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Local Scour Characteristics Around Varied Pier Geometry

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Abstract: Scour is the process whereby rushing water removes streambed silt. Aggradation is the gradual build-up of the stream bed in reach as a result of silt deposition. The failure caused by scouring ranks second in terms of overall bridge failures, behind floods. There hasn't been any research done to far on the maximum scour depth, particularly for piers with rectangular and triangular shapes. In order to do this, a number of tests were carried out in a recirculating flume at the Shantilal Shah Government Engineering College in Bhavnagar, Gujarat, which is 6.0 meters long, 0.30 meters wide, and 1.0 meters deep. The sediment's d_{50} size is 1.3mm. Four different pier forms were used in a total of 16 runs, with the triangular shape showing the greatest scour depth and measuring 48.7% greater than the circular pier.

Keywords: Aggradation, Scour, Pier Geometry, Temporal variation.

I. INTRODUCTION

Scouring is a natural occurrence brought on by water movement in rivers and streams, and it is most obviously evident in alluvial soil. Everything in a stream bed will deteriorate over time. It will happen in due course. However, some substances, like stone, may take hundreds of years to degrade. Additionally, streams with sand beds will erode to their maximum scour depth over a set period. Scour is the hydraulic activity of water removing particles from a channel's bed and banks. The lowering of the bed causes this to happen. Look up the more exact version of the word "Erosion". Scour phenomena occur in both cohesive and non-cohesive soil.

1.1 FACTORS AFFECTING THE SCOUR

The following are the key elements influencing scour at piers:

- Fluid parameters, such as kinematic viscosity and flow density.
- Bed Sediment Parameters include soil cohesiveness, sediment density, and particle size.
- The characteristics of stream flow, such as flow depth, Froude number, and flow velocity.
- Pier characteristics, including pier size, shape, and placement.

1.2 TYPES OF SCOURS

With respect to bridge structure mainly two types of scours are known, general scour and local scour. And also, other sub-division of scour is shown in Figure 1.

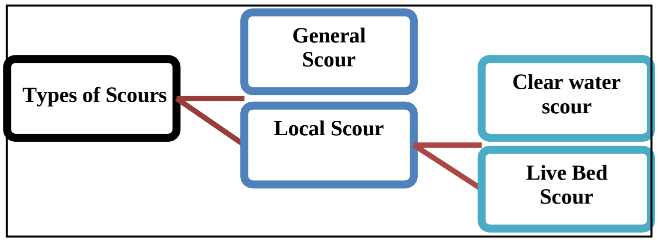

Figure 1: - Types of Scours

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1.3 GENERAL SCOUR

A decrease in channel width, whether naturally occurring or caused by a barrier like a bridge, which reduces flow area and increases velocity, can result in general scour at the bridge. As a result, the bed is lowered and sediment transportation from the bed rises.

1.4 LOCAL SCOUR

This kind of scour includes the removal of particles from the base of bridge structures like abutments and piers and is clearly tied to the presence of a river obstruction. When water flow crosses a bridge pier or abutment, the flow moves down towards the river bed and also around the sides of the obstruction, indicating three-dimensional flow around the pier and abutments. Sediment is transported away from the base of the bridge structure as a result of the water moving downward. Additional information about the scour around bridge piers is provided in section 2.

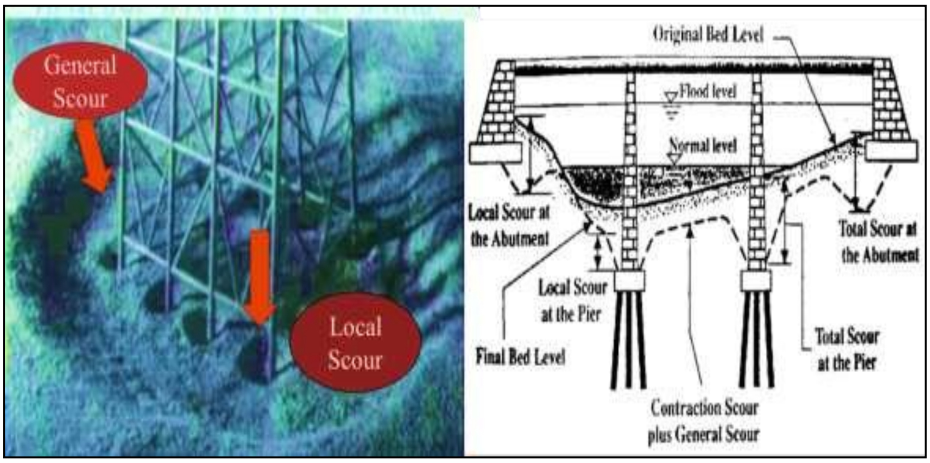

Figure 2: - Concepts of types of scours

1.5 Objective of study

1. To investigate how scour changes over time when different pier geometries are used

2. To assess the maximum depth of pier water scour around various pier geometry.

1.6 Litrature surway

REVIEW OF BRIDGE PIER SHAPE TO MINIMIZE LOCAL SCOUR

The three different velocities (0.18, 0.25, and 0.3 m/sec) in this study, the shape of the pier is the primary focus, while other variables like flow depth, bed material, and so on, are constant across all tests. Sand was used as the bed material in a laboratory flume that was operated under clear water conditions for the experiments. Ten different shapes—circular, rectangular, octagonal, chamfered, hexagonal, elliptical, sharp, Joukowsky, oblong, and streamlined—were tested using the test programme. were employed to examine the impact of the bridge pier's shape on local scour and determine the ideal design that provides the least amount of scour. Pier models were placed in the centre of the working section and secured vertically. A 10-cm-thick layer of sand was placed on the working section's bed. The results showed that the streamline design produced the lowest scour depth of 3 cm, while the rectangular pier produced the highest scour depth of 7.6 cm. In comparison to a rectangular design, the streamline shape is said to be the optimum one for piers because it lowers the maximum scour depth by 60%.

