LABORATORY EVALUATION OF THE CROWN IMPACT ON THE CONTROL OF PIER SCOUR PROTECTION AT A 90 DEGREE BENDS

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ABSTRACT

Bridges are among the most important river structures. One the most effective factor for the destruction of bridges is the local scour around bridge piers. Every year, many bridges around the world are damaged because of not considering the role of hydraulic factors. Accordingly, for a reliable design, precise estimation of scour around bridge piers is necessary. In this study, the impact of the crown in the 90-degree bend scour at bridge pier is studied. Moreover, the bases of 2.5 cm and 5 cm in both modes, with the crown and without the crown were studied, including crowns with 2.5 cm and 5 cm and 7.5 cm diameter in a rectangular channel at an angle of 30 degrees and by measuring the water flow in three modes of 12 and 14 and 16 liters per second. The water depth in the channel for each flow was considered in the order of 8 cm and 10 cm and 12 cm that the D_s / y means the maximum depth of scour had an acceptable significance in two modes with scour and without scour and therefore, we obtained the results of processing by using two statistical software Excel and Spss that respectively are graphs and regression equation for both modes.

Keywords: *pier, scour, crown*

INTRODUCTION

Bridges are generally built on rivers, but most rivers have a winding path. Bridges are typically built in the range of river that the rivers are more stable. In this path, may be due to the limitations of constructing roads or lack of stability of the river in the direct ranges, the opinion will be issued on constructing the bridge at River Bend. Scour occurrence around the bridge piers is one of the main reasons for the destruction of bridges. After the collision of flow to the nose of the bridge at the base, according to the fact that the velocity from the reverbed increases to the water surface, more pressure is created in the higher levels on the base and thus the pressure gradient will be created from the top to the down, that causes a downward flow in front of the base. Downward flow will act such as a vertical jet and after hitting the river bed, will dig the bed, and will scatter in all directions, some of the flow that return upward have to move in the direction of flow in hitting with the general flow of the river, and hit the base again. This flow rotation and its return inside the cavity will create a vortex that gradually extends on both sides of the base, and will form a shape like a horseshoe that is called a horseshoe vortex. (Brosez et al., 1997)

Horseshoe vortex formation inside the scour hole will accelerate its drilling and the particles separated from the bed are carried out by the mainstream of the river to the downstream, due to the separation of the flow on the sides of the base, vortices are formed that their axis is perpendicular to the river bed and they are called lift-off vortex. These vortices isolate particles on the bed and expose them to the

flow, and help the transfer of the particles from the front and around the base of the downstream. Scour hole dug by the horseshoe vortex continues so that the volume of water in the scour hole increases and amortizes the vortex energy. In this case, the scour depth reaches the equilibrium. (Radkirvi et al., 1983)

There are many methods proposed to prevent or reduce scour around bridge piers, which can be divided into two categories: direct and indirect. In the direct method, the bed resistance against stresses will increase, this can be done by replacing existing materials to more resistant materials, the most common method is using stiles. In an indirect method, by modifying the flow pattern around the base, destructive forces are reduced, including the use of the crown and gap. There are numerous experimental relations to predict scour depth and the most famous of them is the relations that are presented by the American highways central Bureau.

$$D_s = 2y_2 k_2 k_3 k_4 \left(\frac{D}{y_1}\right)^{0.65} F_r^{0.65 \cdot 0.43}$$

Where D_s is depth scour, D is the coefficient of the particles forming the bed, F_r is Froude number, Y is the depth of water in the base upstream, and k is a coefficient that is determined according to the channel bed conditions. These experimental formulas show the scour depth more than the actual amount. (Kaya, 2010)

RESEARCH HISTORY

Several studies have been conducted by researchers in both fields of dealing with scour, including the study of Sing et al (2010) that reviewed the performance of the crown, test results showed that if the distance between the bed level and the crown installment level increases, the maximum scour depth increases, the diameter $D \propto 1$. The best place to install crown in the experiments was under the bed surface, which in this case, the crown decreases the scour up to 91 percent with a diameter twice the base diameter. (Aghli, 2012)

