IFERP
connecting engineers... developing research

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 8, August 2021

Alternative Material Selection and Analysis of Solar Panel Mounting Structure

[1]Sumit Kangane, [2]Sumedh Kirve, [3]Sumedha Thorat, [4]Bhagyashree Tanpure, [5]Panvanraj Khade

[1][2][3][4] Student, Department of Mechanical Engineering, Marathwada Mitra Mandal's College OF Engineering, Pune, India
[5] Assistant Professor, Department of Mechanical Engineering, Marathwada Mitra Mandal's College OF Engineering, Pune, India

***Abstract---* One of the applications of using solar energy is photovoltaic systems. So in order to install a durable photovoltaic system that will last for over a desirable period of time and work efficiently, selecting the most suitable components is crucial. Although it represents only a small proportion of the overall construction, the mounting system carries a heavy responsibility, providing the necessary support for the most important and expensive part of the system – the solar modules. Thus the paper brings forth various alternative materials to the conventional ones, loads the structure is subjected to, design and analysis of the structure using CAD, ANSYS and STAAD Pro and then the cost analysis of the same.**

***Index Terms*— ANSYS, Mounting Structure, Photovoltaic System, STAAD Pro, SOLIDWORKS**

I. INTRODUCTION

Photovoltaic system surely consists the expensive component- solar modules but the responsibility of supporting the modules is solely carried out by the structure on which modules are mounted. Hence the design and material of the structure should be promising in all the factors. The paper discusses various materials right from the steels to the composites, various loads the structure has to withstand, analysis by applying the materials and loads with creating model in CAD and followed by analysis using ANSYS and STAAD Pro to determine pressure distribution on the solar panel area and structure. It also presents the estimated cost of the structure. This paper hence brings forth the promising alternatives to the conventional practices in the photovoltaic mounting system.

II. MATERIAL STUDY

Various materials were studied and the ones that fit to the requirements are shortlisted below with their properties, advantages and limitations.

Stainless Steels

Stainless steels are iron-base alloys that contain a minimum of about 12% Cr, the amount needed to prevent the formation of rust in unpolluted atmospheres. They achieve their stainless characteristics through the formation of an invisible and adherent chromium- rich oxide film. This oxide forms and heals itself in the presence of oxygen.

Aluminium Alloys

An aluminum extrusion alloy is simply a mixed metal, made from a predetermined mixture of one or more elements together with aluminum. Alloying aluminum with elements such as manganese, magnesium, copper, silicon, and/or zinc, produces a variety of desirable characteristics, including corrosion-resistance, increased strength, or improved formability.

Galvanized Steel

Galvanized Steel is carbon steel coated with zinc on two sides by a continuous hot-dip process by immersing the metal in a bath of molten zinc at a temperature of around 450 °C (842 °F).This method tightly adheres the coating to the steel with an iron-zinc alloy bonding layer formed by a diffusion process while the heated steel strip is in contact with the molten zinc. One of the drawbacks of Galvanized is that if the Zinc coating is scratched off the steel, the Steel is left unprotected, and is subject to failure.

Galvalume steel

Essentially it is 55% aluminum to 45% zinc alloy coated sheet steel. This blend is what makes it different than Galvanized Steel which is covered with a zinc-only coating. With Galvalume the aluminum and zinc act together to resist corrosion and provide barrier protection on the roofing surface. Another great feature of Galvalume Steel is that as the material is cut, the Zinc and Aluminum combine to prevent corrosion at any exposed edges.

Composite materials

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. The two constituents are reinforcement and a matrix. Pultrusion is a

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 8, August 2021

manufacturing process for converting reinforced fibers and liquid resin into a fiber-reinforced plastic, also known as fiber-reinforced polymer (FRP).

Material Comparison

After further study of above materials and all the factors such as good sustainability, easily manufacturable and available and cost effectiveness; following materials are short listed.

