MODULAR SABO DAM CONSTRUCTION METHOD WITH PRECAST MODULES TO CONTROL LAHAR FLOW IN VOLCANIC AREAS

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***Abstract*- Conventional sabodams built in volcanic areas are often damaged and even collapsed by the high impact force of the lahar flow, namely the debris flow that occurs due to the eruption of a volcano [8]. As a solution, modular sabodam innovation was carried out using high quality precast modules consisting of J-shape, C-shape, T-shape and box-shape modules for the main dam and subdam bodies. The sabodam wing uses a box-shape module. The apron uses an apron-shape module. The purpose of this research is to find out how to install these precast modules so that apart from having high quality, their construction can also be carried out more quickly.**

***Index Terms*—Modular, sabo, innovation, installation** *(key words)*

I. INTRODUCTION

The existence of volcanoes in Indonesia plays an important role in the development of the surrounding area related to soil fertility or as a tourist destination and others, but there are challenges that need to be overcome when a volcano is in a phase before, during, and after eruption [3]. The disasters caused are in the form of primary eruption disasters, such as pyroclastic flows, volcanic ash and secondary disasters in the form of lahar flows [6]. Both types of disasters have caused many casualties and property losses.

To control the lahar flows, various types of sabo dam have been built, both open and closed types [4]. The magnitude of the impact force of the lahar flow causing many sabo dams being damaged and even collapsing. Therefore, apart from the need for high-quality sabo dam, the implementation of sabo dam structures in this very dangerous area must also be carried out more quickly.

To solve this problem, in 2016-2017 a research collaboration was carried out between the Sabo Technical Centre and a private company, namely the Research and Development Division of PT. Wijaya Karya Beton Tbk. to create a modular sabodam innovation that will be applied in areas prone to lahar flows [7] upto the preparation of detailed engineering designs. In 2018 a modular sabodam pilot project was carried out in the Konto River, Mount Kelud area, Siman Village, Kepung District, Kediri Regency, East Java Province, Indonesia (Fig. 1), located at coordinates 7°48'37.33" South Latitude and 112° 18'19.55" East Longitude. This modular sabo dam pilot project will be the first in Indonesia, and perhaps also a first for other places.

Fig.1 Modular sabo dam pilot project site.

II. METHODS

In principle, the method of implementing modular sabo dam construction is to move and arrange precast concrete modules into the outer layer of sabo dam which then becomes a complete building by direct casting as filler and fastening between modules using heavy equipment. Therefore, the construction implementation phase requires a variety of heavy

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equipment and a small number of workers according to the needs in the field.

III. Results

The application of modular sabo dam is carried out through the following stages.

- Carry out preparations (land clearing, evasion channels, stock yards, mobilization of heavy equipment),
- Making precast modules consisting of J-shape, C-shape, T-shape, apron-shape, and box-shape [9, 10],
- Creating a work floor
- Arrange layer 1 for main dam and subdam bodies consisting of J-shape, T-shape and in-situ concrete modules.
- Arrange layer 2 for main dam and subdam bodies consisting of C-shape, T-shape and in-situ concrete modules
- Making connections between layers, where the J-shape and C-shape modules have dowel holes anchored with screw iron filled with mortar,
- Arrange the protective wings using box-shape, anchored with screw iron, then cast with in-situ concrete.
- Arrange the apron with apron-shape modules and in-situ concrete as filler between modules, so that it becomes a modular sabo dam construction.

IV. Discussions

Before installing precast modules, it is necessary to understand the design of the sabo dam pilot project, the precast modules used, and the advantages of modular sabo dam and how to install them.

A. Modular Sabo dam Construction

Modular sabo dam construction uses precast modules whose construction uses a modular system (Fig.2, Fig.3 and Fig.4). Precast modules as a constituent of modular sabo dams have the advantage that they use high-strength concrete, are resistant to impact and abrasion and have high resistance to weather changes because the concrete is produced in factories [11].

