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Tensile Structures using Solar Flexible Panels.

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Abstract: ***Renewable and sustainable energy generation technologies have been in the forefront due to concerns related to environment and fossil fuel costs. Photovoltaics technology have attracted an increasing interest in the past decade and have been shown as a feasible renewable power generation technology.[1] Thin film flexible photovoltaics are paving the way to low-costelectricity. Solar cells are deposited over flexible substrate via means of high throughput technologies to have funds for lightweight solar modules that can be includedinto or on diverse surfaces. [3] Due to the increasing demands of the electricity it is very important to make the buildings energy efficient, which uses less electricity and mainly runs on the renewable source of energy. Invention of the solar flexible panels have increasingly affected the power generation of the tensile structures, making it energy efficient. Combination of both the thin film of solar andthe structural fabric of tensile structure will result in an efficient way of the power generation. This paper will focus on all the properties of the solar flexible panels and how it is useful for energy generation, the different ways and technologies for using the panels in a tensile structure. The paper will focus on whether the panels can be used as a replacement for structural fabric inatensile structure.***

Keywords: [Solar Flexible Panels, Thin Film Solar]

I. INTRODUCTION

Due to growing concerns about the pollution owing to the energy sources related to fossil fuels there is no alternative other than to use renewable energy. renewable energy sources are those, which are naturally and continuously being replenished. Energy obtained from such sources is known as renewable energy. It may be sun or other sources that are indirectly dependent on sun, wind, rain, tide, waves and geothermal heat). Renewable energy is generally used for energy generation. A flexible solar cell which is also known as thin film solar cell that is made by depositing very thin photo voltaics material on any kind of substrate such as paper, tissue, plastic, glass, metal. It is one of the most revolutionary technology in the sector of solar power. The significance of word ‘flexible’ is that, these kinds of solar cells are not like those traditional big, bulky solar panels which are nowadays used, these are literally flexible, verythin, lightweight, have a little installation cost, and can be installed anywhere without goingmuch trouble. The structural fabric used in the tensile structures takes the tension loads and bear allthe wind loads of the surroundings. This paper compares the properties of both the solar flexible panels and structural fabric.

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There is no tensile structure which has been made only with the help of solar flexible panels, there are a lot of materials involved in the construction of the tensile structure.

The research is conducted through reading various books related to tensile structures and its construction techniques, through discussions and interviews of the professionals. The paper analyses the data from the projects of Tata consultancy, India, from the brochures of the pavilion company manufacturing the solar flexible panels, Newyork and Flexible solar power by solar cloth system, France. The paper analyses the data obtained from the research papers regarding solar flexible panels and building integrated photovoltaic. Analysis of different case studies of the projects were solar flexible panels are used is done. The research paper focuses on studying the combination of solar energy and tensile structures and the parameters on which the solar panels can produce energy. Different case studies are done to explain these parameters. These case studies give brief description about the solar flexible panels and its use in the construction industry. The paper focuses on the properties of solar cloth panels, its specifications and features and studies the comparison between the structural fabric and solar flexible panels. the paper focuses on the possibilities of its use in a tensile structure. the scopeof the project is to study how the panels can be used in construction of tensile structure.

II. PROPERTIES OF SOLAR FLEXIBLE PANELS

We can understand the properties of the solar cloth panels. Some of the relevant properties are as follows

Efficiency of the panel is 14%, maximum power output per sq.m. is 140 W, KWh provided per sq.m. per year is 192, carbon offset per sq.m. per year is 191 kg CO2 and the lowest weight is 30 gm.[5] It also gives the detailed specifications for the performance of the solar cloth panels. Weight of the structural fabric is more than the flexible solar panels, therefore it can bear more wind loads. The tensile strength of the solar flexible panel is less than the structural fabric. the solar flexible panels have a very thin film Therefore it can be fixed to any of the structure without any compromises done to the structure. [5] The solar panels are waterproof therefore they are not affected by water and they can sustain in any environmental condition. the panels are lightweight hence they are very easy to handle.during the process of construction the panels are brought to the site in the form of rolls, the rolls are cut down as per the requirements of the structure.

Some types of the solar flexible panels comes in a particular size that is 205x91x1mm.these types of the panels are used only in parking sheds, and tents. Structural fabric 22g per square foot. the weight of the solar flexible panels is very less as compared to the conventional bulky solar panels which are used nowadays. [1] They are ultra-thin silicon wafers designed to capture solar energy. unlike conventional solar panels that are heavy and bulky flexible solar panels are only a few micrometers in thickness.

