SIMULATION OF FLOW OVER PIANO KEY WEIR USING NUMERICAL AND PHYSICAL MODEL – CASE STUDY FOR DAMIL 2 WEIR

Pham Van Song[1]

Abstract: *The Piano Key Weir (PKW) is the new shape of labyrinth, is an interesting alternative. The structure of PKW provides a longer total effective crest length for a given spillway width and it has been used to increase the discharge capacity of the related spillways. PKW has been applied in many projects in several countries in the world. However, the hydraulic behavior of PKWs is still not complete understood. All the current projects under development to assess the hydraulic capacity are based on physical modelling.*

Numerical modelling is nowadays another powerful tool to solve many of hydraulics engineering problems and to predict with accuracy flow patterns on a large set of hydraulic structures. Such an approach is currently widely used by engineers all over the world. Indeed, numerical models have low application costs compared to physical models, are flexible and enable easy results analysis.

In this study, combined application of physical and numerical modelling techniques, called composite modeling has been implemented for investigation of flow over Piano Key Weirs (PKW). It enables combining the inherent advantages of both approaches, which are complementary, while being beneficial to the delays as well as the quality of the analysis.

Experimental investigations are performed on several PKW models. The effects of the variation of each of its geometric parameters on the discharge coefficient were assessed using sensitivity analysis. 3D numerical model of the flow over a PKW has been performed by using the commercial software Flow3D® and 2 cases of model are applied. One is obtained from 2D physical model with constant width W, the inlet widths (W_i) and outlet widths (W_o) are changed. The other is 3D model of Damil 2 PKW project. The experiment results are used for calibration of numerical model. Based on results, geometric parameters of Dakmi 2 PKW and operating procedures of weir have been proposed.

Keywords: Numerical model; Physical model; Piano Key Weir

1. INTRODUCTION

The reservoir is an important role in socio-economic development of each country. In which, spillway is an very important role in the reservoir project. Most pre-construction works have studied, calculated and selected to satisfy the following conditions:

- Small building volume and reasonable
- Safety and large discharge capacity
- Small flooded area
- Fast construction, convenient and easy to manage and operate
- Compliance with environmental landscape

Normally, the majority of flood spillway was built in the traditional style with Creager shape. To increase the discharge capacity, the elevation of spillway crest was decreased and the gate height was increased or expanded the spillway gates. For projects with large discharge capacity, large gate system or multiple gate layouts will make construction with high costs, difficult operation and sometimes dangerous for the work (such as gate valve stuck ...).

With increasing demand for reservoir water storage and discharge capacity, many spillways require replacement or increased storage by

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[1] *Water Resources University, Viet Nam*

optimizing their shape. The search for an optimal spillway shape maintaining high performance and low cost led to the concept of nonrectilinear spillway. The innovative shape of a non-rectilinear spillway, known as Piano Key weir (PKW), increases the total effective crest length, thereby increasing the discharge capacity of the spillway (Laugier 2007, Leite Ribeiro et al. 2009).

A PKW is a modified labyrinth weir with specific geometric characteristics such as the up- and downstream overhangs or inclined up- and downstream key floors, forming a new set of variables (Figure 1 and Figure 2). Vertical walls founded on a flat area are replaced by lateral vertical walls and sloping slabs upstream and downstream of the crest. These slabs are partially a cantilever structure, upstream and downstream. Therefore the overall structure is self balanced and plan view of PKW is not trapezoidal, but rectangular. The main advantage of the PKW as compared with labyrinth weirs is its reduced footprint, which enables it to be placed on top of structures such as gravity dams and internal slopes in the alveoli, thus reducing the forces acting on the lateral walls and hence the structural cost.

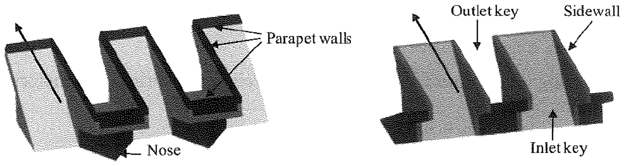

Figure 1. Components considered in the convention (left) and constitutive basic elements (right)

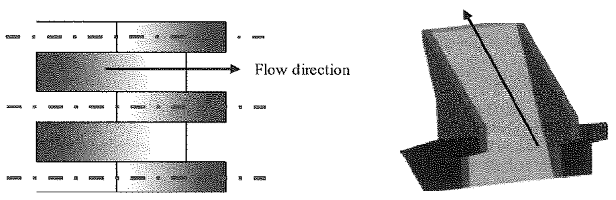

Figure 2. Plan view of the segmentation principle (left) and 3D-view of a PKW unit (right)

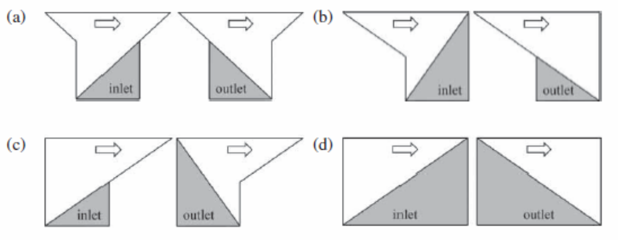

Figure 3. Different types of PKWs (Lempérière et al. 2011)

