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# Optimization of Technical Calculation of Precast Wall Application for Kawo Secondary Canal Improvement in Sempor Irrigation Area, Kebumen, Central Java

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**Abstract:** This study aims to perform technical calculations using precast lining in the repair of secondary channels. The planning data used included a concrete grade of f'c 18.68 MPa and a reinforcement grade of f'y 500 MPa. The service condition analysis was carried out by taking into account the loading during the most critical condition, where the channel is empty and active soil pressure and external water pressure are the main loads. The fixed load calculation was the main focus, where the active earth pressure (PD) was calculated by considering the soil-specific gravity, soil shear angle, and soil coefficient. The calculation results show that the PD reaches 12.24 kN, which gives an idea of the load that the structure has to bear. Furthermore, the internal force analysis provides a deeper understanding of the moments occurring at specific points in the structure. For example, the maximum negative moment at point A was calculated by considering the moments due to fixed load and transient load, which reached 12.73 kNm. Channel wall reinforcement planning is also a concern, taking into account concrete quality, reinforcement quality, and loading conditions. The determination of the β value for reinforcement calculation is based on a certain equation, which results in a tensile reinforcement area required for each meter of U-ditch length of 184 mm. When mobilizing precast using an excavator, it is important to take into account the lifting capacity of the excavator and the diameter of the steel sling according to the weight and type of precast to be installed. For example, in the Kawo Secondary Channel project with type 4 precast measuring 1.80 x 1.00 x 0.10 m, the minimum excavator that can be used is PC 45 with a minimum of 8 diameter steel slings for precast setting. The results show that an excavator with a certain capacity and steel sling with a certain diameter is required for setting precast with a certain size. This research contributes to improving efficiency and safety in the application of precast lining for secondary channel improvement.

**Keywords:** *Precast Wall, Secondary Channel, Excavator and Steel Sling, Load Analysis*

## 1. Introduction

Aqueducts are vital infrastructure in irrigation systems, supporting agriculture and providing water supply to communities. Secondary channels play an important role in providing water and conveying excess water to primary channels. However, over time, these channels can degrade, requiring repairs to maintain their function. Irrigation, according to the Regulation of the Minister of Public Works and Housing, includes various types such as surface irrigation, swamps, underground water, pumps, and ponds. The purpose of irrigation is to meet water needs outside the rainy season for agriculture, including watering, fertilization, soil temperature regulation, and pest control. Irrigation is directed to provide water benefits that are efficient, integrated, and environmentally friendly, and to improve the welfare of farmers and society in general. The main function of irrigation is to maintain and increase land productivity to achieve optimal agricultural yields, without neglecting other interests [1].

In principle, irrigation is a human effort to take water from the source, drain it into the channel, distribute it to rice fields, give it into the channel, distribute it to rice fields, provide water to plants, and dispose of excess water to the waster network [2][3]. The purpose of direct irrigation is to wet the soil to achieve a good soil condition for growth about the percentage of water content and soil grains [4][5]. Irrigation canals are generally built using concrete materials with the in-situ method. Concrete itself is a mixture of fine and coarse aggregate materials with cement paste (sometimes admixtures are added), the mixture when poured into a mold and then allowed to stand will become hard like rock. The hardening process occurs due to a chemical reaction between water and cement that continues over time, this causes the hardness of concrete to increase over time [6].

The application of precast wall construction technology has become a popular choice in infrastructure projects, including in the repair of waterways. Precast concrete walls promise advantages in time efficiency, cost, and construction quality [7]. However, to ensure its successful application, careful optimization of technical calculations is required in its design and implementation. precast is a concrete element or component with or without reinforcement that is pre-molded before being assembled into a building. All precast components and their connections must be able to withstand all loading and restraint conditions from initial fabrication to final use in the structure, including formwork demolition, storage, transportation, and erection [8]. Precast concrete also called precast concrete is a concrete material that has been made in a factory with a shape according to the mold, then the molded concrete will be transported and installed to the building construction site. Precast concrete is a construction product resulting from casting concrete in reusable molds. Precast walls are made to facilitate the process of starting work and the time required. In the Sempor Irrigation Network Improvement Project, the use of Precast walls was chosen because it considered several factors including, among others, significant time savings so precast walls were chosen to replace other materials.