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REVIEW OF DIFFERENT SHAPES OF BRIDGE PIERS TO MINIMIZE LOCAL SCOUR

The trials were carried out in the P.G. Hydraulic Laboratory of BVDU College of Engineering, Pune, in a 10-metre-long, 0.30-metre-wide, and 0.45-metre-deep tilting flume. Three distinct pier forms, including circular, diamond, and elliptical, were used in the trials to examine the impact of shape on local scour with a nonuniform sand bed and flow depths of 14 cm and 16 cm. Determine the flume's scour depth around variously shaped bridge piers, identify the pier form that produces the least scour depth, and compare it to other studies.Take sediment samples that are not homogenous and have various standard deviations. to compare experimental findings using various formulas.It is necessary to conduct that statistical analysis in order to determine the accuracy of the outcome. The minimal depth of scour occurs at y = 14 cm, and the greatest depth of scour occurs at y = 16 cm. As a result, as downflow increases (as velocity increases), so does scour depth, and vice versa. The computed scour depth from theoretical equations (Colorado State University, CSU, and Laursen) and the measured scour depth of the pier models in this study were in good agreement. The experimental analysis's final finding was that elliptical piers have shallower scour than other shapes. Since an elliptical pier is more effective than other traditional shapes like circular and diamond at protecting against local scour

REVIEW OF LOCAL SCOUR AROUND GROUP BRIDGE PIER WITH DIFFERENT SHAPES

In this work, laboratory tests were used to calculate the local scour depth (ds) around the group bridge pier. Three bridge piers with identical specifications were included in each of the five groups of the fifteen bridge pier models that were built and tested for this purpose. The diameter of the downstream bridge piers (D2) was set at 10 cm for all, whereas the diameter of the upstream bridge piers (D1) varied from 2, 4, 6, 8, and 10 cm. For each group, the distance (S) between the bridge piers was changed three times to 20, 30, and 50 cm. They each take 57, 48, and 38 l/s discharge. For all different diameters and spacings, the first upstream bridge piers showed the greatest scour depth. The scour depth rises as the flow depth and flow velocity increase for group bridge piers with a constant upstream diameter. The scour depth grew as the diameter of the bridge pier increased. By widening the distance between the bridge piers, the depth of the scour increased.

REVIEW OF BRIDGE PIER SHAPE ON DEPTH OF SCOUR

Five various pier shapes—circular, rectangular, square, octagonal, elliptic, and lenticular—are examined in this study. In this work, the scour depth is actually measured, and the results are compared to CFD (computational fluid dynamics) and a 3D flow model. A bridge pier's scour was simulated using the Flow-3D CFD code. The programme uses a structured orthogonal grid and applies the fractional area/volume approach (FAVOUR), which permits rectangular computational cells to be partially blocked by an obstruction, to highlight the complicated boundaries of the solution domain.In this investigation, data is gathered for 30 minutes.Maximum scour is obtained analytically at 3.6 cm and experimentally at 4 cm, resulting in 10 percent inaccuracy. The results show that scour depth rate varies with pier design, with rectangular piers developing maximum scour depth, much higher than for other shapes, and lenticular piers generating minimum scour depth, much lower than for other shapes, because they have the least exposed area without side corners. The findings show that as pier width increases, scour depth also increases to a maximum value; rectangular piers have a maximum scour depth ratio of 1.7 at a maximum pier width ratio of 0.2, whereas other cases, particularly the lenticular pier, have a scour depth of approximately 1.01 at a maximum pier width ratio of 0.2.

REVIEWCOMPARISON OF BRIDGE PIERS SHAPES ACCORDING TO LOCAL SCOUR COUNTERMEASURES

The goal of the current study is to provide a novel technique for decreasing scour depth in front of bridge piers. In this system, the position of two piers—a standard pier (10–4 cm) and a straight aerofoil-shaped pier—depends on the direction of the flow. These piers are referred to as the opposite bridge pier and the opposite aerofoil pier. The horseshoe-shaped vortex shrinks and has no impact on the piers since the downflow is directed away from the front by the opposing piers. Five piers were examined in the current study under live-bed conditions with a flow intensity of 58 l/sec for a duration of three hours: a standard pier (10-4), an opposite pier (4-10), a straight aero foil, an opposite aero foil, and a circular pier. The Hydraulic Laboratory of the Civil Engineering Department at Gaziantep University served as the site of the experiments. The flume, which has glass sides and a steel bottom, is 12 m long, 0.8 m wide, and 0.9 m deep, as depicted in Figure 3. A magnetic flow metre that was installed in the pipe network prior to the inlet of the channel was used to

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monitor flume discharge. A laser metre mounted on a manually operated carriage that slid along rails on top of the flume wall was used to measure the height of the bed and the scour hole. a cross-section of the ensuing scour, the depth of the scour hole at the centre line, and the length of the scour hole. When compared to countermeasure strategies like riprap and slot, shifting the position of the pier is not only substantially more cost-effective at reducing scour.The effect of moving the pier had a smaller downflow compared to a straight aerofoil and a conventional pier. In comparison to a conventional pier and a circular pier, the maximum depth of scour for the opposing pier was lowered by 40% and 54%, respectively. In comparison to the circular pier, the opposing pier's scour hole volume was reduced by 83%. In comparison to a straight aerofoil and round pier, the opposite aerofoil decreases scour depth by 58% and 69%, and the scour hole volume by 89%. In comparison to a circular pier and a regular pier, the top scour hole width of the opposite bridge pier was 40% and 17%, respectively. The top scour hole width for the opposing aerofoil was 52% smaller than the circular pier and 29% smaller than the straight aerofoil. The results show that opposite aerofoils and opposing piers are excellent ways to reduce scour depth. In particular, the opposite aerofoil works well because it diverts a significant portion of downflow away from the pier, which lessens the strength of the horseshoe and decreases scour depth.

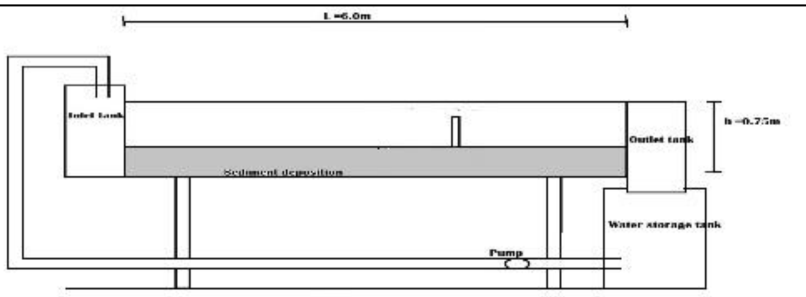
REVIEW OF SCOURING AROUND VARIOUS SHAPES OF BRIDGE PIERS

Three various pier shapes—circular, hexagonal, and octagonal—are examined in this study.A few of the many variables that determine the scour pattern around piers include the shape of the pier, the angle of inclination between the pier axis and the flow direction, and the arrangement of piers with respect to the flow direction. The flume's flat surface, which is 2.2 metres long, 0.23 metres wide, and 0.2 metres deep, was employed for the experiments. Plexiglas was used to construct the flume's walls and bottom. Three portions were created for the rectangular flume: an entrance segment, an output section, and a test section in the middle.
A few of the many variables that determine the scour pattern around piers include the shape of the pier, the angle of inclination between the pier axis and the flow direction, and the arrangement of piers with respect to the flow direction. One of the main reasons for the bridge's failure is the local scour around its piers. River water scouring in the area has disastrous effects on engineering structures. They are left in hazardous, maintenance-intensive situations, and it occasionally results in fatalities. Due to the interference of the horseshoe vortex formations of individual piers, the flow will get complicated around a collection of piers. The design of the pier has a big impact on how the scour hole that forms around it behaves.

