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An Evaluation of Improvement Plans Bridge Abutment Penaga in Bintan Island

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ABSTRACT

The bridge is a construction that connects one place to another. Generally, the bridge structure is divided into two, namely, the upper structure and the lower structure. The upper structure carries the load directly above the surface, while the lower structure carries the load received above and then transmits the load to the foundation layer on hard soil. In the bridge structure, one part has a unique dual role in supporting the load on its surface, namely the abutments. The abutments are located at both ends of the bridge pillars, which aim to carry the live and dead loads on the bridge. Usually, a support bridge is built at the end of the bridge located on the riverbank with an important role in maintaining the bridge's stability. The method used in this study is the quantity method and literature review. As for the process of processing data using search techniques and collecting information related to the research to be carried out. The purpose of this research is to repair the abutments that have been damaged by considering the rules according to the standards. The results of the analysis that has been carried out state that for structural stability, the abutments under normal conditions, when an earthquake occurs, can withstand maximum and minimum earth stress forces. So it can be concluded that the abutment structure can withstand the thrust that occurs at maximum and minimum conditions. While the results of the structural analysis of shear forces are stated to be unsafe because the strength of the bridge structure to withstand shear forces is less than the required safety factor based on national standard provisions. This research also provides information to the public for bridge users.

1. Introduction

The bridge is a construction that connects one place to another. Generally, the bridge structure is divided into two, namely, the upper structure and the lower structure. The upper structure carries load directly above the surface, while the lower structure carries the load received above and then transmits the bag to the foundation layer on hard soil. In the bridge structure, one part has a unique dual role in supporting the load on its surface, namely the abutments. The abutments are located at both ends of the bridge pillars, which aim to carry the live and dead loads on the bridge. Usually, a support bridge is built at the end of the bridge located on the river bank, with an important role in maintaining the bridge's stability [1]. Bridge stability is affected by the loads fixed on the bridge spans connected by supports and connectors [2].

In planning, the abutment structure on the bridge must comply with applicable regulations. Based on the times, planning regulations that can be used are bridge planning regulations from BMS 1992, SNI-T-02-2005, SNI T-12-2004, and SNI 2833:2008. Bridge abutments have a complex structure that requires routine maintenance during their use. So that the costs used during the treatment period are high, this is an interesting discussion. The abutment to be built is analyzed, which is strengthened by using soil structure calculations to create a front wall and sloping wings on both supports [3].

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Planning abutments in bridge structures must be considered for factored loads and strengths. In analyzing bridge structures, especially abutments, planning data and regulatory guidelines set by the government are needed, such as RSNI T01-205, SKBI 1.3.28.1987:624.042.624.21, and No. 12/1970. In addition, secondary data can be obtained from several agencies related to the structural planning of bridge abutments [4]. In an abutment structure, the load is received through the dynamic action of the soil, and the top gear is subjected to significant inertial forces caused by the amount of soil mass involved.

In abutment structures where conditions occur when conditions reach the limit make the structure unstable, causing instability of the entire structure and capacity failure. On the other hand, the ability limit that occurs in the abutment fails due to several factors, such as damage or deformation. This can affect the structure that is in the ground [5]. This study aims to analyze and review the loads acting on abutment structures that can function safely, so they do not experience landslides [6]. For continuous bridges with long spans without deck connections, deformation can occur in one of the significant parameters [7].

In interacting bridges having a dynamic effect, the abutments are considered to have masses connected via a nonlinear shear force [4]. The bridge structural components are divided into 2, namely the upper and lower structures. The brittleness-specific bridge method presented in this paper can efficiently incorporate bridge design details into the fragility estimation method. This breakdown acts as a conditioning variable in the fragility equation and analysis. Thus, one of the needs of this study was to find the design details that have the most significant effect on the response of the different components of a bridge class two-span integral box girder (used as an illustrative case here) to seismic ground motions. The three basic steps involved in the generation of BSFM are (1) generation of a multi-parameter demand model, (2) fixing of the boundary state (or capacity), and (3) generation of the fragility curve by the logistic regression approach [8].

