Spring 2018

Exchange Parking Deck Solar Feasibility Study

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THE UNIVERSITY OF AKRON

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Honors Project

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4/28/2017

Table of Content

Abstract

The purpose of this project is to conduct a study showing the feasibility of installing solar panels over the Exchange Parking Deck at the University of Akron. For this study 10 different solar panels were analyzed. Three different types of panels were researched; thin-film, monocrystalline, and polycrystalline however, thin-film panels were ruled out during background research and not used in the study. To install the solar panels onto the parking deck a canopy structure was designed to support the panels. The panel selected for this project was the Polycrystalline Violin Chsm6610P series panel by Astronergy because of its low cost per panel compared to its high energy generated. The cost of the panels and structure were analyzed to determine if the project is feasible. The cost of the panels was $702,900, and the cost of the structure plus installation was $1,341,733, for a total cost of $2,044,633. Over a period of 50 years the panels will only save the University of Akron $1,609,082.49. With the total time of investment is over 50 years the project was considered unfeasible.

Introduction

In the United States 81% of our energy demands can be met through the use of fossil fuels (1). The current rate at which we used fossil fuels is unsustainable; things like oil, natural gas, and coal will be gone in 53, 54, 110 years respectively (2). This means that within a generation we will be out of fossil fuels, and as we run out of these resources the price for energy will go up. According to the U.S. Energy Information Administration, the cost of electricity per kilowatt hour will increase from $10.37 to $10.49, and $10.64 for 2016, 2017, and 2018 respectively for the commercial sector (3). In 2016, The University of Akron (UA) budgets

$8,241,055 for utilities, which was $0.3 million more than in 2015 (4). Through the use of renewable resources, places like UA can lower the cost of utilities.

One way that UA is trying to reduce utility cost is by reducing the amount of electricity it uses. UA has already implemented ideas to reduce electricity using more efficient lights, motion sensors on lights in rooms, and solar panels on buildings (5). These installations have already helped UA reduce the energy it uses which in turn reduces the cost for students. However, there are more ways UA can reduce its expenses. One is to invest in more solar panels. UA has five different parking decks on its campus that could be used to collect solar energy. Parking decks are an ideal spot for solar energy because they are elevated away from objects that could block the sun. This would guarantee the rate cost of electricity and as the rates increase, the payback period for the investment into the panels would go down. House Bill 251 required that a 15 year plan for implementing energy efficient and conservation projects, this also includes reducing energy expenses by at least 20% by 2014 (6) which Akron is still working on achieving.

The goal of this study is to determine the feasibility of installing solar panels on a canopy structure on the top level of the exchange parking deck at UA. The location for this study was chosen due to the open area, which allows for more coverage with nothing blocking sunlight. It was also chosen because of its steel frame which allows the canopy structure to be tied into the existing parking deck more easily. This study will choose a solar panel that best fits the project, design a canopy structure, analyze if the current structure can safely hold the canopy, and conduct a cost benefit analysis on the payback period of the project. The types of solar panels investigated are thin-film, monocrystalline silicon, and polycrystalline silicon.

Solar Panel Background

In the simplest of explanations solar panels work by taking the sun's energy and transferring it to electricity. This process is done by allowing particles of light to free electrons, which generate a flow of electricity (7). Solar panels are comprised of many cells called photovoltaic cells. Each cell is comprised of two thin wafers, usually silicon, with one side positively charged and the other negatively charged through the addition of phosphorus gas and boron (7, 8). Because of the opposing charges the cells have an electric field, which allows them to transfer electrons as a direct current to an inverter (7). This inverter turns direct current into alternating current (8).

The first type of solar panel investigated was the thin-film panel. There are four types of thin-film panels, cadmium telluride, amorphous silicon, copper indium gallium selenide, and gallium arsenide; all are made using the same process (9). Depending on the type, thin-film panels have an efficiency of 6-12% (10). Thin-filmed panels are the cheapest type of cell on the market, due to the ease at which they can be mass produced (11). They also have the highest resistance to heat compared to monocrystalline silicon and polycrystalline silicon panels. With the low efficiency of these panels, one would need up to four times as many panels to produce the same power as the other two types of panels. Due to this, thin-film panels were deemed insufficient and ruled out of the study.

