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Physical Hydraulic Model Test for the Flow Pattern of Pool Passes Fishway

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***Abstract*— *Fishway water velocity is the main factor to determine wether or not a fishway can work maximally and be passed through by fish. In some conditions, fishway flow velocity is beyond the fish swimming ability, so that they refuse to swim through the fishway. Fishway flow velocity can be set by adjusting the water level and flow director to control the flow distribution pattern. The present study performed a physical model test by using three discharge variations and three fishway variations with additional baffle as flow director. The flow velocity is measured using Acoustic Doppler Velocimeter (ADV). The parameter used in the present study were water level, velocity distribution pattern, and submerged orifice velocity.*

I. INTRODUCTION

Fishway is a structure that is used as a fish swimming path from downstream to upstream. Fishway success rate depends on its hydraulic factors.

Pool passes, cross-wall, and orifice fishway are potential to turbulence. This occurs because the discharge flows from the wider cross-section to the smaller cross-section, before flows to the initial cross-section. Due to the constriction, fishway pool flow velocity is supercritical. Such a hydraulic condition hampers fish to swim against the flow and needs much time for the fish to return to tranquil flow. Tranquil flow and smooth flow transition will prevent fish from stopping swimming or from refusing swimming through *fishway*.

This study was conducted in fishway physical model in the laboratory. This study utilize pool passes fishway with free flow orifice and submerged orifice. This study employed various discharge and pool form. The variations were 7,07 l/sec, 5,69 l/sec, and 4,48 l/sec, for the pool, they were fishway pool without baffle, fishway pool with one baffle, and fishway pool with two baffles.

II. PROBLEM STATEMENT

Hydraulic condition of a fishway greatly affects its the function of a fishway. Some fishway flow conditions that hamper fish to swim through fishway are as follow:

1) Flow velocity beyond the lowest fish swimming speed.
2) Disproportionate flow velocity pattern.

In this study the flow velocity distribution was controlled by controlling the discharge, which resulted in maximum and minimum water level as required by the fishway, and by adding baffle as the flow director.

III. METHODOLOGY

Three discharge variations and fishway variations were modeled in the present study. Pool passes Fishway consisted of Thompson measurement, upstream resting pool, ten fishway pools, and downstream resting pool. The measurement was only conducted in two pools that were considered representing the flow condition of all fishway pools.

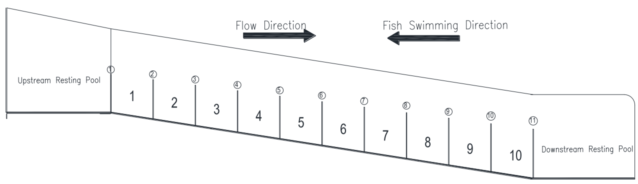

Fig. 1. Fishway pool passes in laboratory

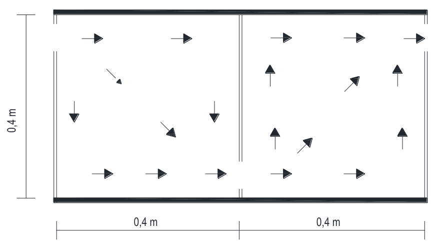

Fig. 2. Upper view fishway model 1

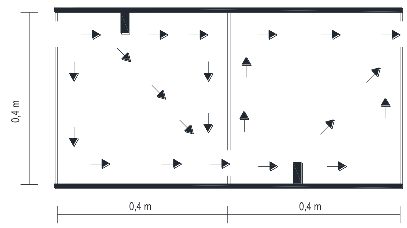

Fig. 2. Upper view fishway model 2

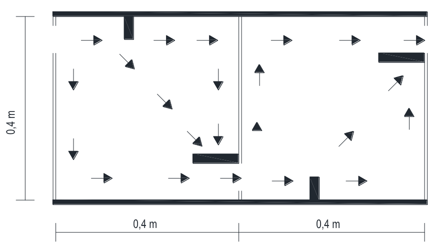

Fig. 3. Upper view fishway model 3

A. Flow Velocity

The flow velocity in the fishway pool was measured using Acoustic Doppler Velocimeter (ADV). The measured data were directly recorded in the computer. The measured flow velocity holds three values of velocity, for axis x, y, and z. In order to find out the velocity in the measured area, the