The construction of irrigation projects often involves the mobilization of heavy equipment, but problems arise when sites are difficult to reach or road access is inadequate, especially for cranes. Narrow and unreinforced roads become serious obstacles, potentially damaging and disrupting the activities of other vehicles. To overcome this, an alternative solution of using an excavator for precast installation is proposed. The use of excavators is more efficient and safe as they takes up less space on the road, allowing for smooth traffic flow. With sufficient trials, the use of excavators is considered safe and efficient for the D.I Sempor Irrigation Network Improvement project, it is expected to reduce delays and increase project success.

## 2. Research methode

The research method is a scientific approach to collecting data and information to solve research questions or solve certain problems. One type is quantitative research with a descriptive approach, which aims to describe a particular phenomenon or situation. This approach is useful for testing hypotheses and producing objective findings. [9]. D.I Sempor Irrigation Network Improvement Project is one of the irrigation network improvement projects where the construction must adjust to the characteristics of the system under review, therefore it is necessary to conduct analytical studies on the D.I Sempor Irrigation Network Improvement project. This irrigation area is very prone to damage so it is necessary to re-establish the improvement of irrigation networks.

## 3. Result and Discussions

This precast installation work is located in Kawo Secondary Channel using type four precast with a panel size of 1.80 x 1.00 x 0.10m. The installation of precast panels on the working floor was carried out carefully using a PC 75, PC 40, or PC 100 excavator, the type of excavator and steel slings used can be seen in the table below to avoid damage to the precast lining plane.

**Table 1.** Minimum excavator and steel slings for precast setting

| No. | Precast Panel Type | Weight (kg) | Excavator Lifting Equipment | ø Steel Slings |
|---|---|---|---|---|
| 1 | Panel 3,50 x 1,00 x 0,10 m | 840 | min. Exca PC 88 | min. 8 |
| 2 | Floor Panel 2,70 x 1,00 x 0,10 m | 648 | min. Exca PC 70 | min. 8 |
| 3 | Panel 2,30 x 1,00 x 0,10 m | 552 | min. Exca PC 70 | min. 8 |
| 4 | Panel 1,80 x 1,00 x 0,10 m | 432 | min. Exca PC 45 | min. 8 |
| 5 | Panel 1,30 x 1,00 x 0,10 m | 312 | min. Exca PC 35 | min. 8 |

### Technical Calculation Using Precast Lining

Concrete strength was achieved at an f'c value of 18.68 MPa, while reinforcement strength was achieved at an fy value of 500 MPa.

### Serviceability Analysis

Service condition loading is taken into account during the most critical condition, where the channel is empty (no water), so that the loads acting in the form of active soil pressure and water pressure from outside when the groundwater level rises. In the calculation, it is assumed that the channel wall is perpendicular to the floor so that the maximum force is obtained that can be seen on Fig. 1.

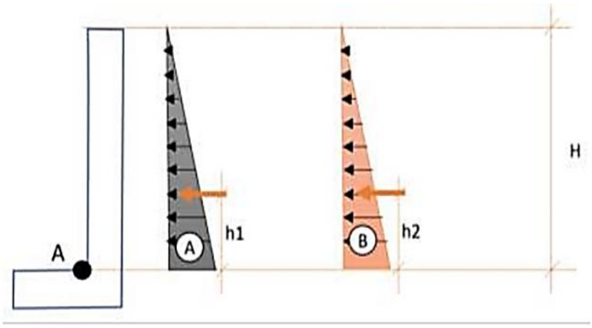


**Fig. 1.** Soil and Water Pressure Diagram

Description:
A = Active ground pressure
B = Sea water pressure
where,

H = 1880mm
H = 627 mm
h2 = 627 mm

### Load Calculation

a. Fixed expenses
   Active ground pressure (PD) – Lateral force due to active soil stress
   γ soil = 19,2 kN/m$^3$
   soil shear angle (φ) = 28 degrees = 0.4889 radians

than

K0 $= \frac{1 - Sin\ \varphi}{1 + Sin\ \varphi}$ = 0,36

And sho

σD = γ × H × K0 × 1m
= 19,2 × 1,88 × 0,3609×1 = 13,026 kN/m

PD = 1/2 × σD × H
= 0,5 × 13, 026 × 1,88 = 12,24 kN

With load factor = 1

So that the factored load = 1 × 12,2

b. Transient load

External water pressure (PL)

With load factor = 1

γ water = 9,8 kN/$m^3$

and so:

H = 1072 mm

σL = γ × H × Ka × 1m
= 9,8 × 1,0716 × 1 = 10,502 kN/m

PL = 1/2 × σD × H
= 0,5 × 10,502 × 1,0716 = 5,627 kN

With load factor = 1

So that the factored load = 1 × 5,6 = 5,63 kN

**Inner force calculation**

The side plate is assumed to be a cantilever plate since the cover plate above it has a freely located support. With this condition, the maximum moment that occurs is calculated at point A.

