

# Ibu\_Rita\_2.pdf

*by*

---

FILE	IBU_RITA_2.PDF (776.58K)	WORD COUNT	4385
TIME SUBMITTED	16-JAN-2021 11:35AM (UTC+0700)	CHARACTER COUNT	22234
SUBMISSION ID	1488488370		

5

**International Journal of Civil Engineering and Technology (IJCIET)**

Volume 10, Issue 2, February 2019, pp. 671–683, Article ID: IJCIET\_10\_02\_065

Available online at <http://www.iaeme.com/ijciyet/issues.asp?JType=IJCIET&VType=10&IType=2>

ISSN Print: 0976-6308 and ISSN Online: 0976-6316

©IAEME Publication



Scopus Indexed

# EFFECT OF FRP STRENGTHENING ON FLEXURAL CAPACITY OF PRECAST U-DITCH CHANNEL

12

**Rael Rabang Matasik**

Doctoral Course Student of Civil Engineering Department, Hasanuddin University, Makassar

3

**M.W. Tjaronge**

Professor, Civil Engineering Department, Hasanuddin University, Makassar

**Rudy Djamaluddin**

Professor, Civil Engineering Department, Hasanuddin University, Makassar

3

**Rita Irmawaty**

Associate Professor, Civil Engineering Department, Hasanuddin University, Makassar

## ABSTRACT

The precast channel system (U-Ditch) is one of the innovations of precast concrete designated as a channel for drainage and irrigation systems. The U-Ditch must have sufficient bending capacity to carry a major load due to ground pressure. However, the addition of wall thickness will lead to the heavy construction product. Therefore, a new product innovation was developed in this study, where the wall thickness was reduced and strengthened using fiber reinforced polymer (FRP). In these regards, this study aims to investigate the effect of FRP strengthening on the behavior of precast channel systems. Three types of specimens were tested in this study. Type N was normal U-ditch which without a reduction of wall thickness. Type C was U-ditch with a reduction of wall thickness (corrugate). Type CF was U-ditch with a reduction of wall thickness (corrugate) and strengthened using fiber reinforced polymer (FRP). The dimension of all specimens was 500x500x1000 mm<sup>3</sup>. The specimens were tested based on Japan Industrial Standard (JIS). The results indicated that the weight reduction can be achieved by reducing the wall thickness in the area between the main reinforcement. However, it reduced the bending capacity of the wall. The strengthening using FRP sheet in the thickness reduction section was effectively to increase the bending capacity of wall, which had relatively the same with Type N (normal). Finally, all the specimens failed due to the flexural cracks around hook area of the precast channel.

**Key words:** U-ditch, Flexural Capacity, Corrugate, Fiber Reinforced Polymer.

1

<http://www.iaeme.com/IJCIET/index.asp>

671

editor@iaeme.com

**Cite this Article:** Rael Rabang Matasik, M.W. Tjaronge, Rudy Djameluddin, Rita Irmawaty, Effect of FRP Strengthening on Flexural Capacity of Precast U-Ditch Channel, *International Journal of Civil Engineering and Technology (IJCIET)* 10(2), 2019, pp. 671–683.

<http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=10&IType=2>

## 1. INTRODUCTION

The use of precast construction system provides several advantages, such as a good structure quality, faster construction work, and longer durability. Precise construction has also evolved to the construction of drainage channels (U-Ditch). In developed countries such as Japan, almost all the drainage systems used precast system. In Indonesia, precast U-ditch has also started to develop and is used in some drainage infrastructure. The existing precast U-ditch produced in Indonesia with high strength has still problems in transportation. This will be an obstacle when the application in areas that still lack of road infrastructure. In general, weight reduction will have an impact on the strength. At present various thicknesses between 6 cm and 10 cm are used to produce sufficient strength to withstand the loads. Figures 1 shows U-Ditch product manufactured in Indonesia with dimension of 800x800 mm.



a. Local Product A



b. Local Product B

**Figure 1.** Example of precast channel produced in Indonesia

In general, the thicker the wall of the channel will be the higher the capacity of the channel structure in carrying the load of soil pressure and vehicle loads. The production of precast system especially the channel is still not equipped with standard and complete standard, so there are various variations both geometry and system structure. In some developed countries such as Japan already have standards related to precast structures including channels. This is as a standard reference so as to obtain a quality channel system with optimum structure thickness. Figure 2 shows an example of a pre-cast production channel of 800 × 800 mm which is produced by Japanese company. Preprinted concrete well produced using standard will result in a well-resilient construction system [1]. Some precast elements have been developed for important structural elements to ensure their durability as for connection systems [2].



