clear water conditions. The equilibrium scour depths at lateral sides and downstream of the piers were also measured. The shape factor values were also investigated based on the experimental findings and the obtained values were compared to those available in literature. The performance of the obtained empirical relation for circular pier was tested by using limited experimental data available in the literature. The smallest scour hole was observed for the rectangular with sharp noses pier. The increase in the scour hole dimensions for other cross-sections was in the following order: sharp nose, elliptical, Oblong rectangular piers.

Keywords: Unsteady flow, local scour, scour hole, pier, shape coefficient.

2. Introduction

The structure, including its supports, that is built over a depression or obstruction like a river, road, or railway. It has a track or passageway for carrying traffic or other moving loads, and it has an opening that is more than 20 feet wide between its abutment copings along the centre of the roadway[1].A pier is a part of bridge that is effectively transfer the load from superstructure to foundation without failure

Scouring is a process of removal of soil or rocks from the channel by running water. The amount of sediment which is removed from the boundary of bridge pier is called bridge pier scouring and the depth up to which sediment is removed is called scour depth. Scouring results, the exposure of foundation, eventually leading to bridge failures. According to

Shirhole and Holt [2], 60% of 283 bridge failure were caused by hydraulic and scouring effects, in United States since 1951. Melville and coleman [3] found that every year, one bridge was failed due to scouring in New Zeeland. Study of 383 river bridge failures by Brice and Blodgett [4] identified the scour as primary reason of the 50% of these failures. 17 bridges were damaged and demolished in 1987 in New York and New England due to scouring.

Billions of dollars are spent by the federal, state, and private agencies on the maintenance of highway and railroad bridges. Scour failure is one of the main problems that bridges in the United States are facing these days. More than 80% of the highway and railroad bridges in the United States are constructed over water bodies [5]. In the United States, scour monitoring and estimation is conducted mainly by the Federal Highway Administration (FHWA) [6]. Some of the bridges in the US were not designed for scour erosion caused due to flooding. During the construction of bridges, the channel geometry has significantly changed and for some of the old bridges the type of foundation is unknown [7]. If the scour is not properly monitored, it will lead to the failure of the bridge which will affect the local economy and safety of the public [8]. The research on the bridge scour in the United States was initiated during the 1950s [9]. During the early days of the scour research the scour dimensions were determined by using analytical equations which were not accurate. Failure of the bridges increase the indirect costs through the increase in fuel usage and vehicle operating costs due to the temporary or permanent closures of bridges. Underwater inspection of scour ensures the safety of the public and vehicles travelling over the bridge. The underwater bridge scour is not visible from the land for most of the cases. As per the National Bridge Inspection Standards (NBIS) the parts of the bridge located under the water must be inspected at regular time intervals not less than 60 months [1].

Most of the DOTs (Department of Transportations) in the United States perform the critical member inspection every 24 months [10]. The period of 24 months for fracture critical members and 60 months for underwater bridge elements are not enough for effective detection of scour. Scour must be constantly evaluated to reduce the maintenance cost of the bridge and avoid the failure of the bridge. Scour erosion causes structural instability, deflection of beams and eventually leads to the failure of the bridges [11], hence the early detection of the bridge scour is needed. The soil around the bridge pier provides the stability for the pier. Due to scour, the soil around the bridge pier is displaced which affects the stability of the bridge pier.

More than 60% percent of the bridge failures in the US are caused due to scour [12]. The removal of the materials due to wearing action of moving water from the river and stream bed is defined as scour. Scour is classified into three types (i) local scour (ii) general scour and (iii) contraction scour [13]. Local scour is observed near the bridge piers when horseshoe vortices are developed which separates the flow in the upstream and downstream regions of the bridge pier [14]. The horse vortices will further develop into wake vortices. Local scour poses a threat to the stability of the bridge pier [15]. Contraction scour occurs when the transverse-sectional area of the river or stream is reduced. When the transverse sectional area is reduced, the velocity and sediment movement will increase. General scour occurs when there is a change in the flow parameters of the channel [16]. Scour measuring devices are classified mainly into (i) in-contact measuring devices, and (ii) non-contact measuring devices.

Al-Shukur et al. [17] have carried out experimental investigation using ten different shapes of piers and found that scour depth is minimum for streamline shapes where maximum for rectangular pier.

Most of the scour depth studies have been accomplished by means of physical modelling [18]; the present work also studies the significance of shape factor on local scour using physical modelling of obstacle shapes chosen. Shape factor was defined as a ratio of scour depth of non-circular obstacle to that of the circular obstacle [19].

Murtaza et al. [20] studies on the effect of shape of pier on scour depth. They were used four piers of different shapes (square, circular, oval, octagonal) of equal width as pier model.They were investigated on shapes and it was concluded that minimum scour depth is observed for octagonal bridge pier and maximum scour depth for square bridge pier while circular and oval faced intermediate scour depth relative to square and octagonal bridge pier. It is concluded that scour depth has reduced to 22% when octagonal bridge pier was used in compare to circular one.

ROY[2017]investigated and found that local scour around bridge pier is the main reason for failure of a hydraulic structure like as bridge piers, abutment etc. Local scour is a complex phenomenon which depends on the discharge, depth of flow, geometry of the pier and type of sediment particle. In this study, geometry i.e. shape of the pier is the main concern. Research is carried out by considering three different geometry pier of rectangular, circular and oblong shape to conclude the optimal shape of the pier at a different flow Results show an idea that the scouring at the upstream face is directly proportional to the exposed upstream nose area of the pier. It is also shows that the scouring is highest in all cases for the rectangular pier and minimum for oblong pier.

Talibet et al. [22] found that the maximum scour depth around bridge piers is very important in design the foundations of bridges. They presented the experimental data for local scour around different shapes of bridge piers. They also found that effect of velocity, Froude Number and pier shape factor on the maximum scour depth. After analyzing the data ,they formulated an empirical equation to estimate the maximum scour depth around various shapes of bridge piers which gave a good coefficient of determination between the observed and predicted scour depths and give a good idea to calculate the maximum depth of scour in cases similar .

Misuriya et al. [23] recognised the influence of pier geometry on the neighbourhood scour under the unstable flow conditions of the flow hydrograph. They discovered that neither the flow instability nor the pier's design had an influence on the maximum scour depth. The scour depth in the case of a flow hydrograph was considerably less than the scour depth at equilibrium discharge.

Garde andKothyari[27] found that scour around bridge pier depends on different types soil existing around bridge pier. In case of clayey soil around bridge pier the different type of forces act between soil particles which resist the dislodgement of particles that cause scour around bridge pier.

Singh and Maiti [28]studied local scour around a circular pier in an erodible bed. They noticed that the highly unsteady complex flow field around a circular pier produced scour-hole mainly because of the vortices. They concluded that the prime mechanism which caused the formation and evolution of the scour-hole around the pier is horseshoe vortex motion.

Deshmukh and Raikar [29] reported that the scour depth increases with time up to a certain limit and then it attains a constant depth of scour which can be considered as an equilibrium scour depth. Maximum depth of scour was observed on the upstream side of the pier. They concluded that the scour depth increases with an increase in the pier size/diameter keeping all the parameters related to flow and sediment characteristics as the same.

Raikar and Dey [30] performed experiments on scour of gravel bed around bridge piers and abutments. It was found that equilibrium scour depth at piers depend on the gravel size. It was also found that equilibrium scour depth increases with decrease in gravel size and with increase in pier width.

Parameter influences local scour The parameters that influences the magnitude of the local scour depth at bridge piers can be divided into four main groups:

1. Parameters characterizing the fluid: dynamic viscosity (μ), the acceleration due to gravity (g) and density of water (ρ).
2. Parameters characterizing the stream flow: Flow intensity, flow depth (y), mean velocity (V), shear velocity and critical mean flow velocity (Vc)
3. Parameters characterizing the bed materials: sediment density (ρs), particle shape, geometric standard deviation of the sediment particle size distribution (σg), angle of repose and soil cohesiveness. 4) Parameters characterizing pier foundation; pier size, pier length (a), pier width (b),spacing between piers and angleof attack (θ).

Dimensional Analysis Engineers should rely on interpretation and judgment based on experimental observations and experiences. Dimensional analysis is a powerful tool in formulating problems. The physical mechanism of the local scour can be understood better if appropriate dimensionless parameters describing the phenomenon are defined. A dimensional analysis is made below for the parameters that affect the local scour mechanism and governed in this paper by using Buckingham π-theorem. The variables that used in this study can be summarized by this relationship:

$$f\, ys, \rho, V, g, \ , b, Ks = 0 \quad \text{eq. 1}$$

The repeated parameters are selected as ρ, V, and b so the dimensionless π-terms that influence the scour depth around piers can be rested the following form:

$ys\ b = f1\ \ , \text{Ks}\ , V\ gb$ eq. 2 Where: the term $V\ gb$ is known as pier Froude number (Frp).

2. Materials and Methods

2.1 .1 Methodology: Following methodology was utilize:

1. Using an experimental flume, calculate the scour depth around bridge piers with various geometry and identify the pier geometry that results in the lowest scour depth. Then, compare your results to previous studies.
2. Use a uniform Sediment sample having a distinct standard deviation and median.
3. 3.To contrast experimental outcomes using various formulas.

2.1.2 Experimental Work :-

The experimental set-up for the experiments, material used and the procedure adopted is given in the proceeding sections.

