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An Investigation on the Scour of Bridge Piers with Various Geometry and Length Width Ratio on a Sandy Bed

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Abstract

In this study, the scour depth and dimensions of the scour depth around different shaped piers were compared. Maximum and Minimum scour depth were found out.Sharp nose, elliptical, oblong, and rectangular piers were used in the experiments to compare the various scour hole geometries under the identical flow conditions. In a rectangular flume (25.0 m long, 0.95 m wide, and 1.00 m deep) with a bridge pier having a length to width ratio of 2 and 4, numerous tests were carried out. The 20 cm thick flume bed is made of unevenly graded material with a d50 value of 0.65 mm. The studies were conducted in clear water. Also, the equilibrium scour depths at the downstream and lateral sides of the piers were measured. Based on the experimental results, the shape factor values were also examined, and the results were matched with those found in the literature. Using the sparse experimental data that was published in the literature, the effectiveness of the empirical relation that was developed for circular piers was evaluated. The rectangular pier with sharp noses had the smallest scour hole. Sharp nose, elliptical, oblong, and rectangular piers saw the greatest rise in the scour hole dimensions for the other cross-sections.

Keywords: **Unsteady flow, local scour, scour hole, pier, shape coefficient, rectangular flume, downstream.**

1. Introduction

A building that is constructed over a depression or impediment, such as a river, road, or railroad, including all of its supports. It has an aperture that is more than 20 feet wide between its abutment copings along the middle of the roadway, and it contains a track or passageway for carrying traffic or other moving loads [1]. A pier is a component of a bridge that safely transfers loads from the superstructure to the foundation. The removal of soil or rocks from a channel by rushing water is known as scouring.Bridge pier scouring is the process of removing sediment from the edge of a bridge pier, and scour depth refers to the depth at which this removal occurs. The exposed foundation caused by scouring eventually causes bridge failures. In the United States since 1951, 60% of 283 bridge failures were attributed to hydraulic and scouring impacts, according to Sithole and Holt [2]. According to Melville and Coleman [3], scouring in New Zealand results in the failure of one bridge each year. Brice and Blodgett's study of 383 river bridge failures [4] found that scour was the main cause of 50% of these failures. In 1987, scouring caused damage to and demolition of 17 bridges in New York and New England.The upkeep of railroad and highway bridges costs the federal, state, and private sectors countless amounts of money. One of the major issues American bridges are currently having is scour failure. In the US, more than 80% of highway and railroad bridges are built across bodies of water [5]. The Federal Highway Administration (FHWA) in the US is primarily in charge of monitoring and estimating scour [6]. Some US bridges weren't built to withstand scour erosion brought on by flooding. The channel shape has drastically changed during bridge construction, and the type of foundation for certain older bridges is unknown [7].If the scour is not carefully managed, it will lead to the failure of the bridge which will harm the local economy and safety of the public [8]. In the 1950s, American researchers first started studying the bridge scour [9]. During the early days of the scour research the scour dimensions were computed by utilising analytical formulae which were not correct. Due to temporary or permanent bridge closures, bridge failure raises indirect costs by increasing fuel consumption and vehicle operating expenses. The public's and passing vehicles' safety is ensured by underwater inspection of the scour.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]. The two basic categories of scour measuring equipment are I in-contact measuring devices and (ii) non-contact measuring devices. In an experimental study using 10 various pier forms, Al-Shukur et al. (2016) discovered that the scour depth is minimum for streamline shapes and largest for rectangular piers. Physical modelling has been used to complete the majority of scour depth studies [18]; the current work also examines the impact of shape factor on local scour using physical modelling of selected obstacle forms.According to one definition, the shape factor is the ratio of the scour depth of a circular obstacle to that of a non-circular obstacle [19]. Studies on the impact of pier shape on scour depth were conducted by Murtaza et al. They employed four equal-width piers in the following shapes: square, circular, oval, and octagonal. They were researched on shapes and it was found that minimal scour depth is observed for octagonal bridge pier and maximum scour depth for square bridge pier while circular and elliptical faced intermediate scour depth relative to square and octagonal bridge pier. It has been determined that using an octagonal bridge pier instead of a circular one resulted in a 22% reduction in scour depth. Variable affects regional scour.Four major categories can be made out of the variables that affect the local scour depth at bridge piers:

1. The fluid's dynamic viscosity (μ), gravitational acceleration(g), and water density(ρ) are its defining parameters.
2. The flow intensity, flow depth (y), mean velocity (V), shear velocity, and critical mean flow velocity are the parameters that describe the stream flow (Vc).
3. The following parameters describe the bed materials: soil cohesiveness, angle of repose, geometric standard deviation of the sediment particle size distribution(ϭg), and sediment density (s).

4. The pier size, pier length (a), pier width (b), spacing between piers, and angle of attack (θ) are the parameters that define a pier foundation.Measurement Analysis The interpretation and judgement of engineers should be based on experimental observations and experiences. A strong technique for creating difficulties is dimensional analysis. The physical process of the local scour can be understood better if adequate dimensionless parameters defining the event are defined. The parameters that have an impact on the local scour process and are controlled in this work by the Buckingham -theorem are analyzed in more detail below. The following relationship can be used to summaries the variables used in this study:

$$(y_s, \rho, V, g, b, K_s) = 0 \quad \text{eq. 1}$$

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:

$$y_s/b = f_1\left(V/Vc, \mathrm{Ks}, \frac{V}{\sqrt{gb}}\right) \quad \text{eq. 2}$$

Where: the term $\frac{V}{\sqrt{gb}}$ is known as pier Froude number (Fr_p).