Dehghani et al (2009) in a study entitled Experimental Study of local scouring around the series of L-shaped breakwaters, writes that breakwaters are structures that are used for the purposes of diverting water flow from the erodible river beach, creating the right path to guide the flow, flood control, establishing the necessary depth for the Ship navigation, protecting outer wall of arches and reforming initiatives of the river. Among the major issues in the design of breakwaters is local scouring of their nose that occurs due to cross flow narrowing and the presence of strong vortex flows. If this depth is not calculated correctly, it can lead to the destruction of the breakwater structures. A review of previous research shows that most previous research was based on the blade breakwater and little research has been done with the L-shaped breakwater. Due to the fact that in practice, a series of water break is used to stabilize an erodible area of the river, so this study is based on a series of L-shaped breakwaters. In this study, with an experimental study in clear water conditions, experiments with three different aggregation, 4 distances between breakwaters and in 3 different flow rates was done. The results showed that the maximum depth of scour occurs around the first breakwater, and the more average particle diameter of the substrate increases, the less maximum scour depth will be. Also in a specific grading, by increasing the distance between the breakwaters, the maximum depth of scour decreases and this negative trend is more intuitive with increasing Froude numbers.

Khosravi et al (2011) has conducted a study entitled the impact of crown on reducing the scour around the breakwaters at the University of Tabriz. They write, the breakwaters are built to protect and control the sides and river banks. Methods of controlling and preventing of breakwaters' scour are based on studies of the scour mechanism. One of these methods is to install a crown around the breakwater. The crowns will protect the bed against the vortex system around the breakwater and will reduce the rate of scour. In the present study, scour around three breakwaters, with a length of 6, 8 and 10 cm was examined and trapezoidal crowns performance with different dimensions was compared for placement on the surface of the bed, and on the breakwater of clear water conditions of breakwaters without a

crown. The results showed that by increasing the width of the crown, the crown performance increases in depth reduction and the scour time delay increasing. Moreover, the percentage of scouring reduction was variable from 15 to 100% for crown with different width.

Aronghi (2009) has conducted a study entitled the appropriate dimension determination of the rectangular crown in decreasing pier scour. Various procedures are presented to prevent or reduce scour around bridge piers. Using the crown is one of the methods that are considered by researchers. In this research, by using a rectangular crown in cylindrical base, it was found that crown, speed of scour and depth of scour hole will decrease the bridge piers scour. The crown dimensions have an important role in reducing scour around bridge piers. In the present study, the crown in upstream and downstream of the bridge pier model and the width of the crown was investigated. Suitable amounts of the rectangular crown length in the upstream and downstream that were measured in the body bridge base model body respectively were determined 0.92 and 1.42 equal to the base diameter. Furthermore, the suitable crown width was also estimated three times of the base diameter. It should be noted that with the above dimensions after 62 hours, a small scour was observed around the bridge piers model.

Englis and Lisi (1959), these two researchers have collected the scour information around bridge from 17 bridges in India. The flow discharge of these bridges was between 29063 to 325000 cubic feet per second and the diameter of bed particles were varied between 17% to 39% mm. The flow depth in areas where scour occurred, were between 25 and 115 feet. This relation is as follows.

$$d_s = 0.946 \left(\frac{Q}{1.76 D_{50}^{0.5}} \right)^{1/3} - y$$

Where in

d_s : scour depth (ft)

y the depth of water in the base upstream (ft)

Q : flow discharge $\frac{ft^3}{s}$

D_{50} : average particle diameter of the bed (ft)

