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Effect PF Pillar at Channels Bend on the Changes of Superlevation Coefficient

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ABSTRACT

Ideally, to build a bridge should be done on a straight section of the river in order to minimize the scouring around the pillar in the middle of the river, but this is often difficult to implement, especially in urban areas, and when straightened river or stream flow with create a shortcut channel will have an impact to the social, economic aspects of the people and it will changed the river in hydraulic aspects. Build bridges with pillars in the middle of meandering river will caused the alteration of river morphology. This study are examines the effect of the presence of bridge pillars at the channel bends that lead in transformation of the water, alteration of water velocity, as well as the morphology of the river bed. The research method conducted quantitative method approach by creating a model of the channel in laboratory. This experiment was applied at subcritical turbulent flow and 0.5<u/uc<1. The experiment was carried out by current in the channel with no sediment and tested by using sediment. For both conditions was tested without pillars, the other condition was tested by using the pillar that moved the pillar at every intervals of 30^0 along the bend line, and the third condition pillars installed together at intervals of 30^0, and intervals of 60^0 along the bend line. Refers to the maximum value of Cs for each test results were as follows; testing without pillars and sediment the value of Cs is greater than the value of Cs with any variations by applying pillar except when pillar shifted by interval of 30^0. Meanwhile the Cs value is higher when the testing using sediment without pillar compared with the test conducting pillar with any variations. Generally from the tested, the Cs value is greater when it was running conducting sediment compared the test without sediment

K**eywords**: *bend of the river, sediment, pillars, super elevation*

1. INTRODUCTION

In general, the river is a long groove on the earth's surface where the flow of water from rain or parts that always touched by the water, or an unification between groove of river and flow of water is called river (Sosrodarsono S. et al. 1994). The behavior of river generally in the upstream is steep and straight, get into the middle part has begun meandering and sloping, and the area of downstream near the embouchure is getting very gently sloping, sediments with a certain diameter when passing through the upper and middle parts of the river still floating but now those sediments sink into the bottom of the river due to meander and the velocity is very slow, while the volume of water flowing through a cross section per unit time is called “discharge”. Measurement of river discharge on an ideally done using the data continuously measuring the water level using measurement device called *“Automatic Water Level Records (AWLR)”* where the discharge data can be known by using some theoretical calculations for both river discharge and flow velocity measurement (French R.H., 1985, Daryl B. Simon, 1977, Chow V.T., 1985) recommended 0.2 h and 0.8 h but especially for shallow stream is recommended 0.6 h.

Ideally to build a bridge on a straight section of the river in order to minimize the scouring around the pillar in the middle of the river, but this is often difficult to implement, especially in urban areas, and when done the straightening rivers will have been an impact on social and economic aspects. If in a stream or river is performed a shortcut to straight the river line or making the normalization of the river, the change of hydraulic will be happened among others; slope of the river became more steep than ever before because the river becomes shorter, the water flow becomes more rapid velocity, most of base sediment become the drift sediment and the diameter of the sediment that settle at the bottom of the river becomes larger, the soil water becomes more decrease especially along the river because the river water surface elevation is drop, reduced pool of water in inland areas, accelerate the drainage of water to the sea, reduced recharge area, increasing the land area that no longer function as a river, meeting between shifting freshwater with increasing sea water inland.

Some researchers on the bend of the river has been formulated that the centrifugal force occurs on the flow along curves that affect on increasing the water level at the outside of the river bend but decreasing the water level at the inside of the river bend. That occurrence is defined as super elevation (Ahmed Shyukri, 1950 in Chow V.T., 1989, CL Yen et al., 1971, Duan G. J., 2004), but for basic flow the scour occurs at the outside of the bend but in the inside of the bend occurs the continuous precipitates (Mozaffari J. et al., 2011, Masjedi A. et al., 2007). As has been known that the presence of obstacles in a flow will affect the water level changes especially at the bend of the river will be changes in the pattern of velocity, changing topography of the bottom line, and changes in water level. Therefore, this study will examine the extent of the influence of the presence pillars those are placed in the different variations of coordinate at the channel bends that made with the model bend of 180^0 for the changes in water level that will be formulated in the form of super elevation coefficients.