2. Materials and Methods

2.1 Methodology:

The methods used was as follows:

1. Determine the pier shape that produces the lowest scour depth by calculating the scour depth around bridge piers with various geometries using an experimental flume. Finally, compare your findings to those of earlier research.
2. Make use of a homogenous sediment sample with a defined median and standard deviation.
3. To compare experimental results using different formulas.

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

2.3 Experimental Set-up:-The experiment was conducted in a tilting flume that was 25 metres long, 1 metres high, and 0.95 metres deep. It was housed in the Fluid Mechanics Laboratory of the Water Resources Department at MAMIT Bhopal.

The glass flume utilised in the investigation is seen in Figure 1. The flume had concrete base with appropriate provisions for water supply regulation and measurements, and glass side walls. According to a model [24] where the obstacle width is 1/10th of the channel width, the obstruction diameter shouldn't be greater than 10% of the flume's width. In this instance, the size of each barrier that faces the flow direction was estimated to be roughly 100 mm.Figure 2 provides the cross section of the obstacle shapes. The shapes used for this study were chosen with consideration for the most typical obstruction shapes found in hydraulic constructions found in nature, such as bridge piers and overlooks built in bodies of water.

Except than the glass walls depicted in figure 1, the channel is entirely made of concrete. a pump that uses a pipe to transport water from an underground storage to a flume (shown in figure 3). depicted on picture 1. Using a pipe line, water is fed to an overhead tank and an underground storage tank. As shown in Fig. 1, there was a valve installed between the overhead tank and the storage tank to control the flow.To achieve the aim of this study, four piers with the shapes illustrated in figure 4 (circle, square, oblong, and ogival) were tested in clear water with homogeneous coarse sand bed material.

The working portion was 8.00 m long and 0.2 m deep, and it contained erodible, homogenous, uniform coarse sands with an upward slope of 1:17 and 1:20 at its entrance and outlet, respectively, to ensure a steady flow during testing. A venture metre was used to gauge the discharge at the flume's inlet. An adjustable vertical gate at the downstream, as depicted in figure 1, was used to regulate the depth of the tail water.Two movable point gauges with an accuracy of 0.1 mm that are mounted on a brass rail at the top of the flume's sides are used to measure all depths. The flow's velocity close to the pier was measured using a pitot tube. As shown in fig. 1, one by one (out of four) [10] piers are vertically implanted in bed material.

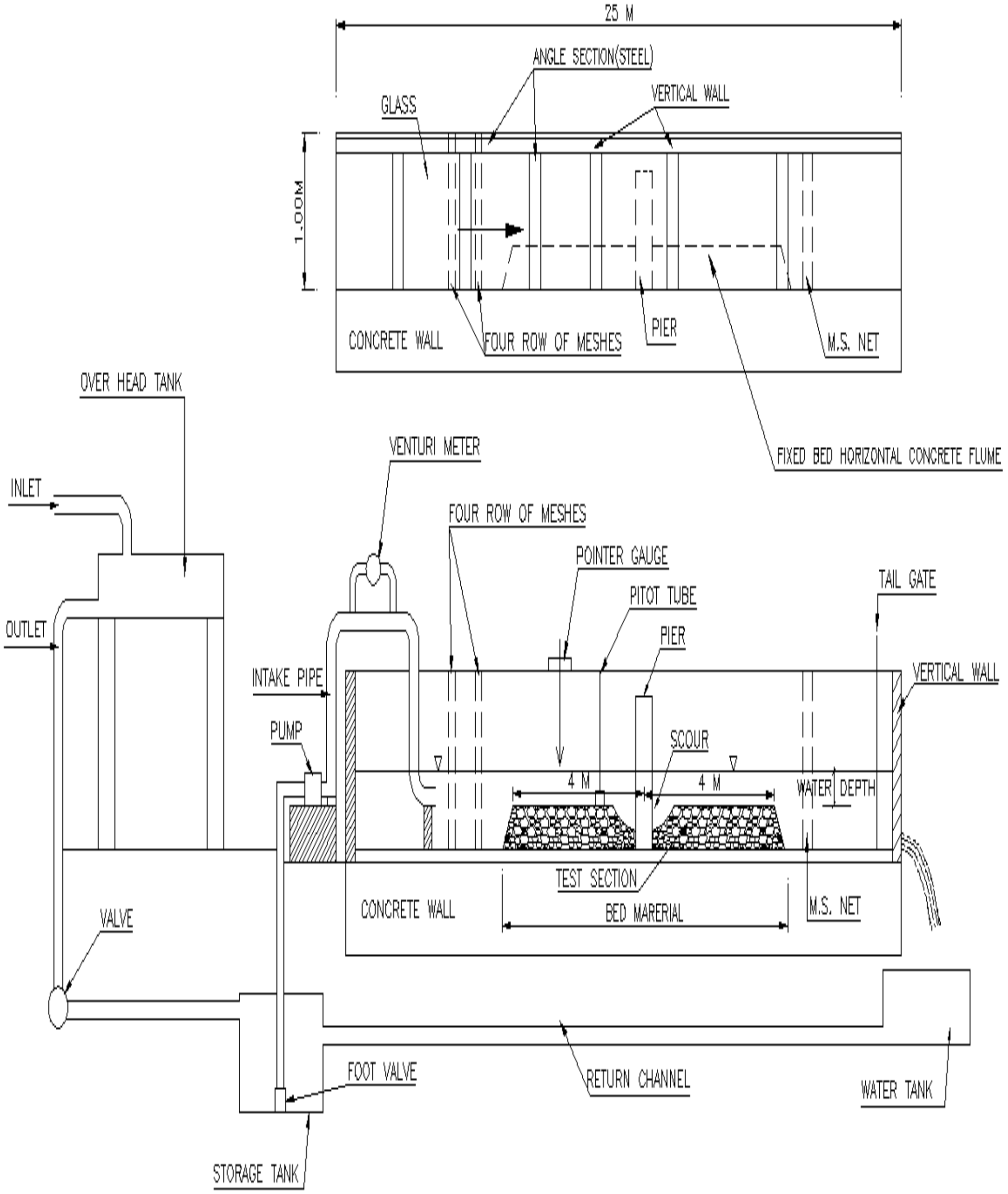

Figure-1 The Flume (25 meter long,0.95-meterbreadth and 1 meter deep)

