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Alternative Design of Concrete Gutter Structure at Sugih Channel, Cibedug Village, Ciawi District, Bogor Regency

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ABSTRACT
The provision of water in wet farming is very important to support optimal crop yields. The irrigation system on the Sugih Canal in Cibedug Village, Ciawi, Bogor Regency was affected by a landslide with a depth of 8 meters, which resulted in a 28 meter long canal being cut off. This study aims to plan the construction of reinforced concrete gutters with a size of 60 cm and a height of 80 cm to repair broken points. The design of reinforced concrete gutters refers to SNI 03-2847-2002. It is planned that the floor plate thickness is 20 cm and the channel wall thickness is 15 cm, using concrete with quality K-250 (fc' = 25 MPa). Based on the analysis that has been carried out, the live load is 250 kg/m, the dead load is 748 kg/m, and the factored load is 1297.6 kg/m. The maximum moment (Mmax) that occurs at the pin support is 38,281 kNm. Concrete reinforcement on the channel floor plate is in the form of main reinforcement D12-135, and reinforcement for D8-300. Reinforcement for wall plate is main reinforcement D12-115, reinforcement for D8-255.
Keywords: gutter channel, irrigation canal, reinforced concrete beams and slabs, SNI 03-2847-2002.

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INTRODUCTION

Canals are an important structure in irrigation systems. The canals function to carry water from the source to the rice fields that need it. Any damage to the canals can result in obstruction of water flow. As a result, the productivity of rice fields will be disrupted. Because during its growth period, rice needs water. Sugih Canal, located in Cibedug Village, Ciawi District, Bogor Regency, which is a tertiary irrigation canal, was cut off by a landslide on February 8, 2018. As a result of the incident, hundreds of hectares of rice fields were confirmed to have failed to harvest.

After the landslide, the Sugih Channel has yet to be repaired. The steepness of the landslide location is one of the obstacles to building a new channel. From the results of the field survey, the length of Sugih Channel that experienced a landslide reached 28 meters, with the depth of the landslide reaching 8 meters. To restore the channel to its existing condition, a very large volume of soil fill is required, and of course requires a large amount of money in its implementation. (Chayati et al., 2022). Therefore, the use of gutters is one of the alternatives to replace the channel. (Aji, 2019; Kesumowati, 2022).

Therefore, a gutter will be planned in the Sugih channel, Cibedug Village, Ciawi District with a span length of 28 meters supported by 6 pillars with a height of 6.8 meters at each span per 4 meters. A comprehensive knowledge of fluid mechanics, engineering mechanics, and soil mechanics is required in its planning. Knowledge of reinforced concrete engineering is also required, for gutter structures made of concrete. For the Sugih Channel gutter structure, it is planned to use concrete, considering the ease of obtaining materials and workmanship. This research aims to analyze the planning of the channel in the gutter structure, starting from load calculation to construction drawings.

Figure 1 Channel damage condition

Research on the planning of concrete gutter structures in irrigation canals has been carried out previously in the Bukol Tambak Irrigation Network (Fikri, 2022), Opiyang Irigation Area (Sultan et al, 2022) and in Ngarum Irigation Area (Yuono & Mulyandari, 2021).

RESEARCH METHOD

Place and Time of Research

The research time was carried out for five months, from March to July 2020, including field and laboratory testing.

The research site, namely in Sugih Channel, located ini Cibedug Village, Ciawi district, Bogor Regency, West Java Province. The location of the research in the field is shown in the following figure.

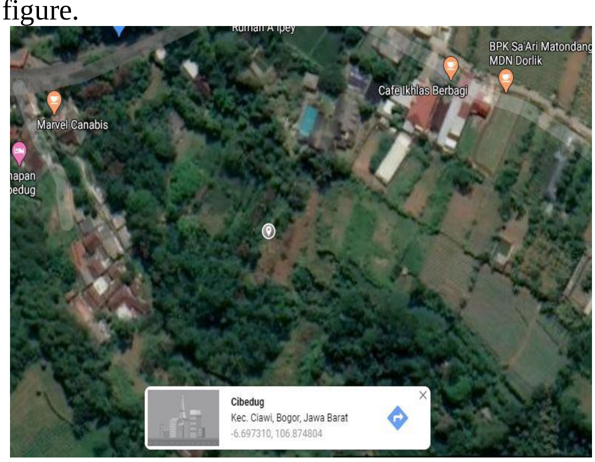

Figure 2 Research site

Materials and Tools

The tools used in this research are coordinate applications, laser distance meters and stationery, while the materials used in this research are water discharge data from the location of Sugih Channel, Cibedug Village, Ciawi District.

