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Aerator Performance in Reducing Phenomenon of Cavitation in Supercritical Flow in Steep Channel Bed

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Abstract—*This research aims to (1) describe an index of cavitation on a steep slope that has a channel with a horizontal plane by 20° and 25°; and (2) find a solution in the form of hydraulic structure in a low its index cavitation value. The hardware in the instrument consists of a series of reflective light sensor with flexible rubber membrane. One unit ADC 0809 used to transform analog electrical quantity into binary data. Microcontroller software in this study made by using assembly language and computer software using the programming language Delphi 6.0. These instruments are implemented on the long acrylic flume 11 m, width 0.2 m and a height of 0.4 m and tilts 20° and 25°. At the end of the upper acrylic flume associated with ponds that are located at 5.00 m above the floor of the laboratory. Discharge inflow was 20.9 l/s. cavitation index measured at the location of the 4,530 m, 3,530 m, 6,203m, and 7,203 m on the lower inlet flume. Based on research on the slope of flume with 20° of the horizontal plane as well as discharge 20.9 l/s are: (1) on the location of 3,530 m from inlet flume; the size of σ (index of cavitation)=0,41, p_0 or pressure at the channel bed = 330,58 N/m^2, Froude number = 5,49; (2) on the location of the flume inlet 4,530 m, the size of σ (index of cavitation) 0,41, p0 or pressure at the base of the channel = 270,48 N/m2, Froude number = 5,61; (3) on the location of 6,203 m from inlet flume, the size σ (index of cavitation)=0.40, p_0 or pressure at the base of the channel = 210,37 N/m^2, Froude number = 5,74; and (4) on the location of 7,203 yards from the inlet flume, the size σ (index of cavitation)=0.39, p_0 or pressure at the base of the channel = 180.32 N/m^2, Froude number = 5.88. Based on research on the slope of flume with 25 of the field horizontally debits as well as 13 l/s are: (1) on the location of 3,530 m, of the inlet flume, the size σ (index of cavitation) =0,328, p_0 or pressure at the base of the channel = 300,53 N/m^2, Froude number = 6.5; (2) on the location from the inlet flume 4,530 m, the size σ (index of cavitation)= 0,326, p_0 or pressure at the base of the channel = 270,48 N/m^2, Froude number = 6.6; (3) on the location of 6,203 m from inlet flume, the size σ (index of cavitation)=0.333; p_0 or pressure at the channel bed = 180.32 N/m^2, Froude number = 6.7; and (4) on the location of 7,203 m from the inlet flume, σ (index of cavitation) 0,335, p_0 or pressure at the channel bed = 120 N/m^2, Froude number = 6.8. Based on the results of the study, the aerator is mounted in the location from inlet flume of 7,203 m, on 20.9 l/s discharge, and the slope of flume by 25°. The dimensions of the aerator based on research results and calculations are (1) high deflector 6 mm, length 30 mm, width 200 mm; (2) duct size is 20 mm, length 80 mm, and (3) air vents diameter 10 mm. Installation of aerator design results in the 7,203 m location from the lower inlet flume benefit prevent the occurrence of cavitation, due to the concentration of air bubbles at the channel bed reaching 57,98%.*

Keywords—*Index cavitation ; concentration an air bubble C; aerator.*

I. INTRODUCTION

According to Borman as quoted by Falvey [1], the self air entrainment regime in the chute spillways involving three regions are (1) no air entrainment; (2) developing; and (3) fully developed. Supercritical flow that occurs in the chute and the region of no air entrainment as well as developing region can cause cavitation. Cavitation occurs in an area where the pressure is lower as well as in regions where air bubbles have yet to touch the channel bed or in developing region.

The higher the flow velocity in steep channels, the greater the chance of the occurrence of cavitation. High velocity flow cause the occurrence of negative or low pressure in the flow, especially at the bed of the steep channels. The force caused by negative pressure will draw the elements at the bed of the steep channels that would lead to exfoliate the surface of the bed. Gradually a bed peel steep channels will form small holes which subsequently became a huge hole that is endangering the structure. The symptoms described above are often referred to as cavitation.