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following formula was applied.

$$u = \sqrt{V_x^{\,2} + V_y^{\,2} + V_z^{\,2}}$$

B. Flow Velocity Distribution

Flow velocity distribution depends on the discharge (Q) and water depth (Yo) and the measured depth (Y). Accordingly, the flow distribution, theoretically, can be calculated by using the following formula.

$$U = V + \frac{U_*}{K}\left(1 + ln\frac{Y}{Y_o}\right)$$

C. Submerged Orifice Flow Velocity

Submerged Orifice flow depends on water depth and orifice dimension. Regarding the submerged orifice flow velocity, the affecting water depth was the depth difference (Δh) between the inlet and outlet pool. Orifice velocity can be theoretically calculated by the following formula:

$$V = \sqrt{2g\Delta h}$$

IV. EXPERIMENT RESULT

The result of water depth measurement in each pool fishway are as follow:

TABLE I. The result of water depth measurement

Pool Fishway	Water Depth (cm)		
	7,07 l/sec	5,69 l/sec	4,48 l/sec
Pool 1	18.50	17.00	9.00
Pool 2	18.50	17.00	9.00
Pool 3	18.50	17.00	9.00
Pool 4	18.50	17.00	9.00
Pool 5	19.00	18.00	10.00
Pool 6	20.00	19.00	12.00
Pool 7	21.00	20.00	14.00
Pool 8	22.00	21.50	15.00
Pool 9	23.00	22.00	17.00
Pool 10	24.00	22.50	21.00

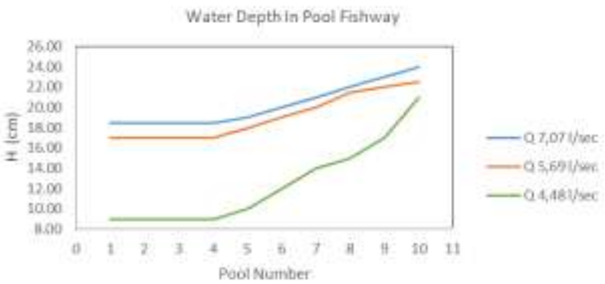

Fig. 4. Water level escalation in pool fishway

From Table 1, it can be seen that pool 1 until pool 4 have same water depth, water depth in pool 5 until 10 fluctuates due to backwater from downstream resting pool. The result in Table 1 is used as a reference to determine the domain of measurement pool. Therefore, the flow velocity measurement was conducted in pool 4 and pool 10.

A. Flow Velocity Distribution Pattern of Pool 4

The maximum flow velocity, based on the measurement, was in 0.04-0.08 m from the bottom. It occurs due to the flow velocity resulted by submerged orifice. Accordingly, the flow distribution pattern was described according to the data of flow velocity measurement in 0.04-0.08 m deep for all model. The following is the Flow Velocity Distribution Pattern of Pool 4:

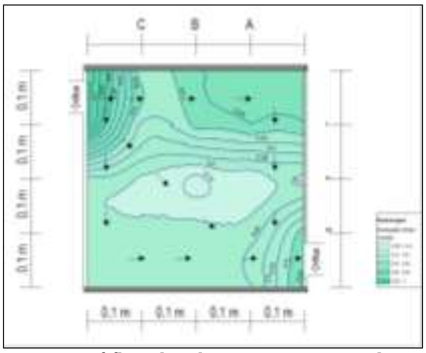

Fig. 5. The upper view of flow distribution pattern in pool 4 model 1 Q 7,07 l/sec

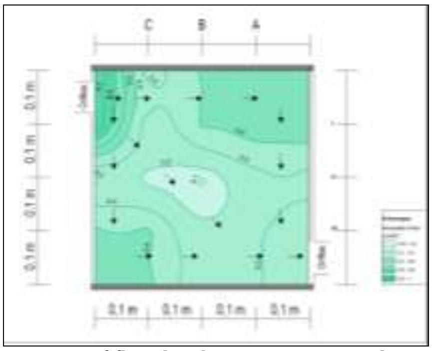

Fig. 6. The upper view of flow distribution pattern in pool 4 model 1 Q 5,69 l/sec