The PK weir was originally developed by Blanc and Lempérière (2001). First model studies indicated that a PKW increases the discharge capacity by up to four times that of conventional frontal weirs at equal head (Lempérière and Ouamane 2003). The first PK weir was installed in 2006 at Golours dam in France (Laugier, 2007). Since then PKweirs have been used to increase the flood discharge capacity of the three other EDF dams, namely St. Marc (2008), Etroit (2009) and Gloriettes (2010). In the research world, many researcher groups have deep study about the PKW. The design procedure was first reported by Machiels et al. (2011b). Historical reviews on the evolution from the labyrinth to the PKW are summarized by Schleiss (2011) and Lempérière et al. (2011). Initially, two main types of PK weir have been identified (Lempérière & Ouamane, 2003): Type A and type B. Type C and type D have also been created according to the presence or absence of overhangs. The chutes (apex) of type A are overhangingon both the upstream and downstream sides. Types B and C include only up- or downstream overhangs, respectively. Although type D has an inclined floor, it does not contain overhangs (Figure 3).

Many institutions in the world have performed in the meantime systemic research model investigations related to PKW hydraulics, including a wide parameter range e.g. Electricité de France (EDF), the Isfahan University of Technology (Iran), the Ecole Polytechnique Fédérale de Lausanne (Switzerland), the

University of Liège (Belgium), Utah State University (USA), University of Technology and Southern Institute of Water Resources (Vietnam) (Anderson & Tulis, 2011, Hai, N.T. et al. 2010, Hien, T.C. et al. 2006). The results of these basic research studies were published.

To unique the parameter, the standard nomenclature related to PKWs as given in Figure. 4 is applied by Pralong, J. et al. (2011)

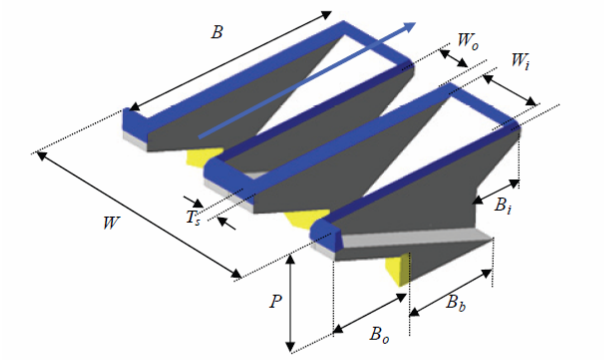

Figure 4. Standard PKW notation

As for the traditional labyrinth weirs two different approaches may be used to describe the hydraulic performance of PK weirs.

The first approach uses the standard weir equation and considers all specific PK weir parameter in a modified discharge coefficient:

$$Q = C_w L \sqrt{2g} H^{\frac{3}{2}} \qquad [1]$$

With Q as discharge, H as total head, L as developed weir length and C_w as global discharge coefficient. In such a way Machiels et al. (2009a,b) have presented C_w curves as a function of the ratio head over weir height H/P for certain PK weir designs.

The second approach uses the concept of effective crest length (Leite Ribeiro et al., 2007, 2009). A discharge enhancement ratio *r* between PK weir discharge Q_{PKW} and a sharp crested weir discharge Q_w has been defined:

$$r = \frac{Q_{PKW}}{Q_w} = \frac{C_d L_{eff} \sqrt{2g} H^{\frac{3}{2}}}{C_d W \sqrt{2g} H^{\frac{3}{2}}} = \frac{L_{eff}}{W} \qquad [2]$$

Hence, W corresponds to the total width of the PK weir. The discharge coefficient Cd of the sharp crested standard weir can be assumed as almost constant with C_d=0.42 (Hager & Schleiss, 2009). Relating the ratio of the PKW discharge to that of a linear sharpcrested weir for identical H. As PKWs spill higher discharges per width W than equivalent linear sharp-crested weirs, r>1, particularly for small H.

2. PHYSICAL MODELLING OF FLOW OVER PKW

2.1.Experimental setup

Nowadays, the combined application of physical and numerical modelling techniques, called composite modelling, is obviously the most effective response to most flow problems analyses. It enables combining the inherent advantages of both approaches, which are complementary, while being beneficial to the delays as well as the quality of the analysis (Erpicum et al., 2012a). In this study, to simulate the flow the flow through PKW and analysis of factors affecting the flow through the weir, the 2D physical model was built and implemented at the Hydraulic Laboratory in Southern Institute of Water Resources research (SIWRR).