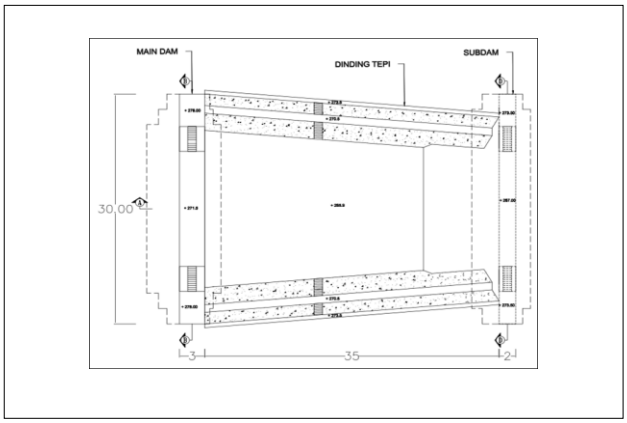

Fig.2 Modular sabo dam top view

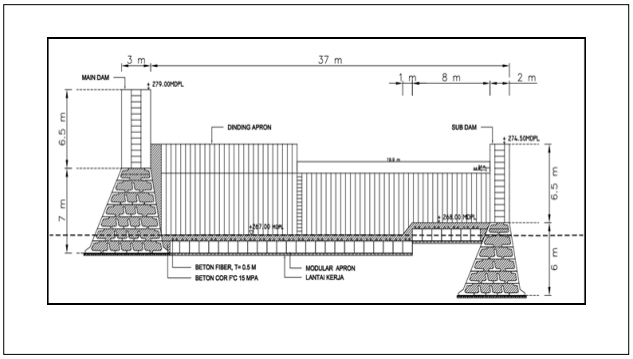

Fig.3 Modular sabo dam longitudinal section

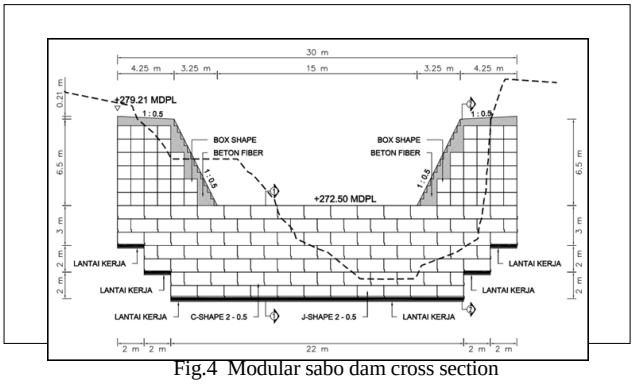

Fig.4 Modular sabo dam cross section

Precast modules can be mass produced so that the execution time of the work can be faster, it does not require a lot of formwork, requires less manpower, and in its implementation does not disturb the environment. The construction of modular sabo dam with precast modules is combined with in-situ concrete as a filler so that the sabo dam becomes a composite.

B. Precast Module

There are five different types of precast modules that make up the modular sabo dam. The precast module is designed with a length and height of 1 m so that it is easily adjusted to the dimensions of the planned sabo dam [5] and makes it easier to transport and install. The mold of this module is made of steel to obtain precise results with a tolerance of 1 cm for installation in the field. Bonding between modules in the horizontal direction uses a male-female connection while the vertical direction uses an anchor connection filled with grouting.

Each type of module designed is named as a nomenclature, namely J-shape, C-shape, T-shape, apron-shape, and box-shape modules. For the main dam and subdam body using J-shape and C-shape modules for the outside and T-shape modules for the inside and cast in situ concrete for composite. For the wings using box-shape module. For the apron using an apron-shape module.

By utilizing precast modules in this modular sabo dam construction, a better quality sabo dam will be obtained and an easier and faster installation.