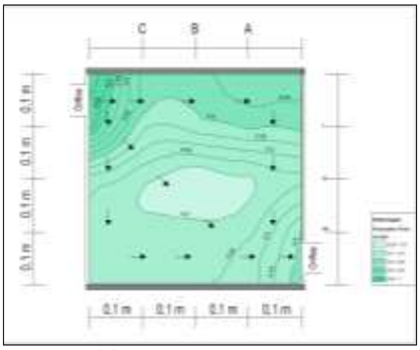

Fig. 7. The upper view of flow distribution pattern in pool 4 model 1 Q 4,48 l/sec

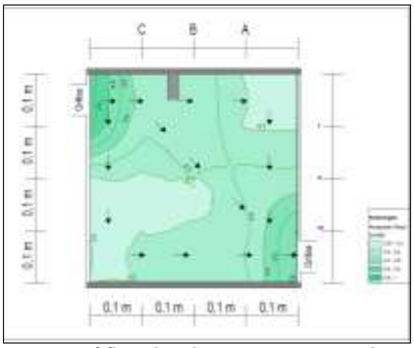

Fig. 8. The upper view of flow distribution pattern in pool 4 model 2 Q 7,07 l/sec

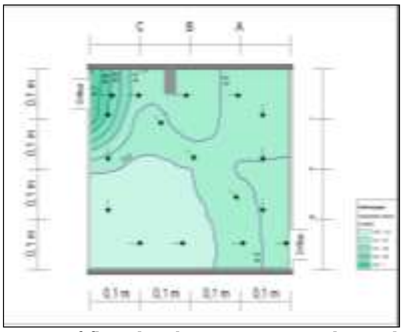

Fig. 9. The upper view of flow distribution pattern pool 4 model 2 Q 5,69 l/sec

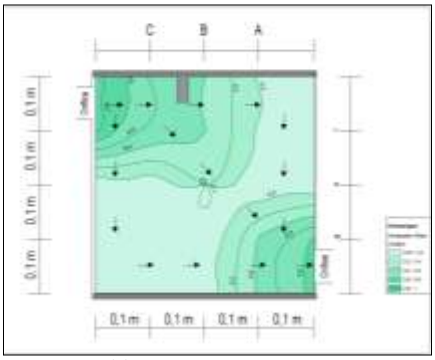

Fig. 10. The upper view of flow distribution pattern in pool 4 model 2 Q 4,48 l/sec

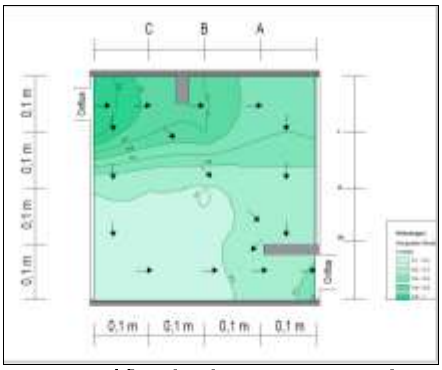

Fig. 11. The upper view of flow distribution pattern in pool 4 model 3 Q 7,07 l/sec

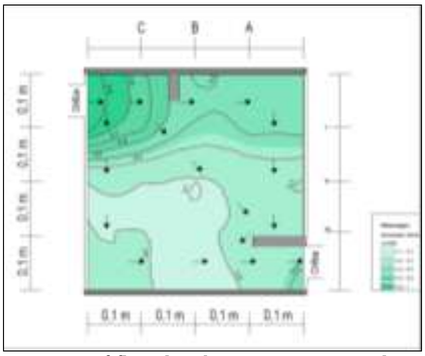

Fig. 12. The upper view of flow distribution pattern in pool 4 model 3 Q 5,69 l/sec

