Analyzing Solar Structure Table for One Megawatt System and Validating Using Indian Standards

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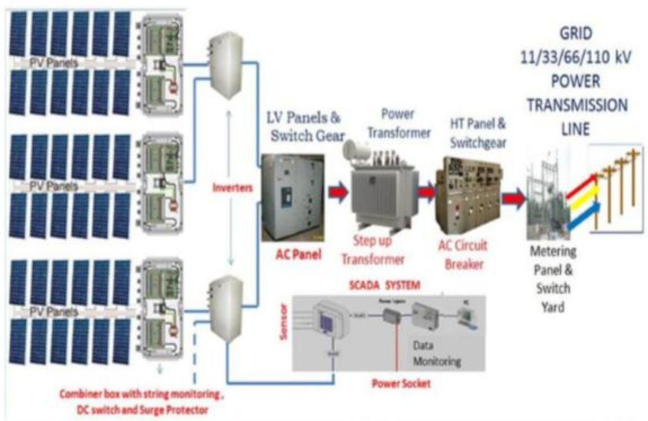
Abstract - *The structure plays an important role in a PV solar plant. The expected life of the structure is twenty years. There are various loads, which a structure has to bear. Thus keeping these factors in mind, the flexibility of structure becomes crucial. There for four major types of loads that act on the structure such as it's self-weight, live load due to weight of panel, wind force and earthquake load acting on the structure. Thus, the structure is prone to failure and has to endure fatigue for a long period. Computational analysis plays an important role in determining the failure of a system. Also the CAD softwares enhances the product design through optimization which increases productivity.*

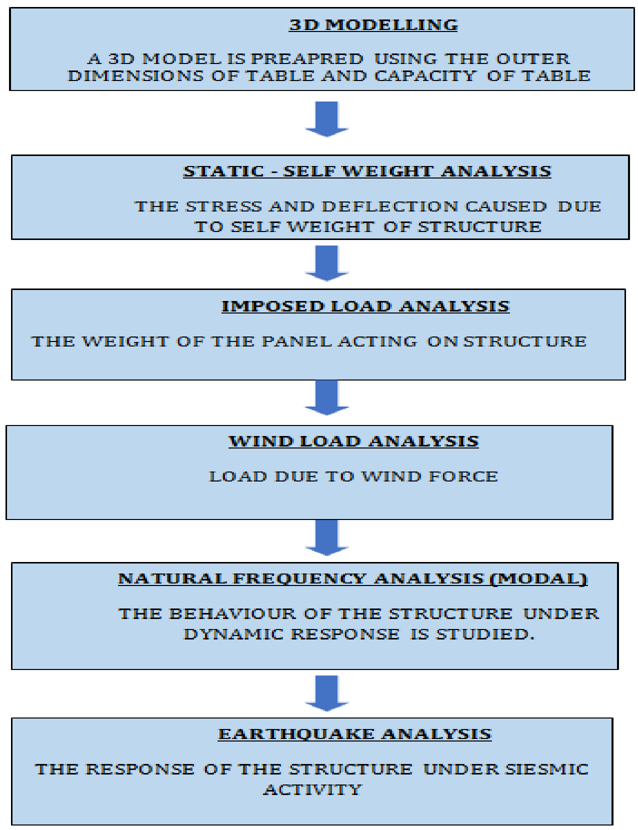
1. INTRODUCTION

The solar panels are arranged as per the space and requirement into an array system. Each standalone table produces certain fraction of power. The table are connected to form a string pattern to a combiner box. The combining box is connected to a SCADA system to monitor the energy produced by each string. The power is then sent to inverters which convert the DC power supply to AC. Usually ten to fifteen inverters are used for one megawatt system depending upon the power distribution system. A step up transformer is used to distribute the power to the transmission lines. An AC circuit breaker is provided to regular the power. Such huge system are on-grid system.



