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# Structural Design Tuak River Pedestrian Suspension Bridge Anchor Block Type Rigid Symmetric with LISA

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**Abstract:**

Anchor blocks are one of the components and elements that are very risky for suspension bridge construction, because almost The ability The Suspension bridge resistance rests on the cables held in place by the anchor block. This anchor block behavior study is to find out the major stress information occurring in the anchor block elements. In this research, the researcher refers to the Circular Letter of Design Criteria for Rigid Symmetrical Pedestrian Suspension Bridge, and conducts structural modeling using the finite element method-LISA program on anchor blocks. Condition of the anchor block after receiving the appropriate tensile force from the round table at a span of 96 meters, the tensile force of the suspension bridge cable is 664.6 kN, resulting in a stress of 6.184 N/mm<sup>2</sup> on the concrete surface of the anchor block using the concrete grade is  $f_c$  30 MPa, in the suspension cable of the bridge there is a tension of 22.26 N/mm<sup>2</sup> at the point of work. The results of the analysis of the anchor block used on the Tuak River Suspension Bridge with a span of 96 m can meet the required criteria, namely the axial load-bearing capacity, which is greater than the maximum axial force that occurs in the Borpile configuration. In the analysis of the finite element method using the LISA FEA device, a significant stress occurs in the anchor block section with the suspension bridge cable as shown in Figure 9, this occurs because of the large tensile force on the suspension bridge cable and the ability of the anchor block to remain in a stable condition is known.

**Kata kunci:** Anchor Block; FEM; LISA; Suspension Bridge; Stress

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## Introduction

The Tuak River Suspension Bridge is planned as a route connecting the roads from the villages of Sungai Tuak and Tanah Priuk. The two villages are separated by a river with a river width of 73 meters. Suspension bridge access plan on the Sungai Tuak village side connected to Regency Road +300 meters, while the suspension bridge access plan on the side of the village of Tanah Priuk is directly connected to the national road + 1 km. Community access between the two villages is via boat transport. Information on the location of the field can be seen in Figure 2 below and Figure 5 sketch of the proposed location of the suspension bridge. The results of the needs assessment indicate that the proposed construction of the suspension bridge on the Tuak River is feasible as it will serve the needs of the community, improve access to healthcare and reduce transportation costs. The local community and students use small boats to cross the river or bypass a very distant road, so the access road connecting the villages is very much awaited by the local community.



**Figure 1.** Map of the Pasir district



**Figure 2.** The proposed location of the River Suspension Bridge

In addition to the connection between the villages, the suspension bridge to be built should also act as a link between educational and health facilities. Where the children of Tanah Priuk village are still attending primary school, they go to Sungai Tuak village and use a local resident's ketinting boat to cross it. Healthcare and educational institutions, shown in Figure 3, serve the needs of the community by facilitating access to healthcare and reducing transportation costs. The local community and the students use small boats to cross the river or to bypass a very long road, so the access road connecting the villages is very much awaited by the local community.

This research was conducted due to the problems hampering the development of rural areas, namely the lack of road and bridge infrastructure. Bridges are expensive infrastructure, so the construction is uneven throughout the village, suspension bridges are a solution to create connections between villages, and with reasonable means, anchor blocks are one of the components and elements that are very risky for suspension bridge construction, because almost The ability The Suspension bridge resistance rests on the cables held

in place by the anchor block. This anchor block behavior study is to find out the major stress information occurring in the anchor block elements.



*Figure 3. Facilities owned by Sungai Tuak Village*



**Figure 4.** Field sketch of Tuak River Suspension Bridge site, Sungai Tuak Village

### **Study of Literature**

As an archipelagic country with a geographical location full of rivers, straits, canyons and mountains, infrastructure is a very important thing needed to support the advancement of Indonesian economy. Bridges, as one of them, are needed to connect areas that are separated by an obstacle, be it rivers, valleys and others. In addition to supporting economy, bridges are a very important need to connect an area for both vehicles and pedestrians, moreover, bridges are also an alternative to connecting roads to shorten the direction of the road(Wijaya, 2019).