2. Literature Review

The bridge is a construction built to connect one place to another. In designing a bridge, it is better to consider the technical functions and architectural values contained in the bridge. In addition, designing a bridge must follow the rules set with good specifications. Bridges are the essential part of road infrastructure that connects each region by estimating the distance that can be passed [9].

2.1 Components of Bridge

Generally, the bridge structure is divided into two parts: the upper and lower structures. The upper and lower structural parts have their respective roles in resisting the loads on the bridge.

a. Superstructure

The upper structure of the bridge is the part that receives direct loads such as dead loads, additional loads, vehicle loads, passers-by loads, and others. The superstructure was built continuously and supported by elastomeric bearings at the internal piers. The piles were rigidly connected to the bottom of the abutment and fixed at the pile tips [10].

b. Substructure

The lower structure of the bridge has a function, which is to accommodate all the loads that occur on the superstructure, which are then channeled downwards to the foundation. The load will later be distributed to the ground after being transferred from the foundation. The bridge substructure has insufficient strength and is vulnerable to hazards such as ground movement, deformation, and scouring [11].

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2.2 Kinds of Bridge

Bridges have several types based on the material used, namely as follows:

1. Wood Bridge

In ancient times, before the discovery of concrete and steel-forming materials, people used wood to make infrastructure such as houses and bridges. Wood is a product available by nature/forest, so it is relatively easy to obtain. Wood is a material that is strong and stiff enough to be used as a building material, and wood is also relatively easy to shape and cut into desired pieces. However, with the advancement of technology and knowledge about materials, people are switching to using concrete or steel in making infrastructure (in this case, I am specifically for bridges). Wood could substitute a few of these materials mainly due to its low weight ratio compared to its high endurance. Bridges in the wood often attract attention due to their creative design and structure, the ability to assemble them in record time, and their fascinating economic and functional efficiency [12].

2. Steel Bridge

Bridges that use various steel structural components and systems: decks, girders, trusses, arches, supports, and cable hangers, on steel bridges I will describe steel frame bridges, namely bridges formed from trusses that form a triangular unit and could distribute the load to each frame. The truss consists of tension rods and compression rods. A tensile rod is a rod that receives a tensile load. The design for tension rods is based on allowable tensile stress, where the stress that occurs must not exceed the allowable stress. If holes exist, the cross-sectional area is the net area (gross area-area of the hole). To withstand applicable loads, a sufficient safety factor is used against damage. To determine the fatigue load effects, the computation of dynamic stresses due to vehicle loadings is a fundamental step in the fatigue evaluation of steel bridges [13].

3. Concrete Bridge

Bridges made of concrete were first used in the 19th century, the cement industry dominated after 1865, and concrete is widely used for arch bridges and under construction. Reinforced concrete bridges were first built after the discovery of reinforced concrete manufacturing techniques for structures in France in 1875. Over the decades, reinforced concrete bridges were constructed for short-span bridges, especially in the early 1890s and increasingly in the 20th century. Slabs and reinforced concrete bridge girders were widely used for short spans for many decades. Reinforce concrete bridge and pre-stressed concrete bridge. The pre-stressed concrete bridge is one type with concrete containing steel cables material to provide initial stress to the concrete due to the concrete's character, which cannot hold tensile forces [14].

4. Composite Bridge

A bridge that combines two or more materials with different material properties and forms a unit to produce better-combined properties. The commonly used composite bridge combines steel and poured concrete construction materials, namely by combining steel as the deck (girder) and reinforced concrete as the bridge floor plate. Based on the experience with their application, it has been shown that timber–concrete composite bridges can be a competitive alternative to commonly used reinforced concrete and steel structures [15].

