Design Analysis of Loading Structures in The Baruta Cable-Stayed Bridge Construction using Hand Method

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ABSTRACT- The purpose of this study was to determine the forces that occur in the construction of stayed cable structure bridges using the philosophy of the triangle and Pythagoras. The research method is to use the triangle philosophy and Pythagoras will be used to design the bridge cable-stayed bridge construction, the design is done using hand-method or manual method by utilizing the help of the goodness of Microsoft Excel. In this study only looks for unknown dimensions that will be used to look for forces that occur due to live and dead loads, then we will get a description of the forces that occur and the total forces that occur. The result of this research is the force that propagates on a cable and is held by a column, but the column is tilted and forms a certain angle away from the Y axis and approaches the X axis, then the amount of force will be accepted by the column, but the magnitude of the force is not the same as the force planned, the magnitude of the force that occurs will be large, according to the angle of the cable and the angle of the column itself.
Keywords: Cable-stayed, Loads, Forces, Hand Method, Manual Method, Formula Text, Microsoft Excel.

1 INTRODUCTION

The bridge maintenance system and the monitoring and supervision of the bridge are very necessary, especially on the bridges of the cable hanging system, whatever its type [1], any type of suspension cable bridge must receive routine maintenance and regular maintenance, if not done it will be fatal and can be fatal endanger. Inspections are carried out on the structure of steel cables, bolts, rubber platforms, concrete structures and all components used to support bridge construction. The maintenance of bridges in this era is sophisticated, can be controlled remotely using an IT system, but it must be supported by a reliable network and what difficulties will it have if the availability of networks in remote areas where steel bridges are generally located. Then the bridge maintenance system must still be done manually.

A bridge model, both a regular span girder bridge and especially on bridges that use cables as load-bearing, needs special attention regarding initial planning with the addition of earthquake loads [2], a combination of dead load, live load and earthquake load and added to the load - other expenses, it is of particular concern to the planners of bridges and other civil buildings. Why is that, this is because all burdens will greatly affect the construction structure, therefore all burdens together will still burden and inevitably will occur. It's just that in planning an engineer will calculate starting from the live load and dead load, then the earthquake load will be calculated based on the value of the two previous loads. Earthquake loads will not work or will not appear if live loads and dead loads do not exist as well as wind loads.

Concrete bridges or steel frame bridges, especially the bridge using cables as the main support, which is used for trains is very vulnerable and affected by vibrations [1,2], the planning of the issue of vibration is also a thought that needs attention. However the strength of construction will usually be greatly influenced by the emergence of vibrations, it's just that in determining the loading, vibration is not included in the load category even though the shock due to vibration is very strong and felt. So the engineers are looking for a solution with what is called vibration dampening, it is not 100% able to eliminate vibrations, but the actual vibration can be reduced, thus appearing a vibration-damping device such as spicy, clutch, absorber and other types. But there is also that train vibrations can be overcome by including in modeling using the SAP2000 application [3], vibrations of a side effect of energy use, non-dense are avoided and will remain. A strong construction model for the railroad bridge, vibration will still occur, and can not be avoided except the addition of other devices.

Cracks in bridge concrete are the things that we often encounter in lanate construction and bridge girder [4,5], this is due to several factors, such as the influence of hot temperatures and expansion will occur, due to the load so that the steel reinforcement experiences elasticity and concrete itself does not experience elasticity, but if in a reasonable gap this is not a problem, there are also other causes. In general, concrete bridge

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cracks only occur on the surface while inside there are no cracks at all, but this is also a serious matter that we need to handle so that cracks in the concrete bridge do not cause doubts for its users.

The imposition of a railroad bridge in a design needs to be given special emphasis on the live load and the additional vibration load that comes from the train itself [6], thus it is better to design a bridge for a train. directly in the form of abutments and girders as on the highway in general. It is better if the short span uses indirect construction, that is, in the form of a water tunnel or a road that is between thick concrete supported by piles of soil so that vibrations originating from trains are naturally absorbed. This is a cheaper way to reduce vibration so that it does not damage the bridge construction.

Shear behavior of bridges on bridges using pre-strained concrete can be anticipated by design using finite elements [7,8] basically, shear stresses in a concrete girder will always be present, only the magnitude is in accordance with the load and the profile of the construction section. , to overcome the shear stress, the best way is to take into account when the shear stress design will occur at certain points, then subsequently will be given additional reinforcement with the name of shear reinforcement. In general, shear reinforcement will be placed at a distance of a quarter of the span calculated from the pedestal.

In designing a bridge, the planner or engineer must have parameters to determine the level of error, no matter how small it must be known [9], this is very useful to know the level of security, if declared insecure then the engineer will take steps until the stated design will. In the design of the bridge, many factors are taken into consideration the level of security, such as vehicle speed, maximum vehicle weight, water discharge, ten-yearly floods, and fifty-year floods, all to be the design work of engineers who will be used for the benefit of many people.

A force that occurs in the column in an upright position and forms an angle of 90° to the X-axis [10], then there is a cable pulling or load to form a certain angle, then the transfer of these forces will experience an increase in force in accordance with the angle formed. Thus that a force acting and the direction of the force forming a certain angle than the force will experience an increase in force. Why should an angle be formed which results in increased force? This certainly must be done, although the risk is that there is an increase in force, this is because the most ideal structure of construction is already like that and still retains the principles of triangular philosophy and the philosophy of Pythagoras.

