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Comparative analysis of the stability of the left aboutment of the concrete bridge and the stone on the Karian Dam, Lebak Banten District

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Abstract: The abutment of the Karian Dam bridge, which is a gravity type, has a height of 25.5m, so the abutment is at high risk of damage in the form of subsidence, shifting, overturning and so on. Therefore, it is necessary to analyze the stability of the abutments on the Karian Dam bridge by calculating the stability against sliding, overturning, eccentricity and soil bearing capacity so that the abutments can be declared safe. This research aims to determine the safety of the bridge abutments on the Karian Dam and also compare them with the abutment design. stone pairs. The method used to analyze abutment stability in this research is the Coulomb method. The abutment planning stage, such as in retaining wall structures, basically uses a trial and error system by analyzing stability which must meet the safety factors of Bolting≥ 1.5, Shear FK ≥ 1.5, Eccentricity FK≤ 1/6 B, DDT FK ≥ 3. The results of the stability analysis of reinforced concrete abutments state that the abutments can withstand shear, overturning, the bearing capacity of the soil, but the eccentricity is not in the core area (1/6 B), while the abutments of river stone masonry state that the abutments can withstand shear, overturning, soil bearing capacity, and eccentricity.
Keywords: Abutment, Safety Factor, Stability

INTRODUCTION

Indonesia, especially Banten, is a region that is developing in the economic sector, which is characterized by development. The high level of physical development related to civil buildings such as roads, bridges, dams and buildings is built and planned safely. Planning for safe civil buildings means that the buildings are suitable and can be used according to their function during a predetermined lifespan. Bridges are one of the important infrastructures in people's lives for traffic and increasing economic growth. The bridge structure consists of two parts, where there is the superstructure of the bridge and the substructure of the bridge, (Lapis, J.O, 2013).

A common problem that occurs in bridge construction is structural failure, for example subsidence at the abutment/head of the bridge, even though the superstructure of the bridge does not experience significant damage, the overall structure of the bridge becomes tilted making it unsafe to walk on, and the worst impact is that it can cause collapse. in total. Problems that can occur in bridge substructures, especially abutments, can be avoided by learning how to design and analyze substructures.

The author chose the bridge project in Karian Dam, Lebak Regency as his final project because the Karian Dam Bridge has a fairly high abutment height of 25.5m, the height of the Karian Dam bridge head is very prone to danger and can cause subsidence and sliding movements. , overturning and structural strength of abutments/bridge abutments. Thus, to avoid these things, it is necessary to analyze the stability of the abutments according to safety factors so that the function of the abutments as a support and successor to the superstructure of the bridge is safe.

METHODS

Research sites

The place or location of the project for research on the structure of the left bridge head (left abutment) is a strategic government project, namely the Karian multi-purpose dam construction project located in Pasir Tanjung Village, Rangkas Bitung District, Lebak Banten Regency.

