Design of steel structure for installation of solar panels at Trinity Academy of Engineering

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Abstract : The project of 'Design of steel structure for installation of solar panels on Trinity Academy of Engineering, Pune' deal with the study and design of steel structure for implementation of solar panels at campus which gives an effective and easy way to introduce clean energy with proven technology. Following project fulfill requirement of clean and renewable energy which is need of campus.

Use of terrace to harvest green energy is important because if we install solar panels on ground obstruction like shadow of nearby structure may occurs that will reduce efficiency of solar panels and that land can be utilized for another application. As we are designing steel structure for installation of solar panels at suitable height the floor area of terrace can be used.

The north facing steel truss is choose for application because this truss in one side sloped so, the shadow of one panel doesn't interrupt another solar panel therefore we get higher energy. There is consideration about design and analysis of solar panel support structure by considering environmental effects like wind load, structural load and height of structure. The design will be done by using load calculation and analysis will be done by creating model in software and followed by analysis using 'STAAD-Pro' software to determine failure against loading.

The structure will support the solar panels without failure again the loading and we will overcome the problems faced by conventional method. The energy consumption of campus can be partially fulfilled by the energy generated.

***Key words*: **STAAD Pro.V8i, Solar panels, renewable energy

I. INTRODUCTION

The main motto of this project is to harvest solar energy at campus of Trinity Academy of engineering. In proposed structure we focus mainly on design of steel structure for implementation of solar panels on Trinity Academy of Engineering. Solar panels are economically and environmentally beneficial especially at Trinity Academy of Engineering, Pune where energy consumption is quite high. The energy is to be served by for undergraduate population of 5000 students, major labs, auditorium hall, research and development labs, etc. Our project outlines the design and analysis of steel structure required for installation of solar panels on Trinity Academy of Engineering, Pune. The truss is structurally designed to support the solar assembly in absence of non-structural top chord.

The panel enclosure have an air space underneath the solar panel, to airflow cooling and water drainage structural consideration for solar installers provides a comprehensive outline of considerations of structure which is associated with simplified solar installations and recommends a set of best practices which can be followed by installers while assessing such considerations. Various case studies are studied and analyzed to form this manual. Its objective is to ensure safety and structural durability for rooftop solar installations and to potentially accelerate the permitting process by identification and finding out remedy for structural issues which is prior to installation.

Sun is the ultimate and renewable source of energy. The solar energy released from sun in one second is more than that what mankind had used since the dawn of human civilization. Solar panels convert the sun energy into usable form structures which support solar panels of different sizes and shape are in abundant. Its main function is to provide safe, economical aesthetical support to solar panels.

II. METHODOLOGY:

2.1 Design Assumptions

At the end of moment cannot be developed by members.
The members are subjected to axial forces.
Connections are perfectly pinned/ hinged through frictionless pins to other members.
Cross sectional area of all members is uniform.
Entire structure is in one plane.
The loads act the joint only. Loads acting between joints are split into equivalent support end reactions and added to joint loads.
Self-weight of the truss can be ignored as assumed to be equally distributed as loads at the joints.
No fixity is assumed even if the members are connected at the ends with gusset plates and welded.
A nominal moment is simply ignored that actually develops due to imperfect huge connection.

2.2 Applicable standard codes:

Design and analysis of educational building and lattice truss is done according to the Indian codes that has been referred to the design.

Loads described in the design summary sheet have been applied on the structure in accordance with IS-875

Part-I, Part-II, Part-III, 1987 code of practice for design loads for building and structures.

According to IS-800 1984 code of practice for general construction in steel sections and built-up components are designed.

2.3 Design of steel roof truss:

Truss members are regarded as pinned joints.

They are assumed to be joined together so as to transfer only the axial forces neglecting moments and shears from one members to the adjacent members.

Assumption; loads are acting only at the nodes the truss.

The trusses may be provided over a single span, simply supported over the two end supports, they are usually statically determinate.

Analysis of trusses can be done manually by two methods namely-

Method of joint

Method of sections

Computer programs are also available all around the world for the analysis of trusses.

Axial forces in different members of the trusses are found out from the analysis based on pinned joint assumption.