2. THEORETICAL BASIS

Research on the water flow such as Castelli 1628, Robert Manning (1816-1897), Osbort Reynolds (1842-1912), Leo C. van Rijn 1990, Nikuradse 1933, French R.H., 1985, Daryl B. Simon 1977, Chow V.T., 1989, Jansen, 1979, Bagnold 1966, Einstein H.A., 1950, which focuses on open channels, detention flow, sediment movement, as well as the distribution of flow velocity. Further research on the bend of the river as Mozaffari J. et al., 2011, doing research on turn 1930, with dimensions of width 1.3 m, 1.7 m radius, hydraulic B/h = 10, 10.8, 13, Fr = 0.5 and 0.56, Re = 43,000, 58,000 and 73,000.

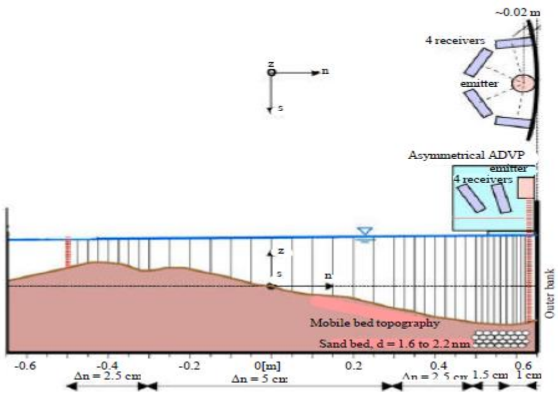

Figure 1: Cross-sectional of sediment surface at the bend angle of 70^0 (Mozaffari J. et al., 2011)

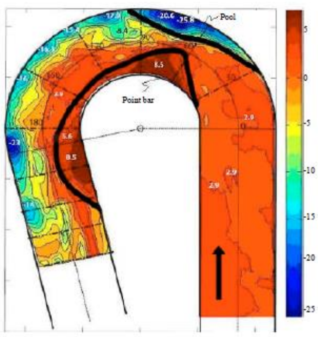

Figure 2:

Topographic of flow for the discharge of 63 l/sec (Mozaffari J. et al., 2011)

The results show that occurs the changes of topography for the discharge of 63 liters/sec with the maximum scour channels at the outside of the bend, and on the inside of the bend of channel occurs silting, also shown the existence of scour at 6 points , while the deepest is at the outside of the bend at an angle of 70^0. The slope of the line started at the angle of 31^0 , and scour began to decline after the bend angle of 90^0 .

The spiral flow at the bend of channel was observed first time by James Thomson in 1876 in Chow, 1989. The main cause of the spiral flow symptoms is friction in the channel wall that causes the higher of velocity at the area near the center than the area near the channel wall, the centrifugal force around the arch gave rise to an unique thing that causes an increase water level at outside and decreases water level at inside of the bend line. In an effort to illustrate the effect and magnitude of the spiral flow in the different bends, and the varying flow conditions, so Ahmad Shukry, 1950 in Chow, 1989, who used the term called "spiral flow strength", power of the spiral flow is defined as the percentage ratio of kinetic energy of the average lateral movement on the total kinetic energy of the flow at the reviewed cross section. The kinetic energy of the flow depends on the velocity square of the flow as follows;

$$S_{xy} = \frac{U_{xy}^2}{U^2} \text{ x } 100$$

Where : U_{xy} is the projection of the average velocity vector in the plane of xy and U is the average velocity in the cross section, so for a straight channel $S_{xy} = 0$.

Changes in water level in the transverse direction of the channel is called super elevation, where at the outside of the bend line, the water level is up while at the inside of the bend line the water level is down, practically the super elevation estimated on the effect of the average flow velocity and the ratio between the width of the water surface with the radius of the bend. The main cause of the symptoms spiral flow is the friction in the channel wall, the centrifugal force which deflecting the water particles, and distribution of the vertical velocity that occurs in the channel, super elevation is influenced the present helical movements and changes the topography of the bottom line of the channel.

Model simulations conducted by Jenniver G. Duan, 2004 on two results of the channel bends research and different hydraulic conditions that are performed by de Vriend, 1979 and Rozovskii, 1961indicated that the reduction in velocity at the inside of the bend line, while occurs an increase of velocity at the outside. Acceleration on the changes flow at the inside of the bend line due to a shift in the transverse direction of the flow to the momentum changes of the secondary flow, flow curves having longer radius of bend compared with the width of the water flow and having a very little effect on the secondary flow in the direction of the channel cross section.