2. METHODOLOGY

Once the area is decided, the available land is divided in areas for power generation. The land is divided as per the area available or as per the power division required. In the above image, it is seen that the land is divided into two parts. Total capacity of plant is 1000 KW and thus the larger area is 700 KW and the smaller area is 300 KW. Once land division is done, the columns and rows are decided as per the supply system. Each table structure is decided as per its capacity. The electrical capacity of each table is 5400 watt as per distribution required. Thus 18 solar panels are used for each table with 300 watt each. 18 solar panels are used for one table. Dimensions of each panel are 2m X 1m. They as installed as two rows and nine columns in vertical orientation.



2.1 DEAD LOAD ACTING ON STRUCTURE

As per IS code 875, part-1, the first type of load that act on the structure is the self-weight of the structure. Weight per meter of few standards are present in the standard. For non-standard items, the weight can be calculated using density and volume of that component. The material used for such structures is structural steel. The density of the structural steel is taken as 7850 Kg/m3. Also the members which carry the load should be sturdy to carry the weight of the components. The base member or column in this case takes the load of members above it. The column takes weight of purlin, rafter, solar panels, and connector plates. The weight of such components is called self-weight. In certain cases, the weight of the supporting members is such that it introduces stresses and deformation in base members.

2.2 DEAD LOAD ACTING ON STRUCTURE

Weight of the solar panel is one live load acting on the solar panels. As per IS standard 875 part -2, any loading that adds in a base structure or component is termed as live loading. The weight of the solar panel is 22.765 Kgs. The weight overall dimensions considering extrusion allowance is 2000 X 1000. The weight for 300-Watt panel is 22.765 Kgs. The panels are mounted on the purlins. Eighteen panels are used per table. Therefore, the total weight of panels acting on the structure is 409.77 Kgs.

2.3 WIND LOAD ACTING ON STRUCTURE

The wind load is considered as a live load that acts on the solar panels. Wind load produced high forces on the surface on the panels. The wind speed is ranges from 20 Km/hr to 120 Km/hr. In cluster area the max wind speed is taken as 40-50 Km/hr. The maximum wind speed to be taken as worst case scenario mentioned in IS 875 is 120 Km/hr. The wind speed needs to be converted into a pressure value to be applied on the surface of the panels. The process of converting wind force to pressure value is mentioned below. IS 875-part 3 will be used for converting wind force to pressure value. As per section 5.3 pg. no. 8 the mathematical expression for design wind pressure is given below. Taking maximum wind speed in case of worst case scenario – 120 Km/hr.

$V_z = V_b \times k_1 \times k_2 \times k_3$

Where,

V_b - design wind speed in m/s; 120 km/hr – 33.3 m/s

k1 - risk coefficient.

k2 - terrain, height and structure size factor

k3 - topography factor.

The k1 table. The structure is to be designed for 25 years. The K1 factor for 25 is 0.92 as the Vb lies between 33 and 39 m/s. Taking 39 m/s, so value is 0.92.

As per 5.3.2.1, terrain factor, there are four terrains. Category 1 is for exposed terrain in which average height of obstruction less than or up to 1.5m. Category 2 is for exposed terrain between 1.5 to 10 m. Category 3 is closely spaced building height up to 10m. Category 4 is highly spaced buildings. As per 5.3.2.2, there are three classes for further determining k factor. Class A specifies length or height of structure/components less than 20m. Class B specifies length or height of structure/component between 20-50m and Class C specifies length or height of structure/component greater than 50m. We will consider category 1 as the plant is installed in an open field. In addition, we have considered class A for table 2. From these above sections the value for K2 is 1.05.

For K3 as per 5.3.3.1, the value is taken as 1 as mentioned in the section. No particular uphill/slope present at site.

Now,

$V_b = 33.3$ m/s

k1 = 0.92

k2 = 1.05

k3 = 1.0

Therefore,

$V_z = 33.3 \times 0.92 \times 1.05 \times 1 = 32.16$ m/s

Design Wind Pressure (as per clause 5.4)

$P_z = 0.6 \times V_z2$ ...N/m^2

V_z = Design wind speed

$P_z = 0.6 \times (32.16)2 = 620.86$ N/m2 (IS 875 part 3 table 7)

Where Cpe = External pressure coefficient,

Cpi = Internal Pressure coefficients.