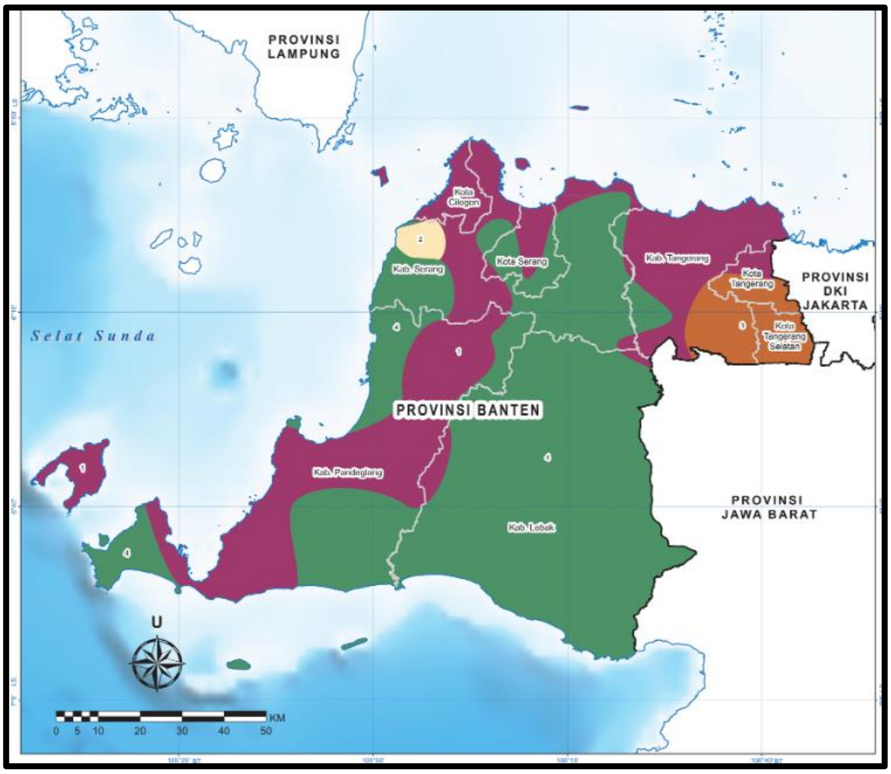

Figure 1. Research Location

Data Collection Technique

Observation

According to Sugiyono (2018), observation is a data collection technique where this technique has special characteristics compared to other techniques. Observations relate to people and other natural objects. The observations made in this research by the author carried out direct observations in the field to determine the condition of the bridge head and soil at the project location. The data obtained included primary data, namely data regarding the bridge head (abutment) obtained from the person concerned, namely the Karian Dam bridge supervisory consultant, and secondary data obtained was a picture of the bridge head.

Literature

Literature techniques are techniques obtained from written works that can be accounted for. Literature in bridge head research is in the form of books about foundations, bridges, as well as bridge head (abutment) journals.

Flow diagram

In Figure 2, there are stages of the research flow diagram that the author will carry out, the stages are as follows:

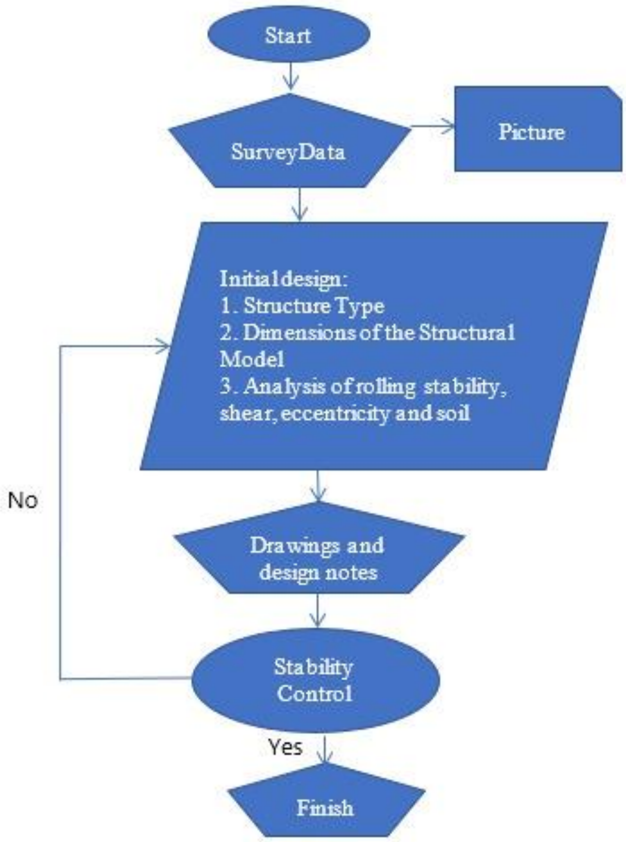

Figure 2. Research Flow

RESULTS AND DISCUSSION

Bridge Data

The results of observations on the Karian dam bridge are that the bridge was built as a pedestrian access and vehicle crossing, as well as for the operation and maintenance of water gates. The bridge with a width of 7.5 meters and a length of 52.395 meters has 2 abutments and 2 pillars to transmit the load from the superstructure to the foundation and soil, as shown in Figure 3.