Figure-2 Different shape bridge pier[10].

2.4 Pier Models: In this study, four pier models were compared to one another. Piers made of sapwood will be coloured and covered in paint to improve smoothness and avoid contact with water. This experiment will be conducted with a 7.0 cm wide pier at a constant flow depth (0.16 m). It should be noticed that the diameter of the experimental flume is ten times greater than the pier's. So, in this study, the cross section of each pier is 13 cm long, 6.5 cm wide (l/b=2), and 30 cm long, 7.5 cm wide (l/b=4). The length to width ratio is 2 and 4respectively.

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

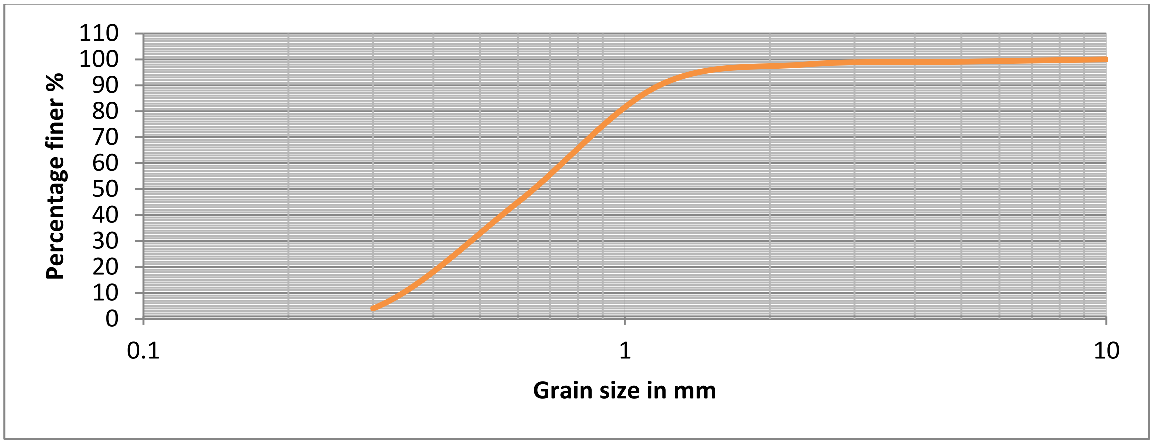

Figure 3 The curve of grain size distribution

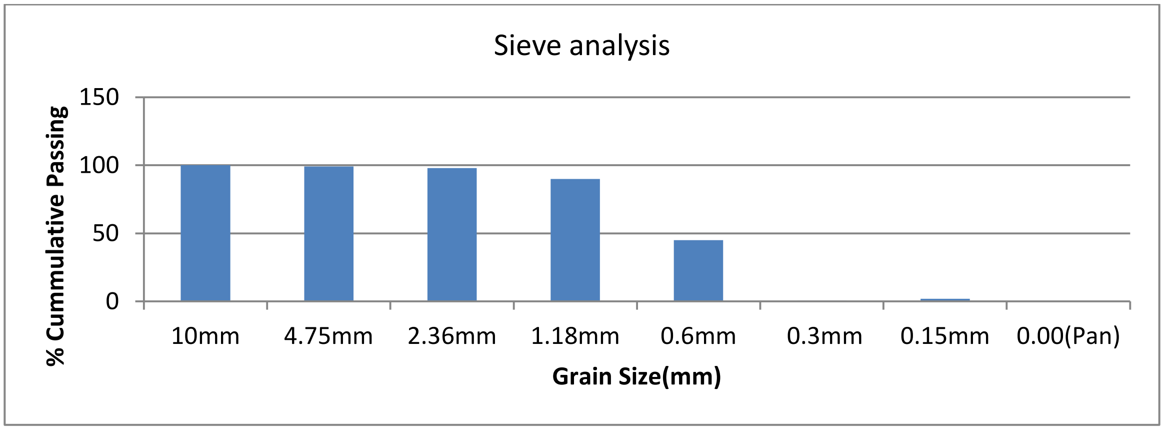

Figure 4 A particle size distribution histogram.

According to Melville [25], the diameter of the pier should be carefully selected in order to minimise the impact of sediment size on the depth of scour. It was well known that if the ratio of pier width to grain size is more than around 25, the grain size of the bed material has no effect on the depth of scour.

Also, the diameter of the pier was carefully selected to minimize the impact of particle size on the depth of scour. If the pier width to grain size ratio is more than around 25, it is known that the grain size of the bed material has no effect on the depth of scour [31].The ratios for this study's pier of 65 mm and 75 mm are around 100 and 115.4, respectively, which meet Melville's 1997 criteria. The test was conducted on a bed material with d_{50} = 0.65 mm, as calculated from figure 3, and a specific gravity of 2.722 for coarse sand. A sample of medium sand's geometric standard deviation (g), which is 1.62 and higher than 1.4, shows that the sand is not uniform [26]. It is obvious that the coarse sand's size distribution is not regular because it has a geometric standard deviation of 1.62.The definition of the geometric standard deviation $(\alpha_g) = \sqrt{(\frac{d_{84}}{d_{16}})}$. 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.