In actual design, the members of the trusses are joined together by more than one bolt or by welding either directlyof through larger size end gussets.

Chord members (some of them) may be continuous over many nodes. Generally such joints enforce compatibilityof rotation of members meeting at the joint.

As a result, the members of the trusses experience bending moment in addition to axial force. This may not be

Negligible, at the eaves points of pitched roof trusses, where the depth is small and in trusses with members whichhave a smaller slenderness ratio.

Loads may be applied in between the nodes of the trusses further, causing bending of the members. Such stressesare referred to as secondary trusses.

Due to eccentric connection of members at the joints, the secondary bending stresses can be caused.

2.4 Load calculation

Dead Load

Dead Load of roof= weight of roofing + self-weight of purlins + weight of solar panels

= (130 N/m^2) + (100 N/m^2) + (200 N/m^2)

=430 KN/m^2

Dead load/m run on rafter = 430*4*10^{-3} = 1.72 KN/m

Live Load

Live Load of roof = as per IS 875 part 2

= up to 10^o degree slope LL= 0.75 KN/m^2

= 0.75*4 = 3 KN/m

Wind Load

Design wind speed, Vz = k1 k2 k3 Vb

From Table 1; IS: 875 (part 3) – 1987

k1 = 1.0 (risk coefficient assuming 50 years of design life)

From Table 2; IS: 875 (part 3) – 1987

k2 = 0.8 (assuming terrain category 4)

k3 = 1.0 (topography factor)

Assuming the building is situated in pune, the basic wind speed is 39 m/sec

Design wind speed, Vz = k1 k2 k3 Vb

V z = 1 * 0.8 *1 * 39

V z = 31.2 m/sec

Design wind pressure, Pd = 0.6*Vz2

= 0.6 * (31.2)^2

= 0.58 KN/m2

Wind Load on individual surfaces

The wind load, WL acting normal to the individual surfaces is given by

WL = (Cpe – Cpi) A*Pd

(a) Internal pressure coefficient

Assuming buildings with low degree of permeability

Cpi = ± 0.2

(b) External pressure coefficient

External pressure coefficient for walls and roofs are tabulated in Table 1 (a) and Table 1(b)
Calculation of total wind load
For column h/w = 5.19/13.29 = 0.39
Exposed area of wall per frame @ 4 m
c/c is A = 5.19*4 = 20.76 m2
Wind load on column/ frame,
A*Pd = 20.76 * 0.58
= 12.04 KN

Table 1 (a): Total wind load for column

Wind Angle θ	Cpe		Cpi	Cpe – Ci		Total wind(KN) (Cpe-Cpi)Apd	
	Windward	Leeward		Wind ward	Leeward	Wind ward	Leeward
0^0	-0.86	-0.4	0.2	-1.06	-0.6	-12.76	-7.224
			-0.2	-0.66	-0.2	-7.94	-2.408
90^0	-0.8	-0.4	0.2	-1	-0.6	-12.04	-7.224
			-0.2	-0.6	-0.2	-7.224	-2.408

Table 1 (b): Total wind load on column

Wind Angle θ	Windward KN/m		Leeward KN/m	
	Corner	Intermediate	Corner	Intermediate
00	-1.24	-2.48	-0.70	-1.41
900	-1.175	-2.35	-0.70	-1.41

(b) For Truss
Truss No1
Dead Load
Replacing the distributed dead load of 1.72kN/m on rafter by equivalent
Concentrated loads at two intermediate points corresponding to purlin locations on each rafter,
W_D = (1.72*13.29)/8 = 2.85 KN
2.2 Live Load
Live Load = 3 kN/m
W_L= (3*13.29)/8 = 4.98 KN
2.3 Wind Load along the ridge

Exposed area of each slope of roof, per frame (4m length) is
A = 4*√ $(13.22^2+1.19^2)$ = 53.09 m^2
For roof, Apd = 53.09*0.58 = 30.79 KN
h/w = 5.19/13.29 = 0.39