The bed erosion cause of the steep channel damage can be prevented by improving high pressure or by way of building the wall bed and side channels on a very fine condition. However, building the bed and walls of very fine channels are usually not easily put into practice or are very difficult to achieve. For example, damage to concrete structures due to erosion caused by the velocity of the flow of 29,4 m/s for 3 hours, this has resulted in a hole as deep as 1.25 cm. On the conditions the same velocity if the polymer concrete is used, the size of the hole of 1.25 cm was achieved after 6 hours of occurrence of erosion. However, the use of the material as above also have physical limitations, and can only withstand erosion for a certain time.

The method is relatively new and highly effective way to prevent damage due to erosion bed how to eliminate air pockets along the boundary flow. This is done by installing air entraiment slots. It is designed specifically so that incoming air along the layer boundary. This method has been carried out to prevent damage due to erosion bed on a variety of high velocity flow including on the chute spillways. Test of aeration device shows that in the boundary layer, this tool affect an increase in pressure. Based on the simulations indicated that aeration is able to increase the pressure on average up to 50% on top of the conditions before the tool is plugged. Geometry and location of the placement of the aeration of slot until now continue to be studied, because there hasn't been any recommendations that have been approved by the experts of hydraulics.

A combination of ramps and groove can form a space greater pressure behind the its ramps, compared to the ramp without the groove. This is possible due to a combination of ramps and the groove was able to increase the size of the incoming air. The main design for various aerator at Goupitan Project adopted this type of combination, i.e. with ramps and groove.

This research aims to (1) describe an index of cavitation in flow more in steep channels that have a slope with the horizontal plane by 20° and 25°; (2) find a solution in the form of hydraulic structures/aerator in a low its index cavitation value; and (3) describe the effectiveness of aerator in preventing the phenomenon of cavitation in at the supercritical flow in the steep channels bed.

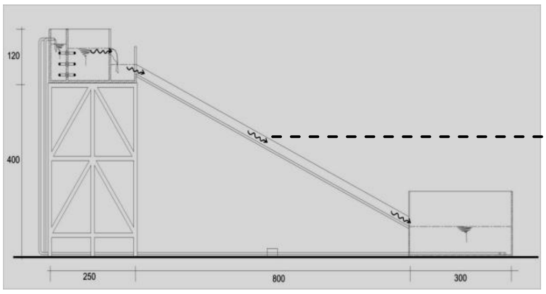
II. RESEARCH METHOD

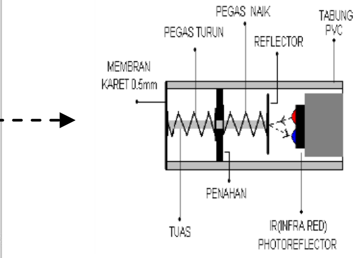
II.1 The Steps to Determine Cavitation Index

ADC (Analog-Digital Converter) of 8 bits, the interface with the Assembly language

Computers that process data into graphs or curves using the Delphi language. Relationship between computer and data logger using the USB Port

Amplifiers, amplifies the output signal from the sensor to be able to read ADC





Pressure Sensor using reflective light sensor

Fig.1. Data acquisition system of flow chart the pressure at steep channel bed

The pressure at the bed of a flow is read by the transducer that is manifested in the form of the vertical scale of the ADC in the computer screen. The vertical scale is not yet a pressure scale, therefore this scale must be calibrated, so that a scale expressed in real terms as the pressure scale in mm H2O. Calibration steps follow the stages such as in the following. (1) in the form of a rubber membrane diaphragm mounted in cap the diameter is 0.5 inches; (2) further cap is connected to the pipe which diameter 0.5 inches that vacuum conditions; (3) rubber membrane diaphragm is connected to the pre amplifier and amplifier DC and DC output transducer; (4) was next with software in the computer; (5) cap pipe in step 1 is connected to the vacuum pump through rubber hose; (6) a vacuum pump connected to a rubber hose through the manometer, manometer is instrument calibration of vertical scale as a comparison between the results of transducer to the scale of the real pressure; (7) vacuum pump is pressed, this is a manifestation of positive pressure, then the computer will show the scale of the response is positive, so that this form of positive scale is the scale of the real positive pressure, then the scale of the manometer must read also, which is the content of the liquid in the manometer is water, and then its pressure $p=\rho_{air}gh_{air.}$

