Design the guyed-tension structure of the influence of the wind load on the radio antenna height of 40 meters

Sunaryo[1], Adris A Putra[2], Arsetyo[3], Eso Sulasman[4]

ABSTRACT- The purpose of this study is to only calculate the wind load on the radio antenna tower, the calculation of the wind load is only viewed from the angle of 0°, 30° and 60° to the main towing cable on each section to the most angles on the two types of antenna tower frames, triangle type, and square type. In both of these types will suffer due to wind loads that will work based on the angle of arrival, thus it can be seen which angle is greatest. The research method is to use the empirical analysis method, only calculating the consequences of wind loads that occur, for other loads not included. As a result of the influence of the wind load, the retaining cable at each segment of the voltage and then will be collected at a point that will result in the amount of the resultant force and direction of the force. At the end of the forces will change to lift, this lift must be resisted using an anchor, this anchor will be calculated how much area and depth. The results obtained were based on two types of towers, based on the wind direction from the 0° direction on the triangle tower of 1688.4091N and on the square tower of 2387.7711N, and based on the wind direction coming from the 60° direction and it turns out that due to the influence of the lighter wind load, this is due to the fact that the influence of the wind load is held by the two sides of the towing cable. Based on the calculation of the two types, then the triangle type the amount of vertical force or lift force that arises is relatively lighter that is equal to 2064.4530N and to the heavier square type that is equal to 2919.5774N. Then it can be concluded that the triangle type is highly recommended.
Keywords: Guyed tension, wind loads, antenna towers, triangle model**,** square model.

1 INTRODUCTION

An antenna tower structure will fail to withstand the wind load that occurs, the failure is calculated using the maximum stress theory [1], this structure is assumed to accept wind loads at maximum conditions. Thus the higher a construction eats the influence of a greater wind load, and the wind load is also strongly influenced by a wider cross-section of the construction, the greater the wind load to be received, as well as the aerodynamic conditions of the construction greatly affect the wind load to be received by a construction.

The structure of the radio transmitter antenna tower construction is determined by a reliable planner to be able to stand upright and will be able to withstand wind loads, so usually, the designer uses the finite element method [2], this method can determine the strength of the antenna towing cable to be able to withstand wind loads. And still, use where the wind comes from 0, 60 and 90, this direction is the basis for determining the strength of the cable that can provide balance frame-press and pull-frame, this antenna tower still takes into account the truss that forms including the vertical frame model, horizontal and diagonal frames, in addition to continuing to use the triangle and square models as the main construction model, the use of other models has not been specifically calculated.

The balance of the guyed-tension structure on the antenna tower basically remains in the balance of axial forces [3], but the balance on the guyed-tension structure changes very insignificantly, a balance will increase where when the structure is in dynamic conditions. In fact, the structure of the construction of the radio antenna mast is actually the biggest one, only the wind load, whereas other loads are not a problem. In research on the influence of wind, swings have been predicted starting from 0, 60 and 90, this direction is crucial to calculate the condition of the cable that will withstand wind loads, if it comes from 0 then the cable will withstand 100% of the wind load that occurs and the cable will receive a load a very mild wind if only the wind came at a large angle.

Telecommunication transmitter tower structure made of steel construction with a guyed-tension model is an antenna tower structure that uses tension cables that will provide balance [4], in this study remains based on a combination of dead load and wind load that will become a burden and is a major factor in determining the strength of construction that will occur. The strength of the structure is also largely determined by the main construction of the tower, this concerns the strength of the steel used, the connection at the vertex, the condition of the steel profile used and most importantly the aerodynamic model that will withstand the wind strength. The segment of each vertex coefficient node becomes the main priority in determining the

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strength of the antenna tower construction, the longer each node point will be weakened in the main construction.

In the tower structure construction of the guyed-tension model antenna, the wind load becomes the main priority in doing the design [5], still concentrating on the wind load that cannot be driven unless the construction treatment that is designed must be taken into account, starting from the tower model to be made of quality. Material and tower models are also a concern between the triangle and square models and the more aerodynamic pipeline models for receiving wind loads from all directions.

Natural conditions in an area are crucial to design a radio transmitter antenna tower, both from the model or from wind load conditions that will affect [6], wind load is still a top priority in designing tower antennas. For analysis or the method used depends on the needs, some are designing using SAP2000 [7] [8], there are also those who use manual or hand methods, it's just that in today's times many remain only by hand or manually, it's just that it uses the help of the goodness of Microsoft Excel so that everything becomes easier and faster.

Designing radio transmitting antenna towers, specifically for subtropical areas, the combination of wind loads and snow loads becomes an obligation to be combined, otherwise construction failure will occur [9] [10], in this combination the arrival of the wind direction will be taken into account including snow loads coming horizontally, This combination can be calculated together or each of them becomes a burden that must be considered.

Radio frequency transmitter towers get wind loads from various directions, ranging from 0 to 90, and are often done in designing [11]. For the triangle tower model, it will receive a little wind load, especially from 0 because this direction causes aerodynamic forces, where the wind is not directly held by the cross-section, but can be avoided, however it is still considered a wind load that is held back by the cross-section area of the anther tower.

The type of pipe antenna radio tower broadcasting, very good because it has a cylindrical shape, the wind load will be more easily avoided, thus it is very good to be used as tower antennas [12], the effect of the wind load on the cylinder model can reduce up to 50% of the wind load, this is due to its aerodynamic shape, it's just that the cylinder model has a heavier dead load than the triangle frame or square model, of course, there are all advantages and disadvantages.

2 LITERATURE REVIEW

A force is defined as an action that occurs on an object against another object and is generally expressed in a point, the magnitude and direction of the force itself. For the magnitude of the force expressed in units of Newton (N) for the unit of cost and for multiples of 1000, it is written as kilonewtons (kN), with mathematical equations being 1000N and 1kN. Furthermore, a force acting on an object must have the same point. A force also has a direction, the direction is indicated by an arrow. A straight-arrow without a limit is a force of action, the force of action forms the angle formed by a force. In figure 1, it is explained that a force marked with an arrow will then have a scale or commonly called the length of the arrow. A force in two forces that has the same magnitude and then added the same active line and will be drawn into different parts, as in figures 1.a and 1.b, thus will have a direct reverse effect on the particles themselves [13].

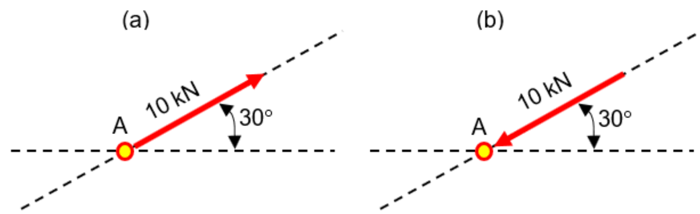

Figure 1 The direction of force

An experiment in two P and Q forces, the force works with particle A (figure 2.a) these forces can be replaced by a Resultant (R) and the resultant has an influence on the particle (figure 2.c). Thus the force is the resultant of force P and forces P. Then in figure 2.b it turns out that there is a parallelogram due to the resultant force formed by a diagonal line resulting from the results of both forces passing through a point A which is an outcome. This method or method is called a parallelogram law from the results of an experiment, and it can be mathematically proven.