L= 9400 mm; w= 4050 mm; h = 2250 mm

Using the IS 875 part 3: table 7 with roof angle – 20 ° and solidity ratio ø = 0; (The obstruction area is less than canopy area.

Positive internal pressure will act towards the panels while negative internal pressure coefficients will be away from the panels. The net design pressure coefficients shall be either +0.8 or -1.3.

Therefore,

620.86 X 1.3 = 807.12 N/m2 (Bottom to Top)

620.86 X 0.8 = 496.68 N/m2 (Top to bottom)

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 02 | Feb 2021 www.irjet.net p-ISSN: 2395-0072

2.4 SEISMIC LOAD ACTING ON STRUCTURE

The important parameters studied in this test are acceleration and deflection of components. In seismic analysis, the behavior of a component due to movement of the earth's surface is studied. The movement of the earth's surface during an earthquake is recorded in the form of a velocity/ acceleration or displacement data. The following image is the seismic data provided by the company to carry out earthquake analysis. The following data is obtained from geological department of Gujarat. Each state has a different graph with respect to the seismic activity in that area. The following graph is velocity and displacement graph. We will be taking the displacement graph for calculation.

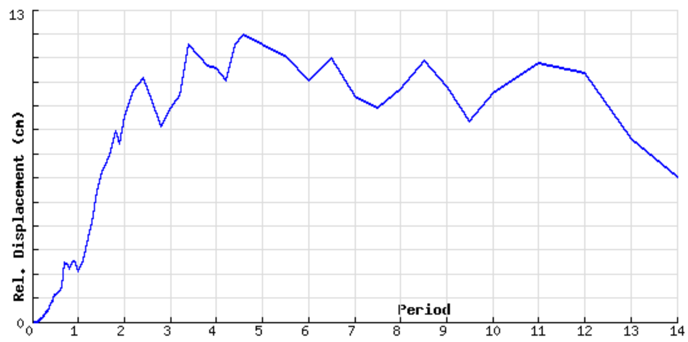
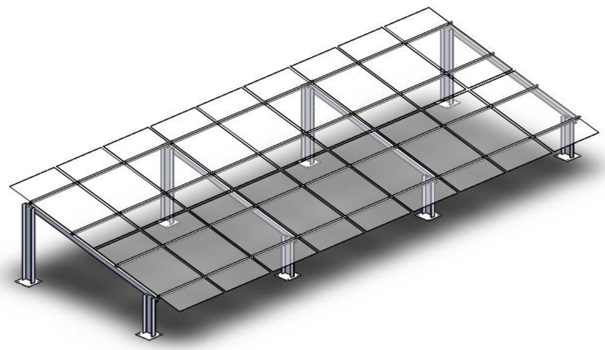


Fig -1: Name of the figure

3. ANALYSIS



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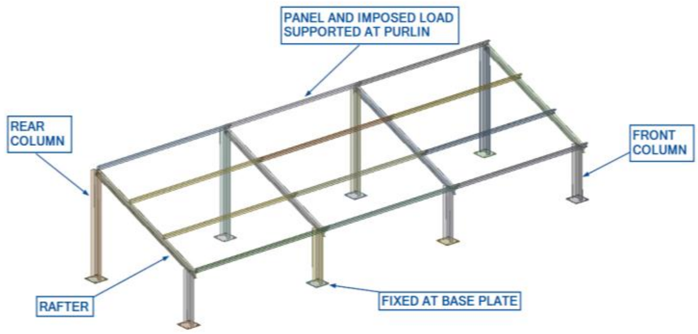

