Pultruded FRP Cooling Tower - Design, Development and Validation

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Abstract- **Cooling tower is an essential part of any industry or power plant, which is used to cool the condenser circulating water or hot water by the principle of evaporation cooling. The whole system may fail when there is failure or absence of cooling tower.**

According to cooling tower industries and research scientist working in the field of cooling towers, it is observed that conventional cooling towers have fewer life cycles and high cost. Hence FRP cooling towers are introduced to increase tower's life cycle. The requirement of industries is to produce a structural FRP cooling tower (like M.S or Timber cooling tower) instead of package FRP cooling tower which can be made up to 14 ft X 14 ft only. Hence by comparing M.S, Timber & FRP it can be observed that FRP towers are less costly, structurally stable and also have more life cycles. However package FRP cooling tower cannot be erected for sizes greater than 14 ft X 14 ft, we in collaboration with the company have introduced the structural FRP cooling tower to solve these problems.

So for the first time FRP cooling tower is developed in association with 'M-Square Engineers', Pune-38.

Keywords - **Cooling tower, Pultrusion, FRP, Drift Eliminators, Fills, etc.**

I. Problem Definition:

To make a prototype of FRP cooling tower of size 900 X 900 X 1200 mm and to check the structural stability with approximate loadings by using software and also by hand calculations and validate the design and results.

II. Introduction

A cooling tower is an equipment used to reduce the temperature of hot water by extracting heat from water and emitting it to the atmosphere by the principle of 'evaporative cooling'.

III. Various Types of Mechanical Draft Cooling Towers

Mechanical draft towers have large fans to force or draw air through circulated water. The water falls downwards over fill surfaces, which helps to increase the contact time between the water and the air - this helps to maximize heat transfer rate between the two. Cooling rates of mechanical draft towers depend upon various parameters such as fan diameter and speed, fills for system resistance etc.

Mechanical draft towers are available in a large range of capacities. Towers can be either factory built or field erected – for example concrete towers are only field erected.

Many towers are constructed so that they can be grouped together to achieve the desired capacity. Thus, many cooling towers are assemblies of two or more individual cooling towers or "cells." The number of cells they have, e.g., an eight-cell tower, often refers to such towers. Multiple-cell towers can be linear, square, or round depending upon the shape of the individual cells and whether the air inlets are located on the sides or bottoms of the cells.

The three types of mechanical draft towers:

- **Forced draft cooling tower:**

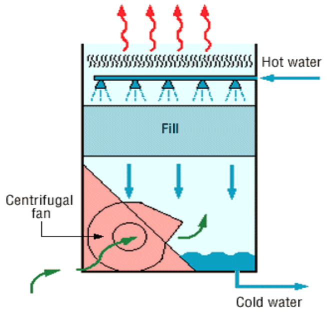


Figure-1 Forced Draft Cooling Tower

- **Induced draft cross flow cooling tower:**

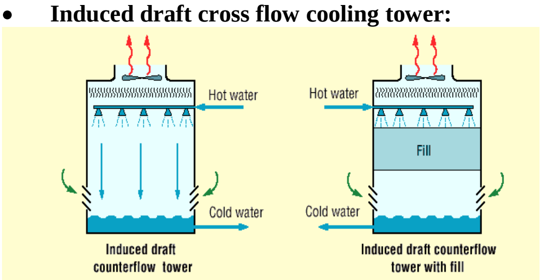


Figure-2 Induced Draft Counter Flow Cooling Tower

- **Induced draft counter flow cooling tower:**

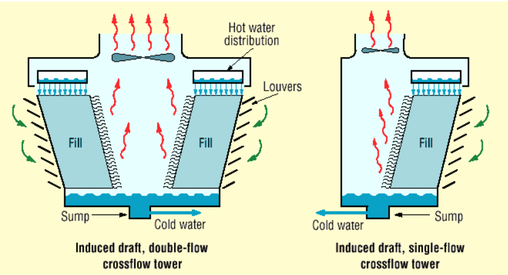


Figure-3 Induced Draft Cross Flow Cooling Tower

Existing Different Types of Cooling Towers

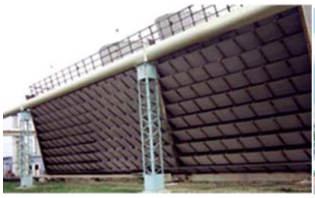


Figure-4 Timber made Cooling Tower

Figure-5 RCC made Cooling Tower

IV. What is FRP?

FRP stands for Fibreglass-Reinforced Plastics. Other terms that are used interchangeably with FRP are Reinforced Thermoset Plastic (RTP), Reinforced Thermoset Resin (RTR) and Glass-Reinforced Plastic (GRP).