The research conducted by Ahmed Shukry, 1950 in Chow V.T., 1985 showed that the value of super elevation coefficient Cs = 2 for the flow without sediment, but for flow with sediment Cs = 2.2, while the research was conducted by Chin-Lien Yen and Ben Chie Yen, 1971. The calculations performed to create a physical curves model of 90^0 and mathematical models in three dimensions.

$$S_r = \frac{U_m^2}{2gr}\left[-2\frac{r}{h}\left(\frac{\bar{u}_*}{U_m}\right)^2 \sin\emptyset + \int_{z_0/h}^{z_1/h} 2\left[\left(\frac{\bar{u}}{U_m}\right)^2 - \frac{\bar{u}}{U_m}\frac{\partial\left(\frac{\bar{v}}{U_m}\right)}{\partial\theta}\right] d\left(\frac{z}{h}\right)\right]$$

Where, Sr = slope of the transverse channel in bend line, sin Ø = v/ū, Ø = angle of channel bends g = gravity, h = height of water surface, $u_* = \sqrt{\tau_0/\rho}$ = shear velocity, U_m = average velocity of channel segments, ū = average velocity flow in the longitudinal direction, v = average velocity transverse flow, ρ = mass density of water substance, r = radius of the bend line, z_0 = roughness of channel basis, z_1 = z = height of water. The magnitude of z_o can be calculated by grouping the flow in the form the regime of flow. Leo C. van Rijn, 1990;

Hydraulic smooth regime:

$$z_0 = 0{,}11\frac{\nu}{u_*} \text{ for } \frac{u_* k_s}{\nu} \leq 5$$

Hydraulic rough regime:

$$z_0 = 0.033\, k_s, \text{ for } \frac{u_* k_s}{\nu} \geq 70$$

Hydraulic transition regime:

$$z_0 = 0{,}11\frac{\nu}{u_*} + 0.033 k_s \text{ , for } 5 < \frac{u_* k_s}{\nu} < 70$$

Calculation the value of Super elevation coefficient Cs as the formula below, the results are as in the Figure 3 where the value of Cs = ± 4.2 (*equilibrium bed models*) at the channel bend of 45^0, while the average value of Cs = ± 2.2 (*trapezoidal model*);

$$C_s = \frac{H_s}{\frac{U_m^2}{2g}}\frac{r_c}{B_s} = \int_{r_i/r_c}^{r_o/r_c} \frac{C_r}{r}\, d\left(\frac{r}{r_c}\right)$$

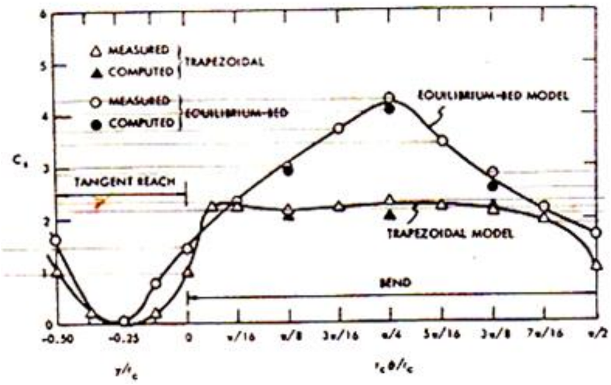

Figure 3: Coefficient of super elevation Cs (Yen C. L., 1971)

Research conducted by Leopold L.B. 1982 in the natural channel on the analysis of water surface, basic topography, and shear stress of the channel base, showed that the inner zone of the channel may not necessarily bring about the largest shear stress, which in fact showed that the shallow water sediments was eroded.

While the researchers of the bend of the river with obstacles, as was done by Agung Wiyono et al, 2006, with a classification of flow based on the flow that is occurred in rivers, among others;

a. General scour is a natural process that occurs in the river.
b. Scour due to constriction in the river groove.
c. Local scour is a scour that generally occurs due to presence of water building, for example the pillars of the bridge, there are two kinds of local scours namely:
   - Clear water scour
     Sediment movement just occurs only in the pillars. There are two kinds of clear water scour:
     - For u/uc≤0.5, local scour does not occur and sediment transport processes do not occur.
     - For 0.5≤u/uc≤ 1, local scour occurs constantly and sediment transport processes do not occur.
   - Live bed scour
     For u/uc ≥1, is due to the displacement of sediment

Where; u = the average flow velocity (m/s), u_c = Critical Flow Velocity (m/sec).

