DESIGN AND CONSTRUCTION OF METALLIC ARTIFICIAL PALM TREE FOR STREET LIGHT AND SURVEILLANCE CAMERA INSTALLATION

1. Buhari ABUBAKAR
Department of Mechanical Engineering,
Faculty of Engineering and Technology,
Nigerian Defence Academy, Kaduna.
buharinmec@gmail.com

2. GARBA, D. K
Department of Mechanical Engineering,
Faculty of Engineering and Technology,
Nigerian Defence Academy, Kaduna.

3. YAKUB Salihu Ochetega
Department of Mechanical Engineering,
Faculty of Engineering and Technology,
Nigerian Defence Academy, Kaduna.

4. ABUBAKAR UMAR
Nigeria Institute for Oil Palm Research,
Benin City, Nigeria

ABSTRACT: The design and construction of a metallic artificial palm tree for street lights and surveillance camera installation is an innovative solution to enhance urban landscapes while incorporating vital functionalities. This work aims to blend seamlessly with the surrounding environment, providing aesthetically pleasing street lighting and discreet surveillance capabilities. The metallic Artificial Palm tree will be engineered using advanced materials and technology, ensuring durability, weather resistance, and high structural integrity. It will mimic the appearance of a natural palm tree, featuring intricate details such as realistic bark texture, lush foliage, and graceful fronds. The design will consider all the environmental factors for smooth construction and installation of the product so as to provide efficient and eco-friendly illumination, promoting safety and enhancing the overall ambiance of the area. By combining the functionality of street lighting and surveillance cameras with the beauty of a natural palm tree, this work aims to create

a harmonious and technologically advanced urban environment. It will enhance the safety, aesthetics, and sustainability of public spaces, fostering a sense of community and well-being.

Keywords: Artificial Palm Tree, SolidWorks, Surveillance Camera, street light

1.0 INTRODUCTION:

Palm trees are not just majestic and iconic; they play a vital role in enhancing the beauty of our surroundings[1]. With their graceful stature and distinct features, palm trees bring a touch of tropical elegance to any landscape, making them an essential element for beautifying our environment. One of the primary reasons palm trees are crucial for enhancing aesthetics is their unique appearance[2]. With their tall trunks and lush, vibrant crowns, palm trees add a sense of grandeur and tranquillity to any setting. Whether they are swaying in the breeze along a beachfront or lining the streets of a city, palm trees create a visual spectacle that captures the imagination and instils a sense of serenity.

The design and construction of a metallic artificial palm tree for streetlight and surveillance camera installation, carried out in this work, is an innovative and creative approach to blending functionality with aesthetic appeal in urban areas. The artificial palm tree was a specially crafted structure that emulated the natural beauty of palm trees while serving practical purposes. Its primary objective is to provide a discreet and visually pleasing solution for streetlight and surveillance camera placement. By mimicking the appearance of a real palm tree, it seamlessly integrates into the urban landscape, creating an atmosphere that is both inviting and secure. The design process of this Tree involves careful consideration of various factors.

The materials to be selected should be typically sturdy metals, which ensure durability and longevity. The base of the structure should also be designed to be strong and stable, capable of withstanding wind forces and other environmental elements[3]. The streetlights and surveillance cameras, if installed on the artificial Tree, will add an element of functionality to the design. The streetlights will provide essential illumination, enhancing visibility and safety in the surrounding area, while the cameras will discreetly monitor the surroundings, enhancing security and deterring potential criminal activities.

In this research work, all the components were meticulously constructed and assembled at the Mechanical Engineering Workshop, Nigerian Defence Academy (NDA). The Trunk of the Tree was constructed with precision, replicating the organic patterns and textures found in real palm trees. The branches are strategically positioned to accommodate streetlights and surveillance cameras, ensuring optimal lighting and surveillance coverage.

2.0 MATERIALS AND METHOD

This work was carried out in three phases, they are:

i. Manual Design of the Components
ii. Laboratory tests and
iii. Fabrication and installation of the Tree according to design

4.1 Manual Design of the Components:

The tree branches, Trunk, and base of the Tree are the most essential constituents of the artificial Palm tree. The well-arranged leaves and branches bring out the aesthetic nature of the Tree. In designing the leaves and stems, For the structural property, each of the leaves/branches is assumed to be a cantilever beam fixed at one end and subjected to shear stress occasioned by the wind loads/pressure of the area [4]. Thus, these loads were evaluated considering the maximum wind speed of Afaka and its environs (where NDA is situated) for a couple of years, as gathered from the Nigerian Metrological Agency (NiMET).