2.3 Bridge Abutments

The bridge abutment is part of the underside of the bridge building. The abutment carries all the loads that work on the bridge's superstructure and safely continues the load that the building on the subgrade layer bears, as well as a soil retaining structure that receives pressure and is forwarded to the foundation. The bridgehead (abutment) is the structure under the bridge, which is located at both ends of the bridge pillars, functions as a bearer of all live and dead loads, and functions as a retaining

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wall, namely resisting active earth pressure. Abutments are suitable for conveying forces of inertia during the earthquake [16].

The design code for loading bridges used by SNI 1725 – 2016 is a revision of SNI 1725 – 1989 concerning bridge loading and RSNI T – 02 2005 entitled Standard for loading for bridges. Some revised technical provisions include load distribution D in the transverse direction, load distribution factor T, load loads, earthquake loads, wind loads, and fatigue loads. SNI 1725 – 216 is intended as a guide or guide for the planning community in carrying out bridge technical planning, especially the loading aspect. The SNI 1725 – 2016 design code conveys the design loads used in bridge planning and the newest loading combination formula. SNI 1725 – 2016 defines the loads to be analyzed on bridge structures in the form of endless loads, including the self-weight of the structure, additional dead loads, as well as quick actions in the form of vehicle lane loads, loads due to braking, loads due to pedestrians, while environmental actions are in the form of structural wind loads. , vehicle wind, temperature, and earthquake loads [5].

3. Method

In conducting research, several steps can be used to solve the problems described in the background section, so it is necessary to do data analysis. Data is one of the main strengths in compiling research and scientific modeling [31] [32] [33] [34] [35]. After getting the data, the next thing is to determine the method to be used. The method used in this study is the quantity method and literature review as for the process of processing data using search techniques and collecting information related to the research to be carried out. The process of systematic scientific research must begin with the identification of the right problem [17] [18] [19].

Location This research was conducted at Penaga Sei Dark Bridge, Banse, Penaga Village, Kec. Bintan Bay. In the research process for the Penaga bridge abutment, Bintan District, Kepualaun Riau Province, it is necessary to obtain some data directly, namely by conducting direct observation of the field (primary) or data obtained from related agencies or literature (secondary), as well as other supporting data, with the aim that it can conclude in determining the stability of bridge abutments.

4. Result and Discussion

4.1 Specification of Bridge

After knowing the various forces that occur in the abutment, as a basis for analyzing the strength of the abutment, it is necessary to know the specification data of the abutment. Here is data needed in planning abutments on this bridge are as follows:

Table 1. Technical Specification of Bridge

Description	Specification
Type of Bridge	Concrete Bridge
Length	30.45 m
Width	7.2 m
Number of Spans	1
Traffic Width	5 m
Sidewalk Width	1.2 m
Number of Main Girders	6
Distance of Main Girders	6.08 m

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Description	Specification
Abutments Height	3.60 m
Support Pole	8
Distance of Support Pole	2.0 m

4.2 Bridge Abutment Parts

In the bridge, there are two main components, namely, the upper construction and the lower construction. The bridge's construction accommodates loads received by traffic loads and then distributed to the lower construction structure. The function of the upper part of the construction is to receive the load received by the superstructure and then channel it to the foundation. Related to the top and bottom of the bridge can be explained in Figure 2 below.

This base plate binds and unites the abutments and piles or foundations when using pile, drilled, or well foundations. Peat Elastomer Bearings are bearings that dampen vibrations in the girders due to loads and moving vehicles.