II.2 Steps Determining The Distribution Of Air Bubbles Concentration

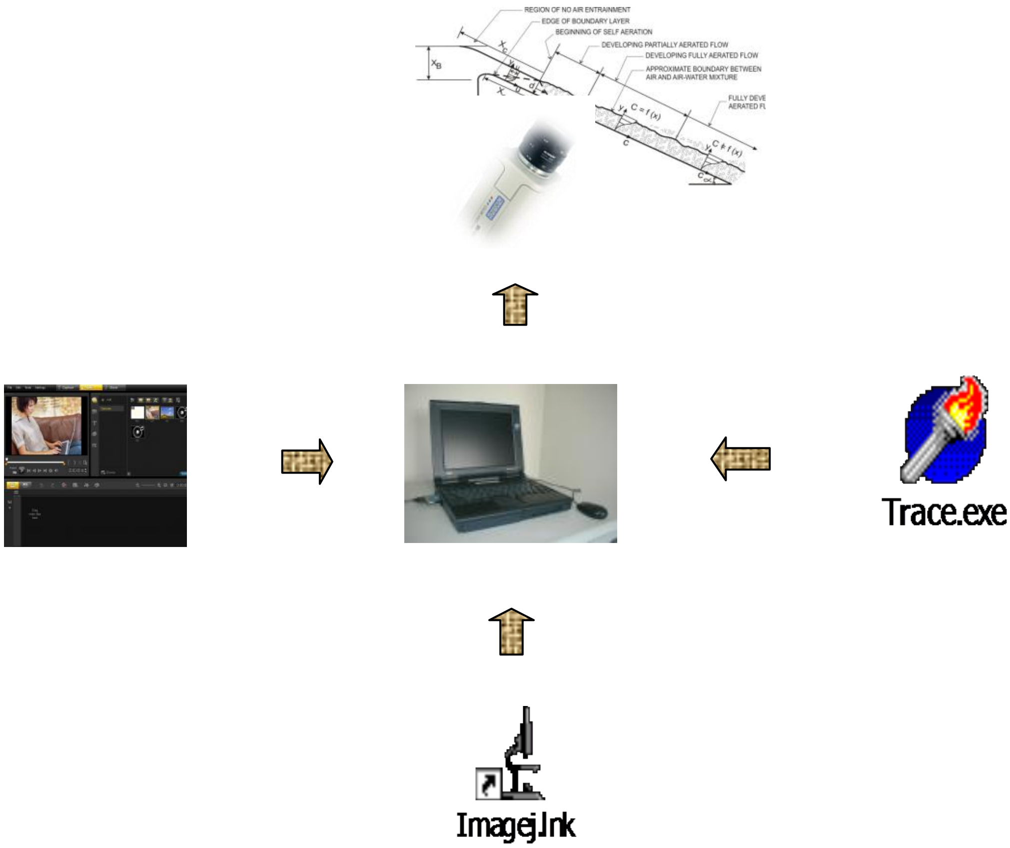


Fig. 2. Flow chart to determine concentration of air bubbles

The steps determine the concentration distribution of air bubbles C: (1) take a picture of air bubbles using a CCTV camera fitted with a CCD sensor; (2) picture of the air bubbles are read using software video capture; (3) the video image is stored inside the file software video capture; (4) the video image was made into a still image (still image) using a special Batch Convert; (5) describe the dimensions and levels of greyish air bubbles with the Image software; (6) arranging the table preparation concentration distribution of air bubbles C using a spread sheet software; (7) make the curve is the relationship between the depth z and concentration C air bubbles using a spread sheet; and (8) to calculate the equation of distribution air bubbles using a spread sheet.

III. THE RESULTS OF RESEARCH AND DISCUSSIONS

III.1 Froude Number And Cavitation Index At The Bottom Of Steep Channel

Table 1. Index of cavitation in a four point downstream of discharge flume inlet 20,9 l/s slope of flume 20°

Position	ρ_{air} (kg/m^3)	g (m^2/s)	h *pressure head* (mm)	p_0 pressure at the channel bed N/m^2	U (flow rate) m/s and Froude Number	σ (cavitation index)
7,203 m on downstream inlet flume	998,228	9,81	18,414	180,3212	3,291536/5,88	0,365
6,203 m on downstream inlet flume	998,228	9,81	21,483	210,3748	3,240741/5,74	0,377
4,530 m on downstream inlet flume	998,228	9,81	27,621	270,4819	3,191489/5,61	0,389
3,530 m on downstream inlet flume	998,228	9,81	33,759	330,5889	3,143713/5,49	0,401

Source: Draft report of the dissertation, Yeri Sutopo[3]

Based on Tables 1 and 2. below, it appears that the aerator can be mounted on the inlet downstream 7,203 m flume, because the value of the cavitation index σ ; (Thoma Number) between the value of 0.17 to 0.25 and Froude Numbers > 6,Arora [4]; while in the position of the other basic channels required refinement. According to Henry t. Falvey [1] σ = 3 cavitation does not occur, σ = 1.8 was the early onset of cavitation, and 0, 3 < σ< 1.8 cavitation has been growing, while σ<0.3 included in category supercavitation.