2 LITERATURE REVIEW

The force is an object that has a mass located on another object so that at one point there is an action and causes a reaction to other objects by the magnitude of the force and direction of the force. Then the inventor of the quantity was given the Newton unit (N), according to the inventor's name Isaac Newton, this name until now has become a unit of force. For the smallest unit, only Newton (N), while for a fold of 1000 to kiloNewton (kN), mathematically written to 1000N will be written as 1kN. A force acting on an object has the same point, and the force also has a direction, thus the direction of the force is indicated by an arrow, where the arrow pointing is where the direction of the force is, thus the arrow is called the action force. In the action force that forms an angle formed by the force. In figure 1 shows that the force indicated by the arrowhead also has a scale according to the length of the arrowhead itself, the greater the force that occurs the longer the arrowhead is formed. The force itself has power, this power is indicated by the addition of an active line that is exactly the same, this will be attracted to each other into a different part, the statement is as in Figure 1.a and 1.b, for that it will have a direct reverse effect which occurs in the particle itself [11].

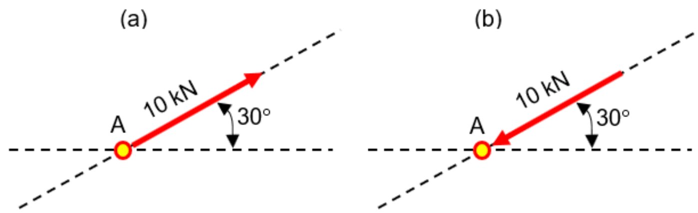


Figure 1 The direction of force

There are two forces namely P and Q as shown in figure 2, a, where a force acting at a point A, then those forces can form a resultant (R) then the resultant will have an influence on those points displayed in figure 2.c. So thus that the force is a resultant force P and force Q. And it turns out eventually will form a structure called a parallelogram, this is due to the diagonal lines of the two previous forces. This way is then called a parallelogram proposition.

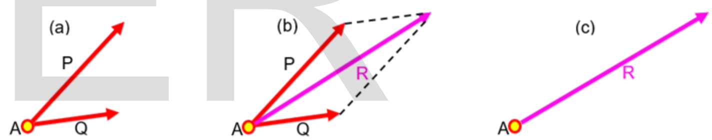


Figure 2 The force resultant

A vector is designating a force that does not have the influence of a mathematical principle or by using an ordinary algebra system, a force that can form a certain angle and have a certain mass of forces, then there will be an increase in the force itself. With the result, it will form a parallelogram, have displacement and have speed and momentum is another characteristic of a physical quantity that has magnitude and direction. A vector illustrated with an arrow is a scale ($\vec{P}$). Two vectors that have the same magnitude and direction are also the same, then the vector is the same, see in Figure 3.a, then the vector is written with the letter P which means a vector of magnitude equal to P, only the direction is opposite to P, see in Figure 3.b, so that it has a negative value of a vector P. Thus, a vector P and -P for it is called the same and opposite direction, mathematically is as follows:

$$P + (-P) = 0$$

Figure 3 The vectors

Adding a vector means to use a parallelogram law, in the sum of the two vectors P and Q obtained from two vectors from point A and so a P and Q parallelogram will form (see figure 4.a). The diagonal line that approaches a point A is the sum of a vector P and Q, so the addition operation is P + Q. Then the + sign has the meaning to show a vector, the addition of a scalar, a vector, and a scalar will be very different. Then the magnitude of a P + Q vector will generally not be equal to the sum of P + Q from the size of a vector P and Q. Then a parallelogram formed of P and Q will not depend on the cumulative P and Q, mathematically can be described as follows :

P + Q = Q + P

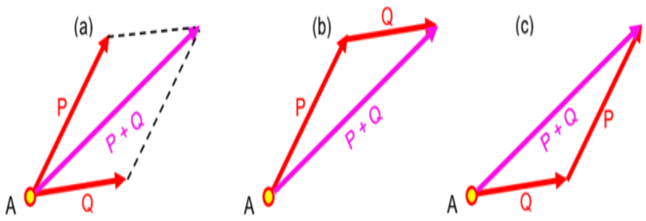


Figure 4 The parallelogram

Based on Figure 4 is a parallelogram, another way to determine the number of two vectors is by a triangle method and can be described as follows: in Figure 4. a number of vectors P and Q are due to the parallelogram law. On the opposite sides of the parallelogram P and Q also have a magnitude and direction, with a parallelogram which is only half (figure 4.b). In addition to the two vectors, this can be done using adjusting P and Q by pulling the ends of P and Q (figure 4.c), this is what is called adding cumulative vectors. A vector, a reduction is the addition of an appropriate negative value vector. A P + Q vector has the difference between the P and Q vectors that occur due to adding a vector that is negative P - Q (figure 5), mathematically described as follows:

P - Q = P + (- Q)

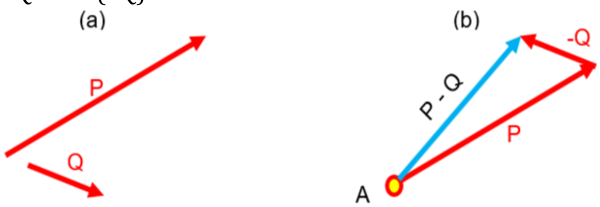


Figure 5 The addition vector

Thus, in general, you can use the following equation:

$$R = \sqrt{a^2+b^2} \quad (1)$$

$$W_{0-10}=\left[\frac{h}{2}\right].w.g.CSC.(d-\left[\frac{w_{1-10}}{360}\right].2.\left[\frac{r}{2}\right]\pi.1.5 \quad (2)$$