Indonesia is an archipelagic country with geographic conditions that feature many rivers, valleys and canyons. This makes it difficult for communities to provide adequate infrastructure, especially in rural

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areas. Type I pedestrian suspension bridge is a type of bridge that can only be used to cross people and light vehicles. Since 2016, the Ministry of Public Works and Public Housing of the Republic of Indonesia (PUPR RI) has built at least 300 pedestrian suspension bridges to connect areas that are still isolated. There is a bridge in this village which is the only access used by the local community. The condition of the existing bridge is no longer suitable for use, so that the bridge has to be redesigned according to the needs and environmental conditions (Andreas, 2020).

The traffic load uses the provisions of the Road and Bridge Research and Development Center, namely a uniform load of 3kPa, this load includes light vehicle loads. The analysis was carried out using the SAP2000 application, namely calculation of the value of bending resistance, axial resistance and deflection that occurred on the bridge using the RSNI-T 03-2005 calculation standard and the Guidelines for the design and execution of suspension bridge structures for pedestrians. The analysis result must be less than the valid approval value. If the analysis result is above the approval value, a redesign of the bridge components is required (Hidayat et al., 2020).

The backstay length on suspension bridges does not always correspond to the given standard, there are also regional conditions that make it necessary not to use the standard backstay length. This study aims to determine the major influence of wind load or traffic load on the force absorbed by the main cable and to determine the effect of the force on the main cable due to differences in backstay length. This study uses a comparative method by comparing the difference in backstay length to the force on the main cable and comparing traffic load and wind load. The backstay lengths compared are 10m & 10m, 20m & 20m, 35m & 35m and 10m & 35m, the traffic load used is 3KN/m<sup>2</sup> and the wind load used is 2.4KN/m<sup>2</sup>. The difference in backstay length does not have a large effect on the force absorbed by the main cable, but it does have an effect on the force absorbed by the backstay cable, and traffic load has a greater effect than wind load on the force absorbed by the main cable (Ramadhan, 2019).

## Research Method

In this research, the researcher refers to the Circular on the Design Criteria of the Rigid Symmetric Pedestrian Suspension Bridge, as a reference, the researcher also uses the 1992 BMS Bridge Design Code with Revisions in Part 2 with Loading for Bridges (SNI 1725:2016), Section 6 with the design of concrete structures for bridges (RSNI T-122004), according to the Decree of the Minister of Public Works No. 260/KPTS/M/2005; SNI 03-3446-1994 Procedure for the engineering design of direct foundations for bridges, according to SNI 03-3447-1994 Procedure for the engineering design of well foundations for bridges, according to the reference of SNI 03-6747-2002 Procedure for the engineering design of Pile foundations for bridges and with reference to SNI 2833:2016 Bridge design against seismic loads.

Design criteria from sub-side planning about rigid-symmetrical pedestrian suspension bridge 2020. The design of the bridge must meet the following planning points is strength and stability of the structure, comfort and safety, ease (implementation and maintenance), frugal, consideration of environmental, social and road safety aspects, long term durability and viability and aesthetics. Suspension bridge lifetime is 50 years for components. Main bridges (foundations, substructures, cables, piers/towers, girders, trusses framework, system floor). Loading of the pedestrian suspension bridge with payload of 3 kPa in the form of distributed load and 20 kN in the form of concentrated load movement.

Then comes the vertical and horizontal space under the bridge planning standards/specifications on ship traffic characteristics/patterns at free board, if no ship traffic takes place then:

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at least 0.5 meter (for controlled flow/irrigation channel)

at least 1.0 meter (for river currents that do not involve drifts)

at least 1.5 meters (for drifting river courses) from high water level with a return period of 20 years.

Bridges must be equipped with inspection ladders and stands superstructure.