Table No. I Comparison of Materials

Material	***Stainless Steel***	***Aluminium Alloy***	***Composites***
Density (g/cc)	7.9	2.69	2.15
Young's Modulus (GPa)	200	71.97	72
Tensile strength (MPa)	215	214	900
Poisson's ratio	0.33	0.3	0.21
Advantages	Good corrosion resistance. Excellent hot and cold forming process and performance. Good weldability.	Offers a high quality finish. An excellent option for extrusion. Has resistance to corrosion, including stress corrosion cracking when it is in its heat-treated condition.	High strength and stiffness. Low density, when compared with bulk materials, allowing for a weight reduction in the finished part.
Limitations	In wet conditions, sensitive to corrosion. Non hardenable by heat treatment but can be cold worked.	Aluminum requires special processes to be welded. Parts exposed to casual friction (freight moving) would wear faster.	Higher viscosity of melt. Warpage. Low surface Quality.

III. DESIGN

Fig. (1) Structure of Solar module

Table No. II Design Inputs

No.	Parameter	Details
1	Ground	Ballast type structure
2	Site Location	Pune
3	Basic wind speed	140.4 km/h
4	Elevation	Roof top, G+3, 15m high
5	PV Module	Standard PV Module of 24.5 kg wt.
6	Tilt angle	20˚ fixed tilt
7	Minimum ground clearance	~ 300 mm
8	MOC	-
9	Fasteners	-

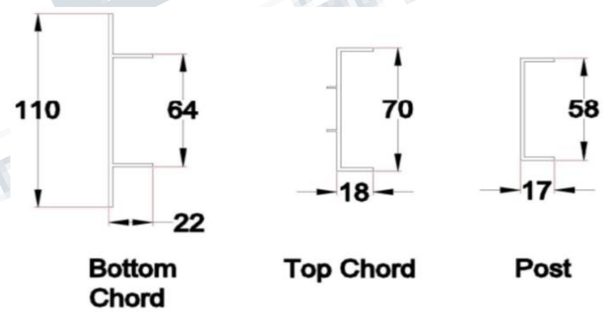

Fig. (2) (a) Cross-sectional dimensions for metals

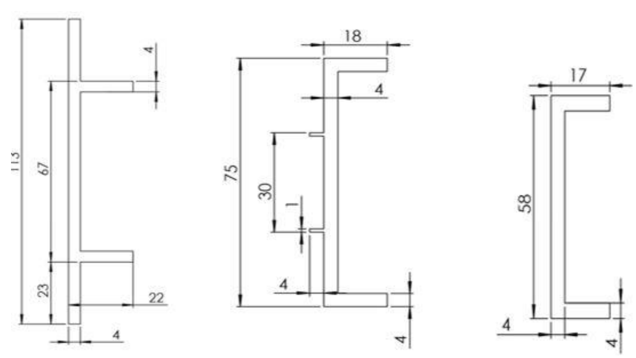

Fig. (2) (b) Cross-sectional dimensions for composites

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 8, August 2021

IV. DESIGN LOADS

Table No. III Design Considerations

Design as per IS 875 (3)	
Panel size:	Length-2180 mm Width-996 mm
Weight of one panel:	24.5 kg
Allowed pressure on PV module:	2400 N/m^2
Designed for location:	India
Tilt angle of modules:	20 deg

Following are the loads the structure is subjected to.

Table No. IV Design Loads

Design Wind Pressure	766.44 N/m^2
Downwind load per m of purlin	663 N/m
Up wind load per m of purlin	1077.4 N/m
Wind load lateral per m in direction of post	20.705 N/m
Panel load	220.504 N/m
Dead load	110.25 /m

V. V. ANALYSIS

FINITE ELEMENT ANALYSIS

Contact Connections

- The Structure is connected using the bolted joint, thus the connections between bolted joints are of prime importance
- Modeling of bolt is done with solid elements avoiding the threads