The experimental set-up is installed in a straight flume with length L=25m, width b=1,2m and high h=1,0m (Figure 5). Based on the experimental requirements, site conditions, the laboratory's capacity and the accuracy of the measuring equipment, physical model has been built with scale λ = 1/50. Froud law is applied and physical parameters of the flow are be converted as follows:

Velocity scale: $\lambda_v = \lambda_L^{0,5} = 7.071$; Discharge scale: $\lambda_Q = \lambda_L^{2,5} = 17.677$; Roughness scale: $\lambda_n = \lambda_L^{\frac{1}{6}} = 1.919$ and Time scale: $\lambda_t = \lambda_L^{0,5} = 7.071$

Scale effects on PKWs were so far rarely discussed, so that the rules of sharp-crested weirs were applied herein. The flow condition in model has been checked in which the model flow condition is similar to the flow condition in prototype.

$$Re_m = \frac{V_m h_m}{\nu} = \frac{Q_m h_m}{\omega_m \nu} = \frac{Q_m}{B_m \nu} \qquad [3]$$

With B_t = 29 m and $Q_{t(min)}$ = 60 m^3/s, Re_m = 7244 > [Re] = (5000 ÷ 6000).

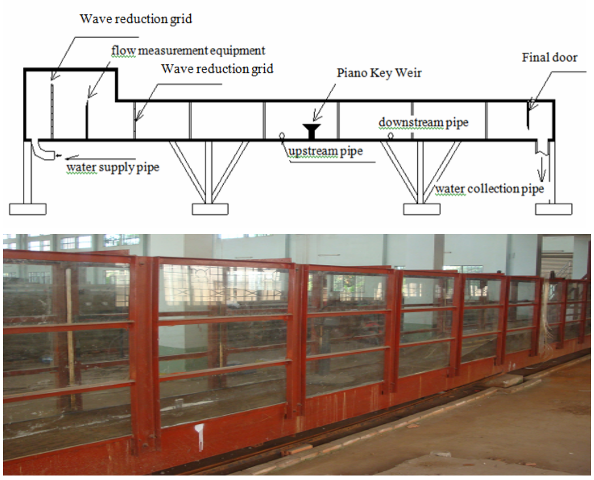

Figure 5. Section of flume model

2.2.Experimental results

In experiment, 2D model of PKW type B is implemented. The ratio between the inlet (W_i) and outlet widths (W_o) are changed while the parameters L/W=5; W/P=1.5; W_u=9.0m; P=14m are maintained constant. The experimental results are shown in Table 1 and Figure 5.

Table 1. Experimental results of flow over PKW with different ratio W_i/W_o – Comparison with Creager Weir

W_i/W_o = 0.73		W_i/W_o =1.73		W_i/W_o =2.0		Creager Weir	
H_u (m)	Q (m³/s)	H_u (m)	Q (m³/s)	H_u (m)	Q (m³/s)	H_u (m)	Q (m³/s)
0.21	16.6	0.25	23.1	0.15	11.2	0.2	8.8
0.53	77.5	0.58	99.8	0.40	58.4	0.5	32.0
1.05	244.6	0.90	222.4	0.58	113.4	0.7	62.3
1.78	481.4	1.44	405.7	0.78	192.6	1.1	127.4
2.07	573.5	2.04	599.0	1.14	316.5	1.5	207.3
2.62	750.6	2.58	777.5	1.62	474.7	1.7	252.5
3.20	938.2	3.42	1056.2	2.16	650.9	2.0	324.5
4.04	1.222.2	4.11	1301.9	2.64	810.5	2.8	558.0
4.89	1.531.7	5.06	1656.5	3.13	978.1	4.6	1163.8
5.64	1.820.1	5.86	1977.0	3.45	1.092.3	6.3	1914.6
6.10	2.001.2	6.60	2281.3	4.02	1.300.5	7.0	2268.4
6.57	2.189.2	7.41	2627.4	4.53	1.497.2	7.9	2759.1
7.10	2.401.9	8.06	2900.8	5.17	1.735.5	8.7	3210.5
7.61	2.610.7	8.37	3030.8	5.72	1.961.6	9.7	3837.9
8.22	2.857.1	8.74	3192.5	6.34	2224.8		
8.78	3.084.0	9.35	3463.5	7.03	2512.8		
9.48	3.371.7			7.82	2866.0		
				8.42	3143.2		
				8.98	3389.8		

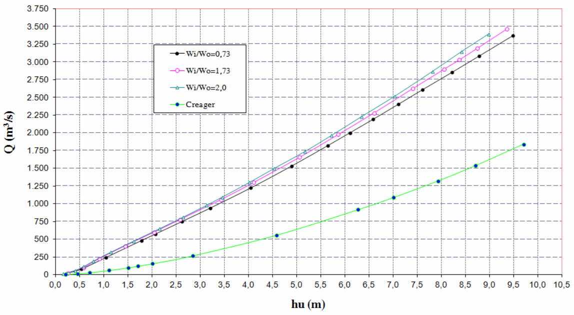

Figure 3.1. Relation curve between Q and hu – Experimental results

To define the discharge coefficient, the discharge over the PKW is determined by the standard weir equation (equation 1). From equation 1, discharge coefficient C_w can be defined:

$$C_w = \frac{Q}{W.\sqrt{2g}.h_u^{\frac{3}{2}}} \qquad [4]$$

Figure 6 shows the relation curve between discharge coefficient Cw and the water head over PKW with different ratio Wi/Wo after experiment and compare with Creager weir.