2.1.3 Experimental Set-up The experimental set-up used for the purpose consisted of a tilting flume 25 m long having a height of 1.00 m and 0.95 m deep, located in the Fluid Mechanics Laboratory of Water Resources Department, MAMIT Bhopal.

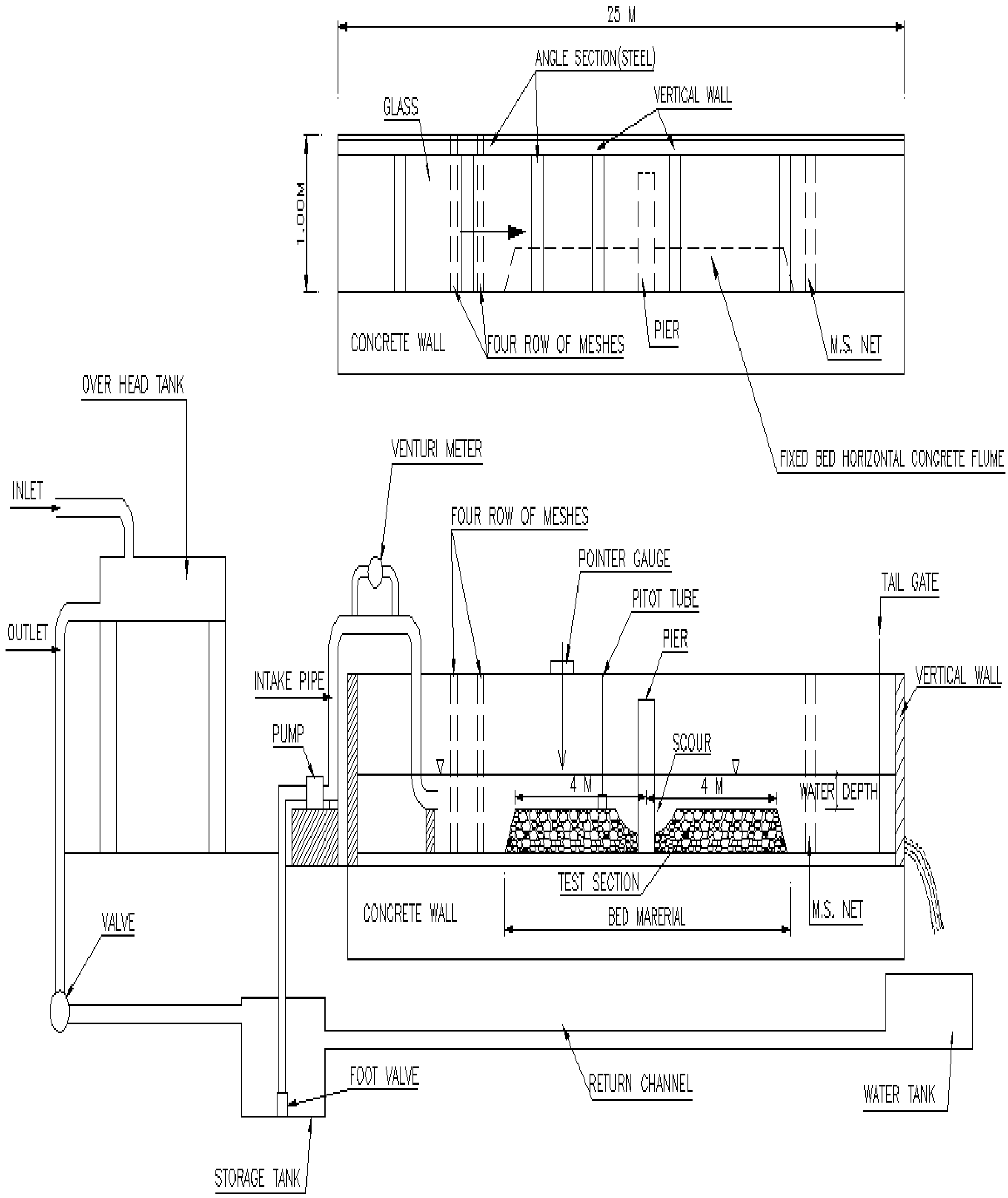

Figure-1 The Flume (25 meter long,0.95 meter breadth and 1 meter deep)

Figure 1 shows the glass flume used in the study. The flume had glass side walls and a concrete base with necessary arrangements for water supply regulation and measurements. The width of the obstacles was modelled as 1/10th of the channel width[24] recommended that the obstacle diameter should not exceed 10% of the flume width. In this case, dimension of each obstruction facing the direction of flow was modelled to be about 100 mm. The cross section of the obstacle shapes is given in Fig. 2. The shapes selected for this study have been chosen keeping in mind the most commonly encountered obstruction shapes in real-life hydraulic structures, e.g. bridge piers, viewpoints constructed in the water bodie

The channel is entirely composed of concrete except for glass walls shown in figure 1. A pump that transfers water from an underground storage to flume (shown in figure 1)through a pipe to supply water. shown in figure 1. Water is supplied to underground storage tank to overhead tank through a pipe line A valve that was put in place between storage tank and over head tank as seen in Fig. 1 which was used to control the flow. Four piers with the shapes shown in figure 2 (circle, square, oblong, and ogival) were tested in clear water with uniform course sand bed material to meet the goal of this study.

The working section measured 8.00 m in length and 0.2 m deep in erodible homogeneous uniform course sands having upraise inclination at ends of 1: 17 and 1:20 respectively are present at the working section's inlet and outflow to provide a consistent flow during testing. At the flume's inlet, a venture metre was used to measure the discharge. Tail water depth was controled by a moveable vertical gate at the downstream as shown in figure 1.. All depth measurements are made with the aid of two movable point gauges that are fixed on a rail which was made in brass at the peak of the sides of flume having correctness of± 0.1 mm. Pitot tube was used to assess the flow's velocity close to the pier. One by one(out of four) [10] pier embedded vertically in bed material as display in fig-1

Sharp nose Elliptical Rectangular

Figure-2 Different shape bridge pier[10].

2.1.4 Pier Models:

Four pier models were contrasted with one another in this study.To promote smoothness and prevent contract with water, piers made of sal wood will be painted with colours and covered with paint. This experiment will be carried out with a width of pier (7.0cm) at a constant depth of flow (0.125m and 0.155m). It should be noted that the experimental flume's diameter exceeds ten times that of the pier.So the cross section of each pier is 13 cm in length , 6.5 cm(l/b=2) in width and 30 cm in length , 7.5 cm(l/b=4) in width in this study. The ratio of length to width is 2 and 4. To prevent the impact of wall friction on local scour, Chiew and Melville said in 1987 that the diameter of the pier should not be higher than 10% of breadth of flume. More than ten times as wide as the pier is the flume.

2.1.5 **Test Material** The obstacles used were modelled in four different shapes.

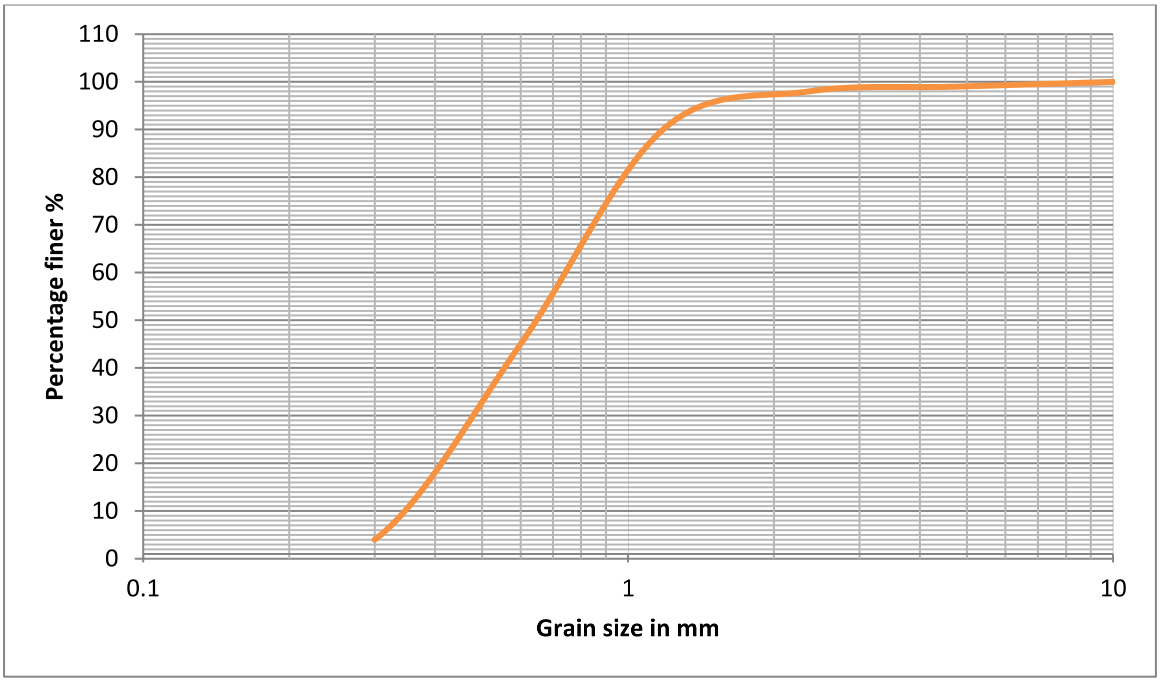

Figure 3 The curve of grain size distribution

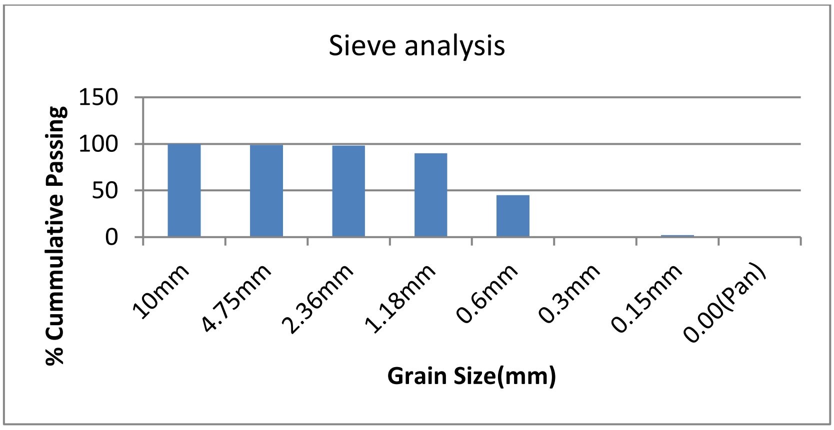

Figure 4 A partical size distribution histogram.

