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The Development of Trash Diverter System for Tenom Pangi Hydro Power Station Intake, Sabah

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Abstract: Clogging of water intakes caused by accumulation of floating trash is a common problem experiencing by many run-off-river hydro power plants. Tenom Pangi Hydro Station is significantly affected by it which leads to reduction of power generation or sometime station shutdown. A trash diverter system was developed to prevent the clogging and to accommodate existing station operational constraints. The development involves mainly a brainstorming session to finalize the conceptual design, and computer modeling. Commercial computational fluid dynamic program was utilized to create computer model to analyse and evaluate the river flow characteristics due to trash diverter installation in order to determine the trash diverter location for effective diversion of trashes and minimum flow resistance into the water intakes. Finite element analysis program was used to do stress analysis on the trash diverter structure. The power station requirement, the design of existing water intakes from other local hydropower and water treatment plants were also considered in finding the effective solution. The results from the modeling and analysis were used to establish preventive measures for preventing existing water intakes clogging and specification for the construction of the trash diverter system.

Key words: Modeling, trash diverter, trashes, clogging, transect line, intake

INTRODUCTION

Development involves several important processes such as problem definition, design specification, constraints identification, modelling and analysis in realizing practical design. Many engineering problems required adequate modelling and analysis to understand the problem, and proposed the solutions before it can be translated to sound engineering design. This requirement directly related to the scenario experienced by Tenom Hydro Power Station. The station is a run-of-river hydroelectric scheme that produces power according to the flow of water in the river it is built on. The water resources of several nearby rivers were combined to fall through as great a height as possible to maximize the generation capacity. Nevertheless the near-by-rivers not only provide water resources for power generation, but also transporting the debris or trashes such as bamboos, twig and household wastes from the river's surrounding or catchments areas. Additionally, uncontrolled logging activities, opening of new lands for agriculture and housing development in the catchments zone contribute to the increasing capacity of trash in the affected rivers. All of these trashes, that were dumped into the river eventually accumulating in front of the water intakes and clogging them. As a result, there is less water entering the water intakes and this force the station to shut down due to pressure head loss. This paper describes development of the trash diverter system and CFD analysis of the river flow characteristics with and without the trash diverter. It also briefly describes the stress analysis on the trash diverter structure.

The main objectives for this study are to develop trash diverter system, to determine it's location for effective diversion of trashes and minimum flow resistance into the water intakes, as well as identifying the possible risk of soil erosion on the riverbank due to trash diverter installation. The findings become the input data for the stress analysis and for design specification of the trash diverter system.

MATERIALS AND METHODS

The tasks to achieve the research objectives were divided into several subtasks. Descriptions of these tasks are as follows:

Problem definition: In order to understand the real trash problem experienced by the Tenom hydro station, a site visit to the plant was arranged and an interview session

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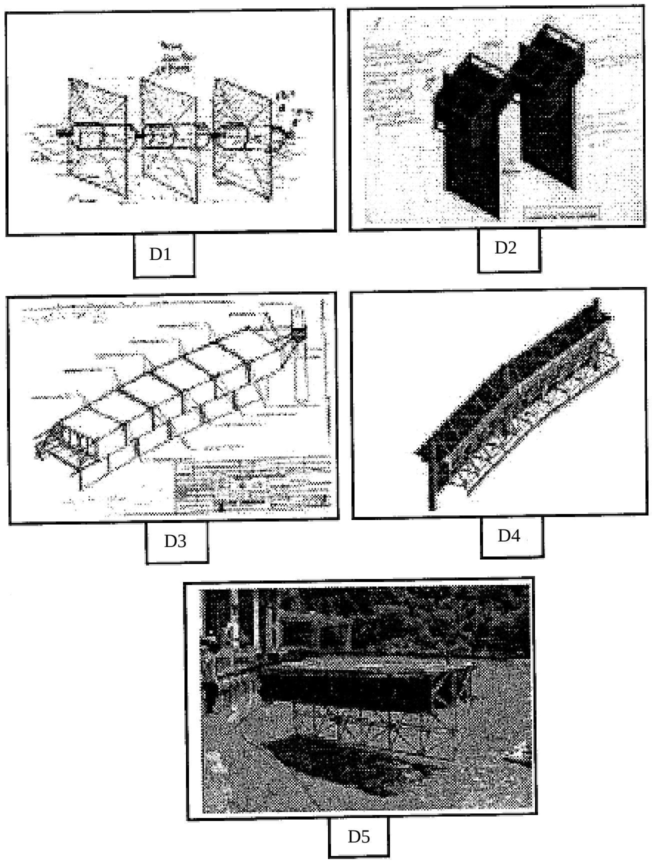

Fig. 1: D1 indicates the first conceptual design and it changes until the final design as in D5 which was used in the computer simulation

was conducted with the station staffs. In addition, a boat ride to the upstream of Padas River provided valuable information on the sources of trashes. Cleaning records and operational log sheets were also collected for analysis and trending.