Table 2. Index of cavitation in a four point downstream of discharge flume inlet 20,9 l/s slope of flume 25°

Position	ρ_{air} (kg/m^3)	g (m^2/s)	h *pressure head* (mm)	p_0 pressure at the channel bed N/m^2	U (flow rate) m/s and Froude Number	σ (cavitation index)
7,203 m on downstream inlet flume	998,228	9,81	12,276	120,2142	3,633218/6,8	0,299
6,203 m on downstream inlet flume	998,228	9,81	18,414	180,3212	3,59589/6,7	0,306
4,530 m m on downstream inlet flume	998,228	9,81	27,621	270,4819	3,559322/6,6	0,313
3,530 m m on downstream inlet flume	998,228	9,81	30,69	300,5354	3,52349/6,5	0,319

Source: Draft report of the dissertation, Yeri Sutopo[3]

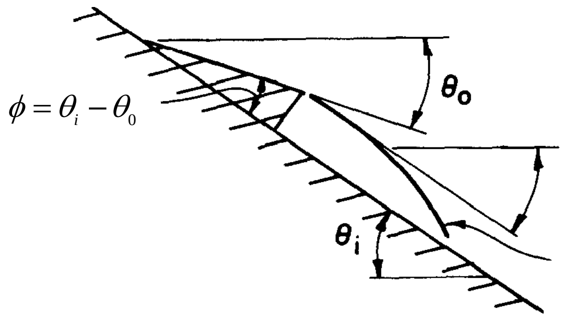
III.2 The Draft Aerator Research

a. Specify the index of the cavitation flow in the entire length of flum's research, particularly on the lower air intake point for the first time this has happened or in downstream region of no air entrainment;

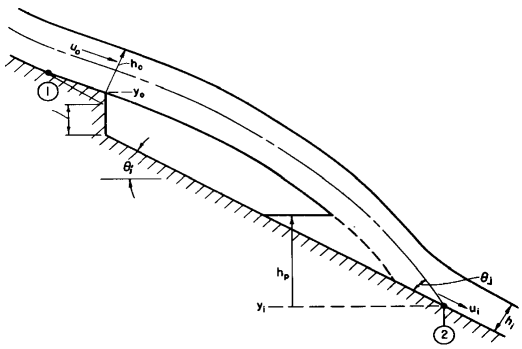
$\sigma = \dfrac{p_0 - p_v}{\rho U_0^2 / 2}$ where σ : Index of cavitation; p_0 : Pressure point review the potential location of the aerator; p_v : Vapor pressure of water at a temperature of 20°C; U_0 : Average flow rate; b : Base width flum =0,20 m; ρ : Density of water at 20°C=998,228;

b. Determine the location aerator based on the value of the index cavitation on at a step a;

c. Estimate the angle of incline of the horizontal (ramp), θ_0 , use the following Equation $Cos^2\theta_0(\tan\theta_i - \tan\theta_0) = \dfrac{gX_i}{2U_0^2}$ in which X_i : the distance from the tip of a horizontal incline to the point that influenced the trajectory of water (jet); θ_i : the angle between the base of the spillway with the horizontal; θ_0 : angle of the ramp (ramp) towards horizontal; θ_e : the angle between the tangent to the trajectory of the jet at ramp to the horizontal is calculated using the equation $\theta_e = \theta_i(1 - A_r) + A_r\theta_0$ where A_r is a (jet trajectory coefficient) or (the relative ramp height factor); ϕ : angle of the ramp (ramp) towards basic flum;