2.6. Experimental Technique: To accomplish the goal of this study, four different types of piers were used in the inquiry. A bed of uniformly coarse sand contained a pier with a variety of shapes. A working section was created at the flume that was 20 cm deep and filled with non-uniform medium sand that had a d50 of 0.65 mm. A scraper was used to level the bed surface. Point gauges are used to verify levels as well. An electric motor connected to a centrifugal pump turned on and the pump began to run. Water was initially delivered from upstream towards downstream at a relatively modest rate in order to prevent scouring owing to slope, and later a steady discharge was controlled by a valve.When pumping has started, the tail gate is gradually lowered until the required water depth in the flume is reached. It is possible to calculate the depth using a point gauge.At the flume's inlet, a venture metre was employed to measure the discharge. As shown in Fig. 1, point gauges were employed to measure flow depth while pitot tubes were used to track flow velocity.The test lasts for ten hours. Every experiment ended with the flow being closed and the power being turned off. The depth of the scour was calculated with the use of a point gauge.The flume is progressively emptied as the uniform coarse sand is allowed to dry in order to avoid any moderations to the scour hole.While changing the pier's design, the uniform coarse sand was relelled and the aforementioned steps were repeated.

2.7 Test Program

With a primary focus on the amount of time required to reach an equilibrium scour state, the test programme was broadened to address the geometry of the pier as a local scour mitigation technique. The test programme was run at various water discharges, including 33.8 lit/sec and 47.5 lit/sec experiments were conducted in clear water, and the depth of the highest scour was computed. A bridge's perimeter can have four different geometries, including sharp nose, elliptical, oblong rectangular piers, and this test programme was performed at these discharges.

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)**
1.	0.751	0.125	0.285	33.8	0.257
2.	0.823	0.155	0.323	47.5	0.261

2. Results and Discussion

Table 2 gives a summary of the laboratory results from tests carried out in succession on the four pier shapes. This experimental study showed that when the pier's design was altered, scour considerably decreased. The results showed that the sharp nose shape had the lowest scour's depth, measuring 47 mm and 50 mm for velocity 0.285 m/sec, while the rectangular pier gave the maximum scour depth, measuring 75 mm and 74 mm when l/b=2 and 4 respectively. The results also showed that the sharp nose shape had the lowest scour's depth, measuring 63 mm and 68 mm for velocity 0.323 m/sec, while the rectangular pier.

Table-2 Measured 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 circularpier

K_2= Angle of attack
b =pier width,
y=flowdepth

Where Critical velocity(V_C) = $6.19y^{\frac{1}{6}}(d_{50})^{\frac{1}{3}}$
Where d_{50}=Median of bed material

Table-3 Measure value of scour depthcompared with theoretical value in different velocity, discharge and flow depth which is calcuiated 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

Table 4,shape factor(l/b=2) is compared withshape 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

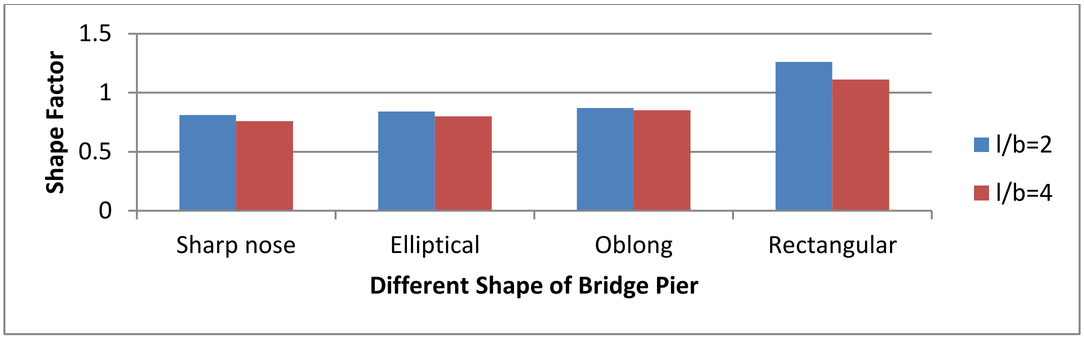

Figure 5 drawn to compare the results of the current study's shape factor calculations using various pier shapes for various length to width ratios represented by histrogram.

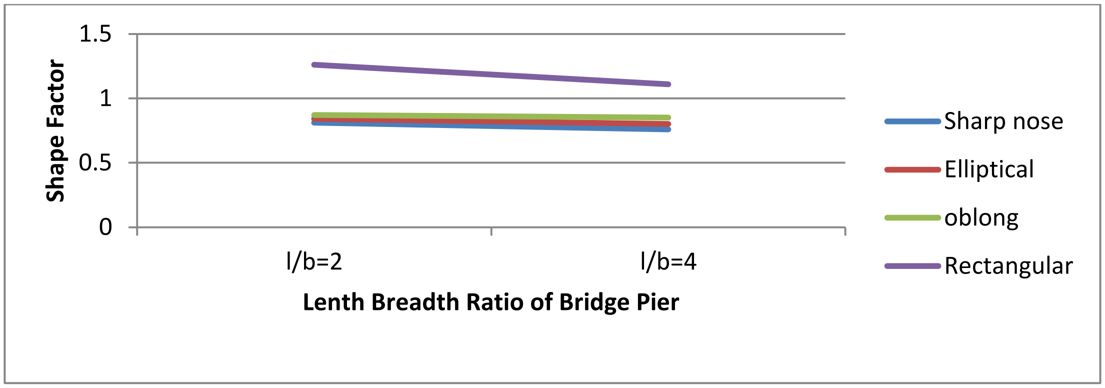

Figure 6 drawn to compare the results of the current study's shape factor calculations using various pier shapes for various length to width ratios represented by graphically.

