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HYDRAULIC MODEL TEST OF "SKI JUMP SPILLWAY WITH MULTI FLIP BUCKETS" APPLIED TO THE NAM NGIEP 1 HYDROPOWER PROJECT (*)

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1. INTRODUCTION

The site of the Nam Ngiep 1 hydropower project (Project) is located along the Nam Ngiep River, 145 km northeast of Vientiane, the capital of Lao PDR and 50 km north of Paksan city as shown in Fig. 1.

The Project consists of a main dam and a re-regulation dam. The crest length and dam height for the main dam, RCC gravity dam, are 530 m and 148 m respectively. The reservoir created by the dam will store water of around 10 billion m^3 to generate the electricity of maximum output of 272 MW for exporting to Thailand. The re-regulation dam, concrete gravity dam, labyrinth spillway, are located 6.5 km downstream of the main dam, and its crest length and dam height are 252.6 m and 20.6 m respectively. Main feature of the project is shown in Table 1.

(*) *Test du modèle hydraulique du « déversoir tremplin à auges de déflexion multiples » appliqué à l'aménagement hydraulique de Nam Ngiep 1.*

The topography around the main dam has characteristic of narrow gouge and lots of deposits including big boulder on the river bed. Considering these conditions, the Multi Flip Bucket Type is adopted for the spillway of the main dam in order to improve its economy.

Fig. 1
Project location
Emplacement du projet

It is probable that sediments on riverbed could be moved to downstream by diving water from the ski jump spillway, thereby formulating the deposition of sediment which leads the increase of the tail water level. This may result in decreasing the energy generation. Multi Flip Bucket Type has multi chutes with different elevations and angles for discharging water to disperse diving points. It can mitigate the impact of diving water to prevent the increase of the tail water level and the decrease of energy generation due to moved river deposits.

Although there are lots of precedent studies of ski jump spillway, the hydraulic model tests have been carried out due to the characteristic of the Project site as follows;

- Precipitous gouge and narrow river compared to the width of the spillway chute
- Probability of damage to powerhouse and access road
- Large amount of discharge with high elevation of chutes
- Large amount of deposits at diving points including big boulders

Due to the lack of precedent studies of similar spillway, it has not been established how to estimate the total amount of scored and deposition volume, and therefore, hydraulic model tests have been carried out to confirm the hydraulic characteristics of the spillway of the main dam. The application of “Multi Flip Bucket Type“ to the Project is verified considering the following issues;

- Design of the spillway gates, chutes, guide walls, aerators, flip buckets and deflector for appropriate diving point, stable discharge, and reduction of splash is carried out.
- Width, angles, radius, and elevations of flip buckets are determined to minimize the scoring and deposition of riverbed, and to prevent the increase of the tail water level. Additionally, the effect of pre-excavation of downstream riverbed is evaluated.

Table 1
Main features of the project

Facility	Items	Unit	Specifications
Main Reservoir	Effective storage capacity	10^6 m^3	1,192
	Catchment area	km^2	3,700
	Average annual inflow	m^3/s	148.4
Main dam	Type	-	Concrete gravity dam, Roller-Compacted Concrete
	Dam height	m	148.0
	Crest length	m	530.0
	Dam volume	10^3 m^3	2,245
Spillway (Ski jump type)	Gate type	-	Radial gate
	Number of gates	-	4
	Design flood	m^3/s	5,210 (1,000-year)
Turbine and generator	Maximum plant discharge	m^3/s	230.0
	Effective head	m	130.9
	Rated output	MW	272 at Substation

2. SKI JUMP SPILLWAY WITH MULTI FLIP BUCKETS OF NAM NGIEP 1 HYDROPOWER PROJECT

In many cases, a ski jump or hydraulic jump type of spillway is adopted as its energy dissipator. Energy dissipation by means of hydraulic jump type of spillway is controllable as designed though it requires more excavation and concrete for dissipators, apron, and guide walls. On the other hand, ski jump type requires less facilities and smaller volume of excavation as shown in Fig. 2 but has more impact to downstream, causing scoring and deposition.

Ski jump type, which can have more economical advantage, is adopted for the Project, in light of the characteristics of the energy dissipation of both types, and features of the topography at the site.

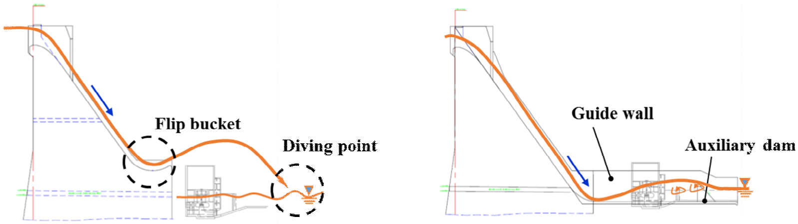

Fig. 2
Left: Ski jump type, Right: Hydraulic type
A gauche : type tremplin, à droite : type hydraulique

Basic design of the ski jump spillway was studied with reference to precedent projects and its main features of the spillway are described in Table.2.

The layout of relevant facilities is described in Fig.3 and 4. In addition to the normal ski jump type as shown in (a) of Fig.5, the hydraulic model tests with Multi Flip Buckets Type as shown (b) of Fig.5 were also carried out.