$$W_0=\frac{b_2}{2}.h.w.g.CSC \quad (3)$$

$$M_{primer}=\frac{3}{4}.h.W_0 \quad (4)$$

$$N=\frac{M_{primer}}{M_{angle}} \quad (5)$$

$$Rxy=\sqrt{\Sigma Rx^2+\Sigma Ry^2} \quad (6)$$

$$(Rxy)Y=Arctan\frac{\Sigma Rx}{\Sigma Ry} \quad (7)$$

$$(Rxy)X = Arctan\frac{\Sigma Ry}{\Sigma Rx} \quad (8)$$

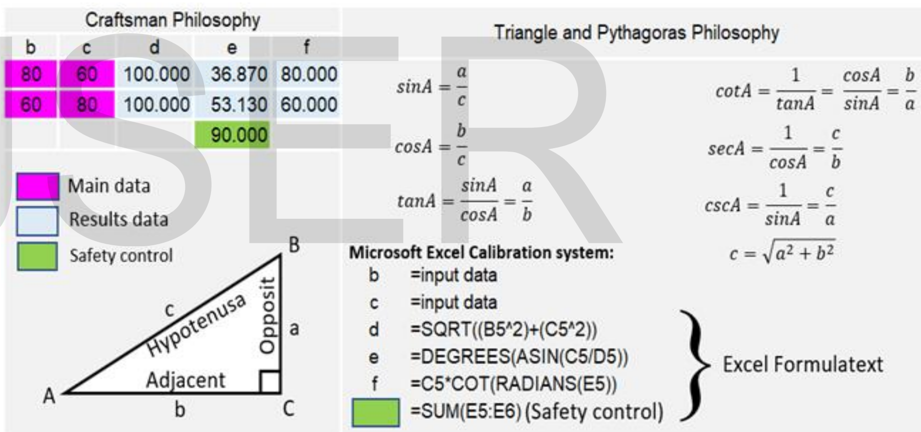
$$\theta=(Rxy)Y+(RXy)X \quad (9)$$

$$N=\sqrt{\Sigma X^{o2}+\Sigma Y^{o2}} \quad (10)$$

The use of Microsoft Excel must really be able to perform operations as in table 1, if the software is not used frequently so it needs to calibrate or try it out if it has produced such a value then the software is declared good.

The use of certain formulas in Microsoft Excel must be the user who will input, this is because not all the formulas we need are available and available in Microsoft Excel, however, this research will be guided and explained in detail. It's just that, the ways and explanations are formulated in tabular tables so that they are easier to understand and appear clearer.

Table 1 Calibration table before using Microsoft Excel



b	c	d	e	f
80	60	100.000	36.870	80.000
60	80	100.000	53.130	60.000
			90.000	

b	=input data
c	=input data
d	=SQRT((B5^2)+(C5^2))
e	=DEGREES(ASIN(C5/D5))
f	=C5*COT(RADIANS(E5))
(Safety control)	=SUM(E5:E6) (Safety control)

3 RESEARCH METHODS

The research method is to use the triangle philosophy and Pythagoras will be used to design the bridge cable-stayed bridge construction, the design is done using hand-method or manual method by utilizing the help of the goodness of Microsoft Excel. In this study only looks for unknown dimensions that will be used to look for forces that occur due to live and dead loads, then we will get a description of the forces that occur and the total forces that occur.

4 RESULTS

The architectural model of the stayed cable bridge that will be the object of this study, is shown in Figure 6 and 7. In the architectural drawing is the initial part of this research process, the architectural drawing is a part that shows all the components together, then will be followed by model drawings structure that will be an illustration of the completeness of structural analysis, without being equipped with pictures, the analysis is meaningless.

Fig. 6. Map of cable-stayed Baruta bridge

4.1 Longitudinal Cross section

In this section all dimensions and loads are viewed from the elongated direction, starting from the data and the main known variables to the dimensions, angles and loads, it will be useful to become a load acting on a construction structure. More will be described in the following table:

TABLE 2
Longitudinal cross section structure model analysis

No.	Distance (m)			Diaginal (m)	α°	Loads (tons)			Force Resultant		
	Vertical	Section	Horizontal			Life	Dead	kN (0)	Linier	Radian	kN (1)
b	c	d	e	f	g	h	i	j	k	l	m
1	67	12	158	171.619	67.021	10	783.4	21.8038	3445	14.0368	245.427
2	64	12	146	159.411	66.329	10	783.4	21.8038	3183.36	13.892	229.15
3	61	12	134	147.231	65.524	10	783.4	21.8038	2921.71	13.7233	212.902
4	58	16	120	133.282	64.204	10	1044	29.0718	3488.61	17.9291	194.578
5	55	16	104	117.648	62.128	10	1044	29.0718	3023.46	17.3494	174.269
6	52	16	88	102.215	59.421	10	1044	29.0718	2558.32	16.5934	154.177
7	49	16	72	87.092	55.763	10	1044	29.0718	2093.17	15.5718	134.42
8	46	20	54	70.937	49.574	10	1306	36.3397	1962.34	17.3046	113.4
9	43	20	34	54.818	38.333	10	1306	36.3397	1235.55	13.3809	92.3371
10	40	24	12	41.761	16.699	10	1567	43.6076	523.292	6.99496	74.8098

Formula Text	
e	=E7+(D7/2)+(D6/2)
f	=SQRT((C6^2)+(E6^2))
g	=DEGREES(ASIN(E6/F6))
j	=(I6+(D6*12*H6))*9.8067/1000
k	=J6*E6
l	=D6*RADIANS(G6)
m	=K6/L6

Charts data
Main data input
Results data

Based on table 2, the column is an input-data is the plan of the main column height of the stayed-structure bridge construction, in this design the closest vertical or cable height is 40 meters and 12 meters for horizontal distance (in column e), the most distant cable or the 10th cable is 67 meters high and 158 meters for horizontal distance (in column e). In column d is the length of each section, the length of the closest or 1st section is 12 meters and the farthest or 10th is 6 meters. In column f is the length of cable results obtained mathematically, the 1st cable has obtained a length of 41.761 meters and the farthest or 10th cable is 171.619 meters.