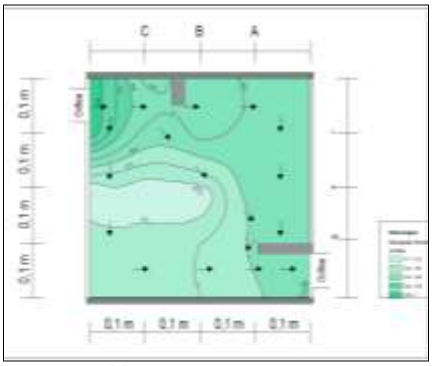

Fig. 13. The upper view of flow distribution pattern in pool 4 model 3 Q 4,48 l/sec

From the flow distribution pattern in Fig. 5 to Fig. 13, it was found that baffle addition affected flow distribution pattern. In Fig. 5 to Fig. 7, minimum flow velocity was in the middle of the pool after baffle was added in model 2 and 3, the minimum velocity happens in the near side of the line.

B. Flow Velocity Distribution Pattern of Pool 10

The maximum flow velocity in pool 10 was in 0,04-0,08 m from the bottom of the line. Accordingly, the flow distribution pattern of Pool 10 was described based on the measurement in that depth. The following is the Flow Velocity Distribution Pattern of Pool 10:

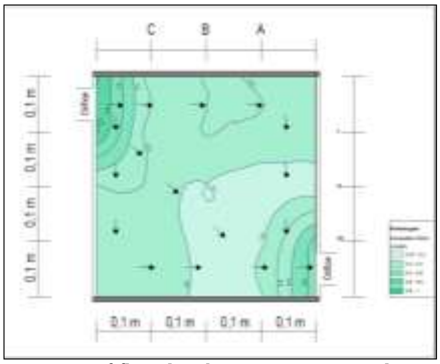

Fig. 14. The upper view of flow distribution pattern in pool 10 model 1 Q 7,07 l/sec

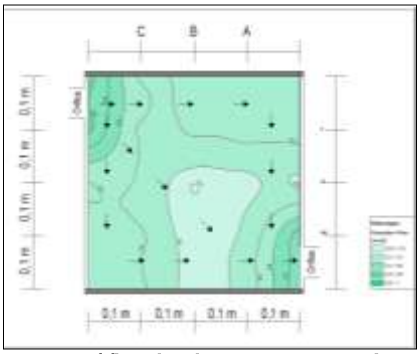

Fig. 15. The upper view of flow distribution pattern in pool 10 model 1 Q 5,69 l/sec

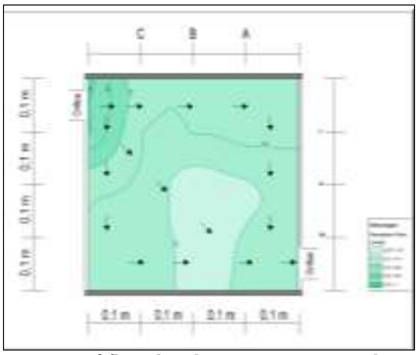

Fig. 16. The upper view of flow distribution pattern in pool 10 model 1 Q 4,48 l/sec

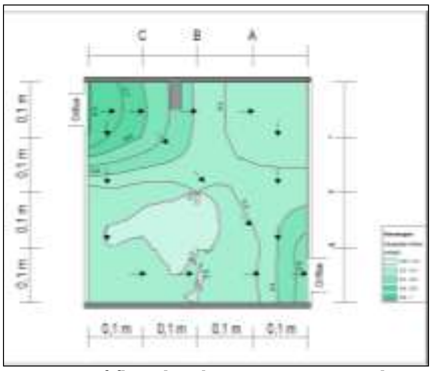

Fig. 17. The upper view of flow distribution pattern in pool 10 model 2 Q 7,07 l/sec

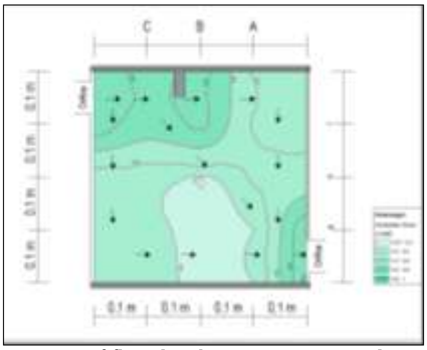

Fig. 18. The upper view of flow distribution pattern in pool 10 model 2 Q 5,69 l/sec

