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Study of Flow Velocity Distribution on Free Intake Structure and its Influence to Intake Capacity

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Abstract: As maritime state, most of Indonesian reside in coastal areas or estuaries, leading sanitation and water supply a major concern of the people. The use of groundwater with considerably limited amount is more limited due to seawater intrusions. On the other side, surplus of freshwater from upstream is very abundant near the estuaries. However, morphological condition of river downstream or in estuaries with huge dimension and depth causes expensive cost in order to utilize freshwater in estuaries. One of the solutions to utilize water downstream or near estuaries as raw water for clean water is to build free intakes around river estuaries. However, as the utilizing proceeding it is found a problem that intake capacity is far below their design capacity. The research is an experimental research conducted in the laboratory which aimed to investigate the relationship of flow velocity distribution on no free intake and with free intake condition and its influence to the capacity of free intake structures. The result shows that either on no free intake and with free intake condition minimum velocity occurs around channel bed and increasing upright and decreasing again when approaching surface of the channel. The positioning of intake pipe is highly influencing intake capacity. Maximum condition is achieved when intake pipe is positioned on channel bed and near channel surface while minimum condition is achieved when pipe is around middle part of the channel.

Key words: Free, intake, velocity, distribution, intake capacity, positioned

INTRODUCTION

Water is one of the basic needs of living creatures in this world. According to the World Health Organization (WHO), water-borne diseases are the leading cause of death in some developing countries. The World Bank, meanwhile, noted that around 780 million or 11% of the world's population get water from unprotected sources. The Global Water Market also reports that in 2010 about 1.9 billion people in the world did not get clean water services. Generally they live in developing countries in the regions of Africa Asia Pacific and South Asia. In Indonesia, about 31% of the population in the year 2010 or 165 million people without clean water services. Meanwhile, the population of the world in the future is expected to continue to grow. In 2050 the world's population is estimated at 9.3 billion with a high rate of development primarily in developing countries such as Indonesia. At the same time, the level of water consumption tends to increase. For example in the 1990's, water consumption for households in several big cities in Indonesia reached 130 l/capita/day. While the current needs of water in several big cities such as Jakarta, Surabaya, Denpasar and Makassar is estimated to reach 190 l/capita/day. If this condition is not addressed immediately by preparing adequate clean water infrastructure facilities, the number of people not served by clean water will continue to increase every year.

As a maritime country most of the Indonesian populations reside in the vicinity of the beach or estuary, so that, sanitation, especially, clean water is one of the problems perceived by people around the beach or estuary. Utilization of groundwater is very limited due to the influence of sea water intrusion. On the other hand, the morphological conditions of rivers in the downstream or estuary have great depth and dimension, so, there is a high cost of exploitation in utilizing the water. One solution that is currently done to utilize the water as raw

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water for clean water is to build free intake. The existence of the intake is very helpful in supplying raw water for theneeds of clean water, especially, in coastal areas. However, over the course of the utilization it was found that the capacity of the intake was far below the design capacity. Variables that greatly affect the capacity of an intake are the shape and velocity of the stream, the river profile and the placement of the pipeline from the river to the intake. Hence, the application of hydraulics theory to free intake design can produce sufficient results in accordance with actual conditions and thus accurate enough for practical design purposes. This research is an experimental study conducted in the laboratory to find out the distribution of flow velocity in free intake building and the influence of intake placement elevation on free intake building capacity.

Free intake: The design of water utilization for clean water needs requires a concept to achieve high efficiency in meeting future needs (Bakri *et al*., 2015). The free intake building is one of the river structures designed to allow diverting of river water into irrigation networks/aqueducts without changing the condition of the river, if the river water level is high enough to reach the watered stream (Ahn *et al*., 2017). The structure is an intake pipe to tap water into the intake wells in sufficient quantities and then flowed to the Water Treatment Plant (WTP) by pumping. The flow from the intake pipes to the intake wells is carried out by gravity without raising the water level in the river (Wang *et al*., 2016). The free intake capacity is highly dependent on the diameter of the retrieval pipeline, the flow velocity, the river profile and the elevation of the retrieval pipeline (Brandt *et al*., 2017). One of the difficulties faced in determining the capacity of free intake is the type of free intake stream that belongs to the type of open and closed channels. Because the free intake is in the stream, the flow around the free intake is categorized as an open channel flow whereas the flow on free intake and raw water distribution typically uses a closed channel (pipe). Illustration of free intake structures can be seen in the following Fig. 1.