**Figure 2.** Example of precast channel produced in Japan

This paper presented the results of the innovation of precast channels by reducing the weight of the structure while maintaining the strength. The channel structure was designed based on Japan Industrial Standard (JIS). The standards used in the production of precast systems include the various standards of JSCE 2012 [3], JIS A 5345 [4], JIS A 5362 [5], JIS A 5363 [6], JIS A 5365 [7]. By using such standards as references, the precast channel system in this study was done by reducing the thickness of the channel wall. By using these standards as a reference in the innovation of precast system, the innovation of precast U-Ditch was done by reducing the thickness of the wall and by applying FRP (Fiber Reinforced Plastics) sheets as a strengthening effect on the channel wall. The application of various types of fiber reinforced polymer in RC members has been increased in the last 20 years [8, 9]. Its application is such as for strengthening beam, columns and floor plates [10-14]. Some of the main advantages of FRP materials are having high tensile stress with a light weight and not corrosion. Therefore, the use of FRP material will affect the increase in capacity without being accompanied by increasing the weight of the structure. Figure 3 shows an example of the application of FRP material on beam structure.



Figure 3. Application of FRP sheet in strengthening of beam

## 2. COMPARATIVE STUDY AND DESIGN DEVELOPMENT

Before making U-Ditch innovation products, a comparative study was conducted on Local and Japanese U-Ditch test materials. This aims to determine the advantages and disadvantages of each product. Figure 4 shows the dimensions of local and Japanese products. In summary, the results of the comparison between Local and Japanese products can be seen in Table 1.

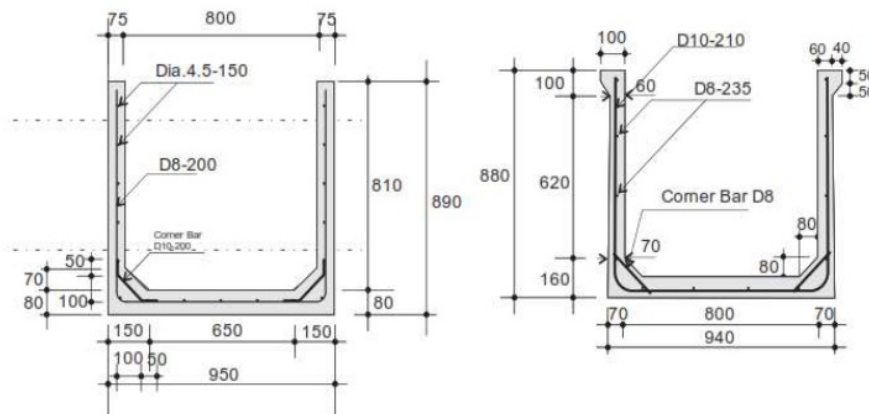
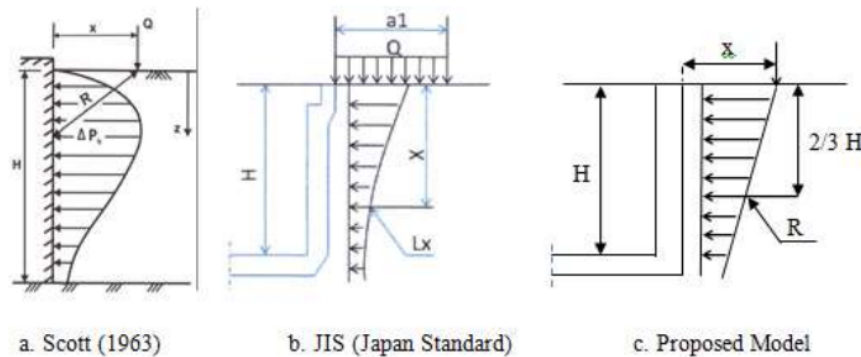


Figure 4. Dimensions of Local Product and Japan Product

**Table 1.** Comparison between Local Product and Japan Product

No.	Comparison Parameters	Local Product	Japan Product
1.	Dimension of wall	Thick	Thin
2.	Reinforcement system	Focused on the symmetrical side of cross section	Not focused on the symmetrical side of cross section
3.	Concrete surface	Relatively rough	Smooth
4.	Concrete strength	Low	High
5.	Weight	Heavy	Light
6.	Moment capacity per weight	Low	High
7.	Crack pattern	Wall	Wall

In addition, a new model to calculate the resultant force on the wall due to wheel load was proposed. The proposed model was the development of the Scott and Japanese models. Figures 5 (a), (b) and (c) respectively show the Scott, Japan and the Proposed Model. As shown in Figures 5 (a) and (b), the resultant wall forces in the Scott and Japanese models are modeled in parabolic forms so that they are complicated in calculations. Therefore, in this study a new simpler and easier model was proposed as seen in Figure 5 (c).