Research Flow Chart

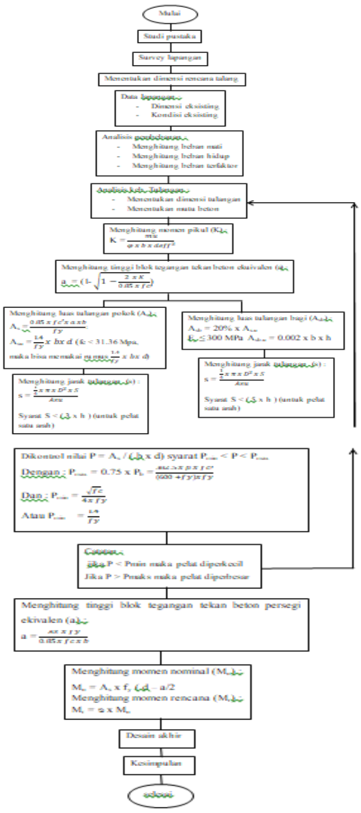

Figure 3 Research flow chart

Soil sampling was conducted during site surveys and laboratory soil testing. The research flow chart is presented in the following figure.

ANALYSIS AND RESULTS

Load Calculation

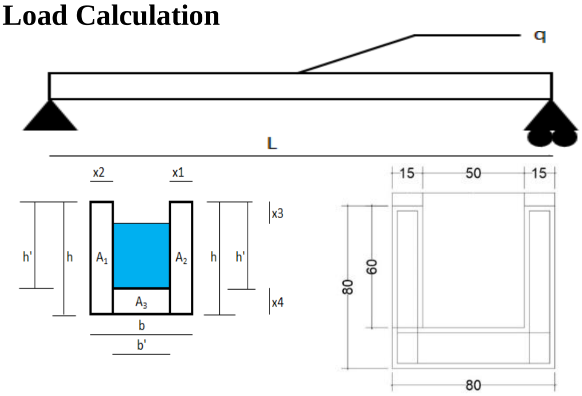

Figure 4 Sketch and dimension of loads

From figure 4 above, it is known that

$L = 4$ m

$h = 0.8$ m $x_1 = 0.15$ m

$h' = 0.6$ m $x_2 = 0.15$ m

$b = 0.8$ m $x_3 = 0.1$ m

$b' = 0.5$ m $x_4 = 0.2$ m

$\gamma_{water} = 1000$ kg/m^3

$\gamma_{concrete} = 2200$ kg/m^3

Live Load

Calculation of channel water as (live load qL) can be obtained by the following formula:

Water load = Wet sectional area x γ_{water}

Wet sectional area = (h'-x3) x b'

= (0.6 - 0.1) x 0.5 = 0.25 m^2

Water load (qL) = 0.25 m^2 x 1000 kg/m^3 x 1 m

= 250 kg/m

Dead Load

Calculation of the structure's dead load (qD) can be obtained by the following formula:

Volume of reinforced concrete x γ_{conc}

(A1 + A2 + A3) x γ_{conc}

A1 = x2 x h = 0.15 x 0.8 = 0.12 m2

A2 = 0.15 x 0.8 = 0.12 m2

A3 = x4 x b' = 0.2 m x 0.5 m = 0,1 m2

Dead load (qD) = (0,12 + 0,12 + 0,1)x 2200 kg/m3

= 748 kg/m

Factored Load

The calculation of the factored load can be obtained with the following formula:

$q = 1{,}2.q_D + 1{,}6.q_L$

q = 1,2 x 748 kg/m + 1,6 x 250 kg/m

q = 1297,6 kg/m

Reinforcement Calculation

From the research results, data has been obtained to calculate the reinforcement, as follows:

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β = 0.85
Slab Thickness = T2 = 200 mm
Concrete Cover = 20 mm
Main Reinf. Ø = 12 mm
Reinf. Bars Ø = 10 mm
D_{eff} = Slab Thickness – Conc Cover - 0.5ØReinf
= 200 – 20 – (0.5 x 12)
= 174 mm
Fy' = 294 Mpa
Quality of Conc. = K250 (*fc'* = 25 Mpa)
fc' $= \left(0.76 + 0.2\, x \log\left(\frac{fck}{15}\right)\right) x\ fck$
= 19.7 Mpa
B = 1000 mm
Fulc. Moment (-) $= \frac{1}{16}\ x\ q\ x\ L^2$
$= \frac{1}{16}\ x\ 1297.6\ x\ 4^2$
= 1297.6 Kg/m = 12.7253 Kn/m
Fulc. Moment (-) $= \frac{1}{8}\ x\ q\ x\ L^2$
$= \frac{1}{8}\ x\ 1297.6\ x\ 4^2$
= 2595.2 Kg/m = 25.4506 Kn/m

Channel base plate reinforcement calculation

The channel bottom plate is a plate with parallel supports and is assumed to be elastically wedged as the bottom plate and sidewalls are cast monolith. This plate is a type of one-way plate that produces a positive moment at mid-span and a negative moment at the pedestal. Calculation of plate reinforcement is calculated per meter in the longitudinal direction of the plate (L), so that:
determine the value of β
Based on SNI T-12-2004 Article 5.1.1.1, the value of β taken based on the equation
- for fc' ≤ 30 MPa, β = 0.85
- for fc' > 30 MPa, β = 0.85 - 0.008*(fc'-30) but cannot be lower than 0.65, thus β = 0.85

Calculation of Pedestal Area

Main Reinforcement Calculation

$K = \frac{mu}{\varphi\ x\ b\ x\ deff^2} = \frac{12.725\ x\ 10^6}{0.8\ x\ 800\ x\ 174^2}$ = 0.525Mpa

a = $(1- \sqrt{1 - \frac{2\ x\ K}{0.85\ x\ fc'}})$ x d = $(1- \sqrt{1 - \frac{2\ x\ 0.525}{0.85\ x\ 19.7}})$ x 174 = 5.543 mm

$A_s = \frac{0.85\ x\ fc'x\ a\ x\ b}{fy} = \frac{0.85\ x\ 19.7\ x\ 5.543\ x\ 1000}{294}$ = 315.705 mm²

$A_{su} = \frac{1.4}{fy}\ x\ bx\ d = \frac{1.4}{fy}\ x\ 1000\ x\ 174$ = 828.571 mm²
(terms (article 12.5.1.SNI 03-2847-2002) fc<31.36 MPa, then we can use the formula $\frac{1.4}{fy}\ x\ bx\ d$).

Since A_s is smaller than $A_{s.u}$ then the larger one is taken
$A_{s.u}$ = 828.571 mm²
Reinf. Spacing (s) $= \frac{\frac{1}{4}\ x\ \pi\ x\ D^2\ x\ S}{Asu} = \frac{\frac{1}{4}\ x\ \pi\ x\ 12^2\ x\ 1000}{828.571}$
= 136.496 mm
S < (3 x h = 3 x 80 = 240 mm)(article 12.5.4.SNI 03-2847-2002)
Selected the smaller one, so s = 135 mm
Reinf. Area $= \frac{\frac{1}{4}\ x\ \pi\ x\ D^2\ x\ S}{s} - \frac{\frac{1}{4}\ x\ \pi\ x\ 12^2\ x\ 1000}{135}$
= 837.750 mm² > As (OK)