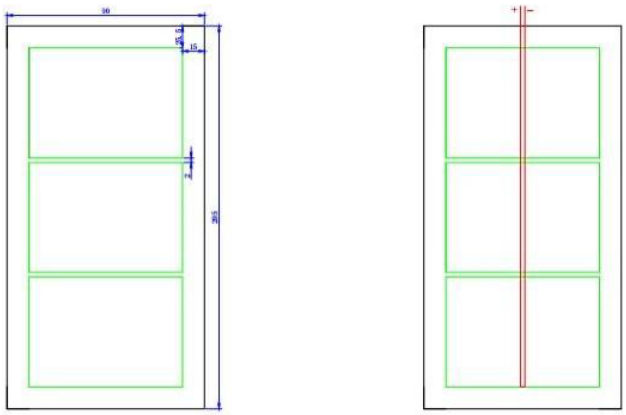

Figure – dimensions of the solar flexible panels [5]

Types of tensile structures

- saddleroof
- mastsupported
- archsupported
- combinations

Saddleroof

Four or more point system when the fabric is stretched between a set of alternating high and low points[9]. A saddle roof is a roof type that follows a convex curve for one axis and a concave curve for the other. The hyperbolic paraboliod shape has been used for roofs at numerous instances considering the fact that it is easily constructed from straight sections of lumber, steel, or other conventional materials. The term is used because the form resembles the form of a saddle.

Mast Supported

Tent like in appearance, mast support structures usually have one or sometimes several peaks which might be supported via means of either, interior or perimeter masts. The fabric is connected to interior mast by uniques connections, normaly a bale ring or cable loop. openings are typically ovoid or elliptical. the cables, which are responsible for the distribution of the tensile stresses and the hardening of the structural fabric, are classified in one of two ways according to the action which they perform: load-bearing and stabilizing. both types of cable cross orthogonally, ensuring strength in two directions and avoiding deformations.[9]

Arch Supported

Curved compression members are used as main supporting elements and cross arches are used for lateral stability. This structural system requires a small amount of material due to the use of thin canvases, which while stretched with the use of steel cables, create surfaces that are able to overcome the forces imposed upon them. Structurally, the system is formalized by combining three elements: membranes, rigid structures such as pole and masts, and cables.[9]

Comparison of structural fabric with solar flexible panels

TECHNICAL SPECIFICATIONS / *CARACTERÍSTICAS TÉCNICAS*

	Précontraint 502 S2-8604S	Précontraint 702 S2-8604S	Standards / *Normas*
Yarn / *Hilo*	1100 dtex PES HT Anti-capillarity treated / *Tratado anti-capilaridad*	1100 dtex PES HT Anti-capillarity treated / *Tratado anti-capilaridad*	TERSUISSE
Weight / *Peso*	590 g/m²	750 g/m²	EN ISO 2286-2
Width / *Ancho* Other widths available: please consult us / *para otros anchos les agradeceremos nos consulten*	250 / 267 cm	250 / 267 cm	
Tensile strength (warp/weft) / *Resistencia a la tracción* (urdimbre/trama)	280/280 daN/5 cm	280/280 daN/5 cm	EN ISO 1421
Tear strength (warp/weft) / *Resistencia al desgarro* (urdimbre/trama)	28/28 daN	30/28 daN	DIN 53.363
Adhesion / *Adherencia*	10/10 daN/5 cm	10/10 daN/5 cm	EN ISO 2411
Finish / *Acabado*	Formula S2 fluorinated varnish weldable / *Fórmula S2 barniz fluorado soldable*	Formula S2 fluorinated varnish weldable / *Fórmula S2 barniz fluorado soldable*	
Light transmission / *Transmisión luminosa*	19%	13.5%	NFP 38 511
Flame retardancy / *Reacción al fuego* 502S Translucent / *Translúcido*	**M2**/NFP 92-507 • **TEST 1**/NFPA 701 • CSFM T19 • **CLASSE A**/ASTM E84 • **B1**/DIN 4102-1 • BS 7837 **1530.3**/AS/NZS • **Classe 1**/UNI 9177-87 • **M2**/UNE 23.727-90 • **VKF 5.3**/SN 198898 Large scale CAN ULC S109 • **Schwerbrennbar Q1-Tr1**/ONORM A 3800-1 • **G1**/GOST 30244.94		
Flame retardancy / *Reacción al fuego* 702S Translucent / *Translúcido*	**M2**/NFP 92-507 • **TEST 2**/NFPA 701 • CSFM T19 • **B1**/DIN 4102-1 • BS 7837 • **1530.3**/AS/NZS SITAC/SINTEF/ETA/SIS 650082 • **Schwerbrennbar Q1-Tr1**/ONORM A 3800-1 • **M2**/UNE 23.727-90 **VKF 5.3**/SN 198898 • **CLASSE 1**/UNI 9177 • CAN ULCS 109 • CAN ULCS 102 • **G1**/GOST 30244.94		
Euroclass / *Euroklasse*			**B-s2,do**/EN 13501-1
Handling temperature range / *Temperaturas extremas de uso*	-30°C/+70°C	-30°C/+70°C	
Management system for quality / *Sistema de gestión de calidad*			ISO 9001

