The Modular Geometry of Precast Concrete for Highway Drainage Channel

Kelik Istanto[1,a)], Ranto Tumangger[1,b)], Eka Febri Astuti[1,c)], Iskandar Zulkarnain[1)], Resti Agustina[1)]

[1]*Department of Engineering, Politeknik Negeri Lampung, Bandar Lampung, Indonesia*

[a)]Corresponding author: kelik@polinela.ac.id
[b)] rantotumangger@polinela.ac.id
[c)] ekafebri@polinela.ac.id

Abstract. This research is based on the phenomenon of failure of masonry drainage channels, especially in locations with steep to very steep slopes. Observing the flow behavior and mechanical properties of the masonry, it is possible due to the erosion of the bottom to the foot of the channel so that the masonry collapsed and/or due to side soil pressured which caused the masonry failure. It could be overcome by replacing the masonry with precast concrete. The obstacle of precast concrete implementation in low cost projects is involvement of heavy equipment when erecting precast concrete for drainage channel (e.g. U-Ditch) which is available on the market. This research aims to design the geometry and dimensions of precast components for open channel of drainage with limitations: component weight (kg/component) is limited so that it could be lifted by man power and is able to flow a design discharge ≥ 0.5 m3/s at 1.5 m /s. Channel was divided into 4 components, namely: foundation (F), bed (B, type I and II), wall (W), and channel cap (C) with 6 cm of thickness, 1:10 (H:V) of wall slope channel, and 75 cm of each component length. Each component weighs no more than 50 kg, so could be carried out without heavy equipment when constructed. The weights of each component are 39.8 kg, 45.36 kg, 28.8 kg, 37.8 kg, and 21.45 kg for foundation, bed type I, bed type II, wall, and channel cap.

Keywords: Drainage, Channel, Failure, Precast, Concrete

INTRODUCTION

One important aspect of highway design was protecting it from surface and ground water. Puddles of water on the highway surface would slow vehicles down and could contributed to accidents due to disruption of the view by splashes and sprays of water. Apart from this, if water entered the highway structure, pavement, and subgrade it could cause the highway construction to be more susceptible to damage [1]. Therefore, highway construction needed to be equipped with drainage support facilities, so that excessive water runoff could be minimized by implementing appropriate construction for highway drainage so that it met the technical requirements of highway infrastructure [2].

Highway drainage construction, especially in rural areas even in urban areas, still used stone masonry construction with or without construction at the bed of the drainage channel. It mostly occurred that stone masonry collapsed / failure in channel wall. By hydraulic and mechanic approach, the failure or collapse was possible due to erosion in the bed of channel, local scoring in the bottom of channel wall, and side soil pressured to channel wall [3].

Based on the flow behavior and mechanical properties of the stone masonry, the construction failure possible due to the erosion of the channel bed to the foot of the masonry wall so that the masonry collapsed and/or due to side soil pressure which caused the stone masonry cracked at weakest point. Therefore, a technical approach was needed to control local scouring and increased structural strength to side soil pressured. When it was related to the phenomenon of drainage channel collapsing due to local scouring and soil pressure, then the use of reinforced concrete material (including precast concrete) in the bed and wall of the drainage channel could control scour and increase the strength of the channel wall against soil pressure. The result of observations on several projects (observations at construction sites), the used of precast concrete material was able to answer technical and environmental problems [4].

Precast reinforced concrete was one of the engineering structural elements of construction with the aim of speeding up the implementation process and providing economic value without reducing the ability of the structural elements to carry the existing load. The basic difference between precast concrete and conventional concrete is that the conventional concrete casting process is carried out in situ cast while the precast concrete casting process is carried out outside the construction site, namely in a prepared factory or workshop [5].

Precast concrete could be produced in modular form, that one precast system consisted of several modules or it could be explained that precast modules with certain geometries, when it connected to one another, would form a unified planned structural system. This technology was able to reduce the need for concrete materials by up to 64% when compared to conventional shotcrete techniques for retaining wall construction [6].

The research on the application of innovative precast concrete technology in construction began from 1970 to 2000. After 2000, research on precast concrete became increasingly massive along with the increasing implementation of precast concrete in the construction industry [7].