a. Due to fixed load
Active ground pressure (PD)
The moment at point A:
Mdu (-) = PDu × 1/3h = 12.24 × 0.6267 = 7.67 kNm

b. Due to the transient load
Due to external water pressure (PL)
The moment at point A:
MLu(-) = PLu2 × 1/3H = 5.627 × 0.6267 = 3.53 kNm

c. Ultimate loading combination
The loading combination at ultimate, then:
Maximum negative moment
The moment at point A:
Mu(-) = 1.2 × MDu + MLu1 = 9.21 + 3.53 = 12.73 kNm

d. Due to the fixed load
Active ground pressure (PD)
The moment at point A:
MDu(-) = PDu × 1/3h = 12.24 × 0.6267 = 7.67 kNm

e. Due to the transient load
Due to external water pressure (PL)
The moment at point A:
MLu(-) = PLu2 × 1/3H = 5.627 × 0.6267 = 3.53 kNm

f. Ultimate loading combination
The loading combination at ultimate, then:
Maximum negative moment
The moment at point A:
Mu(-) = 1.2×MDu + MLu1 = 9.21 + 3.53 = 12.73 kNm = 12733989 Nmm

**Channel wall reinforcement calculation**

The channel walls are assumed to be cantilevered plates that generate negative moments. Calculation of plate reinforcement is calculated per meter in the longitudinal direction of the plate (L)
b = 1000 mm

Determining the value of β:
As per the Indoensia National Standard 2004 article 5.1.1.1, the value of β is taken based on the equation for f'c < 30 MPa, the value of β = 0.85. Thus,

B = 0,85

$Rn = \frac{Mu}{\varphi * b * deff2}$ = 1,73 Mpa

$m = \frac{fy}{0.85 * fc'}$ = 30,51

$\rho b = \frac{0.85 * \beta * fc'}{fy} * \frac{600}{600 + fy}$ = 0,028 × 0,5455 = 0,01512 = 0,0114

$\rho_{max}$ = 0,75 × ρb = 0,75 ×0,01512 = 0,0114

$\rho_{min}$ = 1.4/fy = 0,0028

$\rho_{necessary}$ = $\frac{1}{m}(1 - \sqrt{1 - \frac{2 * m * Rn}{fy}})$ = 0,03 × 0,1116 = 0,004

Check the condition: $\rho_{min} < \rho_{necessary} < \rho_{max}$
Thus, the following is used ρ = 0,00365

a) Tensile reinforcement (transverse direction/x-direction)
   Area of tensile reinforcement required per meter length (L) of U-ditch:
   $AS$required = $\rho_{used} \times b \times d_{eff}$ = 351 mm
   So pedestal tensile reinforcement is used:
   Ø = 8 mm - 150 mm
   The maximum spacing of principal reinforcement shall be less than 360 mm or 3×h = 360 mm.
   Number of tensile reinforcement per meter length = 7 bh of reinforcement
   **Ok**, enough reinforcement installed
b) Tensile reinforcement (transverse direction/y-direction)
   Area of reinforcement required per meter width (Hb) of U-ditch:
   $As'$ = 30% × $A$ = 0,3 × 351 105 mm
   So reinforcement for the pedestal is used:
   Ø = 8 mm – 150 mm
   Maximum spacing of principal reinforcement must be less than 600 mm or 5× $h$ = 600 mm
   Number of reinforcement bars per meter width ($W$)
   $n$ = 6 pieces of reinforcement
   Therefore,
   $As'_{installed}$ = 302 mm > $As_{required}$ 105 mm
   **Ok,** reinforcement installed enough

S = 380 x (280/fs) – 2,5 Cc (ACI 318-08, Ch. 10.6.4)
thus
$S$ = maximum spacing (mm)
$S_{max}$ = 380 x (180/333,333)× 2,5 × 20
= 269 mm
Status: Max > Spacing, **OK**

**Bottom Plate (Floor) Reinforcement Analysis**
Planning data
Plate thickness = 100 mm
Concrete blanket = 50 mm

Principal reinforcement = 8 mm
Reinforcement for = 8 mm
deff = plate thickness - concrete blanket - 0.5 Ø reinforcement = 46 mm
Reinforcement quality = U = 50, fy = 500 Mpa
Concrete quality = K-225, f'c = 18.68 Mpa
Loading
Fixed load
Self weight >> Concrete weight = 25 kN/m3
Channel weight = 20.3 kN/m
Hence, qD1 = concrete weight of channel = 20.32 kN/m'