**Figure 5.** Design model of due to wheel load

In the model, the value of the stress that occurs on the U-ditch extension wall is obtained by integrating the Scott Model (Eq. 1) with z boundaries equal to 0 to H.

$$\Delta ph = \int \frac{4Q}{\pi} \frac{x^2 z}{R^4} \partial z \tag{1}$$

$$\Delta ph = \int \frac{4Q}{\pi} \frac{x^2 z}{x^4 + z^4} \partial z \tag{2}$$

$$\Delta ph = \frac{4Q}{\pi} \int \frac{x^2 z}{x^4 + z^4} \partial z \tag{3}$$

Example:

$$u = \frac{z^2}{x^2} \text{ sehingga } \frac{\partial u}{\partial z} = \frac{2z}{x^2} \tag{4}$$

$$R = \frac{4Q}{\pi} \int \frac{\frac{x^2 z}{x^4 + z^4}}{\frac{x^2}{x^4 + z^4}} \partial u \tag{5}$$

$$R = \frac{4Q}{\pi} \frac{1}{2} \int \frac{1}{1 + u^2} \partial u \tag{6}$$

$$R = \frac{2Q}{\pi} \arctan u \quad (7)$$

$$R = \frac{2Q}{\pi} \arctan \frac{z^2}{x^2} \quad (8)$$

$$R = \frac{2Q}{\pi} \arctan \frac{H^2}{x^2} \quad (9)$$

Thus, the soil pressure on the wall was obtained as shown in Eq. 10.

$$R = \frac{2Q}{\pi} \arctan \frac{H^2}{x^2} \quad (10)$$

where:

$R$  = resultant force on the wall due to wheel load (kN / m)

$Q$  = wheel load (kN/m)

$x$  = distance of wheel load to wall (m)

$\pi$  = 3.14

$H$  = Elevation or height of product (m)

Under loading conditions according to the Japan Industrial Standard (JIS 5343), the assumption of a wheel load of 49.1 kN is applied to the 1 m length of product.

### 3. INNOVATION PRODUCT

As a simulation of the concept developed as a result of the innovation of precast channel products, the precast type 500x500 mm channel with a product length of 1000 mm was chosen. By still referring to the thickness of the main reinforcement concrete cover of at least 20 mm as specified in JIS, the weight reduction of the structure is carried out by reducing the wall thickness in the area between the main reinforcement. The thickness reduction is carried out as wide as 100 mm along the length of the channel wall in each area between the main reinforcements so as to form a corrugate wall. With this thickness reduction method, the concrete cover for each main reinforcement was still in accordance with the minimum concrete cover, which is 20 mm as required by JIS while considering the relevant Indonesian Standards [15,16]. This reduction in thickness will cause a reduction in the channel structure type 500x500 mm by 10%. However, this reduction in thickness will also reduce the stiffness of the cross section of the concrete which in turn will reduce the strength of the channel wall. To increase the strength of the wall due to heavy resistance, a carbon-based FRP (CFRP-Carbon Fiber reinforced plastics) is used on the maximum moment area of 30cm from the bottom of the channel. Figure 4 illustrates the channel product design concept. Figure 6 (a) shows U-Ditch without the reduction of wall thickness (normal) and Figure 6 (b) shows U-Ditch product with the reduction of wall thickness and strengthened with CFRP.

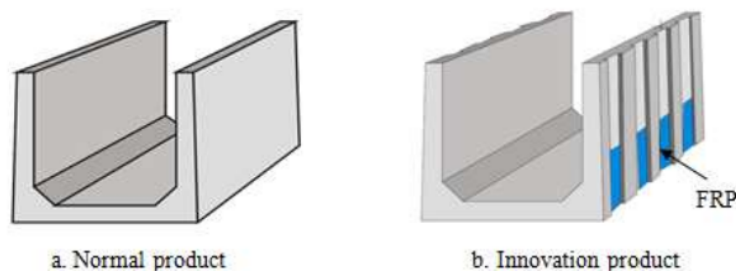


Figure 6. Illustration of innovation product

## 4. EXPERIMENTAL PROGRAM

### 4.1. Specimens

To investigate the effect of thickness reduction and the effect of FRP sheets on the flexural capacity of the wall, the specimens were prepared consisting of 3 types, namely Type P (Standard), Type CP (thickness reduction without FRP) and Type CS (thickness reduction with FRP).

