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Analysis of building planning over cable stayed bridge: The simulation

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ABSTRACT

The purpose of this research is to analyze the building planning process of a cable-stayed bridge through simulation, focusing on assessing the structural integrity, load-bearing capacity, and effectiveness of the design. The study aims to simulate key parameters such as cable configuration, tower dimensions, and overall structural performance to ensure the bridge meets safety and efficiency standards. A preliminary design of the bridge is created by simulating it. The contribution of this study lies in providing valuable insights into the planning and design of cable stayed bridges, using simulation to evaluate and optimize key structural components. This research could also contribute to advancing engineering practices in modern bridge construction, particularly in the application of simulation techniques for efficient planning and execution.

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INTRODUCTION

The rapid economic development has shown that almost the world's population has land transportation. This causes more and more vehicles to cross a track, namely a bridge, carrying various materials that do not cover a load that is quite large. The construction of the bridge is one of the most important means of transportation that will be used (He et al., 2022; Kaewunruen et al., 2020; Montenegro et al., 2021; Srikanth & Arockiasamy, 2020; G. Zhang et al., 2022). In the world, many bridges can withstand heavy loads in tandem with the development of the times with increasing development (Dabous & Feroz, 2020; Graybeal et al., 2020; Rashidi et al., 2020; Xue et al., 2020; C. Zhang et al., 2021) such as the construction of a bridge that can withstand the burden of crossing and facilitate the flow of people, goods, and services as well as information around the world. Infrastructure development in the transportation sector must be based on optimizing functions to achieve service effectiveness and efficiency (Zheng et al., 2024).

Bridges are an essential tool for connecting communities' social and economic needs. Many tasks are carried out to ensure the comfort and safety of the community. One of the most beautiful bridges in the world is the cable-stayed bridge. Bridges are vital for economic and social activities, so they must be well-designed, especially in earthquake-prone areas (Anastasiadis & Mosoarca, 2024; Aryanti & Masrilayanti, 2021; Baig et al., 2023; Edgington, 2022; Pribadi et al., 2021). Cable bridges stayed very well in resisting seismic movements. First, the bridge becomes more flexible and results in a long period of motion, which can significantly reduce the buffering reaction and susceptibility of the structure to seismic loads and deck displacement (Masrilayanti et al., 2021). Due to its beautiful shape and strong crossing capacity, cable bridges are currently part of modern bridge construction. In particular, determining a reasonable cable force and cable construction style is the main focus of cable-stayed bridge construction and its difficulties (Wang et al., 2021).

In Indonesia today, a bridge is a structure that facilitates traffic flow or connects two buildings in different places. Based on their constituent materials, Bridges can be classified into four categories: wood, steel, concrete, and mixed. Currently, Indonesia has 93000 (1138 km) bridges, consisting of 72000 (734 km) on regency, city, and provincial roads and 21000 (404 km) on national highways. Most of these bridges are standard, with a proportion of girders 51% (75% using concrete and steel), culverts 7%, trusses 32%, and others 10% (Safaa et al., 2019). Cable-stayed type bridges are chosen because they stand out among modern long-

span bridges for their outstanding tensile strength, graceful appearance, and windproof stability. The retaining cable plays a vital role as part of the structural bearing of the cable retaining bridge. The service status of a retaining cable bridge is affected by the variable performance of the retaining cable. The large amplitude parametric vibration of the retaining cable is one of the main ways the retaining cable affects the cable retaining bridge. This is different from forced vibration; the first is the movement caused by the buffer; the second is the vibration of the bridge deck or tower when the cable-stayed bridge is affected by wind, traffic loads, or earthquakes (Du et al., 2024).

The use of cable-stayed is used in this article because one of the most critical infrastructures for connecting and moving people between regions is bridges. Using a cable-stayed bridge is a good step because it can withstand all vibrations and become a modern bridge worldwide. Cable-stayed bridges can also become more flexible and result in long periods of motion (Praditya, 2024). Therefore, the purpose of using the cable-stayed bridge upper structure is to plan the concept of the shape of the bridge structure with cable-stayed and perform calculations on the simulation of the cable-stayed bridge structure for the author.

The purpose of this research is to analyze the building planning process of a cable-stayed bridge through simulation, focusing on assessing the structural integrity, load capacity, and effectiveness of the design. The study aims to simulate key parameters such as cable configuration, tower dimensions, and overall structural performance to ensure the bridge meets safety and efficiency standards. The contribution of this research lies in providing valuable insights into the planning and design of cable-stayed bridges, using simulation to evaluate and optimize key structural components. The study offers practical recommendations for improving design accuracy, enhancing load-bearing capacity, and minimizing deflection. This research could also contribute to advancing engineering practices in modern bridge construction, particularly in the application of simulation techniques for efficient planning and execution.