**Water load**
Water weight = 9.8 kN/m3
Weight of water in the channel = 51.45 kN/m
Calculation of internal force
The magnitude of the moment that occurs:

a. Due to self-weight
   It is assumed that the top plate pedestal experiences an elastic pinched condition, so that:
   MDu (+) = ½ × qDu × W2
   = 0.0833 × 21.3318 × 0.81 = 1.4399 kN/m
b. Due to transient load
   It is assumed that the top plate pedestal experiences an elastic pinched condition, thus:
   MTu (+) = ½ × qDu × W2
   = 0.0833 × 51.45 × 0.81 = 3.473 kN/m

**Reinforcement calculations**
The channel walls are assumed to be cantilevered plates that generate negative moments. The calculation of plate reinforcement is calculated per meter in the longitudinal direction of the plate
Determine the value of β
As per Indonesian National Standard year 2004 article 5.1.1.1, the value of β is taken based on the equation,
fc' ≤ 30 MPa, value β = 0.85
fc' > 30 MPa, value β = 0.85 – 0.008 × (fc'-30) but cannot be lass than 0.65
therefore β = 0.85

a. Field tensile reinforcement (transverse direction/x-direction)
   Area of field tensile reinforcement required per meter length (L)
   $As_{required}$ = $\rho_{used} \times b \times d_{eff}$ = 184 mm
   So field tensile reinforcement is used **Ø 8 mm – 150 mm**
   Maximum spacing of staple reinforcement must be less than 360 mm atau 3×h = 360 mm
   Number of tensile reinforcement per meter length (L):
   n = 6 pieces of reinforcement
   Thus, $As_{installed}$ = 302 mm > $As_{required}$ = 184 mm
   Then **OK**, enough reinforcement is installed
b. Reinforcement for field (longitudinal direction/y-direction)
   Area of field reinforcement required per meter of width
   As' = 30% × As = 0,3 × 184 = 55,2 mm
   So field tensile reinforcement is used**: Ø 8 mm – 150 mm**
   The maximum spacing of the reinforcing bars must be less than 600 mm atau 5 × h = 600 mm
   Number of reinforcement bars per meter width:
   n = 6 pieces of reinforcement
   Thus $As'_{installed}$ = 302 mm > $As_{required}$ = 58 mm
   Then **OK**, enough reinforcement is installed

c. Crack control
   S = 380 x (280/fs) – 2.5 Cc (ACI 318-08, Ch. 10.6.4)
   Where is:
   s = maximum spacing (mm)
   fs = 2/3 fy = 0,67 x 500 =333 Mpa
   Cc = concrete blanked = 20 mm
   $S_{max}$ = 380 x (280 / 33,333) - 2.5 x 50 = 269 mm
   **Satus: $S_{max}$ > spacing; OK**
d. Analysis of lifting conditions
   Allowable stress for lifting at the time of stripping, roating, and storage assuming the age of concrete at the time of lifting is 3 days:
   Concrete coefficient = 0,4
   f’c = 18,68 Mpa
   f’ci = Concrete coefficient × f’c = 7,713
   concrete crack condition
   fr =0,7 × √fc' = 1,94406 Mpa
   allowable stress for fastening at the time of erection assuming the concrete reaches 28 days of age
e. concrete crack condition
   Fr = 0,7 × fc’ = 3,073829 Mpa
   Control the lifting stress of the plate during stripping longitudinal bending using the assumption (two point pick up) obtained in the X direction (short span on the precast plate).
   Coefficient = 1,2
   Precast thickness, t = 0.12 m
   Precast width, a = 0.12 m
   Precast length, b = 2.5 m
   Weight of reinforced concrete, Wc = 2500kg/m3
   Weight of precast concrete W = Coefficient ×t× precast ×Wc = 360 kg/m2
   b/2 = 1,25 m
   15t = 1.8 m
   Minimum distance used = 1,25 m
   $Z = 1/6 \times b/2 \times d^2$ = 0,003 m
   Maximum moment Mx = 0,0107 × w × a2 × b
   = 13,8672 kgm
   = ft = fb
   Fb = Mx/Z = 4622,4 kg/m2 = 0,046224Mpa
   Check
   Ft = 0,046224Mpa
   Fr = 1,94406 Mpa
   **ft < fr → OK**

Moment due to lifting shrinkage (X direction). The lifting angle is obtained following Fig. 2. And Table 2. Based on Table 2, we can calculate that the lifting angle is $54^0$ and have force value of 1,16.