II. METHODOLOGY

2.1 EXPERIMENTAL FLUME:

The experiments are carried out in Gujarat, India's Shantilal Shah Government Engineering College's hydraulic lab. It has a 6 m long, 0.3 m wide, and 0.75 m deep recirculating flume. The flume features a working portion that looks like a recess that is uniformly 0.15 m thick with sediment.



2.2 DEPTH MEASUREMENT:

The flow depth is measured by a point gauge and the sedimental bed is measured by a flat gauge.

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2.3 VELOCITY MEASUREMENT:

The flow velocity in the experimental flume is measured by the current meter, as shown in the figure below,

Figure 3: - Current meter & Digital indicator probe

2.4 DISCHARGE COMPUTATION: -

The amount of water flowing per second for a specific valve opening should be estimated after achieving a uniform flow. Using the following continuity equation, this is produced.
The continuity equation

$$Q = A \times V$$

2.5 SEDIMENT PROCUREMENT: -

To carry out the experiment and for analysis on the effect of scour depth due to nonuniform sediment, having a mean grain size of sediment (d_{50}) 1.30 mm.

2.6 PIER PROCUREMENT: -

As per the general consideration, the uniform pier used for the scour experiment should have a uniform pier with different shapes: oblong, square, circular, and triangle with 5 cm diameter and 45 cm.

III.EXPERIMENTAL DATA COLLECTION AND OBSERVATION

Four series of experiments are done in this study, each with four runs. At the nose and wake of bridge piers with various shapes and sizes of 50 mm, the effect of the scouring process was immediately apparent once the test began. These experiments' variable parameters include depth, velocity, discharge, and shape.

As the results demonstrate, the scour depth deepens over time. Before the test was terminated, though, an equilibrium scour condition had not been attained. The experiment was terminated when the rate of scour remained constant for roughly an hour.

The change in scour depth over time (measured in millimetres per hour) is known as the scour rate. Even though the equilibrium was not reached, by the end of the test, the scour rate was low.

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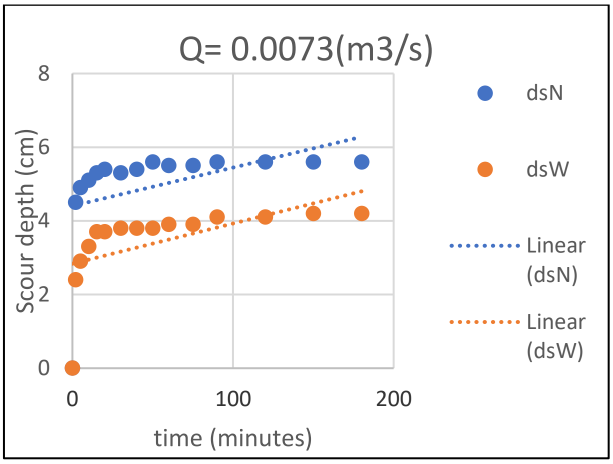
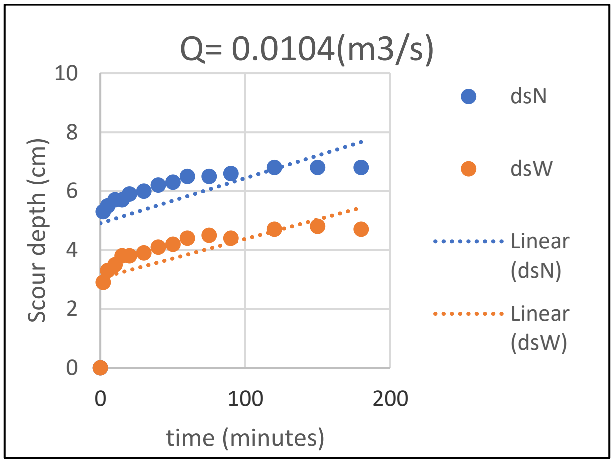
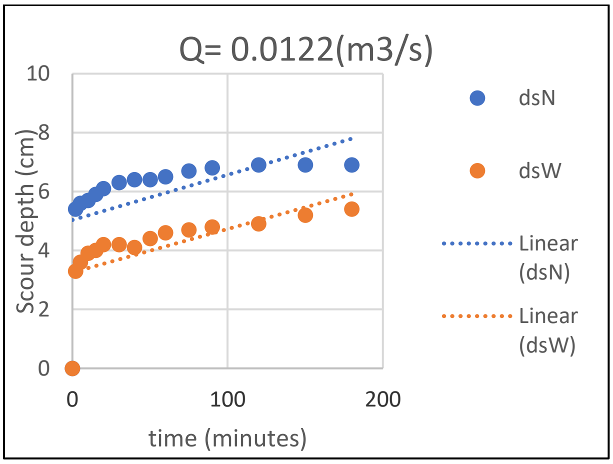
3.1 SERIES 1: - Circular Pier



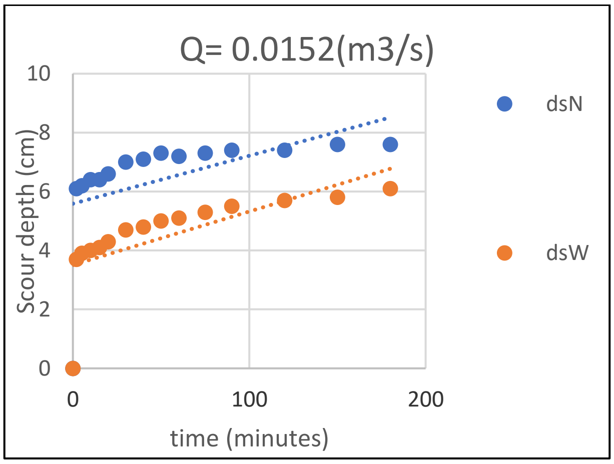
Experiment 1 – A



Experiment 1 – B



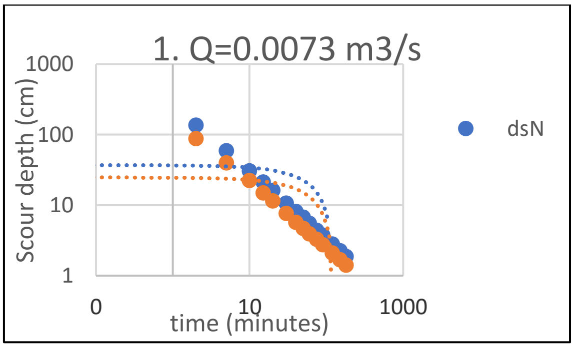
Experiment 1 – C



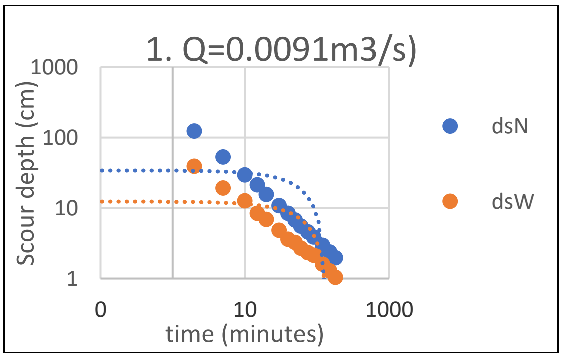
Experiment 1 – D

- This graphical representation of scour depth versis time of circular pier shows that the scour depth increse at both the side at nose as well as wake side with increse in time ande discharge