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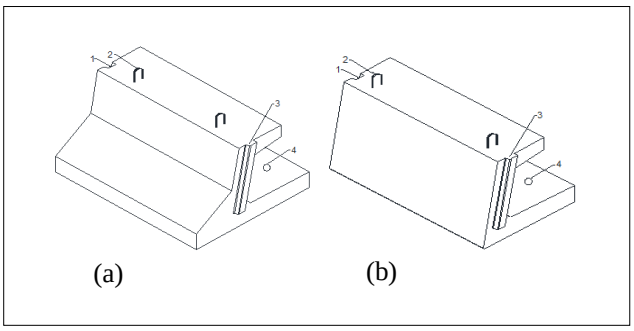

Fig.5 Precast module (a) J-shape, (b) C-shape

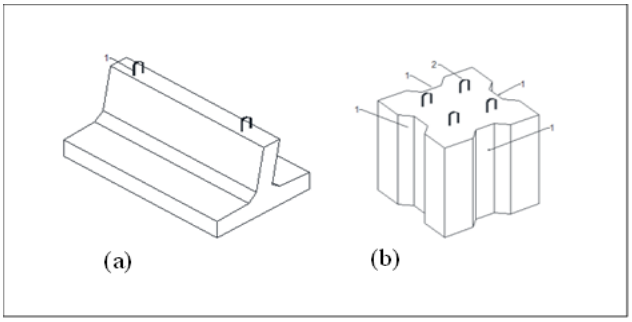

Fig.6 Precast module (a) T-shape, (b) Apron-shape

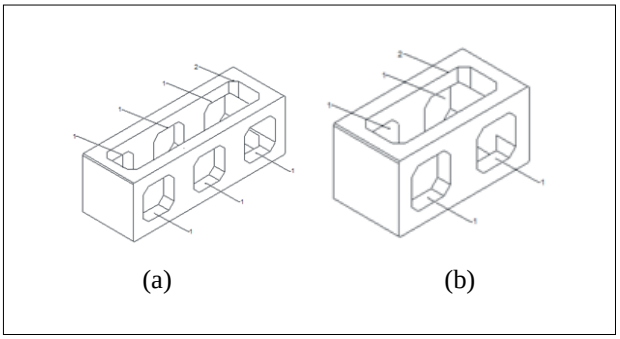

Fig.7 Box shape precast module (a) for main dam (b) for subdam

C. Advantages of Modular Sabo dam

Technically the sabo dam must meet the functional and structural reliability requirements as indicated by performance indicators in the form of the effectiveness of lahar/debris flow control and structural durability [1]. Conventional sabo dam from masonry or normal concrete structures often experience damage and even collapse [3], in addition to the relatively long construction time. While the modular sabo dam has a much better quality and fast construction time (see Table I).

TABLE I. COMPARISON OF CONVENTIONAL SABO DAM WITH MODULAR SABO DAM

Parameters		*Konventional Sabo dam*	*Modular Sabo dam*
1	Concrete quality	• The quality of concrete in the field is difficult to control. • The curing process is affected by the weather.	• The quality of concrete is easy to control, because it is produce in a factory using a batching plan. • Has high resistance to weather changes.
2	Construction time	Concrete casting process takes a long time.	Save time because modules can be mass-produced at the factory.
3	Formwork material	Requires a lot of formwork.	No formwork required.
4	Manpower	A lot	A little
5	Work environment	Dirty	Environmentally friendly, clean, does not pollute the environment.
6	Heavy equipment	Does not require heavy equipment for casting.	Requires a crawler crane for module installation.
7	Product	Conventional	Innovative

D. Modular Installation

Installation of precast modules on modular sabo dams is carried out using heavy equipment such as crawler cranes. J-shape and T-shape modules are installed for the first layer, C-shape and T-shape modules are installed for the second layer and so on according to the height of the sabo dam and box-shape modules are installed for the wings of the sabo dam. In situ concrete casting uses a bucket that is poured with a crane and then compacted with a vibrator. Figures 8, 9, 10, 11, 12 and 13 describe how to install a modular sabo dam.