MATERIALS AND METHODS

Experiments were done in Hydraulic and physical model laboratory of basic studies and comprehensive designs of Ahvaz Water Resource in a rectangular channel with the central angle of 90 degrees and an average radius of 3, width of 6 meters and a height of 6 meter and a length approximately 16 meters. First, we put a bridge pier without a crown in the channel and in a 90 degree arc for the angle of 30 degrees and we also add bed materials with a diameter of $D_{50} = .8mm$ to the bed and we put a gate at the downstream of the bed. Next to adjust the flow rate, for each situation, we received help by using an alignment hose that was installed on the water supply, so that, for example, if we want to choose 12 liters discharge, it was like, when the water level inside the hose reached the height of 13.84, it means, our output discharge is at a rate of 12 liters. For the water level of 14.8 in the hose, the flow discharge rate was 14 and for the water level of 15.62, the flow discharge rate was considered 16. Now, we must examine the bridge foundations in two diameters of 5cm and 2.5cm. First, we put the bridge pier with 2.5cm diameter without a crown in the channel or the bed, and we release the discharge to a limited extent, so that bed material will be almost at saturation level and we close the valve downstream. After that, the bed was quite saturated; we obtain the particle motion threshold. Moving threshold means we enter the discharge into the channel, and by using overflows that we installed in that channel, we continue the last movement of particles, from their initial location to the extent that they move or more clear, to the extent that bed particles do not show any movement for each discharge mode or do not reveal to be suspended which means the other bed particles remain still for that discharge and do not move. We examined the test for the case with two bridge piers, now we place a crown with 2.5cm diameter for bridge pier with 2.5 cm diameter and a crown with 5 diameters and a crown with 7.5 cm diameter at an angle 30 degrees and we increase the input discharge and we open the hatch. We must examine the entries discharge in three modes of 12 lit/s , 14 lit/s , 116 lit/s , which means we examine one time a 12 lit/s discharge for a bridge with 2.5cm diameter for a crown with 2.5cm diameter, a crown with 5cm diameter and a crown with 7.5cm in 30-degree arc that water level in this mode of discharge must be 8 cm and one time a

14 lit/s discharge for a bridge pier with 2.5cm diameter, for a crown with 2.5cm diameter, a crown with 5cm diameter and a crown with 7.5cm that water level in this mode of discharge must be 10 cm and one time a 16 lit/s discharge for a bridge pier with 2.5cm diameter, for a crown with 2.5cm diameter, a crown with 5cm diameter and a crown with 7.5cm that water level in this mode of discharge must be 12 cm that for each three modes of our discharge, we must write three tail water depth in the downstream located in the hatch. For this purpose, we steer the hatch with increasing the discharge gradually toward downstream at the same time, till gives us one depth for each discharge. For the discharge of 12 lit/s , we consider the depth of 8 cm and for the discharge of 14 lit/s , the depth of 10cm and for the discharge of 16 lit/s , the depth of 12cm for the water level inside the flume. We did not have a specific time period for each test. We continued the test till the amount of scour around bridge piers reaches equilibrium, for each mode of discharge, with a specific diameter of bridge piers and specific diameter of a crown, it means the substrate particles do not transfer from the scour hole to the outside or downstream. After obtaining the maximum scour for each mode, we cut off the discharge, and calculated the maximum depth of scour around bridge piers. To do this, we used a laser meter, initially, before we entered the discharge into the channel or flume, we obtained the primary level of the bed with laser meter, after we opened the discharge, and we obtained the maximum scour for each mode. Places where there was a hole or pit, there was the maximum scour, and places where it happened typically downstream, there was our maximum accumulation. Now for the bridge pier, with a diameter of 5cm, we put once a crown with 2.5cm diameter and a crown with 5cm diameter and once a crown with 7.5cm diameter in the angle of 30 degrees and increased the input discharge and opened the hatch. We examined the input discharge in three modes of 12 lit/s , 14 lit/s and 16 lit/s , it means one time a 12 lit/s discharge for a bridge pier with 2.5cm diameter for a crown with 2.5cm diameter, a crown with 5cm diameter and a crown with 7.5cm in 30-degree arc that water level in this mode of discharge must be 8 cm and one time a 14 lit/s discharge for a bridge pier with 2.5cm diameter, for a crown with 2.5cm diameter, a crown with 5cm diameter and a crown with 7.5cm that water level in this mode of discharge must be 12 cm that for each three modes of our discharge, we must write three tail water depth in the downstream located in the hatch. We examined the effect of crown in controlling the scour of the bridge pier that how much scour depth we will have for each mode and the angle of 30 degrees ends of the base of the bridge with 2.5cm and 5cm diameter. After the research concepts and hypotheses were formed carefully and the proper sample was selected, the next step is the preparation of research techniques to collect information. This study was experimental and based on the results of the tests and their analysis, the assumptions will be discussed. The use of statistical software Excel and Spss, the results are plotted as graphs and a relation is presented based on the crown coordination.

METHODS OF DATA ANALYSIS

After the research concepts and hypotheses were formed carefully and the proper sample was selected, the next step is the preparation of research techniques to collect information. This study was experimental and based on the results of the tests and their analysis, the assumptions will be discussed. The use of statistical software Excel and Spss, the results are plotted as graphs and a relation is presented based on the crown coordination.

