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Short Communication

Investigating the existent equations for prediction of maximum scouring depth of side piers using decision tree approach

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ABSTRACT

Scouring is a main cause of bridges breaking. Hence, prediction of scouring depth has been always one of the most important subjects of study. Several studies have been conducted to find an equation for prediction of scouring depth of side piers. Most of the mentioned studies are faced to some errors to predict scouring depth due to complication of scouring issue. In the present study, scouring of piers has been investigated using decision tree approach. At the beginning of the study, experimental data have been extracted using previous studies. Then, existent equations have been investigated and compared using the extracted data. The equations showed that, Hire's equation (1995) has a higher precision when L/y is small, for high piers and when V/V_e is less than 1 as well as for small L/d_{50}.

Keywords: Depth of Scouring, Side Pier, Decision Tree.

1. INTRODUCTION

Most of bridge breakings occur once flood occurrence. Flood can cause collapse of structure by erosion around piers. Therefore, scouring can be considered as a cause of bridges breaking. In the present study, it has been attempted to investigate scouring around side piers. The piers cause to generate some vortexes by blocking the flow path and changing them. The mentioned vortexes are the main cause of scouring around the piers. Finding a way to estimate depth of scouring is important engineers' concerns. Most of empirical equations on the scouring of side piers have been created using dimensionless parameters. In continue, the types of scouring have been investigated and finally have been evaluated using decision tree approach.

1- General scouring: it occurs at two states including A) where the river has not been balanced, and sediment transport potential in a reach is higher than the amount of input sediment to this reach. B) Where flow velocity is increased due to some causes such as reduction of the river cross-section at the bridges' location. Scouring occurs in the narrow section of the river.

2- Local scouring: it occurs where turbulences are increased locally. Local scouring occurs downstream of hydraulic structures such as spillway, shot, valves and piers due to a higher local velocity than critical velocity which occurs because of flow gradient variation and increase of velocity around the structure, and turning the velocity head to pressure head caused by hitting the flow to the structure and consequently flow conduction toward downstream and creation of meandering flows in downstream.

2. Characteristics of Decision Tree

Decision tree places input data in different categories so that, no input data is eliminated. Although some patterns of decision trees may be complicated, understanding of the model of tree and analytical results is easy. Categorizations in decision tree are conducted according to similarity of the input data in predictor parameters. A decision tree is in the form of upside down tree so that, there is a root on top of that, and the leaves are at the bottom. The leaves are actually the output regulations and equations which help predicting the discussed subject. Considering complication and the nature of scouring, decision tree is used in the present study to predict the amount of scouring depth.

3. MATERIALS AND METHODS

Several experiments have been conducted on scouring of side piers. A number of experiments have been collected which form a complete set of various laboratory states. In each experiment, some parameters such as water depth, length of pier, depth of scouring, median diameter of sediment, standard deviation of the sediments size, density of sediment (ρ_s) and shape of pier have been reported. Erosion depth measured in the data is the erosion depth at balance state.

Table1. Number and range of the data

	Number	Foundation type	d_{50}(mm)	σ_g	ρ_s	V/V_e	L/y
Abouseida(2009)	24	Vertical	0.38	1.7	-	0.33-0.95	0.62-1.27
Ballio(2009)	25	Vertical	1.9-5	1.3	2.57	-0.990.84	4.05-4.35
Coleman&Melville(2003)	68	Vertical	0.8-1.02	-	-	0.46-0.99	0.25-151.3
Gill(1972)	23	Vertical	0.9	1.2	2.65	0.65-1.49	1.96-8.82
Kwan(1984)	19	Vertical	0.85-0.9	1.3	2.65	0.9-1	1.64-28
Kwan(1984)	5	Winged	0.9	1.3	2.65	1	2.4-9.5
Kandasamy(1989)	30	Winged	0.9	1.3	2.65	0.95-2.25	1-69
Grade(1963)	7	Vertical	0.3-1	-	2.65	0.83-2.15	1.23-2.06
Lim(1997)	11	Vertical	0.94	1.25	2.65	0.41-0.74	0.33-1
Rajaratnam(1983)	6	Vertical	1.4	1.3	2.65	0.4-0.67	0.99-1.43
Liu(1961)	4	Vertical	0.56-0.64	1.17	2.65	0.5-0.94	2-3.75
Cunha(1995)	7	Vertical	1.6-5.8	-	-	0.45-0.94	2.2
Tey(1984)	8	Vertical- Semicircle	0.8-0.9	1.26	2.65	0.78-1	1.65-6
Ladage(1998)	4	Vertical	0.8	-	-	0.49-0.7	0.75
Dongol(1990)	46	Vertical-Winged	0.9	1.3	2.65	1-6.4	0.25-1.5
Dongol(1994)	119	Vertical- Winged	0.9-18	1.3	2.65	0.76-4	0.25-151.3
Dey&Barbhuiya(2004)	449	Vertical- Winged-Semicircle	0.26-3.1	1.17-1.38	2.65	0.95	0.16-2.4
Total	885	Vertical- Winged-Semicircle	0.26-18	1.17-1.38	2.57-2.65	0.33-4	0.16-151.3