Table 2
Main features of the spillway

Feature		Normal ski jump	Multi Flip Bucket Type
Chute	Bay number	1	3
	Width of the terminal point	36 m	Center lane: 25 m, Outside lane: 12.5m * 2 lane
Flip bucket	Radius	25 m	Center lane: 15 m, Outside lane: 15 m
	Angle	35 degree	Center lane: 45 degree, Outside lane: 0 degree
Spillway	Falling height of effluent	114 m	Center lane: 114m, Outside lane: 123 m
	Discharge intensity	106 m³/s/m	106 m³/s/m
	Flying length	250 m	Center lane: 250 m, Outside lane: 110m

Fig. 3
Site of relevant facility
Site de l'installation concernée

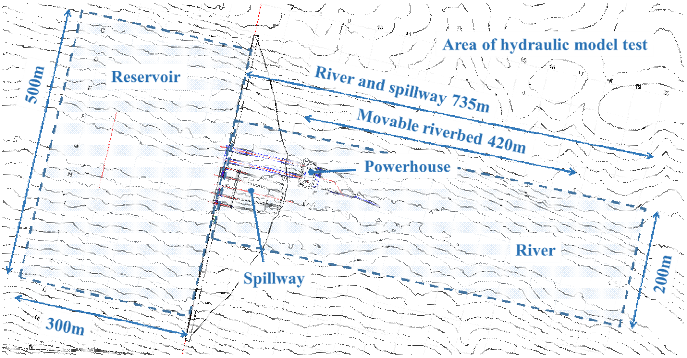

Fig. 4
Layout of relevant facility and area of hydraulic model test
Disposition de l'installation concernée et zone de test du modèle hydraulique

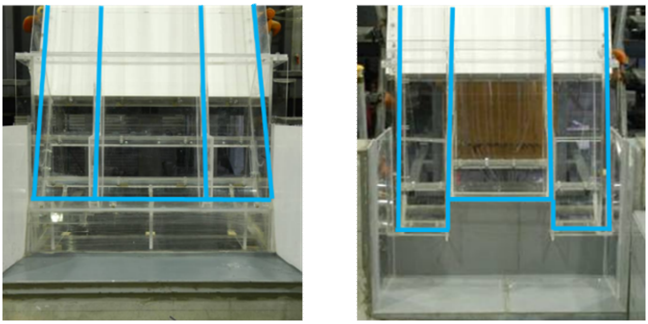

Fig. 5
Left: Normal ski jump, Right: Multi Flip Bucket Type
A gauche : tremplin normal, à droite : type à plusieurs auges de déflexion

3. GENERAL OF HYDRAULIC MODEL TEST

The hydraulic model includes the reservoir, main dam, spillway, and downstream riverbed as described in Fig. 4. The scale of the model is 1:65 which is calculated based on the Fluid rule.

Steel beams are used for the frame material for the reservoir of the hydraulic model tests. The scope of the modeling for the reservoir is 500 m×300 m as shown in Fig. 4, in consideration of the dimension of the spillway gates. The model of the spillway and the main dam is made of acrylic plates.

The scope of the model tests of downstream should be determined in consideration of the hydraulic characteristics including dispersion width of discharge, and the geological conditions including deposits and big boulders on the riverbed around the diving points. The scope of the modeling area includes 200 m in width, 735 m in length, 70 m in height as shown in Fig. 4.

The geological conditions of the downstream of the main dam are evaluated based on the site survey including site reconnaissance, drilling surveys and other laboratory tests. Considering the diving points, 420 m downstream of the main dam is evaluated to be movable riverbed, and the more downstream area is model as fixed river bed. The model structure for the fixed riverbed is made of mortal and the roughness of the riverbed is modeled by brushing the mortal. The movable riverbed of the model tests is made of small stones with the diameter of 15 to 5 mm which represents big stones with the diameter of 975 to 325 mm. The photo of the model structures and grading curves are described in Fig. 6 and 7 respectively.

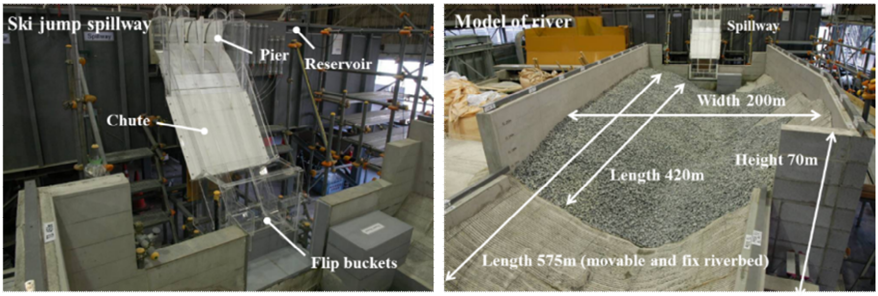

Fig. 6
Model structures
Maquettes

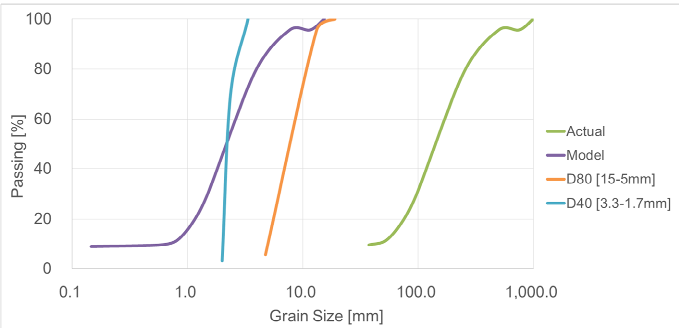

Fig. 7
Grading distribution curve
Courbe de distribution granulométrique

4. TEST PROGRAM

4.1. GENERAL

The test program for the hydraulic model tests is shown in Table 3. In the phase 1 and phase 2, the hydraulic model tests for the normal ski jump spillway and the Multi Flip Buckets Type were carried out respectively. The appropriate shape and dimension of the intake approach, piers, crests, aeration, guide walls, chutes, deflector, and flip buckets are verified through the hydraulic model tests with measuring water level, negative pressure, flow velocity and river bed deposition.