The advantages of implementing precast concrete technology for channels compared to conventional concrete (in situ cast), include: stronger channel walls, guaranteed neatness, and easy repaired during the channel operational period [8]. However, precast concrete had disadvantages that could be reduced by dividing precast concrete panels into several precast modules (precast components) so that the weaknesses were reduced [6].

Heavy equipment was needed in erecting precast concrete that available in market. It became obstacle in low budget and community projects. So that, it was difficult to implement precast concrete in low budget and community projects. There was big question for it, “How precast concrete could be applied in low budget and community projects?”. In line with question, this research aim to design the geometry and dimension of precast components / modules for open channel of drainage with weight limitation in order to erected by man power.

METHODS

The method used in this research is a general method in construction design. Starting with determining design criteria until obtaining modular geometry of precast concrete. The method used is shown in the diagram below.

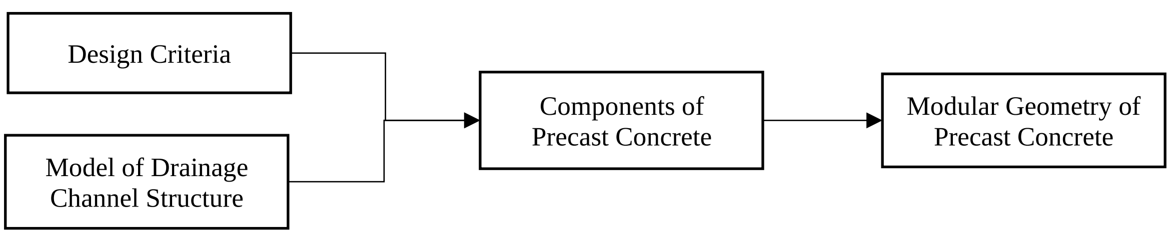

FIGURE 1. The Research Method

Referring to the flow chart above, the steps to obtain precast concrete modular geometry could be explained as follows:

- determined design criteria based on correlation between problems and solutions of this case;
- determined model of drainage channel using design criteria and preliminary design parameters;
- controlled whether the preliminary design result complied with the design criteria;
- analyzed precast concrete system into several modules / components;
- analyzed and designed modular geometry of precast concrete;
- controlled whether each modular geometry of precast concrete complied with design criteria, i.e. modular weight limitation.

RESULTS AND DISCUSSION

DESIGN CRITERIA AND MODEL

The problems had stated as the background of this research were needed to solve through appropriate solutions. Recommended solutions to the problems in this case were presented in the **TABEL 1**.

TABEL 1. Problems and Solution

Problems	Solutions
The masonry wall channel collapsed due to local scoring and soil pressured	Replaced masonry by reinforced concrete to minimize the impact of local scoring
Cast on site was difficult to do and required a long time to dry the concrete	The reinforced concrete used should be precast concrete
Erection of precast concrete (e.g. u-ditch precast) required heavy equipment, for certain locations it was difficult to do due to access and financing capabilities	The precast concrete could be divided into several components and each one could be lifted by man power
The most phenomenon of drainage channel wall collapsed occurs in channels with discharge ≥ 0.5 m^3/s and flow velocity ≥ 1.5 m/s	Precast concrete components could meet the dimension to flow discharge ≥ 0.5 m^3/s and precast system had to able to be dimension adjustment

Referred to recommended solution, design criteria could be determined as constraints of open drainage channel. The design criteria were:

- Implemented precast concrete to constructed open drainage channel;
- Precast concrete system consisted of modules / components that made up open drainage channel;
- Module / component weight had to be limited so that it could be lifted and erected by man power;
- Precast concrete system that made up open drainage channel could flow discharge ≥ 0.5 m^3/s and had to able to be dimension adjustment;
- Freeboard depth was equal to 15 cm.

Design criteria above was used to do preliminary design with given parameters as presented in **FIGURE 2**.