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

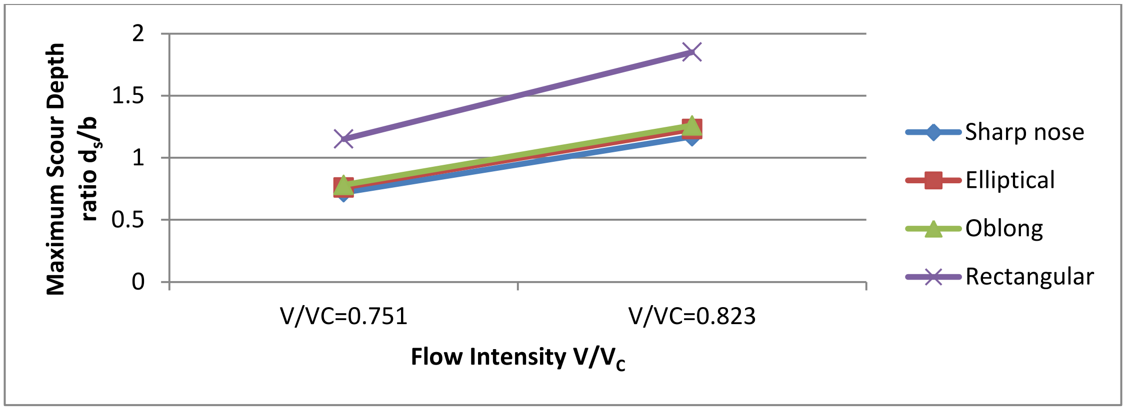

Figure-7 Influence of flow intensity on measure scour depth of different pier shape(b=6.5 cm)

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

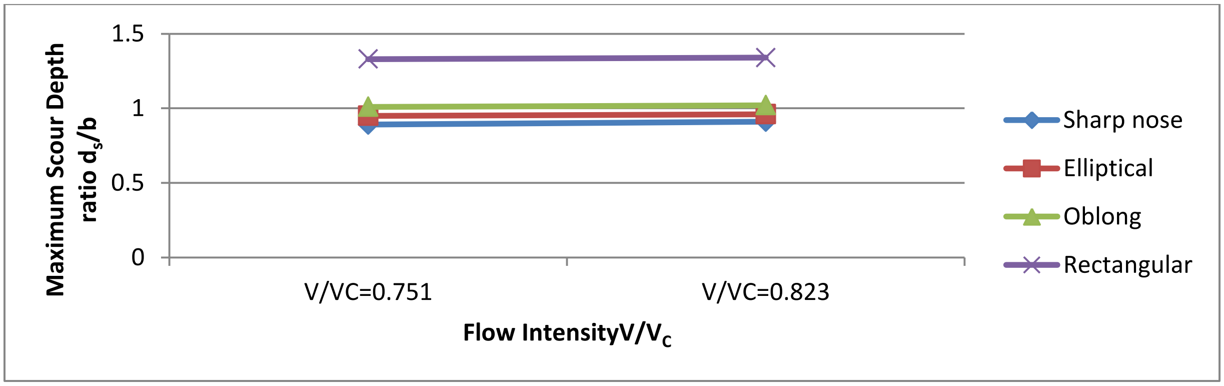

Figure-8 Influence of flow intensity on measure scour depth of different pier shape(b=7.5 cm)

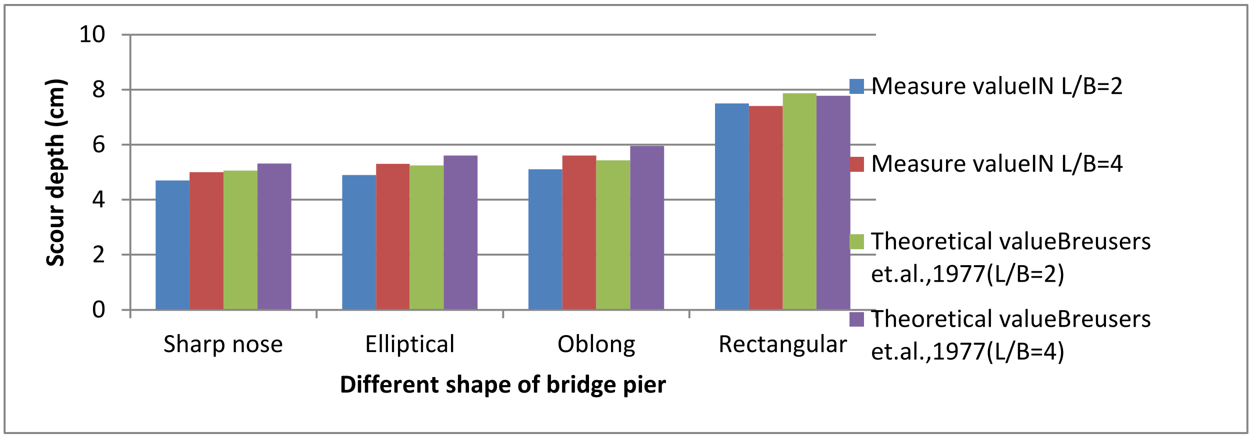

Figure-9 Comparison scour depth of measure value with Breusers et.al.,1977 (at V= 0.0.285 m/s,y=12.5) in various geometry