Quality of the concrete of the substructure (pillars and anchor blocks) and the foundation  $f_c' \geq 30$  MPa or at least  $f_c' \geq 20$  MPa for difficult areas (villages). Reinforcing steel quality with BJTP 24 for  $< D13$  and BJTD 32 or BJTD 39 for  $> D13$  with the least variation in reinforcement diameter many 3 sizes. To facilitate the validation of corrections to plan drawings, plan drawings as far as possible in the form of typical drawings and standard drawings.

Standard procurement for symmetrical pedestrian suspension bridge structures 2020. The suspension bridge for fiscal year 2020 is a suspension bridge rigid - symmetrical with span variations, namely 42 m, 60 m, 84 m, 96 m and 120 m. The substructure of the suspension bridge consists of anchor blocks, piers and composite blocks wind (only for spans 96 m and 120 m). Forces on bearing and cable reactions for service loads at all variations the bridge is supplied in a 3 angle backstay configuration. The substructure is expected to be designed in an angled configuration backstay  $27^\circ$  (most ideal conditions) up to  $35^\circ$ , then the maximum angle is limited backstay is  $45^\circ$ .

For hydrological and river planning, the researcher refers to road surveillance space for upstream and downstream bridges is at least 100 meters or determined by the nature and morphology of the river. The river section of the bridge must be rated at least 500 meters upstream/downstream of the bridge includes hydrology, flow patterns, river morphology, washouts jeopardize the construction of the bridge. The information in point 2 above can be obtained by using a drone, surveys and data obtained from relevant authorities and the surrounding community. The location of the bridge with the placement of the building below avoids the area river bends/curvatures with very complex flow conditions affected by uneven flow and centrifugal force. If the placement of the building under the bridge can't avoid the bend river or near/in the wet cross section of the river, must be built bridge protection/shelter, cliff protection, flow control, etc. Water energy reducer adapted to the existing field conditions. Taking into account the existence of external (environmental) activities such as, water structures upstream/downstream of the bridge, excavation/mining of materials in the nearby river bridge etc.

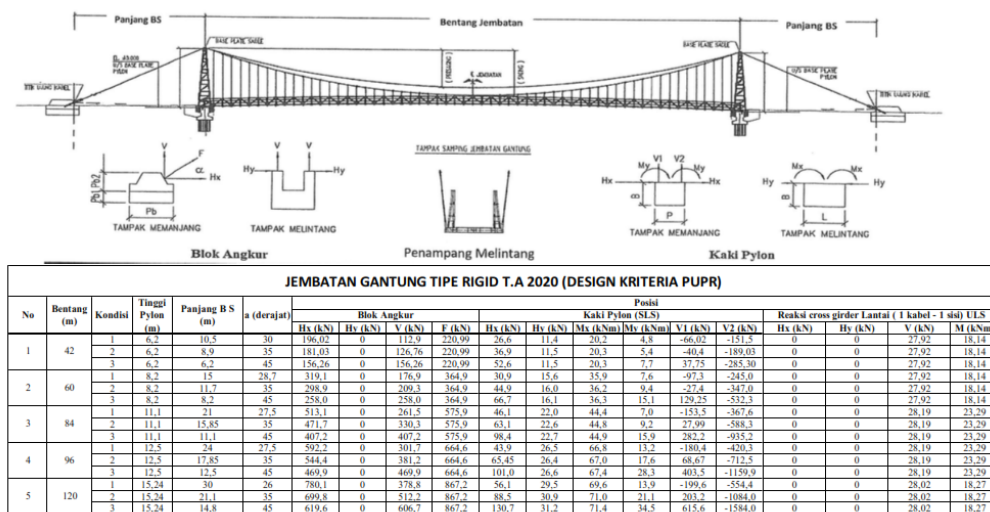
For sub-bridge planning (block anchors and piers), the parameters that must be taken into account when planning the substructure are: topographical conditions, river conditions, soil conditions and bridge spans. When planning, the vertical and horizontal load-bearing capacity must be taken into account and stability of the substructure; Substructure planning with service limit states (SLS). The substructure consists of concrete  $f_c' \geq 30$  MPa on the masonry above and/or below. The anchor block has a cable pull ( $F$ ) with a certain angle ( $\alpha$ ). Style the tensile force is used as a vertical force balanced by the structure's own weight (load dead) and horizontal forces (shear) are balanced by passive drag and shear forces (concrete with the ground) taking into account the groundwater level (MAT). Substructure placement avoids water catchment areas and is safe against washouts and landslides. In the substructure, the scour area can be protected with gabions or brick sheet piling. The substructure should be planned according to the long-term behavior of the material and environmental conditions including: a concrete pavement used at least 30 mm (normal range) and at least 50 mm (aggressive range) or applicable planning regulations.