Table 3
Hydraulic model test program

Phase	Item		Measurement	Discharge [m^3/s]	Comparison cases
Phase 1	Item-1	Intake approach	Discharge capacity	5,210	-
	Item-2	Pier	Air bearing	2,530, 3,413	Additional concrete of: (1) 0 m, (2) 4 m
	Item-3	Crest, Flip bucket	Negative pressure	2,530, 5,210	-
	Item-4	Aeration	Flow turbulence Negative pressure	5,210	(1) None, (2) 12.0m*0.3m
	Item-5	Chute width	Flow turbulence	5,210	(1) 36 m, (2) 50 m
	Item-6	Flip bucket radius	Flow turbulence	5,210	(1) 25 m, (2) 20 m, (3) 15 m
	Item-7	Flip bucket angle	Water level, velocity, riverbed deposition, Flow turbulence	5,210	(1) 45 degree, (2) 30 degree
	Item-8	Middle training wall	Flow turbulence	5,210	(1) With guide wall (2) Without guide wall
	Item-9	Deflector	Flow turbulence	2,530 5,210	(1) 0 m, (2) 1 m, (3) 2 m, (4) 3 m
	Item-10	Moveable riverbed	Water level, Riverbed deposition	5,210	(1) Without pre-excavation (2) 380,000 m^3 (pre-excavation) (3) 470,000 m^3 (pre-excavation) (4) 500,000 m^3 (pre-excavation) (5) 500,000 m^3 (pre-blasting)
Phase 2	Item-7	Flip bucket angle of outside lane	Water level, Riverbed deposition	5,210	(pre-6) 45 degree, (6) 15 degree
	Item-8	Middle training wall	Flow turbulence	2,530 5,210	(1) With guide wall (2) Without guide wall
	Item-9	Deflector	Flow turbulence	2,530 5,210	(1) 0 m, (2) 2 m, (3) 3 m
	Item-10	Moveable riverbed	Water level, velocity, riverbed deposition, Flow turbulence	2,530 5,210	(6) Without pre-excavation (7) 80,000m^3 (pre-excavation) (8) 150,000m^3 (pre-excavation)

[Note] Underlined part is the adopted cases

Various cases of discharge of 1,590 m^3/s (5 years return period), 2,530 m^3/s (30 years return period) , 5,210m^3/s (design flood) were considered.

In this paper, the detail of the results for the flip angle and movable riverbed are mentioned.

4.2. ITEM-7 AND 10 MOVABLE BED [PHASE 1 AND 2]

4.2.1. Movable bed test of original topography

Movable bed tests were carried out to evaluate scoring of the riverbed, deposition of the riverbed, diving points, impacts to the tail water level, and impacts to the current topography. Additionally, both of the hydraulic tests of the normal ski jump spillway and Multi Flip Buckets Type are carried out to compare and evaluate the difference between both types of spillway.

As shown in Table 4, three cases of the hydraulic tests with the water discharge of 5,210 m^3/s (design flood) are carried out to evaluate the hydraulic characteristics of each case.

The results of the hydraulic model tests are as shown in Table 5 and Fig. 8 to 12. The results of the hydraulic characteristics are summarized as follows:

- Large volume riverbed deposits are scored at the diving points as shown in Fig. 8 and 9.
- In the case of the Multi Flip Buckets Type, outside lanes are set to disperse the diving point and results in reducing the total volume of scored riverbed and impact area of the diving water. It follows that such adverse effects due to the diving water as the surging of tail water level and the risk of the failures of both banks of downstream can be reduced as shown in Table 5, Fig. 10 and 11.
- As shown in Fig. 12, diving points from the outside lanes with flip angle of 0 degree is about 110 m downstream (TD.110 m) from the main dam while the diving point from the center lane is TD.250 m according to the results of case pre-6. In this case, river deposits are moved to the tailrace due to the diving impact from the center and outside lanes. The flip angle of the outside lanes is modified from 0 to 15 degree (case 6). As shown in Fig. 12, the diving points become TD.170m, which reduce the deposition to the tailrace and the tail water level become lower due to the reduction of sedimentation around the tailrace. Therefore, the Multi Flip Buckets Type with the flip angle of 15 degree is adopted.
- In the case of the Multi Flip Buckets Type, the tail water level, the average river water level and the elevation of river bed are lower by 6.7 m, 3.0 m and 0.5 m respectively compared to those of the normal ski jump type. Dispersion of diving points due to the Multi Flip Buckets Type and smaller flip angle of

15 degree increases the horizontal energy, resulting in the reduction of the water level as shown in Table 5 and Fig. 10.

- The effects of the energy dissipater are confirmed by measuring the water velocity of the downstream. The water flow at the downstream of the main dam are sufficiently dissipated and the velocities in the hydraulic model tests are around 9.3 m/s conforming to the results of the non-uniform flow calculation by which the water flow velocity is calculated from the conjunction of Nam Ngiep and Mekong River. Both water velocities at the downstream of the main dam are almost the same between the normal ski jump type and the Multi Flip Buckets Type as shown in Table 5.