In open channel flow, the velocity distribution depends on many factors such as shape of channel, wall roughness and flow discharge (Kumbhakar and Ghoshal, 2016). The distribution of velocity is uneven at every point on the cross-profile (Lu *et al*., 2017; Devi and Khatua, 2016). Figure 1 shows the velocity distribution at the channel's cross-profile with various channel forms which is illustrated by the contour lines of velocity. It appears that the minimum velocity occurs near the boundary wall (bed and embankment) and increases with distance to the surface. Maximum speed contour lines occur around the middle part of the channel width and slightly below the surface. For very wide channel's the velocity distribution around the center of the channel width is the same. This is because the sides of the channel have no effect on the area, so, the channel in the area is considered 2 dimensional (vertical). This situation will occur when the channel width is greater than 5-10 times the depth of the flow depending on the roughness of the wall. Vertical velocity distribution can be determined by measuring at various depths. The more measurement points will give better results. Usually the velocity measurement in the field is conducted by using current meter equipment (Fig. 2).

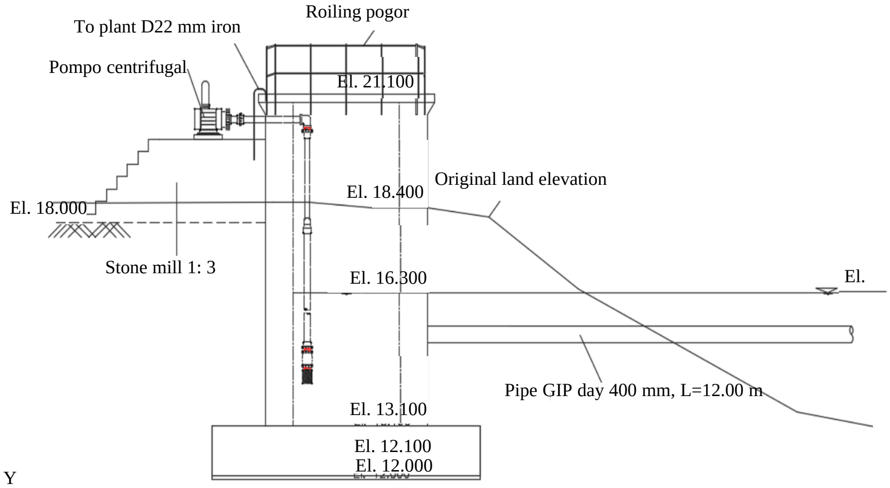

Fig. 1: An illustration of a free intake structure

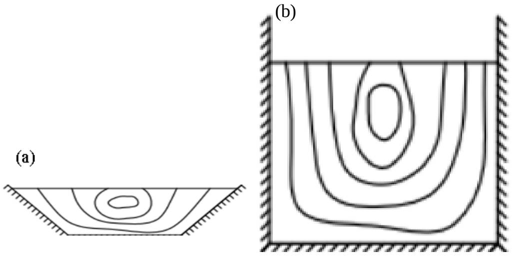

Fig. 2: Velocity distribution in open channel; a) Trapezoidal channel and b) Rectangle channel

MATERIALS AND METHODS

Although, the research was conducted in the laboratory, the parameters used such as flow velocity, discharge and slope of the channel is obtained from the field which is Jeneberang River flow parameters in the estuary by using the scale model thus the water discharge used in the model is 1 L/sec and the basic slope of 0.17%. Jeneberang River is one of the rivers found in South Sulawesi. The river mouth passes through Gowa and Makassar which is the capital of South Sulawesi province. In the middle stream this river also contains Bili-Bili Dam is the largest dam in eastern Indonesia with current effective storage capacity approximately 250 million cubic. In addition, from the Bili-Bili Dam to the lower reaches of the river, there are 6 free intake structure points with a total capacity of approximately 1000 L/sec.

This research was conducted at Hydraulics Laboratory Department of Civil Engineering Hasanuddin University. The river model uses flume in this case to facilitate the analysis used rectangular flume with a flume width of 8 cm, height 20 cm and length 9 m. Figure 3 shows the flume and other complementary tools used in this study Fig. 3.

To simulate the retrieval pipes in a free intake building, one side of this flume is perforated and fitted with a 7 mm diameter pipe that acts as an intake pipe. There are 3 variations of intake intake point intake, respectively, i.e., 0.25, 0.5 and 0.75 H. While the water level (H) used in this study is 20 cm as shows Fig. 4.

