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# Optimum Size of the soil Particles around Bridge Piers in the Curved Channels

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**Abstract**

The scour around the bridge piers is one of the most common reasons for its failure. It is known that the phenomenon of scour is a very complex. Many researchers have tried to infer theoretical, analytical equations as well as make results from laboratory experiments to understand the mechanism of scour around bridge piers existing in both straight and curved channels. The main aim of this research is to find the optimum size of soil grains around bridge piers in curved channels under the used operating conditions. In this research, a 30 degrees curved channel model is used to investigate various models of piers with different shapes were suggested (i.e. Elliptical, Polygon (hexagonal), Oblong, Oblong with curve, Lenticular, and lenticular with curve), were put in the middle of curved part of channel. The experimental channel is rectangular cross section of (30x60 cm) and length is 8 m was made of steel with transparent vertical side, the middle part of channel is curved and the front, rear parts are straight. Discharges used in the research are 13.89 lit/sec, 19.41 lit/sec, 23.77 lit/sec, 28.04 lit/sec and 30.64 lit/sec, the scour for all models was measure by Ahmed Helmy 2017, Depths were measured using an ultrasound device. We collected the remaining soil after completing the scour proses around the models of bridge piers and are investigated using sieve analysis. The collected soil was backfilled around all models and the scour was measured. These results were collected, analyzed, presented, and discussed. It was deduced that the optimum particle size of soil around bride pier in curved channels, where Fr ranges from 0.162 to 0.33 is achieved for relative soil diameter D50/B ranges from $2.33*10^{-4}$ to $3*10^{-3}$ at which the scour depth decreases by a percentage range from 20% to 40%.

**Key words:** Scour, Bridge piers, Curved channels, Optimum particle size, Hydraulic structures

## INTRODUCTION

Bridges are the most important structures. Failure of many bridges around the world is mostly due to the scour around the piers of these bridges during the floods. However, there is not a lot of information's about the scour around the bridge piers, as well as the size of soil particles suitable for filling around these piers, especially in curved channels.

This research presents the optimum size of soil particles around piers in the curved part of channels for different pier shapes.

Many researchers investigate the process of scour around the bridge piers in water ways, experimentally, theoretically and numerically. In 2017 Ahmed Helmy et al, Study of the local scour around unconventional bridge piers in the water ways, six models of piers were tested (i.e. Elliptical, Polygon (hexagonal), Oblong, Oblong with curve, Lenticular, and lenticular with curve) with three different angles rotation around its longitudinal axis of channel. This study designed that the conventional shapes to reducing scour depth reasonably with different inclination angles and he concluded that the polygon (Hexagonal) with angle 2.5o was able to reducing the scour depth by 36% relative to the maximum scour depth Moreover; it was the best shape in conventional shapes. On the other hand for the non-conventional shapes, the Lenticular (curve) with angle $0.^{0o}$ was able to reducing the scour depth by 44% relative to the maximum scour depth. Hassan et al, 2016, study experimentally the bridge pier shape to minimize local scour and he concluded that the optimum shape that gives minimum scour depth compared with scour at upstream is directly proportional to exposed area of upstream nose of pier. He recommended that the rectangular pier gives the maximum scour depth, while the streamline shape gives the minimum scour depth. In 2010, Jueyi et al. explain clear-water scour around semi-elliptical abutments with armored beds. An experimental study of scour in case of clear water has been carried out to explore the local scour around semi-elliptical model bridge abutments provided with armor-layer bed and compared with the local scour process around semi-circular abutment. The researcher concluded that the increase in flow velocity for all of runs the equilibrium scour depth of the scour hole will be increased in both semi-elliptical and semi-circular abutments.

In 2017 Mostafa Ali et Study the local scour around piers in the curved channels, four models were tested (i.e. Elliptical, Polygon (hexagonal), Lenticular, and lenticular with curve). The researcher study the pier shapes after the equilibrium scour condition. It was concluded that the inclination angle of the pier has low-impact the relative scour depth (ds/y) for all studied shapes of the piers. Except for the polygon (Hexagonal). In 2008, Yaser Emami et al, Scour at Cylindrical Bridge Pier in A 180 Degree Channel Bend are studied. This study shows that the lowest scour depth for different flow condition can be occur at straight part of channel, when pier is located in the bend part, the scour depth increases as compare to that in a straight part of channel. The location of scour hole located at the bend and it's close to the outer wall of channel and the point bar is close to the inner wall of channel.