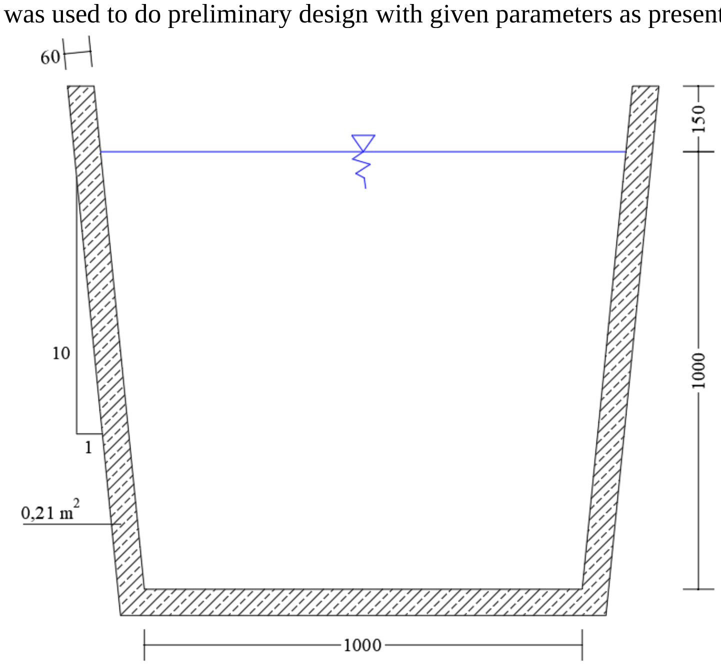

FIGURE 2. Model of Open Drainage Channel (dimensions in mm)

MODULES OF DRAINAGE CHANNEL

Model of open drainage channel in **FIGURE 2** was given parameters were 60 mm of thickness, 10% of channel wall slope (h:v), 1000 mm of wide, 1000 mm of depth, and 150 mm of freeboard. When the given parameters applied in precast concrete segment 750 mm of length and concrete density was about 2400 kg/m^3, therefore the weight of precast segment was about 378 kg. It required heavy equipment in lifting, loading, and erecting. Divided the segment into modules / components would be possible to be lifting, loading, and erecting by man power.

Model of open drainage channel had critical points, they are at intersections between bed and walls. Modified model by added foundation would increase the strength at those points.

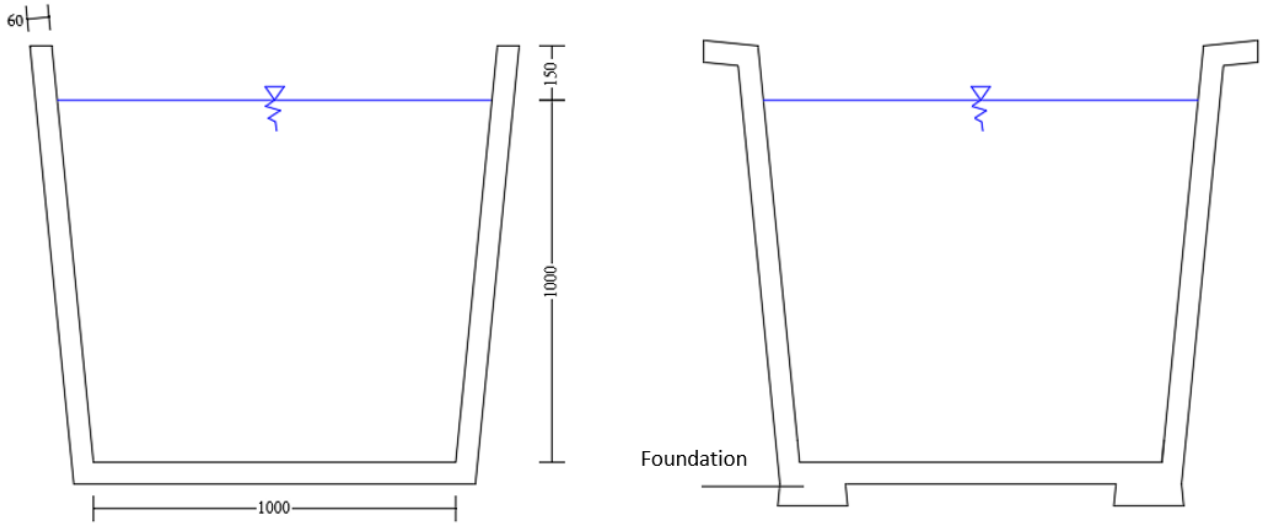

FIGURE 3. Modified Model

In **FIGURE 3**, beside added foundations to the model, also added caps at the top of the model. Caps was added to meet aesthetic need and prevented topsoil erosion. Structure of open drainage channel as generally consisted of wall and channel bed. Therefore the precast system was divided into 4 modules / components namely foundation, base, wall, and channel cap.