Literature review: Effort has been taken to understand the intake design to determine whether the trash problem inherited a design problem. References were made to a few relevant journals as well as design evaluation on other local hydro stations and water treatment plants water intakes. Some information about Padas River hydrological data, geography and climatologic were also being read (Anton, 1999). Two years of station flushing records including the flushing procedures were evaluated and a report from previous consultant on the existing intake design was also considered for improvement. In addition, based on the literature search from CEA (1982) and Carleton and Nielsen (1990) indicated that a common trash diverter structure being used by North America and Canada Utility and Paper Pulps industries are made of log boom and wood.

Brainstorming session: Several brainstorming sessions were conducted to finalize the trash diverter design. The design has evolved to improve its functionality and reliability as indicated in Fig. 1.

The following criteria are used as guidance for the development and improvement of the trash diverter system.

- Some over-design to be considered
- Able to prevent accumulation of trash at the water intakes
- Able to quickly remove the accumulated trash or having self cleaning ability
- Orientation of trash diverter parallel to the river flow
- Consider the bending nature of the river bank
- Prevent or minimize formation of turbulence water at the intake

Table 1: Summary of Justifications for the Design Changes Until Getting the Final Design

No.	Description	Advantages	Disadvantages	Changes
D1	*Perforated deflector plate and arranged at certain angle	*Cleaner water to intake	*Difficult to fix the location and stabilize the plate position	*Location and number of floats
	*Float located at the centre	*Easy to fabricate	*Difficult to remove the trapped trash	*Requirement float protection
	*Flexible structure connected with steel cable		*Shifted from predetermined location as river water level change	
D2	*Longer suspended deflector plate	*Cleaner water more trash can be diverted	*Difficult to fix the location	*Arrangement of floats and deflector plates and also size
	*Two floats inside cage for each def. Plate	*Stable arrangement and floats protected	*Blocking the flow of water	
	*Flexible structure connected with hinge and pin	*Easy to fabricate	*Difficult to remove the trapped trash	*Rigidity of general assembly
			*Shifted from predetermined location as river water level change	
D3	*Perforated deflector plate	*Cleaner water to intake and less clogging	*Shifted from predetermined location as river water level change	*Rigidity of general assembly
	*Relatively rigid structure connected with steel cable	*Stable arrangement and floats protected	*Sluggish up and down movement	*Mechanism to allow up and down movement
	*Two floats inside cage for each def. Plate	*Easy to fabricate		
	*Going up and down according to changes in river water level	*Relatively easy to fix location and remove trapped trash		
D4	*Perforated deflector plate	*Cleaner water to intake and less clogging	*Requires construction of concrete column	*Method to anchored the general diverter assembly
	*Rigid structure from steel	*Stable arrangement and floats protected	*Interruption to plant operation during installation	
	*Two floats inside cage for each def. Plate	*Easy to fabricate		
	*Going up and down according to changes in river water level	*Easy to fix location and remove trapped trash		
D5	*Louvered deflector plate	*Cleaner water to intake and less clogging	*Minimum interruption to plant operation during installation	
	*Rigid structure from steel	*Stable arrangement and floats protected		
	*6 floats inside cage for each module	*Easy to fabricate		
	*Going up and down according to changes in river water level	*Easy to fix location and remove trapped trash		
	*Equipped with rubber damper	*Can absorb greater log impact		

- Consider different type of floating trash
- Future construction of upstream dam
- Avoid concrete structure installation in the river
- Cost within the approved budget
- Facilitate fabrication and installation
- Require minimal station shutdown
- Easy to operate and minimal maintenance or minimal moving parts

The first design as indicated by D1 sketch in Fig. 1 is a line of interconnected floating metal plates consist series of specially arranged perforated plated at particular angle to divert the floating trash. The deflector plates were kept floating by cylindrical floats at the centre of the plate. The design was changed to reduce the disadvantages and increase the advantages while complying with the required criteria. The incremental development of the trash diverter design is summarized in Table 1.