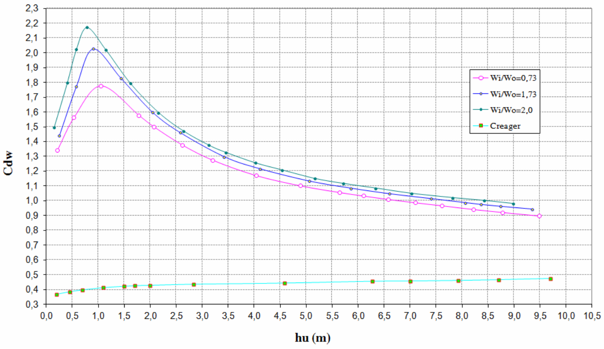

Figure 6. Relation curve between Cw and hu – Experimental results

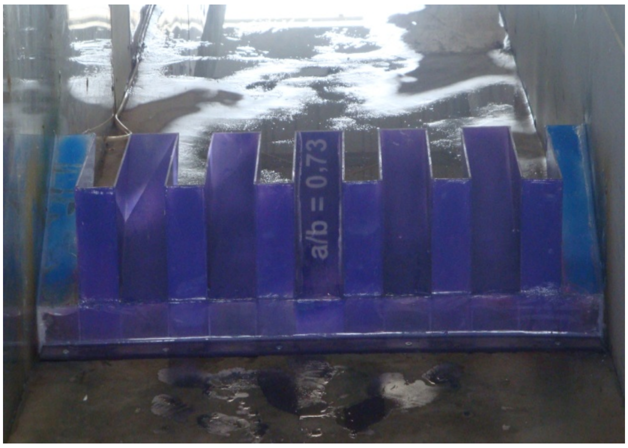

Figure 7. Flow over PKW in physical model

Experimental results show that:

With the same width W, discharge capacity through PKW greater than 3 times traditional spillway (Creager weir).

High value of discharge coefficient occurs when the water head from 0,5m to 1m. When increasing the water head from 1m, discharge coefficient is reduced several times.

Flow through spillway is the best achieved when the ratio Wi/Wo in the range of 1 to 2, the high value of discharge coefficient lies in in this range.

3. NUMERICAL MODELLING

3.1. Introduction

Various numerical hydraulic models have been developed to date in hydraulic engineering, ranging from non-spatially distributed models to full 3D flow solvers (Epicum et al., 2011). In this study, 3D modelling of the flow over a PKW has been performed by Water Resources University (WRU), Vietnam using the commercial software Flow3D®.

FLOW-3D is a well-tested, high fidelity CFD software product developed and supported by Flow Science, Inc, USA. It is designed to assist the investigation of the dynamic behavior of liquids and gases in a very broad assortment of applications. FLOW-3D has been designed for the treatment of time-dependent (transient) problems in one, two and three dimensions. Steady state results are computed as the limit of a time transient. Because the program is based on the fundamental laws of mass, momentum, and energy conservation, it is applicable to almost any type of flow process. For this reason, FLOW-3D is often referred to as a "general purpose" CFD solver. In FLOW-3D, free surfaces are modeled with the Volume of Fluid (VOF) technique. The VOF method consists of three ingredients: a scheme to locate the surface, an algorithm to track the surface as a sharp interface moving through a computational grid, and a means of applying boundary conditions at the surface.

To solve the governing equations of fluid flow, Flow-3D solves a modification of the commonly used Reynolds-average Navier-Stokes (RANS) equations.

Continuity:

$$\frac{\partial}{\partial x}(uA_x)+\frac{\partial}{\partial y}(vA_y)+\frac{\partial}{\partial z}(wA_z)=0 \qquad [5]$$

Momentum:

$$\frac{\partial U_i}{\partial t}+\frac{1}{V_F}\left(U_jA_j\frac{\partial U_i}{\partial x_j}\right)=\frac{1}{\rho}\frac{\partial P'}{\partial x_i}+g_i+f_i \qquad [6]$$

The variables u, v and w represent the velocities in the x-, y-, z-directions; V_F = volume fraction of fluid in each cell; A_x, A_y, and A_z = fraction areas open to flow in the subscript directions; subscripts i and j represent flow directions; ρ = density, P' is defined as the pressure; U_j and A_j are velocity and cell face area in the subscript directions, respectively; g_i = gravitational force in the subscript directions; and f_i represents the Reynolds stresses for which a turbulence model is required for closure. It can be seen that, in cells completely full of fluid, V_F and A_j equal 1, thereby reducing the equations to the basic incompressible RANS equations.

Turbulence models are based on Renormalization Group (RNG). The RNG model uses equations similar to the equations for the k-ε model.

3.2. Geometry, boundary condition, calibration of the numerical model

For numerical model, 2 cases of model have been applied. One is obtained from 2D physical model with constant width W (Figure 8), the inlet widths (W_i) and outlet widths (W_o) will be changed. Other is 3D model of Damil 2 PKW project.