Table 4
Cases of hydraulic model test

Case	Flip bucket	Outside lane		Center lane	
		Angle [degree]	EL. [m]	Angle [degree]	EL. [m]
case 1	Normal ski jump	-	-	45	206.5
case pre-6	Multi Flip Bucket Type	0	197.0	45	206.5
case 6	Multi Flip Bucket Type	15	197.5	45	206.5

[Note]Discharge: 5,210m³/s (Design flood), Width of flip buckets: Severally, Deflector: Severally

Table 5
Summary of test results

Item	Unit	case 1	case 6	Difference	Remarks	(Ref) case pre-6
Tail water level	m	202.8	196.1	(-) 6.7	Lower water level	197.4
Tail water level-GL.193m	m	9.8	3.1	(-) 6.7	Lower water level	4.4
River water level	m	208.4	205.4	(-) 3	-	-
Deposition elevation	m	195.9	195.4	(-) 0.5	-	-
Difference (Score – Deposition) volume	$*10^3\ m^3$	494	279	(-) 215	Reduction of scoring	224
Score volume	$*10^3\ m^3$	709	481	(-) 228	Reduction of scoring	502
Deposition volume	$*10^3\ m^3$	215	202	(-) 13	Increase deposition	278
Velocity of downstream 700 m from dam axis	m/s	10.9	10.5	(-) 0.4	Almost same as the the non-uniform flow calculation of 9.3 m/s	10.8
Vortex	-	No	No	-	-	Adverse vortex

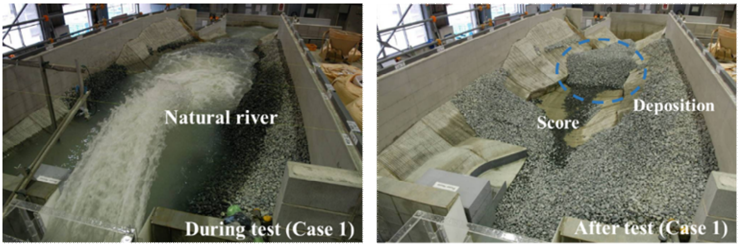

Fig. 8
Hydraulic model tests of case 1
Tests du modèle hydraulique pour le cas 1

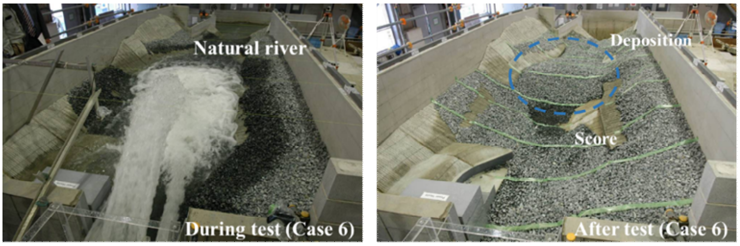

Fig. 9
Hydraulic model tests of case 6
Tests du modèle hydraulique pour le cas 6

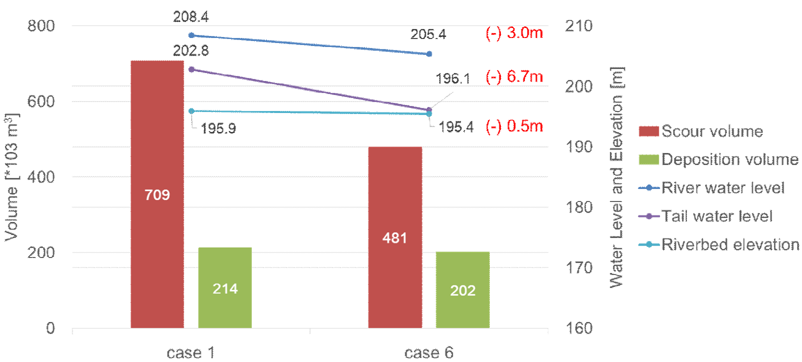

Fig. 10
Result of movable riverbed (case 1 and 6)
Résultat du lit de cours d'eau déplaçable (cas 1 et 6)

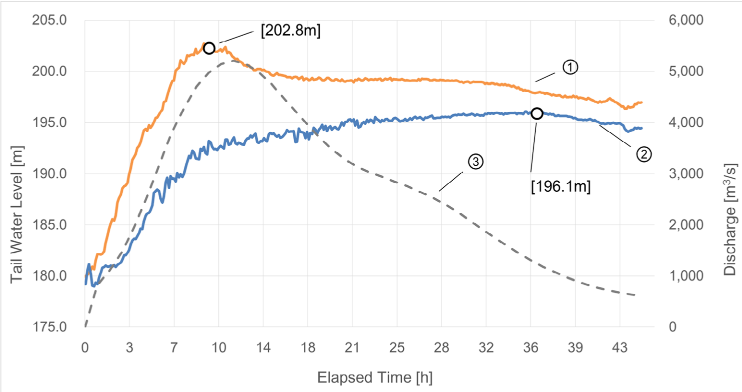

Fig. 11
Variation of tail water level (case 1 and 6)
Variations du niveau d'eau en aval (cas 1 et 6)

1	Case 1	*1*	*Cas 1*
2	Case 6	*2*	*Cas 6*
3	Discharge with hydrograph	*3*	*Décharge avec hydrogramme*

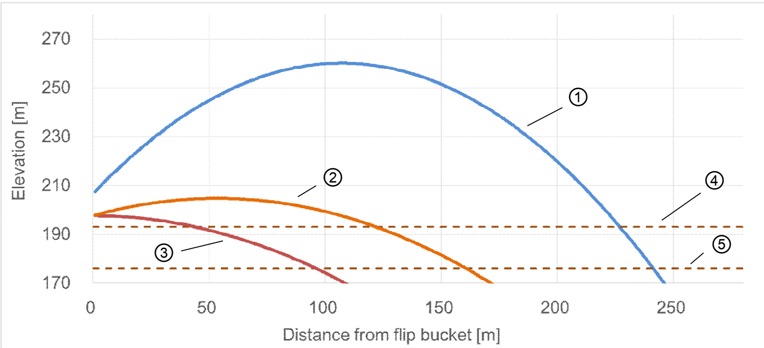

Fig. 12
Diving point (case 1, pre-6 and 6)
Point de déversement (cas 1, pré-6 et 6)

1	Center lane (Radius : 45 degree)	*1*	*Voie centrale (angle : 45 degrés)*
2	Outside lane (Radius : 15 degree)	*2*	*Couloir extérieur (angle : 15 degrés)*
3	Outside lane (Radius : 0 degree)	*3*	*Couloir extérieur (angle : 0 degrés)*
4	GL.193.0 m of powerhouse	*4*	*Cote centrale 193,0 m*
5	GL.176.0 m of riverbed	*5*	*Cote rivière 176.0 m*

4.2.2. Movable bed test of before excavation and before blasting

In order to reduce the volume of scored or deposition movement of the river deposits, the effects of the “pre-excavation” or “pre-blasting without excluding the blasted deposits” which could make river deposits fragment were evaluated in the normal ski jump spillway type and Multi Flip Buckets Type through the hydraulic model tests as shown in Fig. 13 and 14.