d. Usually the structure not only of aerator ramp alone, but required offset duct or all at once. The equation is used to determine the need for offsets or duct is $\dfrac{h_p^2}{z} = \dfrac{2F_0^2}{z_i / z}\{1 - (\dfrac{z_i}{z})^2\} + \cos\theta_i\{(\dfrac{z_i}{z})^2 - 1\}$. The decision required offset or not if the value is $h_p > (Y_0 - Y_i)$ where the depth of the Groove (duct) D is based on the equation $D = \dfrac{d_0}{0,15}$



e. Specify concentration an air bubble in hilir aerator through research;

f. Calculate the concentration of the air in the bottom of the channel downstream launch aerator based on research results. If the concentration of the air base of the channels launch greater than 0.10 or 10%, then the other aerator is not required. If the air concentration of less than 0.08 or equal to 0.10, then at that location should be installed a new aerator;

g. In the construction of the aerator the next. Based on the step (a) to step (g) above, then found the dimensions of the aerator as Figure 3 below.

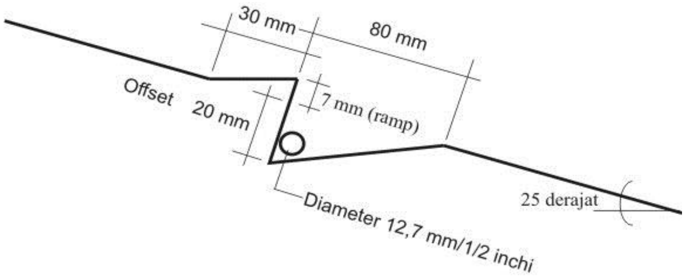


Figure 3. The dimensions of the design of the research results of aerator

III.3 Concentration Distribution Of Air Bubbles In Steep Channels Downstream Aerator

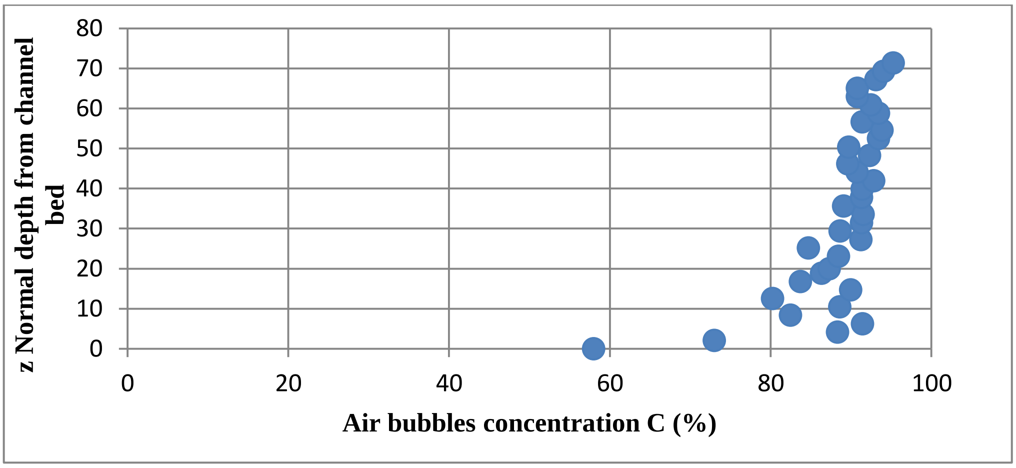


Fig. 4. Concentration distribution of air bubbles that are 1.5 m downstream aerator

According to Figure 4 above, it appears that the concentration of air bubbles at the bed of the flow that is 1.5 m downstream aerator is 57,98%. According to Falvey [1], if the concentration of air bubbles at the bed of the channel is greater than 0.10 or 10%, then the other aerator is not required. If the concentration of air bubbles is less than or equal to 0.10 0.08, then at that location should be installed a new aerator. Thus, the installation of aerator in 7,203 m flume inlet on the lower benefit prevent the occurrence of cavitation, due to the concentration of air bubbles at the bottom of the flow reaching 57,98%. According to Pettersson [2], this is in accordance with the opinion of Peterka that air bubbles that have reached the bed of the channel can prevent damage due to cavitation, as well as according to the Chanson that air bubbles by 5-7% who have reached the steep channels bed can prevent damage due to cavitation.

