MODULAR WEIR: NEW METHOD OF WEIR CONSTRUCTIONTO IMPROVE IRRIGATION PRODUCTIVITY

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ABSTRACT

For many decades, most of the weirs were built as a massive concrete structure across the river. However, there are some cases that a fixed structure weir is not suitable to be used in some rivers for example a river with a high bed degradation rate. This could be a problem for the stability of the structure because the conventional weir cannot accommodate the river bed level change. Furthermore, the cost and time period of the conventional weir construction is quite high. Therefore, a new method of weir construction which called Modular Weir has been developed. The modular weir is made by a modified shape of precast concrete blocks which are hooked and locked with one another to make it as a unit of structure. This structure has been tested on a scale model in the Hydraulic Laboratory of PUSAIR and applied on several rivers in Indonesia. The field test results in Cikarag River shows positive performance in which the modular structure prototype worked well as a weir. The construction method is easier and faster which leads to time and cost saving. Therefore, this new method of weir construction can be an alternative option for weir construction.

Keywords: Modular Technology, Weir, Irrigation, Precast Concrete, Concrete Block

1. INTRODUCTION

Nowadays, modular technologies have been growing fast in many types of construction works such as housing, building, bridge and other infrastructure projects. Based on literature reviews, many studies were conducted by researcher such as Ikuma and Nahmens (2012), Court et al (2009), Moghadam et al (2012), Schoenborn (2012) and Smith (2010), Lacey et al (2018), O'Connor (2016), and Navaratnam et al (2019) related to the effectivity of modular construction method for construction industry. The advantages of the technologies for its efficiency and productivity have attracted attention of the stakeholders. This situation pushes the construction industry to gradually maturing from the conventional method into a modern method i.e. modular technology. Modular construction is a process in which a building is constructed off-site, under controlled plant conditions, using the same materials and designing that meet the same codes and standards as conventionally built facilities (Wozniak and Zhao, 2018). In general, modular construction methods are used in a remote areas where conventional construction may not be possible to implement. Modular construction method are supposed to saves time as modules for modular building are made in a factory and then transported to the field for installation. Therefore, Mcgraw Hill Construction (2011) mentioned that saving time meaning saving money (Figure 1).

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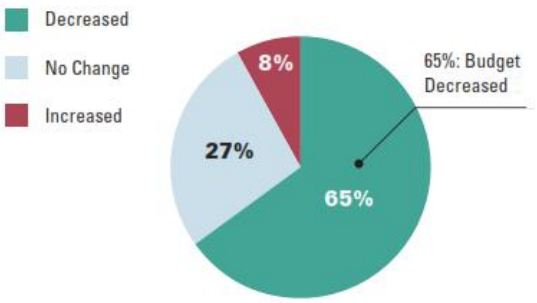


Figure 1. Total Impact of modularization on Project Budget (Source: McGraw-Hill Construction, 2011)

However, most of the project in water resources construction industry is rarely used the modular technology. Although there are some projects that already known for its modular implementation such as drainage channel, dikes, river revetment, etc. But for a large scale projects like dam and weir, the modular technology is never been used yet. In order to support the development of green infrastructure through modular technology, researcher from Experimental Station for Hydraulic Structures and Geotechnic, Research Center for Water Resources (PUSAIR) has done research on this method related to the possibility of modular technology implementation for water resources infrastructure uses. Starting from the river bed armour for scouring protection using a tetrapod (See Figure 2). The performance of the tetrapod is quite impressive to prevent local scouring near the structure. Other projects related to modular construction such as lining for irrigation channel (Figure 3) and river dike and beach revetment (See Figures 4).

Figure 2. River Bed Protection with Tetrapod in Indonesia (source :Pusair, 2006)

Figure 3. Modular Lining Protection for Irrigation channel (source: Pusair, 2019**)**

Figure 4. Modular Revetment for Beach Protection (source :Pusair, 2018)

Currently, the modular concept has also adapted to build a structure for weir construction. The reason is because the most typical problem faced by the weir structures in Indonesia is downstream river bed degradation. For some location, conventional fixed weir structure is not suitable anymore because the high degradation rate which leads to local scouring downstream of the weir structure. One of the example of weir failure caused by river bed degradation can be seen in Figure 5 and 6. The figures show that the most vulnerable part of the weir is the stilling basin due to the combination of high river discharge and river bed degradation.

Figure 5. Debris Flood Over The Weir (source :Pusair, 2017)

Figure 6. Weir Structure Failure (source :Pusair, 2017)

Another problem faced by the weir structure is a wrong selection of stilling basin type for weir which will reduce the stability of the weir structure and finally damage the structure. Therefore, the main goals of the research with modular technology in weir construction is to make a structure that more flexible and adaptable to cope with such problem in the river. In this study, a new concept of construction is introduced to enhanced the growing infrastructure development. This paper will disscuss the implementation of the modular technology in Indonesia with more focused on weir construction.