ANALYSIS OF THE RESULTS

Correlation analysis is a statistical tool to determine the type and intensity relation of a quantitative variable with another quantitative variable. The correlation coefficient is a measure used to determine the correlation between two variables. To examine the relation between the dependent variable D_s / y and independent variables in this study, by using SPSS software of the data obtained from direct observation were analyzed and the following results were obtained.

1. The mode with a crown

For better assessing, the relation between dependent and independent variables is detailed above; the correlation matrix for the variables is expressed below. Description of Table 1 is the same as similar description of the correlation in the tables of this chapter.

Table 1- Correlation matrix between the variables in the mode with a crown

			Correlation								
			Ds/y	Dc	fr	Dc/y	Dp/y	d50/y	Y	Dp	Ds
Spearman correlation coefficients	Ds/y	The correlation coefficient	1.000	-.316	.622*	-.052	.591**	-.717**	-.625**	.333	.718**
		Bilateral significant	.	.202	.006	.837	.010	.001	.006	.177	.001
		number of samples	18	18	18	18	18	18	18	18	18
	Dc	The correlation coefficient	-.316	1.000	-.084	.926**	.000	.000	.000	.000	-.411
		Bilateral significant	.202	.	.741	.000	1.000	1.000	1.000	1.000	.091
		number of samples	18	18	18	18	18	18	18	18	18
	fr	The correlation coefficient	.622**	-.084	1.000	.281	.400	-.418	-.962**	-.068	.000
		Bilateral significant	.006	.741	.	.259	.100	.084	.000	.788	1.000
		number of samples	18	18	18	18	18	18	18	18	18
	Dc/y	The correlation coefficient	-.052	.926**	.281	1.000	.177	-.185	-.370	.000	-.388
		Bilateral significant	.837	.000	.259	.	.482	.462	.130	1.000	.112
		number of samples	18	18	18	18	18	18	18	18	18
	Dp/y	The correlation coefficient	.591**	.000	.400	.177	1.000	-.239	-.478*	.878**	.415
		Bilateral significant	.010	1.000	.100	.482	.	.339	.045	.000	.087
		number of samples	18	18	18	18	18	18	18	18	18
	d50/y	The correlation coefficient	-.717**	.000	-.418	-.185	-.239	1.000	.500*	.000	-.384
		Bilateral significant	.001	1.000	.084	.462	.339	.	.035	1.000	.116
		number of samples	18	18	18	18	18	18	18	18	18
	Y	The correlation coefficient	-.625**	.000	-.962*	-.370	-.478*	.500*	1.000	.000	.046
		Bilateral significant	.006	1.000	.000	.130	.045	.035	.	1.000	.855
		number of samples	18	18	18	18	18	18	18	18	18

	Dp	The correlation coefficient	.333	.000	-.068	.000	.878**	.000	.000	1.000	.497*
		Bilateral significant	.177	1.000	.788	1.000	.000	1.000	1.000	.	.036
		number of samples	18	18	18	18	18	18	18	18	18
	Ds	The correlation coefficient	.718**	-.411	.000	-.388	.415	-.384	.046	.497*	1.000
		Bilateral significant	.001	.091	1.000	.112	.087	.116	.855	.036	.
		number of samples	18	18	18	18	18	18	18	18	18
**. Two-way correlation, at a significance level 0.01											
*. Two-way correlation, at a significance level 0.05											

In this project, we are looking for the relation between the dependent variable Ds / y with the independent variable, fr, y, Ds, Dc and Dp and with dependent variables Dp / y, Dc / y and d50 / y. Relation description between each of the written independent variables with the dependent variable Ds / y is as follows:

1. The relation between Ds / y and fr at the 0.05 level was significant and changes per unit of fr at the rate of 0.622 per cent increases the amount of Ds / y.
2. The relation between Ds / y and Dc / y at the 0.05 level was significant and changes per unit of Dp / y at a rate of -0.052 reduces the amount of Ds / y.
3. The relation between Ds / y and DP / y at the 0.01 level was significant and changes per unit of Dc / y at the rate of 0.591 increases the amount of Ds / y.
4. The relation between Ds / y and d50 / y at the 0.01 level was significant and changes per unit of d50 / y at a rate of -0.717 reduces the amount of Ds / y.
5. The relation between Ds / y and y at the 0.01 level was significant and changes per unit of y at a rate of -0.625 reduce the amount of Ds / y.
6. The relation between Ds / y and Ds at the 0.01 level was significant and changes per unit of Ds at a rate of 0.718 increases the amount of Ds / y.
7. The relation between Ds / y and Dc was not significant.
8. The relation between Ds / y and Dp was not significant.