In a column, j is the plan load on each section, consisting of 2 load combinations of live load, dead load and other loads ignored, the load acting on the nearest or 1st cable is 43.607kN and on the 10th cable the burden that occurs is equal to 21.803kN. All expenses incurred for each of these expenditures are planned expenses for longitudinal cuts. It's just that the burden is planned the closer the larger, this is because the burden is a dead load and live load, the further the burden is planned the smaller (in full can be seen in the chart and figure 8). In column m is the final result of this analysis, the results will be useful as a comparison, that the value is the smallest so it is not significant if included in the chart. In column n is a force that occurs at the first level so that it is given the symbol kN (1), this force occurs due to the load of each section, which works vertically, then transferred to each cable with the influence of the angle that occurs.

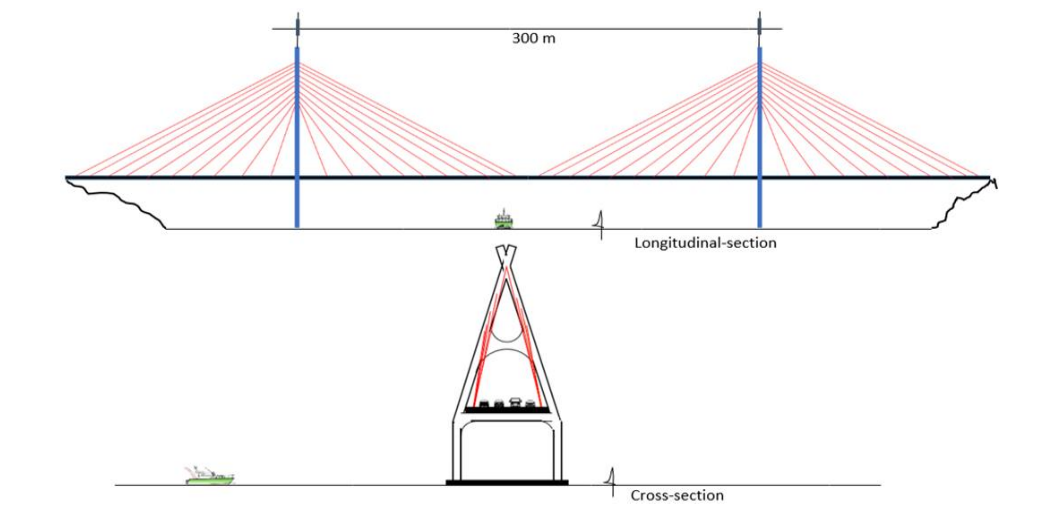


Fig. 7. Model of cable-stayed Baruta bridge Longitudinal-section and Cross-section

To see the burden incurred on construction, then it can be seen in the pictures and charts, as follows:

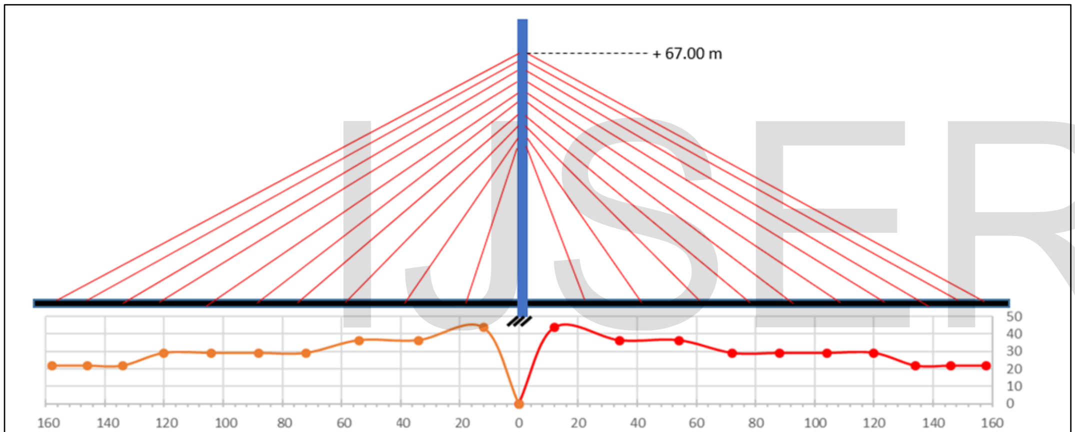


Fig. 8. Longitudinal-section Structure model and loading chart

Based on Figure 8, the load on the first segment is very large compared to the other sections. This is because the length of the segment is the largest, ie the length of the segment is 12 meters, while the length of the 10th segment is only 6 meters. Why is that ratio doubled, deliberately planned at the segment farthest from the fulcrum, the farther the smaller?

4.2 Cross-section

In this section all dimensions are viewed from the transverse direction, starting from the data and the main known variables to the dimensions and magnitude of the angles, it will be useful to be a burden acting on the construction structure. More will be described in the table 3.