To measure the flow velocity an electro magnetic current meter VM2201 was used. The tool is capable to measure the data flow velocity in large numbers per unit time with high accuracy and connected with the computer to show and store measurement data results. Measurement of the flow velocity was conducted vertically as much as 5 points and horizontally as much as 6 points as shows in the following Fig. 5. Complete method conducted in the study is summarized in the following Fig. 6.

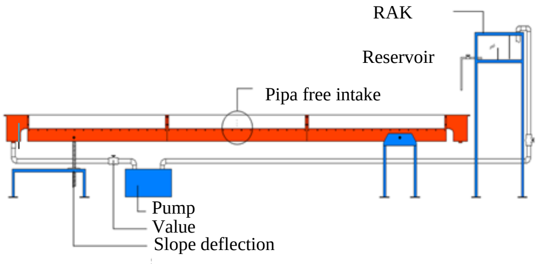

Fig 3: Research flume

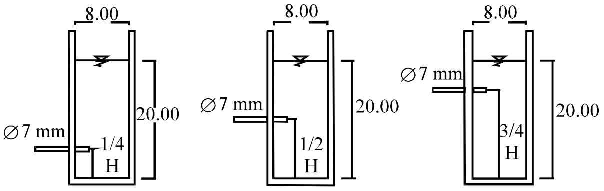

Fig. 4: Variation of intake pipe elevation

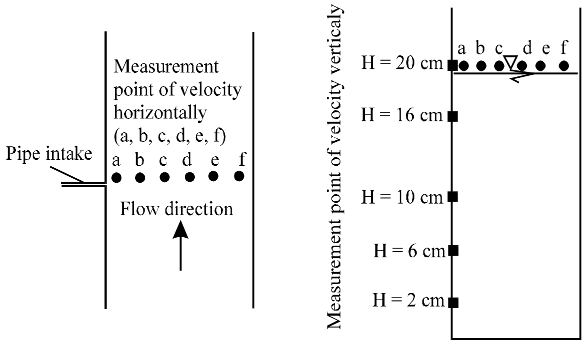

Fig. 5: Location of velocity measurement

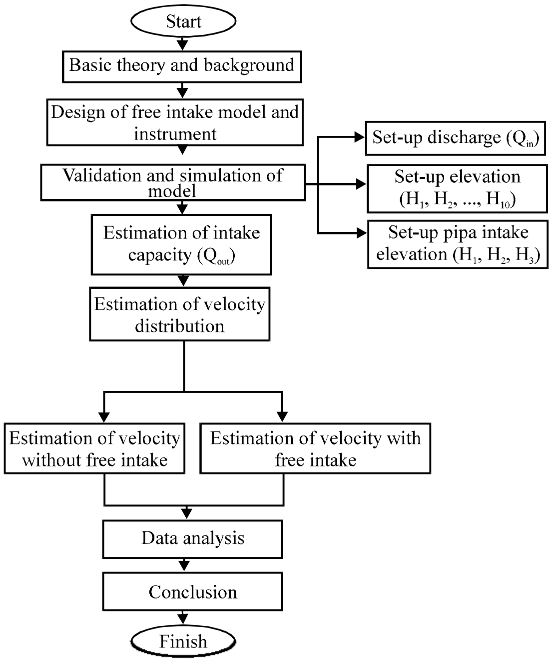

Fig. 6: Research methodology

RESULTS AND DISCUSSION

Distribution of flow velocity without free intake structures: Before the flow process on the intake pipeline model is conducted, the first thing to do is to measure the flow rate without the intake pipes using the current meter. This is done to compare the flow velocity before and after the intake structure.

In the measurement of the flow velocity distribution without the free intake structure, generally the flow pattern at the point of observation H = 2 cm has the minimum speed with an average speed of 30.869 cm/sec this is due to the friction between the flow and the bottom of the channel while the maximum speed is above the span (H = 16 cm) that is 32.026 cm/sec. This is due to the small flow resistance caused by friction force between the bottom of the channel and with the air, then the speed return decreases at the reading point (H = 20 cm), i.e., 31.681 cm/sec. This is because at the surface. the flow velocity is frictionless with the air, thus forming a high flow pattern of the readings to the velocity forming the parabola. This result is in accordance with previous studies and the theory of velocity distribution on the channel that the minimum velocity is obtained at the bottom of the duct and tends to increase upright and lower back on the top of the channel.