Melville[25] recommended that the pier diameter should be carefully chosen so that there may be negligible effect of sediment size on the depth of scour. It was a known fact that the bed material grain size does not affect the depth of scour if the pier width to grain size ratio exceeds a value of about 25.

The pier diameter was also carefully chosen so that there was negligible effect of sediment size on the depth of scour. It is known that the bed material grain size does not affect the depth of scour if the pier width to grain size ratio exceeds a value of about 25 [31]. For this study, the ratios are about 100 and 115.4 for the pier of 65 mm and 75mm, which satisfies the criterion of Melville, 1997.

The material of the bed having d_{50} = 0.65 mm that was determined from figure 3 and having specific gravity of course sand =2.722 was used for the test. The geometric standard deviation (α_g) for a sample of medium sand is 1.62, which is greater than 1.4, indicating that the course sand is non uniform [26]. Since the non uniform medium sand has a geometric standard deviation of 1.62, it is clear that its size distribution is non uniform. The definition of the geometric standard deviation (α_g) = $\sqrt{(\frac{d_{84}}{d_{16}})}$. Particle size d_{84} is 84% finer than d_{16}, which is 16% finer. As seen in figure 3, d_{16}=0.385 mm and d_{84}=1.02 mm.

3. Experimental Procedure:- To achieve purpose of this study, investigation were executed with four various types of pier. Pier having different shape was embedded in uniform coarse sand bed. Working section at flum having 20 cm deep which was filled up with non uniform medium sand having d_{50}=0.65 mm was made. Bed surface was levelled with the help of a scraper. Levels are also verified with the help of point gauge.

A centrifugal pump linked with an electric motor was on and pump started. In order to prevent scouring due to slope in the early stages, water was supplied from upstream toward downstream at a very slow pace and then a constant discharge was controlled by valve. The tail gate is gradually lowered when pumping has begun till the necessary depth of water in the flume is reached. A point gauge is utilized to compute the depth. At the flume's inlet, a venture metre was used to measure the discharge. Pitot tubes were used to monitor flow vel ocity, and point gauges were used to detect flow depth, as illustrated in Fig. 1.

Ten hours are spent on the test. During conclusion of every experiment, the flow was closed by turning off the power. A point gauge was utilized to compute the scour's depth. To bypass any moderations to the scour hole, the uniform coarse sand is permitted to dry while the flume is gradually emptied. Then the necessary measurements of the uniform coarse sand bed are taken at upstream, downstream, transversely and longitudinally. The uniform coarse sand was relevelled and the procedures described above were repeated while altering the design of the pier.

4. Test Program

The test programme was expanded to address the geometry of the pier as a local scour mitigat ion approach, with a primary focal point of the time needed to attain an equilibrium scour situation. With the perimeter of a bridge having four different geometries like : sharp nose, elliptical, Oblong rectangularpiers this test programme was perform at several water discharges, including 33.8 lit/sec and 47.5 lit/sec experiments were executed in clear water and the depth of the highest scour was computed.

Table 1 provides a summary of the test condition for each bridge pier shape.

No.	**Flow Intensity($\frac{V}{V_c}$)**	**Flow depth(y) in meter**	**Velocity (V) in Flume (m/sec)**	**Discharge(Q) in lit/sec**	**Froud number (Fr)**	**Reynold number (Re)**

1.	0.285	0.125	0.285	33.8	0.257	28203
2.	0.323	0.155	0.323	47.5	0.261	37747

2.1.3 **Experimental Procedure** :-The experiments were performed in the fixed bed with zero slope flume described under the experimental set-up subheading. The middle section was chosen for placement of the obstacles so as to minimise the effect of inlet disturbances and tailgates. The flume was then filled with the above-described bed material, up to a depth of 200 mm. The material was properly levelled in order to achieve results nearer to natural conditions. At the entrance section of the flume, four rows of meshes was to prevent inlet turbulence as shown in Fig. 1. Water supply to the flume was regulated with the help of valves located in the supply line fed by a constant head tank.

5.Results and Discussion

The overview of laboratory findings from tests performed in series on the four pier shapes is presented in Table 2.This experimental investigation displayed that scour significantly decreased when the design of the pier was changed. The out come appeared that the Sharp nose shape had the lowest scour's depth 47 mm and 50mm for velocity 0.285 m/sec while the Rectangular pier gave the maximum scour depth 75mm and 74 mm whene l/b=2 and 4respectly and the out come appeared that the Sharp nose shape had the lowest scour's depth 63mm and 68mm for velocity 0.323 m/sec while the rectangular pier gave the maximum scour depth 100mm and 101 mm whene l/b=2 and l/b=4respectly(l/b=length and width ratio of bridge pier)

Table-2 Mesured Scour Depth of bridge pier for test series (each shape)

Sr No	Depth of flow(cm) y	Velocity (V) m/Sec	Discharge(Q) in lit/sec	Shape of pier	Mesured Scour Depth in cm	
					b= 6.5 cm and l/b=2	b= 7.5cm and l/b=4
1	12.5	0.285	33.8	Sharp nose	4.7	5.0
				Elliptical	4.9	5.3
				Oblong	5.1	5.6
				Rectangular	7.5	7.4
2	15.5	0.323	47.5	Sharp nose	6.3	6.8
				Elliptical	6.6	7.2

				Oblong	6.8	7.6
				Rectangular	10.0	10.1

Breusers et.al.,1977 formulas (1)

$$\frac{y_{se}}{b} = 2K_1K_2\left(2\frac{V}{V_C} - 1\right)\tanh\left(\frac{y}{b}\right) \text{ where } 0.5 \leq \frac{V}{V_C} \leq 1$$

Where y_{se}=equilibrium scour depth

K_1 = 1.0 for circular pier

K_2= Angle of attack

b= pier width, y= flow depth Where Critical velocity (V_C) = $6.19y^{\frac{1}{6}}(d_{50})^{\frac{1}{3}}$

Where d_{50}=Median of bed material

Table 2 Measured Scour Depth of bridge pier for test series (each shape)

Table-3 Measure value of scour depth compared with theoretical Value in different velocity, discharge and flow depth which is calculated by above said formula no 1 (Breusers et.al.,1977)

Sr No	Depth of flow y in cm)	Discharge (Q) lit/Sec	Velocity (V) m/Sec	Shape of pier	Mesured Scour Depth in cm		Theoretical Value(cm) Breusers et.al.,1977	
					b= 6.5 cm and l/b=2	b= 7.5 cm and l/b=4	b= 6.5 cm and l/b=2	b= 7.5cm and l/b=4
1	12.5	33.8	0.285	Sharp nose	4.7	5.0	5.06	5.32
				Elliptical	4.9	5.3	5.25	5.60
				Oblong	5.1	5.6	5.43	5.95
				Rectangular	7.5	7.4	7.87	7.78
2	15.5	47.5	0.323	Sharp nose	6.3	6.8	6.68	7.12
				Elliptical	6.6	7.2	6.93	7.50
				Oblong	6.8	7.6	7.17	7.97
				Rectangular	10.0	10.1	10.39	10.41

In table 4, shape factor(l/b=2) is compared with shape factor(l/b=4) bridge pier having different geometry.