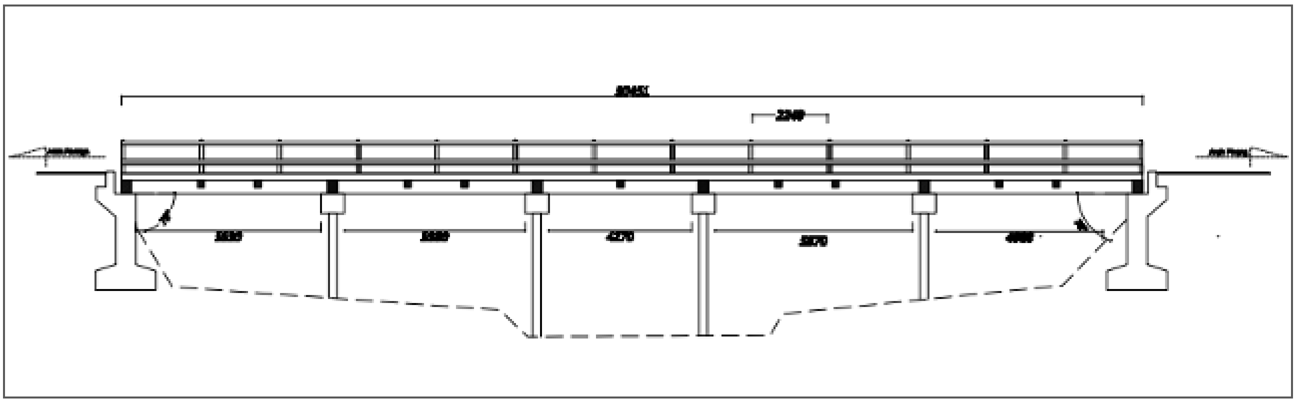

Figure 2. Side View of Bridge

4.3 Abutment Structure Analysis

In the analysis of the abutment structure, the forces and loads that work are taken into account. Previously explained in advance the force acting on the abutment as shown in Figure 4

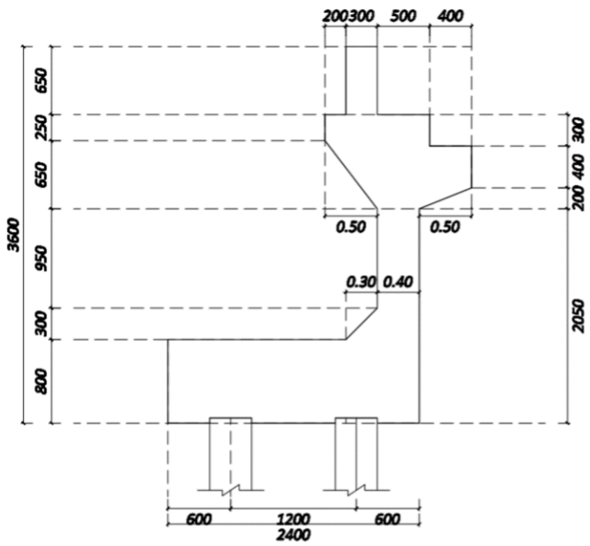

Figure 3. Abutments Planning

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The various forces that occur in the abutment, as illustrated in Figure 3 have the meaning as described in Table 2.

Table 2 Definition Symbol on the Abutment

Symbol	*Definition*
Rv	Compressive force due to load from above
Rrt	Force due to vehicle brakes and traction
G	Self-Weight abutment
G1	Earthquake force due to the upper building.
Hg	Friction due to moving pedestal
Pa1, Pa2, Pa3	Active earth pressure behind the abutment
Pp1, Pp2	The passive compression force of the soil at the front of abutment

Vertical Force

a. Force due to abutment

Table 3. Abutment Loading Analysis

	b (m)	**h (m)**	**A(b.h) (m^2)**	**x (m)**	**y (m)**	**A.x**	**A.y**	**W (T)**
1	0.30	0.65	0.195	1.05	3.275	0.204	0.638	0.825
2	1.00	0.25	0.250	0.90	2.825	0.706	0.176	3.515
3	1.50	0.65	0.975	0.70	2.375	2.315	2.315	8.125
4	0.40	0.95	0.380	0.60	1.575	0.598	0.598	4.227
5	0.70	0.30	2.100	0.75	0.950	1.995	1.995	24.354
6	2.40	0.80	1.920	1.60	0.400	0.768	0.768	20.175
∑			**5.820**			**6.586**	**6.490**	**61.221**