Table 2 (a): Total wind load for roof

Wind Angle θ	Cpe		C pi	Cpe – Ci		Total wind(kN) (Cpe-Cpi)Apd	
	Windward	Leeward		Wind ward	Leeward	Wind ward	Leeward
00	-0.86	-0.4	0.2	-1.06	-0.6	-32.63	-18.47
			-0.2	-0.66	-0.2	-20.32	-6.158
900	-0.8	-0.4	0.2	-1	-0.6	-30.79	-18.47
			-0.2	-0.6	-0.2	-18.47	-6.158

(a) Vertical Load
w @ intermediate points on windward side
w = (32.63/8) cos 3°
= 4.073 KN
(b) Horizontal Load
H @ intermediate points on windward side
H = (32.63/8) sin 3°
= 0.21 KN

Table 2 (b): Loads acting on rafter points

	Vertical Load (KN)	Horizontal Load (KN)
Intermediate Points	4.07	0.21
End Points	2.035	0.106

2.4 Analysis of Truss

2.4.1 Software (STAAD Pro. V8i)

STAAD Pro was developed by a group of practicing engineers for practicing engineers around the globe. It has evolved over 20 years and is constantly guided by a premier industry-based steering committee. It has building codes for most countries including US, Britain, Canada, Australia, France, Germany, Spain, Norway, Finland, Sweden, India, China, Euro Zone, Japan, Denmark and Holland. More are constantly being added. Besides, it supports multi-material design codes such as timber, steel, cold-formed steel, concrete and aluminum. Over the past 20 years, the users have designed everything from residential buildings to skyscrapers to tank to tunnel etc. Complex models can be quickly and easily generated through powerful graphics, text and spreadsheet interfaces that provide interactive model generation, editing and analysis. In STAAD Pro, a structure can be defined as an assemblage of elements. STAAD can be used to analyze and design structures consisting frame, plate/shell and solid elements.

2.4.2 Design of Truss on STAAD Pro.V8i

Geometry of Structure

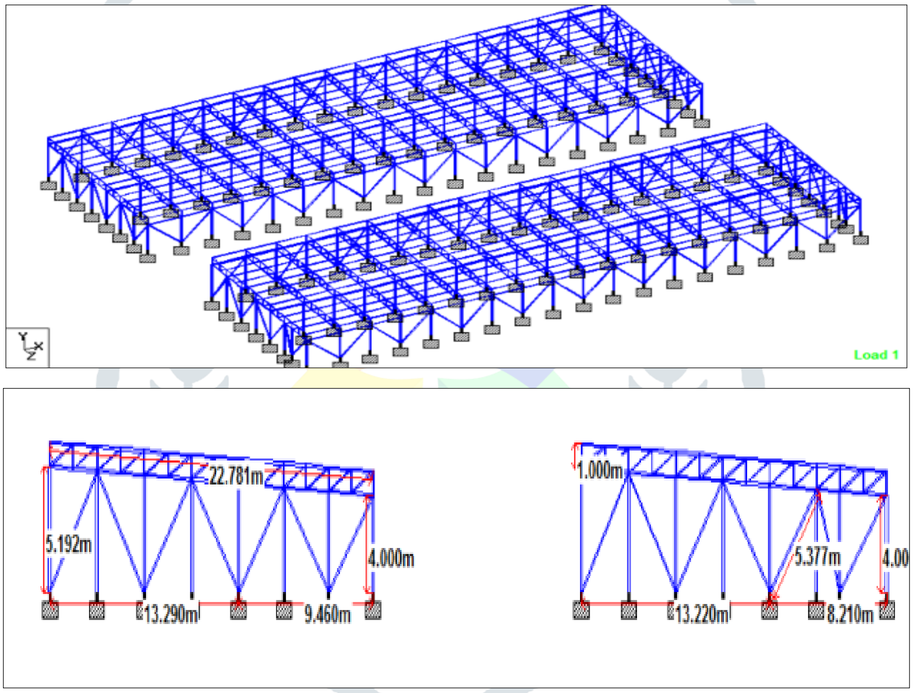

Fig.1 Geometry of structure

2.4.3 Loading on Structure

The forces that act on a structure are called loads. For the safe design of structure, it is essential to have knowledge of various types of loads and their worst combinations to which it may be subjected during its life span. The loads on trusses would depend upon the application for which the trusses are used. In the present application we would discuss about loading on roof truss and the loads under consideration are dead load, live load and wind load.