3.2 Scour rate versus time: -



Experiment 1-a



Experiment 1-b

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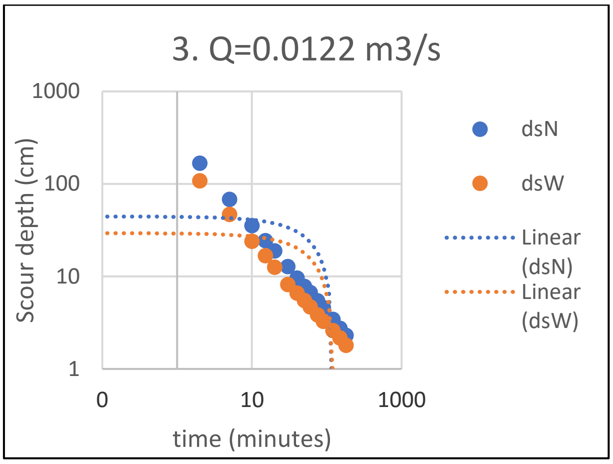
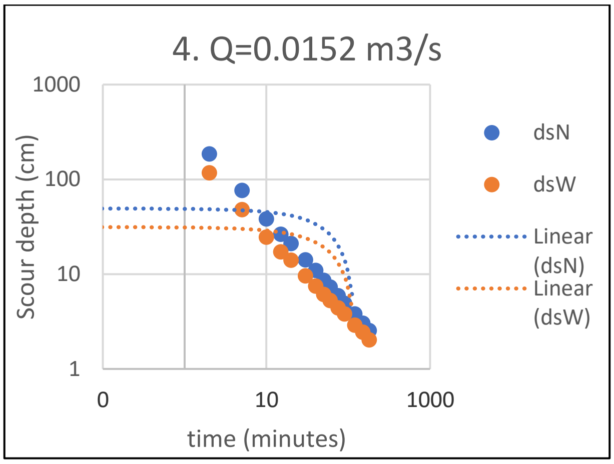


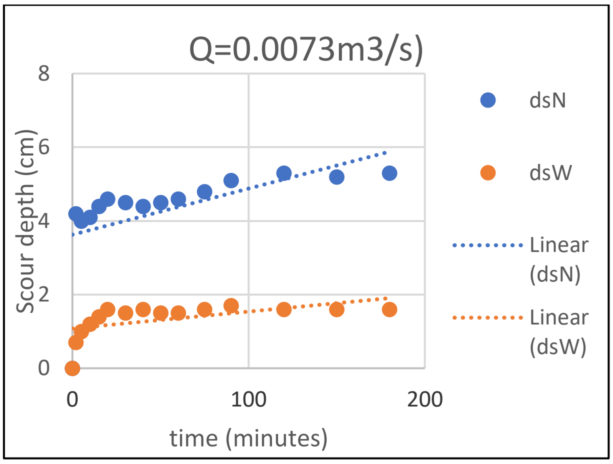
Experiment 1-c



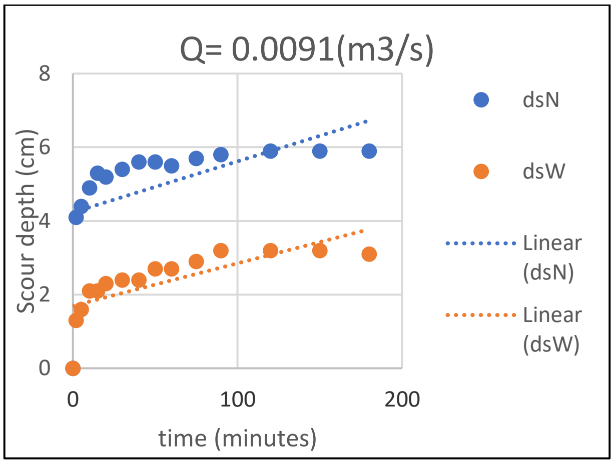
Experiment 1-d

- This graphical representation of scour rate is show that the scour depth is increse with time but its scour rate is higher at initial and then lessare at last and than becomes nearly constant.