Special research on local scour caused by the presence of barrier pillars as the research had been conducted by Alireza Masjedi, et al. 2007 with the title of "*Exprimental Study on the Effect of Cylindricad Bridge Pier Position on the Scoring Depth in the River Bend*" by making a model of the flume in the laboratory with bends of 180^0, rc/B = 4.7 (r_c = radius of the bend, B = flume width), diameter pillar of 6 cm, the pillar shift from position 0^0, 30^0, 60^0, 90^0, 120^0, 150^0, and 180^0, constant water depth of 12 cm, natural sand uniform D_{50} = 2 mm with a uniformity factor 1.7 are used as a basic channels, the discharge of flow is 18.20 ltr/sec.

The results of the research showed that the natural flow in the river, especially in the corners those located pillars turns out to greatly affect on the level of depth of scour, where the greater turbulence and centrifugal force due to the bend was also influential. The results showed that the deepest scour occurs at position pillars of 60^0, the second deepest in the position of the pillars of 90^0, and the shallowest scour at the position pillars of 30^0.

Initial sediment motion occurs when the critical velocity is greater than the flow average velocity, some researchers have formulated about the critical velocity Yang Xiaoqing, 2003, in *Manual on Sediment Manajement and Measurement* as follows:

$$\text{Shamov (1952), } u_c = 1{,}47\sqrt{gD}\left(\frac{h}{D}\right)^{1/6}$$

$$\text{Goncharov (1962), } u_c = 1{,}06\sqrt{\frac{gD(\gamma_s-\gamma)}{\gamma}}\log\frac{8{,}8\,h}{D_{95}}$$

$$\text{Levy (1956), for } \frac{R}{D_{90}} > 90,\ u_c = 1{,}4\sqrt{gD}\log\frac{12\,R}{D_{90}}$$

$$\text{for } \frac{R}{D_{90}} > 10-40,\ u_c = \left(1{,}04 + 0{,}87\log\frac{12\,R}{D_{90}}\right)\sqrt{gD}$$

3. RESEARCH METHODS

To simplify the research was made a flume or an artificial open channels with a size of 0.5 meters wide and 0.5 meters high made of fiberglass, the flume from upstream to downstream is divided into three parts, those are; The first part or upstream part is a straight flume length of 3 meters and in the front of the flume was installed the wave absorbers. The second part of the flume is a bend flume with angle of 180^0 and the radius of 0.75 meters, the third part of flume or the downstream part is a straight flume length of 2 meters, completed with water gate height can be changed according to the needs of research, the photograph of flume as seen in figure 5. The artificial pillar is made of thick wood 3 cm wide 10 cm high and 50 cm length, the material for the base of flume is natural sand with a uniform diameter through sieve no. 8 (2.16 mm) sieve and restrained on sieve no.16 (1.18 mm), the research conducted for subcritical turbulent flow conditions and 0.5<u/uc <1.

The research without and with pillars moved every intervals of 30^0, pillar mounted simultaneously every 30^0, pillar mounted at every intervals 60^0 along the bend of 180^0, in the first two conditions flow without sediment and the second is flow with sediment. Measurement of high water, sediment height measuring is used a tool called "*point gauge*" (Figure 4), with a level of accuracy 0.1 mm, while to measure the velocity of the water was used a tool called "current meter".,measurement along the bend were performed every interval of 30^0, and the last 0.6 m after the bend, measurements were performed in the transverse direction with seven points which is divided equally.

Figure 4: Point gauge

Measurement starts from 0.6 m before the bend, then the measurement along the bend were performed every interval of 30^0, and the last 0.6 m after the bend, measurements were performed in the transverse direction with seven points which is divided equally.

Figure 5: Photo of Flume taken from inside direction of the bend

Figure 6: Photo of flume taken from the side

Figure 7: Coordinates installation of pillars at each intervals of 30^0

The results of measurements of water level, the height of sediment, and the velocity of each cross-sectional then tabulated to get the value of Cs by using the formula, Cs =

(H_s x r_c/B) / (u_m^2/2g) where, Cs = coefficient of super elevation, H_s = difference in water level at each segment, r_c = radius of bend, B = width of the channel u_m = average velocity of each segment, and g = the force of gravity.