## THEORETICAL APPROACH

According to the dimensional analysis technique of Buckingham's π- theorem where methods of dimensional analysis are built up on principle of dimensional homogeneity. All parameters are defined on the figure 1. In this study the scour depth scour (ds), is a function of all other independent variables as follows:

$d_S = \phi (B, b, L_s, T, T_o, t, L_b, y, Q, \phi, \rho, g, \mu, D_{50}, R, S.G, \theta)$.

Where:

B = Width of channel (L).
b = Distance from pier to the side (L).
R = Radius of curvature (L).
t = Thickens of piers (L).
Q = Flow rate ($L^3T^{-1}$).
Y = Normal water depth (L).
ρ = Mass density of fluid ($ML^{-3}$).
g = Gravitational acceleration ($LT^{-2}$).
T = Time interval (T).
$T_O$ =Final time (T).
$d_s$ = Scour depth (L).
$L_S$ = Scour length (L).
θ = Angle of orientation of pier with the direction of flow (dimensionless).
S.G = Soil Specific gravity (dimensionless).
$D_{50}$ = Mean diameter of sediments (L).

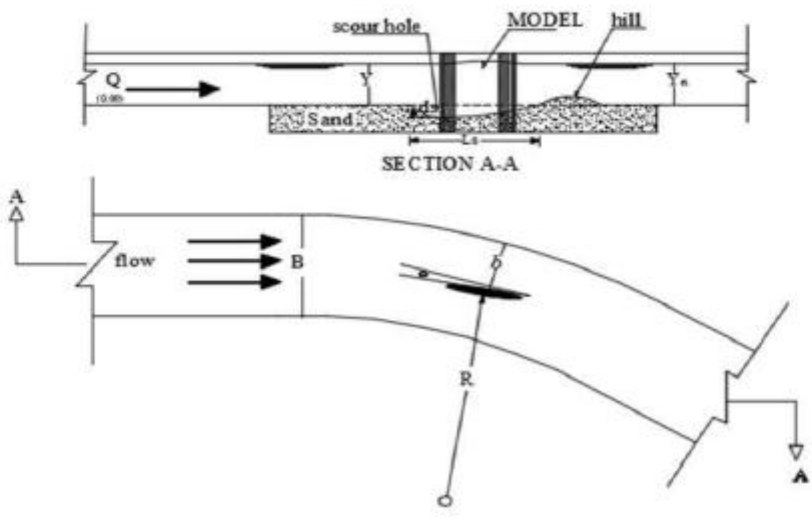


Fig1. Definition sketch

According to Buckingham π-theorem, the general form of the relationship between these variables as follows:

$$\frac{ds}{y} = \emptyset\left(\frac{Ls}{y}, \frac{b}{B}, \frac{Ls}{Lb}, \frac{D_{50}}{B}, \frac{T}{To}, Fr, \theta\right) \quad (1)$$

Where:

$d_s/y$ = Relative scour depth (dimensionless).
$L_s/y$ = Relative scour length (dimensionless).
b/B = Contraction ratio (dimensionless).
Ls/Lb = Length ratio (dimensionless).
$D_{50}/B$ = Relative soil diameter (dimensionless).
T/T0 = Relative time (dimensionless).
$F_r$ = Froude's number (dimensionless).

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## EXPERIMENTAL WORKS

An experimental channel was constructed. An experimental procedures was conducted in the flume at Hydraulic Laboratory of the Faculty of Engineering, Al-Azhar University Cairo, Egypt. Fig (2). The experimental channel is rectangular cross section of (30x60 cm) and length is 8 m supported by steel frames with transparent vertical side. The flume is presented on photo (1) and figure (2). The test models in this research are (i.e. Elliptical, Polygon (hexagonal), Oblong, Oblong with curve, Lenticular, and lenticular with curve), the test conditions for each pier are summarized in table (1) and photo (2). Experiments were conducted conditions for all different Fr (i.e. 0.162, 0.243, 0.262, 0.30 and 0.33). The scour around all models was measure by Ahmed Helmy 2017 by using an ultrasound device. We collected the remaining soil after completing the scour proses around the models of bridge piers and are investigated using sieve analysis. The collected soil was backfilled again around all models then we did the previous experiments and the scour depth and lengths were measured.