2.1.1 Design theory

Trunk/Pole Design theory

Pole Design Requirements: The trunk design is primarily based on the types of loads acting on the pole. These loads include[5]:

- ✓ Dead Load: These are loads of the branches, the camera, and the wireless router at the top of the pole.
- ✓ Lateral Load: These are loads acting on the Trunk due to wind. This includes wind shear, which may be uniform or linearly acting along the Trunk's height or varying by a cubic polynomial function. To accommodate these loads, the Trunk must have adequate:

i) Axial Strength: The critical load capacity of the tower in the axial direction must be greater than the applied axial loads by a safety factor.

ii) Flexural Strength: The flexural strength of the pole must be greater than the bending strength, i.e., it can sustain the moment generated by the wind force. Also, it can maintain local buckling moments considering the pole's slenderness.

2.1.2 Wind Load calculation: Wind load along the Trunk is applied at extreme wind conditions, which is obtained at the hub height of 10m. At extreme wind conditions in NDA Main Campus, Afaka, the speed is 12 m/s; hence, we selected twice (25 m/sec). This could be converted into pressure according to the following equation[5]:

$$P = \frac{1}{2}\rho V^2 C_d \qquad (2.1)$$

Where P = Total pressure of the wind

ρ = Air Density=1.23 kg/m^3

V= 25m/sec

Cd= Drag Coefficient=3.

Accordingly, for Maximum trunk deflection, since we have assumed that the tree trunk behaves as a cantilever beam, the maximum trunk deflection is determined by applying uniform lateral load along its height. So, the maximum deflection δ at the free end is obtained by.

$$\delta \max = \frac{F\ L^3}{3EI} \qquad (2.2)$$

where;

F is the Force acting uniformly along the height of the tower,

L is the length of the Trunk,

E is the Modulus of elasticity of the Material,

I is the second moment of Area of the Trunk ($\Pi R^3 t$),

R is the mean diameter of the Trunk (D+d)/2 and

t is the Thickness of the trunk/pole.

The obtained δ must be less than 1% of the total height of the pole [5]. That is $\delta < 0.01$.

2.1.3 Base Plate Design Theory

The base is to be designed to be flexible with the ability to maintain a linear strain distribution**,** assuming that compression forces are concentrated at the center under the compression flange of the column [6]. Thus;

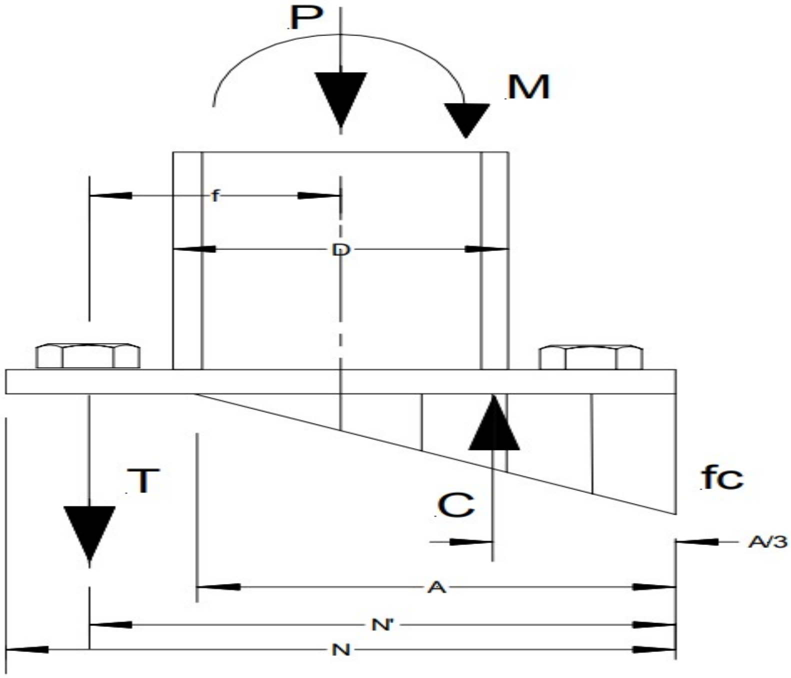

Figure 3.3 Base Plate Force Distribution

From Figure 3.3 above, let B = Base plate width

$$T+P = C = \frac{1}{2}(F_c\,AB) \qquad 2.3$$

$$T = \frac{M-(PD)/2}{F+(\frac{D}{2})} \qquad 2.4$$

$$Fc = \frac{2\,(T+P\,)}{A+B} \qquad 2.5$$

2.1.4 Foundation Footing Design Theory

For the foundation design, two loads are to be considered[7]. They are:

i. Dead load due to the overall weight of the Tree

ii. Wind loads due to the wind speed of the area

The dead load is the summation of load due to the branches, the Trunk, the base plate, and the concrete base. Its expression is as follows.