Sr no	Shape	Shape factor	
		l/b=2	l/b=4
1.	Sharp nose	0.81	0.76
2.	Elliptical	0.84	0.80
3.	Oblong	0.87	0.85
4.	Rectangular	1.26	1.11

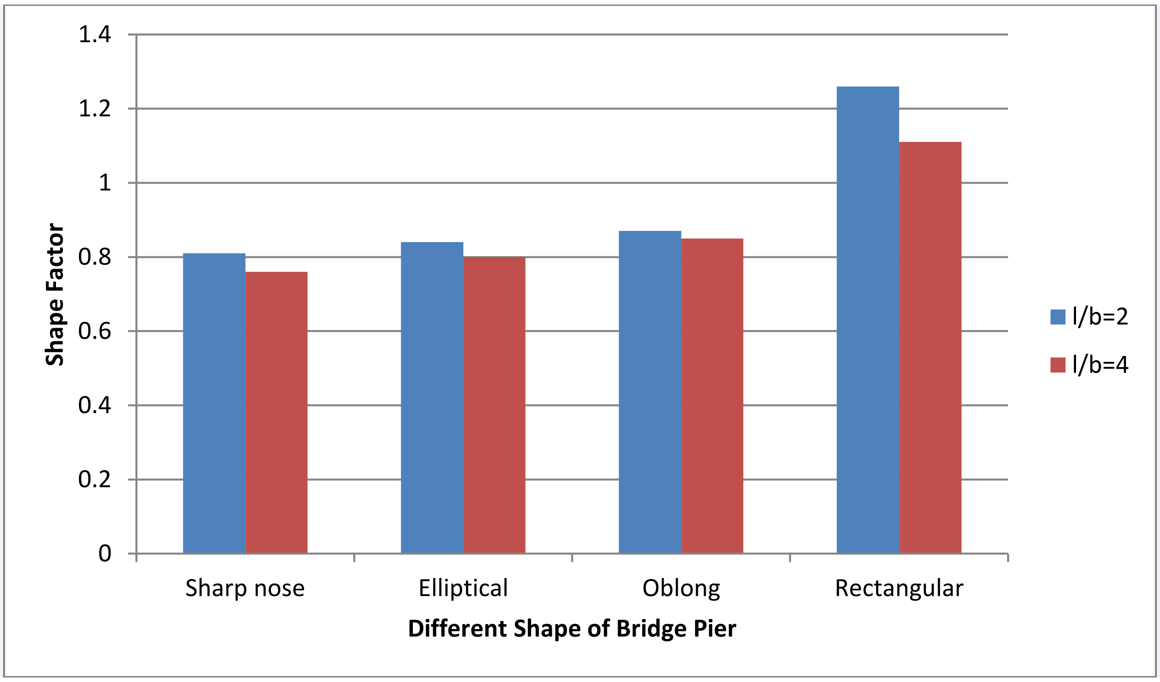

Figure 5
was drawn to compare the results of the current study's shape factor calculations using various pier shapes for various length to width ratios represented by histrogram.

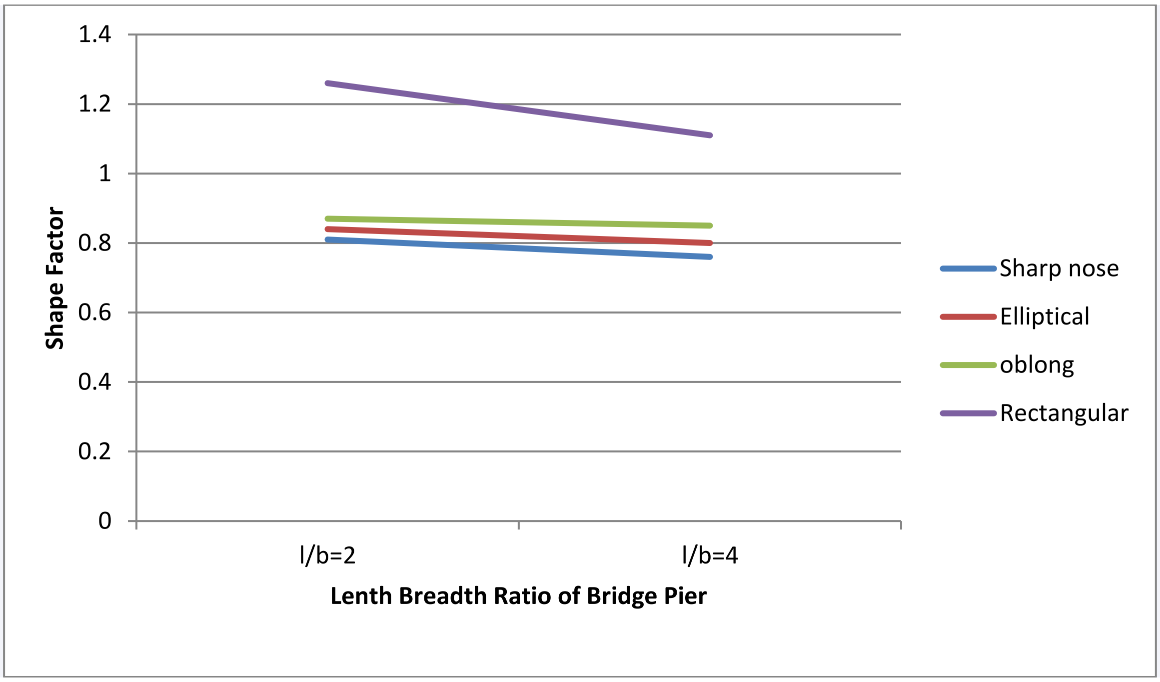

Figure 6
was drawn to compare the results of the current study's shape factor calculations using various pier shapes for various length to width ratios represented by graphically.

Table-5 display flow intensity on scour depth/width of pier of various pier having various geometry(b=6.5 cm).

Shape of pier	**Maximum scour depth ratio d_s/b**	
	V/V_C=0.751	**V/V_C=0.823**
Sharp nose	0.72	1.17
Elliptical	0.75	1.23
Oblong	0.78	1.26
Rectangular	1.15	1.85

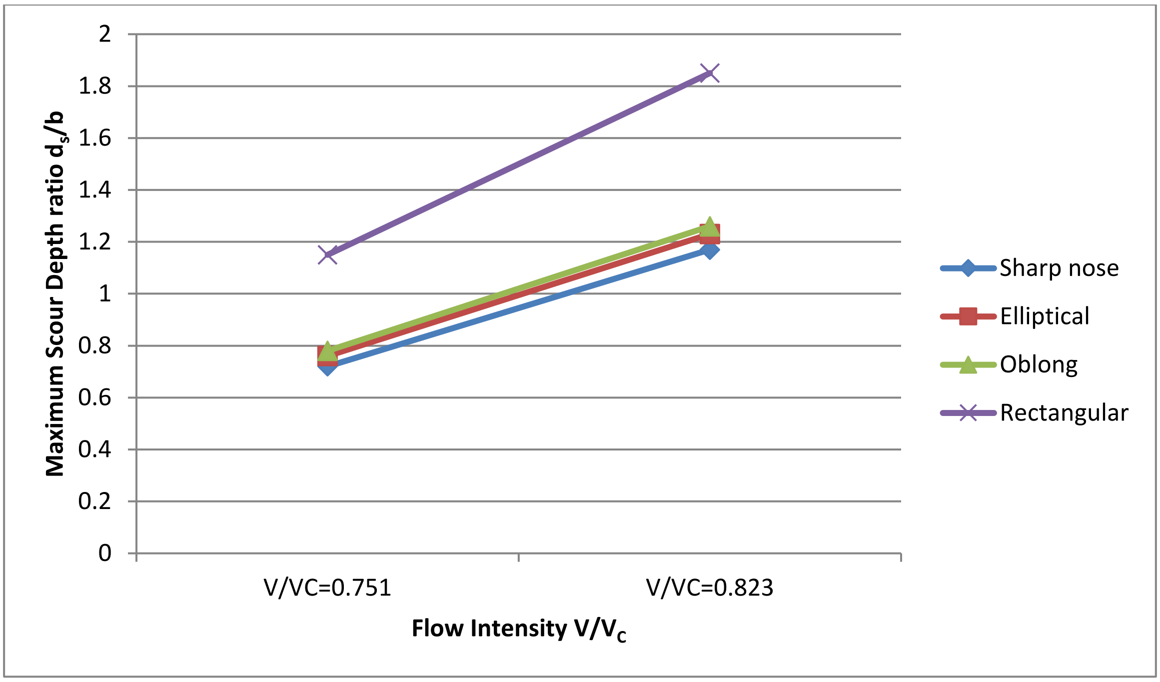

Figure-7 Influence of flow intensity on measure scour depth of different pier shape(b=6.5 cm)

Table -6 display flow intensity on scour depth/width of pier of various pier having various geometry(b=7.5 cm).

Shape of pier	Maximum scour depth ratio d_s/b	
	V/V_C=0.751	V/V_C=0.823
Sharp nose	0.89	0.91
Elliptical	0.95	0.96
Oblong	1.01	1.02
Rectangular	1.33	1.34