**Photo (1) Experimental Flume**

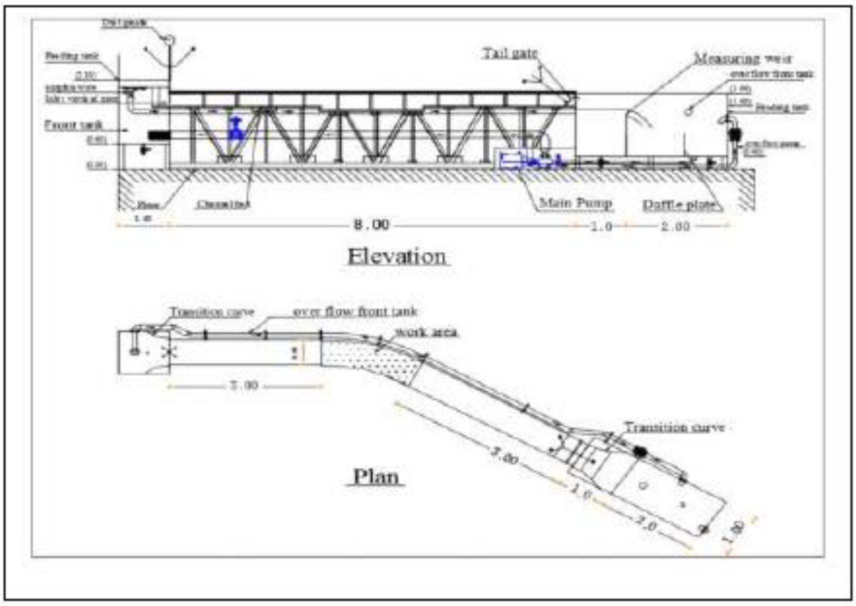
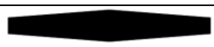
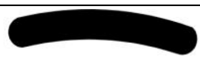



Figure (2) Experimental cannel

Table (1). Tested conditions

| Title | Shape | Fr |
|---|---|---|
| $M_1$ |  Elliptical | From (0.162 to 0.33) |
| $M_2$ |  Polygon (Hexagonal) | |
| $M_3$ |  Oblong | |
| $M_4$ |  Oblong(curve) | |

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| | | |
|---|---|---|
| $M_5$ |  lenticular | |
| $M_6$ |  Lenticular with curve | |

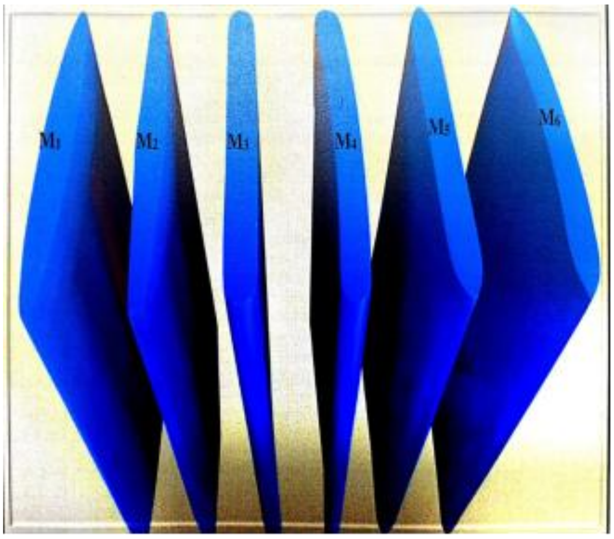

**Photo (2) Tested Models**

## RESULT AND ANALYSIS

Thirty (30) experiments were carried out, where five (5) different discharges for the different six shapes, Sieve analysis was drawn and we get $D_{50}$, $D_{15}$, $D_{85}$.

Measurements were done. Observations were recognized and the photos were taken. These measurements, observations and photos were documented and archived as shown in photo (3). They were analyzed and plotted on graphs. They are interpreted as follows:

## SIEVE ANALYSIS RESULTS

After plotting the sieve analysis curves, we used to determine $D_{50}$, $D_{15}$, $D_{85}$ for all different flow conditions and different shapes. Represented in figures (4) to figure (9) and compered with the original soil figure (3).