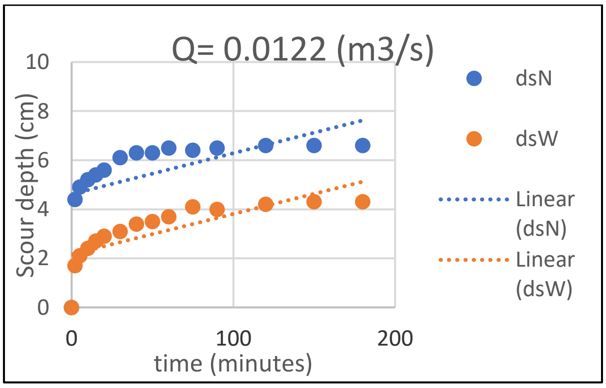
3.3 SERIES 2: - Oblong Pier



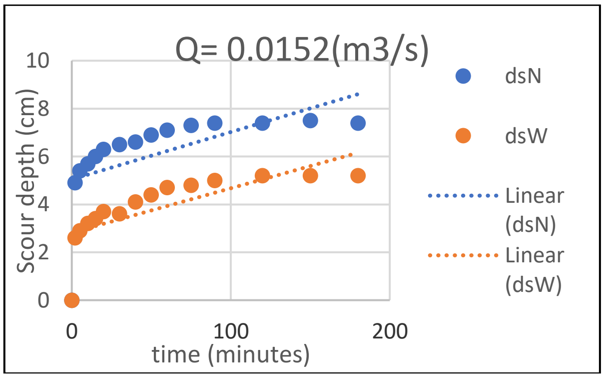
Experiment 2-A



Experiment 2-B



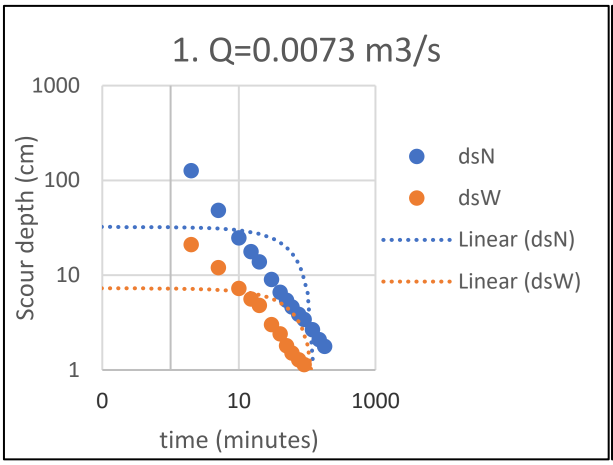
Experiment 2-C



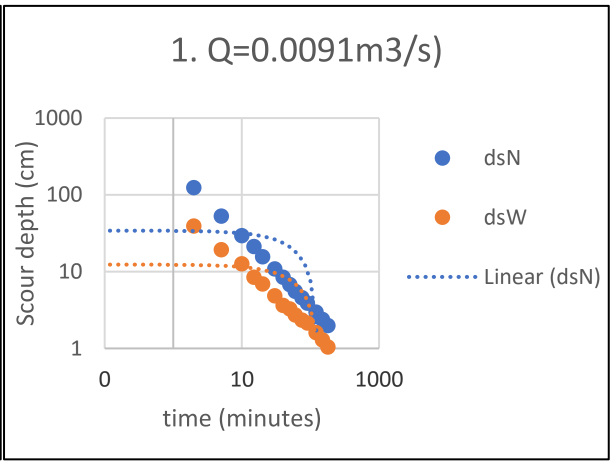
Experiment 2-D

- This graphical representation of scour depth versis time of oblong pier shows that the scour depth increse at both the side at nose as well as wake side with increse in time ande discharge

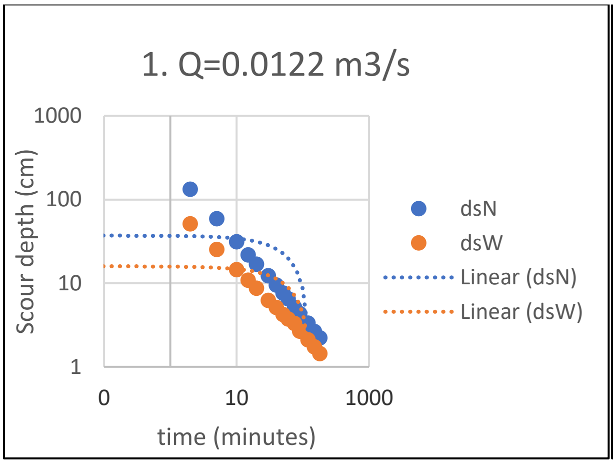
3.3 Scour rate versus time



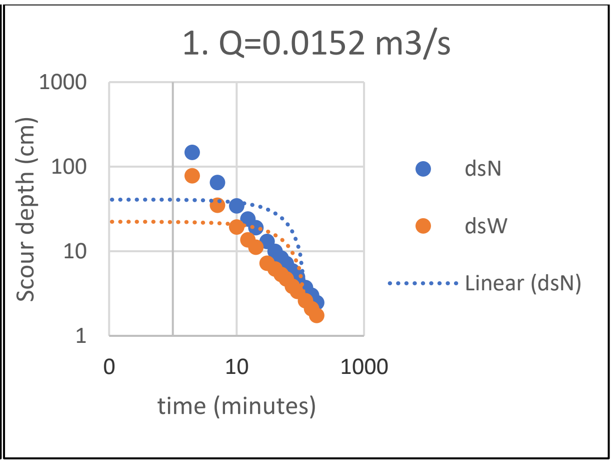
Experiment 2-a



Experiment 2-b



Experiment 2-c



Experiment 2-d

- This graphical representation of scour rate is show that the scour depth is increase with time but its scour rate is higher at initial and then lesser at last and then becomes nearly constant.

3.4 SERIES 3: - Square Pier

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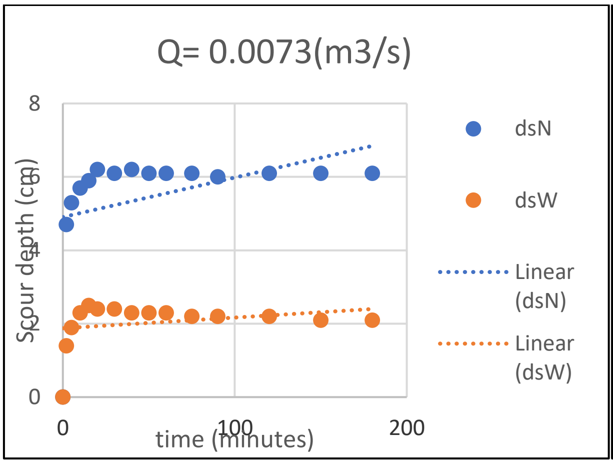
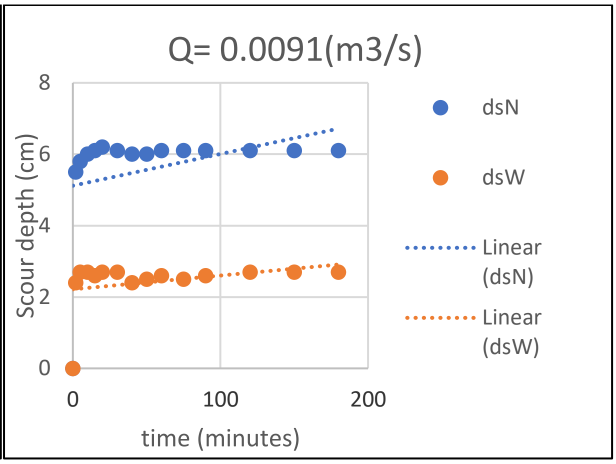
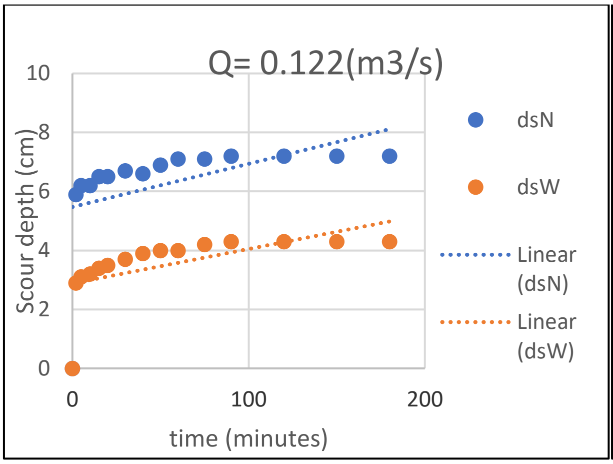