Therefore, there is not a significant relation between the crown diameter of Ds / y. The interpretation of this concept is that crown diameter variable influenced Ds / y through other variables and by other variables cause changes in Ds / y. To investigate this case, we focus on the relation between Dc with other variables.

It is obtained from Table 1 that, the Dc / y was significant at 0.01 levels and changes per unit of Dc at the rate of 0.926 increases the amount of Dc / y. However, the change per unit of Dc / y at a rate of -0.052 reduces the amount of Ds / y. This matter confirms the regression obtained between the diameters of the crown that only 0.003 percent of the objective function Ds / y can be explained by of the diameter of the crown. In addition, the coefficient of determination between the crown diameter and Ds / y was obtained at a rate of 0.083 and this means that the diameter of the crown has a direct impact on the Ds / y.

In addition, there is no significant relation between the diameter of the bridge piers and Ds / y. According to Table 1 at a significance level of 0.01, the diameter of the bridge pier with Dp / y has a positive and constructive effect with the amount of 0.878. It means changes in per unit of the bridge pier, increases Dp / y to the amount of 0.878. In addition, the diameter of the bridge pier on Ds was

significant at the 0.05 level and changes per unit of the bridge pier diameter increases 0.497 percent of maximum depth of scour.

1. The mode without a crown

Like the mode with a crown, in the without the crown mode, the correlation matrix has been presented too. The interpretation of the correlation matrix in Table 2 is similar to the interpretation of the correlation table between two variables in the previous pages.

Table 2-Correlation matrix between the variables in the mode without a crown

			Ds/y	d50/y	fr	Dp/y	Y	Dp	Ds	Phi
Spearman correlation coefficients	Ds/y	The correlation coefficient	1.000	.239	.837*	.829*	-.837*	.488	.879**	-.837*
		Bilateral significant	.	.648	.038	.042	.038	.326	.111	.038
		number of samples	6	6	6	6	6	6	6	6
	d50/y	The correlation coefficient	.239	1.000	.500	.239	-.500	.000	-.239	-.500
		Bilateral significant	.648	.	.312	.648	.312	1.000	.648	.312
		number of samples	6	6	6	6	6	6	6	6
	fr	The correlation coefficient	.837*	.500	1.000	.478	-1.000**	.000	.239	-1.000**
		Bilateral significant	.038	.312	.	.338	.	1.000	.648	.
		number of samples	6	6	6	6	6	6	6	6
	Dp/y	The correlation coefficient	.829*	.239	.478	1.000	-.478	.878*	.886*	-.478
		Bilateral significant	.042	.648	.338	.	.338	.021	.019	.338
		number of samples	6	6	6	6	6	6	6	6
	Y	The correlation coefficient	-.837*	-.500	-1.000**	-.478	1.000	.000	-.239	1.000**
		Bilateral significant	.038	.312	.	.338	.	1.000	.648	.
		number of samples	6	6	6	6	6	6	6	6
	Dp	The correlation coefficient	.488	.000	.000	.878*	.000	1.000	.878*	.000
		Bilateral significant	.326	1.000	1.000	.021	1.000	.	.021	1.000
		number of samples	6	6	6	6	6	6	6	6
	Ds	The	.879**	-.239	.239	.886*	-.239	.878*	1.000	-.239

		correlation coefficient								
		Bilateral significant	.111	.648	.648	.019	.648	.021	.	.648
		number of samples	6	6	6	6	6	6	6	6
	phi	The correlation coefficient	-.837*	-.500	-1.000**	-.478	1.000**	.000	-.239	1.000
		Bilateral significant	.038	.312	.	.338	.	1.000	.648	.
		number of samples	6	6	6	6	6	6	6	6
**. Two-way correlation, at a significance level 0.01										
*. Two-way correlation, at a significance level 0.05										

Now, in the state without a crown, we study the relations between the dependent and independent variables.