Bridge foundation planning must be start-up planning with Working Stress Design (WSD). Foundation planning based on the reaction force of the bearings and ropes used appropriate configuration. If there is a pulling force in the chosen configuration (Heaving) on the pillars, the foundation construction must use a pile foundation friction load capacity. For buoyant configurations, pile capacity is mandatory do not take into account the respective tensile and compressive forces on the pier legs the resultant between the two forces. The foundation planning is carried out taking into account the scour potential that occurs by hydraulic analysis.

The foundation design for the pedestrian suspension bridge is direct foundations with a maximum depth of 4 meters are planned. The well foundation is planned with a maximum depth of 6 meters and minimum diameter of 2 meters. Pile foundations can be made with Strauss piles (hand-drilled piles). the need for local equipment availability with a diameter between 0.25 and 0.4 meter. Other deep foundations (special conditions) follow the bridge design criteria. The type of foundation is uniform for a bridge site, including its dimensions.

Foundation of ASTM-252 Class 2 concrete-filled tubular steel piles reinforced non-shrinking (type II cement) with material quality  $f_c' 30$  MPa, up to at a depth of 8 meters under the bed of the river (river bed), the soil is filled with sand. Direct foundations and wells, soil SF bearing capacity = 2.0; SF shear = 1.5 and SF pad = 1.5. Pile, SF point support = 3 and SF friction pile = 3.

Lateral deformations and settlements in pile foundations are limited by the provisions of as follows, the maximum allowable lateral deflection of the pile foundation is 1 inch or 2.5 cm under the pole cap. The maximum permissible subsidence of the foundation is 1 cm. The depth of the foundation is planned so that it will reach hard ground when hard ground deep enough (> 50 m), then the foundation can be planned Rely solely on the friction bearing capacity with the limitation of the pile settlement. Steel posts: 2.5 cm / 10 hits & 3 - 5 cm concrete posts /10 strokes for end point bearings with appropriate hammer typeso that it can meet the load-bearing capacity of the design pole. If the planned foundation does not reach deep into the hard ground, then a pile test must be carried out.



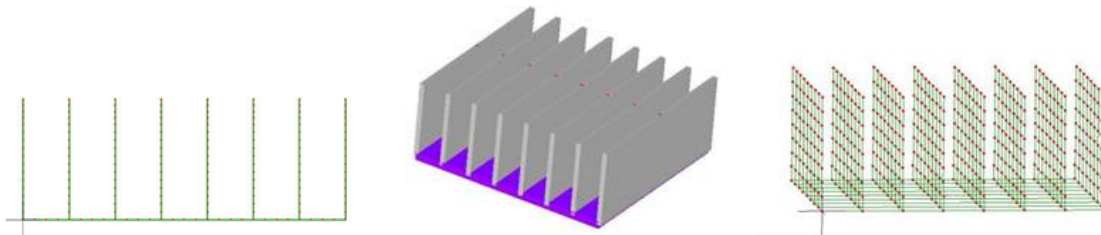
**Figure 5.** Typical pulls and forces occurring in anchor blocks, pylons and wind blocks on suspension bridges with different spans

The finite element method (FEM) is a numerical method for solving technical analysis problems. The finite element method combines several mathematical concepts to generate equations of a linear or nonlinear system. The number of equations generated is usually very large, reaching more than 20,000 equations. Therefore, this method is of little practical value unless a suitable computer is used.