All of the above mentioned terms should not be confused with reinforced thermoplastic which is entirely different. There is a wide selection of thermoset resins available for most corrosion resistant applications. Unlike thermoplastics, thermoset plastics have a highly cross linked molecular structure. The result is a flexural, tensile strength, and temperature performance.

V. Pultrusion Process

Pultrusion is the mechanized process to manufacture GRP structures. Pultrusion uses the extrusion principle of producing having constant cross section to give strength.

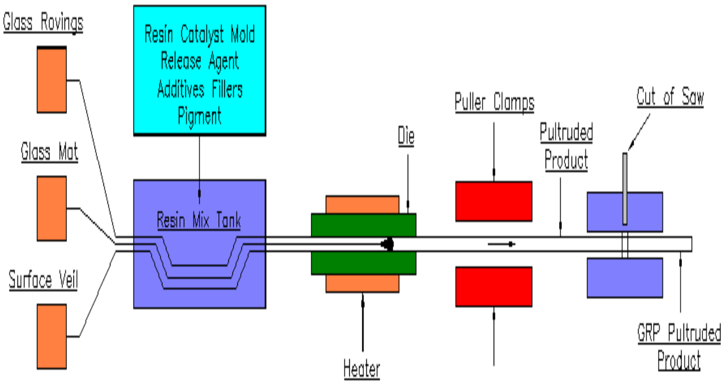


Figure-6 Pultrusion Process

In Pultrusion, the Glass Fibre reinforcements are pulled by means of moving clamps, through a resin bath and then through a die, where it is formed into the required shape. The die is preheated by electric motors, thermal fluids or microwave. The formation of profile, curing and consolidation of the section all takes place in the die. The block diagram of the pultrusion process is as shown in fig-6.

The glass fibres used may be in the form of ravings or strand mats. The other materials that go into the product are resins, fillers, lubricants, pigments for colours, surfacing veils and mats, etc. Mostly phenolic, polyesters and epoxy resins are used for bonding.

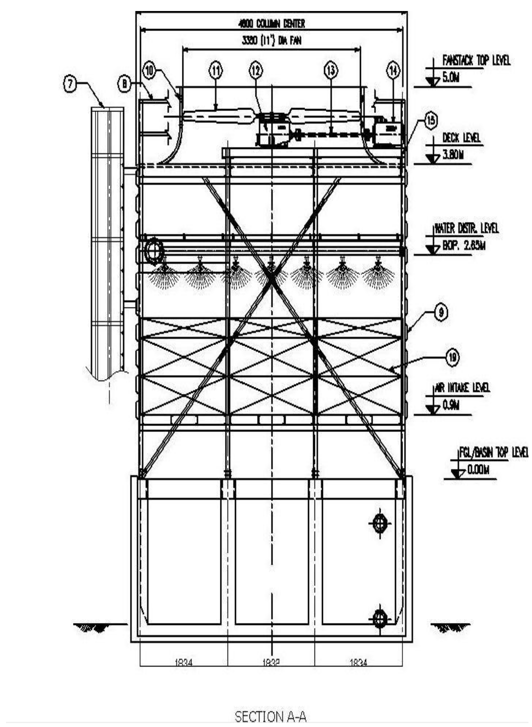
Mechanical Properties of Pultruded Profiles Vs Other Structural Materials

Mechanical Properties	Pultruded FRP	Rigid PVC	Mild Steel	Stainless Steel	Wood
Tensile Strength (N/mm2)	382	44	340	340	80
Flexural Strength (N/mm2)	468.3	70	380	380	12
Flexural Modulus (N/mm2)	22489	2400	196000	196000	700
Izod Impact (Kg.m/cm)	2.15	0.09	1.5	0.53	-