In this project, we are looking for the relation between the dependent variable D_s / y with the independent variable, fr , y , D_s , D_c and D_p and with dependent variables D_p / y , D_c / y and $d50 / y$. Relation description between each of the written independent variables with the dependent variable D_s / y is as follows:

1. The relation between D_s / y and fr at the 0.05 level was significant and changes per unit of fr at the rate of 0.837 per cent increases the amount of D_s / y .
2. The relation between D_s / y and D_p / y at the 0.05 level was significant and changes per unit of D_p / y at a rate of 0.829 increases the amount of D_s / y .
3. The relation between D_s / y and $D50/y$ is not significant.
4. The relation between D_s / y and y at the 0.05 level was significant and changes per unit of y at a rate of -0.837 reduces the amount of D_s / y .
5. The relation between D_s / y and D_s at the 0.01 level was significant and changes per unit of D_s at a rate of 0.879 increases the amount of D_s / y .
6. The relation between D_s / y and D_p was not significant.
7. The relation between D_s / y and the discharge in the nonparametric state at the 0.05 level was significant and changes per unit of the discharge at a rate of -0.837 reduce the amount of D_s / y .
8. The relation between D_s / y and the speed in nonparametric state at the 0.05 level was significant and changes per unit of the speed at a rate of 0.837 increases the amount of D_s / y .

Now, we express the regression, regression coefficient (R), coefficient of determination (R Square), adjusted coefficient of determination (Adjusted R Square), the standard error of the estimate (Std. Error of the Estimate) and computational error (Residua) for two series with a crown and without a crown. As shown in Table 3, to determine the coefficient of determination (r^2) and the regression, at first we consider the variables of D_p / y , D_c / y , $d50 / y$ and fr as year variables and we calculate the function regression of D_s / y for the state with a crown.

Table3- input variables in regression analysis

Model	Input Variables	Deleted variables	Method
1	$D_c/y, D_p/y, d50/y, fr^b$		Enter

a. the dependent variable: $F1$

b. all the requested variables are entered.

In Table 4, the regression coefficient equal to 0.887, and the coefficient of determination, equal to 0.796 and adjusted determination coefficient equal to the same coefficient of determination minus the standard error of the estimates, equal to 0.698.

Table 4– Summary of the regression analysis

Model	Regression coefficient	R Square	Adjusted R Square	The standard error of the estimates
1	.877 ^a	.769	.698	.0258783

a. the predictor variables, Dp / y, D / y, d50 / y, fr

Regression and Residua for the type with the crown are as Table 5.

Table 5- ANOVA

Model		sum of squares	Degrees of freedom	The mean square	F	Sig.
1	Regression	.029	4	.007	10.816	.000 ^b
	Residua	.009	13	.001		
	Total	.038	17			

a. the dependent variable: Ds / y

b. the predictor variables, Dp / y, D / y, d50 / y, fr

After the regression with a crown mode became clear, to obtain the formula between the variables in the case of the criterion, will be in accordance with Table 6:

$$Ds / y = .223 + .118fr - .312Dp / y + .286Dc / y - .692d50 / y$$

Table 6- Table of variables coefficients

Model		Not standardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.223	.039		5.721	.000
	fr	.241	.375	.118	.642	.532
	Dp/y	-.062	.028	-.312	-2.208	.046
	Dc/y	.090	.046	.286	1.962	.072
	d50/y	-10.241	2.796	-.692	-3.663	.003

a. the dependent variable: Ds / y

In addition to the communication matrix and regression tables, we draw the charts of biaxial between Ds / y and four variables d50 / y, Dp / y, fr and Dc / y so that a comprehensive conclusion will be presented from the content.

Figure 1- Graph between D_s / y and f

Figure 2- Graph between D_s / y and D_c / y

Figure 3 - Graph between D_s / y and d_{50} / y

Figure 4 - Graph between D_s / y and D_p / y

But for graphs relating to the mode without the crown, between the dependent variable D_s / y and variables $d50 / y$, D_p / y , fr we have:

Figure 5 - Graph between D_s / y and $d50 / y$

Figure 6 - Graph between D_s / y and f

Figure 7 - Graph between D_s / y and D_p / y

For no crown mode, at first, the variables $d50 / y$, D_p / y , f_r are evaluated along with D_s / y for processing regression. The regression (Regression), regression coefficient (R), coefficient of determination (R Square), the adjusted coefficient of determination (Adjusted R Square), the standard error of the estimate (Std. Error of the Estimate) and computational errors (Residua) are as Table 7 .