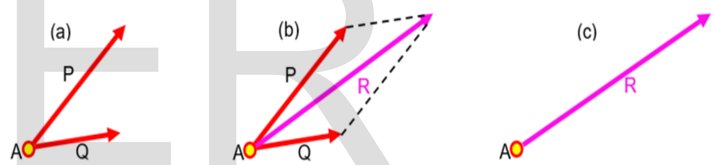

Figure 2 The force resultant

A vector is a force that cannot be influenced in an arithmetic principle or an ordinary algebra, in a force which forms a certain angle and has a certain force strength, thus adding a certain force. Its ability or in the addition of a parallelogram, its displacement, velocity, and momentum is another example of a physical quantity that has the magnitude and direction of a force of parallelogram law. The ability of forces that occur is not represented by using a mathematical vector, while a number of forces have a quantity but do not have a direction, for examples such as volume, mass or energy which is usually symbolized by numbers or scalars. A vector is defined as a mathematical equation that has a value and direction, which is referred to as the parallelogram law. A vector marked with an arrow in the illustration and will give meaning as a number of scalars symbolized by the letter P. The vector is symbolized by an arrow above the letter $\overleftrightarrow{P}$ or with an underscore P.

A vector that will be used to represent a force acting on a particular particle has a very clear point of application, namely the particle itself. For this reason, a vector is called a fixed vector or a bound vector and cannot move without changing the problem conditions.

In two vectors that have a quantity and the same direction is said to be the same vector, in Figure 3.a, then it has the symbol with the same letter. A vector is said to be negative from a vector P which is interpreted as a vector of magnitude equal to P but the direction is very opposite to P, in Figure 3.b, has a negative value of a vector P denoted by the letter - P. So thus a vector P and -P are generally called the same and very opposite direction, in mathematical equations are as follows:

P + (-P) = 0

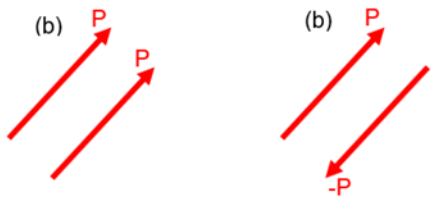

Figure 3 The vectors

For the addition of a vector, it is defined using a parallelogram law, in the sum of the two vectors P and Q obtained from two vectors from point A and will form a parallelogram of P and Q (figure 4.a). On the diagonal line that passes through a point A is the sum of a vector P and Q, then added to P + Q. Then the + sign is used to indicate a vector and the addition of a scalar, this proves that a vector and a scalar will be very different. Thus, the magnitude of a P + Q vector is generally not the same as the number of P + Q of the size of a vector P and Q. So a parallelogram formed of P and Q is very independent of the cumulative selection sequence P and Q, mathematically explained as follows:

P + Q = Q + P

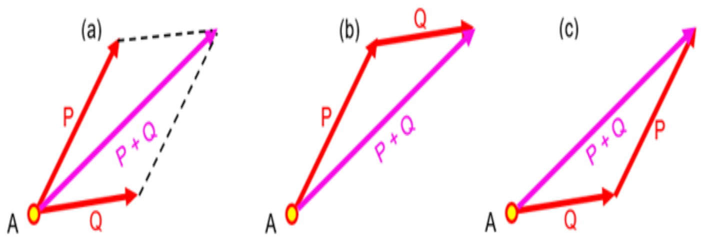

Figure 4 The parallelogram

Based on Figure 4 in a parallelogram, the use of another method to determine the number of two vectors is to use a triangle method, for that it can be described as follows: in Figure 4. a, then the number of vectors P and Q is determined by a parallelogram law. This is because the sides of the parallelogram are very opposite Q and Q also have a quantity and direction, so the parallelogram is only half (figure 4.b). In addition to the two vectors, this can be done by adjusting P and Q by connecting the ends of P and Q (figure 4.c), then this is called adding cumulative vectors. For a vector, the reduction is defined as the addition of an appropriate negative vector. Then a P + Q vector represents the difference between a P and Q vector obtained by adding a negative vector P - Q (figure 5), mathematically explained as follows:

P - Q = P + (- Q)

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

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

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

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

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

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

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

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

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

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

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

3 RESEARCH METHODS

The use of the method in this study is to use empirical analysis, here the researchers only calculate the wind load, for other loads not included in the calculation. This design is due to the direction of the wind load, it will produce a resultant force and will eventually be transformed into a vertical force or lift force, then it will be held by the anchor, at this anchor the anchor dimensions and anchor depth will be determined so that it can resist the vertical force or lift force.

4 RESULTS

This research focuses on the analysis of the structural design of the radio transmitter tower that uses a reinforcing cable as a towing dam giving the stand to the main pillar, the main pillar will stand upright due to the cable working. The main pillar has two types, namely triangle type, and square type, each type has advantages and disadvantages so that in this design it will be known which one is more recommended. In Figure 5 and 6 illustrate the type of tower to be used as well as the height of the tower to be designed, the height of the tower is planned to be as high as 40 meters and the dimensions of the tower are 40 cm x 40 cm in the first 5 sections, and the next segment the tower dimensions become 30 cm x 30 cm. For the length of each segment of 3 meters, while this design is planned to be 4 segments, the first segment consists of 5 segments, the second segment consists of 4 segments, the third segment consists of 3 segments and the fourth segment consists of 2 segments. Each segment is useful to distinguish the dimensions of the structure and cross-section of the structure, the more cross-section the more slender.

The model and dimensions used for tower design are very influential on wind loads, the smaller the dimensions the smaller the wind load that occurs, it's just that the strength of the tower is very doubtful, while the greater the dimensions of the tower will be large wind loads that occur only the tower pole structure is certainly very strong. For this reason, this design will know and determine the ideal design.