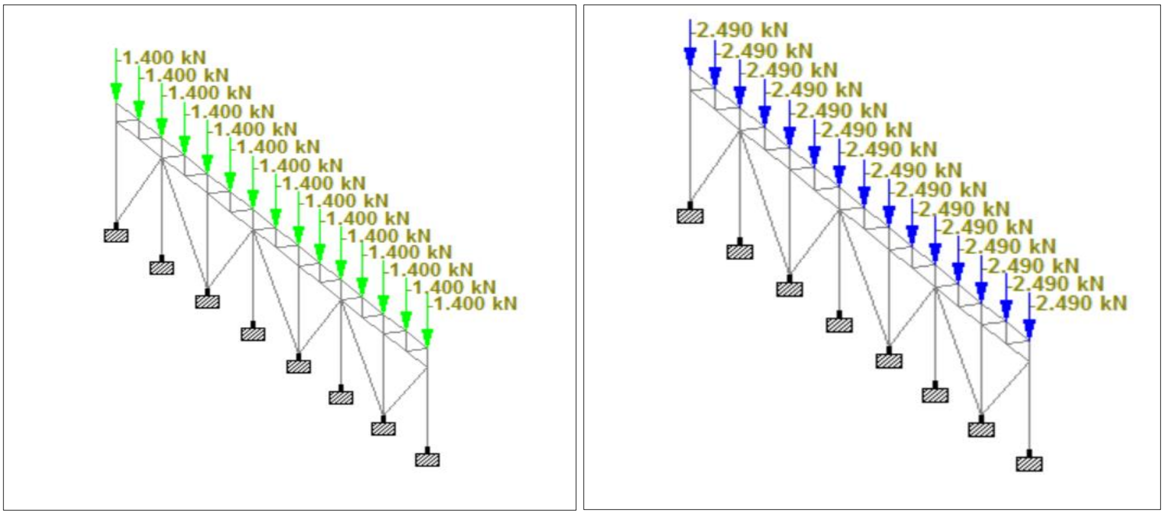

Fig.1 Dead load and Live Load

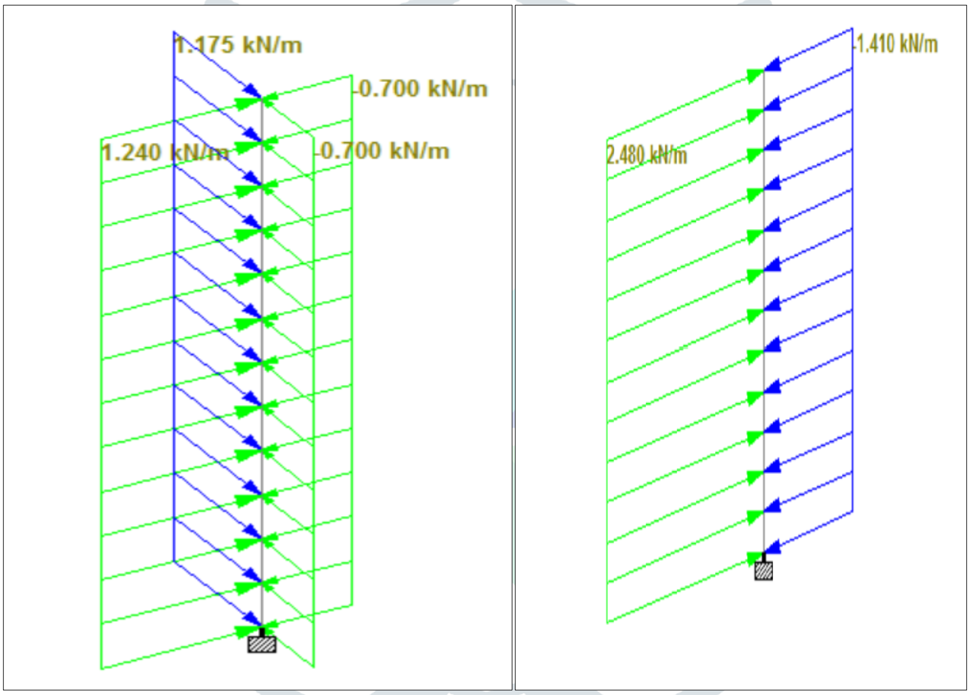

Fig.2 Wind Load on End and intermediate Column

2.4.4 Section properties

Table 3 Section properties

Prop.	Section	Area (cm2)	Iyy (cm4)	Izz (cm4)	J (cm4)	Material
1	TUB1501505	28.400	982.000	982.000	1.52E+3	STEEL
2	TUB100504	10.900	44.900	44.900	109.865	STEEL
3	TUB100504	10.900	44.900	44.900	109.865	STEEL
4	TUB63633.2	7.390	43.200	43.200	68.431	STEEL
5	TUB70704	10.100	720100	720100	114.998	STEEL
6	TUB1001004	14.99	226.000	226.000	353.894	STEEL

3. Results:

After the structure is designed and analyzed, there is check for utility under the post processing mode in SAAD Pro. V8i It should always less than 1.

If utility ratio is greater than 1 the section properties increases until it become less then 1.