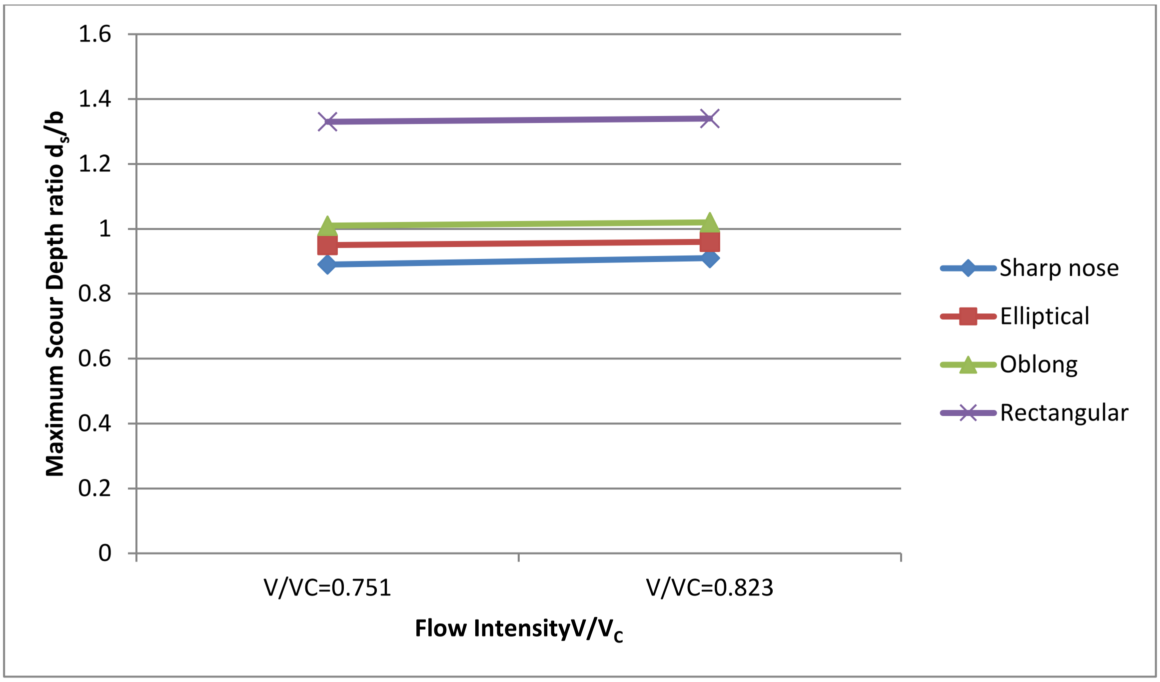

Figure-8 Influence of flow intensity on measure scour depth of different pier shape(b=7.5 cm)

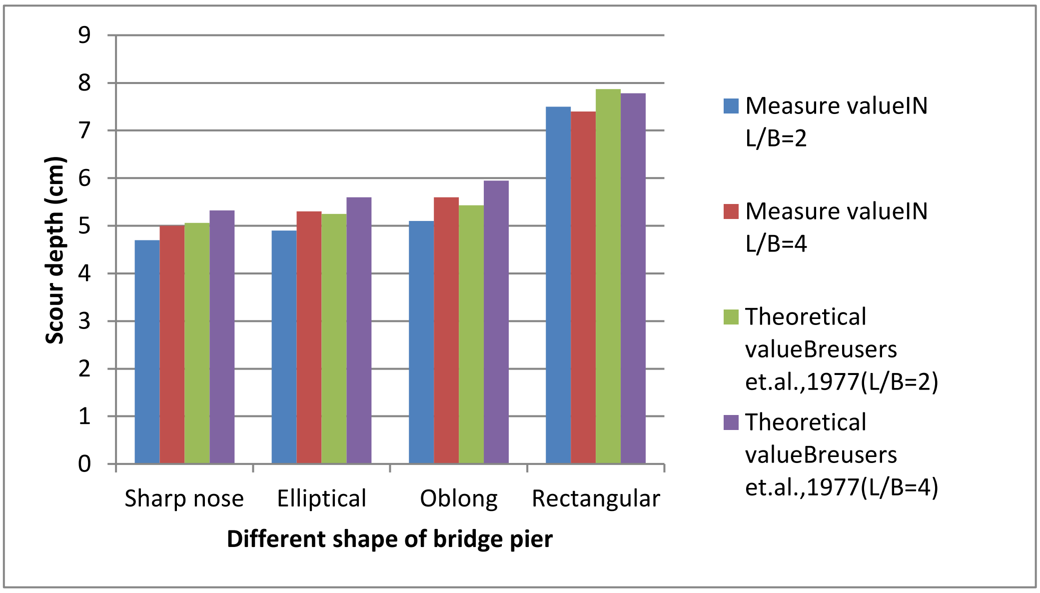

Figure-9 Comparison scour depth of measure value with Breusers et.al.,1977 (at V= 0.0.285 m/s,y=12.5) in various geometry

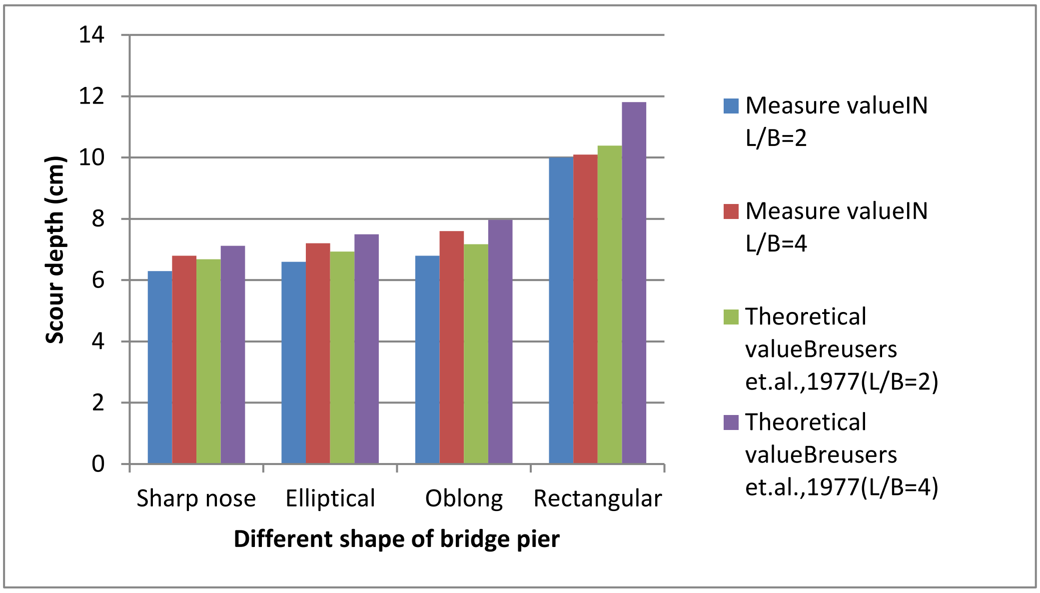

Figure-10 Comparison scour depth of measure value with Breusers et.al.,1977 (at V= 0..323 m/s,y=15.5) in various geometry

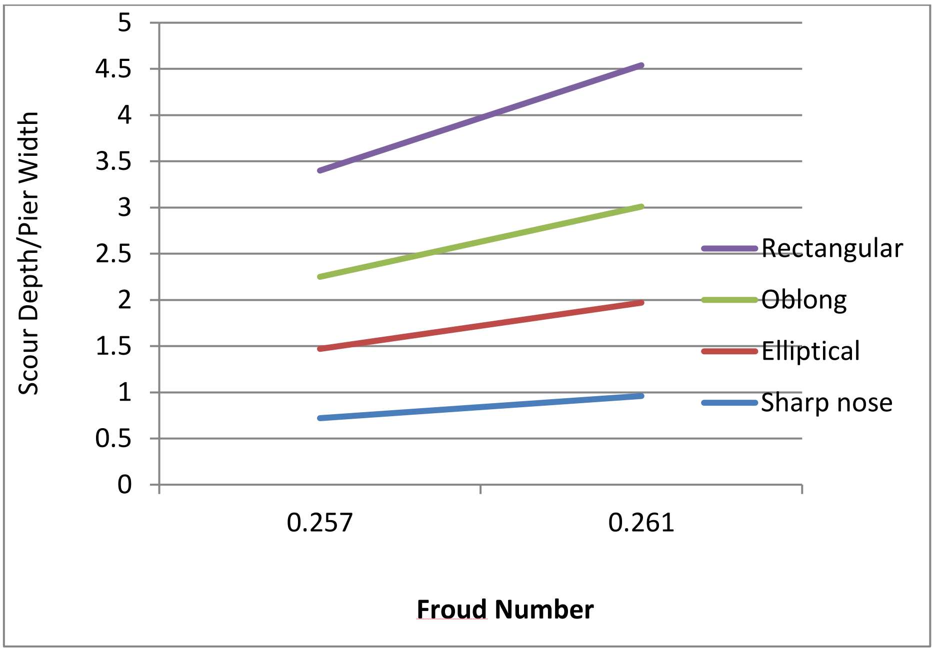

Figure-11 Comparison scour depth/width with Froud Number (at V= 0.285 m/s and V= 0..323,y=15.5 and y=12.5,l/b=2 and b=6.5) in various geometry.

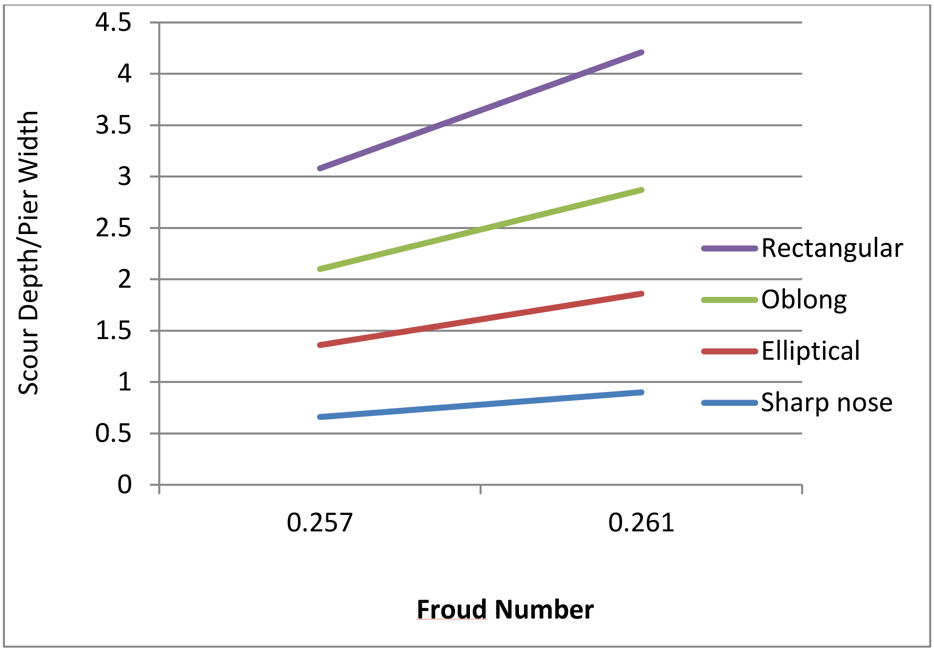

Figure-12 Comparison scour depth/width with Froud Number (at V= 0.285 m/s and V= 0..323,y=15.5 and y=12.5,l/b=4and b=7.5) in various geometry.