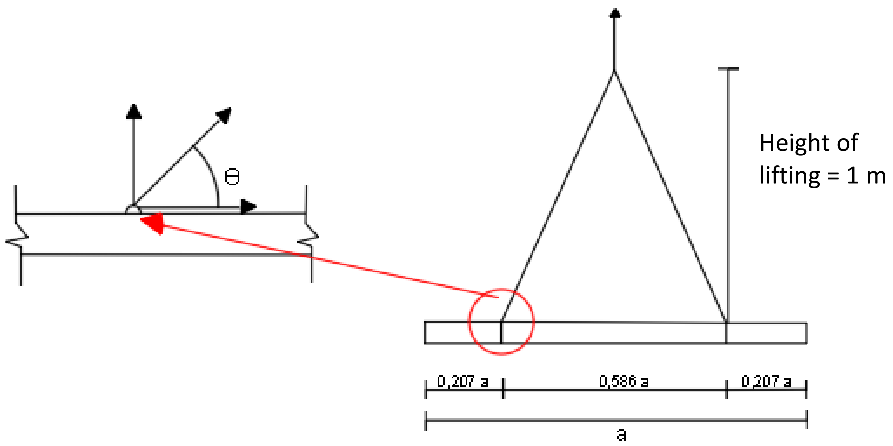


**Fig. 2.** Determining lifting angle

**Table 2.** Correlation between lifting angle and internal force of sling cable

| Angle | 45° | 54° | 60° |
|---|---|---|---|
| F | 1,41 | 1,1578 | 1,16 |

Calculation for eccentric moment

| | | |
|---|---|---|
| Yc = yt + 3" | = | 0,136 m |
| My = Pyc/tan q | = | 106,8715 Kg m |
| M total | = | 120,7387 Kg m |
| Ft = M total / Z | = | 40246,23 Kg/m2 |
| Ft | = | 0,402462 MPa |
| Fr | = | 1,94406 |

**Ft < fr → OK**

Control the lifting stress of the plate when turning

| | | |
|---|---|---|
| b/4 | = | 0,625 m |
| 15t | = | 1,8 m |
| W | = | 187,5 Kg/m |
| $Z = 1/6 \times (15t) \times d^2$ | = | 0,00432 m3 |

The distance between lift points

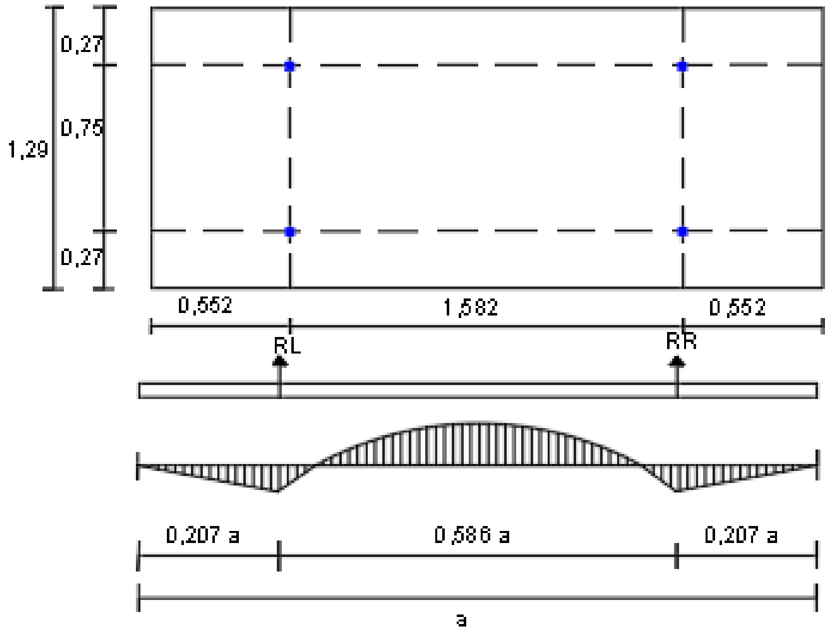


**Fig. 3.** Bending moment diagram of structure when lifted on construction site

SMR = RLx 0,586a – 1/2w ((0,207 a + 0,586$a^2$)
RL = RR = 84,36 Kg
Ma = 1/2w × 0,207$a^2$ = 6,28 Kg m
Fa = Ma / Z = 1452,942 Kg/$m^2$
= 0,014529 MPa
fr = 1,94406 Mpa
**fa < fr → OK**
Mb max = RL / W = 0,45 m
Mb = RL (RL/W – 0,207a) – 1/2w× (RL/W)^2 = 2,85 Kg m
Fb = Mb /Z = 659,8081 Kg/m2
= 0,006598 Mpa
fr = 1,94406 MPa
**fb < fr → OK**
Planning of armature reinforcement (*stud*)
*Precast*