Table 3. The Mean Concentrations of Air Bubbles in Five Successive Frames C (%)

No.	z The normal depth from channel bed (mm)	The mean concentrations of air bubbles in five successive frames C (%)					C mean (%)
		Frame to-					
		17	41	65	89	113	
1	0	61,14	57,81	56,14	62,81	52,02	57,98
2	2,1	76,66	73,33	71,66	78,33	64,83	72,96
3	4,2	92,28	88,95	87,28	93,95	79,02	88,3
4	6,3	95,58	92,24	90,58	97,24	81,41	91,41
5	8,4	84,95	81,62	79,95	86,62	79,02	82,43
6	10,5	91,96	88,63	86,96	93,63	81,73	88,58
7	12,6	81,28	77,95	76,28	82,95	82,63	80,22
8	14,7	91,43	88,1	86,43	93,1	90,55	89,92
9	16,8	84,95	81,62	79,95	86,62	85,39	83,7
10	18,9	87,61	84,28	82,61	89,28	87,74	86,3
11	20	88,62	85,28	83,62	90,28	88,48	87,25
12	23,1	90,16	86,83	85,16	91,83	88,16	88,43
13	25,2	84,95	81,62	79,95	86,62	90,28	84,68
14	27,3	92,92	89,59	87,92	94,59	91,03	91,21
15	29,4	90,16	86,83	85,16	91,83	89,12	88,62
17	33,6	92,71	89,37	87,71	94,37	93,31	91,49
18	35,7	90,16	86,83	85,16	91,83	91,35	89,06
19	37,8	91,91	88,58	86,91	93,58	95,38	91,27
20	39,9	91,86	88,53	86,86	93,53	96,08	91,37
21	42	94,41	91,08	89,41	96,08	93,05	92,8
22	44,1	91,43	88,1	86,43	93,1	94,53	90,72
23	46,2	90,16	86,83	85,16	91,83	93,95	89,58
24	48,3	92,92	89,59	87,92	94,59	96,45	92,3
25	50,4	89,31	85,98	84,31	90,98	97,94	89,7
26	52,5	94,41	91,08	89,41	96,08	96,08	93,41
27	54,6	94,41	91,08	89,41	96,08	98,26	93,85
28	56,7	92,92	89,59	87,92	94,59	91,83	91,37
29	58,8	94,41	91,08	89,41	96,08	96,08	93,41
30	60,9	93,61	90,28	88,61	95,28	94,54	92,46
31	63	91,65	88,31	86,65	93,31	93,95	90,77
32	65,1	91,12	87,78	86,12	92,78	96,08	90,78
33	67,2	93,45	90,12	88,45	95,12	98,15	93,06
34	69,3	94,94	91,61	89,94	96,61	96,98	94,02
35	71,4	96,11	92,78	91,11	97,78	98,31	95,22

Source: draft report dissertation, Yeri Sutopo[3]

IV. CONCLUSION AND RECOMMENDATIONS

IV.1 Cloncusion

First, the slope of flume with 20° of the horizontal plane as well as discharge 20.9 l/s (1) at the location of 3,530 m from inlet flume; the size of σ (index of cavitation)=0,41; (2) at the location of 4,530 m from inlet flume, the size σ (index of cavitation) 0,41; (3) at the location of 6,203 m from inlet flume, the size of σ (index of cavitation)=0.40; and (4) at the location of 7,203 m from inlet flume, the size of σ (index of cavitation)=0.39. Slope of Flume with 25° of the field horizontally discharge as well as 11,4 l/s are: (1) at the location of 3,530 m from inlet flume, the size of σ (index of cavitation)=0,328; (2) at the location of 4,530 m from inlet flume, the size of σ (index of cavitation)=0,326; (3) at the location of 6,203 m from inlet flume, the size of σ (index of cavitation)=0.333; and (4) at the location of 7,203 m from inlet flume,the size of σ (index cavitation)=0,335;

Secondly, the dimensions of the aerator based on research results and calculations are (1) high deflector 6 mm, length 30 mm, width 200 mm; (2) duct size in 20 mm, length 80 mm, and (3) air vents diameter 10 mm;

Third, the installation aerator design results over at the location of 7,203 m flume inlet on the lower benefit prevent the occurrence of cavitation, due to the concentration of air bubbles at the bottom of the flow reaching 57,98%.

IV.2 Recommendation

The number of the aerator is mounted on the chute spillway does not need too much. On the length of chute spillway with up to 240 m and a width of 100 m, it only takes one aerator unit combination of ramp or deflector, offsets, and the duct.

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