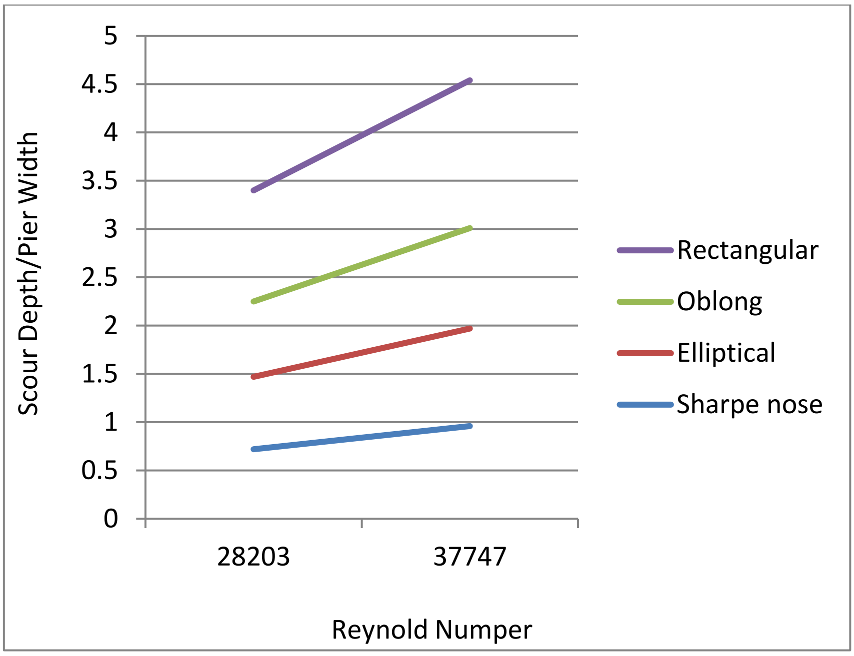

Figure-13 Comparison scour depth/width with Reynold Number (at V= 0.285 m/s and V= 0..323,y=15.5 and y=12.5,l/b=2and b=6.5) in various geometry

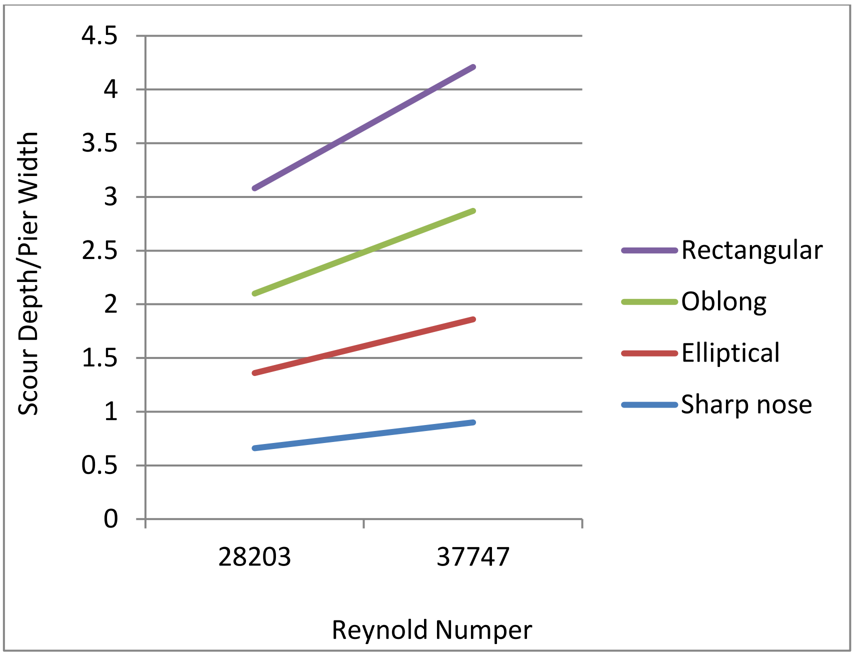

Figure-14 Comparison scour depth/width with Reynold Number (at V= 0.285 m/s and V= 0..323,y=15.5 and y=12.5,l/b=4and b=7.5) in various geometry

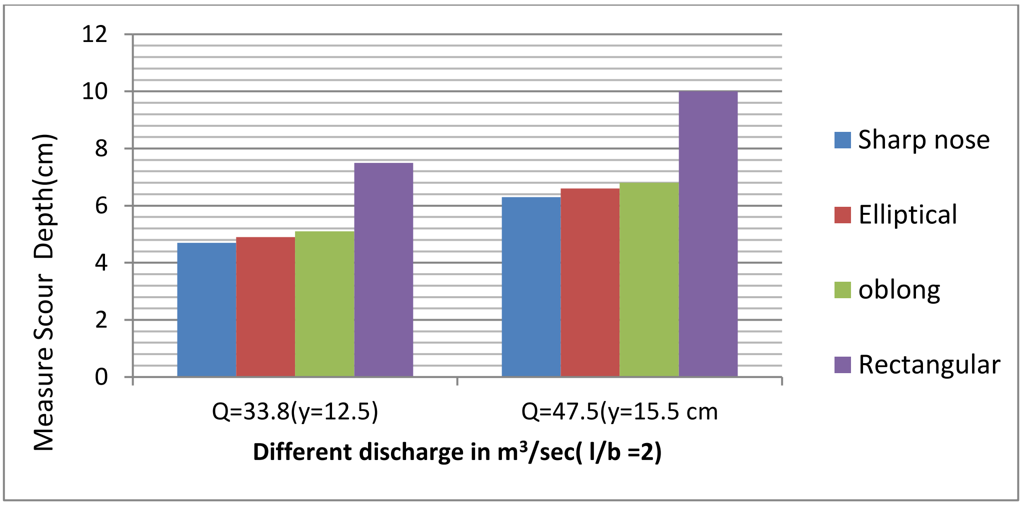

Figure-15 Comparison measure scour depth/width with various discharge (at ,l/b=2and b=6.5) in pier having various geometry

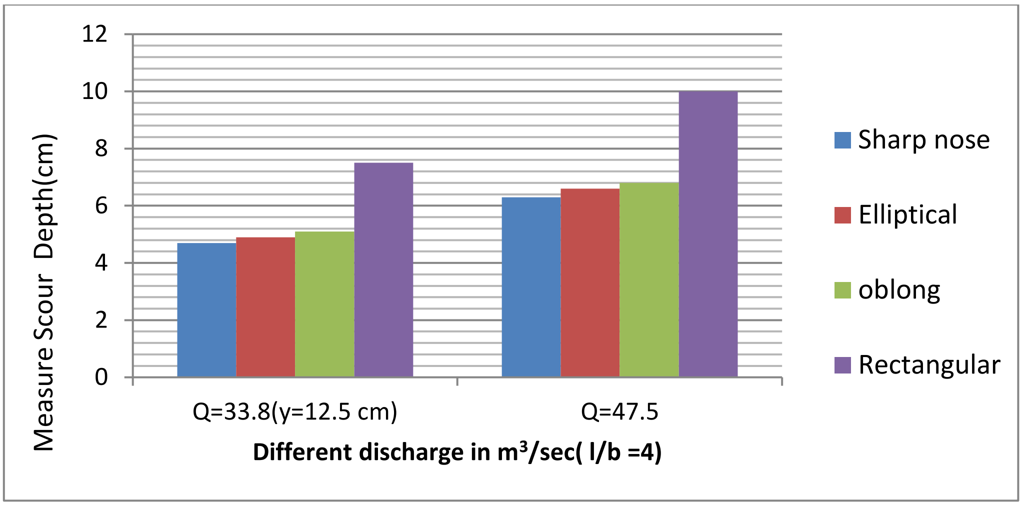

Figure-16 Comparison measure scour depth/width with various discharge (at ,l/b=4and b=7.5) in pier having various geometry which is represented by histrogram