Figure 7 shows the dimension (in mm) of Type P, and Figure 8 shows the dimension of Type CP and CS. The minimum wall thickness was about 60 mm at the top of wall. The thickness gradually reduces to the hook part with a thickness of 70 mm. This was because the soil pressure and vehicle loads gradually increase from the top to the bottom of channels. The thickness of the channel bottom is uniform with a thickness of 70 mm. For Type CP and CS, maximum thickness of the wall was same with Type P but there is a reduction of local wall thickness in each spacing between main reinforcements with a thickness of 20 mm and a width of about 100 mm. This configuration formed corrugate wall. For Type CS only, FRP sheet reinforcement material was then attached to the bottom side of the 300mm wall as reinforcement to replace the weakening effect of thickness reduction. For reinforcement FRP material with carbon base material is used which has a composite tensile strength of 986 MPa with elastic modulus of 95.8 GPa.

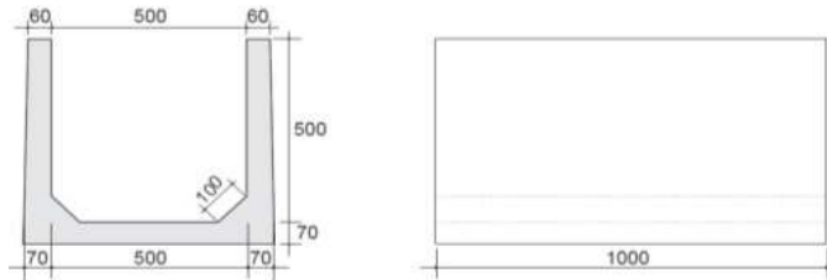


Figure 7. Type P (Normal)

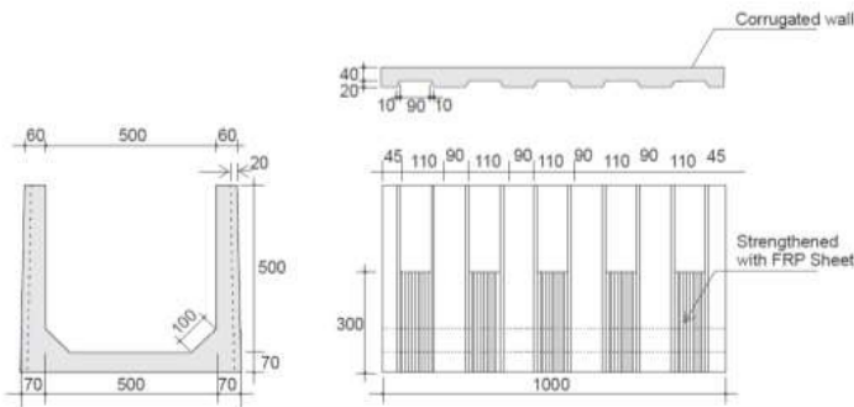


Figure 8. Type CP and CS (with FRP)

Figure 9 shows the arrangement of reinforcement of the specimen. The diameter of main reinforcement was 10 mm with spacing of 190 mm. Meanwhile, the diameter of shrinkage reinforcement was 8 mm with spacing of 200 mm. On the hook section, 8 mm diameter

reinforcement was used for compression reinforcement. All the reinforcements were assembled by welding connection.

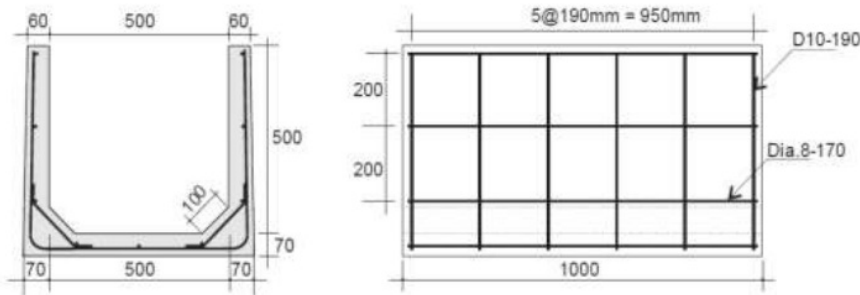


Figure 9. Arrangement of reinforcement

#### 4.2. Materials

The concrete was designed with the average 28-day cylinder compressive strength of 25 MPa. The concrete compressive strength was measured on 100x200 mm concrete cylinder. The 10 mm deformed rebars and 8 mm plain rebars were tested in tensile and the measured yield strength was 400 and 400 MPa, respectively.