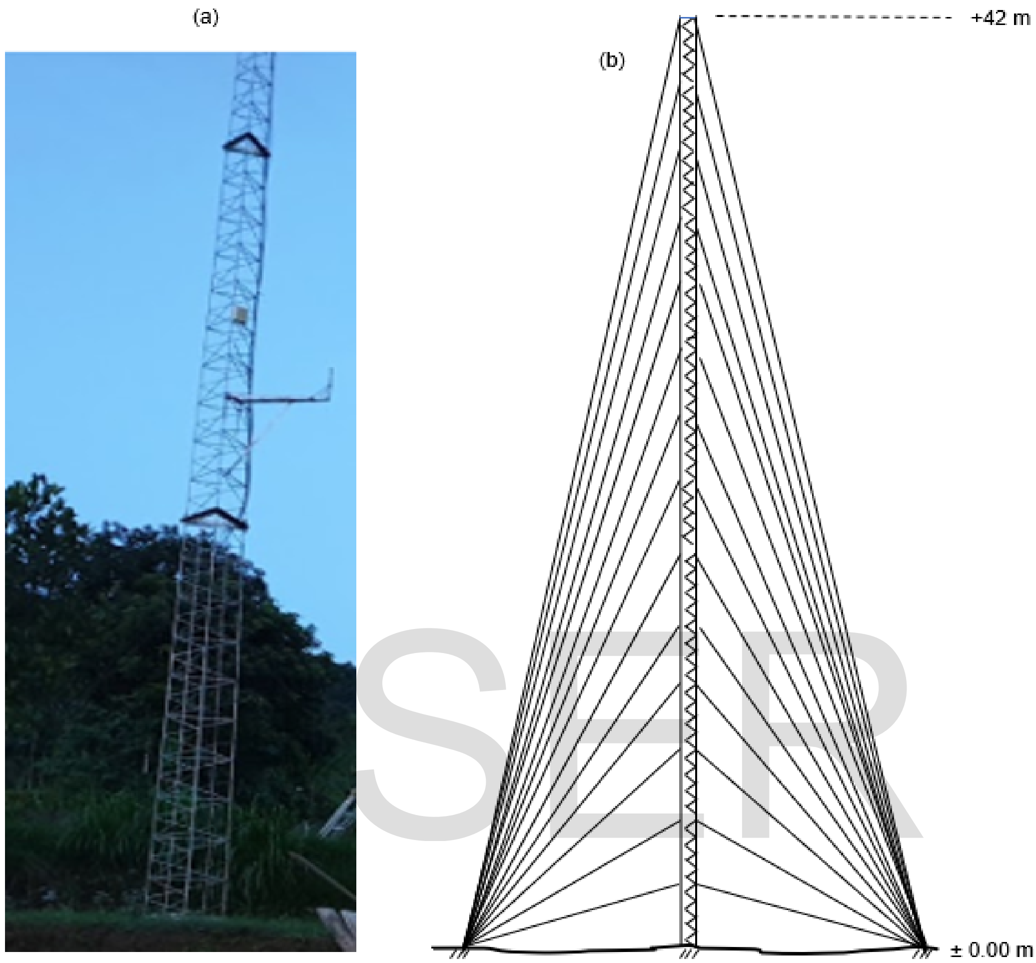

Figure 5 The tower structure type guyed-tension antenna

Based on Figure 5 the antenna tower structure consists of the main pole and a towing cable that will provide balance to the construction, the pole will not stand upright if not pulled by the cable. Each cable from the top to the bottom has different angles and pulls. The more upward the angle formed by the towing cable gets smaller against the tower pole or the Y-axis, thus the greater the load is drawn by the cable, even though the forces are cooperating.

The antenna tower structure is planned with two models and height as illustrated in the following figure 6:

Based on Figure 6.a is a radio antenna tower structure design with a height of 40 meters, the pole will stand upright because it is pulled by a cable that will provide balance, such a structure is very dominated by wind loads, while the useful load is relatively very small.

Based on Figure 6.b is a cross-section of a radio antenna tower with a triangle type or model, the pole will stand upright pulled by a towing cable, wind is predicted to come from 0°, so the overall wind load will be withheld by the cable that, and if the wind direction comes from the direction of 60° then the wind load that occurs will be held by both cables so that the load is divided into 2 parts.

Based on Figure 6.c is a cross-section of a radio antenna tower with a type or square model, the pole will stand upright pulled by a towing cable, wind is predicted to come from 0°, so the overall wind load will be held by the cable, and if the direction of the wind comes from the direction of 45° then the wind load that occurs will be resisted by both cables so that the burden is divided into 2 parts.

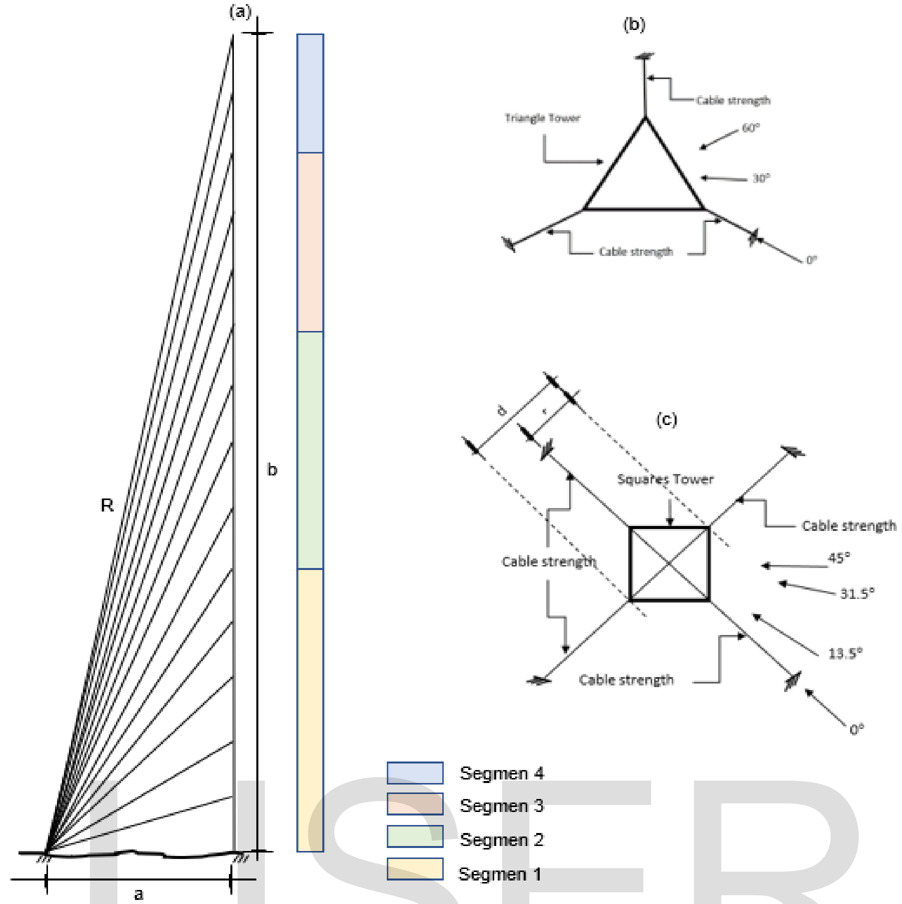

Figure 6 The model construction of guyed-tension antenna towers and cross sections

Referring to Figure 6.a, the radio antenna tower with a height of 40 meters, basically has two types of models, the first is the Triangle type and the square type. Each type or model has several advantages and disadvantages. Thus these advantages are explained in Table 1, as follows:

TABLE 1
Wind load distribution

No.	Section	CSC*	Compressive strength and degree of wind direction (Newton)											Information		
			W_0	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9	W_{10}	Discription	Value	Unit
			0 °	4.5 °	9 °	13.5 °	18 °	22.5 °	27 °	31.5 °	36 °	40.5 °	45 °			
I	Squares Tower															
1	Top Section	0.2	49.928	48.458	46.988	45.518	44.049	42.579	41.109	39.639	38.170	36.700	35.230	Gravity (g)	9.8067	m/s^2
2	Mid 2 Section	0.25	62.409	60.572	58.735	56.898	55.061	53.224	51.386	49.549	47.712	45.875	44.038			
3	Mid 1 Section	0.3	74.891	72.687	70.482	68.278	66.073	63.868	61.664	59.459	57.254	55.050	52.845	Wind load (w)	40	kg/m^2
4	Boton Section	0.4	99.855	96.916	93.976	91.037	88.097	85.158	82.218	79.279	76.339	73.400	70.460	Wide (b_1)	30	cm
				remarks:										Wide (b_2)	30	cm
II	Triangle Tower			$W_{0-10}=\left[\frac{h}{2}\right].w.g.CSC.(d-\left[\frac{W_{1-10}}{360}\right].2.\left[\frac{r}{2}\right]\pi.1.5$										High (h)	3	m
1	Top Section	0.2	35.304	W_0	=$AK$14*$AK$11*0.5*$AK$9*X9*($AK$15-((($Y$7/360)*2*$AK$17/2*3.14)*									Diameter (d)	0.4243	m
2	Mid 2 Section	0.25	44.13													
3	Mid 1 Section	0.3	52.956	$d = \sqrt{b_1^2 + b_2^2}$	=SQRT(((AK12/100)^2)+((AK13/100)^2))									Radius (r) = d/2	0.2121	m
4	Boton Section	0.4	70.608											Wide Triangle (b_2)	30	cm
				Triangle Tower $W_0 = \frac{b_2}{2}.h.w.g.CSC$	=$AK$18/100*$AK$14*$AK$11*0.5*$AK$9*X15											

* Cross-Section Coefficient

Based on table 1, the tower type or square model with a height of 40 meters consisting of 4 segments, where the lowest segment of the cross-section of the pole is larger and the top of the section is the leanest pole. Thus there is a difference in the cross-sectional area of the pole that will withstand wind loads, as in table 1 of the third column, then in that column is the first section that has a value or variable with the name CSC (cross-section-coefficient). This value is calculated based on the cross-sectional area contained in each segment.

The wind load is calculated to come from all directions starting from W_0 0° to W_{10} 45°. Based on table 1, the wind load from W0 0° values 49.928N, 62.409N, 75.891N and 99.855N, at this value the wind load is directly grounded by one towing cable because it fits in the direction of the towing cable, thus the cable is 100% withstand wind loads.

At wind loads from the direction of 22.5° or W_5, values of 42.759N, 53.224N, 63.868N and 85,158N were obtained. And the last from the 45° or W_{10} direction obtained values of 35,230N, 44,038N, 52.845N and 70,460N.

The direction of the wind coming from various directions will be received by the cross-section of the tower starting from 0° at W_0 to 45° at W_{10}. Wind from 0° direction at W_0, thus the cable will hold 100% and the other cable cannot help to hold it because the angle of arrival of the wind is not at the working angle of the cable. Winds originating from the direction of 22.5° on W_5 and wind originating from the direction of 45° on W_{10} this is the smallest load. This difference is caused by a square tower antenna model, if the wind direction is at 0°, then this cross-section is the widest because it uses the diagonal of the square, while for the wind from the direction of the 45° cross-section that holds the wind is as wide as the side of the square, this can be seen in Figure 6.c, where d is the diagonal of the square and r is the radius.

In the tower triangle model, the wind that comes from all angles and is held by 35.304, 44.13N, 52.956N and 70.508N. This is because the triangle model from which direction the wind does not change the cross-sectional area, this can be seen in Figure 6.b. From any direction all sides can be considered diagonal.

Primary moments in the triangle model: Winds that come from varying directions and are resisted by the cross-section of the radio antenna tower, both the triangle model and the square model, with the results shown in table 1, then this is the first step in this analysis, the next is based on the load the wind described in table 1 will then be used to determine the primary moment in the triangle model. Next described in the following table:

TABLE 2
Primary moments in the triangle model

Distance (a)	Segment (b)	Radius	Angle Sin $\alpha°$	Radians	Wind Load W_0	Moment M_{primer}	M_{angle}	Force	Information
9	42	42.953	12.095	0.211	35.304	79.434	0.633	125.433	
	39	40.025	12.995	0.227	35.304	79.434	0.680	116.747	
	36	37.108	14.036	0.245	44.130	99.293	0.735	135.104	
	33	34.205	15.255	0.266	44.130	99.293	0.799	124.309	
	30	31.321	16.699	0.291	44.130	99.293	0.874	113.559	$R = \sqrt{a^2 + b^2}$
	27	28.460	18.435	0.322	52.956	119.151	0.965	123.441	
	24	25.632	20.556	0.359	52.956	119.151	1.076	110.703	$\sin \alpha = \frac{b}{R}$
	21	22.847	23.199	0.405	52.956	119.151	1.215	98.093	$M_{primer} = \frac{3}{4}.h.W_0$
	18	20.125	26.565	0.464	52.956	119.151	1.391	85.662	
	15	17.493	30.964	0.540	70.608	158.869	1.621	97.991	
	12	15.000	36.870	0.644	70.608	158.869	1.931	82.294	$M_{angle} = Rd.h$
	9	12.728	45.000	0.785	70.608	158.869	2.356	67.426	
	6	10.817	56.310	0.983	70.608	158.869	2.948	53.883	$N = \frac{M_{primer}}{M_{angle}}$
	3	9.487	71.565	1.249	70.608	158.869	3.747	42.397	

Based on table 3, at a tower height of 42 meters, the greatest force occurs, that is 125.433N and at a height of 3 meters the force occurs at 42,397N and at an altitude of 0 (zero) meters the force does not occur then the force is expressed as 0 as well. Graphically shown in figure 7.b.

