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# Evaluating the effect of Drawing sand and Grain from River Bed on Scouring at Bridge Piers in SEFIDROUD River

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***Abstract:*** Scour at pier is one of the main reasons behind the bridges destruction especially in the cases of floods. that is why determining scour at piers depth is of great value for bridges design and construction. In order to measure scour at piers, equations with more precision must be used, present research provide a new equation for measuring scour at piers and analyze important factors involved considering the negative effect of sand harvesting in Sefidroud River in north of Iran.

***Key words:*** scour at piers, sand, gravel, Sefidroud River, Iran

## 1. INTRODUCTION

Nowadays, all over the world and also in Iran, various river aggregates such as gravel, sand, fine grains are being used in constructional and industrial projects, and thus daily excavation happen in bed rivers. Different usages are considered for this material, the main which is near 75% is the concrete mixing procedure. Obviously concrete is widely used in all construction projects like buildings, dams, bridges, roads and etc.

The river based aggregates being in long-time contact with water flow are a considerable source, since the round shape and suitable grading. Easy access to this resource and economic aspects are also important factors.

## 2. EFFECTS FOR DRAWING GRAVEL AND SAND OF BED RIVER

Accurate management and logical drawing of gravel and sand from bed river can guarantee the long time existence of the river, but if the excavation exceeds the normal range, negative disasters may occur. The mentioned disasters do not occur exactly at the excavation location, thus kilometers far away in downstream scouring appears. Drawing sand cause the existence of holes in bed river, and then unbalancing the sedimentation equilibrium in river leads to variation in bed slope and current depth. Moreover, if the excavation depth exceeds more, the water fall current influence the upstream sedimentation as well. Drawing sand from riversides also affect negatively the bridges and hydraulic structures along the river stream.

## 3. SCOURING EFFECTS ON BRIDGE PIERS

Bridges are considered among the most important and helpful constructions on the rivers while year after year in the cases of floods many bridges are destructed, just when they are highly needed. Scour at piers is one of the main reasons leading to destruction, which in turn is created by water power circulation around the piers, a leading mechanism for scour at piers, as the time passes, these water circulations create some holes at piers and finally result in bridges destruction. Considering the fact that scour at piers necessitate

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**Figure 1: Sefidroud River in North of Iran**

finding new and highly precise equations, in the recent years, different research has been conducted to measure such phenomenon, subsequently different equations have been presented by researchers. Finding new equations based on limited kinds of data acquired from research on physical models in laboratory cannot work well in the cases of real bridges, that is why analyzing different equations based on field and laboratory data is highly needed so bridges can be designed more precisely and in turn they will be safe enough for commuters. Jonson (1995) conducted a comparison among different existing scour at piers equations based on field data, on the other hand Kopati and Valnatin conducted same kind of research based on laboratory data and acquired results were compared with predicted results for scour at piers depth, results indicate that many today equations present some extra measurements. Present study provides a new formula for scour at pier measurement and leading factors involved.

## 4. GENERAL FORMULA FOR SCOUR AT PIERS

There are many reasons behind scour at piers so considering all these factors at the same time is a complicated task. Regarding this fact some of the most important factors which has been greatly used in previously conducted research, have been regarded. This includes piers geometry and shape, stream variables, and liquid and expedition characteristics.

Scour at piers depth can be shown as a variable based on following factors: $d_s = f(k_s, k_\theta, b, V, y, g, \rho, \mu, \rho_s - \rho, D_{50}, \sigma)$

In this formula ds, ks, bk, v, y, g, m, Ps, p, D50, σ, respectively show, scour at pier depth, pier shape, angel between pier and stream, pier width, speed at which stream approaches the piers, stream depth, acceleration, dynamic density of liquid, expedition special———, liquid special———, relative diameter of bed particles, and geometric standard deviation of bed particles distribution. Thanks to dimension analysis and Buckingham theory omitting of irrelevant groups above- mention formula can be shown as following.

$$\frac{d_s}{b} = f_s\left(k_s, k_\theta, \frac{y}{b}, \frac{b}{D_{50}}, Fr, \sigma\right)$$

### 4.1. Chinese equation

This equation was presented in1993 by Galo based on rivers in China.