Physical & Chemical Properties of Pultruded Profiles Vs Other Structural Materials

Physical & Chemical Properties	Pultruded FRP	Rigid PVC	Mild Steel	Stainless Steel	Wood
Thermal Conductivity (Kcal/hr/m2/ C)	24.4	6.4	1220	732.00	0.4
Coeff. of Linear Expansion (cm/cm C) x 10-6	5.2	37	8	10	1.7
Safe Working Temp. (C)	130	55	600	600	160
Flame Resistance	Good*	Poor	Excellent	Excellent	Poor
Corrosion Resistance :					
a. Acidic	Excellent	Good	Poor	Excellent	Poor
b. Alkaline	Good	Fair	Good	Excellent	Poor
c. Solvents	Fair	Poor	Good	Excellent	Fair

VI. **CAD Modelling**



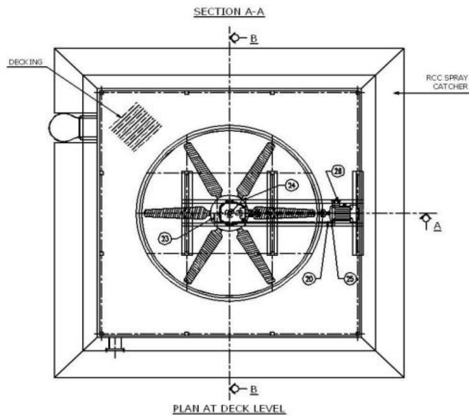


Figure-7 CAD Drawings

VII. **CATIA Modelling**

- **Details**:
  1. Overall Dimensions – 900 x 900 x 1200 mm
  2. Motor Specifications – 1ϕ , 0.5 HP, 1440 rpm
  3. Fan Size – 300 mm in diameter

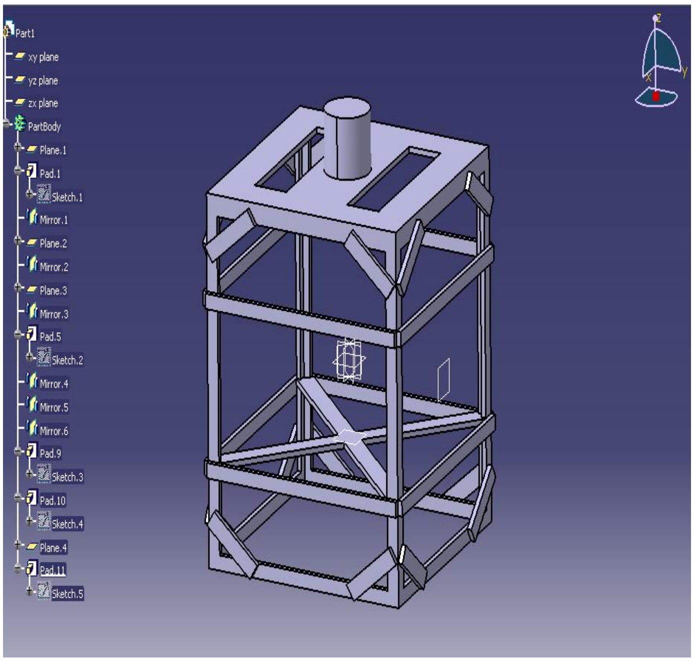


Figure-8 CATIA model (3ft x 3 ft)