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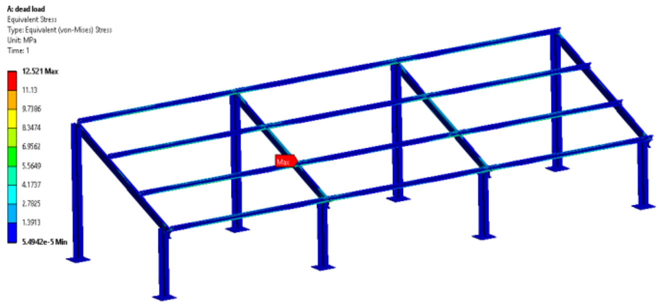
Stress and deflection due to Dead load



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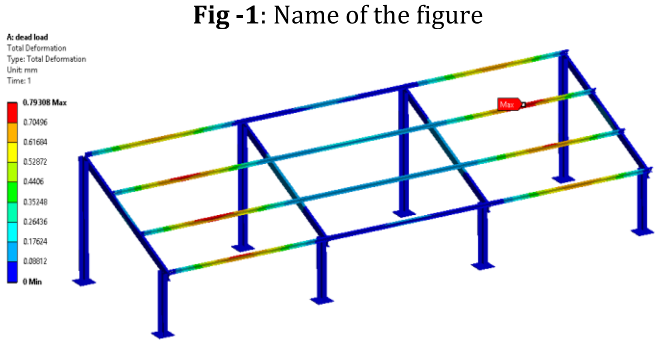

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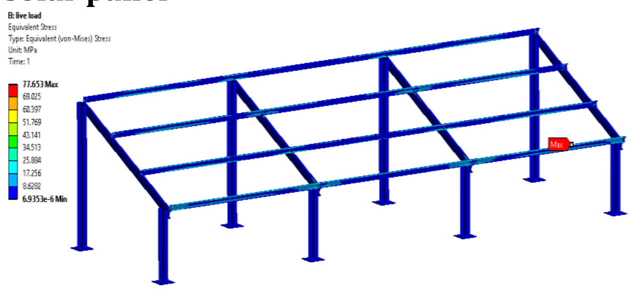
Live load – imposed loads due to weight of solar panel



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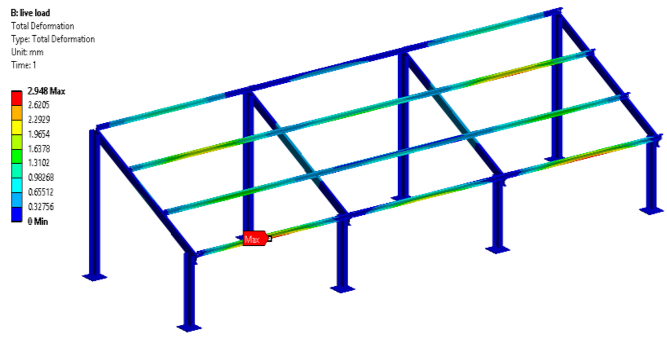

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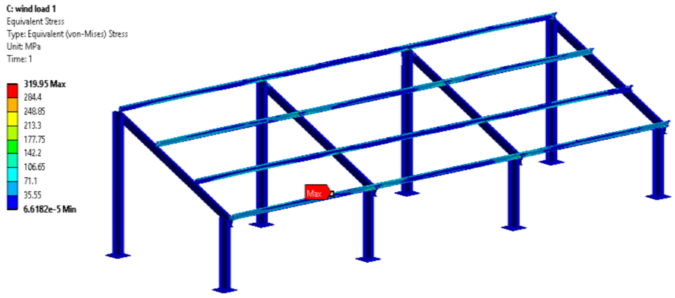
Imposed load due to wind force in upward direction



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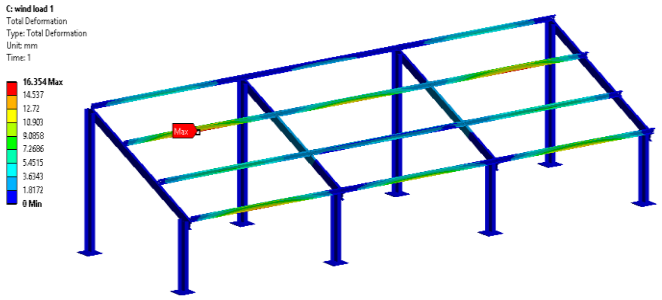