Distribution of flow velocity with free intake structures: The distribution of flow velocity in the presence of free intake with height H_1 = 5, H_2 = 20 and H_3 = 15 cm can be seen in the following Fig. 7.

In measurement of velocity distribution of free intake channel with intake pipes height of 5, 10 and 15 cm, generally the flow pattern at the observation point H = 2 cm has the minimum velocity. This is due to the friction between the flow and the bottom of the channel while the maximum speed is located at high reading (H = 10 cm) because it has no resistance, then the return speed decreases at the reading point (H = 20 cm). This is because at the surface the flow velocity is friction with the air, thus forming the high flow pattern of the readings to the velocity forming the parabola. Besides it can also be seen that at 2, 6 and 20 cm height measurements the measurement of flow velocity is basically divided into 2 groups, i.e., d, e and f which is farthest from the intake point has a lower velocity when compared with points a-c which is closer to the intake while at the point of measurement of the center of the channel is H = 10 and 16 the velocity distribution for each measurement is irregular in other words that in this area the velocity distribution is not affected by the horizontal distance to the intake location.

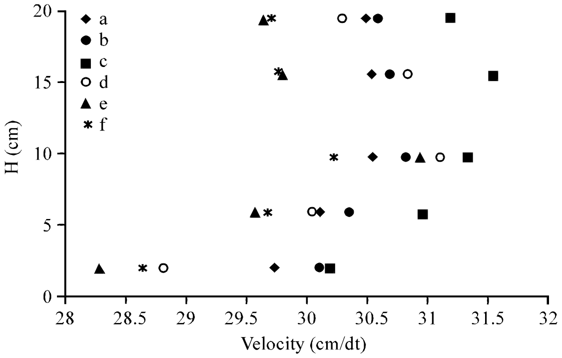

Fig. 7: Distribution of velocity with free intake structures

Comparison of distribution of velocity with and without free intake structures: The comparison graph of the flow velocity distribution with and without the free intake structures for each intake pipe height (H_1 = 0.25, H_2 = 0.5 and H_3 = 0.75H) at each vertical measuring point (2,6,10, 16 and 20 cm) and horizontal measuring points (a-f) are summarized in the following Fig. 8.

The comparison of the velocity distribution with and without free intake structures generally has the same flow pattern that is parabolic where the minimum speed is at H = 2cm, otherwise the average maximum velocity is at the point of measurement H = 16 cm but the velocity turns to decrease in the measurement of H = 20 cm.

The picture above shows that when the intake is at position H_1 = 5cm the average velocity is at the lowest velocity whereas when the intake is placed at a height H_2 = 10 cm it tends to increase when compared to the intake pipe placed at H_1 = 5 cm. The maximum velocity occurs when the intake is placed at H_3 = 15 cm.

The figure above also shows that the measurement of the velocity distribution when the intake H_1 = 5 cm is opened smaller when compared with the velocity distribution without the existence of the free intake building. On the contrary the measurement of the speed distribution when the intake H_2 = 10 cm and H_3 = 15 cm is opened larger when compared with the velocity distribution without the existence of the free intake structures.

Influence of intake elavation to discharge: Result of observation shows that the largest water discharge through the intake is in the position of 0.25 h (H = 5 cm). This is due to the amount of pressure that occurs in the placement area of the pipe and the rate of water velocity is small, so that, there is greater pressure on the walls of the channel. After the intake pipe model is placed in the position of 0.5 h (H =10 cm), the velocity increased from 30.218-32.379 cm/sec but the water discharge through the