When a structure is subjected to forces such as stress, pressure, temperature, flow rate, and heat, the result is strain (deformation), stress, temperature, pressure, and flow rate. The nature of the distribution of the resulting action (deformation) on a body depends on the properties of the force and stress system itself. In the finite element method you can find the distribution of this effect, expressed as displacement.

The finite element method uses an element discretization approach to solve the problem of finding displacements of vertices/connections/lattices and structural forces. The discrete element equations are related to the matrix method for structural analysis and the results obtained are identical to those of classical analysis for structures. The discretization can be done with one-dimensional elements (line elements), two-dimensional (plane elements) or three-dimensional (volume/continuum elements). This approach uses a continuum element to determine a solution that is closer to the truth.

LISA, a popular finite element analysis application, was used to estimate the temperature rise for three different models of heat exchangers. The three types of models are, in order of their simplicity and ease of construction, the line element model, the shell model, and the solid model.



**Figure 6.** Element model on LISA FEA

For line element models only, the convection coefficient of the baseplate surface needs to be determined as half the value used elsewhere since we cannot exclude convection from assembling the baseplate surface with the face selection tool. It's just a matter of common sense.

For the other two models, it's easy to exclude the mounting surface from convection - we just don't select that surface. An internal heat generator is used in each case, and the volume of the entire floor slab is assumed to be the heat source. Care should be taken when applying boundary conditions to a line element model. LISA selects all faces of the line elements when the "face" selection is made (i.e. both "ends" of the line and all "sides" of the line)(A. W. Efendi, 2022).

## Result

From the table of forces that occur in each of the structures examined, the researchers calculated the active earth pressure for the substructure of the bridge, which is composed of the dead weight of the superstructure and the substructure of the bridge, and calculated the seismic force on the substructure of the bridge and the pressure bottom dynamics at anchor, pylon and wind block positions. The following are the results of

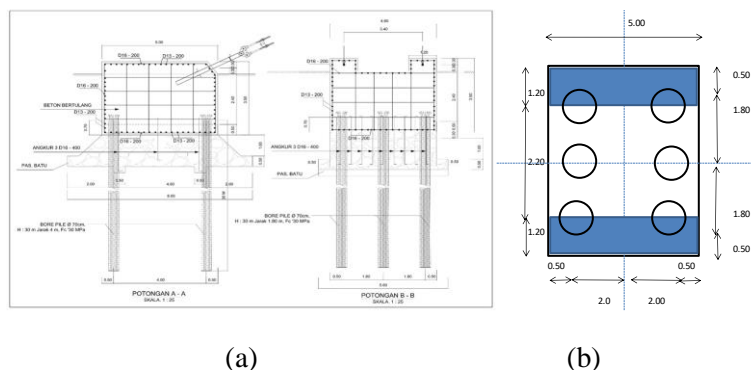
the above calculations and are inventoried into groups of forces occurring in each condition to produce the vertical, horizontal and moment forces encountered.

**Tabel 1.** Recap of the workload created in the building under the bridge

No	Load	Direction	Vertical	Horizontal		Moment	
		Load Factor	V	Hx	Hy	My	Mx
			(kN)	(kN)	(kN)	(kNm)	(kNm)
1	Self weight	1.00	2450.90	1184.40	0.00	4847.86	0.00
2	Earth pressure	1.00	0.00	215.88	0.00	220.33	0.00
3	Earthquake	1.00		150.59	415.12	1660.46	602.35
4	Ground dynamic pressure	1.00		15.58		36.35	
			2450.90	1566.45	415.12	6765.01	602.35

Table 1 shows the results from previous calculations, then the researcher calculates the bearing capacity of the soil from the results of the soil survey at the position of erecting the suspension bridge and also the bearing capacity of the foundation to be used, from the results of the soil survey, at 30 meters depth of the NSPT of soil. The results are still around NSPT 30 indicating that the foundation to be used is a deep foundation with a bored pile. This choice was made because it facilitates the deployment and mobilization of tools and materials to quickly get to the scene.