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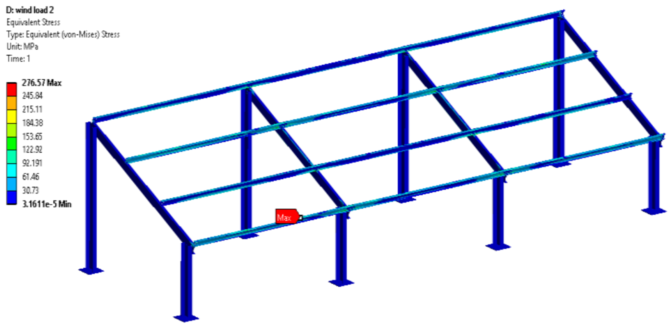
Imposed load due to wind force in downward direction



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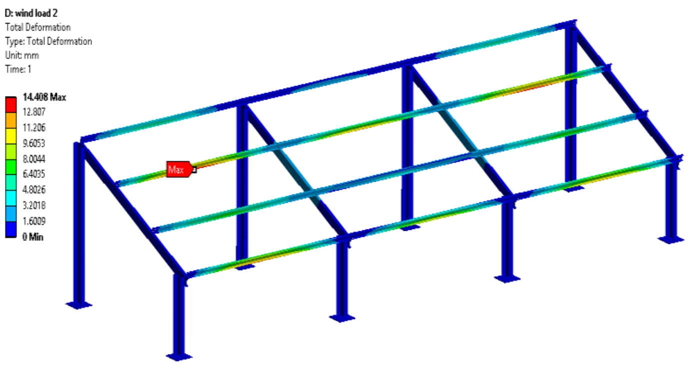

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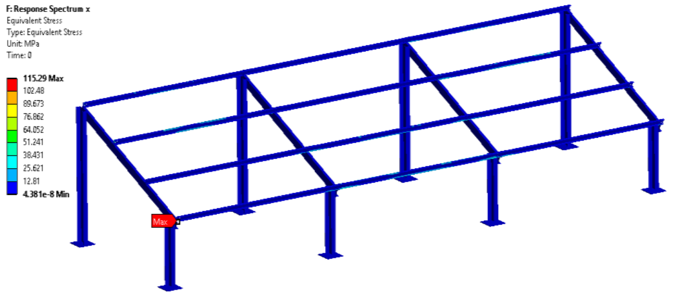
Earthquake analysis

Stress and deformation during excitation in X-axis



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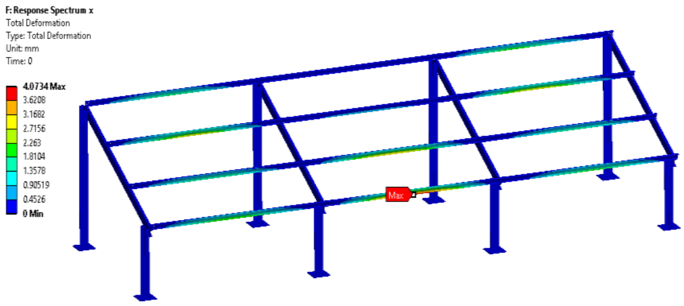

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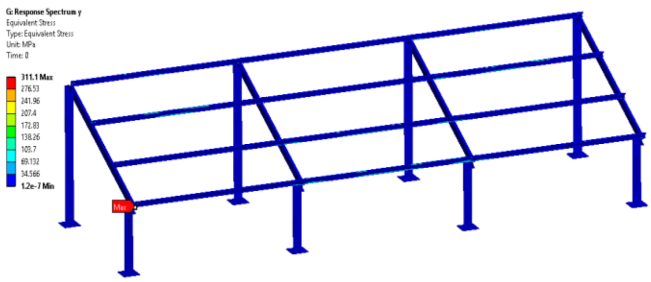
Stress and deformation during excitation in Y-axis