As shown in Table 6, five cases with the normal ski jump spillway type and three cases with the Multi Flip Buckets Type were carried out varying the volume of pre-excavation. The hydraulic characteristics including scored and deposition volume of the river deposits and the tail water level were evaluated through the hydraulic model tests with the discharge of 5,210 m^3/s.

The results of the hydraulic model tests are summarized in Table 7 and Fig. 15 to 20.

(Normal ski jump)

- The effects of pre-excavation (case 2 to 4) or pre-blasting (case 5) are confirmed compared to no countermeasure (case 1).
- The effect for lowering the tail water level and reducing the scored volume becomes lager as the volume of the pre excavation become larger as shown in case 2 to 4 of Fig. 15.
- In order to make the river deposits flush away toward downstream easier, pre-blasting can be alternative to lower the tail water level. The cost for the excavation is quite expensive, and the blasted deposits are not excluded. Case 5 represents the case that the pre-blasting are carried out for making the river deposits smaller to flush them away easily. The modeling for pre-blasting is to make the diameter of sand and gravel smaller. The scored volume are larger but the deposition volume is smaller because the smaller particles of deposits can be flush away toward downstream as shown in Fig. 15.
- Although the deposition volume is small and the tail water level are low at 15 h or later in case 5, the maximum tail water level at 5h is much higher compare to case 4 as shown in Fig. 16. The particle size is smaller and the total volume of scored river deposits is larger than the case of 2 to 4 as shown in Fig. 15. Therefore, the tail water level becomes quite high on a tentative basis.

(Multi Flip Buckets Type)

- The effect of pre-excavation (case 7 and 8) in the case of the Multi Flip Buckets Type is confirmed compared to no countermeasure (case 6).
- The target tail water level is 193 m and the volume of the pre-excavation is made smaller of 80,000 (case 7) and 150,000 m^3 (case 8) compared to the case of the normal ski jump case as shown in Fig. 18. The effect for lowering the tail water level becomes lager as the volume of the pre-excavation

become larger as shown in Fig. 17. However, the scored volume of the river deposits becomes larger as the volume of the pre excavation increases. The pre-excavation area might not be appropriate.

- The maximum tail water level is around at 36h from the start of the flood, although the discharge becomes quite small. It follows that the deposition continues more than 30h in the case of the Multi Flip Buckets Type.

(Comparison between Normal ski jump and Multi Flip Buckets Type)

- The test results are summarized in Fig.19 and Fig. 20.
- The co-relation between the pre-excavation volume and scored volume is quite different between the normal ski jump type and Multi Flip Buckets Type. Although the volume of the scored river deposits should be reduced in the case the volume of pre-excavation increases, the scored volume are rather increased as the pre-excavation volume increased. It is probable that the area for the pre-excavation for the Multi Flip Buckets Type might not be appropriate and further considerations are required.
- The current elevation of the powerhouse is EL.193m. Therefore, the countermeasure is required to prevent the backwater from entering into the powerhouse. Construction of additional wall to the EL.196 m is more reasonable and cost effective than pre-excavation of 150,000 m^3.

Table 6
Cases of hydraulic model tests

Case	Flip bucket	Term of river bed	Outside lane		Center lane	
			Angle [degree]	EL. [m]	Angle [degree]	EL. [m]
case 1		Without				
case 2		Pre-excavation: $380*10^3$ m^3				
case 3	Normal ski jump	Pre- excavation: $470*10^3$ m^3	-	-	45	206.5
case 4		Pre-excavation: $500*10^3$ m^3				
case 5		Pre-blasting: $500*10^3$ m^3				
case 6	Multi Flip Buckets Type	Without	15	197.5	45	206.5
case 7		Pre-excavation: $80*10^3$ m^3	0	197.0	45	206.5
case 8		Pre-excavation: $150*10^3$ m^3				

[Note]Discharge: 5,210m^3/s (Design flood), Width of flip buckets: Severally, Deflector: Severally

Table 7
Summary of the results

Item	Unit	Normal ski jump					Multi Flip Buckets Type		
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	case 8
Pre-excavation or blasting	10^3 m^3	0	380	470	500	500	0	80	150
Tail water level	m	202.8	189.4	190.5	194.2	195.1	196.1	195.0	193.2
Tail water level-GL.193m	m	9.8	1.2	(-) 2.5	(-) 3.6	2.1	3.1	2.0	0.2
River water level	m	208.4	201.9	199.8	199.4	199.6	205.4	205.2	203.3
Deposition elevation	m	195.9	182.5	186.0	190.3	183.6	195.4	196.3	194.4
Difference (Score – Deposition) volume	10^3 m^3	494	65	89	63	632	279	393	383
Score volume	10^3 m^3	709	227	170	116	698	481	583	567
Deposition volume	10^3 m^3	214	162	80	53	66	202	190	184
Velocity of downstream 700 m from dam axis	m/s	10.9	10.3	10.1	8.1	7.9	10.5	9.6	10.8