The general assembly of trash diverter system at site or Tenom Hydro Station water intake is as in Fig. 11.

Computer modelling and simulation: Computer modelling by mean of Computer Fluid Dynamic (CFD) computer program was used to facilitate the design and development of the trash diverter because it is impractical and expansive to test full-size trash diverter prototype. CFD-ACE+ program was used to model the Padas River in 3 and 2D, as well as analyzing the fluid characteristics around the trash diverter. The simulated results assist the determination of effective trash diverter location, effects of trash diverter on river flow and possible risk of river-bank erosion. It is assumed that the velocity and direction of the floating trashes are similar to the velocity and direction of the river flow. FEA program, MSC-Patran was used to perform stress analysis on the diverter structure.

Model creation: The CFD computer model used in the analysis is an approximation of the actual Padas River at selected section of the river. The selected section encompasses the part of the river that may be affected by the installation of the trash diverter. Two types of models, 3 and 2D computer models have been created. 3D model

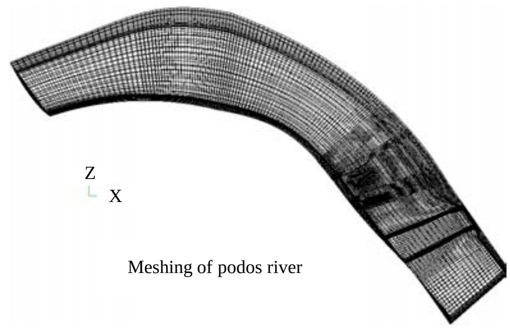

Fig. 2: Computer model of padas river after meshing

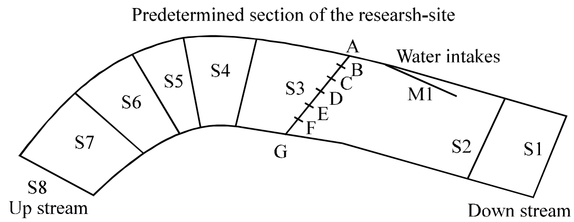

Fig. 3: Transect lines which divide the study-area

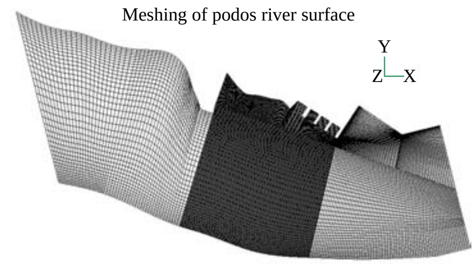

Fig. 4: River surface meshing

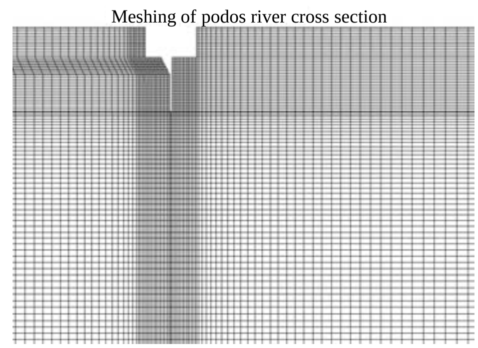

Fig. 5: River cross section with diverter

as depicted in Fig. 2 is used as a reference to analyze the general flow condition before the installation of the trash diverter.

The 3D computer model was created from the depth profile of the Padas River at the critical locations within the selected section of the river as in Fig. 3. At each critical location or coordinate, a transection line made from wire rope was laid on the surface across the river. The plan view of the river and coordinate of the measurement points, were merged and scaled to provide three-dimensional coordinate profile of the river. Later these 3D coordinates were created in the computer by using appropriate functions in the geometrical module of the CFD-ACE+ computer program. The 2D computer model as in Fig. 4 and 5 were used after the diverter being redesigned and relocated to minimize the disturbance on the river flow and project cost to install the diverter.

The new location requires less area to be analyzed. Nevertheless, 2D computer model required plan view and side view to adequately investigate the flow characteristics. The same coordinate points from 3D model were used except the depth z coordinate is ignored. Process of creating the 2D model is similar to what has been done for 3D computer model.