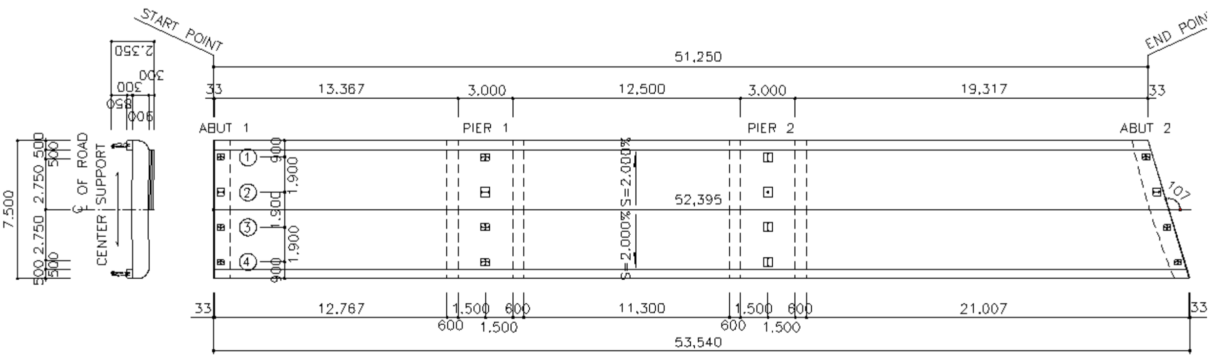

Figure 3. Bridge site plan

Concrete Aboutment Calculation (BBWS C3):

Concrete Abutment Data

Aboument type = gravity
Structure = reinforced concrete
Length = 41,230 meters
Width (B) = 17,250 meters
Height (H) = 25.50 meters
Friction angle (φ) = 30°
Cohesion C = 2 t/m2
γ_tan[illegible]an = 1.7 t/m3

Dead Load Due to Active Pressure (PA) Passive Pressure (PP)

Active coefficient (Ka)

$k_a = tg^2\,(45 - \frac{\varphi}{2})$

$k_a = 0{,}333$

$P_a = \frac{\gamma H^2}{2}\,k_a$

$P_a = \frac{1{,}7 \times 25{,}5^2}{2}\,0{,}333$

$P_a = 184{,}05$ t/m

Even load (Pa')

$Pa' = qK_aH$

$Pa' = 1 \times 0{,}333 \times 25{,}5$

$Pa' = 8{,}5$ t/m

Total active pressure(∑pa)

pa = Pa + Pa′
= 184,05 + 8,5
= 196,55 t/m

Passive Coefficient (Kp)

$K_p = tg^2\,(45 + \frac{\varphi}{2})$

$K_p = tg^2\,(45 + \frac{30}{2})$

$K_p = 3{,}000$

$P_p = \frac{\gamma H^2}{2}\,k_p$

$= \frac{1{,}7 \times 6^2}{2}\,3$

= 91,8 t.m

Self-weight of concrete abutment (W) :

γconcrete = 2.4 t/m3

W1 = Length (p) × width (l) × specific gravity of concrete (γconcrete)
= 19.5× 3 × 2.4
= 140.4 t/m

W2 = 0.5×base (a) × height (t) × specific gravity of concrete (γconcrete)
= 0.5 × 7.25 × 14.5 × 2.4
= 126.15 t/m

W3 = Length (p) × width (l) × specific gravity of concrete (γconcrete)
= 17.25 × 4 × 2.4

= 165.6 t/m

W4 = Length (p) × width (l) × specific gravity of concrete (γconcrete)