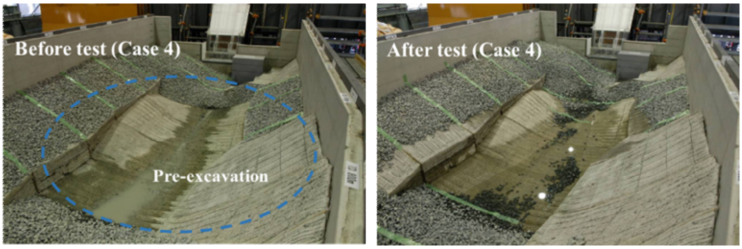

Fig. 13
Hydraulic model tests of case 4
Tests du modèle hydraulique pour le cas 4

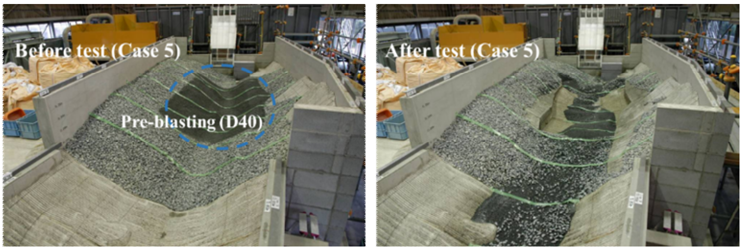

Fig. 14
Hydraulic model tests of case 5
Tests du modèle hydraulique pour le cas 5

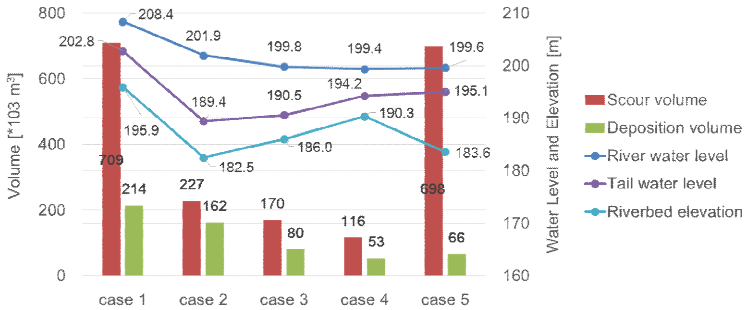

Fig. 15
Result of movable riverbed (case 1, 2, 3, 4 and 5)
Résultat du lit de cours d'eau déplaçable (cas 1, 2, 3, 4 et 5)

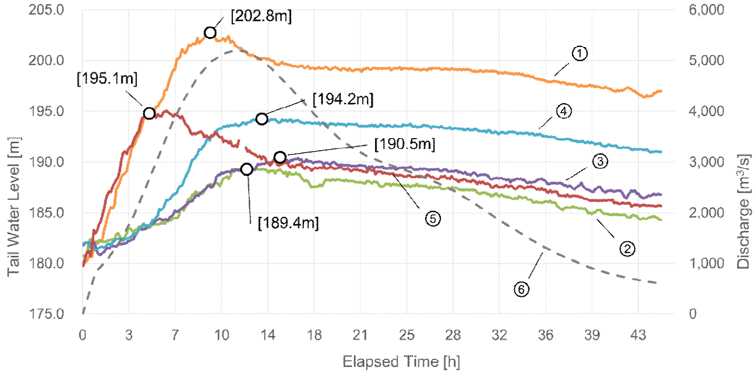

Fig. 16
Variation of tail water level (case 1, 2, 3, 4 and 5)
Variations du niveau d'eau en aval (cas 1, 2, 3, 4 et 5)

1	case 1	*1*	*cas 1*
2	case 2	*2*	*cas 2*
3	case 3	*3*	*cas 3*
4	case 4	*4*	*cas 4*
5	case 5	*5*	*cas 5*
6	Discharge with hydrograph	*6*	*Décharge avec hydrogramme*

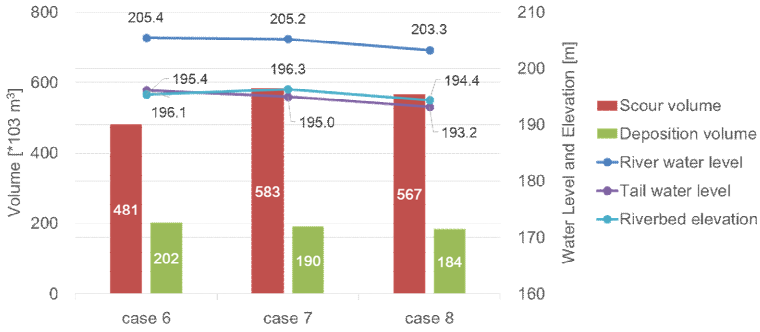

Fig. 17
Result of movable riverbed (case 6, 7 and 8)
Résultat du lit de cours d'eau déplaçable (cas 6, 7 et 8)

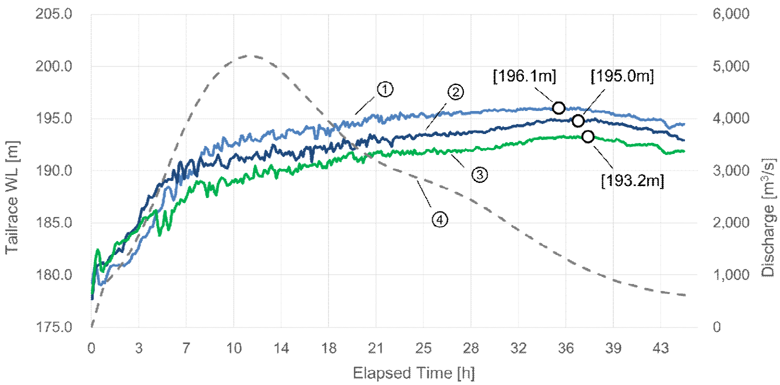

Fig. 18
Variation of tail water level (case 6, 7 and 8)
Variations du niveau d'eau en aval (cas 6, 7 et 8)