As for the dimensions of the bored pile used, the bored pile diameter is 600 mm with a depth of 30 meters and a configuration of 2 x 3 with a total of 6 bored pile points, the bearing capacity of the bored pile is 2087.17 kN, but based on the bearing capacity of the Soil As a result of examining the soil layer, force can be obtained from it. The axial carrying capacity is 2310.90 kN at a depth of 30 meters. From the two carrying capacities, the lowest value is taken for further analysis.



**Figure 7.** (a) Typical of suspension bridge anchor blocks (b) Bored pile point configuration

From the results of this axial capacitance, the researchers then studied the configuration of the bored pile points as shown in Figure 7, where they obtained the value of the reaction force acting on each bored pile point according to the distribution of the working load.

**Tabel 2.** Axial allowable capacity



NO.	P max (kN)	P min (kN)	P Allow (kN)	P Tensile Allow (kN)	Description
1	1162.20	-132.62	2087.17	-1604.04	OK

Table 2 describes the axial play maximum force capability resulting from the calculation results of the bored pile configuration where the maximum P is 1162.20kN and the allowable P is 2087.17kN because the allowable P is still greater than the maximum P In this case, the load-bearing capacity is classified as harmless.

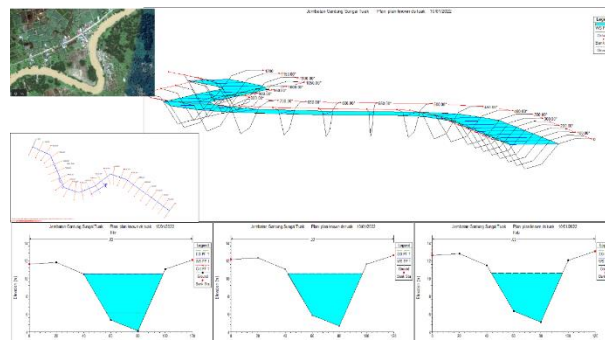
**Tabel 3. Lateral** allowable capacity

NO.	$h_{max X}$ (kN)	$h_{max Y}$ (kN)	$h_{max}$ RESULT (kN)	$h_{allow}$ (kN)	$\delta$ (m)	Description
1	261.07	69.19	270.09	454.95	0.015	OK

From Table 3 in relation to the lateral allowable support capacity of the building under the bridge, it is still in a safe condition if the nominal value obtained from the analysis results is a lateral movement of 0.015 m, this value still being below the lateral movement threshold of 0.02 m. For the calculation of the occurring settlement from the results of the soil laboratory data and analyzed according to the number of boron pile configurations, the nominal settlement is 0.0094 m, where the settlement should not be more than 0.01 m, that is, the capacity of the Anchor Block Building's ability is still in the safe category.

The researcher also performed an analysis of the overturning condition of the building under the bridge by obtaining the nominal reaction moment of 61703.61 kNm and the overturning moment of 3829.39 kNm, and the resulting safety factor value was 16.11, which is greater than the required 3 and it can be concluded that the construction of the bridge substructure is secure against rolling away.

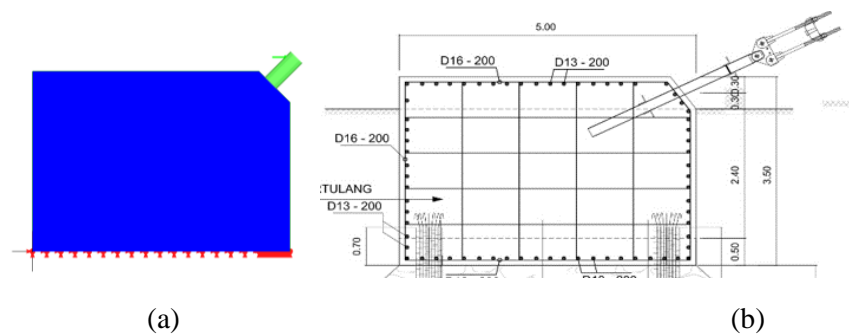
In the hydrological planning, the researchers used data from precipitation and tides at the nearest weather station of Tuak village and an analysis was performed using a hydrological application as shown in Figure 8 to check the tidal behavior of the river and find the position of the substructure was safely in the river with the tide, so that no additional structures are required to secure the anchor blocks and suspension bridge pylons.