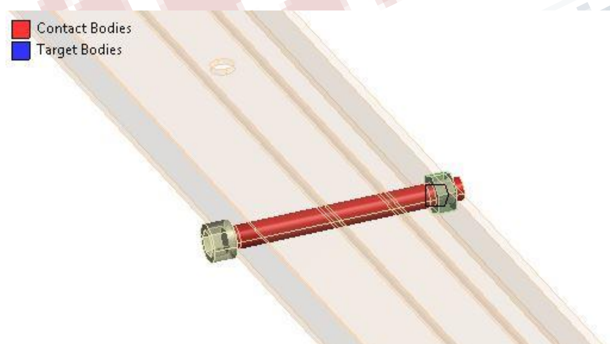

Fig. (3) Penalty Method for Contact Formulation

Meshing

- The structure was meshed with maximum mesh size of 8mm. Bolted connection is meshed with hex Dominant method having max mesh size of 1mm.
- Bolts are finer meshed to capture the maximum stress.

Analysis Results

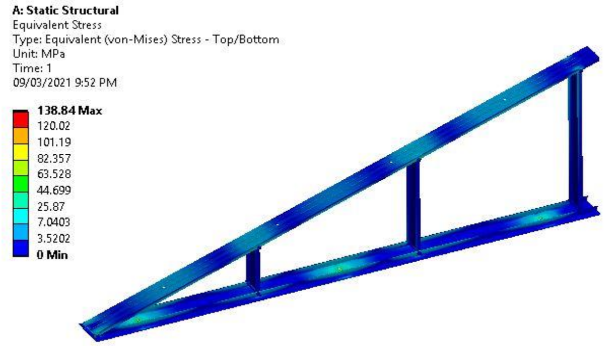

Fig. (4) (a) Von Mises Stress

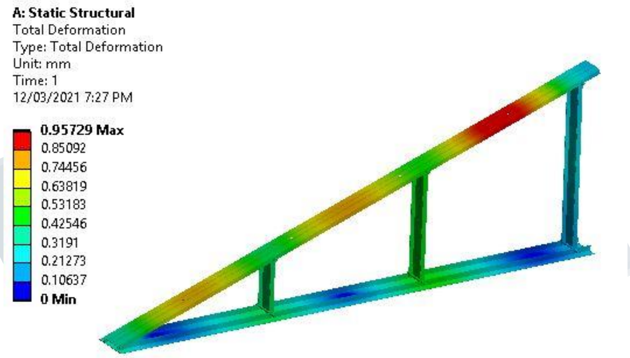

Fig. (4) (b) Deformation

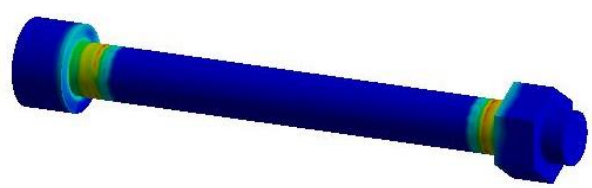

Fig. (4) (c) Bolted Joint

Table No. V FEA Results

Material	***Von Mises Stress (MPa)***		***Deformation (mm)***	
	Wind up	***Wind down***	***Wind up***	***Wind down***
Steel	164	134	0.44	0.346
Aluminum	138	114	1.219	1.00
Composite	288	236	4.57	3.75

IFERP connecting engineers... developing research
ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 6, Issue 8, August 2021

STAAD Pro ANALYSIS

Modelling

- Structure is created by adding nodes and then connecting nodes with beam elements.
- Cross-sectional dimensions are assigned to the beam elements as per top chord, bottom chord and post.