The force that occurs due to wind loads on a cross-section of a triangle: The force that occurs due to wind loads coming from various directions, and for from 0 the wind load will be held by only one cable, more fully explained in the following table:

TABLE 4
The triangle tower cable-strength influence on the direction of the wind load

Segment (b)	Cable strength, N	The triangle tower cable-strength influence on the direction of the wind load									
		6 °	12 °	18 °	24 °	30 °	36 °	42 °	48 °	54 °	60 °
		5	10	15	20	25	30	35	40	45	50
42	125.433	119.161	112.890	106.618	100.346	94.075	87.803	81.532	75.260	68.988	62.717
39	116.747	110.910	105.072	99.235	93.398	87.560	81.723	75.886	70.048	64.211	58.374
36	135.104	128.349	121.594	114.838	108.083	101.328	94.573	87.818	81.062	74.307	67.552
33	124.309	118.094	111.878	105.663	99.447	93.232	87.017	80.801	74.586	68.370	62.155
30	113.559	107.881	102.203	96.525	90.847	85.169	79.491	73.814	68.136	62.458	56.780
27	123.441	117.269	111.097	104.925	98.753	92.581	86.409	80.236	74.064	67.892	61.720
24	110.703	105.168	99.633	94.098	88.563	83.028	77.492	71.957	66.422	60.887	55.352
21	98.093	93.189	88.284	83.379	78.475	73.570	68.665	63.761	58.856	53.951	49.047
18	85.662	81.379	77.096	72.813	68.530	64.247	59.964	55.681	51.397	47.114	42.831
15	97.991	93.091	88.192	83.292	78.393	73.493	68.594	63.694	58.795	53.895	48.995
12	82.294	78.179	74.064	69.950	65.835	61.720	57.606	53.491	49.376	45.262	41.147
9	67.426	64.055	60.683	57.312	53.941	50.569	47.198	43.827	40.456	37.084	33.713
6	53.883	51.189	48.495	45.801	43.107	40.412	37.718	35.024	32.330	29.636	26.942
3	42.397	40.277	38.158	36.038	33.918	31.798	29.678	27.558	25.438	23.319	21.199

Based on table 4, at a tower height of 42 meters, the greatest force occurs, that is 119.161N and at a height of 3 meters the force occurs at 40.397N and at an altitude of 0 (zero) meters the force does not occur then the force is expressed as 0 as well. Graphically shown in figure 7.c.

Primary moments in the square model: Winds that come from various directions and are resisted by the cross-section of the radio antenna tower, both triangle and square models, with the results shown in table 1, then this is the first step in this analysis, the next is based on the wind load described in table 1 then it will then be used to determine the primary moment in the square model. Next described in the following table:

TABLE 5
Primary moments in the square model

Distance (a)	Segment (b)	Radius (R)	Angle		Compressive strength and degree of wind direction												Cable strength, ($M_{primer}O°/M_{angle}$)
			Sin α (°)	Radians (β)	M_{primer} (3/4h x W_{0-10})											M_{angle} (β x h)	
					0 °	4.5 °	9 °	13.5 °	18 °	22.5 °	27 °	31.5 °	36 °	40.5 °	45 °		
9	42	42.953	12.095	0.211	112.337	109.030	105.723	102.416	99.109	95.802	92.495	89.189	85.882	82.575	79.268	0.633	177.389
	39	40.025	12.995	0.227	112.337	109.030	105.723	102.416	99.109	95.802	92.495	89.189	85.882	82.575	79.268	0.680	165.105
	36	37.108	14.036	0.245	140.421	136.288	132.154	128.020	123.887	119.753	115.619	111.486	107.352	103.218	99.085	0.735	191.066
	33	34.205	15.255	0.266	140.421	136.288	132.154	128.020	123.887	119.753	115.619	111.486	107.352	103.218	99.085	0.799	175.800
	30	31.321	16.699	0.291	140.421	136.288	132.154	128.020	123.887	119.753	115.619	111.486	107.352	103.218	99.085	0.874	160.597
	27	28.460	18.435	0.322	168.506	163.545	158.585	153.624	148.664	143.704	138.743	133.783	128.822	123.862	118.902	0.965	174.572
	24	25.632	20.556	0.359	168.506	163.545	158.585	153.624	148.664	143.704	138.743	133.783	128.822	123.862	118.902	1.076	156.558
	21	22.847	23.199	0.405	168.506	163.545	158.585	153.624	148.664	143.704	138.743	133.783	128.822	123.862	118.902	1.215	138.725
	18	20.125	26.565	0.464	168.506	163.545	158.585	153.624	148.664	143.704	138.743	133.783	128.822	123.862	118.902	1.391	121.145
	15	17.493	30.964	0.540	224.674	218.060	211.446	204.833	198.219	191.605	184.991	178.377	171.763	165.149	158.536	1.621	138.580
	12	15.000	36.870	0.644	224.674	218.060	211.446	204.833	198.219	191.605	184.991	178.377	171.763	165.149	158.536	1.931	116.381
	9	12.728	45.000	0.785	224.674	218.060	211.446	204.833	198.219	191.605	184.991	178.377	171.763	165.149	158.536	2.356	95.355
	6	10.817	56.310	0.983	224.674	218.060	211.446	204.833	198.219	191.605	184.991	178.377	171.763	165.149	158.536	2.948	76.203
	3	9.487	71.565	1.249	224.674	218.060	211.446	204.833	198.219	191.605	184.991	178.377	171.763	165.149	158.536	3.747	59.959
																ΣN	1238.073542

Based on table 5, at a tower height of 42 meters, the greatest force occurs, that is 177.389N and at a height of 3 meters the force occurs at 50.959N and at an altitude of 0 (zero) meters the force does not occur then the force is expressed as 0 as well.

The force that occurs due to wind load on a square section: Force that occurs due to wind loads coming from various directions, and for from 0° the wind load will be held by only one cable, more fully explained in the following table:

TABLE 6
Force influence of wind direction on a square tower,

Segment (b)	Force influence of wind direction on a square tower, N (Newton)											Information
	0 °	4.5 °	9 °	13.5 °	18 °	22.5 °	27 °	31.5 °	36 °	40.5 °	45 °	
42	177.4	172.2	166.9	161.72	156.5	151.3	146.1	140.8	135.6	130.4	125.2	$N = \frac{0°\sim45°}{M_{angle}}$
39	165.1	160.2	155.4	150.52	145.7	140.8	135.9	131.1	126.2	121.4	116.5	
36	191.1	185.4	179.8	174.19	168.6	162.9	157.3	151.7	146.1	140.4	134.8	
33	175.8	170.6	165.4	160.27	155.1	149.9	144.7	139.6	134.4	129.2	124	
30	160.6	155.9	151.1	146.41	141.7	137	132.2	127.5	122.8	118	113.3	
27	174.6	169.4	164.3	159.15	154	148.9	143.7	138.6	133.5	128.3	123.2	
24	156.6	151.9	147.3	142.73	138.1	133.5	128.9	124.3	119.7	115.1	110.5	
21	138.7	134.6	130.6	126.47	122.4	118.3	114.2	110.1	106.1	102	97.89	
18	121.1	117.6	114	110.45	106.9	103.3	99.75	96.18	92.62	89.05	85.48	
15	138.6	134.5	130.4	126.34	122.3	118.2	114.1	110	105.9	101.9	97.79	
12	116.4	113	109.5	106.1	102.7	99.25	95.83	92.4	88.97	85.55	82.12	
9	95.35	92.55	89.74	86.934	84.13	81.32	78.51	75.71	72.9	70.09	67.28	
6	76.2	73.96	71.72	69.473	67.23	64.99	62.74	60.5	58.26	56.01	53.77	
3	59.96	58.19	56.43	54.664	52.9	51.13	49.37	47.6	45.84	44.07	42.31	

Based on table 6, at a tower height of 42 meters, the greatest force occurs, that is 177.42N and at a height of 3 meters the force occurs at 59.96N and at an altitude of 0 (zero) meters the force does not occur then the force is expressed as 0 as well. Graphically shown in figure 7.a.