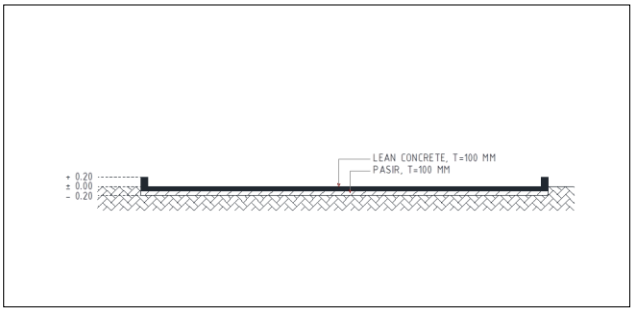

Fig.8 Stages of making work floor

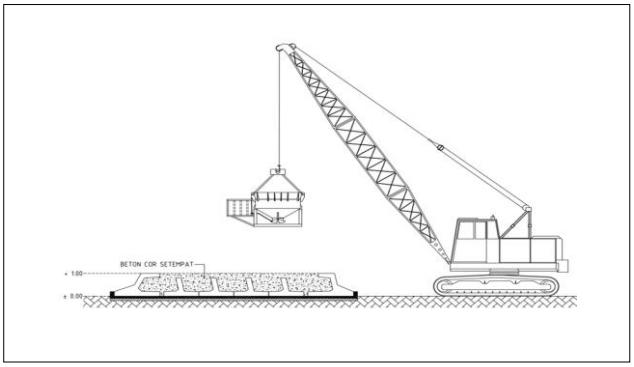

Fig.9 Installation of module at layer 1

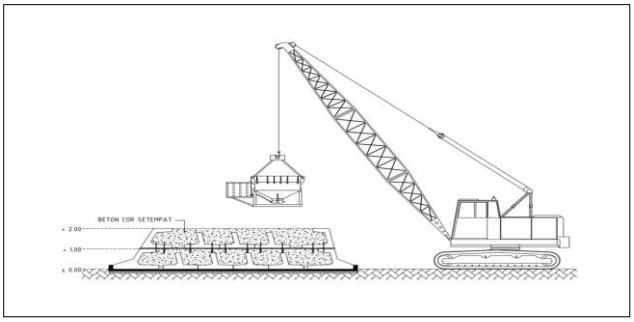

Fig.10 Installation of module at layer 2

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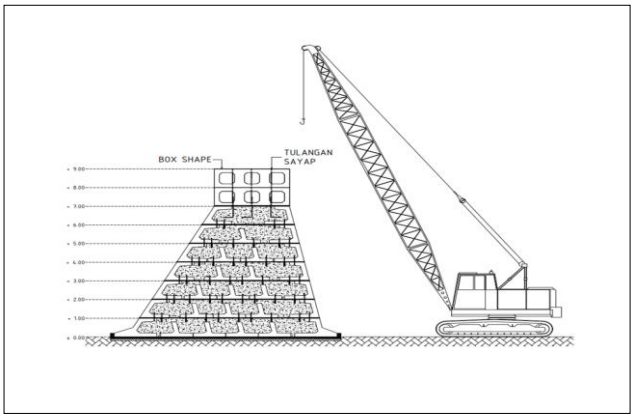