Analysis parameters and criteria: In order to minimize the flow resistance and other adverse effects due to the installation of trash diverter, there are four parameters that have been identified as by Abbort and Basco (1995) and Curie (1993). There are pressure, velocity, turbulence and recirculation that sufficiently describe the characteristics of the Padas river water as it flow around or through the trash diverter. Pressure gradient in the river especially area between the diverter and water intakes as well as in front the diverter are important indication of head lost and possible development of turbulence, vorticity and recirculation. The decrease in pressure in the direction of flow can increase the flow speed and the opposite can reduce the flow speed. Velocity vector is useful in indicating the present of circulation, turbulence and vorticity in the river flow. Since flow path of circulation, turbulence and vorticity normally perpendicular to the direction of flow, it can resist or hinder the existing river flow when its size or magnitude became large. The turbulence flow, which has more kinetic energy and momentum, can induce vibration to the intake structure and turbine. Understanding the changes of the above mentioned analysis parameters provide adequate information to reduce or eliminate the negative impacts practically and economically.

River flow without trash diverter: A flood flow velocity of 4 m sec^{-1} was used throughout the simulations. The results from 3D as Fig. 6 and 2D as Fig. 7 models simulations indicated that the flow velocity gradient

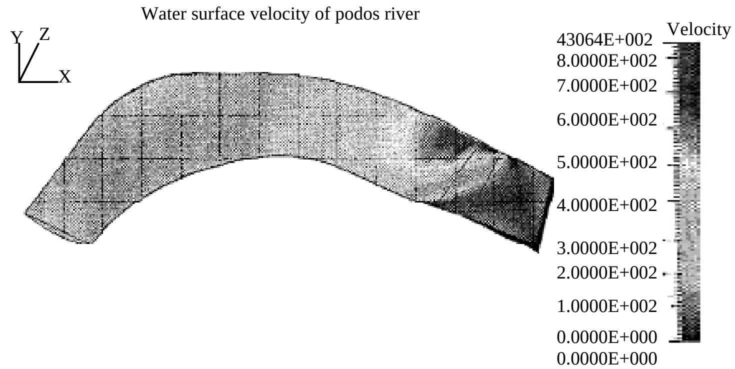

Fig. 6: 3D River velocity without trash

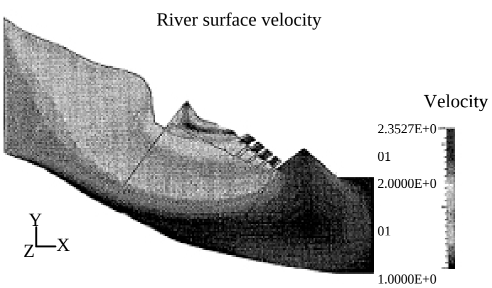

Fig. 7: 2D Velocity plot without diverter

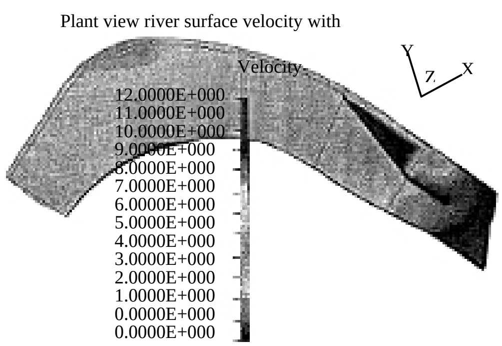

Fig. 8: 3D Velocity plot with diverter installed

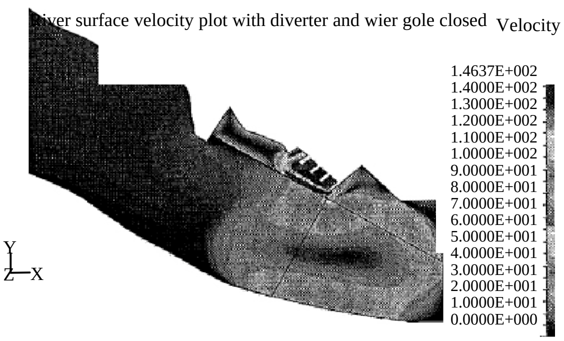

Fig. 9: 2D Velocity plot with diverter installed

generally constant where the flow initially moving at 4 m sec^{-1} and gradually increasing while changing its direction toward the water intakes region with velocity reaching 9 m sec^{-1}. Nevertheless the flow upstream of the water intakes until the closed weir gates in both models were flowing relatively slows at 1 m sec^{-1}.