3.1Displacement

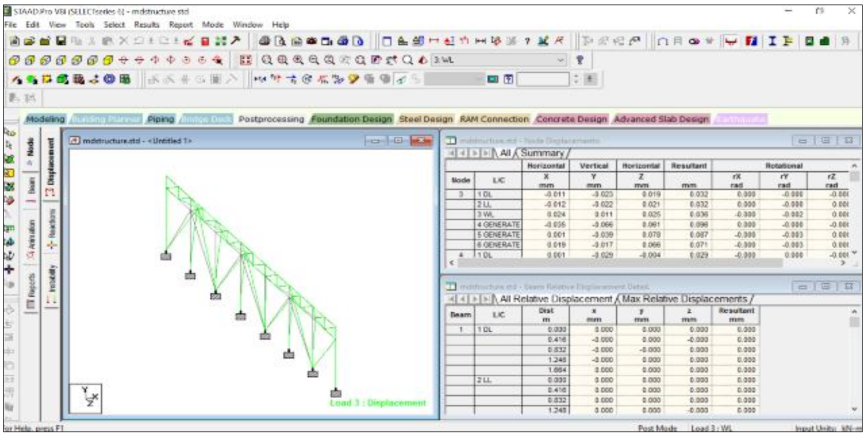

Fig.3 Displacement

3.2 Shear force Diagram

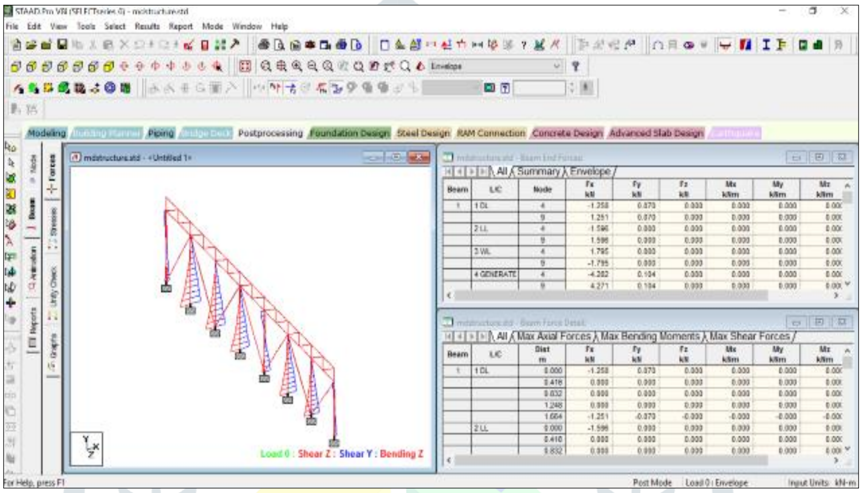

Fig.4 Shear force diagram

3.3 Bending Moment Diagram

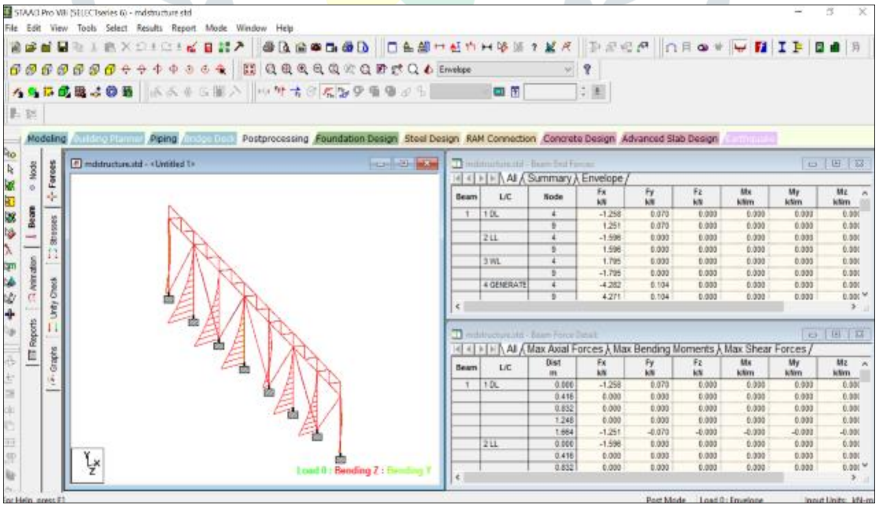

Fig.5 bending moment diagram

3.4 Unity Check

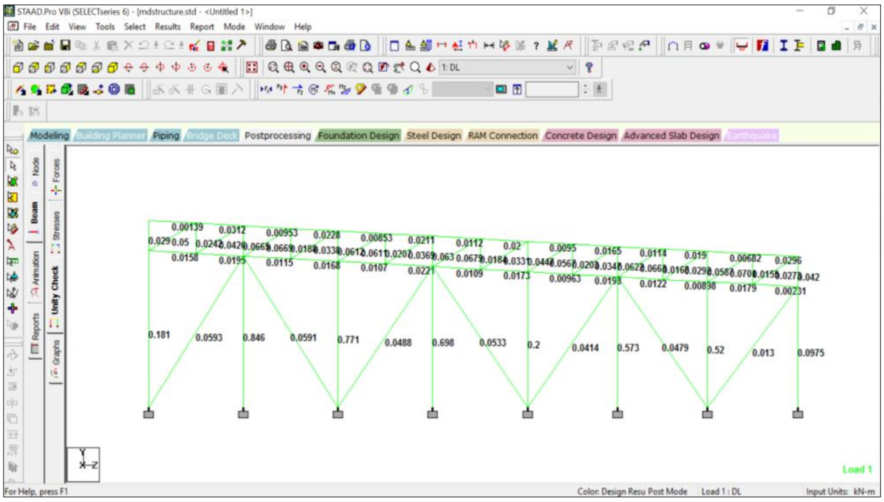

Fig6 Unity check

3.5 Steel Take off

	PROFILE	LENGTH(METE)	WEIGHT(KN)
ST	TUB100504	1795.14	150.313
ST	TUB1501505	600.46	131.001
ST	TUB63633.2	3510.65	199.300
ST	TUB1001004	604.85	69.232
ST	TUB70704	436.98	33.904
		TOTAL =	583.750

= 59524.98 Kg

The cost of structure as per market rate is 58-60 Rs. /Kg

Cost of steel = 35, 71,499.25 ≅ 36 Lakh

IV. Discussions:

The calculation of various loads acting on to the structure was done using codal provisions. Then, load combinations are developed in the foundation design was done based on the loads acting the base of the structure.

Load calculations and designs done by using IS800 2007

Truss was drawn by using STAAD Pro v8i 2007 and utility, safety, economical and must be fulfilled.

Bracings are provided in gable for transmission of forces at the foundation level.

The Truss is check for slenderness ratio.

V. Conclusion:

1. The analysis was done using the software STAAD pro.V8i, which proved to be great potential software in analysis and design section of steel structure in construction industry.
2. Due to lattice frame the structure become light weight which will save time and money.
3. Lattice frame is easy to construct and installation is also easy.
4. The bracing reduces composite action reduces maximum deflection of truss and improve stiffness stability for wind load.
5. Total cost of Structure estimated to be 36 Lakh rupees.

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