Fig.11 Installation of box-shape module

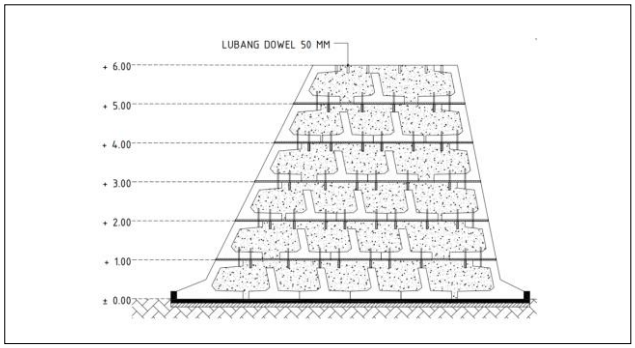

Fig.12 Connection method between layers

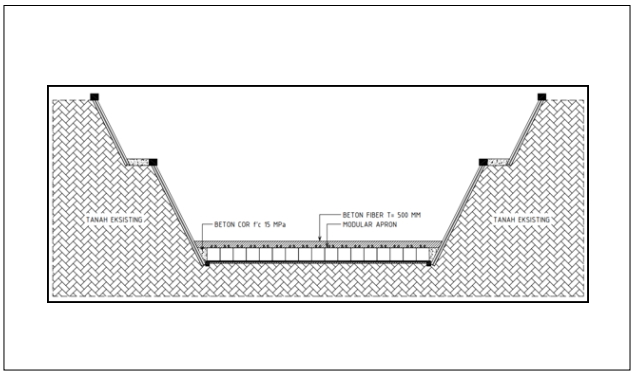

Fig.13 Installation of apron-shape module

Refer to Figure 8. The working floor must be on a level ground condition and in accordance with the axle of the structure. The work floor is composed of two layers, namely the base layer in the form of sand with a thickness of 10 cm and the top layer in the form of lean concrete [11] with a concrete quality of f'c = 8 MPa with a thickness of 10 cm.

Refer to Figure 9. Installation of the J-shape module on the first layer of the main dam and subdam bodies. The J-shape module has two shapes, namely (a) J-shape 1 with a vertical slope of 1:0.2 and (b) J-shape 2 with a vertical slope of 1:0.5. The J-shape module is placed in the first layer of the outer sabo dam by being lifted using a crawler crane, after making the working floor on the base of the main dam and subdam. In the middle of layer 2, the T-shape module is placed, then insitu concrete is cast as a filler so that it becomes a composite part In situ concrete casting uses a bucket that is poured with a crane and then compacted with a vibrator. At the bottom and inside of the J-shape module, the surface was roughened while the entire T-shape module was roughened as the bond between precast concrete and in-situ concrete.

Refer to Figure 10. Installation of the second layer C-shape module for the main dam and subdam bodies. The C-shape module has two shapes, namely (a) C-shape with an upright slope of 1:0.2 [6] and (b) C-shape with an upright slope of 1:0.5. The C-shape module is placed on the outer second layer and so on until the top of the overflow after the first layer work is finished. In the middle of the second layer, the T-shape module is placed, then in-situ concrete is cast as a filler so that it becomes a composite part. In-situ concrete casting using a bucket poured with a crane then compacted with a vibrator. At the bottom and the inside of the C-shape module, the surface was roughened, while the entire surface of the T-shape module was roughened as the bond between precast concrete and in-situ concrete.

Refer to Figure 11. Installation of box-shape modules for main dam and subdam bodies including the protective wing of sabo dam. The box-shape module has two shapes, namely (a) a 3 meter wide box-shape mounted on the main dam wing and (b) a 2 meter wide box-shape mounted on the subdam wing. The box-shape module is placed and lifted using a crawler crane and the box-shape holes are filled with in-situ concrete and the anchors are vertically screwed. In situ concrete casting uses a bucket that is poured with a crane and then compacted with a vibrator.

Refer to Figure 12. The connection between layers uses a 19 mm diameter screw mounted on the dowel holes that have been designed in the precast modules, then filled with mortar.

Refer to Figure 13. Installation of an apron shape for an apron that has a cube shape with certain dimensions and has a U-profile protruding into the four upright sides. Between modules filled with in-situ concrete as a filler so that it becomes a composite part. In situ concrete casting uses a bucket that is poured with a crane and then compacted with a vibrator.

V. Conclusion and Recommendation

Modular sabo dam construction uses precast modules using a modular system and in situ concrete as filler to make it a composite construction. The modular installation relies on heavy equipment such as crawler crane with less manpower and does not require formwork so that the construction of the sabo dam becomes more environmentally friendly [2] because not much material is used in the sabo dam body and the product is very innovative. Modular sabo dam construction in this study uses a closed type, so that in the future it needs to be developed for open type sabo dam and it is possible to develop other complementary structures such as revetment / bank protection and groynes. In addition, hybrid sabodams can also be developed that are tailored to the needs in the field

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