Reinforcement Bars Calculation:
A_{sb} = 20% x $A_{s.u}$ = 20% x 828.571
= 165.714 mm²
A_{sb} = 0.002 x b x h = 0.002 x 1000 x 80
= 160 mm²
Selected the larger one, so
$A_{sb,u}$ = 165.714 mm²
Reinf. Spacing (s) $= \frac{\frac{1}{4}\ x\ \pi\ x\ D^2\ x\ S}{Asb,u} = \frac{\frac{1}{4}\ x\ \pi\ x\ 8^2\ x\ 1000}{165.714}$
= 303.326 mm
S < (5 x h = 5 x 80 = 400 mm) (article 9.12.2.2.SNI 03-2847-2002)
Selected the smaller one, so s = 300 mm
Reinf. Area $= \frac{\frac{1}{4}\ x\ \pi\ x\ D^2\ x\ S}{s} = \frac{\frac{1}{4}\ x\ \pi\ x\ 8^2\ x\ 1000}{300}$
= 167.551 mm² > $A_{s,b}$ (OK)
So the main reinforcement is
A_s = D12 – 135 = 873.750 mm²
And reinforcement bars are
$A_{s,b}$ = D8 – 300
= 167.551 mm²

Table 1 Base plate spesification

No	Spesification	Value
1	Quality of Concrete	K 250
2	Main Reinforcement	D12 - 135
3	Reinforcement Bars	D8 - 300

Field Moment Calculation

Main reinforcement calculation
K $= \frac{mu}{\varphi\ x\ b\ x\ deff^2} = \frac{25.451\ x\ 10^6}{0.8\ x\ 1000\ x\ 174^2}$
= 1.050 Mpa
a $= (1- \sqrt{1 - \frac{2\ x\ K}{0.85\ x\ fc'}})$ x d
$= (1- \sqrt{1 - \frac{2\ x\ 1.050}{0.85\ x\ 19.7}})$ x 174
= 11.101 mm
As $= \frac{0.85\ x\ fc'x\ a\ x\ b}{fy}$
$= \frac{0.85\ x\ 19.7\ x\ 11.101\ x\ 1000}{294}$
= 641.894 mm²

(fc < 31.36 Mpa, the formula is $\frac{1.4}{fy} x\ bx\ d$).

A_{su} $= \frac{1.4}{fy} x\ bx\ d = \frac{1.4}{fy} x\ 1000\ x\ 174$

$= 828.571\ mm^2$

Since A_s is smaller than A_{su}, we take the larger one, so A_{su} is 828.571 mm^2

Reinf. Spacing (s) $= \frac{\frac{1}{4} x\ \pi\ x\ D^2\ x\ S}{Asu} = \frac{\frac{1}{4} x\ \pi\ x\ 12^2\ x\ 1000}{828.571}$

$= 136.496$ mm

In terms s < (3 x h = 3 x 80 = 240 mm), we took the smaller one, so s = 135 mm

Reinf. Area $= \frac{\frac{1}{4} x\ \pi\ x\ D^2\ x\ S}{s} - \frac{\frac{1}{4} x\ \pi\ x\ 12^2\ x\ 1000}{135}$

$= 837.750\ mm^2 > A_s$ (OK)

Reinforcement bar calculation

A_{sb} $= 20\%\ x\ A_{s.u} = 20\%\ x\ 828.571$

$= 165.714\ mm^2$

A_{sb} = 0.002 x b x h = 0.002 x 1000 x 80

$= 160\ mm^2$

Choose the larger one, so $A_{sb,u} = 165.714\ mm^2$

Reinf. Spacing (s) $= \frac{\frac{1}{4} x\ \pi\ x\ D^2\ x\ S}{Asb,u} = \frac{\frac{1}{4} x\ \pi\ x\ 8^2\ x\ 1000}{165.714}$

$= 303.326$ mm

In terms S < (5 x h = 5 x 80 = 400 mm), we took the smaller one, so s = 300 mm

Reinf. Area $= \frac{\frac{1}{4} x\ \pi\ x\ D^2\ x\ S}{s} = \frac{\frac{1}{4} x\ \pi\ x\ 8^2\ x\ 1000}{300}$

$= 167.551\ mm^2 > A_{s,b}$ (OK)

So the main reinforcement is

A_s = D12 – 135

$= 873.750\ mm^2$

And reinforcement bars are

$A_{s,b}$ = D8 – 300

$= 167.551\ mm^2$

Table 2 Field base plate spesification

No	Spesification	Value
1	Quality of Concrete	K 250
2	Main Reinforcement	D12 - 135
3	Reinfocrement Bars	D8 - 300