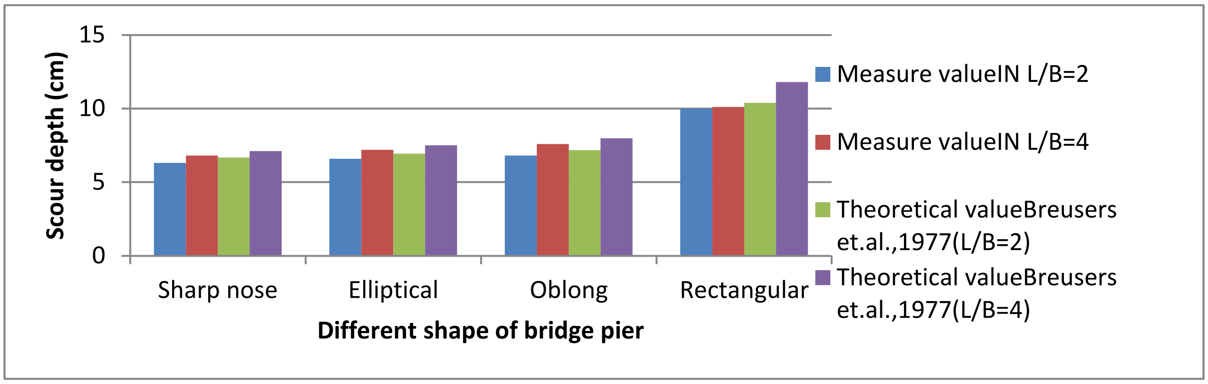

Figure-10 Comparison scour depth of measure value with Breusers et.al.,1977 (at V= 0..323 m/s,y=15.5) in various geometry

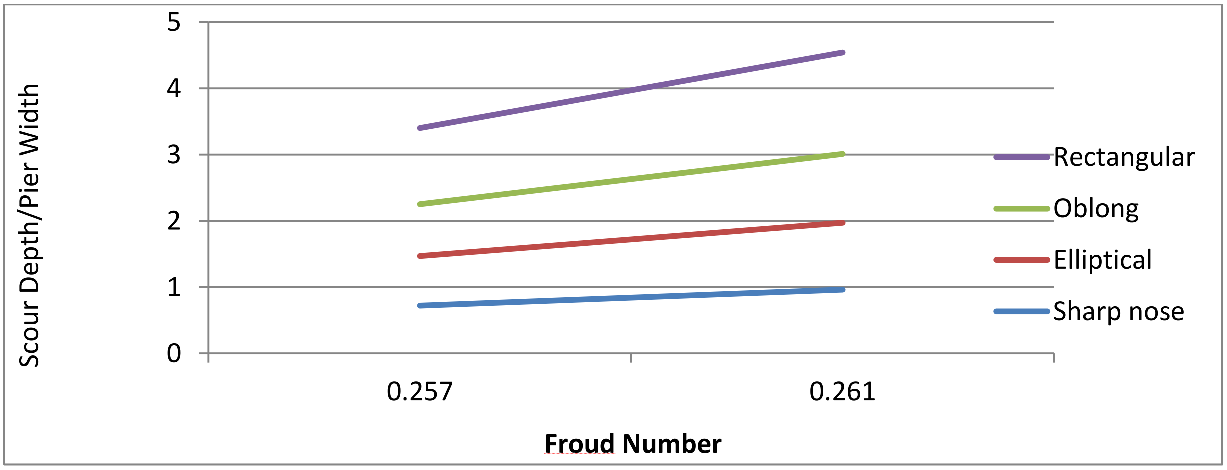

Figure-11 Comparison scour depth/width with Froud Number (at V= 0.285 m/s and V= 0..323,y=15.5 and y=12.5,l/b=2 and b=6.5) in various geometry.

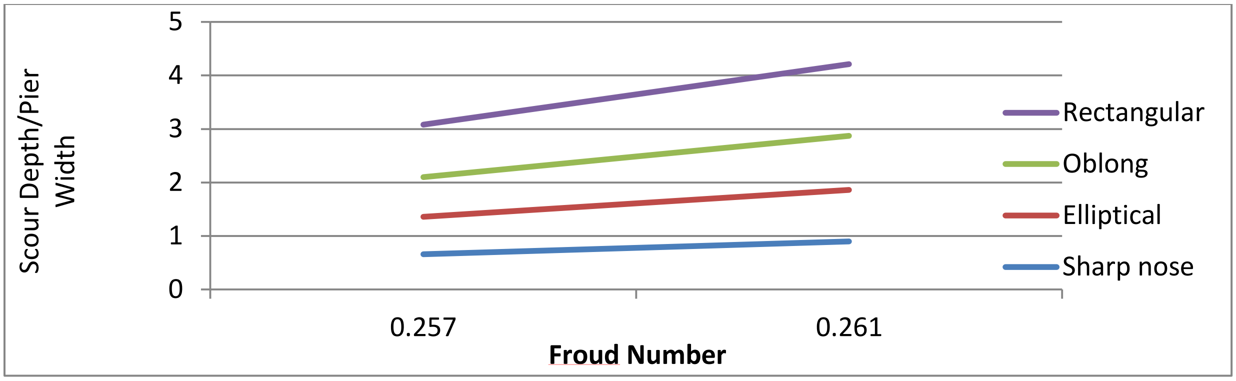

Figure-12 Comparison scour depth/width with Froud Number (at V= 0.285 m/s and V= 0..323,y=15.5 and y=12.5,l/b=4and b=7.5) in various geometry.