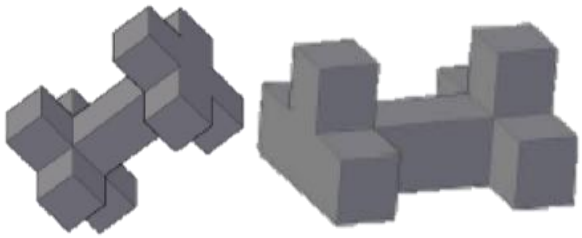
2. METHODS

In this study, the methodology is based on literature study and physical model tests conducted at Hydraulic Laboratory of the Experimental Station for Hydraulic Structures and Geotechnics (Pusair, 2013). A two dimensional model of the weir was built in the flume with scale 1:12 to investigate the modular structure's performance. The model tests include flow and velocity profile test. A field survey and was monitoring also conducted to monitor performances of the weir prototype.

3. RESULTS AND DISCUSSION

3.1 Laboratory Investigations

For weir construction, there are 2 types of modules or units made of concrete block as shown in Figure 7 (Pusair, 2017).This modules are developed in the laboratory and has been tested to analyze its characteristics and hyadraulic behavior. There are more than 2 types of modules, but the final results shows that these two types of modules are the most effective shape among them.



Type. 1 **Type. 2**

Figure 7. Types of PUSAIR's Concrete Blocks Modules

The dimension for this modules for type 1 are 1.8 meters length, 1.35 meter width, and 180 kg weight. While for type 2 are 1.8 meters length, 0.9 meter width, and 170 kg weight. For this concept, a 2 dimensional model test has been conducted at Hydraulic Laboratory with scale 1:12 (See Figure 8).

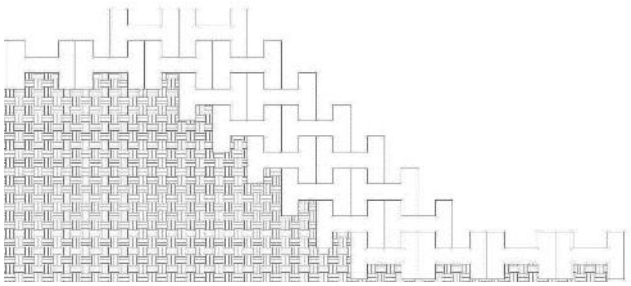


Figure 8. Ilustration for weir design with modular concept

Using the two types of modules, weir structure was built inside flume in the laboratory. The model is tested with various discharges to see the flow profiles and velocity distributions (Figure 9). According to the experiments, the energy dissipation of the structure is more effective to dissipate (Slamet and Hidayat, 2013). The effect of the stepped type spillway helps to reduce the velocity and dissipate the energy.

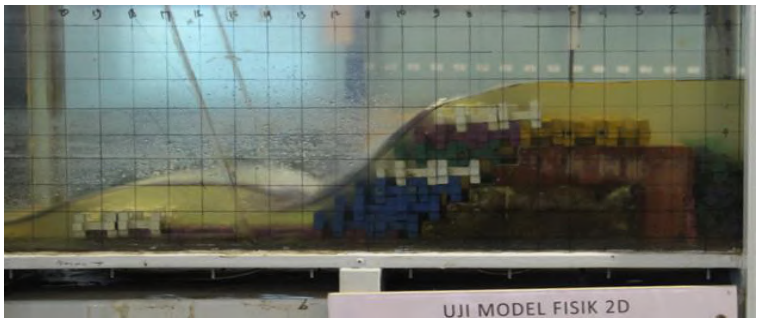


Figure 9. Model Test of The Modular Weir in Hydraulic Laboratory

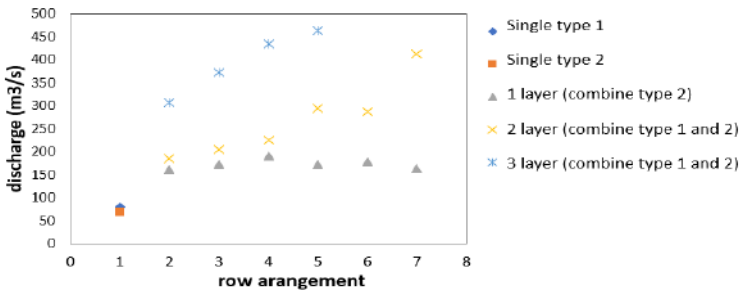


Figure 10. Discharge relation with row arrangement of modules (Slamet and Hidayat, 2013)

On these experiments, the maximum discharge is 500 m^3/s due to available pump discharge capacity in the laboratory. Based on laboratory results, the possibilities of modular technologies for water resources structures become more reasonable. The strength and durability of the modules can significantly improve by combining the two types and adding row and layer (See Figure 10). However, there are no guidelines for modular technology for weir construction. Therefore, guidelines for design and construct the modular weir is being worked on by Pusair based on the experience working on the modular weir construction.

3.2 Case Study

Already 2 modular weir prototype have been built in Indonesia as shown in Table 1.The first prototype of the modular weir was built on a small river called Cikarag River in 2013 as a tributary river of Cimanuk River at West Java Province (Figure 11). The 2nd is Tiley weir built on Gugubali River in 2018 at Morotai Island, North Maluku Province.