= 4 × 2 × 2.4

= 19.2 t/m

W5 = 0.5 × base (a) × height (t) × specific gravity of concrete (γconcrete)

= 0.5 × 1 × 2 × 2.4

= 2.4 t/m

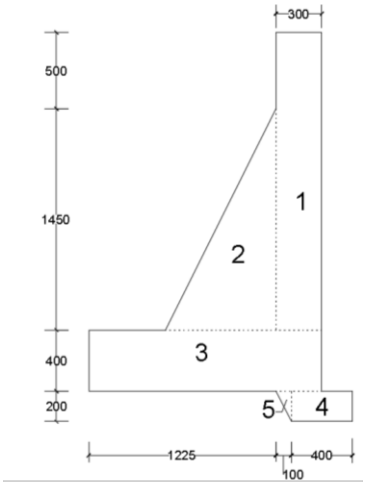

Figure 4. Distribution of concrete abutments

Calculating Concrete Abutment Moment

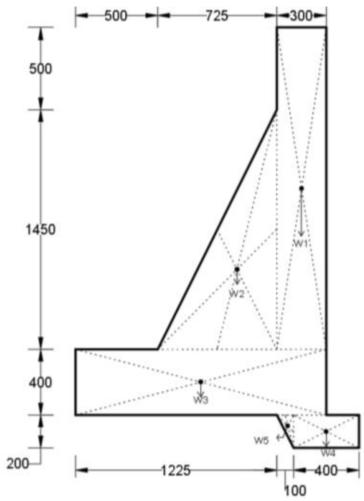

Figure 5. Moment distance to viewing point 0 concrete abutment

LW_1 = $17{,}25 - 12{,}25 - \left(\frac{3}{2}\right)$

= 3,5 m

LW_2 = $17{,}25 - (5) - \left((17{,}25 - (5 + 3 + 2))\frac{2}{3}\right)$

= 7,42 m

LW_3 = $17{,}25 - \left(\frac{17{,}25-2}{2}\right)$

= 9,625≈ 9,63 m

LW_4 = $17{,}25 - 5 - 7{,}25 - 1 - \left(\frac{4}{2}\right)$

= 2 m

LW_5 = $17{,}25 - 12{,}25 - \left((17{,}25 - 12{,}25 - 4)\frac{2}{3}\right)$

= 4,33 m
LPa = 1/3 × 25,5
= 8,5 m
LPp = 1/3 × 6
= 2 m

Table 1. Calculation of Resistance Moment and Overturning Moment to 0 Per Meter

Segment components	Great Style (t/m)	Distance from 0 (m)	Holding Moment (t.m)	Overturning Moment (t.m)
W1	140,40	3,5	491,40	-
W2	126,15	7,42	936,03	-
W3	165,60	9,63	1594,73	-
W4	19,20	2	38,40	-
W5	2,40	4,33	10,92	-
Pa	196,55	8,50	-	1670,68
Pp	91,80	2,00	183,60	-
Amount (∑)	ΣW = 742,1		ΣM_W = 3254,55	ΣM_{gl} = 1670,68

Stability of Concrete Abutments against Safety Factors (FK)

Stability against Overturning

Safety factor against overturning (Fgl) ≥ 1.5.

$F_{gl} = \frac{\Sigma M_w}{\Sigma M_{gl}}$

$= \frac{3254,55}{1670,68}$

= 1,95 ≥ 1,5 OK→(Safe)

Stability against Shear (Fgr)

Pa = 196,55 t/m
Pp = 91,80 t/m
ΣW = 742,1t/m
f = tg φ
= tg 30
= 0,58

$F_{gr} = \frac{pp + \sum W.f}{pa}$

$= \frac{91,80+(742,1\ x\ 0,58)}{196,55}$

= 2,66 ≥ 1,5 OK→(safe)