Table 4. Result Loading Abutments

	$X = \frac{\sum Ax}{\sum A}$	$Y = \frac{\sum Ay}{\sum A}$	∑W	∑W x X
Abutment sectional center of gravity	1.13 m	1.11 m		
Dead Load of Abutment			61.221 T	
Moment				69.17 Tm

b. Dead Loads Superstructure

Vehicle Floor	= 30.45 x 7.20 x 0,3 x 2,4	= 157.85 Ton
Raiwater	= 30.45 x 7.20 x 0,05 x 1	= 10.962 Ton
Sidewalk	= 30.45 x 2 x 0,23 x 2,5 x 1	= 35.017 Ton
Backrest Pole	=0,30 x 0,30 x 1,35 x 2,4 x 5	=1.458 Ton
Backrest	= 3,325 x 0,3 x 1 x 2,4 x 4	= 9,576 Ton
Longitudinal Girder	= 30.45 x 0,45 x 0,85 x 2,4 x 4	= 111.81 Ton
Asphalt (4 cm)	= 30.45 x 7.20 x 0,04 x 2,2	= 19.29 Ton
Bridge Diaphragm	= 7.20 x 0,50 x 0,30 x 2,4 x 5	= 12.96 Ton
P.Total	= **358.923 Ton**	

Deadload received by abutment RVD = 358.46 / 2 = 179.46 Ton

Deadload due to superscstucture

Evenload q = 2.2 t/m q = Evenload L < 30 Meters Traffic Lane width = 3.55 m Because the width of the bridge is equal to or less than 5.5 meters, the load q is 100%

$$\text{RQL} = \left(\frac{2,2}{2,75} \text{x } 5,00\right) = 4,00 \text{ Ton}$$

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Lineload 12 Ton ⟶ PPJR 1987

Because the width of the bridge is equal to or less than 5.5 meters, the load q is 100%

$$K = 1\left(\frac{20}{50+L)}\right) = 1 + \left(\frac{20}{50+30.45)}\right) = 1.248$$

$$RPL = \left(\frac{P}{2{,}75)}\right) x\ KxL$$

$$= \left(\frac{12}{2{,}75)}\right) x\ 1.248x5{,}00$$

$$= 27.22\ Ton$$

Liveload Total = (30,45 x 2,84 + 27,22 x 2 = 129,95 Ton

Load by the segmen abutment = 129,95 / 2 = 64.975 Ton

Horizontal Force

a. **Brake force and traction**

$$Rrt = \left(\frac{5\%\ x\ (Rpl + Rql}{2}\right)$$

$$= \left(\frac{5\%\ x\ (27.22 + 2{,}84}{2}\right) = 0{,}75\ Ton$$

Distance to point A, y = 3,60 + 1,80

= 5,40 meter

Liveload total MRrt = 0,75 Ton x 5,40 m = 4,05 Tm

Friction force on pedestal

Gg = Friction force x Deadload

(RVD) ⟶ Friction Coefficient value is taken from PPJJR pasal 2.6.2

= 0,25 x 179,46 = 44,865 Ton

Distance to point A, y = 3,20 meter

MGg = 44,865 Ton x 3,20 m = 143,56 Tm

b. **Eartquake Force**

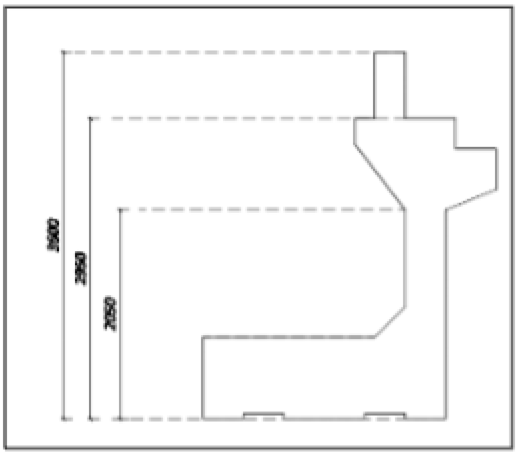

Figure 4. Earthquake Load

a. **Earthquake force due to the superstructure**

Rvd = 179,46 Ton

E_1 = 0,05 x 179,46 = 8,97 Ton

y = 3,60

M_{E1} = 8,97 ton x 3,60 m

= 32,292 Tm

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b. Earthquake force due to abutment