#### 4.3. Fabrication Procedures

Figure 10 shows several procedures in U-Ditch fabrications. The test specimens were casted by using steel formwork to produce a more precise product compared to the wooden formwork. The casting of the specimen was carried out in reverse side, where the bottom side was positioned on the top. This was to facilitate the casting process and also to avoid the segregation of concrete on the bottom surface of the channel. The filling of the concrete started on the channel wall and was done gradually as shown in Fig. 10 (a). Furthermore, the compaction was done manually by using steel bars. After casting, proceed with compaction of specimens by using a vibrator for approximately 20 seconds (Fig. 10 (b)). The curing of specimens was done manually by using a wet sack for approximately 3 days as shown in Fig. 10 (c). After sufficient curing time, the formwork was de-molded. Prior to loading test, the weight of each specimen was measured. The weight of the Type P (normal) was 252 kg and the Type CP and CS (corrugate) was 229 kg. Due to reduction of wall thickness, the weight of Type CP and CS decreased by 10% compared to Type P.



Figure 10. Fabrication procedures

#### 4.4. Instrumentations and Loading Methods

Figure 11 shows the loading setup. It was carried out based on the testing method performed in Japan (JIS) because SNI has not set specific test standards for U-ditch testing. The test was carried out by loading the channel wall from both sides with a pull rod connected to the load cell. The applied load was monitored through the load cells placed on each end of the pull rod. LVDT (Linear Variable Data Transducer) was placed near the load cell to measure the deflection that occurs on channel wall. Strain gauge was attached on the concrete surface near the hook to measure the concrete strain at that location. Moreover, several strain gauges were also attached on the reinforcements. The locations of LVDT and strain gauges are shown in Figure 11.

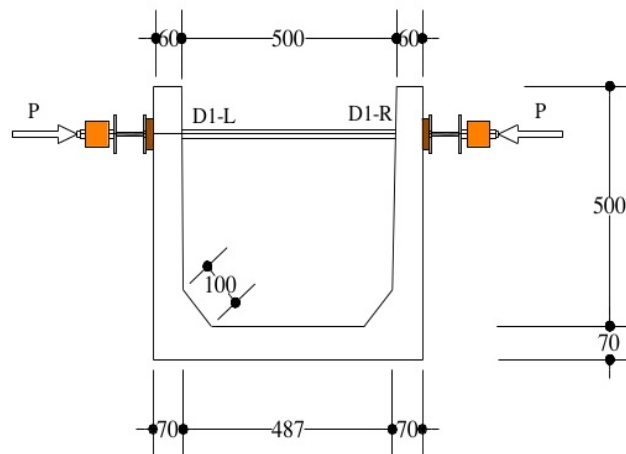


Figure 11. Loading Setup

Figure 12 shows the method for applying the load. The load is given manually by turning 90 degree of the nut on the ends of the pull rod. Hence, it will clamp the sides of the inner wall of the channel to produce the pressure load. The loading was limited until the deflection of the wall about 15 mm because the crack width was large and the load from the load cell was not increased.



Figure 12. Application of load

## 5. RESULTS AND DISCUSSIONS

### 5.1. Ultimate Capacity

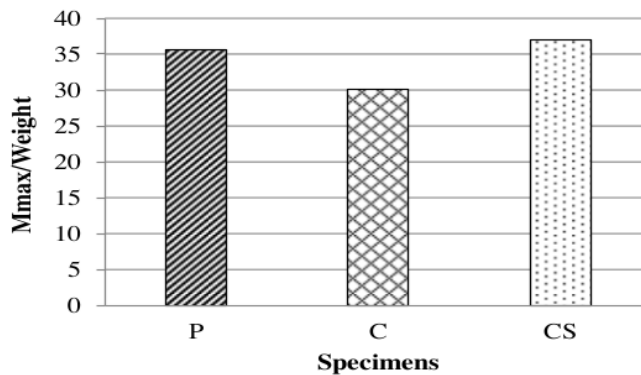
Table 2 shows the experimental results for all specimens. All the data presented in this table are the measured at the displacement of 15 mm. For Type P (normal), the first crack occurred when the load of 10.19 kN. Meanwhile, for Type C (Corrugate) and CS (with FRP), the first crack occurred at the load of 6.26 kN and 6.80 kN, respectively. These indicated that the first cracking load of Type C and CS decreased by 38.56% and 37.6%, respectively compared to Type P. This was because the stiffness of the specimens decreased due to the reduction of the wall thickness. Moreover, the results also indicated that the effect of FRP on Type CS has not been significant enough to increase the crack load.