| | | | |
|---|---|---|---|
| Reinforcement diameter | D | = | 8mm |
| Cross-sectional area | Ag | = | 50,265 mm |
| Steel grade | fy | = | 500 Mpa |

Weight of the concrete
a = 1,2 m
b = 2,5 m
t = 0,12 m
Wc = 2500 Kg/m3
W = 900 Kg/m3
Load received by the sling
T = W × F/2 = 521,017 Kg
T *stud* = Ag × fy × j = 1507,96 Kg
**T occurs < T stud → OK**

The evaluation carried out on the factors of safety, both for the internal force (Fa) and external force (Fb) parts, both parameters show results that meet the requirements, with Fa and Fb values smaller than fr (maximum stress fraction)[10]. In addition, the planning of the reinforcing bars (studs) in the precast has also been verified and declared safe, considering the appropriate reinforcement diameter, cross-sectional area, steel grade, and concrete weight [11]. When lifted, there are parts of the concrete cross-section that experience a negative moment. The top fibers are tensile, so reinforcement is required. The assumption of Ø8 wire-mesh reinforcement will provide a tensile reinforcement area value of As. So that the planned stud diameter reinforcement can withstand the load from the precast plate during lifting.

Based on the data obtained in the precast mobilization process, excavators and steel slings are used to ensure safety in setting precast in the field. After analyzing the use of excavators in the Kawo Secondary Channel with type 4 precast measuring 1.80 x 1.00 x 0.10 m used a minimum excavator. PC 45 with a minimum of 8 diameter steel slings for precast setting.

The technical calculations in the application of precast walls to upgrade irrigation canals involve several important steps. First, a fixed load calculation was performed considering the active soil pressure resulting from the soil-specific gravity, soil shear angle, and soil coefficient. The calculation results showed that the active soil pressure (PD) reached 12.24 kN. Furthermore, the internal force analysis provides an overview of the moments that occur at certain points in the structure, such as the maximum negative moment at point A, which is calculated by considering the moment due to the fixed load and the moment due to the transient load, with a value reaching 12.73 kNm. Channel wall reinforcement planning also takes into account crucial parameters such as concrete quality, reinforcement quality, and loading conditions. For example, the determination of the β value for reinforcement calculation was based on a specific equation, which resulted in a tensile reinforcement area required for each meter of U-ditch length of 184 mm.

In mobilizing precast using excavators, it is necessary to consider the lifting capacity of the excavator and the diameter of the steel slings according to the weight and type of precast to be installed. For example, in the Kawo Secondary Channel project with type 4 precast measuring 1.80 x 1.00 x 0.10 m, the minimum excavator that can be used is PC 45 with a minimum steel sling diameter of 8 for the precast setting process. Thus, the use of this method is key in ensuring the safety and success of the precast installation process in irrigation canal improvement projects.

## 4. Canculation

The calculation of the fixed load was carried out by calculating the active soil pressure (PD) resulting from the specific gravity of soil ($\gamma$ soil), soil shear angle ($\varphi$), and soil coefficient (K0). In the calculation, a PD value of 12.24 kN was obtained. In addition, the internal force calculation gives an idea of the moments that occur at certain points in the structure. For example, the maximum negative moment at point A was calculated by combining the moment due to fixed load (MDu) and the moment due to transient load (MLu). From the calculation, a maximum negative moment of 12.73 kNm was obtained. Channel wall reinforcement planning also takes into account parameters such as concrete quality, reinforcement quality, and loading conditions. For example, in determining the β value for reinforcement calculations, it is based on certain equations. Thus, the tensile reinforcement area required per meter length (L) of U-ditch is 184 mm. In mobilizing precast using an excavator, it is important to take into account the lifting capacity of the excavator and the diameter of the steel sling that is suitable for the weight and type of precast to be installed. For example, in the Kawo Secondary Channel project with type 4 precast measuring 1.80 x 1.00 x 0.10 m, the minimum excavator that can be used is PC 45 with a minimum of 8 diameter steel slings for precast setting.

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