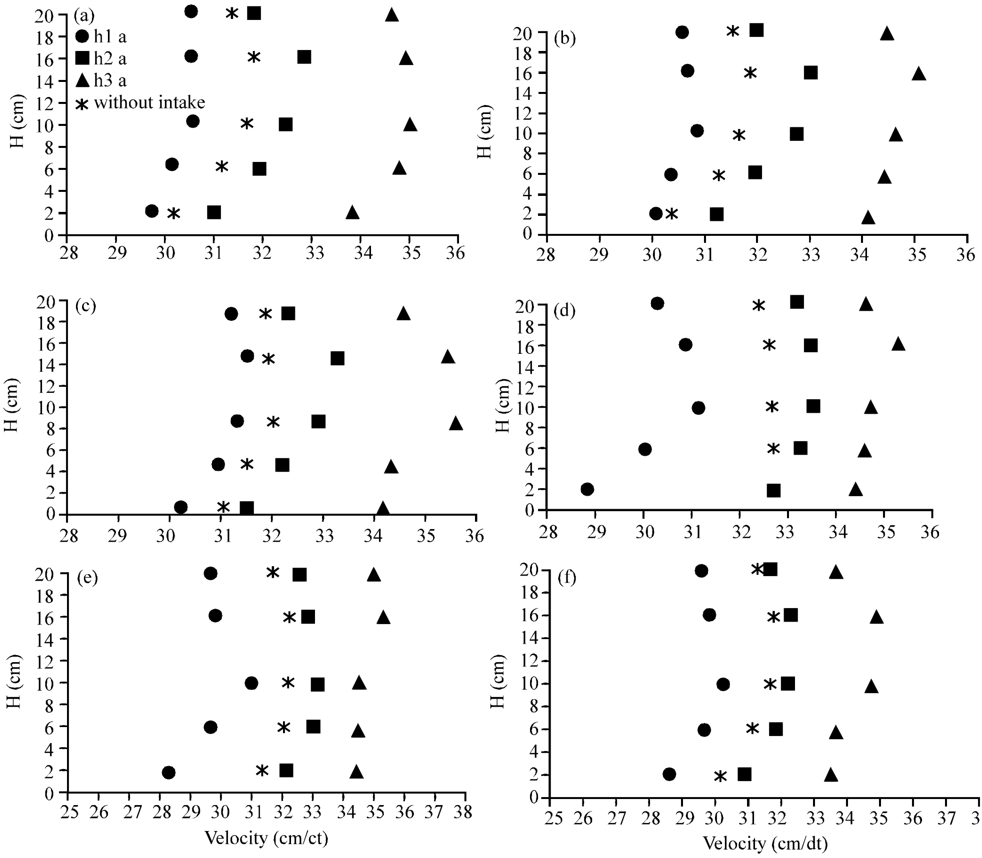

Fig. 8: The comparison graph of the flow velocity distribution with and without the free intake structures for each structure section; a) = Measurement point; at a, b = Measurement point; at b, c = Measurement point; at c, d = Measurement point; at d, e = Measurement point; at e, f = Measurement point at f

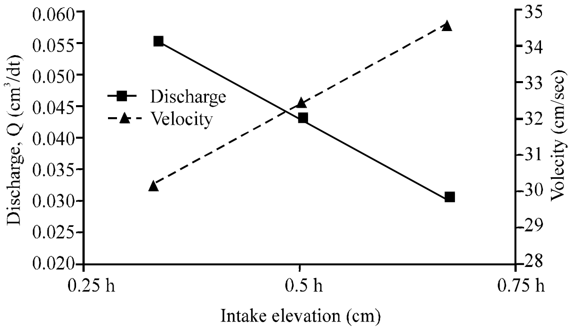

Fig. 9: Diagram of relationship of h, v and Q

intake pipes decreased from 0.55739-0.04306 cm^3/sec. And the maximum velocity is obtained when the intake is placed in a 0.75 H elevation so that the water discharge out of the intake reaches 0.03 cm^3/sec. In other words, the position of the intake pipe that provides the minimum discharge is obtained at the point 0.75 H and the maximum discharge is obtained at the point of 0.5 H as given in the following Fig. 9.

CONCLUSION

Based on the results of research and analysis it can be concluded as follows: the distribution of flow velocity both with and without free intake structures shows that the minimum velocity is obtained around the bottom of the channel and tends to increase to the surface of the channel, until it returns downward as it reaches the channel surface. This is due to the friction between the flow and the bottom of the channel wheresas in the center of the channel has a smaller resistance if it is attached to the base of the channel and around the channel surface is obstructed by the friction between the flow and the air, thus the flow pattern forms a parabola.

Generally, there is no difference in the flow velocity distribution in the presence or absence of free intake structures where the flow velocity distribution of both still form a parabola.

Placement of elevation intake pipe greatly affects the volume of intake capacity. Maximum conditions are achieved when the intake pipes near the bottom of the channel, then near the surface of the channel and the minimum conditions of intake water discharge are achieved when the intake pipes are placed around the center of the channel. This is because the largest velocity distribution is in this area, so that, the flow pressure into the intake hole is getting smaller. In contrary, around the bottom of the channel and the channel surface is the area where the distribution of the smallest flow velocity causing the magnitude of the inlet flow pressure to the intake is thus obtained the maximum discharge intake at this point.

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