The same situation was observed for the flow near the curved riverbank. Small magnitude of turbulence kinetic energy was also present at the water intake region as expected since the velocity is high. High velocity at the water intakes also contributed to low-pressure gradient about $1x10^4$ Pascal at the intake region. Based on the intake flow characteristics, it is decided to protect the intake region at the perimeter of increasing velocity where the trashes are also moving rapidly and if not diverted will eventually clogging the intakes. The diverter was originally planned to be installed at an angle from the riverbank and flow direction until the middle of the river where the second section of the diverter equally dividing the river as in Fig. 8. The purpose is to gradually divert the trashes away from the intakes. Due to high installation cost and longer station shutdown for construction, the idea was abandon. In the second installation the diverter was located parallel to the river flow direction in order to avoid accumulation of trash and facilitate flushing of trash as in Fig. 9. Since it is nearer to the riverbank, support structure can be extended and anchored to the riverbank for better stability.

River flow with installed trash diverter: The simulated flood in 3 and 2D models indicated that the installation of trash diverter where 2.5 m of its body submerged in the water affect the flow of water into the water intakes. Flow velocity after the trash diverter in both models indicated general reduction of more than half of the initial velocity.

There is also increase in turbulence kinetic energy and recirculation in fronts the water intakes. Increase in kinetic energy can induced vibration to the intake structure and water recirculation will hinder flow velocity into the intakes. In addition there is significant pressure different about 8×10^6 Pascal at the diverter wall.

River flow with modified trash diverter: Modification on the trash diverter wall has been carried out by fabricating equally distributed louvers with opening in the same direction of the river flow on the diverter wall. The ratio between the total louvers-opening-area and the diverter-wall-area is about 50%. The louvers as in Fig. 10a was designed such that the river water can pass through the diverter wall but most of the trashes will slide on the louvers and carried away by the river flow due to its inertia. The results of 2D model simulation clearly indicated that the modified trash diverter significantly reduced the problem of increasing turbulence, high differential pressure and reduced water velocity in front the water intakes as in Fig. 10b.

Summary on the CFD-ACE analysis: The results of the 3 and 2D computer modelling have indicated that the installation of the trash diverter affects the flow of water into the water intakes by reduced water velocity, increased water turbulence and increased differential pressure or head loss. In order to minimize this problem, louvers have been fabricated on the diverter wall in such away to partially allow the river water pass through the diverter but restrict the trashes. It is recommended the minimum loading pressure of 6200 kg from the differential pressure of simulated case being considered based on unmodified diverter used for stress analysis of the trash diverter structure. In addition, a diverter length of 72 m and height 2.5 m from 2D model can be considered for the final dimension of the trash diverter since these principal dimensions have been used throughout the analysis to meet the research objectives.

Stress analysis: MSC-Patran was utilized to model and analyzed the diverter structure. Single wire frame elements with steel property were used to construct the structure as in Fig. 11. Appropriate boundary conditions were applied and static stress analysis as in Fig. 12 with

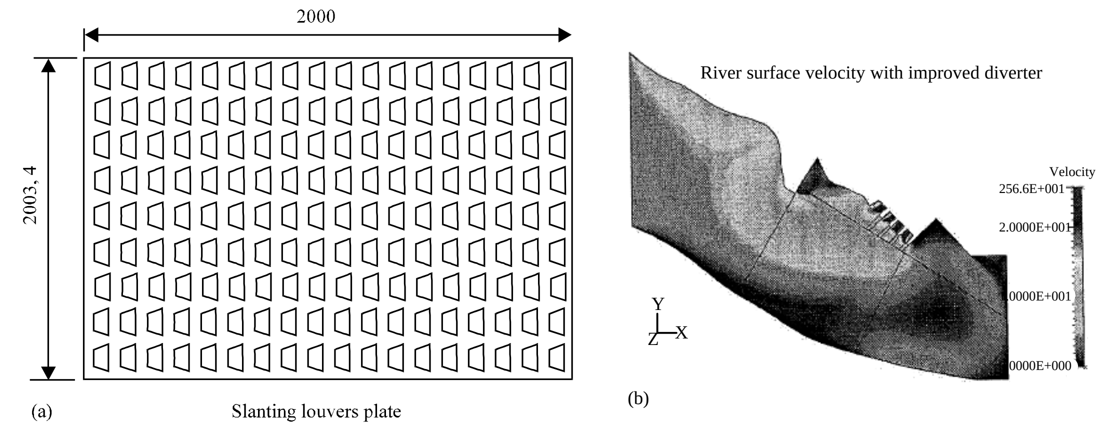

Fig. 10: (a) Louvers on the diverter wall and (b) velocity plot with modified trash diverter