METHOD

The methodology of this research is carried out by conducting quantitative calculation simulations. It also includes secondary data from various sources, such as the internet, books, and journals, which discuss cable-stayed bridges. for this research to conduct a "Simulation on the Ir Soekarno bridge in Manado City." The calculation will be the load on the upper structure on the cable-stayed, followed by the load, such as calculating the dead load, the additional dead load, and cable planning.

This methodology uses a simulation of the load calculation on the bridge with SNI 1725:2016. Then, the calculation of cable planning uses the Gimsing equation (2012), and the modulus of elasticity is calculated according to the equation usually used. Starting from dimensions, cables, girders, and towers, everything will be calculated, and some visualizations will be laid out.

RESULTS AND DISCUSSION

Preliminary Design

The following is a preliminary design of the bridge by simulating the bridge. Starting the secondary structure calculation, the initial dimensional estimate should be made based on the necessary references and adjusted to the current parameters. The initial dimensions, including cable arrangement, girder dimensions, cables, and towers, are needed for structural analysis.

Table 1. Preliminary Design

Bridge Length	**: 220 m**
Bridge Width	: 18 m
Asphalt Thickness	: 12 cm
Plate thickness	: 3 cm
Heavy Rain	: 6 cm
Sidewalk Width	: 1.8 m
Sidewalk Thickness	: 30 cm
Compressive Strength of Concrete	: 28 MPa
Thick Bridge Slab	: 0.2 m
Thick Asphalt Layer + Overlay	: 0.1m
Melting Voltage	: 500 MPa
Cable System	: Fan System

As seen in Table 1 above, it is a preliminary design used to calculate and determine cable planning and inspection checks.

Charging

Then, a load analysis will be conducted by **SNI 1725:2016.**

- Centralized Line Load (BGT): 49 Kn/m (P)
  FBD: 0.3

W BGT : W x L road x (1+FBD) x 0.5
: 49 Kn/m x 12 m x (1+0.3) x 0.5
:382, 2 Kn

- Evenly Split Load (BTR) :

Q: 9 kn/m2
FBD: 0.3
W BTR : q x L road x girder length x (1+FBD) X 0.5
: 9 Kn/m2 x 12 m x 18 m x (1+0.3) x 0.5
: 1263.6 Kn

- Truck Load : 2 x 500 Kn : 1000 Kn
- Assumption dead load result: 3.5 Kn/m2

Q: 3.5 Kn/m
Wdeck: q x L Girder x Girder length x 0.5
: 3.5 x 18 x 20x 0.5
: 630 Kn

- W asphalt : γasphalt x t asphalt x L road x P road x 0.5
  : 7,073 kn/m3 x 0,1 m x 12 m x 20 m x 0,5
  : 84, 876 Kn

- W utility: 30% (WBGT +WBTR) X 0.5
  : 30% (1645.8) X 0.5
  : 246.87 Kn
- Anchor: 4.91 Kn
  - Total load: 2612,456 Kn

The analysis carried out by the SNI 1725:2016 standard shows that the load on the structure has been carefully and accurately calculated. The total value is 2612,456 kilonewtons (KN) after various loading calculations by the guidelines set out in the standard.

Cable Planning

For the planning of the cable dimension of the cable-stayed bridge, the Gimsing equation (2012 Kemudian obtained visualization of the cable planning dimension with AutoCAD using the Gimsing equation approach (2012):

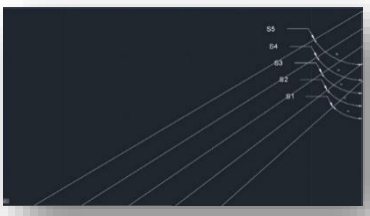

Figure 1. Visualization on Autocad

It appears that AutoCAD's visualization is then arranged on a table. The type of cable used is ASTM A 416-06 grade 270 and Euronome 138-3 grade 270, *Ø* = 15.2 mm; *As* = 140 mm2 For cable planning.