It was observed that the suitable $D_{50}$, $D_{15}$, $D_{85}$ for different shapes of piers and different flow conditions. Figures (4) to (9) represented that the optimum grain size distribution of the soil around the bride pier ranged from 0.14mm to 1.8mm for all shapes.

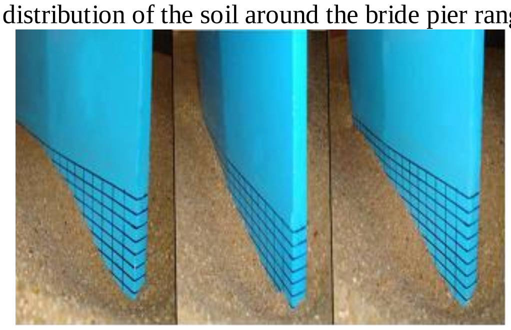

Photo (3) Local Scour.

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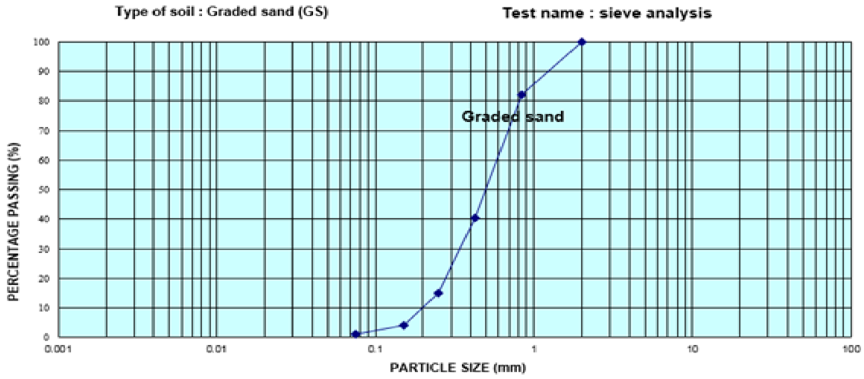
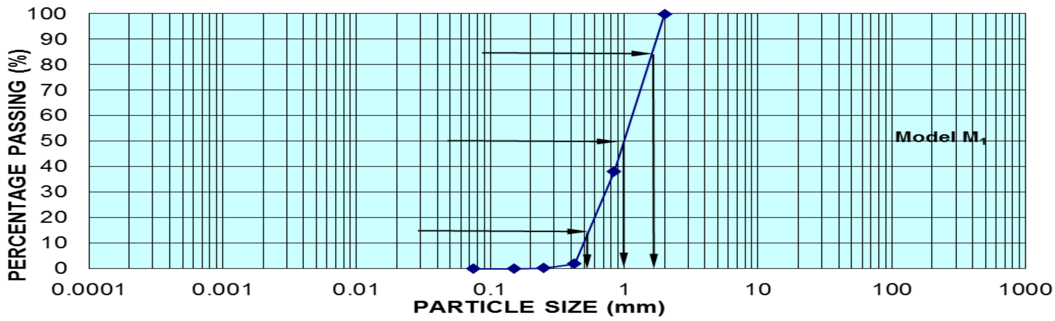
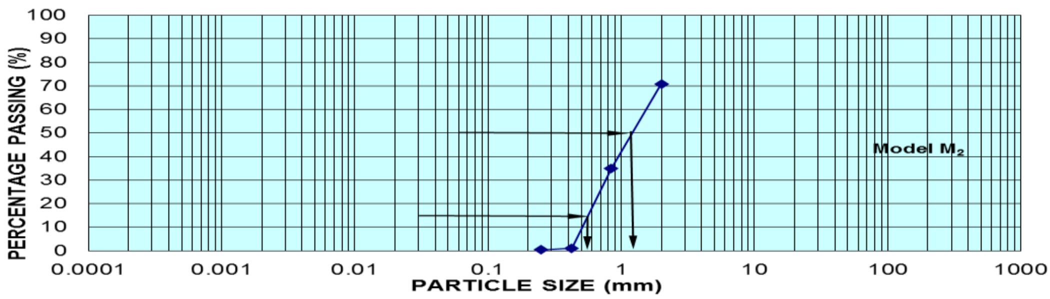