Table 1. Modular Weir Location in Indonesia

no	weir	Location	number of modules/units	river width
1	Cikarag	West Java	470	8 meters
2	Tiley	North Maluku	3140	26 meters

In this paper, the case study will only discuss the Cikarag Weir, Cikarag weir was built in 2013 to replace a traditional stone weir which already broken by the flood and river bed degradation. The weir has 8 meters width and 28.25 m^3/s of design discharge to provide water for irrigation. Cikarag weir was located in a remote area where mobilization access is quite tough. Therefore, all the modules used for these projects were made in the location near the quary area. The forms for the modules are made from woods. One of the important factors of this method is to have a good quality formwork to produce a precise module. This is important because if the module's precision is bad then the installation of the modules will become impossible.

Figure 11. Modular Weir Prototype Location

After the modules isready, the storage area needs to be prepared to put all the modules. While the site is prepared, the modules installation can be done simultaneously. This is one of the advantages of the modular method in construction, where in conventional or traditional construction method the activity is done one by one, in modular construction some of the activity can be done in parallel. Since the weight of the each modules is approximately 170 – 180 kg, the worker can still pull and move the concrete blocks by manual in group of 3-4 people. The installation of the modules can be done from upstream to downstream and vice versa.

Figure 12. Instalations of the Concrete Modules

3.3 Performance of Cikarag Weir

Based on 7 years of monitoring from 2013 to 2019 (See Figures 13 and 14), the structure is still working well as a weir structure to raise the water level and provide water for irrigation. The modules are still hooked and locked with one another though the surface of the concrete modules have already worn out due to high flow velocity. Intake channel is still working to deliver discharge for irrigation area downstream of the weir.

Figure 13. CikaragModular Weir in 2013(Source :Pusair 2013)

Figure 14. Cikarag Modular Weir in 2019 (Source :Pusair 2019)

As shown in Figure 15, the longitudinal section of the Cikarag river from the year of 2012, 2014 and 2019. There are accumulation of sediment upstream of the crest while the downstream area are more dynamic with aggradation and degradation of sediment.

Some challenges occurred during the operational fo the weir related to the material such as branch and wood that stuck in the crest of the weir. Since there is no sluice gate installed in this structure, the sediment accumulated faster in the upstream of the crest. This should be solved by routine maintenance that needs to be done frequently. The local community agree to dredge the sediment material periodically especially near the intake channel.

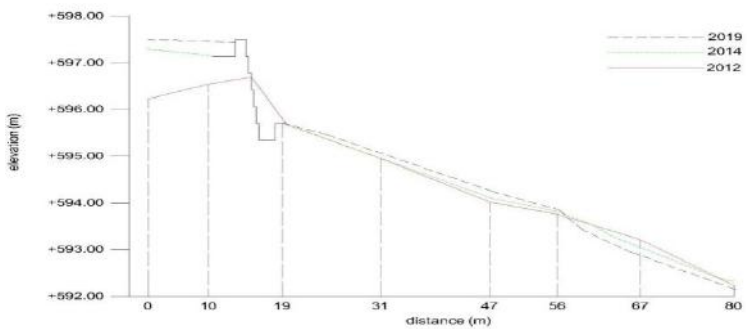


Figure 15. Monitoring of Longitudinal Section of Cikarag River

3.4 Discussions

Modular technology is developed to support the sustainable water infrastructure for irrigation in Indonesia. As an innovation in construction industry, there are some challenges that need to be solved before it can fully implement on the field, some factor are mentioned below :

1. **Culture**

The old and conventional perception of the new technology sometimes reduce the credidibility of the product. Some stakeholder still doubt related to its performance, especially when there is no field implementation and official guidelines yet.

2. **Technical Spesification**

Since the structures consist of many modules, each units has its own quality that needs to be maintained. This is also a challenge for the executor and stakeholder.

3. **Human Resources**

The new technology like modular construction is still unpopular among the stakeholder. This condition means that there is lacks of knowledge of this technologies.

In order to overcome these challenges, the adoption of the new technologies needs to start soon to disseminate the knowledge and experience among stakeholder. Once the advantages and disadvantages of this technology is known, it can be an alternative solution for water resources project in particularly. PUSAIR as a research institute which already have the patent for this modular weir technology, already started to create a standard and guideline for Modular Weir Design, Construction, Operation, and Maintenance based on the experience working on modular construction for weir structure in Indonesia.

4. CONCLUSIONS

Modular technology is a method that uses prefabricated modules that has perfect solution to support construction in remote areas where conventional method may not be possible. Based on the monitoring survey of the modular weir prototype in Cikarag River, the structure apparently is working well to raise the water level for intake discharge requirement while still allowing water to flow steadily over top of the weir crest itself. The construction method is easier and faster through parallel working. Therefore modular construction is more efficient and sustainable for weir construction in Indonesia.

5. ACKNOWLEDGEMENT

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