Table 7 The input variables in the regression analysis ^a

Model	Input Variables	Deleted variables	Method
1	$d50/y$, D_p/y , f_r		Enter

a. The dependent variable: D_s / y

b. All variables were entered

According to the obtained regression coefficients and R Square for no crown mode in Table 8, the mode with a crown is acceptable for controlling the scour.

Table 8– Summary of the regression analysis

Model	Regression coefficient	R Square	Adjusted R Square	The standard error of the estimates
1	.995 ^a	.990	.976	.0245193

a. the predictor variables, D_p / y , D / y , $d50 / y$, f_r

Regression without a crown is obtained 0.122 based on Table 9.

Table 9- ANOVA

Model		sum of squares	Degrees of freedom	The mean square	F	Sig.
1	Regression	.122	3	.041	67.762	.015 ^b
	Residua	.001	2	.001		
	Total	.123	5			

a. the dependent variable: D_s / y

b. the predictor variables, D_p / y , D / y , $d50 / y$, f_r

Now that regressions and correlations between variables involved in the defined equation have been cleared, the regression equation for the non-crown mode by using the hypothesis in Table 10, will be:

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$$Ds / y = .053 + .470fr + .624Dp / y - .368d50 / y$$

Table 10- Table of variables coefficients

Model		Not standardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.053	.032		1.680	.235
	fr	2.886	.479	.470	6.024	.026
	Dp/y	.617	.077	.624	8.023	.015
	d50/y	-.141	.027	-.368	-5.220	.035
	(Constant)	.053	.032		1.680	.235

a. the dependent variable: Ds / y

But, which one of the modes without a crown or with a crown is better to use? Since, the numbers of samples of both modes with and without crowns are not equal and whereas the number of variables involved in the creation of objective functions values 1 and 2 are not equal, according to Tables 3 and 7; the mode without the crown is better. But to confirm this result and to assess the significance of the two given objective function values, the Kolmogorov test is used. This test is in the form of significant measured two variables or two unequal societies and that society or a variable that has a higher significant value, will be selected as the accepted sample in terms of comparisons. Table 11 shows the significant amount of Ds / y for the two modes of with a crown and without a crown. Both modes had the significance higher than 0.05 and therefore the results of both modes are accepted. According to Table 11, the non-crown mode (F₂) had a higher significance at the rate of 0.996 and scour control is acceptable. The first objective function (F₁) is not considered scientific because it has the significant amount below 0.9 and that its implementation is not accepted. Table 11 outlines the above description.

Table 11- The comparison of two populations by using Smirnov- Kolmogorov test

		F2	F1
The total number of samples		6	18
Normal parameters ^b	Average	.402367	.18308
	Standard deviation	.1571092	.047079
Highlights major differences	Total	.167	.148
	Positive	.167	.148
	Negative	-.140	-.105
Kolmogorov-Smirnov		.410	.627
Amount of symmetrical two-sided significance		.996	.827

a. The distribution test is normal

b. Calculations derived from data

CONCLUSION

This research aimed to investigate the relation between the dependent variable Ds / y with the independent variables fr, y, Ds, Dc and Dp and with dependent variables Dp / y, Dc / y and d50 / y. This process was carried out in both modes with a crown (Dc) and without a crown. Regression and correlation analyzes were done with spss software, and charts related to the relations between the dependent variable Ds / y with the dependent variables Dp / y, Dc / y and d50 / y and the independent variable fr in Excel. Results showed that first Ds / y and Dc, Ds / y and Dp in the first mode had no significant relation together. In the mode without a crown Ds / y with Dp and d50 / y had no significant relation. Ds / y had a significant relation with other variables. Second, the second purpose function-without a crown- was evaluated and selected with R Square 0.990 and the regression coefficient 0.995 better than the mode with a crown. After determining the communications and regression, the mode with a crown with the will be as the regression formula $Ds / y = .223 + .118fr -$

$.312D_p / y + .286D_c / y - .692d_{50} / y$ and the mode without the crown was obtained with regression formula $D_s / y = .053 + .470f_r + .624D_p / y - .368d_{50} / y$, respectively.

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