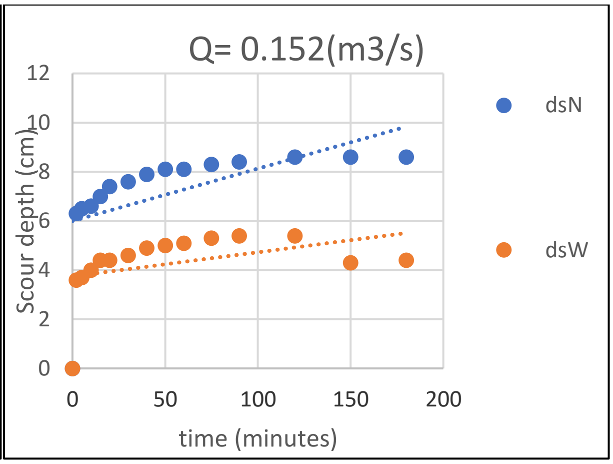
Experiment 3 – A



Experiment 3 – B



Experiment 3 – C



Experiment 3 – D

- This graphical representation of scour depth versus time of square pier shows that the scour depth increases at both the side at nose as well as wake side with increase in time and discharge.
- In this square pier the 80-90% of max scour depth is obtained in initial 20-30 minutes and then it became nearly same.

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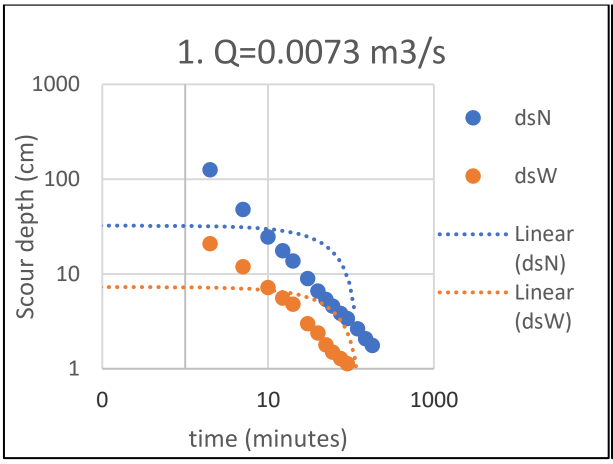
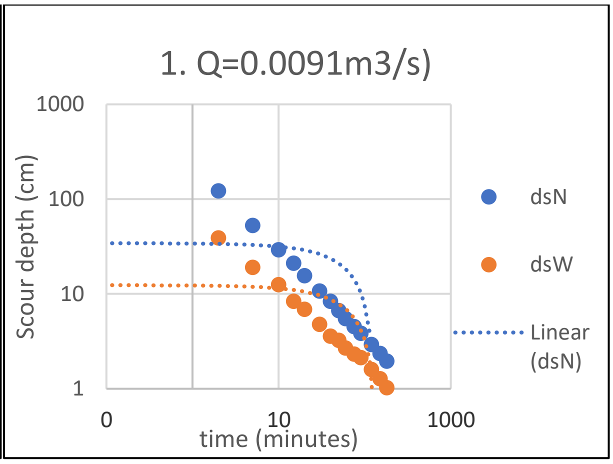
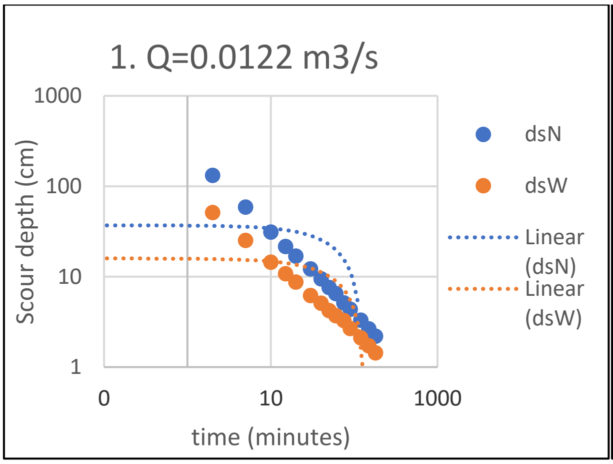
3.5 Scour rate versus time



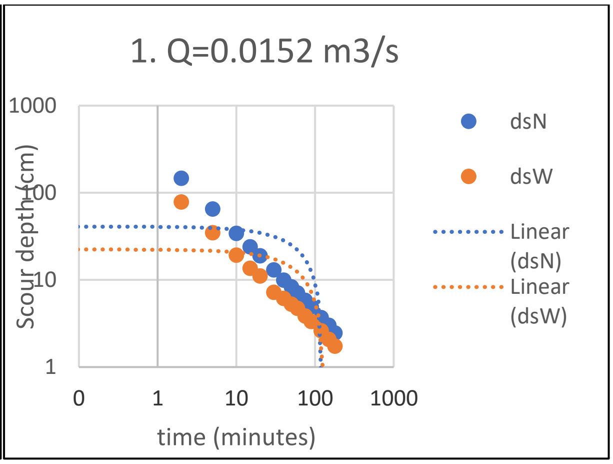
Experiment 3-a



Experiment 3-b



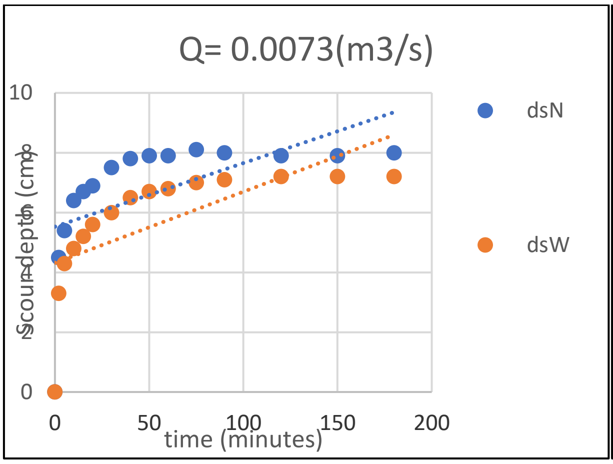
Experiment 3-c



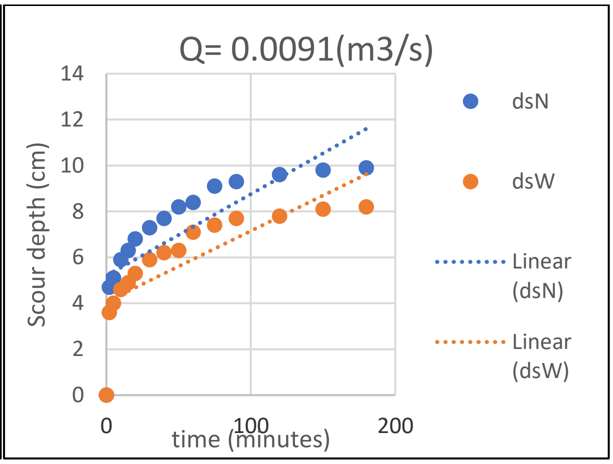
Experiment 3-d

- This graphical representation of scour rate is show that the scour depth is increase with time but its scour rate is higher at initial and then lesser at last and then becomes nearly constant.