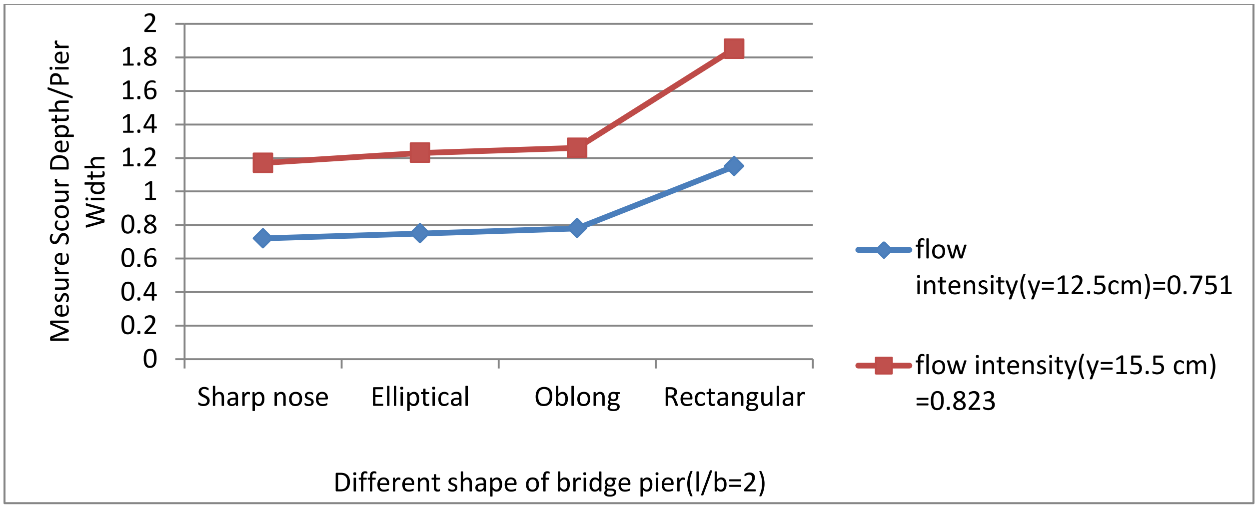

Figure-13 Comparison measure scour depth/width with various flow intensity (at,l/b=2and b=6.5cm) in pier having various geometry which is represented by graph

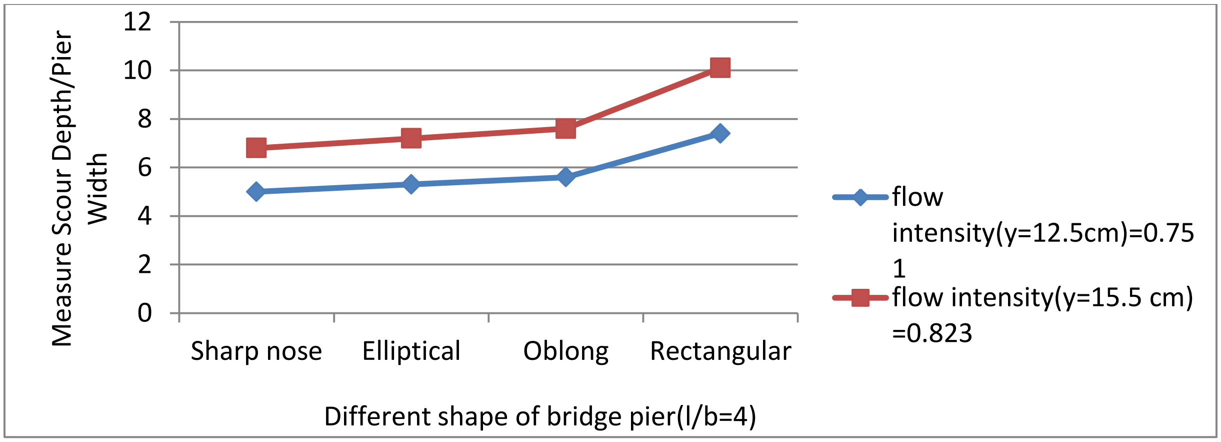

Figure-14 Comparison measure scour depth/width with various flow intensity (at,l/b=4and b=7.5cm) in pier having various geometry which is represented by graph

3.1 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)	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	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 forl/b=2 and b=6.5 cm was shown in the table above. It 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-15.Instead of employing a sharpnose-shaped pier, an elliptical-shaped pier can be used and a 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-15.An oblong-shaped pier can be used and a 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-15.The following tableno 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. It 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-16Instead of employing a sharpnose-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-16.An 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-16.