4. RESULTS AND DISCUSSION

Research to obtain the coefficient super elevation first performed along the bend of 180^0 where the flow does not use sediment, and the second using natural sand sediment which is passed through the sieve no. 8 (2.36 mm) retained on the sieve no. 16 (1.18 mm), for two conditions mentioned above, first is done with the pillar moved at each intervals of 30^0, ranging from the pillar at 0^0, then pillar moved successively at 30^0, 60^0, 90^0 , 120^0, 150^0, and the last pillar was moved into 180^0, both pillar mounted simultaneously at intervals of 30^0, and the third pillar mounted simultaneously at interval of 60^0; first ranging from the pillar at coordinates 30^0, 90^0, and 150^0, and the second moved successively at coordinates 0^0, 60^0, 120^0, and 180^0. The measurement of velocity, the height of water level, the height of sediments surface, where all of the measurements performed in the longitudinal direction at each intervals of 30^0, while in the transverse direction flow measurements were performed by dividing seven segments for each piece . The measurement results then tabulated to calculate the coefficient of super elevation at each interval of 30^0.

a. Superelevation coefficient analysis without sediment

The first research is the flow without sediment using pillars moved at each interval of 30^0, ranging from the pillar at 0^0, then the pillar moved successively at 30^0, 60^0, 90^0, 120^0, 150^0, and the last pillar was moved into 180^0 and the calculation result of the value of super elevation coefficient can be seen in table 1 and figure 8.

Table 1: Coefficient of Super elevation at channel bends without sediment and pillar moved each interval of 30^0

Coordinate	Placement of pillars on the coordinates						
	0^0	30^0	60^0	90^0	120^0	150^0	180^0
Cs 0^0	0,457	0,239	0,405	0,427	0,118	0,098	0,139
Cs 30^0	2,570	2,071	2,185	3,027	2,106	2,172	2,116
Cs 60^0	1,114	2,142	1,702	0,177	1,160	1,415	1,563
Cs 90^0	3,739	2,884	2,374	2,937	2,303	2,764	2,239
Cs 120^0	**3,891**	**3,079**	**3,026**	2,923	**2,442**	**3,413**	**2,792**
Cs 150^0	2,928	1,792	1,963	**3,400**	2,217	2,465	2,385
Cs 180^0	0,953	1,976	1,268	1,788	1,155	1,245	0,560

The results indicated that first pillar placed at coordinates of 0^0, the largest value of Cs on the bend of 120^0 respectively pillar 90^0, 150^0, 30^0, 60^0, 180^0, 0^0. So pillar moved at each interval of 30^0 to end the bend. The value of Cs the trend of its sequence for pillar moved seven times as follows; The largest value of Cs at 120^0, occurred six times, then the second large of Cs in bend of 90^0 occurred five times, The third large of Cs at bend of 150^0 occurred three times, The fourth large of Cs in bend of 30^0 occurred five times, the fifth large of Cs at bend of 60^0 Cs occurred five times, the sixth large of Cs at bend of 180^0 occurred five times, the smallest value of Cs at bend of 0^0 occurred six times. With refer to the maximum value of Cs on placement at each pillar the greatest value in the bend of 0^0 Cs = 3.891, the second large value of Cs, when pillar is in the bend of 150^0 Cs = 3.413, the third large value of Cs when pillar is in the bend of 90^0 Cs = 3,400, the fourth large of Cs when pillar in the bend of 30^0 Cs = 3.079, the fifth large value of Cs when pillar is in the bend of 60^0 Cs = 3.026, The sixth larger of Cs when pillar is in the bend of 180^0 Cs = 2,792, and the smallest value of Cs maximum when pillar is the bend of 120^0 Cs = 2.442.