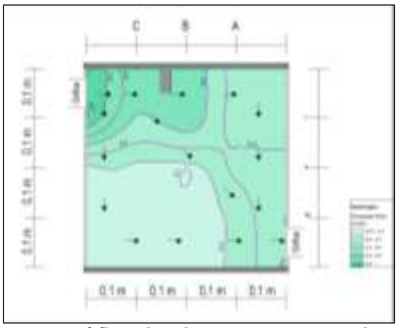

Fig. 19. The upper view of flow distribution pattern in pool 10 model 2 Q 4,48 l/sec

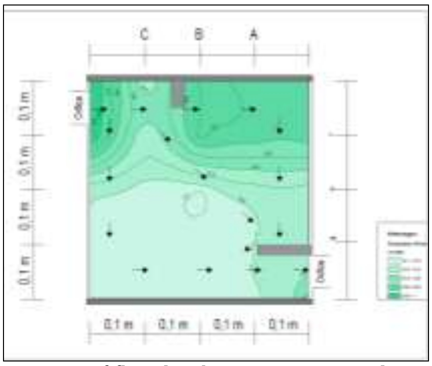

Fig. 20. The upper view of flow distribution pattern in pool 10 model 3 Q 7,07 l/sec

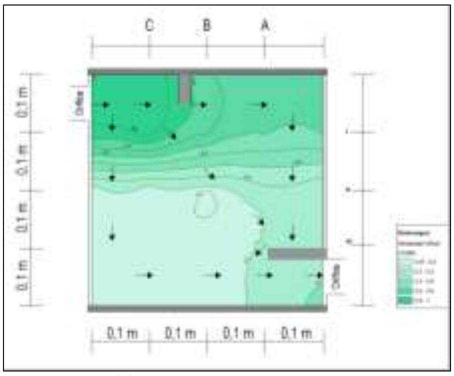

Fig. 21. The upper view of flow distribution pattern in pool 10 model 3 Q 5,69 l/sec

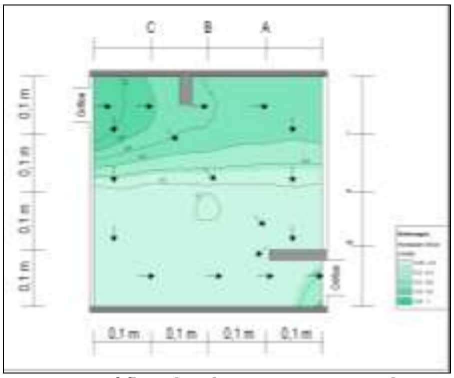

Fig. 22. The upper view of flow distribution pattern in pool 10 model 3 Q 4,48 l/sec

From Fig. 14 to Fig. 21, baffle addition also affect the flow distribution pattern in pool 10. In Fig. 14 to Fig. 18, minimum flow velocity existed only in few fishway pools, while from Fig. 20 to Fig. 22, with fishway model 3, the width of minimum velocity increased. The minimum velocity for fishway model 3 also occurs in the near side of the line.

C. Submerged Orifice Flow Velocity

Submerged orifice flow velocity is also a crucial factor because orifice functions as fish path in swimming through the fishway. The followings are the submerged orifice flow velocity:

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TABLE II. Submerged orifice flow velocity in pool 4

Discharge (Q)	Number of Design Pool Passes		
	1	2	3
l/sec	m/sec	m/sec	m/sec
7.07	1.25	0.99	0.70
5.69	1.17	0.99	0.63
4.48	0.89	0.77	0.44

TABLE III. Submerged orifice flow velocity in pool 10

Discharge (Q)	Number of Design Pool Passes		
	1	2	3
l/sec	m/sec	m/sec	m/sec
7.07	1.17	1.08	0.70
5.69	1.17	1.04	0.70
4.48	0.94	0.89	0.44

Based on Table II and table III, the maximum orifice velocity existed in model 1, the original form of pool fishway. The minimum orifice velocity existed in model 3, a model with two baffle addition. In other words, adding baffle in pool fishway, in addition to be a flow direction, can reduce the submerge orifice velocity.