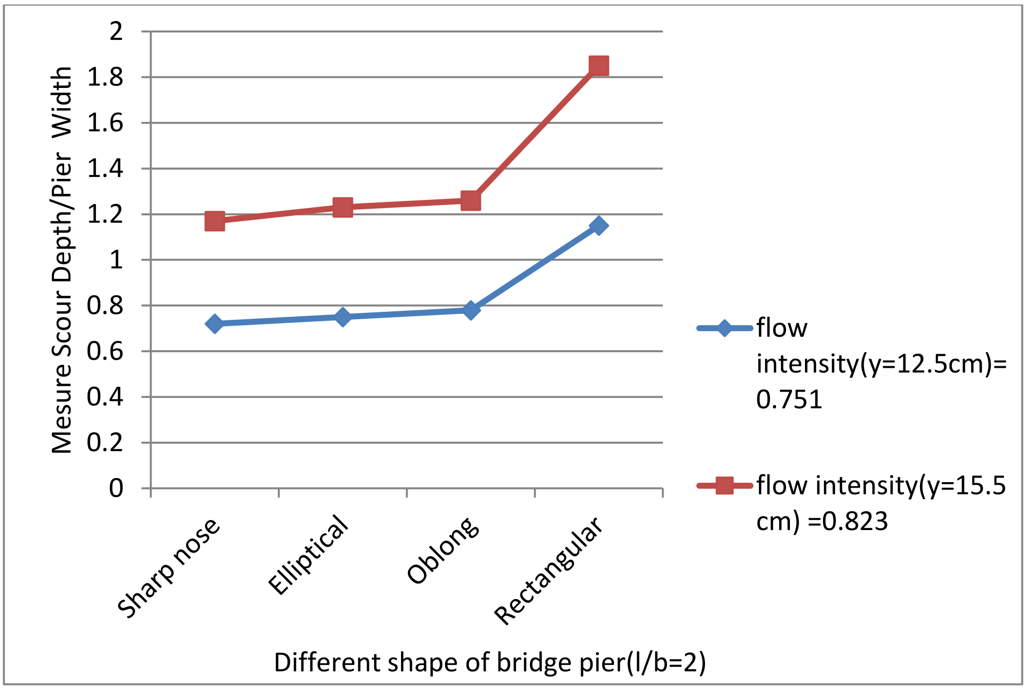

Figure-17 Comparison measure scour depth/width with various flow intensity (at ,l/b=2and b=6.5cm) in pier having various geometry which is represented by graph

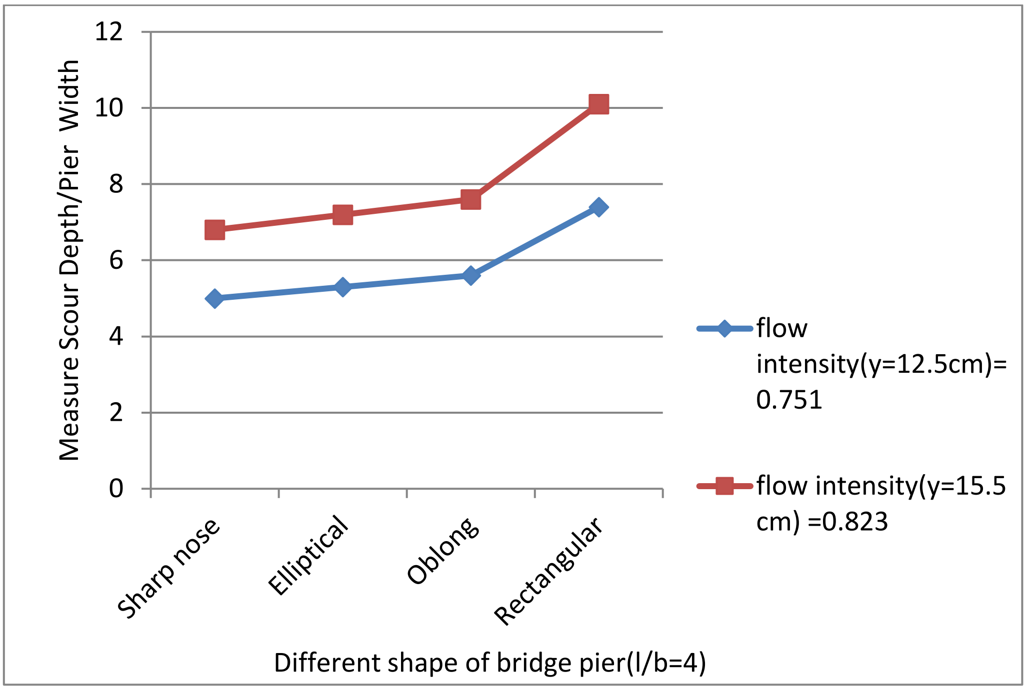

Figure-18 Comparison measure scour depth/width with various flow intensity (at ,l/b=4and b=7.5cm) in pier having various geometry which is represented by graph

9. Percentage Scour Depth Reduction:

The following table shows comparative percentage scour depth reduction between two flow depth conditions (y=12.5 cm and y=14.5 cm) for sediment sample Ϭg=1.62 .

Table 7 Percentage Scour depth reduction (l/b=2 and b=6.5 cm)

Sr.No	Depth of flow (cm)	Discharge (Q) lit /sec	Velocity (V) m/s	Type Of Pier Shape	Measured Scour Depth(cm)	maximum scour depth	% scour depth reduction
1	**12.5**	**33.8**	**0.285**	Sharp nose	4.7	**7.50**	**37.33**
				Elliptical	4.9		**34.66**
				oblong	5.1		**32.00**
				Rectangular	7.5		**0.00**
2	**15.5**	**47.5**	**0.323**	Sharp nose	6.3	**10.0**	**37.00**
				Elliptical	6.6		**34.00**

				Oblong	6.8		**32.00**
				Rectangular	10.0		**0.00**

The depiction of the percentage scour depth reduction between the piers for l/b=2 and b=6.5 cm was shown in the table above. The demonstrated that using sharp nose can result in a measure scour depth decrease of roughly 37.33% and 37.00% compared to Rectangular shaped pier for flow depth 12.5cm and 15.5 cm respectively which is display in table no-7 and figure-19. Instead of employing a sharpe nose-shaped pier, a elliptical-shaped pier can be used and an decrease of 34.66% and 34.00% in measure scour depth can be produced for flow depth 12.5cm and 15.5cm respectively which is display in table no-7 and figure-19. A oblong-shaped pier can be used and an decrease of 32% compared to Rectangular shaped pier inmeasure scour depth can be produced for flow depth 12.5cm and 15.5cm respectively which is display in table no-7and figure-19. The following table no-8 compares the percentage scour depth reduction for sediment sample Ϭg=1.62 under two flow depth circumstances (y=12.5 cm and y=15.5 cm).

Table -8 Percentage Scour depth reduction (l/b=4)

Sr.No	**Depth of flow (cm)**	**Discharg e (Q) lit/sec**	**Velocity (V) m/s**	**Type Of Pier Shape**	**Measured Scour Depth(cm)**	**maximum scour depth**	**% scour depth reduction**
1	**12.5**	**33.8**	**0.285**	Sharp nose	5.0	**7.4**	**32.43**
				Elliptical	5.3		**28.37**
				oblong	5.6		**24.32**
				Rectangular	7.4		**0.00**
2	**15.5**	**47.5**	**0.323**	Sharp nose	6.8	**10.10**	**32.67**
				Elliptical	7.2		**28.71**
				oblong	7.6		**24.75**
				Rectangular	10.1		**0.00**

The depiction of the percentage scour depth reduction between the piers for l/b=4 and b=7.5 cm was shown in the table above. The demonstrated that using sharp nose can result in a measure scour depth decrease of roughly 32.43% and 32.67% compared to Rectangular shaped pier for flow depth 12.5cm and 15.5 cm respectively which is display in table no-8 and figure-20. Instead of employing a sharpe nose-shaped pier, a elliptical-shaped pier can be used and an decrease of 28.37% and 28.71% in measure scour depth can be produced for flow depth 12.5cm and 15.5cm respectively which is display in table no-8 and figure-20. A oblong-shaped pier can be used and an decrease of 24.32% and 24.75% compared to Rectangular shaped pier inmeasure scour depth can be produced for flow depth 12.5cm and 15.5cm respectively which is display in table no-8 and figure-20.