W_{ab} = 61,221 Ton
E_2 = 0,05 x 61,221 = 3,06 Ton
y = 3,90
M_{E2} = 3,06 ton x 2,95 m
= 9,03 Tm

c. Earthquake force due to soil load

W_{ta} = 40,332 Ton + 12,171 Ton
= 52,503 Ton
E_3 = 0,05 x 52,503 = 2,625 Ton
y = 2, 05
M_{E2} = 2,625 ton x 2,05 m
= 5,38 Tm

4.4 Discussion

The following describes the evaluation results of the Penaga Sei Dark Bridge abutments, Banse, Penaga Village, Kec. Bintan Bay. and the calculation of the budget plan is as follows:

1. In the bridge planning book, the H abutment height plan is < 4 meters using a stone masonry gravity abutment type, 1 meter to 8 meters high using reinforced concrete L-type abutments, 8 meters to 20 meters high using T-type abutments with reinforced concrete supports. The abutment type used in this research is reinforced concrete type T with a height of 3.6 meters, a width of 2.4 meters, a length of 7.2 meters, and a depth of 1.7 meters.
2. Analysis of the structure of the upper part of the bridge shows that the total dead load received by 1 abutment is 62.221 tons, the live bag is 64.975 tons, the brake and traction forces are 0.578 tons, the friction force on the abutments is 143.56 tons, the seismic force on the abutments is 3, 65 tons for the earthquake coefficient taken from the earthquake map book
3. In the abutment stability control, we tried using 4 load combinations to get the results:
   - Combination I Stability against shear = 3.086 ≥ 1.5.....OK!
   - Stability against overturning = 7.414 ≥ 1.5.....OK!
   - Stability to eccentricity = 0.143 < 0.667..OK!
   - Combination II Stability against shear = 1.783 ≥ 1.5.....OK!
   - Stability against overturning = 3.243 ≥ 1.5.....OK!
   - Stability to eccentricity = 0.485 < 0.667..OK!
   - Combination III Stability against shear = 2.204 ≥ 1.5.....OK!
   - Stability against overturning = 4.015 ≥ 1.5.....OK!
   - Stability to eccentricity = 0.388 < 0.667..OK!
   - Combination IV Stability against shear = 4.155 ≥ 1.5.....OK!
   - Stability against overturning = 4.524 ≥ 1.5.....OK!
   - Stability to eccentricity = 0.294 < 0.667..OK!

   From the calculation of loading combinations, I – IV, the result is that the abutment is stable against shear, overturning, and eccentricity.
4. The abutment reinforcement uses the Reinforced Concrete Structures table based on SK SNI T-15-1991-03. From the calculation results, the following results show that the head of the bridge abutment uses the primary reinforcement D18-200 and reinforcement for D10 – 320. The abutment body reinforcement uses the primary reinforcement D29 – 200, reinforcement for D13-200, and shear reinforcement D13-200. In the primary abutment, reinforcement uses

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main reinforcement with D29-200, reinforcement for D12-200, and shear reinforcement with D13-200.

5. Conclusion

Based on the observations and reviews that have been carried out on the bridge abutments, landslides have occurred in the vicinity. This research aims to repair the abutments that have been damaged by considering the rules according to the standards. The results of the analysis that has been carried out state that for structural stability, the abutments under normal conditions, when an earthquake occurs, can withstand maximum and minimum earth stress forces. So, it can be concluded that the abutment structure can withstand the thrust at maximum and minimum conditions. While the results of the structural analysis of shear forces are stated to be unsafe because the strength of the bridge structure to withstand shear forces is less than the required safety factor based on national standard provisions. This research also provides information to the public for bridge users. Then to strengthen the cliffs around the bridge, it is necessary to strengthen the structure so that landslides do not occur, which can cause worry and fear.

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