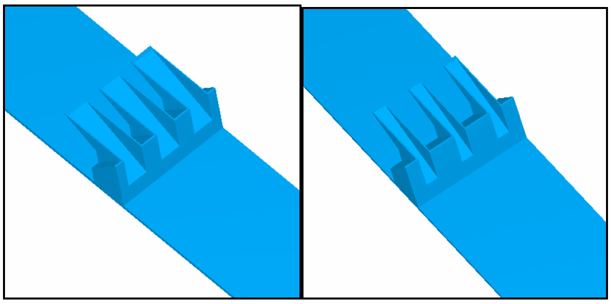

Figure 8. Geometry of PKW: Wi/Wo=0,73 (left); Wi/Wo=2 (right)

The simulation domain was created with 29m wide, 89m long (upstream and downstream stretches out to create a stable flow). PKW is chosen in type B, the inlet (W_i) and outlet widths (W_o) are changed ($W_i/W_o=0.5$; $W_i/W_o=0.73$; $W_i/W_o=1$; $W_i/W_o=1.25$; $W_i/W_o=1.5$; $W_i/W_o=1.73$; $W_i/W_o=2$) while the parameters L/W=5, W/P=1.5; Wu=9.0m; P=14.0m are constant.

The mesh is defined with 3 block: Upstream block (block 1), PKW block (block 2) and downstream block (block 3) (Figure 9).

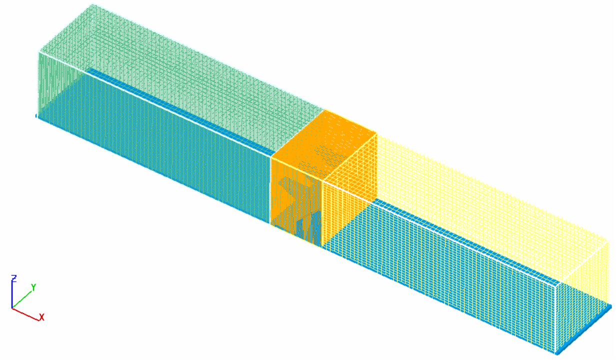

Figure 9. Domain with three blocks

Experimental results corresponding to three pairs of values W_i/W_o will be used to calibrate numerical model. For calibration, the roughness coefficient was changed from 0,00 to 0,03 and even larger but not change the results significantly. The results shows the good agreement between the numerical and experimental results (Figure 10 and 11) and the roughness coefficient is choosen as 0,025.

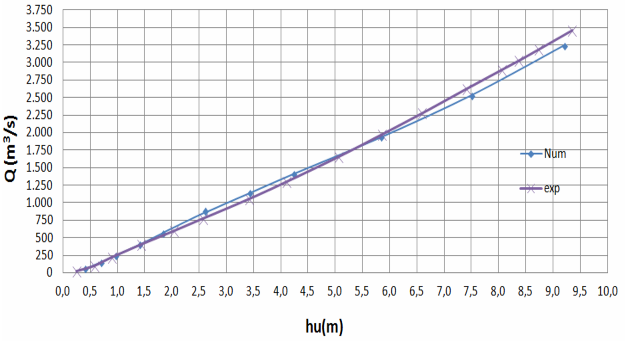

Figure 10. Comparison of discharge capacity between experimental and numerical result (Wi/Wo =0.73)

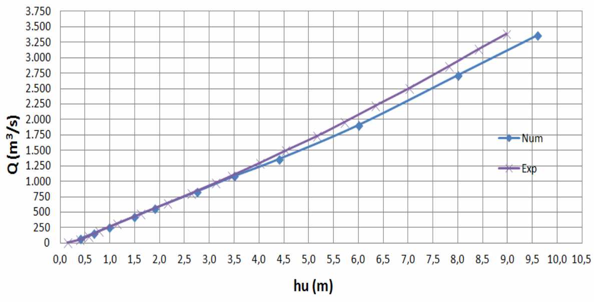

Figure 11. Comparison of discharge capacity between experimental and numerical result (Wi/Wo =2.0)

3.3. Numerical results

Figure 12 shows the simulated water surface profile over PKW and figure 13. shows the velocity field in numerical simulation. Table 2 and figure 14 show the numerical results of flow over PKW.

After simulation with many cases (different ratio of W_i/W_o), maximal discharge coefficient C_W occurs when $W_i/W_o=1$. For design process, the ratio W_i/W_o should be in the range from 1 ÷ 1.25.

The results also show that with the same width W=29m, when hu > 6m, the effectiveness of PKW descending tends to work as a traditional weir. The discharge of flow over PKW in type B is larger 1.7 to 2.9 times than of the Creager weir. When the upstream flow depth over crest increased to hu = (6 ÷ 8.5)m, the flow through the PKW is asymptotic with Creager (figure 14).