Based on table 3, column c is the 10th cable height plan in a column, column d is the bottom column width plan, column e is the length of the sloping column formed and column f is the column angle towards the central-line. Next in column h is the distance between the cables in terms of the transverse direction, the value occurs due to the slope of the pole and the distance of the cable from the top to bottom or the next is planned 3 meters. In column i is the distance from the central-line to each cable, in column k the diagonal line can be determined, in columns, l and m are the angles that occur or are formed and column n is the safety-control for right angles to be controlled by 90.000° and if it is not controlled then there are incorrect calculations and analyzes. All the values in table 3 are still around the construction dimension value, but the most important thing is that all the angles produced can be controlled properly.

4.3 Diagonal section

In this section all dimensions and loads are viewed from the diagonal direction, starting from the data and the main known variables to the dimensions, angles and loads, it will be useful to become a load acting on a construction structure. More will be described in the table 4.

TABLE 3
Cross-section structure model analysis

No.	Main colum					Value results						Safety control	Formula Text
	Vertical	Horizontal	Diagonal	α°	Vertical	Cg	Tcg	Cf	Diagonal	β°	θ°		e =SQRT((C6^2)+((D6/2)^2))
b	c	d	e	f	g	h	i	j	k	l	m	n	f =DEGREES(ASIN((D6/2)/E6))
1	67	44	70.520	18.178	67	0	0	19.000	69.642	15.832	74.168	90.000	h =(G6-G7)*TAN(RADIANS(F6))
2					64	0.985	0.985	18.015	66.487	15.721	74.279	90.000	i =H7+I6
3					61	0.985	1.970	17.030	63.333	15.599	74.401	90.000	j =(D6/2)-3-I6
4					58	0.985	2.955	16.045	60.178	15.463	74.537	90.000	k =SQRT((G6^2)+(J6^2))
5					55	0.985	3.940	15.060	57.025	15.313	74.687	90.000	l =DEGREES(ASIN(J6/K6))
6					52	0.985	4.925	14.075	53.871	15.145	74.855	90.000	m =DEGREES(ASIN(G6/K6))
7					49	0.985	5.910	13.090	50.718	14.956	75.044	90.000	n =SUM(L6:M6)
8					46	0.985	6.896	12.104	47.566	14.743	75.257	90.000	h = cables gap
9					43	0.985	7.881	11.119	44.414	14.499	75.501	90.000	i = cable free
10					40	0.985	8.866	10.134	41.264	14.217	75.783	90.000	j = total cables gap

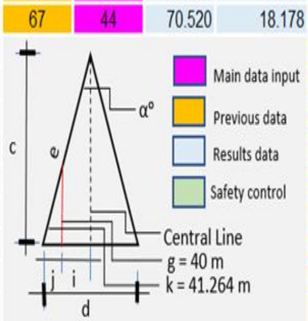


TABLE 4
Diagonal section structure model analysis

No.	Distance (m)			Diagonal			Force kN	Section	Force Resultant			Formula Text
	Vertical	Horizontal	Cf	Horizontal	Vertical	θo	(0)	(m)	Linear	Radian	kN (2)	f =SQRT((D6^2)+(E6^2))
b	c	d	e	f	g	h	i	j	k	l	m	g =SQRT((C6^2)+(F6^2))
1	67	158	19.000	159.138	172.667	67.168	10.902	6	1734.912	7.033823	246.6528	f =DEGREES(ASIN(F6/G6))
2	64	146	18.015	147.107	160.426	66.488	10.902	6	1603.75	6.962631	230.3368	k =F6*I6
3	61	134	17.030	135.078	148.213	65.696	10.902	6	1472.606	6.879718	214.0504	l =RADIANS(H6)*J6
4	58	120	16.045	121.068	134.244	64.402	14.536	8	1759.829	8.99226	195.7048	m =K6/L6
5	55	104	15.060	105.085	118.608	62.373	14.536	8	1527.499	8.708915	175.3949	
6	52	88	14.075	89.118	103.180	59.737	14.536	8	1295.415	8.340821	155.3103	
7	49	72	13.090	73.180	88.070	56.195	14.536	8	1063.738	7.846234	135.5731	Charts data
8	46	54	12.104	55.340	71.962	50.266	18.170	10	1005.52	8.773037	114.6148	
9	43	34	11.119	35.772	55.934	39.757	18.170	10	649.9733	6.938969	93.67001	Previous data
10	40	12	10.134	15.707	42.973	21.438	21.804	12	342.469	4.490066	76.2726	Results data

Based on table 4, in columns f, g and h are the results of dimensions formed based on longitudinal and cross-sectional data, the diagonal dimensions will be very useful to transfer the load that occurs and passed on to the construction parts, in column m the value obtained the force acting on each of the segments. The forces acting on this diagonal section work 2 forces namely elongated and transverse or kN (1) and kN (2) while kN (0) is the main load, on the 10th cable the force occurs at 246.653 kN, (in full can be seen in the chart and figure 9).

4.4 Resultant Longitudinal cross-section

In this section, forces that have worked on the longitudinal cross-section, will be transferred by cable to the column, the force will become a vertical force. More will be described in the table 5.