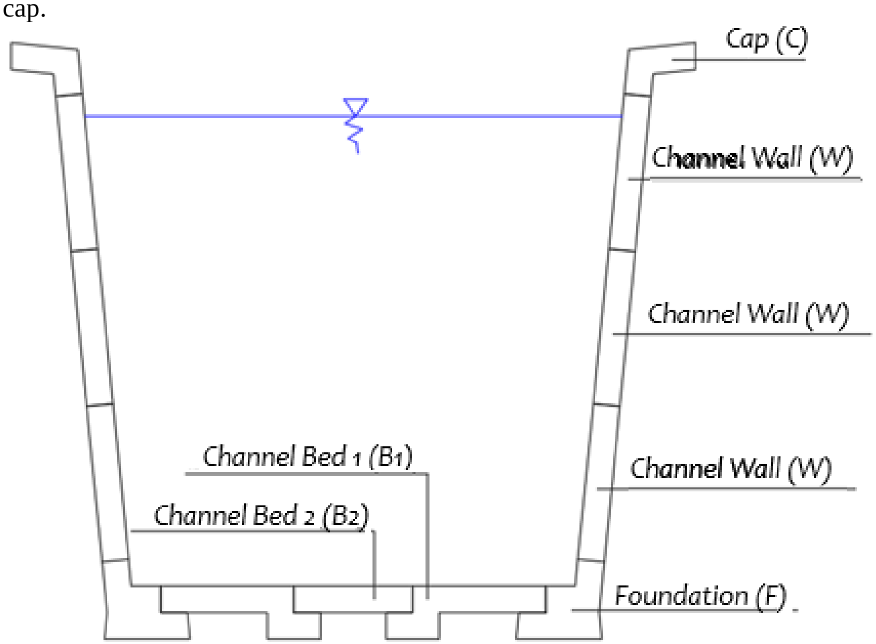

FIGURE 4. The Modules of Precast System

Each module and component had its own function in the precast system that formed the open drainage channel. The function of each component was tabulated in **TABLE 2**.

TABEL 2. The Function of Modules

Module / Component	Function
Foundation; F	Supported channel structure
Bed; B	Prevented erosion at the bottom channel and local scoring at the foot of channel wall
Wall; W	Prevented landslides and increased flow velocity
Cap; C	Prevented topsoil erosion and aesthetic need

Bed and wall component were possible to make adjustment of channel dimension in horizontal and vertical direction that shown in **FIGURE 5** and **FIGURE 6**.