4. Data analysis in prediction equations

In table2, the equations of estimation of scouring depth and their limitations have been presented. In the mentioned equations, Fr is Froude number of flow ($Fr=V/\sqrt{yg}$), g is acceleration of gravity, X is the distance of piers, Fc is critical Froude number, Δ is equal to $\rho_s/\rho-1$, ρ_s is density of sediments and ρ is density of water.

Table2. Equations given for estimation of scouring depth

Reference	Equation	Limitation	Number
Froehlich (1989) **Hire (1995)**	$y_s/y=2.27K_s K_\theta (L/y)^{0.43} Fr^{0.61}+1$ $y_s/y=(4/0.55)K_s K_\theta Fr^{0.33}$	L/y<25 L/y>25	(1-2) (2-2)
Al-Saadi (2013)	$y_s/l=81.41Fr^{-5.1}$	Clear Water	(3-2)
Laursen (1963)	$y_s/y=1.89(L/y)^{0.5}$	Clear Water	(4-2)
Melville (1997)	$y_s=K_{yL} K_I K_d K_\sigma K_s K_\theta K_G$	-	(5-2)
Dey&Barbhuiya (2004) **Vertical base** **Winged base 45 °** **Semicircle base**	$y_s/L=5.857Fc^{0.314}(y/L)^{0.126}(L/d_{50})^{-0.167}$ $y_s/L=6.484Fc^{0.312}(y/L)^{0.101}(L/d_{50})^{0.231}$ $y_s/L=7.287Fc^{0.102}(y/L)^{0.103}(L/d_{50})^{-0.206}$	L/y<1	(A6-2) (B6-2) (C6-2)

At the first step, variations of difference relative to the logarithmic variations of dimensionless pier length have been evaluated to the flow depth which represents the amount of pier height. Equation (1-2) is for short piers and equation (2-2) is for high piers. This method has predicted 7.28 times higher at the worst state. In equation (2-3), it is observed that, it has predicted 5.79 times higher at the worst state. Equation (4-2) has predicted 8.12 times higher at the worst state. By increasing the amount of log (L/y), precision of prediction is decreased and the equation overestimates. Equation (5-2) has predicted 4.7 times higher at the worst state. Equation (6-2) has predicted the scouring 8.03 times higher at the worst state.

At the second step, variations of dR variations relative to logarithmic variations of flow velocity have been evaluated. With regard to the equations (1- 2), (2-2) and (3-2), it is observed that, by increasing the ratio of $V/\log V_c$, precision of the equations is decreased. With regard to the equation (4-2), it is observed that, by increasing the ratio of $V/\log V_c$, precision of the equation is decreased. Equation (5- 2) has an acceptable precision at live bed state. Equation (6-2) stats that, its precision is increased by the increase of $V/\log V_c$. At the third step, variations of dR ratio were evaluated relative to logarithmic variations of sediment diameter. In equations (2-1) and (2-2), by increasing the value of log (L/d_{50}), dR is less than 1 and the equation underestimates in this range. In the equation (3-2), by increasing the value of log (L/d_{50}), the prediction precision is still acceptable. In equation (4-4), the precision decreases by increasing the amount of log (L/d_{50}) and the equation overestimates. Equation (6-2) shows that, by increasing the amount of log (L/d50), the prediction precision is highly reduced.

5. CONCLUSION

At the first step, variations of difference relative to the logarithmic variations of dimensionless pier length has been evaluated to the flow depth, it was found that, when L/y is low, the equation (5-2) has higher precision for high piers than the other equations. Then, investigation of dR variations to the ratio of logarithmic variations of flow velocity to the critical velocity showed that, equation (5-2) acts better when V/V_c is less than 1, as well as the equation (3-2) has a higher precision for live bed. Finally, the equations were investigated while variations of dR were evaluated to the logarithmic variations of pier length to the sediments diameter, and it was concluded that, for the state of small L/d_{50}, equation (5-2) has a higher precision than the other equations, and the equation (3-2) acts better than the other equations for high L/d_{50}.

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