Due to the wind load on the square tower model: Wind coming from various directions is very influential on the cross-section which will inhibit the wind, on the square model, where if the wind is from 0° then the wind load will be held 100% by just one cable and if it comes in the 45° direction then the wind load will be held by two cables, detailed in the following table:

TABLE 7
Force influence of wind direction on a square tower

Segment (b)	Cable strength 0°, (N)	The Square tower cable-strength influence on the direction of the wind load (Cs)										Information
		4.5°	9°	13.5°	18°	22.5°	27°	31.5°	36°	40.5°	45°	
		5	10	15	20	25	30	35	40	45	50	
42	177.389	168.520	159.650	150.781	141.911	133.042	124.172	115.303	106.434	97.564	88.695	
39	165.105	156.850	148.595	140.339	132.084	123.829	115.574	107.318	99.063	90.808	82.553	
36	191.066	181.513	171.959	162.406	152.853	143.299	133.746	124.193	114.640	105.086	95.533	
33	175.800	167.010	158.220	149.430	140.640	131.850	123.060	114.270	105.480	96.690	87.900	
30	160.597	152.567	144.537	136.507	128.478	120.448	112.418	104.388	96.358	88.328	80.299	
27	174.572	165.843	157.114	148.386	139.657	130.929	122.200	113.472	104.743	96.014	87.286	
24	156.558	148.730	140.902	133.075	125.247	117.419	109.591	101.763	93.935	86.107	78.279	
21	138.725	131.789	124.852	117.916	110.980	104.044	97.107	90.171	83.235	76.299	69.362	$Cs = N(1 - \frac{4.5^{\circ} \sim 45^{\circ}}{100})$
18	121.145	115.088	109.030	102.973	96.916	90.859	84.801	78.744	72.687	66.630	60.572	
15	138.580	131.651	124.722	117.793	110.864	103.935	97.006	90.077	83.148	76.219	69.290	
12	116.381	110.562	104.743	98.924	93.105	87.286	81.467	75.648	69.829	64.010	58.191	
9	95.355	90.587	85.819	81.051	76.284	71.516	66.748	61.981	57.213	52.445	47.677	
6	76.203	72.392	68.582	64.772	60.962	57.152	53.342	49.532	45.722	41.911	38.101	
3	59.959	56.961	53.963	50.965	47.967	44.969	41.971	38.973	35.975	32.977	29.979	

Based on table 6, at a tower height of 42 meters, the greatest force occurs, that is 168.520N and at a height of 3 meters the force occurs at 56.961N and at an altitude of 0 (zero) meters the force does not occur then the force is expressed as 0 as well. Graphically shown in figure 7.b.

Based on the calculation results and the description in tables 1 to 7, it can be explained in an illustration in accordance with the following figure:

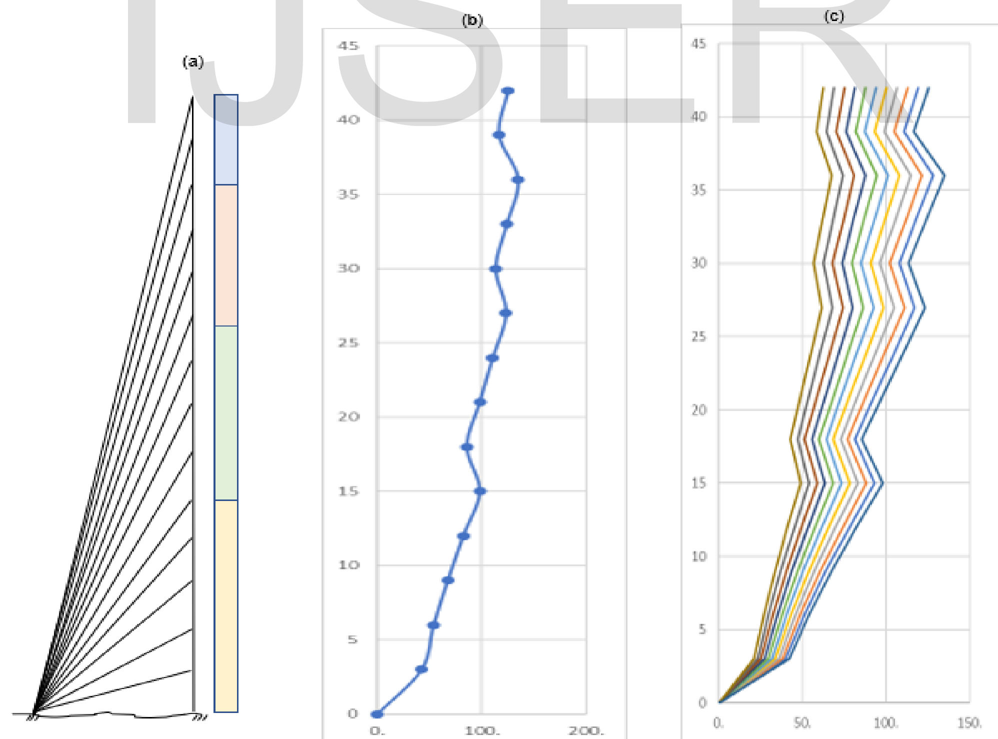

Figure 7 The load chart analysis triangle tower

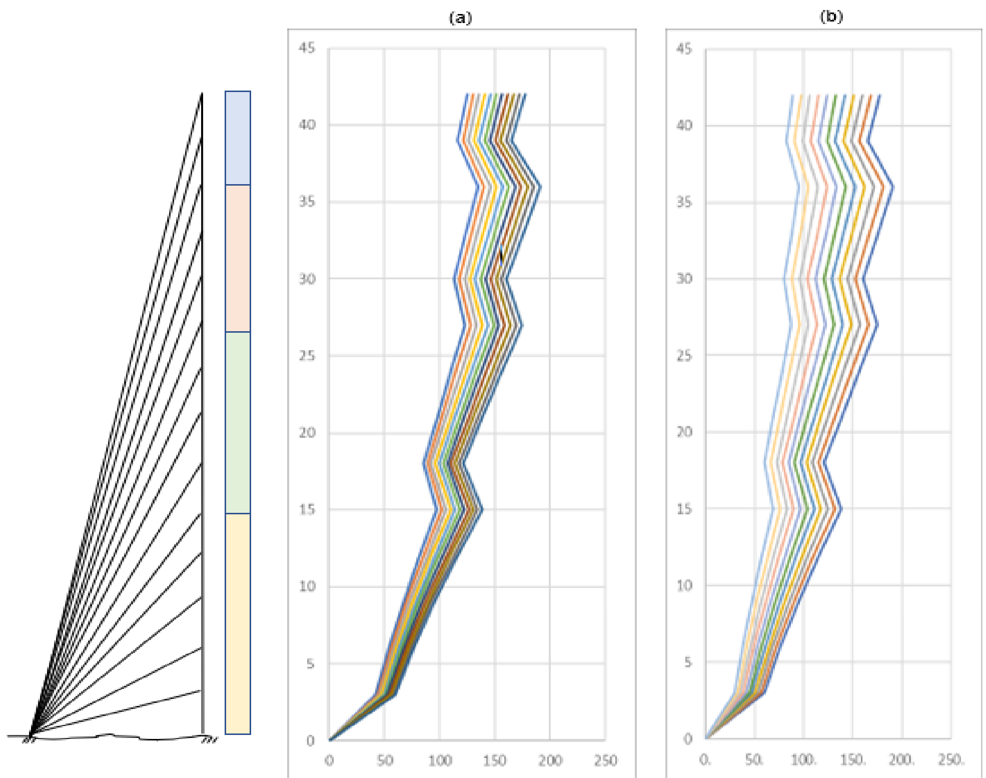

Figure 8 The load chart analysis square tower

Based on table 6.a, it is an actual tower height model with a height of 40 meters and an analysis height of 42 meters, divided into 4 segments, each of which has a different cross-section of the frame cross-section. The distance of the pole and anchor 9 meters.

Based on table 6.b, it is an illustration or illustration due to the wind load on the tower triangle model. At a height of 3 meters to a height of 15 meters the graph is relatively linear, it is evident that in this segment the cross-sectional area and frame width are designed the same.

Based on table 6.c, it is an illustration or illustration due to the wind load on the tower triangle model. At a height of 3 meters to a height of 15 meters the graph is relatively linear, this is evident that in this segment the cross-sectional area and the frame width are designed the same. It's just that on the graph all wind loads from 0° to 60° value occur simultaneously there is no intersection, this indicates that the calculation is correct because there are no inconsistent curves.

Resultant forces in the triangle model: The forces due to wind loads from various directions and held by each cable, will be transformed into forces, in detail will be described in the following table:

TABLE 8

The resultant force for triangle models

Segment (b)	Cable strength (Newton), N	Angle		Angle Resultant				Angle Result			
		Sin α°	Radians α°(Rd)	Cos β°	Radians β°(θ)	(Rx)	(Ry)	strength (Rxy)	(Rxy) X°	(Rxy) Y°	Control θ°
42	125.433	12.095	0.211	77.905	1.360	170.552	26.478	1688.409	70.057	19.943	90.000
39	116.747	12.995	0.227	77.005	1.344	156.908	26.478				
36	135.104	14.036	0.245	75.964	1.326	179.123	33.098				
33	124.309	15.255	0.266	74.745	1.305	162.167	33.098				
30	113.559	16.699	0.291	73.301	1.279	145.281	33.098				
27	123.441	18.435	0.322	71.565	1.249	154.183	39.717				
24	110.703	20.556	0.359	69.444	1.212	134.175	39.717				
21	98.093	23.199	0.405	66.801	1.166	114.367	39.717				
18	85.662	26.565	0.464	63.435	1.107	94.841	39.717				
15	97.991	30.964	0.540	59.036	1.030	100.968	52.956				
12	82.294	36.870	0.644	53.130	0.927	76.311	52.956				
9	67.426	45.000	0.785	45.000	0.785	52.956	52.956				
6	53.883	56.310	0.983	33.690	0.588	31.684	52.956				
3	42.397	71.565	1.249	18.435	0.322	13.641	52.956				
Σ	1377.044				Σ	1587.157	575.898				

Remarks:

$$Rxy=\sqrt{\Sigma Rx^2+\Sigma Ry^2}$$

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

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

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

Based on table 7.a, it is an illustration or illustration due to the wind load on the tower triangle model. At a height of 3 meters to a height of 15 meters the graph is relatively linear, it is evident that in this segment the cross-sectional area and frame width are designed the same.

Based on table 7.b, it is an illustration or illustration due to the wind load on the tower triangle model. At a height of 3 meters to a height of 15 meters the graph is relatively linear, this is evident that in this segment the cross-sectional area and the frame width are designed the same. It's just that on the graph all wind loads from 0° to 45° oo value occur simultaneously there is no intersection, this indicates that the calculation is correct because there are no inconsistent curves.

Based on table 8, the transformation of the force or resultant force into one diagonal force of 1688.409N or 1.688kN with an angle of 70.057° to the X-axis and 19.943° to the Y-axis, both of these angles add up to an angle of 90°, thus the calculation done is correct because it has been controlled by using a right angle.

Vertical forces in the triangle model: The forces that have been transformed into one diagonal force, then the next is to change the diagonal force to a vertical force or lift force, in detail will be described in the following table:

TABLE 9

The vertical force anchor dimensions for triangle models

Resultant strength (Rxy)	Angle Resultant						Angle Result			
	(Rxy) Y°	Radians Y°	(Rxy) X°	Radians X°	(Rxy) X°	(Rxy) Y°	Vertical force N	(Rxy) X°	(Rxy) Y°	Control θ°
1688.409	70.057	1.223	19.943	0.348	2064.453	0.425599	2064.453	89.988	0.012	90.000

Anchor Dimension			
soil density (sd)	1000	kg/m^3	
Gravity (g)	9.8067	m/s^2	
Depth of anchor (h)	1	m	
Anchor area (a)	0.5625	m^2	
Anchor load (W)	5516.269	Newton	OK SAVE
Vertical force N	2064.453	Newton	

Remarks:

W = sd x g x h x a

$$N=\sqrt{\Sigma X^{\circ}2+\Sigma Y^{\circ}2}$$

Based on table 9, the diagonal force that occurs will be changed to a vertical force or lift force with a value of 2064.453N or 2.064kN with an angle of 89.988° to the X-axis and 0.012° to the Y-axis, both of these angles when added to an angle of 90°, thus the calculation done is true because it has been controlled by using a right angle. The vertical force must be resisted or resisted by using an anchor with an anchor area of 0.5625cm² with an anchor depth of 1 meter. Due to the lift dimensions, the lifts cannot be lifted because the anchor strength has a value of 20643N> 5516.269N, thus the construction structure is declared safe.