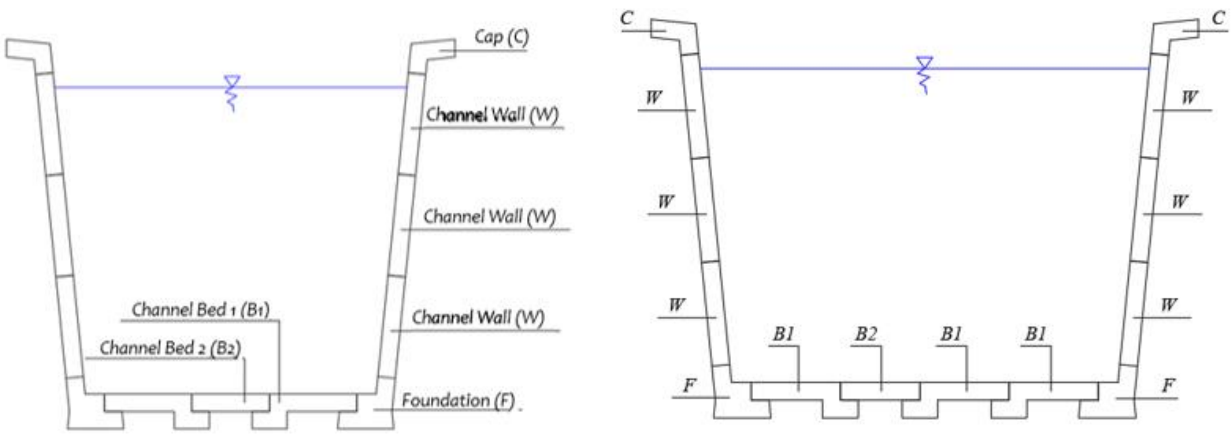

FIGURE 5. Dimension adjustment of horizontal direction

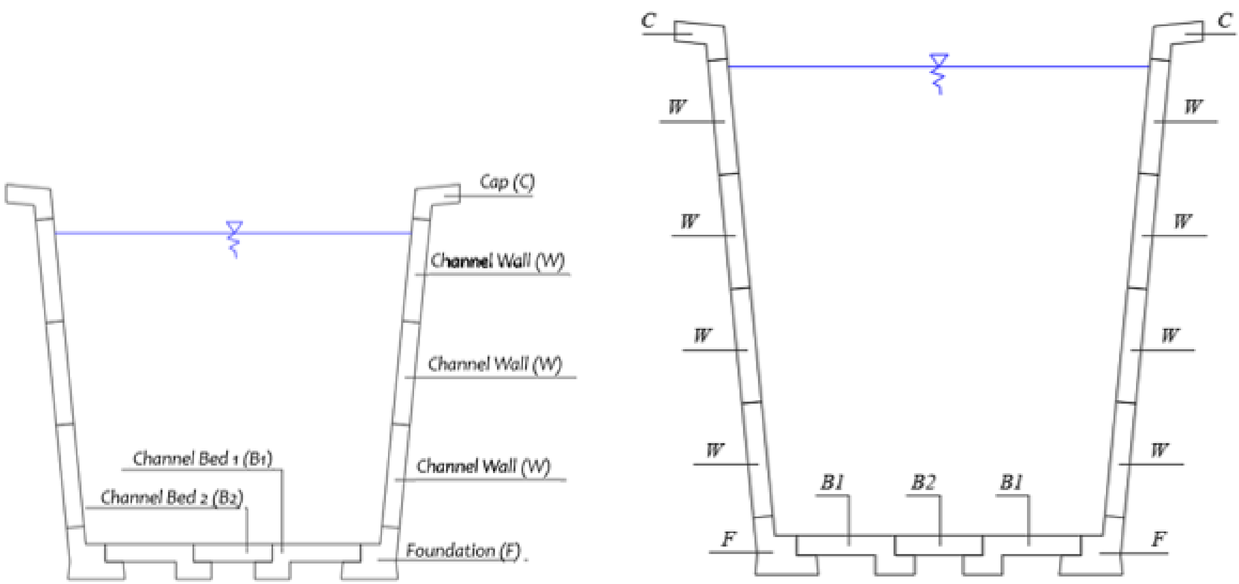

FIGURE 6. Dimension adjustment of vertical direction

MODULAR GEOMETRY

The components/modules that made up the precast system for open drainage channel were designed in such a way that they could be connected to each other easily to form open drainage channel segment with a trapezoidal cross section. Modular geometry of components were shown in **FIGURE 7** to **FIGURE 11**.