**Table 2.** Experimental results

Specimens	Weight	P <sub>cr</sub> (kN)	P <sub>max</sub> (kN) at Δ = 15 mm	Mmax (kN.m)	
				per M'	Per Weight (t)
Type P	252	10.19	25.57	8.98	35.52
Type C	229	6.26	19.73	6.90	30.15
Type CS	229	6.80	24.26	8.49	37.07

The load was continued until 15 mm deflection of the wall because the cracks that appears have been wide enough. The results show that the ultimate load of Type P was 25.6 kN. While the type C was 19.7 kN. This shows that there is a significant decrease in load-bearing capacity due to a reduction in the thickness of the wall (corrugate) on the outer side of the wall. Compared to Type P, in Type C there is a decrease in load capacity of around 25%. However, the CS Type test showed that the load bearing capacity when the deformation of about 15 mm was 24.3 kN which increased compared to Type C or its load capacity was approximately the same as Type P. This indicated that by strengthening FRP on the channel wall provide a significant impact by increasing the load capacity to 25%.

The moment capacity of each specimen was 8.98 kN.m for Type P, 6.90 kN.m for Type C and 8.49 kN.m for Type CS. If the moment capacity was divided by weight to describe the moment capacity per unit of precast channel weight, then Type CS has a moment capacity per weight of 37.1 kN.m / ton while Type P and Type C capacity of the weight moment is 35.5 kN.m/ton and 30.2 kN.m/ton. This shows that the weight reduction by giving corrugate on the outer side of the wall accompanied by strengthening with FRP sheets will have an impact on increasing moment capacity for per unit weight of precast channel construction, as shown in Figure 12.



**Figure 12.** Ratio of Mmax per Weight

## 5.2. Ratio of Moment Capacity to Weight

The ratio of the moment capacity to the weight of the structure is shown in Figure 12. The measurements of the weight of each specimen were performed before the loading test. In this table, it can be seen that the moment capacity of Type P and Type C was 8.98 kN.m and 6.90 kN.m, respectively. If the moment capacity was divided by weight to show the moment capacity per unit of precast channel weight, Type P had the moment capacity per weight of 35.52 kN.m/ton and Type C had the moment capacity per weight of 30.25 kN.m/ton. This indicated that compared to the Type P (normal), there is a decrease in the ratio of the moment capacity to the weight of the structure by 15.11% in Type C (corrugate) as shown in Fig. 12.

## 5.3. Load-displacement Relationship

Figure 13 shows the relationship between the applied load and displacement at the loading point. The load and deflection relationship shows the response of the structure due to the increasing of load. Basically, at the initial load, the behavior of load-deflection relationship follows the behavior of reinforced concrete structure where the compressive stress will be borne by the concrete, while the tensile stress will be restrained by the reinforcement and the concrete. After cracking of concrete in the tension zone, the tensile stress is only restrained by the reinforcement (James K. Wight (2011)). The cracks occur when the tensile stress that occurs in the concrete is greater than the tensile stress of the concrete. The crack will cause a decrease in the stiffness marked by the change in the direction of the load deflection curve.

In Fig. 13 it can be observed that the first crack in Type P occurred at 10.19 kN with deflection of 3 mm. For Type C, the first crack occurred at 6.26 kN with deflection of 0.5 mm. Meanwhile for Type CS, initial crack occurred at 7.00 kN with deflection of 1.5 mm. The subsequent increase in loading was still accompanied by the addition of deformation until there is a widening crack and the formation of new cracks. The loading was limited to the deformation at about 15 mm. It should be noted that the load is limited until the deformation of around 15 mm or when the crack has spread. Load that occurs at the time of deformation around 15 mm for Type P load is 25.6 kN, Type C is 19.7 kN and Type CS is 24.3 kN.

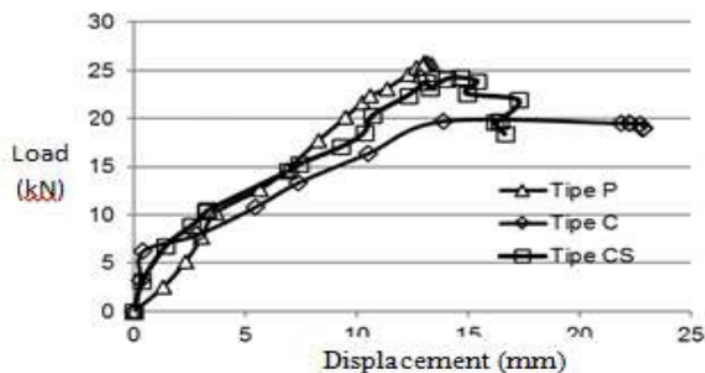


Figure 13. Load-displacement relationships

## 5.4. Load-Strain Relationship

Figure 14 shows the relationship between the loads and the strain that occurs in FRP. As a comparison, the strain on the steel reinforcement is also presented at the appropriate location on the channel wall section. As can be observed, when the maximal load, FRP shows a strain of 1300  $\mu\epsilon$  while the steel shows a strain of 885  $\mu\epsilon$ . Steel strain tend to be smaller because the position of steel reinforcement closer to the neutral line of the channel wall. With the

development of the strain that occurs on FRP sheets as reinforcement on the channel wall shows that FRP sheet material works well in providing a moment effect on the channel wall structure system to resist the external loads. When compared with tensile forces, the total tensile strength arising on FRP sheets was around 56 kN.