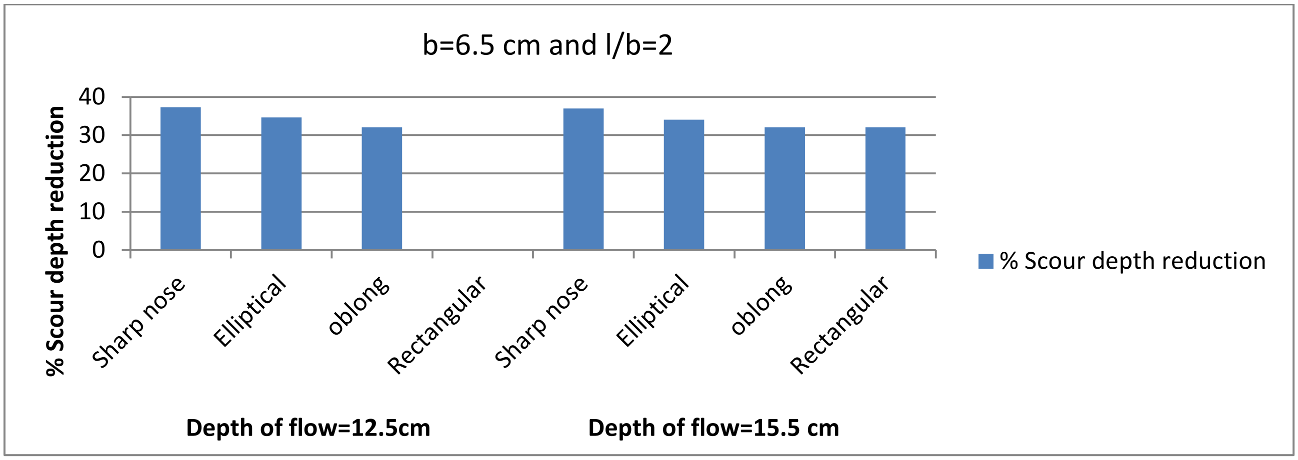

Figure-15 Illustration of percentage for l/b=2 and b=6.5

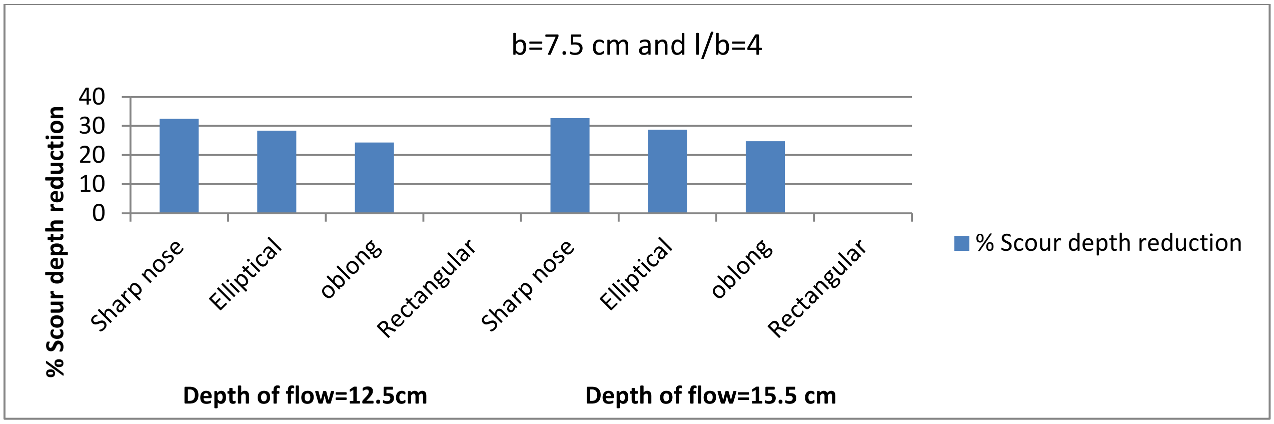

Figure-16 Illustration of percentage forl/b=4 and b=7.5

8. Statistical Analysis

Anova statistical analysis software should be used to determine the accuracy of the results for that statistical analysis. The findings are based on statistical analysis for depths of flow of 12.5

cm, discharge of 0.0338 m3/sec, and velocities of 0.285 m/sec and 15.5 cm, discharge of 0.0475 m3/sec, and velocities of 0.323 m/sec, respectively, presented in tables2, 3,5

Table 9 Summary of Statistical analysis for flow 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 $\alpha=0.05$ Ho: $\mu_1 = \mu_2$

Ha : Not all the means are equal

Where:

μ 1=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 flow 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	0.045
Elliptical (y=12.5 cm)	2	10.2	5.10	0.079
Oblong (y=12.5 cm)	2	10.70	5.35	0.125
Rectangular (y=12.5 cm)	2	14.9	7.45	0.005
Scour depth (cm) l/b=2	4	22.2	5.55	1.716
Scour depth (cm) l/b=4	4	23.3	5.825	1.162

Table 11 Summary of Statistical analysis for flow 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	79.02	0.0146	9.277
(Scour depth. l/b=2 and 4)	0.152	1	0.152	4.22	0.2358	10.128
Error	0.108	3	0.036			
Total	8.795	7				
Accuracy in type of pier			0.9854		98.54%	
Accuracy between (l/b=2 and 4)			0.7642		76.42%	

Table 12 Summary of Statistical analysis for flow 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 flow 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	0.125
Elliptical (y=12.5 cm)	2	13.80	6.9	0.179
Oblong (y=12.5 cm)	2	14.40	7.2	0.319
Rectangular (y=12.5 cm)	2	20.10	10.05	4.99
Scour depth (cm) l/b=2	4	29.70	7.425	2.99
Scour depth (cm) l/b=4	4	31.70	7.925	2.209

Table 14 Summary of Statistical analysis for flow 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. l/b=2,4)	0.480	1	0.48	9.60	0.1292	10.128
Error	0.15	3	0.05			
Total	16.10	7				
Accuracy in type of pier			0.9896		98.96%	
Accuracy between sample l/b=2,4			0.8708		87.08%	

4. 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 velocity, 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 geometry including sharpnose, 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 down flow increases (as velocity increases), so does scour depth, and vice versa.

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 sharpnose pier provides the strongest defense against local scour. Asopposed to more traditional shapes like oblong,elleptical sharpnosepier offers the high est protection against local scour.

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