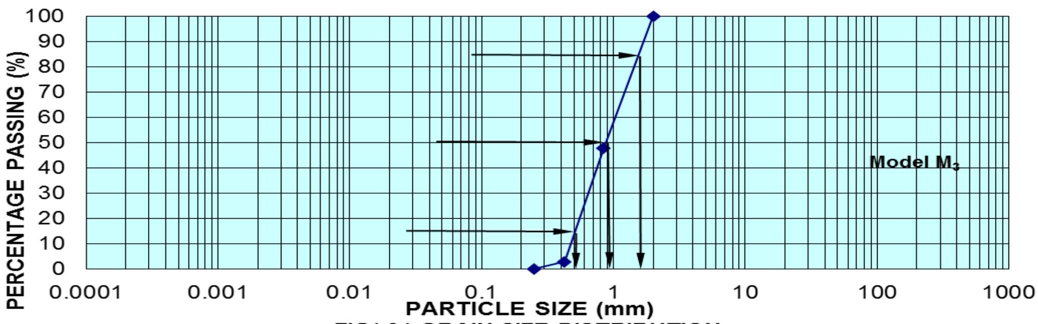

FIG (3) GRAIN SIZE DISTRIBUTION ORIGINAL SOIL




FIG( 4 ) GRAIN SIZE DISTRIBUTION




FIG( 5 ) GRAIN SIZE DISTRIBUTION




FIG( 6 ) GRAIN SIZE DISTRIBUTION

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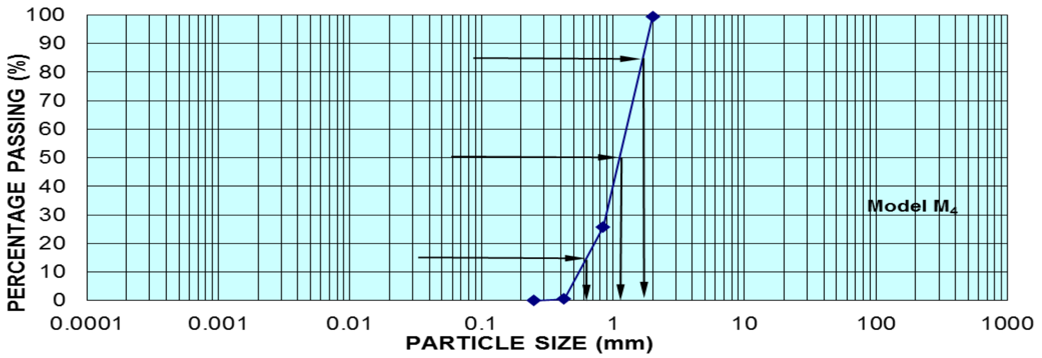
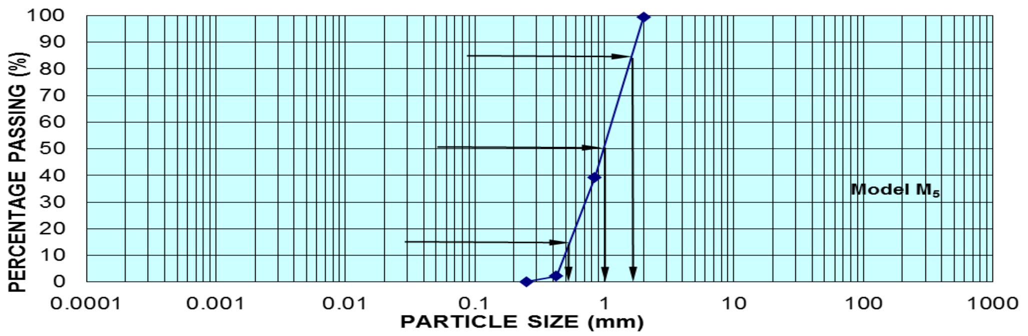
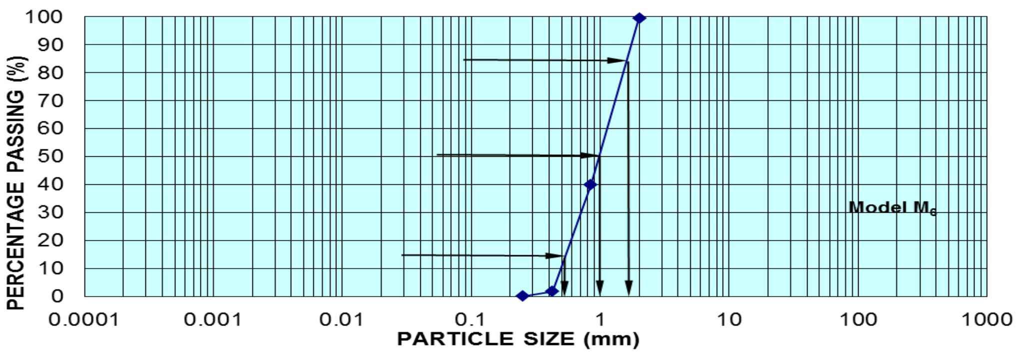