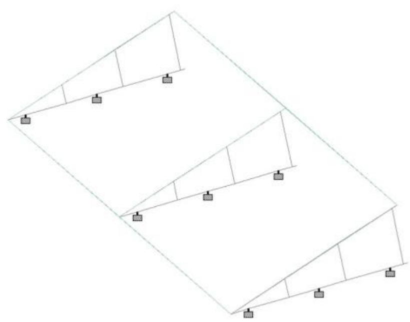

Fig. (5) 1D beam element structure in STAAD Pro

Loading and Analysis Results

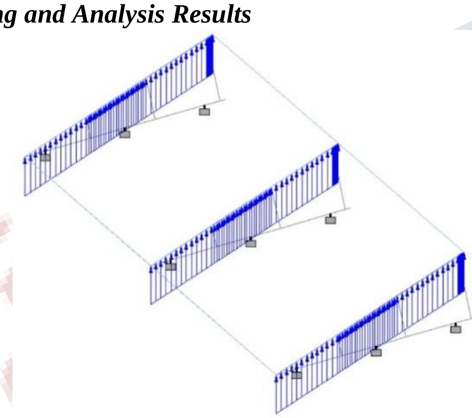

Fig. (6) (a) Wind Up

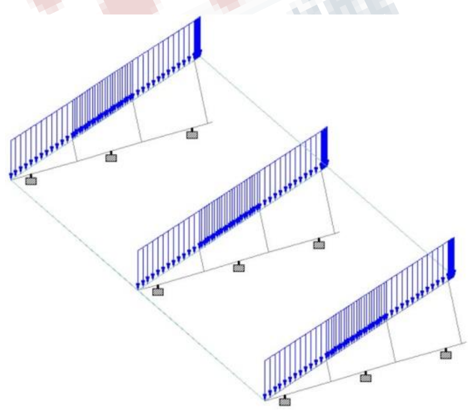

Fig. (6) (b) Wind Down

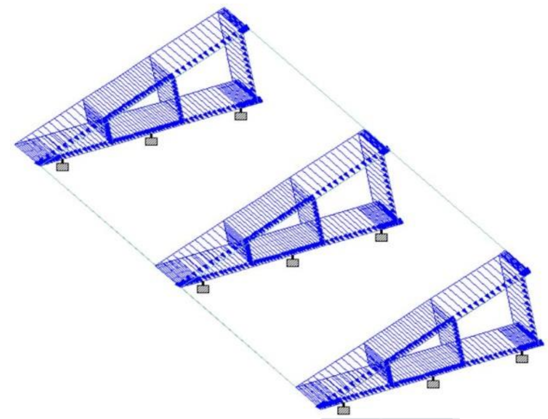

Fig. (6) (c) Wind Lateral

Table No. VI STAAD Pro Results

Material	*Deformation (mm)*		
	Wind Up	*Wind Down*	*Wind Lateral*
Steel	0.624	0.384	0.050
Aluminum	1.780	1.103	0.133
Composite	4.159	2.559	0.039

VI. COST ANALYSIS

Table No. VII Raw Material Cost

Material	*Top Chord*	*Bottom Chord*	*Post*	*Total*
Galvanized Steel	5,076.8	7,649.2	2,066.6	14,792
Stainless Steel 304	11,909.7	17,943.7	4,848.4	34,701.8
Aluminum Alloy 6061-T6	8,038.8	12,112.1	3,270.6	23,421.5
Composites	7,878.4	8,167.6	21,664	37,710.9

Table No. VIII Manufacturing Cost

Material	*Galvanized Steel*	*Stainless Steel 304*	*Aluminum Alloy 6061-T6*	*Composites*
Total	7,000	5,500	5,000	2,800

Note:- All cost is in Rupees.

VII. CONCLUSION

- Each material has its own benefits and their properties can also be enhanced by appropriate processing according to the requirements.
- Steel is the heaviest material and composites are the lightest; in between stands the aluminum.
- Both FEA and STAAD Pro Analysis shows that composites deform more compared to steel and

aluminum.

- To make composites sustain such heavy loads some changes are made in the design of the structure.
- According to the cost analysis, raw material cost of composites is highest while manufacturing cost being the least.
- Thus, composites are found more promising as they are lightest. Also, the issue of more deformation has been solved by little changes in the design.

REFERENCES

[1] IS: 875 (Part I) -1987, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures. Part I dead loads- unit weights of building materials and stored materials.

[2] IS: 875 (Part III) -1987, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures. Part III wind loads.

[3] Stephen Dwyer, Alan Harper, William Lindau, Tom Bosilievac, Kay Schindel and Elizabeth Richards: “Structural Considerations for Solar Installers”, Dec. 2011.