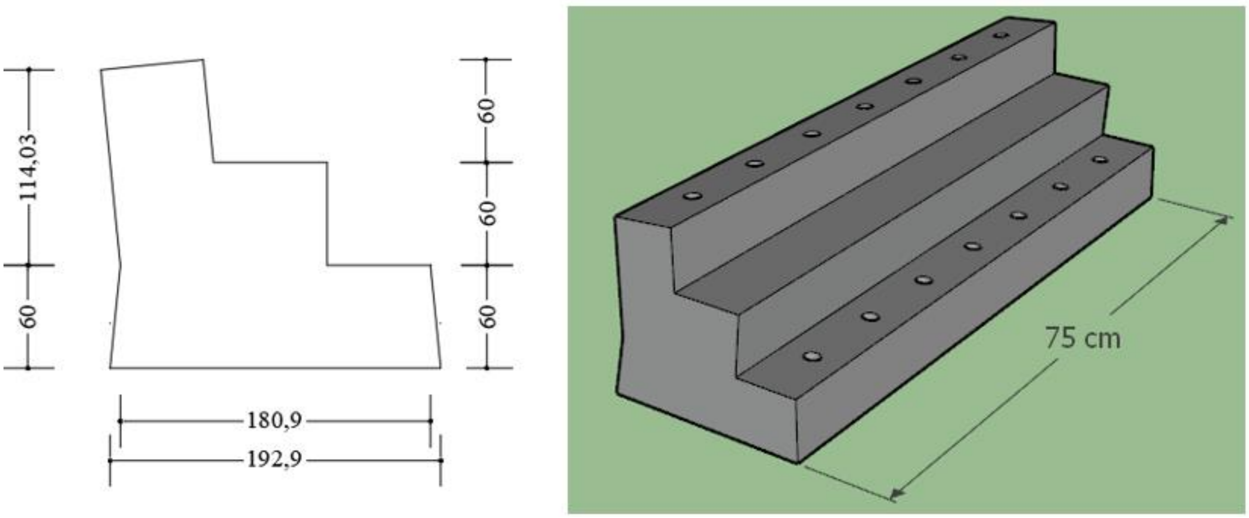

FIGURE 7. Modular Geometry of Channel Foundation (F)

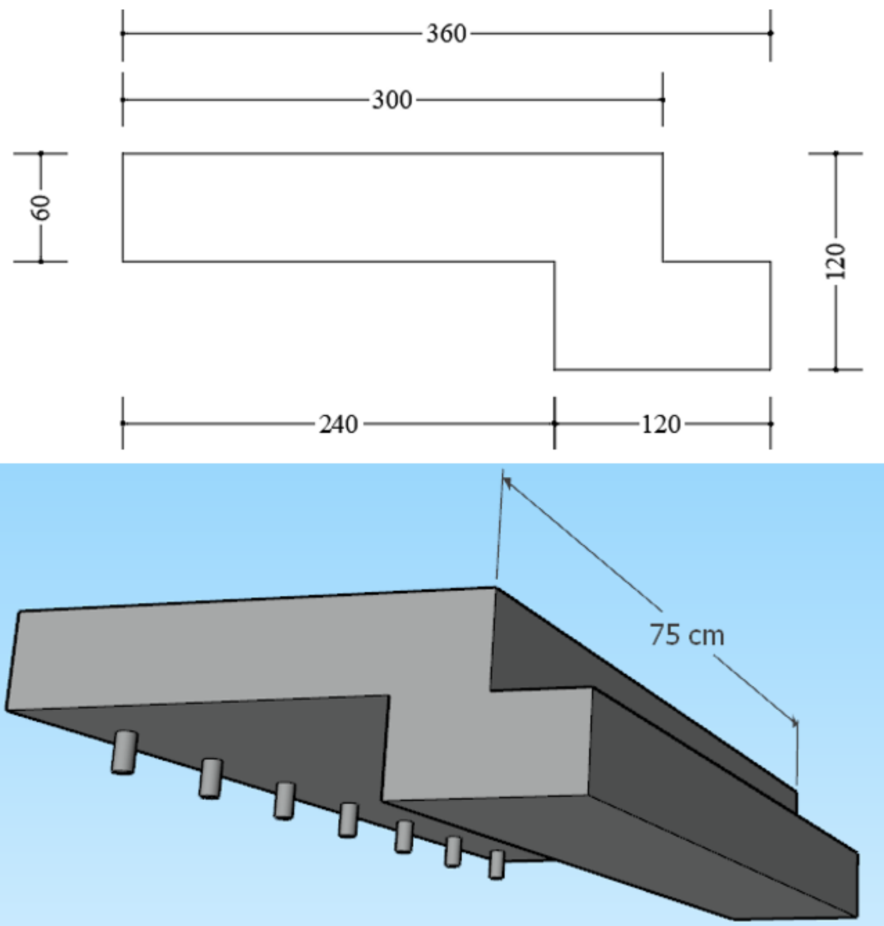

FIGURE 8. Modular Geometry of Channel Bed Type 1 (B1)