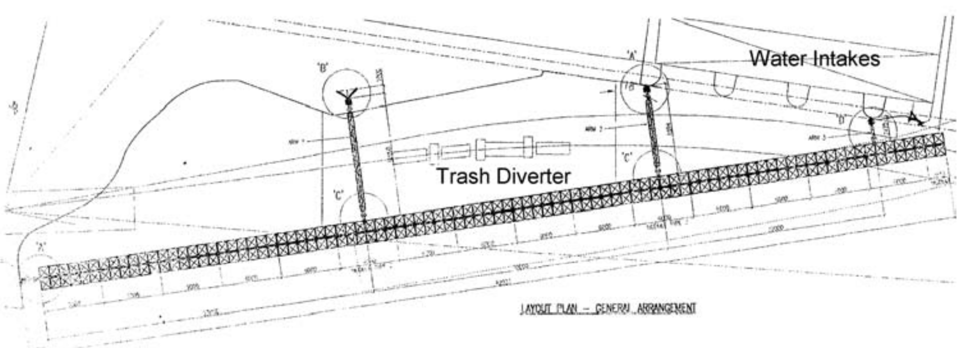

Fig. 11: Trash diverter structure installation

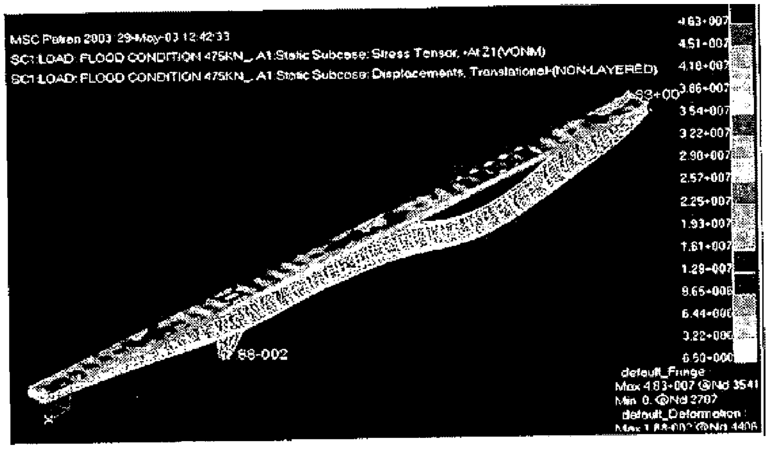

Fig. 12: Stress analysis of the diverter structure

maximum distributed loading of 200 tons was applied to the diverter frontal sections facing the incoming river flow. Impact loading at various location and angle were also simulated to consider the impact of collision with drifting logs. Modal analysis was also performed to determine the diverter structure natural frequency.

CONCLUSION

The analysis on the simulation results provides significant findings that enhance understanding of the problem, as well as provide and validate the probable solutions. The CFD (CFD-ACE+) and FE (MSC-Patran) analysis provided in-depth understanding and high degree of confidence in development of the trash diverter structure. At this stage, the research objectives have be achieved. Nevertheless, final dimensions of the diverter structure were decided not only based on the CFD and FEA analysis, but also safety factor and recommendations from experienced structural engineers. Further analysis on the diverter structure such as dynamic stress analysis due to fluctuating force and temperature can be performed to develop and expand its performance for wider application such as portable floating bridge and wave breaker.

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REFERENCES

Abbort, M.B. and D.R. Basco, 1995. Computational Fluid Dynamics an Introduction for Engineers. Longman Singapore Publisher (Pvt.) Ltd., Singapore..

Anton, A., 1999. Classification of Malaysia Rivers. Vol. 8, Lonely Planet Malaysia, Padas River.

CEA, 1982. Analysis of procedures used in the design of logs and trash booms to protect hydro electric intakes. Shawinigan Consultant Inc., Quebec, Canada.

Carleton, M.G. and J.S. Nielsen, 1990. Study of trash and trash interception devices. Water Sci. Technol., 22: 287-290.

Curie, I.G., 1993. Fundamental Mechanics of Fliuds. 2nd Edn., McGraw-Hill Inc., USA.