V. CONCLUSION

The present study concluded that:

1. The maximum flow velocity was in 0,04-0,08 m water depth, accordingly, the description of flow velocity distribution pattern is done based on the measurement data in that depth.
2. Baffle addition functions as flow director so that the minimum flow velocity distribution can occur in the point predicted as fish swimming path in the fishway. Therefore, based on the flow velocity distribution pattern, pool 4 and 10 in model 3 have maximum result.
3. Baffle addition could also affect submerged orifice flow velocity. The minimum velocity existed in model 3.
4. Based on the result of flow distribution pattern and orifice velocity, model 3 was the most effective model to control the flow velocity in fishway pool passes.

REFERENCES

[1] Clay, C.H, *Design of Fishway and Other Fish Facilities*, Canada: Department of Fisheries, 1995.

[2] Chow, Ven Te, *Hidraulika Saluran Terbuka*, Surabaya: Penerbit Erlangga, 1992.

[3] *Fisheries Handbook*, Fish Passage Development and Evaluation Program, US Army Corps of Engineers, 1990.

[4] J.M. Santos, Ana Silva, C. Katopodi, Paulo Pinheiro, Antonio Pinheiro, Jorge Bochechas, Maria T.F., "Ecohydraulics of Pool-Type Fishways: Getting Past The Barrier," Ecological Engineering, vol 48, pp 38-50, 2012.

[5] Kamula Riitta, "Flow Over Weir With Application To Fish Passage Facilities," Ph.D Dissertation, Departement of Process and Environmental Engineering, University of Oulu, Oulu, Finland, 2001.

[6] Larinier, M, *Chapter 5: Pool Fishways, Pre-Barrages and Natural Bypass Channel*, Bull. Fr. Peche Piscic 364 suppl, pp 54-82, 2002.

[7] Laurent Tarrade, Alain Texier, Laurent David, Gerard Pineau, Michael Larinier, "An Experimental Study of Turbulent Flow in Vertical Slot," in 12th International Symposium on Flow Visualization, Germany, 2006.

[8] Marriner Adam Bryan, "Hydraulics of The Vertical Slot Fishway, A Case Study on The Vianney-Legendre Fishway in Quebec, Canada," Master of Science Thesis, Departement of Civil and Environmental Engineering, University of Alberta, Alberta, 2013.

[9] Maryono, Agus, *Rekayasa Fishway*, Yogyakarta: UGM Press

[10] Rajaratnam, N., Katopodis C., A. Mainali, "Pool Orifice and Pool Orifice Weir," Canadian Journal of Civil Engineering, vol 16, number 5, pp 774-777, 1989.

[11] Ryan Erin, R., "Effects of Hydraulic Structure on Fish Passage: An Evaluation of 2D vs 3D Hydraulic Analysis Methods," Master of Science Thesis, Department of Civil and Environtmental Engineering, Colorado State University, Colorado, 2015.

[12] S.A. Ead, C. Katopodis, G.J. Sikora, N. Rajaratnam, "Flow Regimes and Structure in Pool and Fishways," Journal Environment Engineering Science, vol 3, pp 379-390, 2004

[13] Sosrodarsono and Tominaga, Perbaikan dan Pengaturan Sungai, Jakarta: Pradnya Paramita, 1985.

[14] Subramanya, K, Flow In Open Channels (Third Edition), New Delhi: Tata McGraw-Hill Publishing Company Limited, 2009.

[15] Triatdmodjo Bambang, Hidraulika I, Yogyakarta: Beta Offset, 1993.

[16] Tritico Hans M., "The Effects of Turbulence on Habitat Selection and Swimming Kinematics of Fishes," Ph.D Dissertation, Department of Civil and Environmental Engineering and Natural Resources and Environment, University of Michigan, Michigan, 2009.