TABLE 5
Resultant longitudinal section structure model analysis

No.	Vertical	Force kN (1)	Δo	λo	Force Resultant					Safety control	Formula Text
					Rx	Ry	Rxy, kN (3)	Rxy X	Rxy Y		f =90-E6
b	c	d	e	f	g	h	i	j	k	l	g =RADIANS(F6)*D6
1	67	245.427	67.168	22.832	97.80095	287.7153	303.883	18.774	71.226	90.000	h =RADIANS(E6)*D6
2	64	229.15	66.488	23.512	94.03364	265.9148	282.051	19.475	70.525	90.000	i =SQRT((G6^2)+(H6^2))
3	61	212.902	65.696	24.304	90.30802	244.1175	260.286	20.301	69.699	90.000	j =DEGREES(ATAN(G6/H6))
4	58	194.578	64.402	25.598	86.93036	218.7118	235.355	21.676	68.324	90.000	k =DEGREES(ATAN(H6/G6))
5	55	174.269	62.373	27.627	84.02928	189.7115	207.488	23.890	66.110	90.000	l =SUM(J6:K6)
6	52	154.177	59.737	30.263	81.43511	160.7449	180.196	26.867	63.133	90.000	Charts data
7	49	134.42	56.195	33.805	79.31012	131.8364	153.854	31.030	58.970	90.000	Previous data
8	46	113.4	50.266	39.734	78.64233	99.48659	126.816	38.326	51.674	90.000	Safety control
9	43	92.3371	39.757	50.243	80.97037	64.07244	103.254	51.645	38.355	90.000	
10	40	74.8098	21.438	68.562	89.51921	27.99175	93.794	72.636	17.364	90.000	Results data

TABLE 6
Resultant longitudinal section structure model analysis

No.	Vertical	Force kN (2)	αo	αo	Force Resultant					Safety control	Formula Text
					Rx	Ry	Rxy, kN (4)	Rxy X	Rxy Y		f =90-E6
b	c	d	e	f	g	h	i	j	k	l	g =RADIANS(F6)*D6
1	67	246.653	18.178	71.822	309.1867	78.25461	318.936	75.797	14.203	90.000	h =RADIANS(E6)*D6
2	64	230.337	18.178	71.822	288.7341	73.0781	297.839	75.797	14.203	90.000	i =SQRT((G6^2)+(H6^2))
3	61	214.05	18.178	71.822	268.3186	67.91098	276.779	75.797	14.203	90.000	j =DEGREES(ATAN(G6/H6))
4	58	195.705	18.178	71.822	245.3219	62.09055	253.057	75.797	14.203	90.000	k =DEGREES(ATAN(H6/G6))
5	55	175.395	18.178	71.822	219.8627	55.64687	226.795	75.797	14.203	90.000	l =SUM(J6:K6)
6	52	155.31	18.178	71.822	194.6861	49.27471	200.825	75.797	14.203	90.000	Charts data
7	49	135.573	18.178	71.822	169.945	43.01277	175.304	75.797	14.203	90.000	Previous data
8	46	114.615	18.178	71.822	143.6731	36.36342	148.203	75.797	14.203	90.000	Safety control
9	43	93.67	18.178	71.822	117.4182	29.71834	121.121	75.797	14.203	90.000	
10	40	76.2726	18.178	71.822	95.60999	24.19872	98.625	75.797	14.203	90.000	Results data

Based on table 5, column I has resultant forces on each cable to become a vertical force, for the 10th cable a vertical force value of 303.883kN occurs and in the 1st cable a vertical force value of 93.794kN occurs, this data in full can be seen in the chart and figure 9. In l is a safety-control showing the value of 90.00°, then the resulting calculation is correct, if it does not produce 90.00° then the calculation is wrong. The values seen in column l are all generated with integers, this indicates the level of accuracy and accuracy is very thorough, and if it does not reach integers there may be a mistake in making a formula in Excel, it needs to be checked. Thus all segments or stages can be broken down easily.

4.5 Resultant Diagonal cross-section

Diagonal cross-section shown in Figure 9.b, why should there be a load acting diagonally, this is because the stayed cables ranging from the 1st to the 10th bottom are located on the left and right side of the road and look neat in line if seen from a cross-section, and at the top, it turns out that the position of the guide to the middle of the road starts from the 10th right in the middle of the road 67 meters high from the face of the road until the 1st cable is increasingly getting to the edge with a height of 40 meters from the road face. Thus, the stayed cable works sliding or diagonally. In this section, the force that has worked on a diagonal cross-section will be transferred by a cable to the column, the force will be a vertical force, the details will be described in the table 6.

TABLE 7
Resultant forces towards the oblique column structure model analysis

No.	Force kN (4)	Rxy X	Rxy Y	Primery Momen Linier	Radian	Rxy, kN (5)	Rxy X	Rxy Y	Safety control	Formula Text
b	c	d	e	f	g	h	i	j	k	f =C6*RADIANS(D6)
										g =RADIANS(D6)*RADIANS(E6)
1	318.94	75.7968	14.2032	421.922	0.32794	421.922	89.955	0.045	90.000	h =SQRT((F6^2)+(G6^2))
2	297.84	75.7968	14.2032	394.012	0.32794	394.012	89.952	0.048	90.000	i =DEGREES(ATAN(F6/G6))
3	276.78	75.7968	14.2032	366.152	0.32794	366.153	89.949	0.051	90.000	j =DEGREES(ATAN(G6/F6))
4	253.06	75.7968	14.2032	334.771	0.32794	334.771	89.944	0.056	90.000	k =SUM(I6:J6)
5	226.8	75.7968	14.2032	300.029	0.32794	300.029	89.937	0.063	90.000	
6	200.82	75.7968	14.2032	265.672	0.32794	265.672	89.929	0.071	90.000	
7	175.3	75.7968	14.2032	231.91	0.32794	231.910	89.919	0.081	90.000	Charts data
8	148.2	75.7968	14.2032	196.059	0.32794	196.059	89.904	0.096	90.000	Safety control
9	121.12	75.7968	14.2032	160.231	0.32794	160.231	89.883	0.117	90.000	Previous data
10	98.625	75.7968	14.2032	130.471	0.32794	130.472	89.856	0.144	90.000	Results data
					Σ	2801.230				