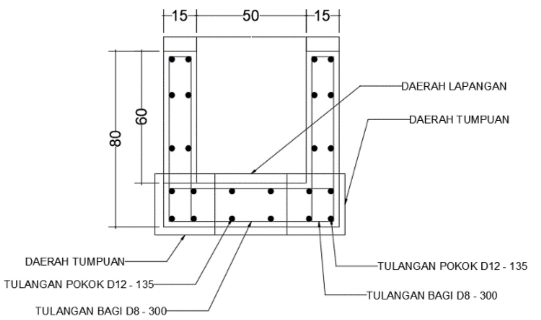

Figure 5 Base plate reinforcement Cross-Section

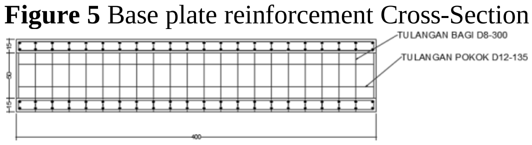

Figure 6 Base plate reinforcement Long-Section

Channel wall reinforcement calculation

This channel top plate is a plate that sits on a parallel support and is assumed to be fixed on its support. This plate is a type of one-way plate that produces a positive moment at mid-span. Calculation of plate reinforcement is calculated per meter in the longitudinal direction of the plate (L), so that:

Qn = slab thickness x concrete weight
= 0.2 x (2200 / 101.97)
= 0.2 x 22 = 4.4 kn/m

Pn = wall thickness x height x concrete weight
= 0.15 x 0.8 x 22
= 2.64 kn/m

Qu = 1.2 x qn + 1.6 x ql
= 1.2 x 4.4 + 1.6 x 250
= 405.28

Pu = 1.4 x pn
= 1.4 x 2.64
= 3.696

Mu = 1/3 x qn x L2 + pu x L
$= 1/3\ x\ 4.4\ x\ 4^2 + 3.696\ x\ 4$
= 38.250

Main Reinfocrement Calculation

K $= \frac{mu}{\varphi\ x\ b\ x\ deff^2} = \frac{38.250\ x\ 10^6}{0.8\ x\ 1000\ x\ 174^2} = 1.579$ Mpa

a $= (1- \sqrt{1 - \frac{2\ x\ K}{0.85\ x\ fc'}})\ x\ d$

$= (1- \sqrt{1 - \frac{2\ x\ 1.579}{0.85\ x\ 20}})\ x\ 174$

= 16.991 mm

A_s $= \frac{0.85\ x\ fc'\ x\ a\ x\ b}{fy}$

$= \frac{0.85\ x\ 20\ x\ 16.991\ x\ 1000}{294}$

$= 982.472\ mm^2$

A_{su} $= \frac{1.4}{fy} x\ bx\ d = \frac{1.4}{fy} x\ 1000\ x\ 174$

$= 828.571\ mm^2$

(fc < 31.36 Mpa, the formula is $\frac{1.4}{fy} x\ b\ x\ d$).

Since A_s is larger than A_{su}, we take the larger one, so A_{su} is 982.472 mm^2

Reinf. Spacing (s) $= \frac{\frac{1}{4} x\ \pi\ x\ D^2\ x\ S}{Asu}$

$= \frac{\frac{1}{4} x\ \pi\ x\ 12^2\ x\ 1000}{982.472}$

= 115.115 mm

In terms s < (3 x h = 3 x 80 = 240 mm), we took the smaller one, so s = 115 mm

Reinf. Area $= \frac{\frac{1}{4} x\ \pi\ x\ D^2\ x\ S}{s} - \frac{\frac{1}{4} x\ \pi\ x\ 12^2\ x\ 1000}{115}$

$= 983.455\ mm^2 > A_s$ (OK)

Reinforcement Bars Calculation

A_{sb} $= 20\%\ x\ A_{s.u}$

$= 20\%\ x\ 982.472$

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$= 196.494 \text{ mm}^2$

$A_{sb} = 0.002 \times b \times h$
$= 0.002 \times 1000 \times 80$
$= 160 \text{ mm}^2$