$$d_s = 1.141.K_s.b^{0.6}.y^{0.15}.D_{50}^{-0.07}\left(\frac{V-V_{ic}}{V_c-V_{ic}}\right)^c \tag{1}$$

In this formula *ds* indicates scour severity, *Ks* indicates piers' shape degree (1 for cylindrical piers, 0/8 for round head piers, and 0/66 for sharp head piers). b and y respectively represent pier width and stream severity, while D5 is referred to particles relative diameters and V represents stream speed while reaching the piers, Vc indicates stream disaster speed which is calculated based on following formula.

$$V_c = 3.28\left(\frac{y}{D_{50}}\right)^{0.14}\left(8.85\,D_{50} + 6.05E^{-7}\left[\frac{10+0.30By}{(0.30488.85\,D_{50})^{0.72}}\right]\right)^{0.5} \tag{2}$$

In this formula $V_{ic}$ is refereed a kind of speed in which particles as big as $D_{50}$ on diameter start moving an is calculated as following

$$V_{ic} = 0.645\left(\frac{D_{50}}{b}\right)^{0.053} V_c \tag{3}$$

C is equal to 1 for clear water and is calculated as following: (4)

### 4.2. Jones equation

This formula is one of the us army formula which was presented in 1995 by Jones and was used in HEC-18 software and is as following

$$d_s = 2.0y.K_1.K_2.K_3.K_4\left(\frac{b}{y}\right)^{0.65} Fr^{0.43} \tag{5}$$

in this formula $F_r$ is forudnumber, K1 is a number dependent on pier head shape (1/1 for square head, 1/0 for the round shape, and 0/9 for sharp head piers).

K2 depend on pier length divided by its width and angels in which stream approach the pier.K3depend on river bed and K4 is calculated as following:

$$K_4 = \sqrt{1-.89(1-V_R)^2} \tag{6}$$

In this formula Vi is speed rate and is calculated through following formula:

$$V_R = \left(\frac{V-V_i}{V_{c(D_{50})}-V_i}\right) \tag{7}$$

In turn in this formula Vi is calculated through following formula

$$V_i = 0.645\left(\frac{D_{50}}{b}\right)^{0.053}.V_{c(D_{50})} \tag{8}$$

Vc(Dn) is disaster speed for particles in the bed D= on diameter.

$$V_{c(D_n)} = 11.21\,y^{\frac{1}{6}}.D_n^{\frac{1}{3}} \tag{9}$$

**Table 1**
**k2 coefficient (considering stream angels and pier length ratio to width)**

| $\frac{L}{b}=12$ | $\frac{L}{b}=8$ | $\frac{L}{b}=4$ | *Angel degree* |
|---|---|---|---|
| 1 | 1 | 1 | 0 |
| 2.5 | 2 | 1.5 | 15 |
| 3.5 | 2.75 | 2 | 30 |
| 4.3 | 3.3 | 2.3 | 45 |
| 5 | 3.9 | 2.5 | 90 |

**Table 2**
**k3 coefficient considering river bed condition**

| $K_2$ | *height* | *Bed condition* |
|---|---|---|
| 1.1 | – | Clear scour |
| 1.1 | – | Flat bed |
| 1.1 | Between 2 and 10 feet | Small embankment |
| 1.1-1.2 | Between 10 and 30 feet | Medium embankment |
| 1.3 | More than 30 feet | Big embankment |

## 4.3. Jonson formula

This formula was presented by Johnson 1996 and is reliable for cases of $\frac{y}{b} < 0/8,\ Fr < 0/8$ which is presented as following:

$$d_s = 2.08\, k_1 k_2 k_3 k_4 \left(\frac{b}{y}\right)^{0.504} (Fr)^{0.639} \tag{10}$$

In this formula all parameters are defined same as Jones equation.