1	case 6	*1*	*cas 6*
2	case 7	*2*	*cas 7*
3	case 8	*3*	*cas 8*
4	Discharge with hydrograph	*4*	*Décharge avec hydrogramme*

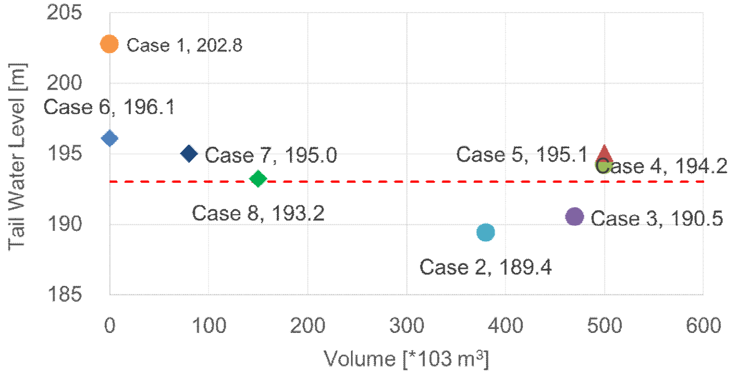

Fig. 19
Tailrace water level (case1, 2, 3, 4, 5, 6, 7 and 8)
Niveau d'eau du point de restitution (cas 1, 2, 3, 4, 5, 6, 7 et 8)

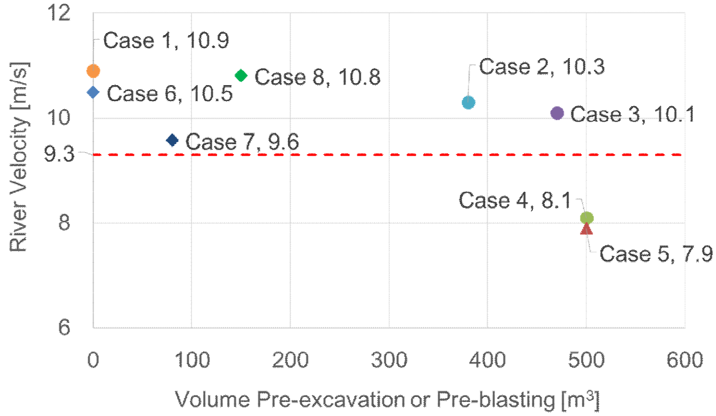

Fig. 20
River velocity of downstream 700m from dam axis (case1, 2, 3, 4, 5, 6, 7 and 8)
Vitesse du cours d'eau 700 m en aval de l'axe du barrage
(cas 1, 2, 3, 4, 5, 6, 7 et 8)

5. FINAL DESIGN

Table 8, Fig. 21 and 22 shows the Final Design of spillway.

The Multi Flip Buckets Type is adopted for this Project. The widths of the center lane and outside lanes are 24 m and 11 m respectively. The flip bucket radiuses, angles and elevations of jumping points of centre lane and outside lanes are 15 m, 45 degree, EL. 206.500m, and 15 m, 15 degree, EL.197.511 m respectively. The deflectors with width of 2m are set on right wall of center lane and right outside lane.

Table 8
Final design

Item		Final Design
Pier	Bay number	4
	Bay and pier width	12.25 m and 3 m
Chute	Bay number	3
	Width of the terminal point	Center rail: 24 m, Outside lane: 11 m * 2 lane
Flip bucket	Radius	Center lane: 15 m, Outside lane: 15 m
	Angle	Center lane: 45 degree, Outside lane: 15 degree
Deflector	Width	Right bank of center lane: 2 m, Right bank of right lane: 2 m
Specifications of Spillway	Falling height of effluent	Center lane: 114m, Outside lane: 122 m
	Discharge intensity of	Center lane: 118 m³/s/m, Left lane: 118 m³/s/m, Right lane: 145 m³/s/m
	Flying length	Center lane: 250 m, Outside lane: 170 m

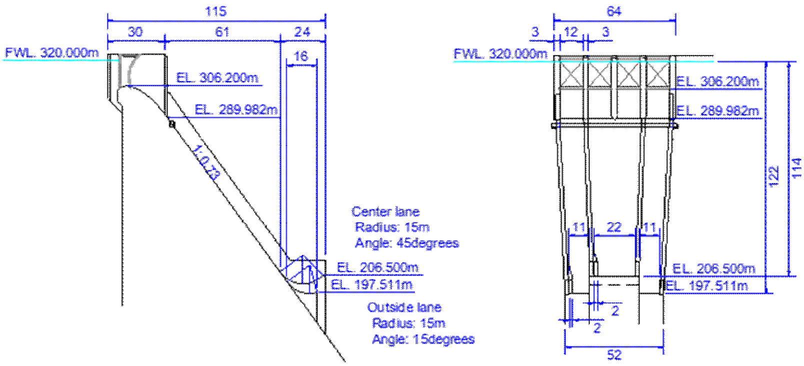

Fig. 21
Final design (Left: Cross section, Right: Downstream view)
Conception finale (à gauche: coupe, à droite: vue depuis l'aval)

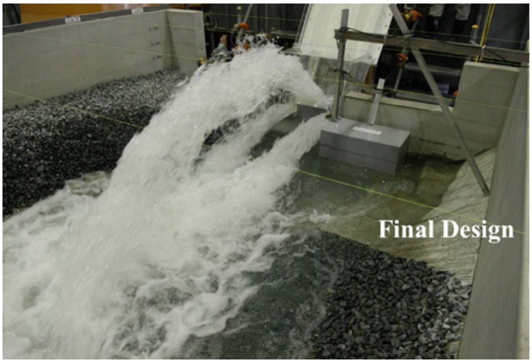

Fig. 22
Final design
Conception finale

6. CONCLUSION

Through a number of hydraulic model tests, the applicability of the Multi Flip Buckets Type to the spillway has been confirmed.