FIG( 7 ) GRAIN SIZE DISTRIBUTION



FIG( 8 ) GRAIN SIZE DISTRIBUTION



FIG( 9 ) GRAIN SIZE DISTRIBUTION

## COMPARISON BETWEEN SCOUR DEPTHS

The results of the scour in the research published by Ahmed Helmy 2017 were compared with the current research represented figure (10) shows that by using relative soil diameter D50/B from 2.33*10-4 to 3*10-3 the scour around the bride pier decreased by 20% to 40%.

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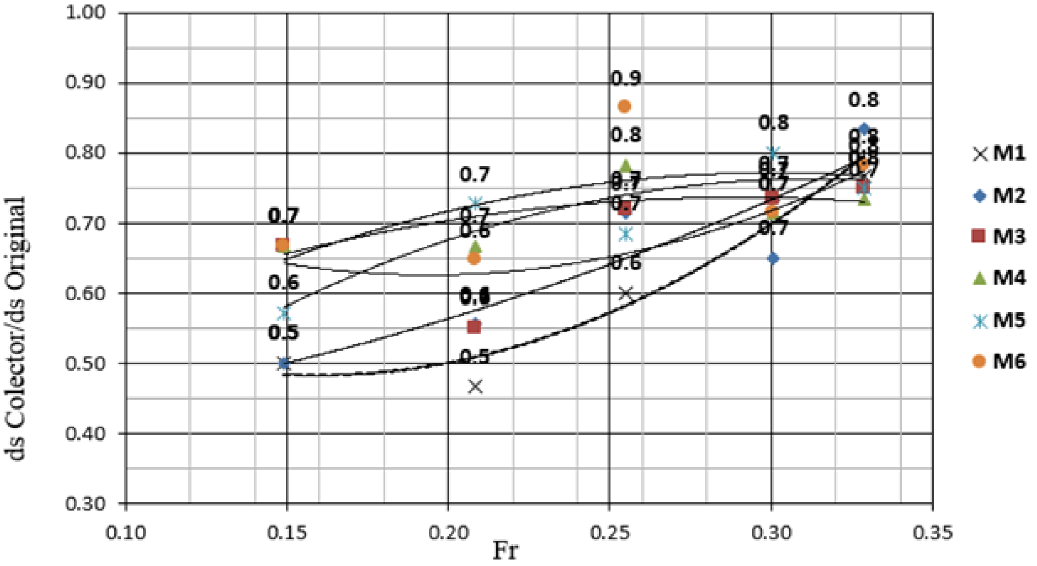


Figure (10) relation between ds collected / ds original

## CONCLUSION

In this study, optimum size of grains of the soil particles around bridge piers in the curved channels were investigated, theoretically, experimentally and inferentially. Regarding the theoretical phase, a literature review survey was carried out from which it was clear that intensive experimental work is needed, as it was concluded that:

1- The optimum grain size distribution of the soil particles around bridge piers in curved channels, Where Fr ranges from 0.162 to 0.33 is the relative soil diameter ($D_{50}$/B) ranges from $2.33*10^{-4}$ to $3*10^{-3}$.

2- The mentioned previous relative soil diameter ($D_{50}$/B) as main soil particles around bridge piers in the experimental models, it was found that the scour depth decreases by a percentage range from 20% to 40%.

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