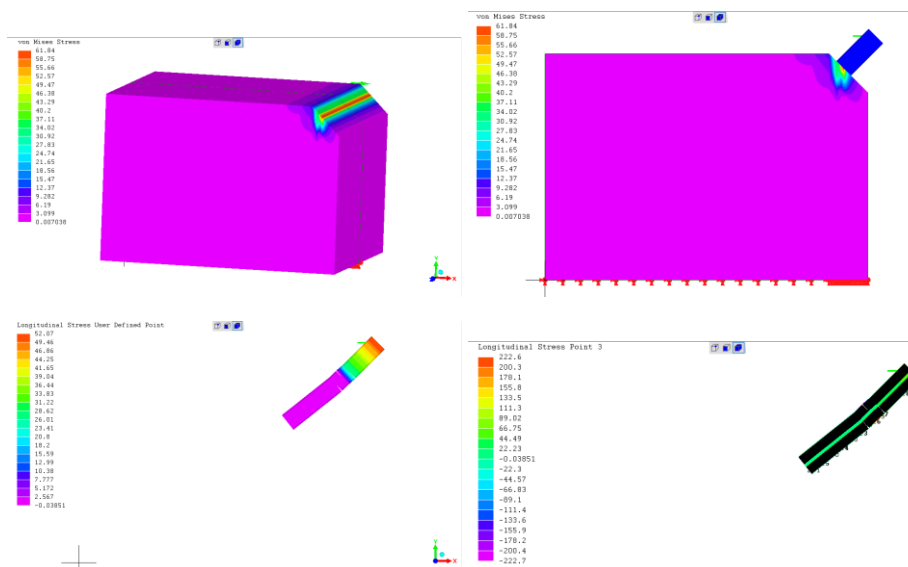
**Figure 8.** The results of the hydrological analysis on the cross section of the river for the construction of a suspension bridge

**Discussion**

Verification of anchor block behavior is done by modeling in finite element software. The researcher uses LISA FEA (license) which is one of the microstructure analysis tools with the finite element method that can be used to determine the local behavior of several structural elements in the form of stress contours and the failure behavior of the elements under review. . to determine the stress behavior that occurs in the anchor block when the bridge has been used and in its operating condition. Anchor block modeling for finite element analysis is mounted on the engineering drawing model as shown in Figure 9.



**Figure 9.** (a) Modeling on finite element software (b) Modeling from design drawings



**Figure 9.** Stress behavior on the anchor block

Figure 9 shows the condition of the anchor block after receiving the appropriate tensile force from the round table at a span of 96 meters, the tensile force of the suspension bridge cable is 664.6 kN, resulting in a stress

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of 6.184 N/mm<sup>2</sup> on the concrete surface of the anchor block using the concrete grade is  $f_c$  30 MPa, in the suspension cable of the bridge there is a tension of 22.26 N/mm<sup>2</sup> at the point of work..

## Conclusion

The results of the analysis of the anchor block used on the Tuak River Suspension Bridge with a span of 96 m can meet the required criteria, namely the axial load-bearing capacity, which is greater than the maximum axial force that occurs in the Borpile configuration, a reduction of less than 100 mm and a lateral displacement of not more than 250 mm. Also, the state of the lower building will not tip over because the value of the safety factor is greater than 3. In the analysis of the finite element method using the LISA FEA device, a significant stress occurs in the anchor block section with the suspension bridge cable as shown in Figure 9, this occurs because of the large tensile force on the suspension bridge cable and the ability of the anchor block to remain in a stable condition is known.

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