VIII. Design and Analysis

Comparison and validation by using ANSYS

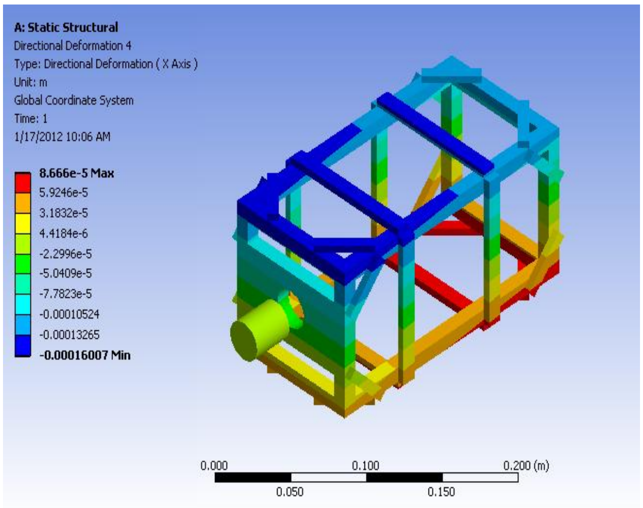


Figure-9 Analysis of 3 ft x 3 ft Model

Design of a 16 ft x 16 ft Cooling Tower

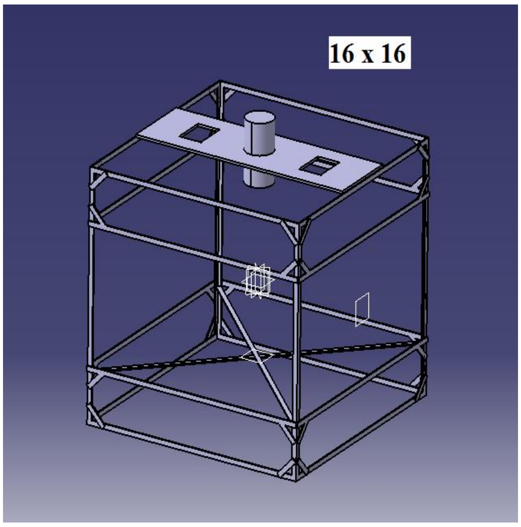


Figure-10 CATIA model (16ft x 16 ft)

Thermal Design

No.	Parameter reference	Units	Cooling tower (CT)
1.	Dry bulb temperature	°C	29
2.	Wet bulb temperature	°C	28
3.	CT inlet temperature	°C	42
4.	CT outlet temperature	°C	31
5.	Average water flow	m^3/hr	500

Readings for 16 ft x 16 ft Cooling Tower

Water flow rate	-	500 m^3/hr
Hot water temperature (HWT)	-	42 ^OC
Cooling water temperature (CWT)	-	31 ^OC
Wet bulb temperature (WBT)	-	28 ^OC
Exit air temperature	-	38 ^OC

(Referring Psychometric Chart)

Enthalpy at 38 ^OC = 150.66 KJ / Kg of air

Enthalpy at 28 ^OC = 89.95 KJ / Kg of air

Δ Enthalpy = 60.708 KJ/Kg of air

Kcal to remove = 500 X ΔT X 1000 Kcal/hr
= 500 X 11 X 1000
= 55, 00,000 Kcal / hr
= 55, 00,000 X 4.186 KJ / hr
=23023000 KJ / hr

Air required in Kg/hr = 23023000 (KJ / hr) / [Δ Enthalpy (KJ / Kg of air)]
=23023000 / 60.708
=379241.6156 Kg / hr
= 379242 Kg / hr

Sp. Volume (at 280 ^OC WBT) = 0.8860 m^3 / Kg

Validation by using ANSYS – 16 ft x 16 ft

Model (C4) > Static Structural (C5) > Solution (C6) > Results

Object Name	Equivalent Stress	Total Deformation	Maximum Principal Stress	Maximum Shear Stress
State	Solved			
Scope				
Scoping Method	Geometry Selection			
Geometry	All Bodies			
Definition				
Type	Equivalent (von-Mises) Stress	Total Deformation	Maximum Principal Stress	Maximum Shear Stress
By	Time			
Display Time	Last			
Calculate Time History	Yes			

Use Average	Yes		Yes	
Identifier				
Results				
Minimum	3.3245e-011 MPa	0. mm	-3.1223 MPa	1.8778e-011 MPa
Maximum	30.547 MPa	529.4 mm	30.579 MPa	15.661 MPa
Information				
Time	1. s			
Load Step	1			
Substep	1			
Iteration Number	1			