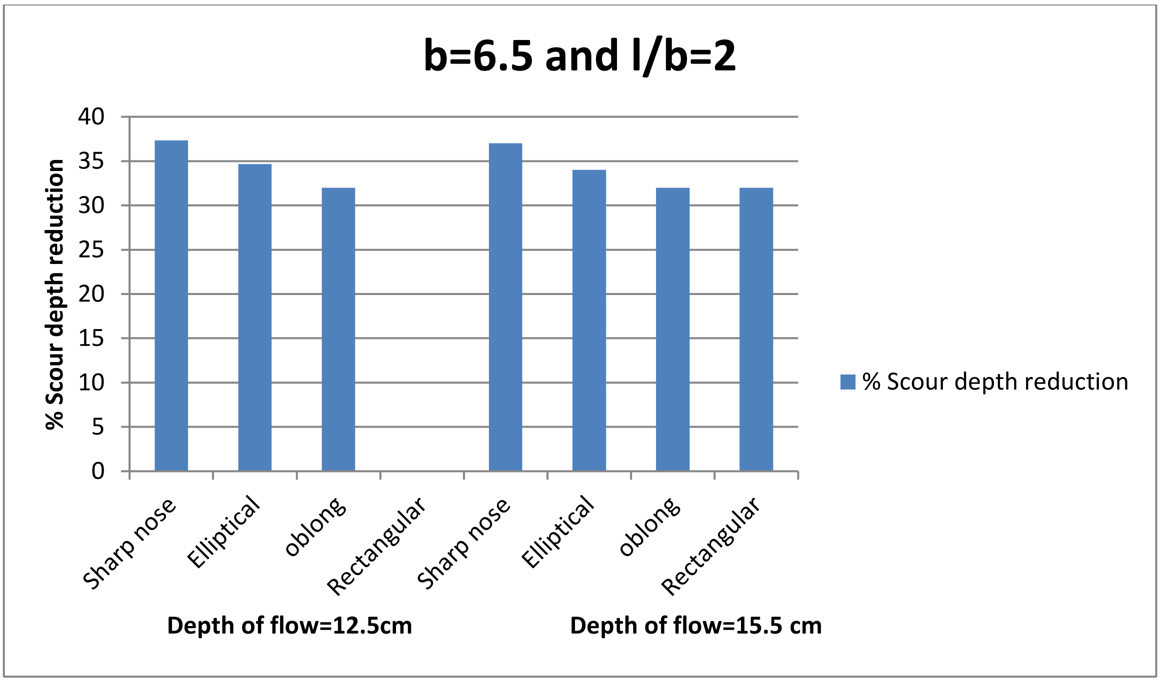

Figure-19 Illustration of percentage for l/b=2 and b=6.5

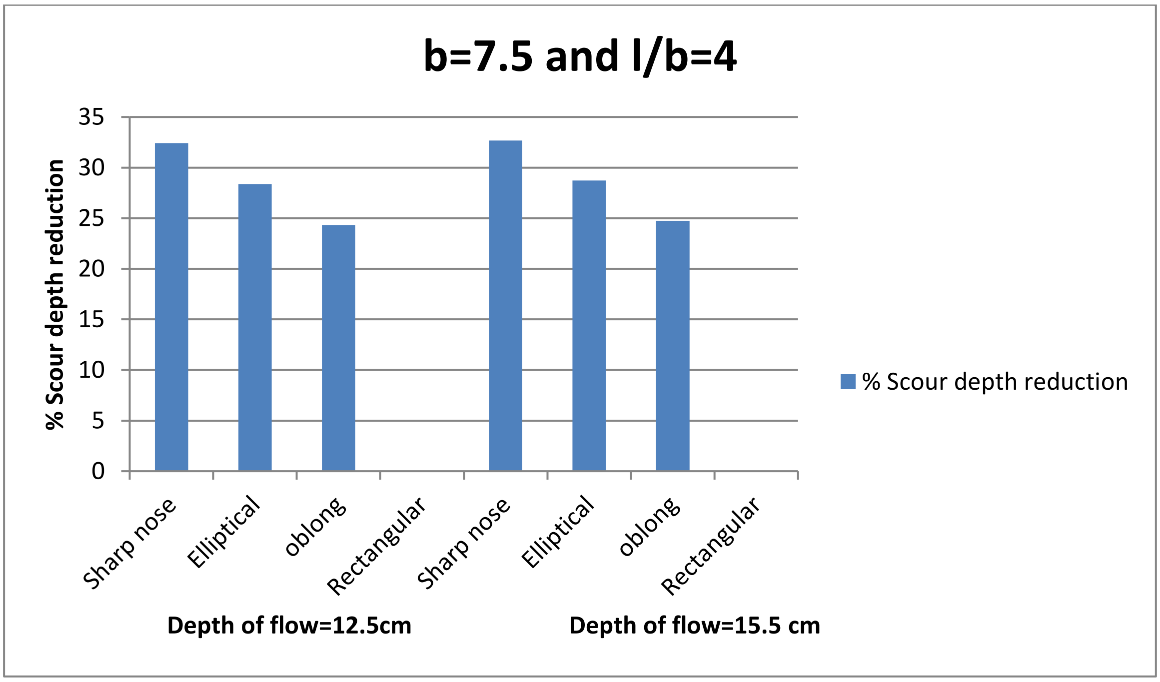

Figure-20 Illustration of percentage for l/b=4 and b=7.5

8. Statistical Analysis:

To find out accuracy of result for that statistical analysis should be done with Anova statistical analysis software. The results comes from the statistical analysis for depth of flow 12.5cm, discharge 0.0338m^3/sec and velocity 0.285 m/sec shown in table 3,4,5 respectively and illustrate in charts 4.And for 15.5cm, discharge 0.0475m^3/sec and velocity 0.323m/sec shown in table 6,7,8 respectively and illustrate in chart 5.

Table 9 Summary of Statistical analysis for scour depth=12.5cm , discharge 0.0338 m3/s and velocity 0.285 m/s.

Sr No.	Pier geometry	Depth of flow (cm)	Discharge (Q) lit/s	Velocity (V) m/s	b= 6.5 cm and l/b=2	b= 7.5cm and l/b=4
					μ_1	μ_2
1	**Sharp nose**	**12.5**	**33.8**	**0.285**	4.7	5.0
2	**Elliptical**				4.9	5.3
3	**oblong**				5.1	5.6
4	**Rectangular**				7.5	7.4

Hypothesis:
Using level of significance α=0.05 Ho: $\mu_1 = \mu_2$
Ha : Not all the means are equal
Where:
μ1=mean number of scour depth using l/b-2
μ2= mean number of scour depth using l/b-4
Analysis Two-Factor without Replication:

Table 10 Summary of Statistical analysis for scour depth=12.5cm , discharge =0.0323 m3/s and velocity 0.285 m/s.

SUMMARY	Count	Sum	Average	Variance
Sharp nose (y=12.5 cm)	2	9.7	4.85	0.2121
Elliptical(y=12.5 cm)	2	10.2	5.10	0.2828
Oblong(y=12.5 cm)	2	10.70	5.35	0.3535
Rectangular(y=12.5 cm)	2	14.9	7.45	0.0707
Scour depth (cm) l/b=2	4	22.2	5.55	1.3102
Scour depth (cm) l/b=4	4	23.3	5.825	1.078

Table 11 Summary of Statistical analysis for scour depth=12.5cm , discharge 0.0338 m3/s and velocity 0.285 m/s.

Source of Variation	Sum of squares	degree of freedom	means square	fisher-ratio	P-value	F crit

Rows(Type of piers)	8.535	3	2.845	7.65	0.1562	9.277
(Scour depth. 6g=1.33,1.39)	0.145	1	0.145	0.39	0.1808	10.128
Error	1.115	3	0.3716			
Total						
Accuracy in type of pier			**0.8438**		**84.38%**	
Accuracy between sample l/b=2,4			**0.8192**		**81.92%**	

Table 12 Summary of Statistical analysis for scour depth=15.5cm , discharge 0.0537 m^3/s and velocity 0.365m/s.

Sr No.	Pier geometry	Depth of flow (cm)	Discharge (Q) lit/s	Velocity (V) m/s	b= 6.5 cm and l/b=2	b= 7.5cm and l/b=4
					μ_1	μ_2
1	**Sharp nose**	**15.5**	**47.5**	**0.323**	6.3	6.8
2	**Elliptical**				6.6	7.2
3	**oblong**				6.8	7.6
4	**Rectangular**				10.0	10.1

Table 13 Summary of Statistical analysis for scour depth=15.5cm , discharge 0.0537 m3/s and velocity 0.365 m/s.

SUMMARY	Count	Sum	Average	Variance
Sharp nose (y=12.5 cm)	2	13.10	6.55	0.3535
Elliptical(y=12.5 cm)	2	13.80	6.9	0.4242
Oblong(y=12.5 cm)	2	14.40	7.2	0.5656
Rectangular(y=12.5 cm)	2	20.10	10.05	0.0707
Scour depth (cm) l/b=2	4	29.70	7.425	1.7289
Scour depth (cm) l/b=4	4	31.70	7.925	1.4863

Table 14 Summary of Statistical analysis for scour depth=15.5cm , discharge 0.0475 m3/s and velocity 0.323 m/s.

Source of Variation	Sum of squares	degree of freedom	means square	fisher-ratio	P-value	F crit
Rows(Type of piers)	15.47	3	5.15	103	0.0104	9.277
(Scour depth. 6g=1.33,1.39)	0.480	1	0.48	9.60	0.1292	10.128
Error	0.15	3	0.05			
Total						
Accuracy in type of pier			**0.9896**		**98.96%**	
Accuracy between sample l/b=2,4			**0.8708**		**87.08%**	

Conclusions

The investigation is carried out to determine the factors influencing the local scour depth near bridge piers. Local scour depth is directly impacted by the flow depth in the channel, flow ve locity, and pier geometry. Numerous researchers have looked on local scour around bridge piers, however the majority of their research is limited to uniform sediments. The prime reason of the study was to examine how the geometry of the pier affected its ability to guard against local scour. This was done through a series of experiments using various geome try including sharp nose, elliptical, Oblong rectangular piers.

1. For flow depth=12.5cm, the minimum depth of scour occurs, Whereas for flow depth =15.5cm, the maximum depth of scour occurs, according to the experimental results. As a result, as downflow increases (as velocity increases), so does scour depth, and vice v ersa
2. The scour depth is more significantly impacted by pier's width and ratio of length and width. Thus, we deduced that scour depth should decrease as width of pier decrease.
3. The measured scour depth of pier models in this study agreed well with the calculated scour depth from theoretical equations Breusers et.al.,1977
4. The experimental analysis's final finding was that, compared to other shapes, the pier having sharp nose geometry has less scour depth.

Instead of more traditional designs like oblong, elleptical sharp nose pier provides the strongest defense against local scour. As opposed to more traditional shapes like oblong, elleptical sharp nose pier offers the highest protection against local scour.

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