- The flip angles of 45 degree and 15 degree for the respective center and outside lane are the appropriate combination for this project, considering the impact to the downstream.
- The reduction of the volume of scored and deposition of the river deposit by adopting the Multi Flip Buckets Type can result in reducing the risk of failures of both banks of downstream and lowering the tail water level.

The following conclusions have been also confirmed through the hydraulic model tests, although details are not described in this paper.

- The discharge capacity of 5,210 m^3/s (design flood) has been confirmed through the hydraulic model tests (Item-1).
- It is confirmed that there is no harmful cavitation caused by negative pressures on the dam crests, chute and flip buckets (Item-3).
- Stable discharge without adverse dispersion can be confirmed through the modification of shapes of the piers, aeration, width of chutes, flip bucket radius, guide walls, and shape and dimension of the deflectors (Item-2, 4, 5, 6, 7, 8, 9)

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SUMMARY

A main dam and a re-regulation dam are constructed for power generation of the Nam Ngiep 1 hydropower project (Project), located in the Lao People's Democratic Republic. A main powerhouse and a re-regulation powerhouse are to be constructed near the main dam and the re-regulation dam, generating electricity which is to be sold to Thailand and Lao People's Democratic Republic. The topography around the main dam has characteristic of narrow gouge and lots of deposits including big boulder on the river bed. Considering these conditions, ski jump spillway with multi flip buckets ("Multi Flip Bucket Type"), which ensures the sufficient function as energy dissipator, is adopted for the spillway of the main dam in order to improve its economy. Multi Flip Bucket Type has multi chute with different elevation and angle for discharging water to disperse the diving points. It can mitigate the impact of diving water to prevent the increase of the tail water level and the decrease of energy generation due to moved river deposits.

Hydraulic model tests have been carried out to confirm the hydraulic characteristics of the spillway of the main dam. The application to the Project is verified considering the following issues;

- Design of the spillway gates, chutes, guide walls, aeraters, flip buckets and deflector for appropriate diving point, stable discharge, and reduction of splash is carried out.
- Width, angles, radius, and elevations of flip buckets are determined to minimize the scoring and deposition of riverbed, and to prevent the increase

of the tail water level. Additionally, the effect of pre-excavation of downstream riverbed is evaluated.

Among other things mentioned above, detailed results of the hydraulic model tests for determining flip bucket angle and movable bed to evaluate the impact to the tail water level are mentioned in this paper.

Multi Flip Buckets Type is economically advantageous compared to hydraulic jump type and is more effective for the energy dissipator, and has less impact to downstream riverbed. Multi Flip Buckets Type can be applied to the dams on narrow rivers where ordinary ski jump spillway cannot be applied.

RÉSUMÉ

Un barrage principal et un barrage de rerégulation sont construits pour la production d'électricité de l'aménagement de Nam Ngiep 1 (« Projet »), en République démocratique populaire du Laos. Une centrale électrique principale et une centrale de rerégulation doivent être construites près du barrage principal et du barrage de rerégulation, afin de générer de l'électricité destinée à être vendue à la Thaïlande et à la République démocratique populaire du Laos. La topographie de la zone entourant le barrage principal se caractérise par une argile de friction fine et de grandes quantités de dépôts incluant de gros blocs dans le lit de la rivière. En prenant en compte ces conditions, le déversoir tremplin avec auges de déflexion multiples, qui assure une dissipation suffisante d'énergie, est choisi comme déversoir du barrage principal afin d'en améliorer son économie. Le type à auges de déflexion multiples dispose de plusieurs conduits d'éjection avec différents angles et élévations pour que l'eau évacuée ait plusieurs points de déversement. Cela peut diminuer l'impact de l'eau évacuée afin d'éviter l'augmentation du niveau d'eau en aval et la diminution de production d'énergie en raison du déplacement des dépôts de la rivière.

Des tests du modèle hydraulique ont été effectués pour confirmer les caractéristiques hydrauliques du déversoir du barrage principal. L'application au projet est vérifiée en tenant compte des points suivants ;

- conception des vannes du déversoir, des conduits d'évacuation, des guideaux, des auges de déflexion et du déflecteur pour des points de déversement appropriés, une évacuation stable et une diminution des éclaboussures.
- largeur, angles, rayons et élévations des auges de déflexion sont déterminés pour minimiser les striures et les dépôts de sédiments, et pour éviter l'augmentation du niveau d'eau d'aval. De plus, les effets de la préexcavation du lit de la rivière en aval sont évalués.

Parmi les éléments mentionnés ci-dessus, les résultats détaillés des tests du modèle hydraulique servant à déterminer l'angle des auges de déflexion et du lit déplaçable pour évaluer l'impact du niveau d'eau en aval sont mentionnés dans ce document.

Le type à auges de déflexion multiples est avantageux d'un point de vue économique par rapport au type à ressaut hydraulique, et il est plus efficace pour la dissipation d'énergie, en plus d'avoir un impact moindre sur le lit de la rivière en aval. Le type à auges de déflexion multiples peut être appliqué à des barrages sur cours d'eau étroits où un déversoir tremplin ordinaire ne peut pas être utilisé.