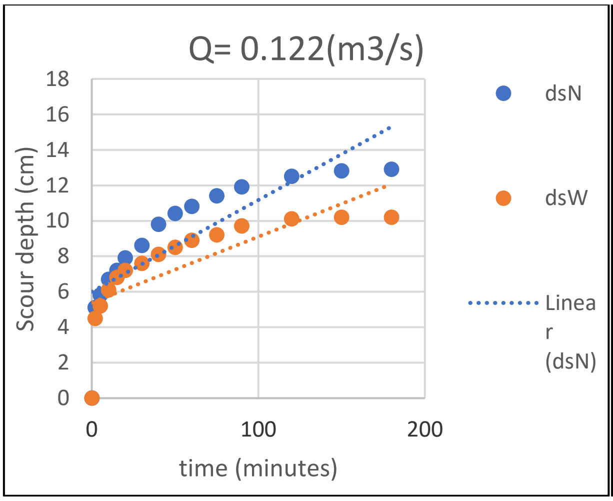
3.6 SERIES 4: - Triangle Pier



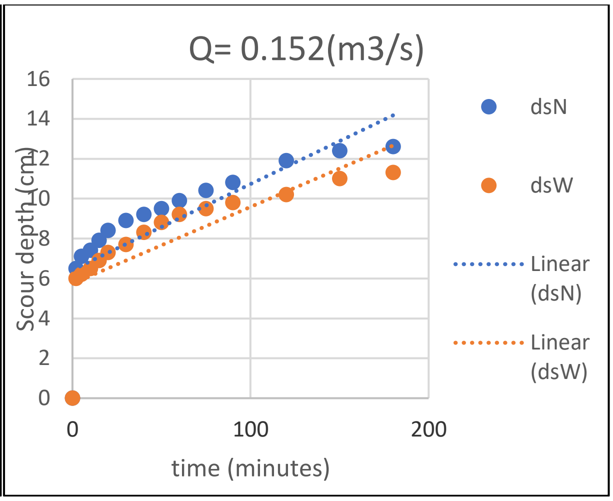
Experiment 4-A



Experiment 4-B



Experiment 4-C



Experiment 4-D

- This graphical representation of scour depth versus time of square pier shows that the scour depth increases at both the side at nose as well as wake side with increase in time and discharge.
- This shape shows the max scour depth as compare to other pier shapes in all four discharges.

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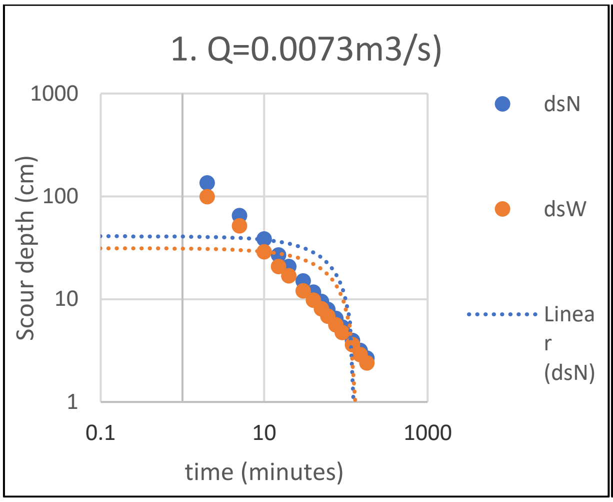
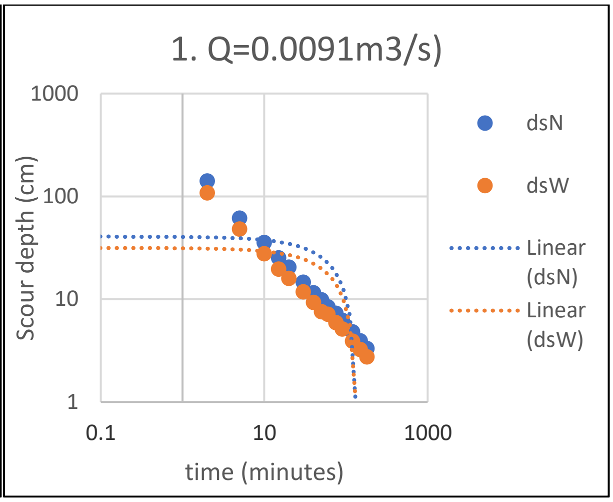
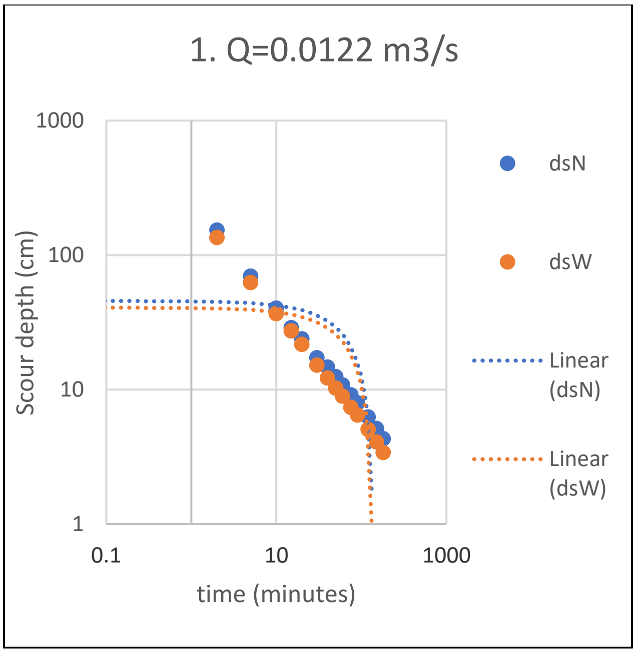
3.7 Scour rate versus time



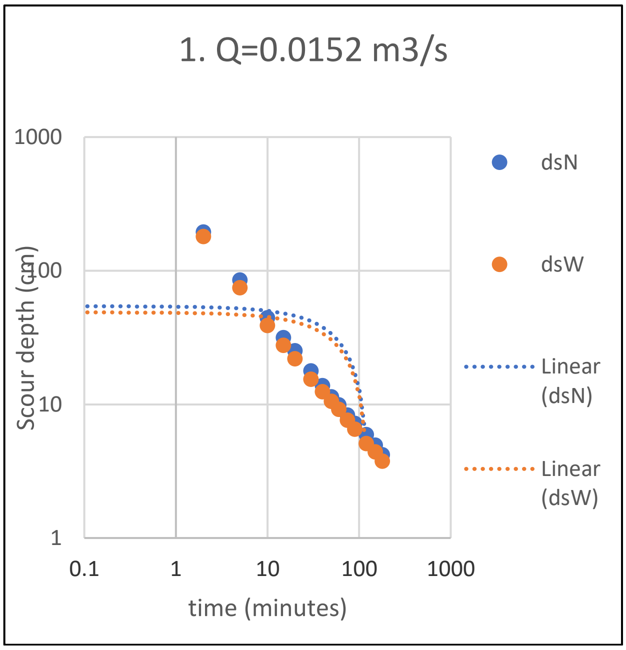
Experiment 4-a



Experiment 4-b



Experiment 4-c



Experiment 4-d

- This graphical representation of scour rate is show that the scour depth is increase with time but its scour rate is higher at initial and then lesser at last and then becomes nearly constant.