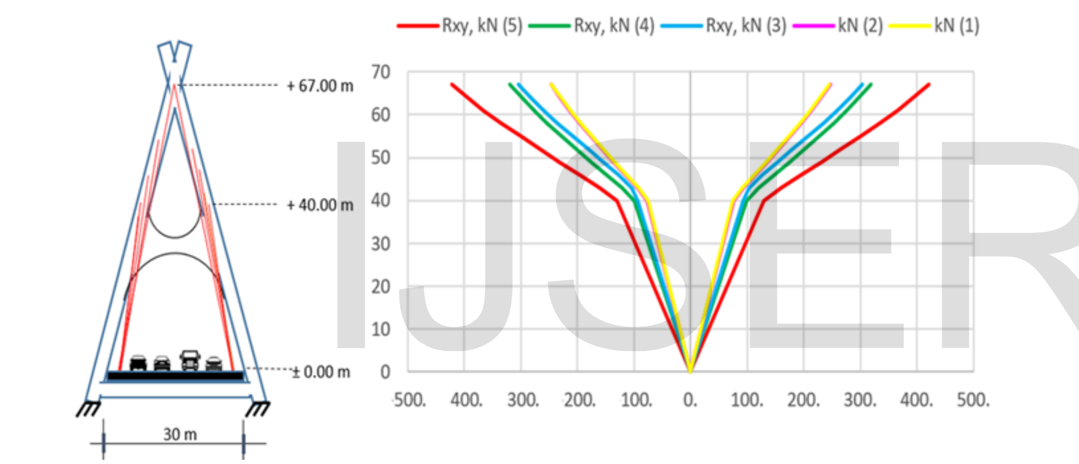


Fig. 9. Cross-section Structure model and forces chart

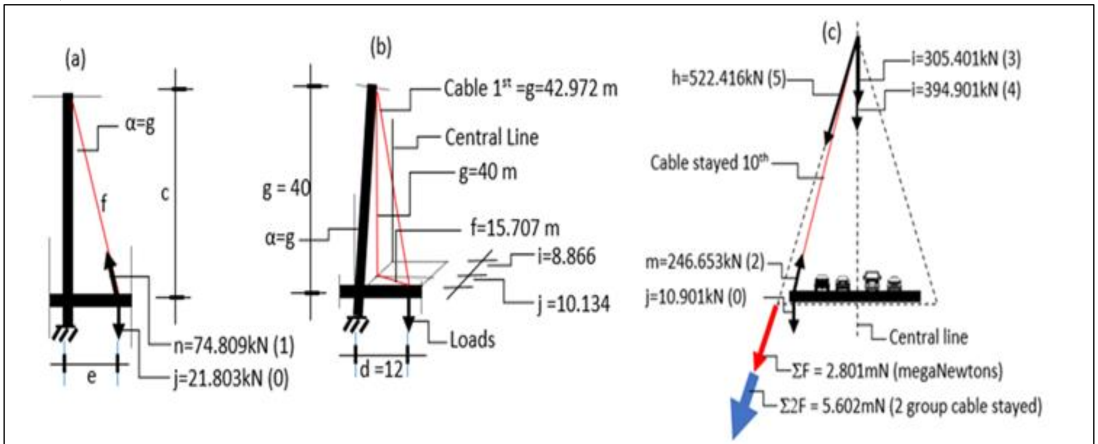


Fig. 10. The sigma forces that are worked on structure model

Based on table 6, in column i the resultant force has occurred on each cable into a vertical force, for the 10th cable a vertical force value of 318.936N occurs and in the 1st cable a vertical force value of 98.625kN occurs. In column l is a safety-control showing a value of 90.00°, then the resulting calculation is correct, if it does not produce 90.00° then the calculation is wrong, (in full can be seen in the chart and figure 9).

4.6 Resultant forces towards the oblique column

Based on tables 5 and 6, the maximum forces that occur will be transferred to follow the column in an oblique condition, thus from the two forces the greatest force is taken and then transferred to the inclined column. More will be described in the table 7.

Based on table 7, the resultant force has occurred in each cable into a vertical force, for the 10th cable there is a value of the oblique direction in the direction of the oblique column of 421.922kN and in the 1st cable the oblique direction in the direction of the oblique column is 130.472kN, (in full can be seen in the chart and figure 9).

In column i is the value of the magnitude of the angle that occurs is 89.955° on the 10th cable and 89.856° in the 1st column, the angle should be 90.00°, thus mathematically will not reach that value, still less 0.045° and 0.144° this number is very insignificant, thus it can be rounded to 90.00°. More can be seen in the chart and figure 9.

Based on Figure 9, the main column is in the form of letter A, the 1st stay cable is hung on a column with a height of 40 meters, then followed by the next cable with a distance of 3 meters to arrive at the 10th stayed cable at a height of 67 meters. The floor width of the bridge is 30 meters and on the face of the road ±,0.00 meter is determined. On the chart, the most extreme last force occurs in the resultant force towards the sloping column, with data taken from table 7 column h.

In figure 9, the chart only shows 4 colored charts namely red, green, blue and yellow for the purple color is not visible or the value of kN (2) is not visible on the chart, this is because the values of kN (1) and kN (2) are very close together so that there is one color that definitely cannot be seen, but the legend still appears purple.

4.7 Sigma forces on the column

All the amount of force acting on the main column has been described from table 2 to table 7, but clearly and concisely found in table 7 column h, in that column there is a description of each force that occurs in the cable starting from 1st to 10th cable, hence this is called one group, for each column burdened by 2 stayed cable groups, complete can be seen in Figure 10.