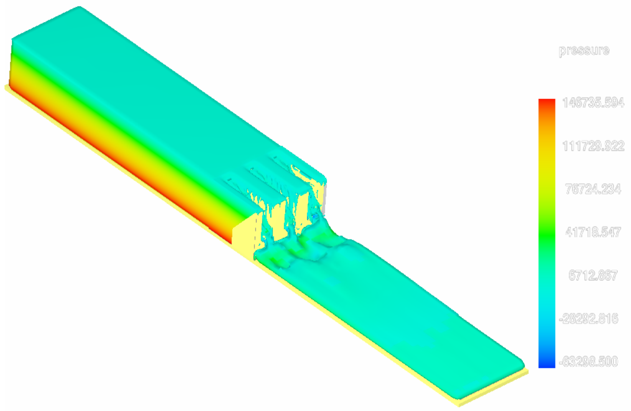

Figure 12. Pressure field of flow over PKW – Numerical result

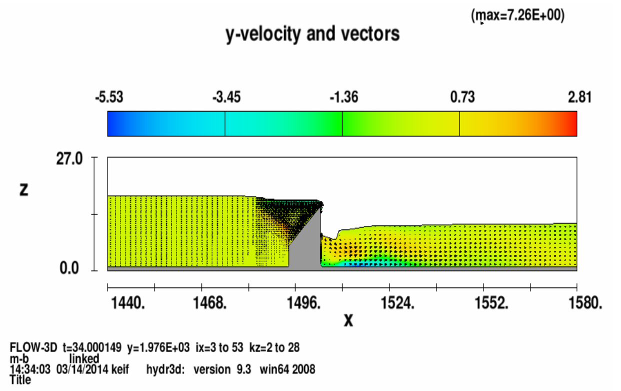

Figure 13. Velocity field of flow over PKW – Numerical result

Table 2. Numerical results of flow over PKW with different ratio W_i/W_o

W_i/W_o = 0.5		W_i/W_o = 0.73		W_i/W_o = 1.0		W_i/W_o = 1.25	
H_u (m)	Q (m^3/s)	H_u (m)	Q (m^3/s)	H_u (m)	Q (m^3/s)	H_u (m)	Q (m^3/s)
0.40	67.0	0.40	60.4	0.30	41.0	0.40	67
0.69	155.0	0.69	155.0	0.40	66.0	0.69	165
0.97	243.0	0.96	248.0	0.69	169.0	0.96	261
1.42	400.0	1.40	405.0	0.95	265.0	1.40	434
1.85	555.0	1.83	570.0	1.40	436.0	1.83	613
2.66	845.0	2.62	885.0	1.83	608.0	2.66	926
4.30	1322.0	3.43	1193.0	2.63	932.0	3.50	1233
5.80	1827.0	4.23	1418.0	3.44	1245.0	4.33	1493
7.36	2398.0	5.84	1935.0	4.27	1552.0	6.05	1970
9.00	3042.0	7.50	2551.0	5.92	2122.0	7.72	2547
		9.20	3174.0	7.68	2716	9.39	3150

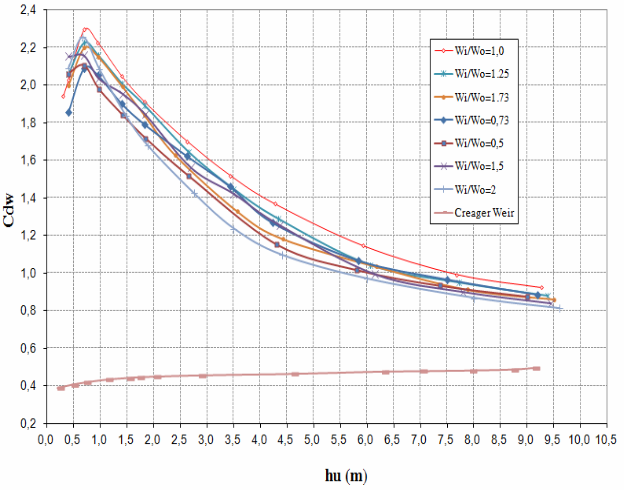

Figure 14. Relation curve between discharge coefficient (C_w) and water head (hu) – Numerical results

3.4. Numerical simulation of flow over Dakmi2 weir

3.4.1. Introduction of Dakmi2 project

Dakmi 2 is a multipurpose scheme with irrigation and hydro features (98MW) in Dakmi River, Quang Nam province, Vietnam. The dam is a 38m high, 145m wide concrete gravity structure in a narrow valley with a high flood discharge.

The dam has been designed with a 31m wide, central gated spillway, and 37.5m wide PKW (type B) on each side of the structure (Figure 15). The maximum discharge capacity of the gates spillway is 3000m^3/s and combined capacities of PKW is 3440m^3/s, and together they are designed to pass a 1000-year flood of 6500m^3/s.

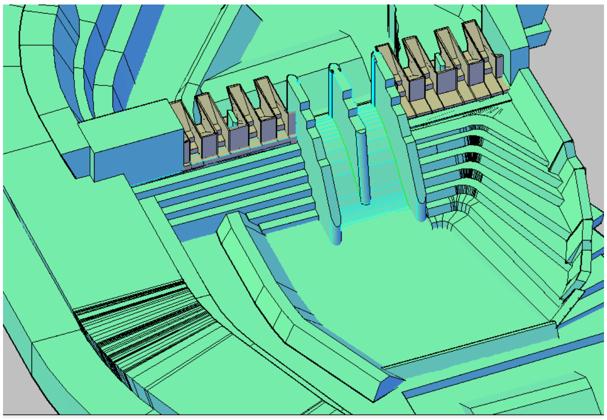

Figure 15. 3D view of Dakmi 2 project (gated spillway combined with PKW)

In preliminary design process, the preliminary parameters of the PKW were selected as follows:

Height of the wall: P_m = 6m; Base length: B_b = $1.5P_m$ = 9.0m; Upstream (outlet key) overhang crest length: B_o = $1.5P_m$ = 9.0m; Upstream-downstream length of the PKW: B = $3P_m$ = 18m; Width of a PKW unit: W_u = 1.5Pm = 9.0m and developed length of the PKW unit: $L_u = W_u + 6P_m$ = 45m.