Choose the larger one, so $A_{sb,u} = 196.494 \text{ mm}^2$

Reinf. Spacing (s) $= \dfrac{\frac{1}{4} x\, \pi\, x\, D^2\, x\, S}{Asb,u}$

$= \dfrac{\frac{1}{4} x\, \pi\, x\, 8^2\, x\, 1000}{196.494}$

$= 255.811 \text{ mm}$

In terms s < (5 x h = 5 x 80 = 400 mm), we took the smaller one, so s = 255 mm

Reinf. Area $= \dfrac{\frac{1}{4} x\, \pi\, x\, D^2\, x\, S}{s}$

$= \dfrac{\frac{1}{4} x\, \pi\, x\, 8^2\, x\, 1000}{255}$

$= 197.119 \text{ mm}^2 > A_{s,b}$ (OK)

So, the main reinforcement is

A_s = D12 – 115
$= 983.455 \text{ mm}^2$

And reinforcement bars are

$A_{s,b}$ = D8 – 255
$= 197.119 \text{ mm}^2$

Tabel 3 Wall section spesification

No	Spesification	Value
1	Quality of Concrete	K 250
2	Main Reinforcement	D12 - 115
3	Reinforcement Bars	D8 - 225

Calculation of slab bearing moment

Main Reinforcement

A_s = D12 – 115
$= 983.455 \text{ mm}^2$

$P = A_s / (b \times d)$
$= 983.455 / (1000 \times 174)$
$= 0.005$ %

$P_{max} = 0.75 \times P_b = \dfrac{382.5\, x\, \beta\, x\, fc'}{(600+fy) x\, fy}$

$= \dfrac{382.5\, x\, 0.85\, x\, 20}{(600+294) x\, 294} = 0.024$ %

There is two ways to calculate P_{min},

$P_{min} = \dfrac{\sqrt{fc}}{4\, x\, fy} = \dfrac{\sqrt{20}}{4\, x\, 294} = 0.003$ %

$P_{min} = \dfrac{1.4}{fy} = \dfrac{1.4}{294} = 0.004$ %

Choose the larger ones

$P_{min} = 0.004$

The Requirements $P_{min} < P < P_{max}$

$P_{min} = 0.004 < 0.005 < 0.024$ (OK)

$a = \dfrac{As\, x\, fy}{0.85\, x\, fc\, x\, b}$

$= \dfrac{983.455\, x\, 294}{0.85\, x\, 20\, x\, 1000}$

$= 17.007$ mm

$M_n = A_s \times f_y (d – a/2)$
$= 983.455 \times 294 (174 – 17.007 / 2)$
$= 47850957.959$ Nmm
$= 47.851$ kNm

$M_r = \phi \times M_n$
$= 0.8 \times 47.851$
$= 38.281$ kNm > dari M_u (OK)

So, $M_r = 38.281$ kNm

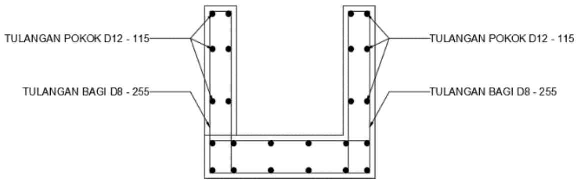

Figure 7 Wall Reinforcement Cross-Section

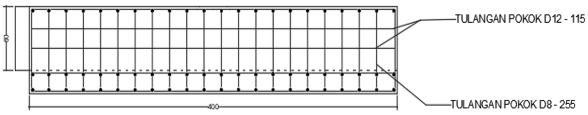

Figure 8 Wall Reinforcement Long-Section

CONCLUSION

Based on the results of the analysis of the concrete structure of the Sugih channel gutter building in Cibedug village, Ciawi sub-district, it can be concluded that based on the results of the load calculated in this channel in the form of dead load with the result of 748 kg / m, live load with the result of 250 kg / m, and the factored load or total load = 1297.6 kg / m, with the result of M_{maks} = 38,281 kNm. The concrete quality used in the planning is K-250 (fc'25), with reinforcement of the base plate in the form of D12-135 main reinforcement, D8-300 reinforcement. Reinforcement of the gutter wall in the form of D12-115 main reinforcement, D8-255 reinforcement..

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