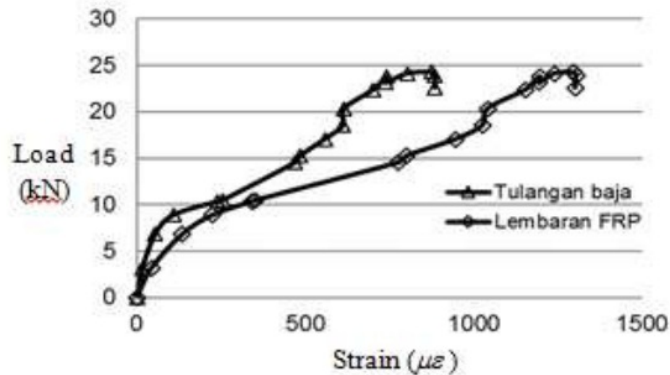


Figure 14. Load-displacement relationships

### 5.5. Crack pattern and failure mode

The crack pattern in all specimens was the flexural cracks. The first crack was observed around the hook part of the channel as shown in Fig. 15. The failure occurred due to the propagation of the cracks.



Figure 15. Crack pattern

## 6. CONCLUSIONS

The investigation on the effect of FRP strengthening on the flexural capacity of precast channel system (U-Ditch) has been presented. The results are summarized as follows:

- Considering the minimum concrete cover of 20 mm based on Japan Industrial Standard, the minimum thickness of the precast channel of 60 mm was obtained. Therefore, it can produce more effective moment resistance from the interaction of reinforcement and concrete material.
- Weight reduction of U-Ditch can be done by reducing the wall thickness in the area between the main reinforcement locations. But it will reduce the flexural strength of the wall.
- Strengthening of FRP sheets in the thickness reduction section is effective to increase the flexural capacity of the channel wall where relatively the same flexural strength without a reduction in thickness (Type P).

- With a reduction in thickness combined with reinforcement of FRP sheets, the higher moment capacity per structural weight was obtained (Type CS) compared to normal structures (Type P).

## ACKNOWLEDGMENT

The authors wish to acknowledge JICA C-Best in Engineering Faculty, Hasanuddin University for the financial supports of this research project. A special acknowledgement also wishes to YAMAU Corporation Japan for the assistance during the loading test.

## REFERENCES

- [1] James K. Wight (2011). Reinforced Concrete Mechanics and Design, 6th Edition, Pearson Education, Inc., Upper Saddle River, New Jersey.
- [2] Kim Elliott (2002), Precast Concrete Structures, Butterwoth-Heinemann.
- [3] JSCE guideline for concrete (2012), "Standard specification for concrete structures", JSCE, Japan.
- [4] Japan International Standard, "Reinforced concrete gutters for roadside", JIS A 5345.
- [5] Japan International Standard, "Required performance and methods of verifications", JIS A 5362.
- [6] Japan International Standard, "General rules for methods of performance test", JIS A 5363.
- [7] Japan International Standard, "General rules for method and inspection", JIS A 5365.
- [8] Bakis, C. E., Bank, L. C., Brown, V. L., Consenza, E., Davalos, J. F., Lesko, J. J., Machida, A., Rizkalla, S. H. and Triantafillou, T. C. (2002). Fiber-reinforced polymer composites for construction-state-of-the-art review, Journal of Composites for Construction, ASCE, Vol. 6, No. 2, pp. 73-87.
- [9] Wu, Z., Wang, Z. and Iwashita, K. (2007). State-of-the-art of advanced FRP applications in civil infrastructure in Japan, Composites and Polycon, Vol. 37, pp. 1-17.
- [10] Yuan, H., Teng, J.G., Seracino, R., Wu, Z.S and Yao, J. :Full-range behavior of FRP-to-concrete bonded joints, *Engineering Structures*, Vol.26, pp. 553-565, 2004.
- [11] Reed, C.E and Peterman, R. J.: Evaluation of prestressed concrete girders strengthened with carbon fiber reinforced polymer sheets, ASCE, Journal of Bridge Engineering, Vol. 9, No. 2, pp. 185-192, 2004.
- [12] Kang, T. H. K. and Ary, M. I. : Shear-strengthening of reinforced & prestressed concrete beams using FRP: Part II – Experimental investigation, International Journal of Concrete Structures and Materials, Vol. 6, No. 1, pp. 49-57, 2012.
- [13] Dong-Uk Choi, Thomas H.K.Kang, Sang-Su Ha, KilHee Kim and Woosuk Kim., Flexural and bond behavior of concrete beam strengthened with hybrid carbon-glass fiber reinforced polymer sheet. ACI Struct. J., 108(1) (2011) 90-98.