Simulation results on 2D model shows that for PKW in type B, discharge coefficient C_w reached a maximum value when ratio W_i/W_o = 1. In this case, discharge through PKW will be the highest efficiency. Hence, the inlet key width (W_i) and the outlet key width (W_o) are selected as $W_i = W_o = W_u/2$ = 4.5m in this project.

3.4.2.Numerical simulation

The 3D model of Dakmi 2 spillway was built with purposes:

- Optimizing the general width selection and the width of the inlet and outlet key on the basis of the 2D model.
- Selection of appropriate operating procedures for gated spillway to serve the flood discharge.
- Decrease the time and cost of the physical investigations.

The simulation domain is created with 160m wide, 360 long, 47m high. The meshes of domain consist of five blocks with parameters as follow (see figure 16):

- Block 1: 160m wide, 75m long, 47m high. The grid size is 2.5m for X direction, 2.5m for Y direction and 1.5m for Z direction.
- Block 2: 160m wide, 105m long, 47m high. The grid size is 1.5m for X direction, 1.5m for Y direction and 1m for Z direction.
- Block 3 (PKW on the right): 42m wide, 23m long, 20m high. The grid size is 0.6m for X direction, 0.3m for Y direction and 0.6m for Z direction.
- Block 4 (PKW on the left): 42m wide, 23m long, 20m high. The grid size is 0.6m for X direction, 0.3m for Y direction, 0.6m for Z direction.
- Block 5: 160m wide, 180m long, 47m high. The grid size is 2.5m for X direction, 2.5m for Y direction and 2.5m for Z direction.

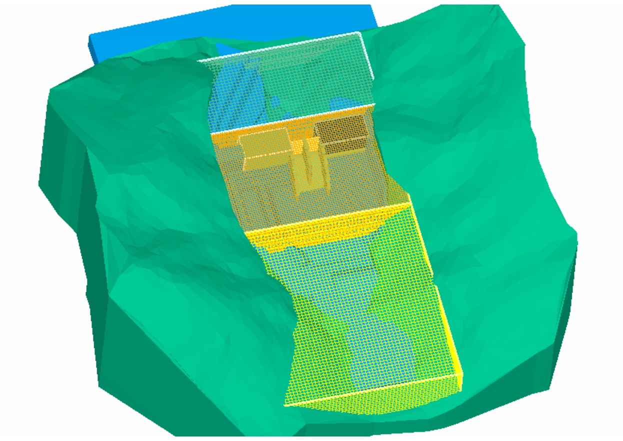

Figure 16. Simulation domain with five blocks in FLOW – 3D

Figure 17 shows the numerical result of flow over Damik 2 weir and Table 3 shows the detail discharge capacity of weir with different water levels of reservoir.

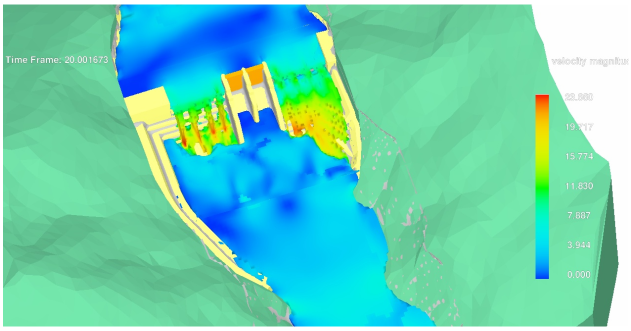

Figure 17. Numerical results of water surface profile in Dakmi 2 project

Table 3. The discharge capacity of DakMi 2 weir - Numerical result

Reservoir water level (m)	Q_{total} (m^3/s)	Q_{gate} (m^3/s)	Q_{PKW} (m^3/s)
635.20	6492	3022	3470
635.00	6319	2951	3368
634.00	5608	2675	2933
633.46	5096	2538	2558

633.00	4589	2418	2171
632.00	3573	2167	1406
631.00	2581	1941	640
630.00	1723	1723	0.0
629.00	1512	1512	0.0
628.00	1340	1340	0.0
627.00	1145	1145	0.0
626.00	969	969	0.0
625.00	790	790	0.0

The results show that when the gated spillway combined with PKW, flood discharge capacity will increase significantly. Based on the simulation results, operating procedures of Dakmi 2 weir are proposed as follows: When the upstream water head hu ≤ 0.7 m, the gate system is closed, only PKW is working. When the upstream water head over crest hu > 0,7 m, the gate will open and regulate until hu = 0,7 m ($Z_{reservoir}$ = 630,7 m) to serve power generation.

Parameters of Dakmi 2 PKW are also proposed after analyzing simulation results.