Calculating Eccentricity

Abutment width (B) = 17.25 m
ΣM_w = 3254,55 t/m
ΣM_{gl} = 1670,68 t/m
Σ_V = 742,1t/m

e $= \frac{B}{2} - \frac{\sum Mw - \sum Mgl}{\sum v} \leq \frac{B}{6}$

$= \frac{17,25}{2} - \frac{3254,55-1670,68}{742,1} \leq \frac{17,25}{6}$

= 6,49 ≥ 2,875 The resultant force does not enter the kernel/core→not OK

Calculating Carrying Capacity (Terzaghi)

φ=30°; Nc' = 19,0; Nq'= 8,3; $N_{\gamma'}$= 5,7; c= 2 t/m^2
Df = 25,5m; γ = 1,7 t/m^3; B = 20 m.
Ultimate carrying capacity (qu):

qu $= cN_C + Df\gamma Nq + 0{,}5B\gamma N_y$
= (2 × 19) + (25,5 × 1,7 × 8,3) + (0,5 × 20 × 1,7 × 5,7)
= 494,71 t/m^2

If a trapezoidal distribution is used, the pressure of the abutment to the subgrade:

q max $= \frac{2v}{3(B-2e)}$ if $\geq \frac{B}{6}$
$= \frac{2\ x\ 742{,}1}{3(17{,}25-2\ x\ 6{,}49)}$
= 115,86 t/m^2

Soil bearing capacity safety factor

F $= \frac{q_u}{qmax} \geq 3$
$= \frac{494{,}71}{115{,}86} \geq 3$
= 4,27 ≥ 3 OK→(safe)

Kali Stone Pair Abutments (Author)

Dimensioning

Estimate the size of the bridge head as a start in planning as follows:

Height (H) = 25,5 m
Top width = 0,25 H
= 0,25 × 25,5
= 6,37≈ 6,5 m – 8m
Bottom width = 0,7 H
= 0,7 × 25,5
= 17,85 ≈ 20 m
D (tread height = H/6
= 25,5 /6
= 4,25 ≈4,5 m – 7m

Dead Load Due to Active Earth Pressure (Pa) and Passive Earth Pressure (Pp)

$$k_a = tg^2\,(45 - \frac{\varphi}{2})$$
$$k_a = tg^2\,(45 - \frac{30}{2})$$
$$k_a = 0{,}333$$
$$P_a = \frac{\gamma H^2}{2}\,k_a$$
$$= \frac{1{,}7\ x\ 25{,}5^2}{2}\ 0{,}333$$
$$= 184{,}05\ t/m$$
$$K_p = tg^2\,(45 + \frac{\varphi}{2})$$
$$K_p = tg^2\,(45 + \frac{30}{2})$$
$$K_p = 3{,}000$$
$$P_p = \frac{\gamma H^2}{2}\,k_p$$
$$= \frac{1{,}7 \times 7^2}{2}\ 3$$
$$= 124{,}95\ t.m$$

Self-weight (W) of river stone abutments

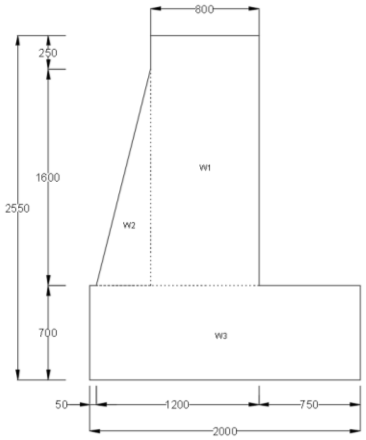

Figure 6. Distribution of abutments for river stone pairs

γ pas batu kali = 2,2 t/m^3.