## 4.4. New equation

New equation was obtained based on acquired statistics from Sefidroud river and the relevant bridge on it, definitely the drawing of sand and gravel are also considered, yet it is assumed to be in normal range not excessive. The obtained data were analyzed through SPSS, Regression degree is R = %94 which is a desirable amount based on field data.

$$\frac{d_s}{b} = 0.636.k_s, k_\sigma.\left(\frac{b'}{b}\right)^{-0.53}.\left(\frac{y}{b}\right)^{0.69}.(Fr)^{-0.05} \tag{1}$$

In this formula $K_S$ is coefficient for the piers shape. (%8 for sharp head piers, 1 for cylindrical and round head piers, and1 /2rectangular head piers)

$k_6$ is a kind coefficient which involves the bed standard deviation in scour at piers, and is acquired based on following,

$$k_\sigma = \left(\frac{D_{84}}{D_{50}}\right)^{-0.52} \tag{11}$$

In addition b' is bridges piers width and in turn is acquired based on following.

$$b' = b\cos\theta + L\sin\theta \qquad (12)$$

In this formula L indicates piers length; θ is forming angel between the stream and piers, in addition

$\left(\frac{b'}{b}\right)^{-0.53}$ is $k_\theta$. (13)

## 5. NEW AND PREVIOUSLY CONDUCTED SCOUR AT PIER FORMULA COMPARISON

In this part based on statistics acquired from bridges located in north of Iran on Sefidroud, acquired results are compared.

**Table 3**
**(Statistics based on bridges)**

| | *L(ft)* | *θ(deg)* | *b(ft)* | *V(ft/s)* | *y(ft)* | $D_{50}$ *(mm)* | $D_{90}$*(mm)* | $D_{84}$*(mm)* | *ds(ft)* |
|---|---|---|---|---|---|---|---|---|---|
| MIN | 20 | 0 | 2 | 3.7 | 2.2 | 55 | 88 | 83 | 0.6 |
| MAX | 41.7 | 3 | 15 | 11.5 | 21.5 | 110 | 300 | 222 | 5.5 |

First scour at pier was calculated based on new formula and real statistics for scour at pier, and were compared with real scour at piers depth. Based on obtained results RMSE considered to be 1/7. After that by using new Chinese formula and real statistics, scour at pier was calculated. As can be seen, there is little diversity around the datas, which indicates precision.in addition real scour at piers was compared with measured scour at pier through Johnson formula. As can be seen from chart, amount of scour at pier measured through Johnson formula appeared to be less than that of real scour at pier, so it can be concluded that this formula work well and is more precise in lower depth. Here RMSE is equal to 2/5 .finally in 4$^{th}$ chart scour at pier depth has been shown in comparison with real scour at piers. As can be seen acquired results through this formula appear to be precise, here RMSE is considered to be 5/4. Comparison shows that new relation is precise enough.