For Dead Load,

Load P_d = Σ Weight of the component multiplied by acceleration due to gravity

Hence, the summation of the weight in (Kg) is

i. Weight of the branches W_b (Kg)
ii. Weight of the Camera Wc
iii. Weight of the Palm Nut Wp
iv. Weight of the Street light Ws
v. Weight of the Trunck Wt
vi. Weight of the Base Plate Wbp

Therefore, load $P_d = (W_p + W_c + W_s + W_t + W_{bp})$ x $9.81 = 9.81\ \Sigma W_d$ (2.6)

Accordingly, for wind load, applying equation 2.1, Wind Load P_w is given by

$$P_w = \frac{1}{2}\rho V^2 C_d A \quad (2.7)$$

Hence, the overall load P is given by $P_d + P_w$

$$P = 9.81\ \Sigma W_d + \frac{1}{2}\rho V^2 C_d A \quad (2.8)$$

Therefore, SBC is defined as P/A

Where SBC is the Soil Bearing Capacity of the site

P is the overall load acting on the foundation and

A is the area of foundation

3.0 RESULT AND DISCUSSION

The overall result involves all the design calculations, as well as the stages carried out in the construction and installation of the components.

3.1 Soil Bearing capacity Test for foundation design

A soil sample of the site was obtained for the design of the foundation footing of the Artificial Palm tree. This is to determine its soil-bearing capacity and design the area for the foundation casting[8]. The test was conducted using a Direct Shear Box machine, and the results were obtained using the Terzerghi Principle[9], as presented below.

(a) **(b)**

Plate 3.1 a and b Soil Bearing Capacity Apparatus

Accordingly, the test results obtained are presented below:

i. Mold Dimension = 0.06m by 0.06m by 0.025

ii. Cross-Sectional Area= **0.0036 m^2**

iii. The volume of the Mold is = **0.00009 m^3**

iv. Force (KN) = **(9.81*NL)/1000**

v. Normal Stress **= Force/ Cross-sectional area**

vi. Shear Stress = [(Dial gauge reading) x (Machine Calibration factor)] ÷ (Mold Cross-sectional area)

vii. Machine Calibration factor = **0.0043**

viii. Unit weight of the soil (Ɣ) = **18.92KN/m^3** and

ix. Dept of the foundation (D_f) = **2m**

Table 3.1 Test result from Direct Shear box machine

Test No.	Normal load (kg)	Dial gauge reading (KN)	Force (KN)	Normal Stress (KN/m^2)	Shear Stress (KN/m^2)
1	10	31	0.0981	27.25	37.03
2	20	37	0.1962	54.50	44.19
3	30	43	0.2943	81.75	51.36

From the above table, a graph of Shear stress against Normal stress was plotted on the same scale as shown below to get Apparent cohesion (C) and Friction Angle (Ø).

C is the point at which the graph cut the Y-axis, while Ø is the angle at which the graph made with the X-axis and is used to trace the Terzaghi factors from the chart shown below:

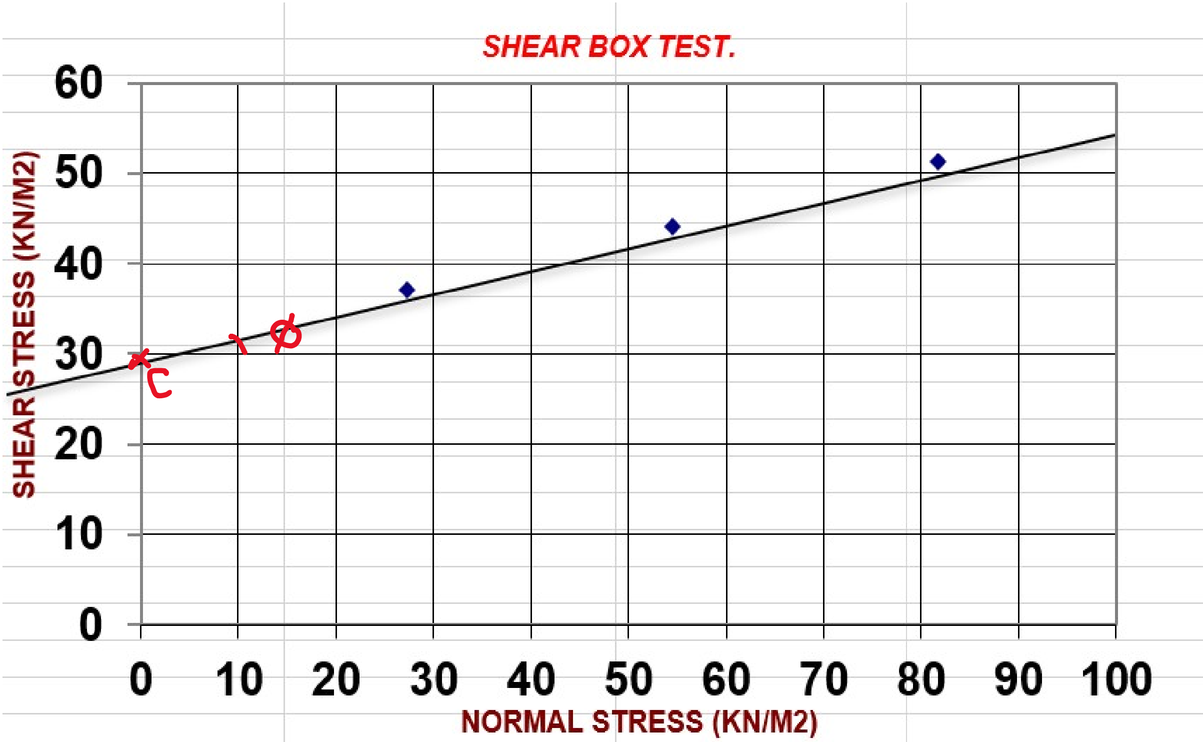

Figure 3.2 Graph of Shear Stress against Normal Stress

Terzaghi's Bearing Capacity Factors

ϕ'	N_c	N_q	N_γ	ϕ'	N_c	N_q	N_γ
0	5.70	1.00	0.00	26	27.085	14.210	9.84
1	6.00	1.10	0.01	27	29.236	15.896	11.60
2	6.30	1.22	0.04	28	31.612	17.808	13.70
3	6.62	1.35	0.06	29	34.242	19.981	16.18
4	6.97	1.49	0.10	30	37.162	22.456	19.13
5	7.34	1.64	0.14	31	40.411	25.282	22.65
6	7.73	1.81	0.20	32	44.036	28.517	26.87
7	8.15	2.00	0.27	33	48.090	32.230	31.94
8	8.60	2.21	0.35	34	52.637	36.504	38.04
9	9.09	2.44	0.44	35	57.754	41.440	45.41
10	9.60	2.69	0.56	36	63.528	47.156	54.36
11	10.16	2.98	0.69	37	70.067	53.799	65.27
12	10.76	3.29	0.85	38	77.495	61.546	78.61
13	11.41	3.63	1.04	39	85.966	70.614	95.03
14	12.11	4.02	1.26	40	95.663	81.271	115.31
15	12.86	4.45	1.52	41	106.807	93.846	140.51
16	13.68	4.92	1.82	42	119.669	108.750	171.99
17	14.56	5.45	2.18	43	134.580	126.498	211.56
18	15.52	6.04	2.59	44	151.950	147.736	261.60
19	16.56	6.70	3.07	45	172.285	173.285	325.34
20	17.69	7.44	3.64	46	196.219	204.191	407.11
21	18.92	8.26	4.31	47	224.549	241.800	512.84
22	20.27	9.19	5.09	48	258.285	287.855	650.67
23	21.75	10.23	6.00	49	298.718	344.636	831.99
24	23.36	11.40	7.08	50	347.509	415.146	1072.80
25	25.13	12.72	8.34				

Plate 3.1 Terzaghi's Bearing Capacity Factors

From the graph, C is approximately 29 while Ø is around 15 degrees, and the Terzaghi factors Nc, Nq, and Nγ are as shown in the table below[10]:

Table 3.2 Terzaghi's Bearing Capacity Factors

C	Ɣ	Ø	D_f	Nc	Nq	Nγ	B	F.S
29	18.92	15	2	12.86	4.45	1.52	1	3

Applying the Terzaghi equation for square footing[11],

$$Q(ult) = 1.3C\,N_c + ƔD_f\,N_q + 0.4ƔBN_\gamma \quad (4.1)$$

Substituting the values above, Q(ult) = 664.71336

Q(safe) = Q(ult)/ FS = 664.71336/3 = **221.51 KN/m^2**

We use 220 KN/m^2

3.2 Design Calculations for the Tree Components

Below are the design calculations that will guide in the construction of the Tree

Data

i. Maximum wind speed for Afaka General Area in the last ten years (m/s) =12

ii. Adopted wind speed (m/s) = 25

iii. Length of Tree (m) = 10

iv. Inner radius of tree trunk (m) = 0.1083m

v. The external radius of tree trunk (m)= 0.1143m

vi. Branch length (m) = 2 each

vii. Branch weight (kg) = 6.5 each

viii. Camera weight (kg) = 7.5

ix. Palm nut weight (kg) = 5 each

x. Weight of Trunk (kg) = 450

xi. Weight of base plate (kg) =38

xii. Adopted wind speed (m/s) = 25

xiii. Density of air (kg/m^3) = 1.225

xiv. Drag coefficient C_d = 3

xv. Length of Tree (m) = 10

xvi. Inner radius of tree trunk (m) = 0.1083m

xvii. The external radius of tree trunk (m)= 0.1143m

xviii. Soil Bearing capacity SBC (KN/m^2) = 220

xix. Area of engagement $A = \pi r^2$ = **12.568 m^2**

xx. Dead Load $P_d = 9.81\ \Sigma W_d$ = 588.5 x 9.81 = **5,773.185 N**

xxi. Live Load $P_w = \frac{1}{2}\rho V^2 C_d A$ = **28,867.125 N**

xxii. **Load P = 5,773.185 + 28,867.125 = 34,640.31 N = 34.64 kN**

Considering the data above, the components of the Tree will be designed to withstand the load and pressure. Thus;

Component	**Formulas**	**Design**
Foundation footing (Concrete)	Fr square footing, ✓ Area = L^2 ✓ Load (P)= $P_d + P_w$ ✓ SBC = Load/ Area ✓ Safety factor SF = 2	From the relation SBC = Load/ Area Therefore, Area = Load/ SBC = 34.64 /220 = 0.1574545 Hence, length L = sqr (0.1574545) = 0.396 Applying S F = 2,

		L= 0.396 X 2 = 0.7936 **We select 1m**
Pull down bolt (Y32 steel rod selected)		1. Bolt Size: Considering the load of 34.64 kN, the minimum bolt size would be an M20 bolt. We select M32 bolts with a diameter of 32mm, which provides sufficient strength to handle the load. 2. Anchoring Depth: For a 2-meter depth foundation, anchoring the bolt at least 1.5 times the depth is recommended. So, we select an anchoring depth of 3 meters. 3. Thread Design: we use a coarse thread pitch for the bolt, such as 2.5mm or 3mm, to ensure a secure grip and a minimum engagement length of at least five times the bolt diameter, which in this case would be 100mm. 4. Nut and Washer: We use an M32 nut and a hardened washer to match the bolt size and material. A grade 8 nut and a hardened steel washer were selected for this application.
Base plate (Iron manganese Alloy selected)	For square base plate, ✓ Area = L^2 ✓ L= 0.5m ✓ Load (P)= $P_d + P_w$ ✓ Maximum stress = total load ÷ area	From this relation, Maximum stress = Total load ÷ area Therefore, = 34.64 / $(0.5)^2$ = 138.56 kN/ m^2 However, the tensile strength of iron manganese alloy is **350 MPa,** which is far higher than the maximum stress of 138.56 kN/ m^2 to be applied on the base plate. Hence, the design is appropriate.
Trunk design (Galvanized iron round pipe selected)	For a trunk of 10m high, ✓ external diameter D (9	From this relation, Maximum stress = Total load ÷ Cross-sectional area Therefore,

	inches) = 228.6 mm ✓ internal diameter d (9inch – 6mm) = 216.6 mm ✓ Cross-sectional area = π * $(D/2)^2 - (d/2)^2)$ ✓ Stress = Total Load ÷ Cross-sectional Area ✓ Load (P)= $P_d + P_w$	= 34.64 / (0.042) = 824.762 kN/ m^2 But the tensile strength of Galvanized steel is **521.277 MPa,** which is far higher than the maximum stress of 824.762 kN/ m^2 to be exerted on the Tree trunk. Hence, the design is appropriate.