W$_1$ = Panjang (p)×lebar (l) × berat jenis beton (γ_{beton})
= 18,5 × 8 × 2,2
= 325,60 t/m

W$_2$ = 0,5 × alas (a) × tinggi (t) × berat jenis beton (γ_{beton})
= 0,5 × 4 × 16 ×2,2
= 70,40 t/m

W$_3$ = Panjang (p) × lebar (l) × berat jenis beton (γ_{beton})
= 20 × 7 × 2,2
= 308 t/m

Calculating the moment of abutment of river rock pairs

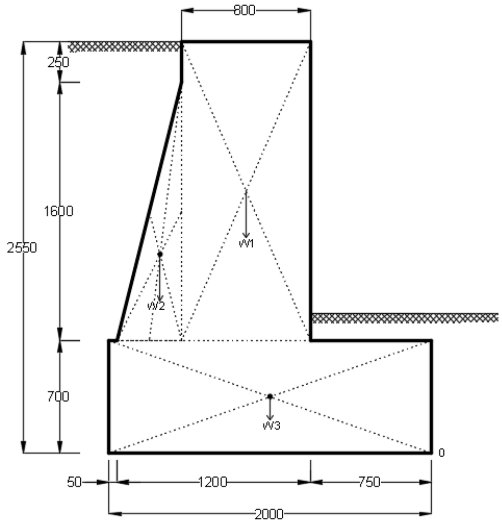

Figure 7. Distance from moment to viewing point 0

W$_1$ = $20 - 0{,}5 - (20\text{-}0{,}5\text{-}8\text{-}7{,}5) - (\frac{8}{2})$
= 11,5 m

W$_2$ = $20 - 0{,}5 - ((20 - (0{,}5 + 8 + 7{,}5))\,\frac{2}{3})$
= 16,8 m

W$_3$ = 20 / 2 = 10 m

Pa = 1/3 × 25,5
= 8,5 m
Pp = 1/3 × 7
= 2,33 m

Table 4.2. Calculation of Moments on Kali Stone Pair Abutments

Segment components	Force Size (t/m)	Distance from 0 (m)	Holding Moment (t.m)	Overturning Moment (t.m)
W1	325,60	11,5	3744,50	-
W2	70,40	16,84	1185,55	-
W3	308	10	3080	-
vehicle	12	10	120	1564,42
Pa	184,05	8,50	-	
Pp	124,95	2,33	291,55	-
Amount (∑)	ΣW = 1025		ΣM_W = 8421,6	ΣM_{gl} = 1564,42

Stability of Concrete Abutments against Safety Factors (FK)

Stability against Overturning

$F_{gl} = \frac{\sum M_w}{\sum M_{gl}}$

$= \frac{8421,6}{1564,42}$

$= 5,38 \geq 1,5$ OK→(Safe)

Stability against Shear (F_{gr})

Pa = 184,05 t/m
Pp = 124,95 t/m
ΣW = 1025 t/m
F = tg φ
= tg 30
= 0,58

$F_{gr} = \frac{pp + \sum W.f}{pa}$

$= \frac{124,95 + (1025 \times 0,58)}{184,05}$

$= 3,90 \geq 1,5$ OK→(Safe)

Calculating Eccentricity

Abutment width (B) = 20 m
ΣM_w = 8130,05t/m
ΣM_{gl} = 1564,42t/m
Σ_V = 1025 t/m

e $= \frac{B}{2} - \frac{\sum Mw - \sum Mgl}{\sum v} \leq \frac{B}{6}$

$= \frac{20}{2} - \frac{8421,6 - 1564,42}{1025} \leq \frac{20}{6}$

$= 3,30 \leq 3,33$ resultant enters core/kern→OK (Safe

Calculating Carrying Capacity (Terzaghi)

φ=30°; Nc' = 19,0; Nq'= 8,3; $N_{y'}$= 5,7; c= 2 t/m^2
Df = 25,5m; γ = 1,7 t/m^3; B = 20 m.
Daya dukung ultimit (qu):

qu $= cN_C + Df\gamma Nq + 0{,}5B\gamma N_y$
$= (2 \times 19) + (25{,}5 \times 1{,}7 \times 8{,}3) + (0{,}5 \times 20 \times 1{,}7 \times 5{,}7)$
$= 38 + 359{,}81 + 96{,}9$
$= 494{,}71$ t/m^2