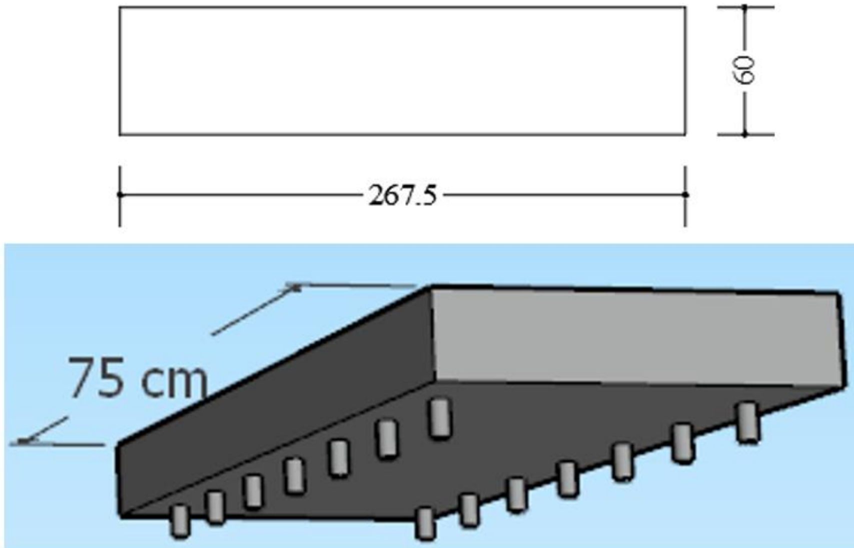

FIGURE 9. Modular Geometry of Channel Bed Type 2 (B2)

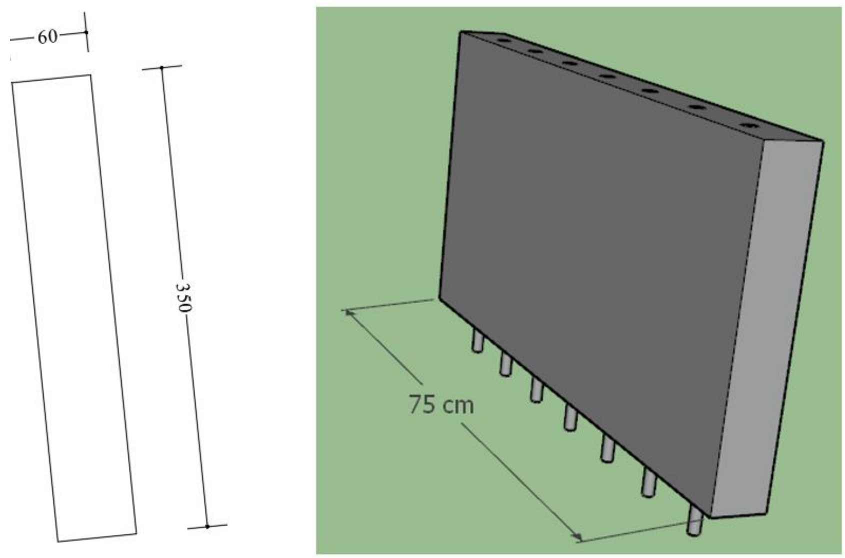

FIGURE 10. Modular Geometry of Channel Wall (W)

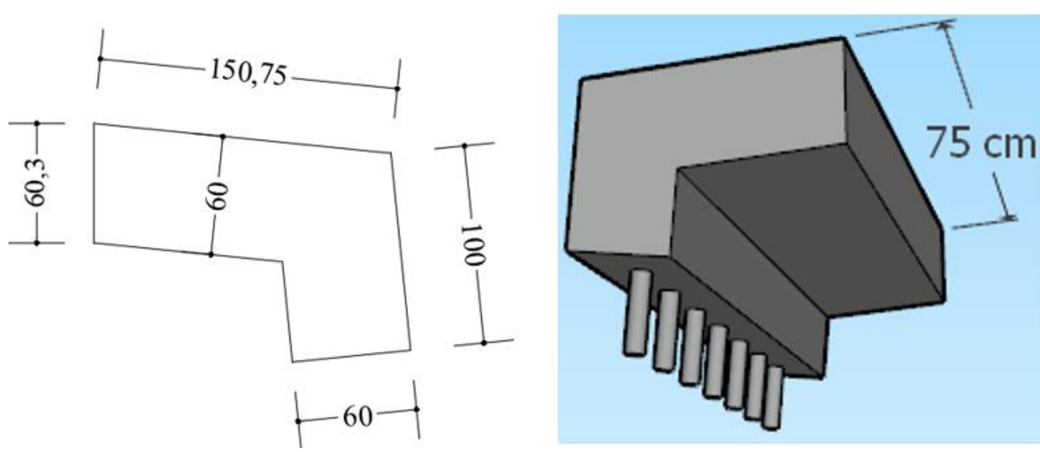

FIGURE 11. Modular Geometry of Channel Cap (C)

The weight of each module/component with 60 mm of thickness, 750 mm of length, and 2400 kg/m^3 of density was presented in **TABLE 3**.