3.8 Comparison of Scour depth vs Time Graph for all discharges through different Piers

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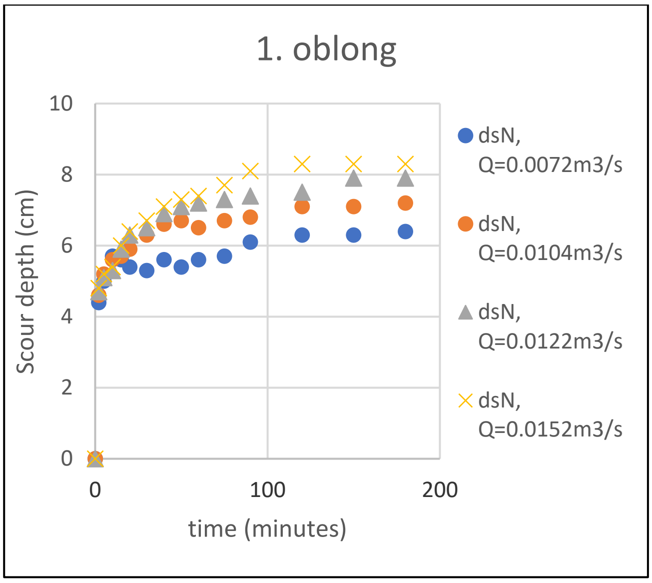

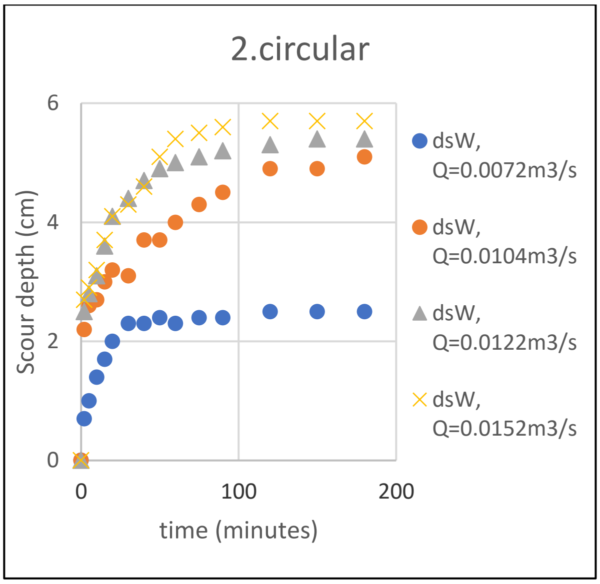

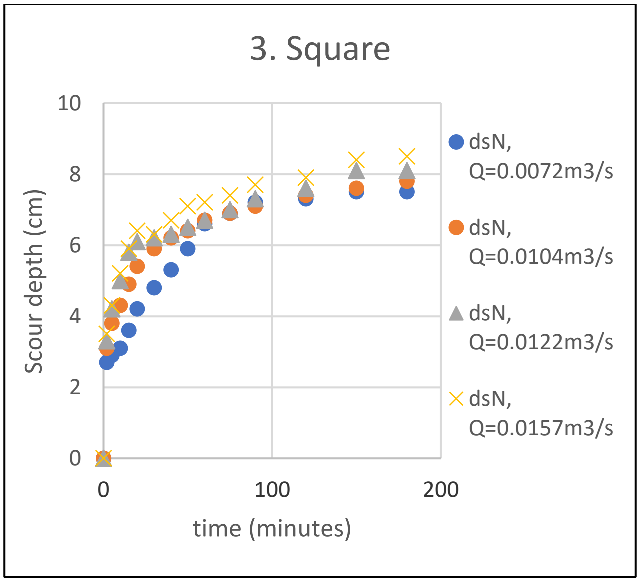

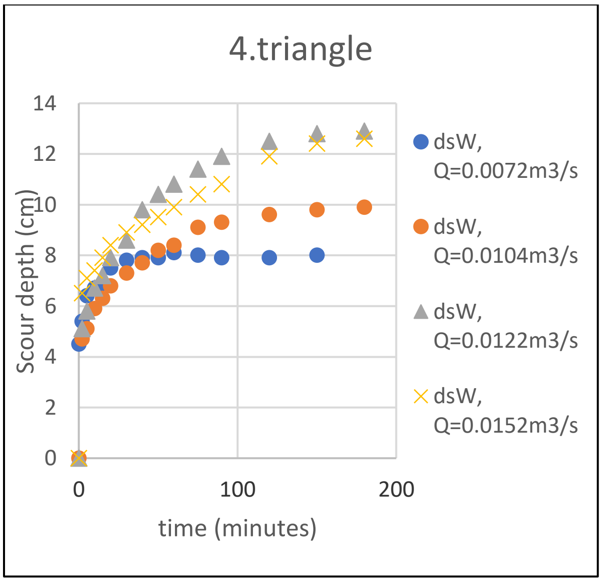

- This graphical representation shows the scour depth at nose side of all four-shape pier for all four discharges.
- this experimental data show that the scour depth is increase with increase in discharge.

IV. CONCLUSION

The experimental analysis demonstrates that the flow velocity, turbulence, and pier shape all have a significant impact on the scour depth. By examining the relationship between pier shape and maximum scour depth, it is evident that piers with triangular shapes and apexes oriented anticlockwise have greater maximum scour depths than other pier types. With an increase in discharge, the maximum scour depth as well as the depth at the nose and wake constantly rose. The scour depth in a triangle is 48.7% more than in a circle. Scour initially occurs quickly and then intensifies with less amount. After analysing the graph, it was discovered that the scour depth grows over time and that it can be completed in 1-2 hours, or about 90% of the time, before becoming practically constant. It is evident from the data that as time passes, scour depth increases while its rate slows. When compared to the beginning of the run, the scour rate is seen to be significantly lower by the end.

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