The value of e ≤ B/6 then find the pressure due to the structure load (q) using Eq

q $= \frac{v}{B}\left(1 \pm \frac{6e}{B}\right)$
$= \frac{1025}{20}\left(1 \pm \frac{6\ x\ 3{,}3}{20}\right)$
$=51{,}25\ \left(1 \pm \frac{6\ x\ 3{,}3}{20}\right)$
$=51{,}25\ (1 \pm 0{,}99)$

q_{max} $= 51{,}25\ (1 + 0{,}99)$
$= 51{,}25 \times 1{,}99$
$= 101{,}99$ t/m^2

q_{min} $= 51{,}25\ (1 - 0{,}99)$
$= 51{,}25 \times 0{,}01$
$= 0{,}51$ t/m^2

Soil bearing capacity safety factor

F $= \frac{q_u}{qmax} \geq 3$
$= \frac{494{,}71}{101{,}99} \geq 3$
$= 4{,}85 \geq 3$ OK→(Safe)

Comparison of the Stability of Reinforced Concrete Abutments (BBWSC3) with Stone Pair Abutments (Author)

Table 3. Dimensions of Reinforced Concrete Abutments and River Stone Abutments

S	Component	Reinforced Concrete Structure Abutment (BBWSC3)	Masonry Structure Abutments (Author)
1.	Tall	25,5 m	25,5 m
2.	Bottom width	17,25 m	20 m
3.	Ata width	3 m	8 m

Table 4. Stability of Reinforced Concrete Abutments and River Stone Abutments

No.	Component	Reinforced Concrete Abutment (BBWSC3)	River Stone Abutment (Writer)
1.	Stability against Overturning	1,95	5,38
2.	Stability against Shear	2,66	3,90
3.	Eccentricity	6,49	3,30
4.	Stability of soil bearing capacity	4,27	4,85

CONCLUSIONS

The results of calculations and discussion of the stability of the bridge abutments/heads can be concluded as follows: First, The magnitude of the force on the concrete abutment is 742.1 t/m, while the magnitude of the force on the stone masonry abutment is 1025 t/m. Second, The safe overturning value for reinforced concrete bridge abutments/heads is obtained = 1.95. And the SF of rolling for the abutment/head of the river stone bridge is obtained = 5.38. The safe shear value for reinforced concrete bridge abutments/heads is found to be = 2.66. And the rolling SF for the abutment/head of the river stone bridge was obtained = 3.90. The safe value of eccentricity for reinforced concrete bridge abutments/heads is found to be = 6.49.

And the eccentricity SF for the abutment/head of the river stone bridge was found to be = 3.30. The safe value of soil bearing capacity for reinforced concrete bridge abutments/heads is found to be = 4.27. And the SF of the soil bearing capacity for the abutment/head of the river stone bridge was found to be = 4.85. Third, Comparison of stability Based on the overturning number from the calculation of the two abutments it is said to be safe against overturning forces, while the shear number from the calculation of the two abutments is said to be safe, for the eccentricity number from the calculation of the reinforced concrete abutment the result (R) does not enter the core/corner because the eccentricity SF is ≥ 1/6 B, while the eccentricity figure for the river masonry abutment R is included in core/core/corn, meaning it is safe because the eccentricity SF is ≤1/6 B, and the soil bearing capacity figure from the calculation of the two abutments is said to be safe for the soil bearing capacity because the SF bearing capacity soil ≥ 3. Comparison of the dimensions of the reinforced concrete abutment (BBWSC3) is height = 25.5 m, top width = 3 m, and bottom width = 17.25 m, while the river stone abutment is height = 25.5 m, top width = 8 m, and bottom width = 20m.

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