- [14] Rudy Djamaluddin, Rita Irmawati, Arbain Tata (2016), " Flexural Capacity of Reinforced Concrete Beams Strengthened Using GFRP Sheet after Fatigue loading for Sustainable Construction", Key Engineering Materials, Vol. 692, pp 66-73
- [15] Standar Nasional Indonesia (SNI) (2002). "Tata Cara Perhitungan Struktur Beton untuk Bangunan Gedung", SNI 03-2847-2002.
- [16] Standar Nasional Indonesia (SNI) (2012). "Precast concrete and prestressing concrete", SNI-7833-2012.
- [17] Yasser, Herman Parung, M. Wihardi Tjaronge, Rudy Djamaluddin (2013). Study on the Efficiency using Nature Materials in the Structural Elements of Reinforced Concrete Beam. International Conference on Engineering and Technology Development (ICETD 2013) ISSN 2301-6590.
- [18] Asst. Prof. Abdul Ridah Saleh Al-Fatlawi and Ahmed Hadi Hassan, CFRP Strengthening of Circular Concrete Slab with and without Openings, International Journal of Civil Engineering and Technology, 7(1), 2016, pp. 290-303.
- [19] N. Sundar, P. N. Raghunath and G. Dhinakaran, Flexural Behavior of RC beams with Hybrid FRP Strengthening. International Journal of Civil Engineering and Technology, 7(6), 2016, pp.427-433

ORIGINALITY REPORT

% **6**

SIMILARITY INDEX

%

INTERNET SOURCES

% **6**

PUBLICATIONS

%

STUDENT PAPERS

PRIMARY SOURCES

**1**

Mindaugas Daukšys, Vytenis Girčys, Svajūnas Juočiūnas. "Research on Installation Technology of Floating Stone Columns", Journal of Sustainable Architecture and Civil Engineering, 2020

Publication

% **2**

**2**

Xianlei Cao, Chao Cheng, Min Wang, Wen Zhong, Zhengyi Kong, Zongping Chen. "Experimental study on the flexural behavior of flat steel-concrete composite beam", Canadian Journal of Civil Engineering, 2020

Publication

% **1**

**3**

Nini H Aswad, Herman Parung, Rita Irmawaty, A Arwin Amiruddin. "The Effects of Reduced Beam Section on Castellated Beam", MATEC Web of Conferences, 2017

Publication

% **1**

**4**

"Permeation Properties of Geopolymer Concrete Made with Partial Replacement of Recycled Coarse Aggregates", International Journal of Innovative Technology and Exploring

% **1**

## Engineering, 2019

Publication

---

5

"Regression Examination of Factors Influencing the Chatbots usage in Banking Industry of India", International Journal of Recent Technology and Engineering, 2019

Publication

---

<% 1

6

Kitamura, Takayuki, Takashi Sumigawa, Hiroyuki Hirakata, and Takahiro Shimada. "Growth of Interface Crack", Fracture Nanomechanics Second Edition, 2015.

Publication

---

<% 1

7

Rudy Djamaluddin, Hijriah, Rita Irmawati, Faharuddin, Rossy T. Wahyuningsih. "Delamination mechanism of GFRP sheet bonded on the reinforced concrete beams", MATEC Web of Conferences, 2019

Publication

---

<% 1

8

"CIGOS 2019, Innovation for Sustainable Infrastructure", Springer Science and Business Media LLC, 2020

Publication

---

<% 1

9

G. Ji. "Strength Enhancement of Advanced Grid Stiffened FRP Tube Confined Concrete Cylinders under Fire", Journal of Composite Materials, 10/01/2009

Publication

---

<% 1

10

"International Conference on Intelligent Data Communication Technologies and Internet of Things (ICICI) 2018", Springer Science and Business Media LLC, 2019

Publication

<% 1

11

Xianglin Gu, Bin Peng, Gonglian Chen, Xiang Li, Yu Ouyang. "Rapid Strengthening of Masonry Structures Cracked in Earthquakes Using Fiber Composite Materials", Journal of Composites for Construction, 2012

Publication

<% 1

12

"ICCOEE2020", Springer Science and Business Media LLC, 2021

Publication

<% 1

EXCLUDE QUOTES ON

EXCLUDE ON

BIBLIOGRAPHY

EXCLUDE MATCHES

< 5 WORDS