3.3 Tensile Strength Test

A laboratory test for the tensile strength of the selected samples was also carried out[12]. This is to reconfirm that the materials purchased for the construction are in tandem with the result obtained from the design. Hence, the test is presented below:

Plate 4.6 Galvanizes steel before the tensile test

Plate 4.7 Galvanizes steel after tensile test

Result data

Total length (Lt) = 100mm

Original gauge length (Lo) = 25mm

Final gauge length (L) = 29mm

Original width (Wo) = 4.7mm

Final width (W) = 3.7mm

Original thickness (to) = 4mm

Final thickness (t) = 3.2mm

Load at failure (Pmax) = 9800 N

Ultimate Tensile Strength is given by the equation $\sigma max = \frac{Pmax}{Ao}$ (2.9)

But Ao = Wo x to = 18.8 mm^2

Hence σmax $= \frac{\mathbf{9800}}{\mathbf{18.8}}$ = **521.277 MPa**

= **5.21 X 10^8 Pa**

Accordingly, Axial Strain is given by $\varepsilon = \frac{\Delta L}{Lo}$ (2.10)

Hence $\varepsilon = \frac{4}{25}$ = **0.16**

Meanwhile, Elastic Modulus E $= \frac{\sigma}{\varepsilon}$ (2.11)

Hence E $= \frac{\sigma}{\varepsilon} =$ **5.21 X 10^8 / 0.16**

= **3.26 x 10^9 Pa (Modulus of Elasticity of the Material)**

3.4 Material selection based on designed results[13][14][15]

Table 2.0 Material Selection Table

s/n	Tree component	Proposed Materials	Selected material	Reason of selection	Yield Strenght
1	Leaves	i. Mild steel ii. Galvanize steel iii. Stainless steel iv. Fiber material	0.7mm Mild steel sheet	Ductility, availability, machinability, and cost[16]	250-350 MPa
2	Petiole (stem)	i. Y16 mild steel rod ii. 16mm galvanized round pipe iii. Stainless steel round pipe	Y16 mild steel rod	Versatility, weldability, availability, and cost[17]	250-350 MPa
3	Trunk	i. Mild steel pipe ii. Stainless steel pipe	Galvanize iron pipe	Strength, corrosion resistance, and cost[18]	200-400 MPa

		iii. Galvanize iron pipe iv. Wood v. Concrete			
4	Trunk bottom (Bucket-like)	i. Mild steel sheet ii. Aluminum sheet iii. Stainless steel sheet	Aluminum sheet	Heat resistance and corrosion resistance[19]	137-483Mpa
5	Trunk base (Base Plate)	i. Mild Steel ii. Iron manganese alloy iii. Galvanize steel plate	Iron manganese alloy	Strength, Toughness, corrosion resistance, and cost[20]	200- 500Mpa

3.5 Construction of the Palm Tree

The step-by-step procedures performed in the construction of the artificial palm trees are itemized below:

Step I: Leaves and Branch Construction

i. 4X8 feet length of 0.7mm steel sheet was obtained
ii. A natural palm tree leave was equally obtained from a life palm tree
iii. The raw leaves were placed on top of the sheet and traced to bring out their shape
iv. A cutting scissors was used to cut the traced pattern of the leaves
v. A mold was also used to create the stem pattern in the middle of the sheet
vi. A flat metal bar was used on each leave to produce the V-shape on the leaves

vii. A Y16mm steel rod was welded at the center of the sheet/leaves to form the stem

viii. The worked sheet was bent to create an arc of a leaf shape.

ix. A quarter rod was welded at both sides of the leaves for brazing and separation purposes

x. A body filler was applied to the leaves sheet to give it a better shape and address possible corrosion

xi. The whole leaves and branch were painted green color, as shown in the figure below:

Plate 3.5 Artificial palm leaves

Step II: Trunk Construction

i. A 9-inch by 6mm thick galvanized iron round pipe was obtained in two segments (6m and 5m long)

ii. 1m length was removed from the 5m length pipe using cutting stone to remain only 4m length

iii. The 9inch diameter of the 1m pipe was trimmed down to $8^3/_4$ inch slim pipe to be used as an internal socket connecting the two pipes

iv. The slim pipe was inserted into the two pipes midway, forming a socket joint of a total length of 10m

v. A plumb was used to align the pipe before final welding

vi. The pipe was then welded at the joint of the two end pipes and equally rivet welded at various positions, as shown in the figures below:

(a) (b)

(c) (d)

Plate 3.6 Socket joint fabrication

Step III: Base plate and foundation bolt Construction

i. 20 inches by 20mm Iron Manganese Alloy was obtained as a base plate
ii. Four holes of 35mm diameter were created using gas cutting machine at an interval of 200mm from the midpoint of the plate
iii. Four pieces of Y32mm by 6 feet steel rod were also obtained
iv. The rods were threaded to M32 at the top end of the rods for about 4inch (102mm) length
v. All four rods were bent at the other end to about 6-inch (152mm) length
vi. Six rings were also constructed with Y12mm steel rod and welded to the Y32mm at equal interval
vii. Another Y12mm steel rod was used to build a foundation basket of 1square meter with the aid of a binding wire
viii. A foundation base plate and anchor bolt were built as shown in the figure below:

Plate 3.7 Base plate and foundation board

Step IV: Construction of Foundation

i. One square meter by 2m depth foundation hole was dogged

ii. The base of the hole was blended with a concrete mixture to about 12 inches (305mm)

iii. The already constructed basket was placed on top of the blending.

iv. The constructed foundation bolt is also placed at the center of the basket and tied with binding wire.

v. Several sizeable stone rocks were inserted into the hole, and a concrete mixture was added to a reasonable level.

vi. Plumb was used to adjust the position of the foundation bolt to align vertically.

vii. Further concrete mixture was finally put up to the surface level. Figure 4.22 shows the constructed foundation base.

Plate 3.7 Hold down bolt and Basket Assembly and Casting.

Plate 3.8 Foundation casting

3.6.5 Palm Tree and surveillance system assembly

To assembly the components of the palm tree, the steps are as follows:

Step I

i. With the help of spirit bob and square plumbs, the base plate was welded to the end of the round pipe.
ii. Eight brazing plates were also welded to the pipe and the base plate at equidistance to each other.
iii. The pipe was painted in two segments (Green on the upper side and dark ash on the lower side)
iv. With the aid of a motorized forklift, the pipe was raised and fixed to the foundation bolt.
v. A Plumb was used again to align the pipe vertically before tightening the foundation bolts.
vi. A scaffold was assembled around the erected pipe for easy access to the top of the pipe.
vii. With the help of a rope, the leaves were taken up and assembled, as shown in the figure below:

Plate 3.9a Erection of tree trunk

Plate 3.9b Alignment of the tree trunk

Plate 3.9c Assembling of leaves

Plate 3.9d Assembled Palm tree

4.0 CONCLUSION

This novel work designed and constructed an artificial Palm Tree. In line with its objectives. The successful construction of an artificial palm tree has proven to be a remarkable achievement in combining functionality and aesthetics. The designed results of this palm tree have surpassed expectations, offering a multitude of benefits to the environment, community, and overall visual appeal. By seamlessly integrating this lifelike palm tree into its surroundings, we have created a harmonious and natural landscape that captivates the imagination. The realistic design, down to the finest details, ensures that the artificial palm tree blends in seamlessly, maintaining the beauty and integrity of the environment. Not only does this artificial palm tree provide a stunning visual element, but it also serves a practical purpose. The ability to incorporate energy-efficient LED lights within the Tree's structure will ensure efficient and eco-friendly illumination of public spaces. This innovative feature not only enhances safety but also contributes to reducing energy consumption and operational costs.

Additionally, the discreet placement of surveillance cameras within the artificial palm tree enhances security measures without compromising the aesthetic appeal. This strategic positioning helps create a safer environment, promoting peace of mind for residents and visitors alike. Furthermore, the successful construction of this artificial Tree showcases our commitment to sustainability. With durable and weather-resistant materials, this Tree requires minimal maintenance, reducing expenses and conserving resources in the long run. By opting for an artificial palm tree instead of real ones, we are also preserving natural habitats and ecosystems.

In conclusion, the results of this artificial palm tree design have demonstrated the incredible potential for sustainably combining functionality and aesthetics. This creation highlights the importance of innovation in enhancing our environment, community, and overall visual appeal. Through this achievement, we have not only beautified our surroundings but also contributed to creating a greener and more sustainable future.

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