- Inlet key width: W_i = 4.5m
- Outlet key width: W_o = 4.5m
- Height of the wall: P_m = 6m
- Base length: B_b = 9.0m
- Upstream (outlet key) overhang crest length: B_o = 9,0m
- Upstream-downstream length of the PKW: B = 18.0m
- Width of a PKW unit: W_u = 9.0m

4. CONCLUSIONS

In this study, combined application of physical and numerical modelling techniques, called composite modeling has been implemented for investigation of flow over Piano Key Weirs (PKW).

Experimental investigations were been performed on several PKW models. The effects of the variation of each of its geometric parameters on the discharge coefficient were assessed using sensitivity analysis. Beside the physical model, 3D numerical model of the flow over a PKW has been performed by using the commercial software Flow3D®.

For numerical model, 2 cases of model have been applied. One was obtained from 2D physical model with constant width W, the inlet widths (W_i) and outlet widths (W_o) were changed. Other was 3D model of Damil 2 PKW project. The experiment results are used for calibration of numerical model.

The results indicate that with the same width W, discharge capacity through PKW greater than 3 times traditional spillway (Creager weir).

High value of discharge coefficient occurs when the water head from 0,5m to 1m. When increasing the water head from 1m, discharge coefficient is reduced several times.

Discharge capacity is the best achieved when the ratio Wi/Wo in the range of 1 to 2, the high value of discharge coefficient lies in in this range.

The results also show that with the same width W=29m, when hu > 6m, the effectiveness of PKW descending tends to work as a traditional weir. The discharge of flow over PKW in type B is larger 1.7 to 2.9 times than of the Creager weir. When the upstream flow depth over crest increased to hu = (6 ÷ 8.5)m, the flow through the PKW is asymptotic with Creager.

Based on results of Damik 2 weir numerical model, detail geometric parameters of Dakmi 2 PKW and operating procedures of weir have been proposed.

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Tóm tắt

MÔ PHỎNG DÒNG CHẢY QUA TRÀN NGƯỠNG PHÍM PIANO BẰNG MÔ HÌNH VẬT LÝ VÀ MÔ HÌNH TOÁN – ÁP DỤNG CHO TRÀN XẢ LŨ ĐĂKMIL 2

Phạm Văn Song

Tràn có ngưỡng kiểu dạng phím Piano (PKW) là dạng tràn mới, biến thể từ dạng tràn Lybarinth. So với tràn truyền thống với cùng bề rộng, khả năng tháo của tràn PKW tăng lên do cấu trúc của tràn làm tăng chiều rộng hiệu quả. Tràn PKW đã được áp dụng cho nhiều dự án ở một số quốc gia trên thế giới. Tuy nhiên cơ sở khoa học về chế độ thủy lực của tràn cũng như các thông số về thủy lực chưa được làm rõ và xác định cụ thể. Trong tất cả các dự án về tràn PKW, việc xác định các thông số thiết kế cũng như khả năng tháo của tràn phải dựa trên kết quả thí nghiệm trên mô hình vật lý.

Hiện nay, mô hình toán là một công cụ hiệu quả để giải quyết các vấn đề về thủy lực nói chung cũng như các vấn đề cụ thể trong việc thiết kế các công trình thủy lợi nói riêng. Cách tiếp cận này được các nhà khoa học sử dụng rộng rãi do tính ưu việt của nó. Việc thực hiện mô phỏng trên mô hình toán tiện lợi, linh động, truy xuất và phân tích kết quả dễ dàng và rẻ hơn so với mô hình vật lý.

Trong nghiên cứu này, việc khảo sát dòng chảy qua tràn PKW được thực hiện bởi sự kết hợp cả hai phương pháp mô hình vật lý và mô hịnh toán. Phương pháp tích hợp này kết hợp điểm mạnh của cả hai phương pháp để khảo sát dòng chảy qua công trình. Thí nghiệm mô hình vật lý được thực hiện trên một số phân đoạn tràn PKW. Thông qua thí nghiệm mô hình vật lý, ảnh hưởng của các thông số mặt cắt tràn tới khả năng tháo của loại tràn này sẽ được đánh giá, phân tích rõ. Mô hình toán 3 chiều mô phỏng dòng chảy qua tràn PKW được thực hiện thông qua phần mềm Flow-3D với 2 trường hợp. Một trường hợp được lấy từ mô hình 2D đã được khảo sát trên mô hình vật lý với chiều rộng tổng thể W là cố định, chiều rộng ô đón nước (W_i) và ô tháo nước W_o thay đổi. Trường hợp mô phỏng thứ 2 được thực hiện trên mô hình của tràn xả lũ Đakmi 2, tỉnh Quảng Nam. Kết quả thí nghiệm trên mô hình vật lý được sử dụng cho việc cân chỉnh, hiệu chỉnh mô hình toán. Dựa trên kết quả mô phỏng, các thông số thiết kế của tràn Dakmi 2 cũng như quy trình vận hành tràn có cửa kết hợp với tràn PKW được đề xuất.

Keywords: Mô hình toán; Mô hình vật lý; Tràn Piano

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