Based on Figure 10.a, the detail is seen from the direction of the longitudinal section, this is an explanation of the stay cable to the red color line 1st, there is a load of 21.803kN, the load works at a distance of 6 meters from the main column, then transferred to the stayed 1st cable 74.809kN. In Figure 10.b, the detail is the forces acting in the diagonal direction, in picture there is a red triangle, that is the diagonal direction, in picture there is a red triangle, that is the diagonal position referred to, that is only for the 1st stayed cable, for the 2nd to 10th stayed cables will line up to the central-line bridge. Based on Figure 10.c, there is a force sigma of 2.801mN (megaNewtons), this value for 1 group consists of only 10 stayed cables and for 2 groups, the total sigma force occurs is 5.602mN. All the forces that occur in the column will be used to calculate the mechanics that will be discussed in the next research.

4.8 Summary Forces

Forces that have been obtained from the calculation results will still be re-analyzed to find or evaluate whether there is an imbalanced value, by using a chart, on the chart, whether there are intersecting lines, the full is shown in table 8 and the following figure 11.

Based on table 8, at first glance there is no longer a mathematical process, only collecting style values to analyze whether there is an imbalance. If seen with the eye, then the force values are difficult to analyze whether or not lame, so we must use the help of charts to be able to display whether there are lines that intersect. For this reason, it will be explained in the following figure chart 11.

Based on Figure 11, the chart is that all the force values do not occur inequality, all lines have a very ideal and consistent distance interval. These lines logically indicate that reflecting the results of calculations using the hand-method using the help of the goodness of Microsoft Excel is true, if the calculations are wrong then the lines of force values will intersect. It's just that in style number 3 or Rxy, kN (3) occurs inconsistently but does not touch what else intersect, there is a change in the interval, but this is not significant.

TABLE 8
Summary forces structure model analysis

No.	Distance (m)			Summary Forces						Information
	Vertical	Section	Horizontal	kN (0)	kN (1)	kN (2)	Rxy, kN (3)	Rxy, kN (4)	Rxy, kN (5)	
1	67	12	158	21.80382	245.4273	246.653	303.883	318.936	421.922	Previous data
2	64	12	146	21.80382	229.1503	230.337	282.051	297.839	394.012	Charts data
3	61	12	134	21.80382	212.9019	214.050	260.286	276.779	366.153	
4	58	16	120	29.07177	194.5779	195.705	235.355	253.057	334.771	
5	55	16	104	29.07177	174.2688	175.395	207.488	226.795	300.029	
6	52	16	88	29.07177	154.1766	155.310	180.196	200.825	265.672	
7	49	16	72	29.07177	134.42	135.573	153.854	175.304	231.910	
8	46	20	54	36.33971	113.4004	114.615	126.816	148.203	196.059	
9	43	20	34	36.33971	92.33712	93.670	103.254	121.121	160.231	
10	40	24	12	43.60765	74.8098	76.273	93.794	98.625	130.472	
								Σ	2801.230	

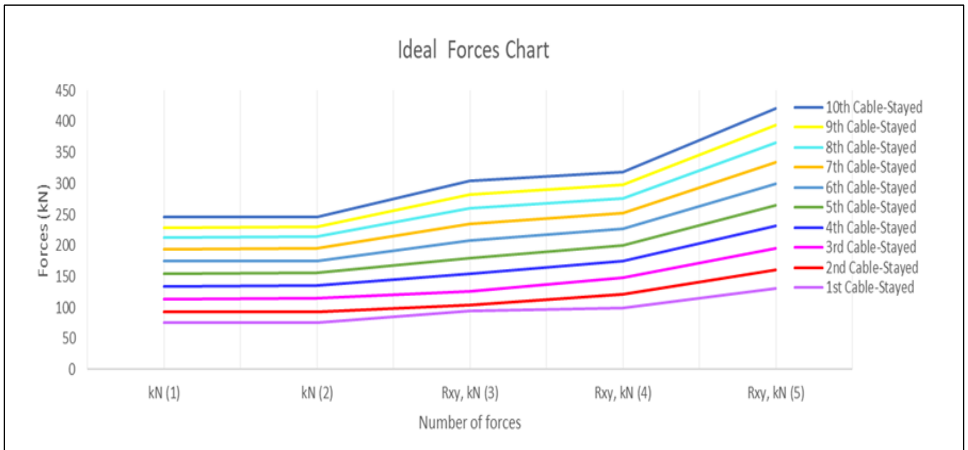


Fig. 11. The Ideal of force chart on structure model

Mathematically described that the 1st cable-stayed force occurs with a value of 93.794kN while the 2nd cable-stayed force occurs with a value of 103.254kN there is still a very significant force interval that is equal to 9.461kN.

5 CONCLUSIONS

The force propagates on a cable and is held by a column, but the column is tilted and forms a certain angle away from the Y-axis and approaches the X-axis, then the magnitude of the force will be accepted by the column, but the magnitude of the force is not the same as the planned force, the magnitude the force that occurs will be large, according to the angle of the cable and the angle of the column itself. This is proven in the study that the forces that occur in kN (3) and kN (4), the force is still working vertically, then transferred in accordance with the slope of the column, the force will occur at kN (5), this is called the resultant force.

A force that is hung using a cable in a column, the force acting on the segment closest to the largest planned column, and the farthest segment with the lightest planned column. However, it is evident and proven that the column accepts the lightest nearest segment (in table 2 column j) and the farthest segment (in table 7 column h).

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