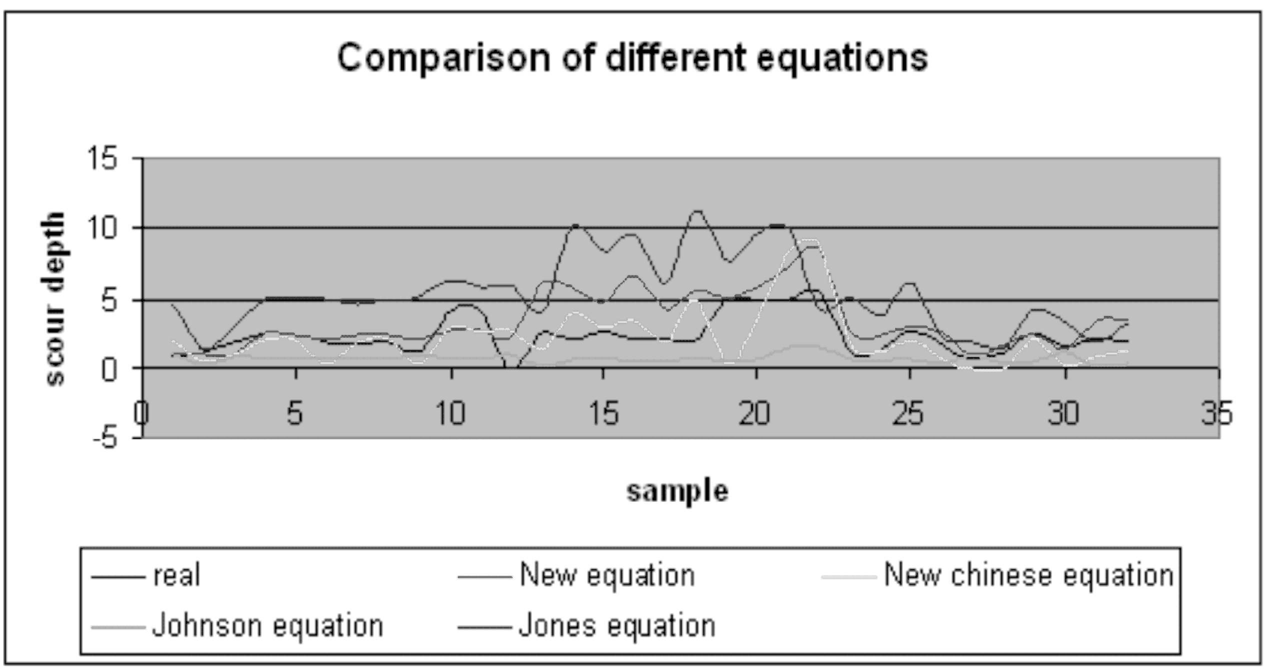


**Figure 2: Comparison of different equations on scouring at bridge piers**

**Table 4**
**Scouring depth**

| | Scouring depth (ft) | | | | |
|---|---|---|---|---|---|
| *order* | *New equation* | *New chinese* | *Johnson equation* | *Jones* | *real* |
| 1 | 1.18 | 2.01 | 1.04 | 4.49 | 0.8 |
| 2 | 0.92 | 0.41 | 0.36 | 1.35 | 1.2 |
| 3 | 0.93 | 0.97 | 0.8 | 2.93 | 1.9 |
| 4 | 2.47 | 1.95 | 0.58 | 4.83 | 2.5 |
| 5 | 2.38 | 2.07 | 0.63 | 5.02 | 2.3 |
| 6 | 2.07 | 0.34 | 0.7 | 5 | 1.9 |
| 7 | 2.39 | 1.78 | 0.57 | 4.56 | 1.6 |
| 8 | 2.28 | 1.98 | 0.64 | 4.85 | 1.8 |
| 9 | 2 | 0.31 | 0.74 | 5.02 | 1.1 |
| 10 | 2.66 | 2.84 | 0.69 | 6.22 | 4 |
| 11 | 2.67 | 2.51 | 0.63 | 5.76 | 4 |
| 12 | 2.18 | 2.75 | 0.94 | 5.93 | 2..3 |
| 13 | 6.18 | 1.26 | 0.21 | 4.09 | 2.5 |
| 14 | 5.71 | 3.83 | 0.6 | 10.03 | 2 |
| 15 | 4.78 | 2.86 | 0.61 | 8.26 | 2.5 |
| 16 | 6.63 | 3.38 | 0.46 | 9.51 | 2 |
| 17 | 4.17 | 1.78 | 0.52 | 6.04 | 2 |
| 18 | 5.55 | 4.93 | 0.7 | 11.17 | 2 |
| 19 | 4.91 | 0.34 | 0.5 | 7.59 | 5 |
| 20 | 5.72 | 3.47 | 0.56 | 9.49 | 5 |
| 21 | 7.38 | 8.29 | 1.44 | 19.94 | 5 |
| 22 | 8.57 | 8.61 | 1.47 | 24.3 | 5.5 |
| 23 | 2.51 | 1.6 | 0.61 | 5.07 | 1.1 |
| 24 | 2.27 | 1.12 | 0.52 | 3.79 | 1.4 |
| 25 | 2.93 | 2.06 | 0.61 | 6.15 | 2.7 |
| 26 | 2.56 | 0.68 | 0.26 | 2.25 | 1.7 |
| 27 | 0.94 | 0.04 | 0.78 | 1.82 | 0.6 |
| 28 | 1.69 | 0 | 0.3 | 1.49 | 1.2 |
| 29 | 2.43 | 1.95 | 0.55 | 4.22 | 2.5 |
| 30 | 1.25 | 0.17 | 1.16 | 3.25 | 1.5 |
| 31 | 3.41 | 0.78 | 0.18 | 1.89 | 2.1 |
| 32 | 3.38 | 1.31 | 0.32 | 3.18 | 1.8 |

## 6. RESULTS AND DISCUSSION

In this study a new formula was presented based on real statistics and was compared with three other formula, new Chinese 1993,Johnson 1996 and Jones 1995.considering acquired results, new Chinese and new formula were precise enough to calculate scour at piers in Sefidroud River, while Jonson was more practical for shallow streams and Jones indicates a kind of limited results.

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