Figure 1- Technical details of structural fabric [10]

Performance*

Performance at Standard Test Conditions (STC: 1000 W/m², 25° C, Spectrum AM 1,5 G)

Nominal Power P_{max}	[W]	25
Voltage at Nominal Power V_{mp}	[V]	79.8
Current at Nominal Power I_{mp}	[A]	0.288
Open Circuit Voltage V_{oc}	[V]	108.8
Short Circuit Current I_{sc}	[A]	0.379

Temperature Coefficients

Temperature Range	-10 ....+90 °C
Temperature Coefficient of V_{oc}	Voc(t)= Voc(28)×(1-0.0035×(t-25))
Temperature Coefficient of I_{sc}	Isc(t)= Isc(28)×(1+0.0008×(t-25))
Temperature Coefficient of P_{max}	Pmax(t) = Pmax(28)×(1-0.0015×(t-25)-0.000017(t-25)2)

*The compensation formulae shown above have been determined from the results of measurements obtained with the solar modules incorporating solar cells.

Mechanical Specifications

Module Construction	Barrier Foil/ Encapsulant/ Solar Cells/ Encapsulant/ Polymer
Number and Type of Solar Cells	68 a-SiGe cells FSA0682AAA0
Dimensions (L x W x T)	832 mm x 414 mm x 0.8 mm (20 mm with junction box)
Weight	0.280 kg
Junction Boxes	2 pieces, HC4 connectors
Certifications	VDE, IEC EN 61646, IEC EN 61730
Product Guarantee	2 years
Performance Guarantee	10 years 90%, 20 years 80% (of specified nominal power rating)

Figure 2- Technical details of solar flexible panels [5]

- Weight of the structural fabric is more than the flexible solar panels, therefore it can bear more wind loads.*[5][9]*
- tensile strength of the structural fabric is more than the solarpanels.
- solar flexible panels come in a particular size , but the structural fabric comes in sq.mt, and can be taken as per requirements. .*[5][9]*
- cost of the structural fabric is less as compared to the solar flexiblepanels.
- solar panels ranges from -10 deg. C / +90 deg.C
- Structural fabric ranges from -30 deg. C / +70 deg. C.*[5][9]*

Therefore out of all these comparisons the conclusion can be taken as the solar cloth panels cannot replace the structural fabric in the tensile structures. The panels have low weight ,low tensile strength, more cost. The panels can't be cut because it may suffer from the loss of the photovoltaics cells, the thickness of the solar panels is 0.8 mm and that's of structural fabric it is mm, therefore the structural fabric can bear more loads as compared to solarflexible panels. The structural fabric comes in sq.mt but the solar cloth panels have a limited size that is 832 x 414 x 0.8 mm , that is way smaller. The solar panels cannot be stitched together because there are chances of loss of photovoltaics cell , it can be stitched together with the help of the cloth, a bag of cloth can be made under which these panels will be placed ,repeat these bags and stitch all bags with one another in order to make a chain of solar panels, but it can't be used in a structure. [7]

How the solar flexible panels can be used in a tensile structure

The solar flexible panels are very flexible and can take any shape , therefore it can be applied in many ways on the structures. The solar panels can be mounted on the structural fabric and can be pasted with a suitable adhesive. The solar panels should face the sun for a long time, so they should be fitted as per the direction of the sun. The solar flexible panels can be fixed to any type of tensile structure whether it is saddle roof ,arch supported roof , mast supported or can be combination of both.

In order to fix the solar flexible panels to saddle roof or any other roof the diagonal ends of solar flexible panels should be stretched and should be mounted on the structural fabric so as to attain strength and resists wind and other loads. The structures may be permanent or temporary , so if

the solar flexible panels is fixed over a tensile structure It can be removed easily without causing any disturbance to the existing structure . It is fixed with the help silicone adhesive, which can be removed easily if required.Solar flexible panels are fixed by calculating the proper angle, will this panels should absorb heat for a longer duration. Fixing the solar flexible panels on the surface of tensile structure which faces the sun throughout the day as a wise decision, the generation of electricity will be more and the cost of the electricity will be less. Because it is unbreakable it is used to resist win loads. In process of fixing panels on tensile structure there is a very less chance of damage to the solar panels on the construction site.