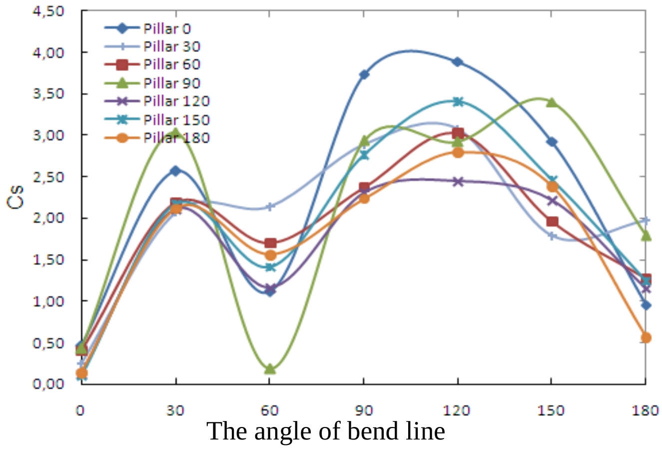

Figure 8: The curve of relationship between Cs with bend angle channel for the flow without sediment pillar moved each interval of 30^0

The first research above is for pillar moved at each interval of 30^0 indicated that largest value of Cs when pillar was placed in the bend of 0^0 with a value of Cs maximum = 3.891 at coordinates of 120^0, that largest value was used to compare with other variation of researches. The second research is for the flow without pillar, the third research when pillar installed simultaneously along the bend line with intervals of 30^0, the fourth research when pillar installed simultaneously at the interval of 60^0 along the bend on two conditions, those are pillars at 30^0, 90^0, 150^0, and pillar at 0^0, 60^0, 120^0, 180^0. Flow with different variations of pillar as the result of the calculation can be seen in table 2 and figure 9.

Table 2: Coefficient value to flow without sediment Cs

Coordinate measurement	without pillars	Pillars moved every intervals of 30^0	Pillar mounted simultaneously interval 30^0	Pillar mounted simultaneously intervals of 60^0	
				Pillars at 30^0, 90^0, 150^0	Pillars at 0^0, 60^0, 120^0, 180^0
Cs0^0	0,239	0,457	0,426	0,339	0,335
Cs30^0	1,973	2,570	2,311	2,028	2,231
Cs60^0	1,095	1,114	1,304	1,405	1,144
Cs90^0	2,081	3,739	2,304	2,154	2,472
Cs120^0	**3,134**	**3,891**	2,026	**2,859**	**2,849**
Cs150^0	1,849	2,928	**2,429**	2,154	2,672
Cs180^0	1,337	0,953	1,022	1,632	0,796

From the five variation of researches for the same hydraulic conditions indicated that the trend the greatest value of Cs is in the coordinate bend of 120^0 the trend as much as four times, the second in the bend of 90^0 it trend as much as three times, the third in coordinate bend of 150^0 it trend as much as two times, the fourth in the bend of 30^0 it trend as much as three times , fifth in the bend of 60^0 it trend as much as three times, sixth in the bend of 180^0 it trend as much as three times, and the smallest value of Cs in the bend of 0^0 it trend as much as five times.

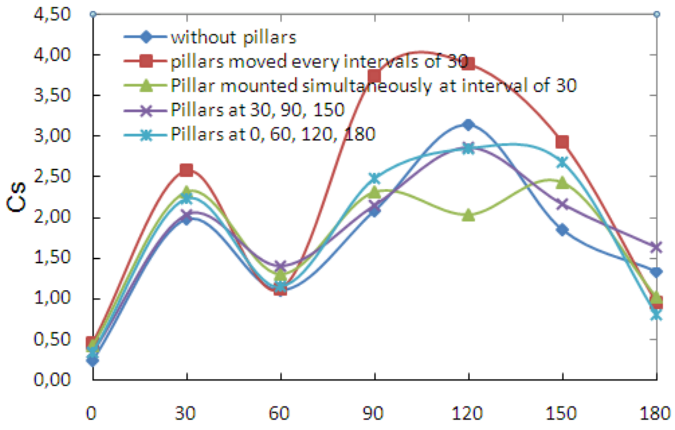

Figure 9: Curve of relationship between the values of Cs with an angle of channel bend for the flow without sediment

Refers to the maximum value of Cs for the five of variation above indicated that the largest maximum of Cs on testing with pillar moved at each interval of 30^0 Cs = 3.891, the second largest of Cs on testing flow without pillar Cs = 3.134, The next test by applied pillar with interval 60^0 along the channel bend and pillar at 30^0, 90^0, 150^0 resulted the Cs is 2, 859. The sequence of Cs value by placing together at intervals of 60^0 along the bend line of channel pillars at the 0^0, 60^0, 120^0, 180^0 the value of Cs is 2.849, while the smallest value of Cs, by placed the pillar along the channel bend with interval of 30^0 the Cs maximum is 2.429.

b. Analysis the coefficient of super elevation with sediment

The next test was applying the uniform sediment placed at the base line of the channel as recommended in the design of this research and then leveled the sediment along the channel, the first test by shifting the pillar with intervals of 30^0 that started at the bend 0^0 to 180^0 therefore it shifted by seven times. As shown in table 3 the trend Cs value of Super elevation coefficient can be seen in figure 10.