Table 2. Cable dimension calculation

Cable	α (°)	Load (kN)	a (m)	Asc (m^2)	Asc (mm^2)	ASTM A416-Grade 270	n	Euronorme 138-3	n (Euro)
S1	47	2612.456	25.5	0.004440	4439.704	140	32	150	30
S2	51	2612.456	33.5	0.004181	4181.445	140	30	150	28
S3	54	2612.456	41.5	0.004021	4021.430	140	29	150	27
S4	56	2612.456	49.5	0.003929	3928.600	140	28	150	26
S5	58	2612.456	57.5	0.003846	3845.816	140	27	150	26
S'1	47	2612.456	25.5	0.004440	4439.704	140	32	150	30
S'2	51	2612.456	33.5	0.004181	4181.445	140	30	150	28
S'3	54	2612.456	41.5	0.004021	4021.430	140	29	150	27
S'4	56	2612.456	49.5	0.003929	3928.600	140	28	150	26

S'5	58	2612.456	57.5	0.003846	3845.816	140	27	150	26

It is obtained in table 2 the calculation of cable dimensions by installing an armature facing the bridge with a distance of 8 meters. It will also produce the number of cables for the bridge, which will be 220 meters long.

Cable Deflection Check

The following will be carried out to check the deflection of the cable using the modulus of elasticity equation:

$$E_{eq} = \frac{E}{1+\frac{(\gamma l)^2}{12.\sigma^3}E}$$

Eeq: equivalent elasticity modulus
E: modulus of elasticity of the cable= 200000 Kpa
γ: cable type density
Ϭ: Tensile stress in the cable
1: Cable length
Then, it is arranged in a table to determine the amount of deflection.

Table 3. Cable deflection check

Cable	L	L*	Eq	Eq%
T1	47	48.41	199921024	99.96051
T2	51	52.53	199907015.7	99.95351
T3	54	55.62	199895760.5	99.94788
T4	56	57.68	199887900.5	99.94395
T5	58	59.74	199879755.3	99.93988

It can be seen in Table 3 above that the correction rate obtained is 0.5%, with the correction still usable in the form of a straight cable.

Cable Strength Check

The cable strength check is carried out by comparing the cross-sectional capacity against the factored load, which is measured in the strength check.

Table 4. Cable strength check

Asc1	Asc2	Pn	pn	ØPn	ØPn	Check cable 1	Check cable 2	Load (kN)
Actual	*Actual*							
4439.703887	4439.703887	5780.494461	5500.793	5202.445	4950.714	OK	OK	2612.456
4181.445301	4181.445301	5444.241781	5180.811	4899.818	4662.73	OK	OK	2612.456
4021.429899	4021.429899	5235.901728	4982.552	4712.312	4484.296	OK	OK	2612.456
3928.599686	3928.599686	5115.036792	4867.535	4603.533	4380.782	OK	OK	2612.456
3845.816103	3845.816103	5007.252566	4764.966	4506.527	4288.47	OK	OK	2612.456
4439.703887	4439.703887	5780.494461	5500.793	5202.445	4950.714	OK	OK	2612.456
4181.445301	4181.445301	5444.241781	5180.811	4899.818	4662.73	OK	OK	2612.456
4021.429899	4021.429899	5235.901728	4982.552	4712.312	4484.296	OK	OK	2612.456
3928.599686	3928.599686	5115.036792	4867.535	4603.533	4380.782	OK	OK	2612.456
3845.816103	3845.816103	5007.252566	4764.966	4506.527	4288.47	OK	OK	2612.456
			Total					**26124.56**

It can be seen in Table 4 that the overall cable strength is in good condition and can be used in the planning of the stayed cable.

Pylon Planning

Pylon height

- Methods used according to Troitsky 1977:
  H: height of the tower
  L: bridge span
  h: L/6
  : 220/6

: 36 m

- According to Gimsing 2012:

h : 0.291 x L
: 0.291 x 220
: 64.02 m

In planning the tower's height, you must be careful with the load to be carried. The shorter the pylon carried, the greater the axial force that the main girder can carry, and vice versa; if the tower is higher, the axial force will be smaller.

CONCLUSION

Indonesia has 93000 bridges, with 72,000 on regency, city, and provincial roads and 21000 on national roads. Most of these bridges are used, with a proportion of girders (51%), culverts 7%, trusses 32%, and other components 10%. A preliminary design of the bridge was created by simulating it, and a total load of 2612,456 Kn was obtained to calculate the cable dimensions. The overall cable strength is in good condition, and the tower's planning is excellent, with a height of 36 m. Future research should explore the long-term performance and durability of cable-stayed bridges in Indonesia, considering environmental factors such as humidity, temperature fluctuations, and potential corrosion in tropical climates. Additionally, studies could investigate the optimization of materials and cable configurations to enhance structural efficiency and reduce costs. Research into the use of eco-friendly materials or technologies, such as smart monitoring systems for real-time structural health monitoring of cable-stayed bridges, would also be valuable. Analyzing the impact of increasing traffic loads and seismic activity on the structural integrity of bridges could provide crucial insights for improving the design of future infrastructure projects in Indonesia.

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