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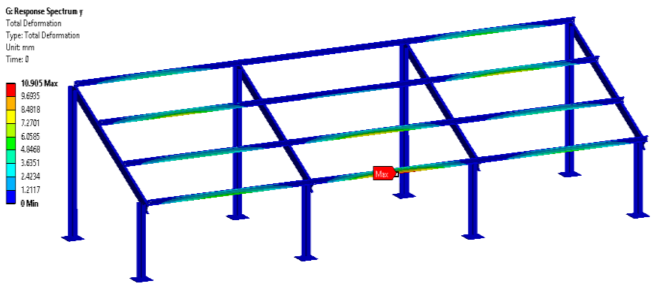

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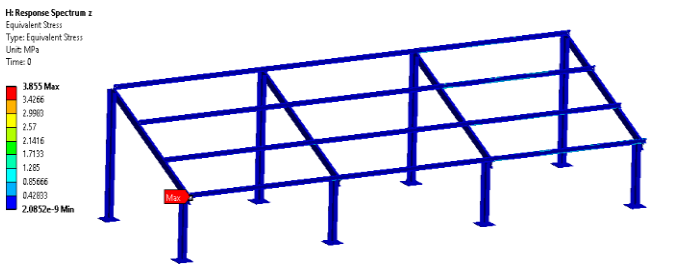
Stress and deformation during excitation in Z-axis



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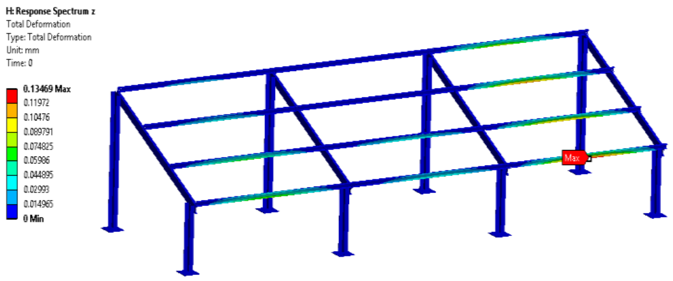

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As per IS 1893: 2002 6.3.4.2 - combined effect of the three components can be obtained on the basis of 'square root of the sum of the square (SRSS) that is

$$EL = \sqrt{(ELx)^2 + (ELy)^2 + (ELz)^2}$$

ELX – 64
ELY – 172.83
ELZ – 2.99
EL – 183.54 MPa

4. CONCLUSIONS

IS 800 : 2007

Table 1 (*Concluded*)

Sl No.	Indian Standard	Grade/Classification	Properties: Yield Stress MPa, *Min* (d or t) < 20	20-40	> 40	Ultimate Tensile Stress MPa, *Min*	Elongation, Percent, *Min*
(1)	(2)	(3)	(4)			(5)	(6)
viii)	IS 2062	E 165 (Fe 290)	165	165	165	290	23
		E 250 (Fe 410 W) A	250	240	230	410	23
		E 250 (Fe 410 W) B	250	240	230	410	23
		E 250 (Fe 410 W) C	250	240	230	410	23
		E 300 (Fe 440)	300	290	280	440	22
		E 350 (Fe 490)	350	330	320	490	22
		E 410 (Fe 540)	410	390	380	540	20
		E 450 (Fe 570) D	450	430	420	570	20
		E 450 (Fe 590) E	450	430	420	590	20

We have used E 250 (Fe 410 W) C as our material and for that material, the yield limit is 250 Mpa. Thus if the stress value crosses the yield limit, the material enters the plastic deformation region and thus may lead to permanent deformation. Thus, 250 Mpa is our threshold value for stress.