The results showed that first pillar placed at coordinates 0^0 and shifted each interval of 30^0 to 180^0. The trend of Cs value when pillar moved seven times as follows; the largest value of Cs at 30^0 occurred five times in the test, then follows the bend of 90^0 which three times, the third largest of Cs at bend of 120^0 occurred three times, The fourth large

Table 3: Coefficient of super elevation at the bends of the channel with sediment, pillar moved every interval of 30^0

Coordinate	Placement of pillars on the coordinates						
	0^0	30^0	60^0	90^0	120^0	150^0	180^0
Cs 0^0	0.563	0.405	0.759	0.364	0.346	0.364	0.724
Cs 30^0	2.757	2.128	**3.242**	**3.352**	**3.184**	**3.509**	**3.312**
Cs 60^0	1.799	1.870	1.705	1.920	2.542	1.919	2.123
Cs 90^0	2.383	**3.378**	3.142	2.137	2.732	2.697	2.821
Cs 120^0	**3.259**	2.671	2.448	2.438	2.597	2.861	2.584
Cs 150^0	2.181	2.064	2.508	2.463	2.296	2.155	2.848
Cs 180^0	1.556	1.472	1.495	1.143	1.381	1.323	0.621

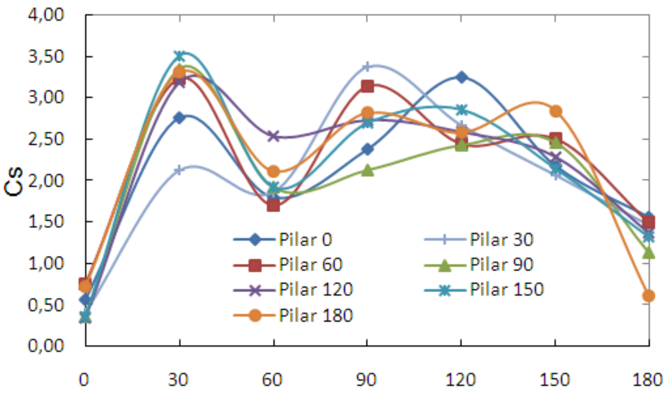

Figure 10: Curve relationship between Cs in the bend of the channel with sediment, pillar moved every interval of 30^0

of Cs in bend of 150^0 occurred four times, and follow the bend of 60^0 Cs occurred seven times, the next at bend of 180^0 occurred seven times, while the smallest value of Cs was happened at bend of 0^0 which is take place seven times.

Regarding to the maximum value of Cs that place pillar at all test, the greatest value was occur in the bend of 150^0 Cs with the value is 3.509, the second large value of Cs when pillar is in the bend of 30^0 the Cs value is 3.378, the third large value of Cs when pillar is in the bend of 90^0 Cs = 3,352, the fourth large of Cs when pillar in the bend of 0^0 Cs = 3.259, the fifth large value of Cs when pillar is in the bend of 180^0 Cs = 3.312, The sixth larger of Cs when pillar is in the bend of 60^0 Cs = 2,242, and the smallest value of Cs maximum when pillar is the bend of 120^0 Cs = 3,184.

The set value of Cs for the flow with sediment, the first testing without pillar, and the second is testing with pillar was moved at each intervals of 30^0, the Cs values which are taken from table 3 above is the largest maximum Cs when the pillars are placed in bend of 150^0, the third when pillars installed simultaneously along the bend line with intervals of 30^0, The fourth testing with pillar mounted in the intervals of 60^0 along the bend line on two conditions, those pillars at 30^0, 90^0, 150^0, and pillar at 0^0, 60^0, 120^0, 180^0. Overall super elevation coefficient calculation results can be seen in table 4 and figure 11.