Resultant forces on the square model: The forces due to wind loads from various directions and held by each cable, will be transformed into forces, in detail will be described in the following table:

TABLE 10

The resultant force for square models

Segment (b)	Cable strength (Newton), N	Angle		Angle Resultant			
		Sin α°	Radians α°(Rd)	Cos β°	Radians β°(θ)	(Rx)	(Ry)
42	177.389	12.095	0.211	77.905	1.360	241.197	37.446
39	165.105	12.995	0.227	77.005	1.344	221.901	37.446
36	191.066	14.036	0.245	75.964	1.326	253.319	46.807
33	175.800	15.255	0.266	74.745	1.305	229.339	46.807
30	160.597	16.699	0.291	73.301	1.279	205.458	46.807
27	174.572	18.435	0.322	71.565	1.249	218.048	56.169
24	156.558	20.556	0.359	69.444	1.212	189.753	56.169
21	138.725	23.199	0.405	66.801	1.166	161.740	56.169
18	121.145	26.565	0.464	63.435	1.107	134.125	56.169
15	138.580	30.964	0.540	59.036	1.030	142.790	74.891
12	116.381	36.870	0.644	53.130	0.927	107.920	74.891
9	95.355	45.000	0.785	45.000	0.785	74.891	74.891
6	76.203	56.310	0.983	33.690	0.588	44.807	74.891
3	59.959	71.565	1.249	18.435	0.322	19.292	74.891
Σ	1947.434					2244.579	814.443

Angle Result			
strength (Rxy)	(Rxy) X°	(Rxy) Y°	Control θ°
2387.771	70.057	19.943	90.000

Remarks:

$$Rxy=\sqrt{\Sigma Rx^2+\Sigma Ry^2}$$

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

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

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

Based on table 10, the transformation of the force or resultant force into one diagonal force of 2387.771N or 2.387kN with an angle of 70.057° to the X-axis and 19.943° to the Y-axis, both of these angles add up to an angle of 90°, thus the calculation done is correct because it has been controlled by using a right angle.

Vertical forces in the square model: The forces that have been transformed into one diagonal force, then the next is to change the diagonal force to a vertical or lift force, in detail will be described in the following table:

TABLE 11
The vertical force anchor dimensions for square models

Resultant strength (Rxy)	Angle Resultant						Angle Result			
	(Rxy) Y°	Radians Y°	(Rxy) X°	Radians X°	(Rxy) X°	(Rxy) Y°	Vertical force N	(Rxy) X°	(Rxy) Y°	Control θ°
2387.771	70.057	1.223	19.943	0.348	2919.577	0.425599	2919.577	89.992	0.008	90.000

Anchor Dimension				Remarks:
soil density (sd)	1000	kg/m^3		W = sd x g x h x a $N=\sqrt{\Sigma X^{\circ}2+\Sigma Y^{\circ}2}$
Gravity (g)	9.8067	m/s^2		
Depth of anchor (h)	1	m		
Anchor area (a)	0.5625	m^2		
Anchor load (W)	5516.269	Newton	OK SAVE	
Vertical force N	2919.577	Newton		

Based on table 11, the diagonal force that occurs will be changed to a vertical force or lift force with a value of 2919.577N or 2.919kN with an angle of 89.992° to the X-axis and 0.008° to the Y-axis, both of these angles when added to an angle of 90°, thus the calculation done is true because it has been controlled by using a right angle. The vertical force must be resisted or resisted by using an anchor with an anchor area of 0.5625cm^2 with an anchor depth of 1 meter. Due to the lift dimensions, the lifts cannot be lifted because the anchor strength has a value of 2919.577N>5516.269N, thus the construction structure is declared safe, the anchor dimension is declared safe. More can be seen in Figure 8.

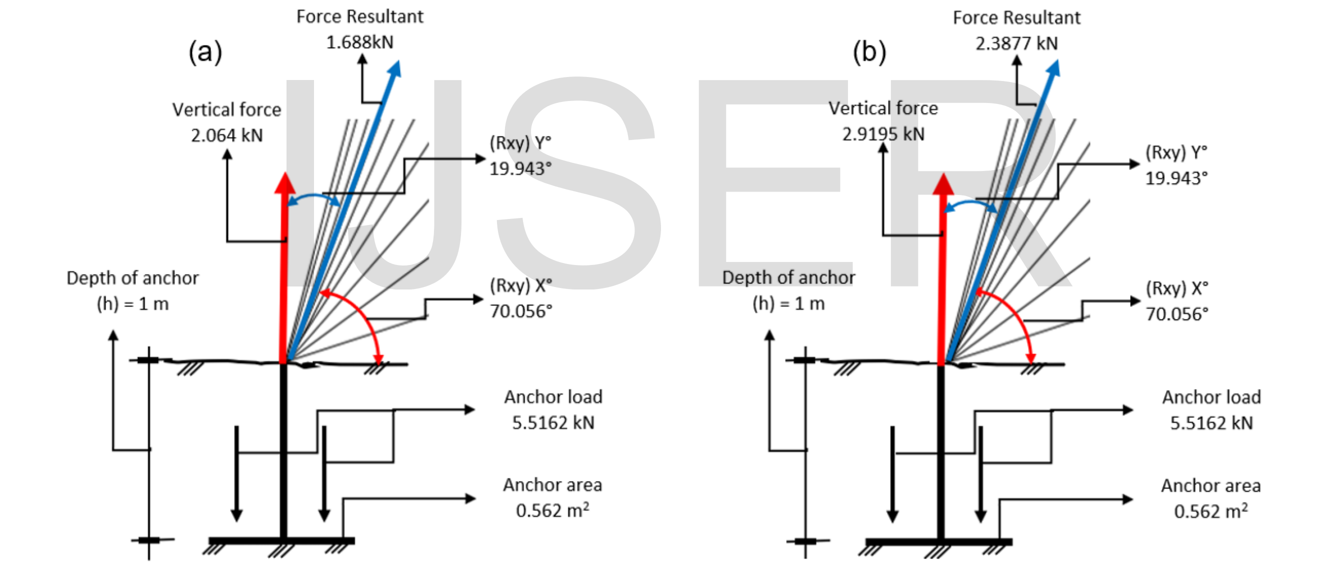

Figure 8 The resultant force and Anchor dimensions

Based on Figure 8, it is a detailed design of the anchor design that will be used against the lift force, in the two anchor models of the tower triangle and square models, the resultant angles of the two are relatively similar, not occurring in Figure 8.a and Figure 8.b, this is caused by the angular division of the 14 tower antenna towing cables are the same, both antenna models have the same height that is 42-meters in calculation theory and 40 for the common name, the difference that occurs is the force influence of the wind load only, thus the vertical force on Figure b.a is 1393,971N or 1.393971kN and Figure 8.b is 1971,373N or 1.971373kN. To withstand the lifting force, the anchor is made with the following dimensions: 1-meter anchor depth and 0.562 m^2 anchor area.

5 CONCLUSIONS

The structure of the triangle antenna radio tower construction is highly recommended, this is reasonable because the wind load that occurs from all directions does not increase, whereas in the square model has increased, this is evidenced by the vertical force it turns out heavier the square model with a value of 2064.453N compared to the triangle model only for 2919.577N.

By reducing the cross-sectional area in each segment, there will be a reduction in wind load, so that the increase in the wind load curve is very non-linear in each of the segments and very linear in each segment. Thus reducing the cross-sectional area is highly recommended to reduce wind loads.

The force that occurs on a pole, then the pole stands upright held by a group of cables according to the segment, then the cable will form a different angle. The force acting on the cables that converge at one point (anchor), then all these forces will be transformed into a vertical force or lift force and this lift force must be held by the anchor with the anchor force that must be greater than the lift force or vertical style.

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