Table 6 Deflection Limits

Type of Building	Deflection	Design Load	Member	Supporting	Maximum Deflection
(1)	(2)	(3)	(4)	(5)	(6)
Industrial Buildings	Vertical	Live load/ Wind load	Purlins and Girts	Elastic cladding	Span/150
				Brittle cladding	Span/180
		Live load	Simple span	Elastic cladding	Span/240
				Brittle cladding	Span/300
		Live load	Cantilever span	Elastic cladding	Span/120
				Brittle cladding	Span/150
		Live load/ Wind load	Rafter supporting	Profiled Metal Sheeting	Span/180
				Plastered Sheeting	Span/240
		Crane load (Manual operation)	Gantry	Crane	Span/500
		Crane load (Electric operation up to 50 t)	Gantry	Crane	Span/750
		Crane load (Electric operation over 50 t)	Gantry	Crane	Span/1 000

The above table displays the deflection limitation of members. The member with maximum length is purlin, whose length is 3150 mm. The maximum deflection allowed as per above table is Span/180. Thus, the allowable deflection is 3150/180 – 17.5 mm.

Deflection table

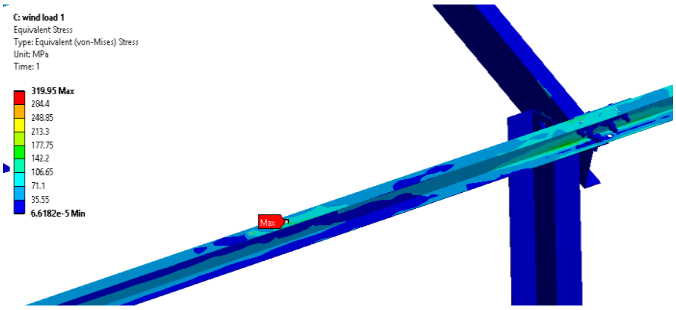
Sr. no.	Analysis	FEA deflection value (mm)	Maximum Allowable deflection as per standard in (mm)	Status
1	Dead load (Self-weight)	0.79	17.5	Safe
2	Live load (Panel weight)	2.95	17.5	Safe
3	Wind load upwards	**16.35**	17.5	Safe
4	Wind load downwards	**14.4**	17.5	Safe
5	Earthquake in X-axis	4.07	17.5	Safe
6	Earthquake in Y-axis	**10.9**	17.5	Safe
7	Earthquake in Z-axis	0.13	17.5	Safe

Stress table

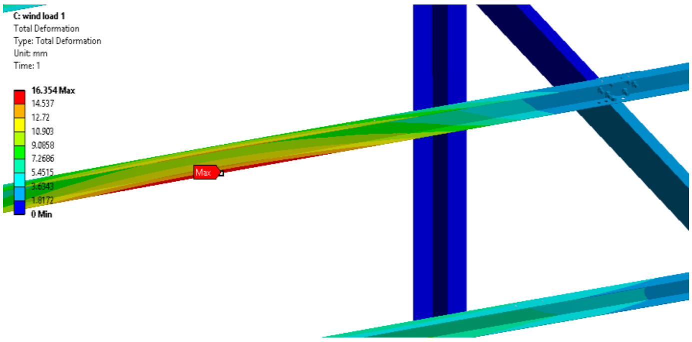
Sr. no.	Analysis	FEA Stress value covering maximum area in (MPa)	Maximum Allowable stress – uptil yield point (Mpa)	Status
1	Dead load (Self-weight)	8.34	250	Safe
2	Live load (Panel weight)	43.14	250	Safe
3	Wind load upwards	**213.3**	250	Safe
4	Wind load downwards	**184.85**	250	Safe
5	Earthquake in X-axis	64	250	Safe
6	Earthquake in Y-axis	**172.83**	250	Safe
7	Earthquake in Z-axis	2.99	250	Safe

From the above table, following are the conclusions that can be drawn-

1. The maximum stress value reached is 184.85 during upward loading. The maximum FEA value is less than the yield value in standards. The peak stresses are neglected due to stress singularity and local maximum stresses are considered.



2. The maximum Deflection is 16.75 near purlin region but is safe than the standard value (17.5). The maximum deflection occurs at the purlin region.



3. Thus, we can conclude that the table is safe during dead, live, wind and earthquake loading.

5. REFERENCES

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