Table 4: Coefficient value Cs to flow with sediment

Coordinate measurement	without pillars	Pillars moved every intervals of 30^0	Pillar mounted simultaneously interval 30^0	Pillar mounted simultaneously intervals of 60^0	
				Pillars at 30^0, 90^0, 150^0	Pillars at 0^0, 60^0, 120^0, 180^0
$Cs0^0$	0.199	0.364	0.619	0.563	0.513
$Cs30^0$	2.679	**3.509**	2.602	2.757	3.040
$Cs60^0$	1.665	1.919	0.962	1.799	1.333
$Cs90^0$	**3.511**	2.697	2.804	2.383	2.572
$Cs120^0$	2.865	2.861	**2.947**	**3.259**	2.095
$Cs150^0$	2.539	2.155	2.683	2.181	**3.048**
$Cs180^0$	1.344	1.323	1.344	1.556	0.797

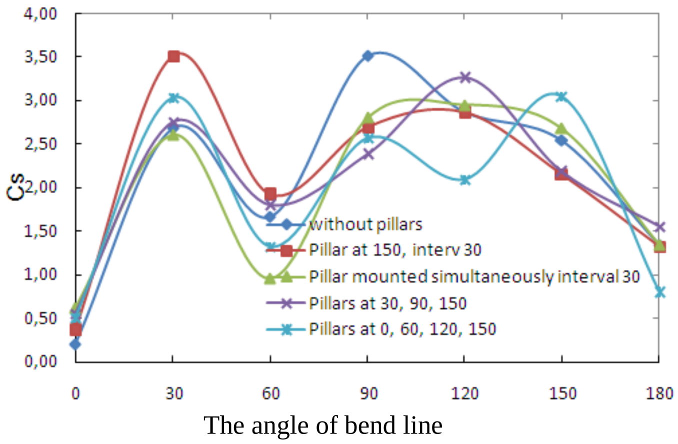

Figure 11: Curve relationship between the value of Cs with the bend angle of channel for the flow with sediment

The flow with the different variations of the pillars as seen in table 4 indicated that the largest value of Cs maximum is 3,511 with the flow without pillar in the bend of 90^0. The next test was carry out by shifting the pillar with interval of 30^0, the result shows the Cs maximum is 3.059 when the pillar placed on the bend of 150^0 with coordinates of 30^0, The third test was done by placed the pillars with intervals of 60^0 pillar at coordinate of 30^0, 90^0, 150^0, the maximum of Cs value is 3.259 in the bend of 120^0. The final tested by placing the pillar with intervals of 60^0 at coordinate of 0^0, 60^0, 120^0, 180^0 the result shows the Cs maximum is 3.048 in the bend of 150^0. From all experiment the smallest value of Cs when with pillar placed simultaneously at intervals of 30^0 along the bend line of channel the biggest value of Cs is 2.947 in the bend of 120^0.

5. CONCLUSIONS AND RECOMMENDATIONS

The research was conducted in subcritical turbulent flow and 0.5<u/uc<1 in the two conditions, the first research without sediment, the second testing using the sediment with the results as follows;

a. The result of flow with no sediment was indicated that the result of flow without pillars is Cs = 3,134, it was greater than the flow conducted the pillars. Exception for the pillars those are moved with interval of 30^0 the Cs value is 3,891.
b. For flow with Sediment results showed that the greatest value of Cs which is tested without pillars, the maximum of Cs is 3.511 in the bend of 90^0, compared with some varieties of pillar position.
c. The maximum value of Cs occurs in the flow with no sediment without pillar is 3,134 in the bend of 120^0, it is smaller than the channel with sediments without pillar, the Cs = 3.511 in the bend of 90^0. While variation of tested while the flow with different variations of pillar position conducted sediment or no sediment showed a maximum Cs value are without sediment, variations in the coordinates 0^0 pillar having the maximum Cs = 3.891 in the bend of 120^0.
d. The trend Cs value of maximum flow with no sediment which is the pillar shifted by interval 30^0 occurs at the bend 120^0, while the trend of flow with sediment shifted at intervals of 30^0 pillars the Cs maximum value occurs in the bend of 30^0.
e. The expansion of next research should be carried out with smaller intervals such as 5^0, as the trend shows the increasing of Cs value at the angle of 90^0 to 120^0 however it is the trend value is the with smaller or bigger interval. Therefore it needed to do a test by smaller interval.

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