Model (C4) > Static Structural (C5) > Solution (C6) > Total Deformation > Image

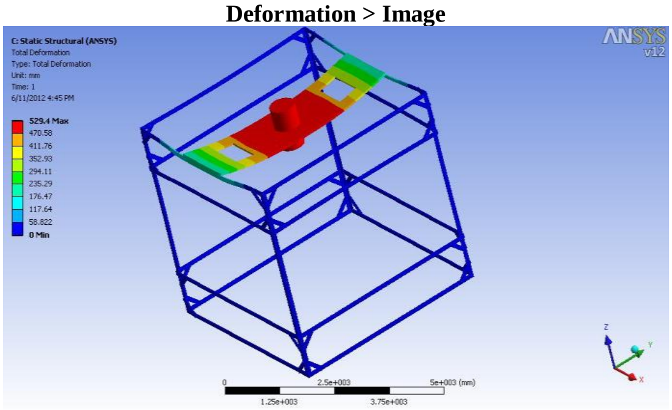


Figure-11 Total deformation

Model (C4) > Static Structural (C5) > Solution (C6) > Maximum Shear Stress > Image

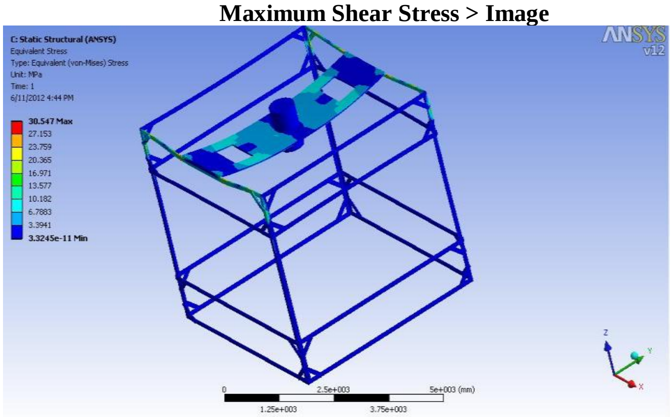


Figure-12 Maximum shear stress

IX. Worksheet of key technical specifications

No.	Parameter	Units	Cooling tower Reference
1.	Type of cooling tower		Counter Flow Natural Draft
2.	Number of tower		1
3.	Number of cells per tower		1
4.	Water flow	m^3/hr	500
5.	Pumping power	kW	-
6.	Pumping head	m	-
7.	Fan power	kW	0.375
8.	Design hot water temperature	^0C	42
9.	Design cold-water temperature	^0C	31
10.	Design wet bulb temperature	^0C	28

X. Prototype - 3 ft x 3 ft

Figure-13 Prototype – 3 ft x 3 ft
(Presently at MMCOE, Pune-52)

XI. Cost Comparison

Pultruded Gratings with M.S. & S.S. for the quantity of 100 sq. Meters

Various Costs in Rs.	Material used for the Gratings		
	GRP	M.S.	S.S.
Raw Material Wt., Kg.	1150	4500	4550
Raw Material Cost	230000	90000	500500
Galvanizing Cost	Na	45000	Na
Welding Charges	Na	54000	182000
Accessories / Hardware	250	300	1400
Transportation Cost	2000	2000	2000
Installation Charges	1600	3300	4000
Total =	235000	199100	694450
Total Life, Years	20	5	15
Life Cycle per year	11750	39820	46297
Cost in a span 0f 20 years	235000	796400	925940

XII. Conclusion

- **Structural Design:** Model is analysed by using ANSYS software and it is observed that stresses induced in the model are within permissible limits.
- **Thermal Design:** According to case study even though the material of the structure is changed thermal properties/design does not get much affected.
- Weight of the proposed structure is considerably reduced and it is compact.
- Aesthetical design is improved.
- Life cycle of the structure increases with the reduced cost.

Hence, it will be preferred to use the Pultruded FRP Cooling Tower over conventional cooling towers.

XIII. References

- Hand book – Bureau of Energy Efficiency
- Power Plant Engineering by Prof. D.K.Chavan, Std. Book House, New Delhi.
- Power Plant Engineering by R.K.Rajput.
- Mechanical Design by Shigley, Mcgrawhill Publication
- Shivaraman T. Shiriram Towertech Ltd. Selection and Design of Cooling towers
- www.shiriramtowertech.com
- www.compositecooling.com/images/frpcomponents.pdf
- ASHRAE Handbook