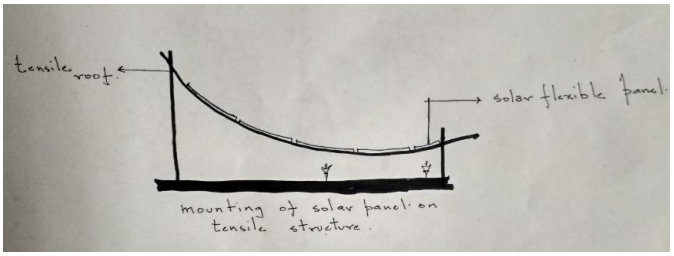

Figure 3- shows the mounting of the solar flexible panels on the tensile structures.

Case studies

1. Modular Easily Deployed Shelters in USA[11]

Features

Solar flexible panels are attached to tents in order to increase the energy generation of the tents. The electricity required for the tents is less, therefore solar panels can be fixed over the tents and make them zero energy tents. The entire structure can be erected in less than 5 Minutes. Range from 41sq.ft to 660sq.ft. Outer fabric is a heavyweight protective PVC material that can withstand I any environmental condition. They are strong, can withstand extreme weather conditions and are durable in any environmental conditions and offers 1440 Watts of solar power.

Figure 4- solar flexible panels mounted on tents [11]

2. Pvilion Solar Sail Canopy New York, Brooklyn[2]

The revolutionary light-weight structures provide shade and solar energy as well as led lighting and mobile charging with built in supports that are both grid tied and off grid, these canopies are customizable with scalable battery backup system depending on the installation needs Made with a pvc coated polyester fabric.thesecanopies can be engineered for a single,two,or four pole configuration. All the solar cloth panels have mounted on the pvc fabric because the weight of the solar panels is less.the combination of both fabric and panels give the best result as in stability and power generation.

Figure 5- solar flexible panels mounted canopy [11]

3. Solar Fabric Carport[11]

Modular carport that uses its high efficiency solar cells and long-lasting fabric technology. All the solar cloth panels have mounted on the pvc fabric because the weight of the solar panels is less. The combination of both fabric and panels give the best result as in stability and power generation, shading of the cars and power generation together makes this carport more efficient. The power generation of the carport is huge, because there are thirty solar canopies are provided in the overall carport as a shading device for the cars. This solar carport have the capacity of 2000 cars at a time, the biggest carport in New York.

Figure 6- carport with solar flexible panels mounted on top of it [11]

4. 2014 Solar Decathlon Techstyle House [11]

The techstyle haus is the world's first fabric pssive house -the 5kw solar array produces more energy than home will use.the solar panels are mounted on the concrete building .as the solar cloth panels are flexible they can achieve anyshape and size ,therefore it can be mounted on any freeform structure. The concrete structure had taken one year to complete and it's the first house that contains solar flexible panels. The slab is 120m thick with a structural fabric base on it, the solar flexible panels are mounted over the structural fabric, the solar panels are fixed on the structural fabric with the help of a silicon adhesive. The solar flexible panels can be removed if required[4]

Figure 7- solar decathlon techstyle haus [11]

III. CONCLUSIONS

Solar flexible panels are very thin and hence they are less expensive and use substrates that are low cost and easier to work with.[1] They are easy as FPD (Flat Panel Display) and they are very easy to install at any construction site. [1] The solar flexible panels are highly efficient, the power generation of the building increases as there is an increase in using renewable energy. It is weather resistant that is it can withstand in any temperature conditions. It is durable that is it has more wear and tear strength. They are extremely easy to manufacture and are highly profitable. The combination of both tensile fabric and solar flexible panels results in a better way of power generation at a building level. No matter the structure is permanent or temporary, the solar flexible panels are suited for both types of structures. [5] [10] The replacement of the structural fabric by solar flexible panels in tensile structures is not possible due to its low tensile strength, if the tensile strength is not appropriate then there may be a structural failure. [3] These panels have a limited width available because of which it cannot be used in a large-scale project directly, it must be fixed or mounted on the top of the structural fabric, some of the flexible panels come in a form of rolls and there is no limitation to size, but the tensile strength is not appropriate. Solar cloth panels is a great invention which has helped to build better world as well as enhancing the importance of the renewable energy.[4]

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