TABEL 3. The weight of module/component

Module / Component	Weight (kg)	Maximum Weight (kg)
Foundation; F	39.78	45.36 The weight of B1 component
Bed Type 1; B1	45.36	
Bed Type 2; B2	28.8	
Wall; W	37.80	
Cap; C	21.45	

It was known that the maximum component weight was 45.36 kg (the weight of module B1), therefore erecting precast system modules of open drainage channel had not to involve heavy equipment, otherwise, erecting it could be carried out by man power. Thus, the designed precast modules could be applied to low budget and community projects.

CONCLUSIONS

Based on the results and discussion, it could be concluded that open drainage channel was designed with 6 cm of thickness, 1:10 (H:V) of wall slope channel, divided into 4 components namely: foundation (F), bed (B, type 1 and 2), wall (W), and channel cap (C) with 75 cm of each component length. Each component weight no more than 50 kg, so could be carried out without heavy equipment when constructed. The weights of each component were 39.8 kg, 45.36 kg, 28.8 kg, 37.8 kg, and 21.45 kg for foundation, bed type 1, bed type 2, wall, and channel cap.

REFERENCES

[1] N. K. S. Kartika, W. M. I, and S. D. R. A.A, “Evaluasi Fungsi Saluran Drainase Terhadap Kondisi Jalan Gunung Rinjani Di Wilayah Kecamatan Denpasar Barat Evaluation Drainage Channel Function Against Road Condition Gunung Rinjani in Denpasar Barat District Area,” *WICAKSANA J. Lingkung. Pembang.*, vol. 2, no. 1, pp. 17–24, 2018.

[2] E. Rihandiar and M. Dikriyanto, “Perencanaan Sistem Drainase Jalan Raya (Studi Kasus Jalan Aria Wiratanudatar Cianjur),” *J. Momen Tek. Sipil*, vol. 3, no. 1, p. 33, 2020, doi: 10.35194/momen.v3i1.1021.

[3] R. Heska Desrian Habibullah *et al.*, “1578 | Perencanaan Saluran Drainase Dalam,” vol. 4, no. 2, pp. 1578–1588, 2021.

[4] A. Ospanova, M. Milani, and C. Kaviratne, “Use of Precast Concrete to Minimize Environment Impacts in the Construction Industry,” *Artic. Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 9001, no. January, p. 14223, 2022, doi: 10.15680/IJIRSET.2022.1112003.

[5] V. Aditama, S. Indra, and D. E. Priskasari, “Panel Beton Pracetak Untuk Elemen Struktur Rumah Dua Lantai,” *J. Infomanpro*, vol. 10, no. 2, pp. 54–66, 2021, [Online]. Available: https://ejournal.itn.ac.id/index.php/infomanp

[6] T. T. Bui, M. Bost, A. Limam, J. P. Rajot, and P. Robit, “Modular precast concrete facing for soil-nailed retaining walls: laboratory study and in situ validation,” *Innov. Infrastruct. Solut.*, vol. 5, no. 1, 2020, doi: 10.1007/s41062-019-0250-z.

[7] D. Terzis, “Monitoring innovation metrics in construction and civil engineering: Trends, drivers and laggards,” *Dev. Built Environ.*, vol. 9, no. December 2021, p. 100064, 2022, doi: 10.1016/j.dibe.2021.100064.

[8] H. Darmawan, “Perubahan Pekerjaan Beton Lining in Situ ke Beton Precast pada Jaringan Irigasi D.I. Tapin Kabupaten Tapin,” *J. Teknol. Berkelanjutan*, vol. 11, no. 01, pp. 47–55, 2022, doi: 10.20527/jtb.v11i01.218.