Monocrystalline solar panels are among the oldest and most dependable panels on the market (12). Monocrystalline solar panels are the most efficient and therefore take the longest to make. This process starts by melting silicon dioxide, in the form of quartz or quartzite, in an arc furnace to produce carbon dioxide and molten silicon (13). At this point the silicon has a 99%

purity, which is purified even further using the floating zone technique. This technique works by pulling a rod of impure silicon through a heating zone in one direction several times to pull the impurities to one side. Once the desired purity is reached, usually 99.999% (14), the end with impurities is removed (13). Next, a silicon crystal is put in a Czochralski growth apparatus. This device works by dipping the crystal in molten polycrystalline silicon, with a small amount of boron (12). When the crystal is removed, it is rotated, which pulls silicon with it, leaving impurities behind, forming an ingot of pure silicon (13). The ingot is then sliced into thin wafers, which are sealed back to back and placed in a furnace with phosphorus gas at 2,570°F. The gas "burrows" into the wafers which are almost a liquid due to the extreme heat. This process is controlled so the junction is at the proper depth and uniform. The main advantage of monocrystalline panels is the high efficiency, which means the panels can produce more energy using less space than other panels (15). These panels also perform better in warmer temperatures than polycrystalline panels; however, both panels have lower efficiencies in warmer climates. Being the most efficient monocrystalline panels are the most expensive type of panel on the market. Both monocrystalline and polycrystalline panels are prone to breaking compared to thin-film panels from high wind, and debris (11). The shape of the cells on monocrystalline panels have rounded edges, which reduce the surface area of solar cell per panel.

Polycrystalline panels are made from multiple silicon crystals instead of 1 crystal used in monocrystalline panels (16). The process for making polycrystalline panels is similar to monocrystalline panels, but the Czochralski growth apparatus is not used (11). Instead, the silicon is simply melted and poured into a mold that forms a square wafer. By skipping steps in the process, these panels are cheaper, with sacrifices to efficiency. With the improvements of manufacturing techniques, the difference in efficiency between mono and polycrystalline panels is shrinking (12). However, polycrystalline panels have a larger efficiency loss at higher temperatures (15).

Canopy Design

The Exchange parking is comprised of steel framing with concrete decking. The parking deck has five floors including a roof and basement level. There is one entrance in the northeast corner of floor one and one exit in the southeast corner of floor one. Along with these exits and entrances, there is an entrance/exit in the southwest corner of the parking deck that is closed off due to the removal of the access road. On the fourth floor of the parking deck is a pedestrian walk way to Schrank Hall, along with a small bridge to the South Campus parking deck. The Exchange deck was rehabilitated in the 2000 by Braun & Steidl Architects Inc.

Given the layout of the parking deck, seven canopies is the maximum number that can be used. This is done due to the angle of 13 degrees from parallel to the roof to the top of the structure. Seven was decided to as the optimal number to keep the total height of the structures from being too tall. This angle was found to be the best for absorbing direct sunlight throughout the year in Akron. This optimal angle is based on latitude and the varying position of the sun over the course of a year (17). The angle varies for each structure because the width of each structure is not consistent due to the spacing of the columns in the existing parking deck. The heights were kept the same for each canopy for ease of construction. From the position of the sun in Ohio, the height of each canopy will be 21 feet on the north side and 10 feet on the south side as shown in Figure 1. The 10 foot clearance above the floor level will also give adequate clearance for vehicles on the fifth floor. This clearance is based on current clearance levels throughout the parking deck, along with the 8 foot maximum vehicle height permitted in the parking deck. The canopies will run east-west for the entire length of the deck; however. the canopies will start 20 feet in from the north and south ends. This is because the deck is not a perfect rectangle; each corner of the deck is missing a 20 foot by 20 foot square. Due to this missing area, the canopies were designed to start 20 feet in from the ends to avoid the lack of supports over these area. The general shape of each canopy will be a triangle, with girders running the length from east to west, and beams running north to south with metal sheeting running east to west on top of the beams.

The loads taken into consideration for the canopy structure are dead, snow, and wind. Due to the angle of the canopy and the durability of the solar panels, walking on the panel is not permitted therefore live load was neglected. Dead load was assumed 3 pounds per square foot (psf) as a conservative estimate for the weight of the panels. This value was determined using the heaviest panel investigated, assuming it covered the entire area of the roof and rounding the dead load up from 2.5 psi to 3 psi. Snow loads were calculated using section 7.3.4 of (18) and wind loads were calculated using chapter 29 of the same design manual (18). The factored load for the roof of the structure is 48.8 psf (19) before the addition of material weight.

In most canopy designs for solar panel structures, metal sheeting is used due to its rigidity, affordability, and the ease which panels can be connected to it. Structural designs were made using five different types of metal sheeting. The different types of sheeting along with manufacturer given information are shown in Table 1. The limiting factor for the design is the beam spacing, which is given by manufacturers in tables based on loading. The manufacturer's recommendation for maximum unbraced length was used as a starting point for beam placement. The main consideration used in picking material to be used is the added load to the current structure. The optimal design is the design that adds the least load to the current parking deck structure. Taking into consideration total weight of the designed canopies, the BoxRib sheeting was found to be the best because of its weight to maximum unbraced length ratio.

The beams were analyzed for yielding and buckling for the largest of the seven canopies, with lateral torsional buckling being the governing factor. The maximum shear and moment were calculated for the beam with the greatest contributing area using the 48.8 psf factored loading. Using Chapter F of the Steel Construction Manual (19), moment capacity for bucking (M_n) was calculated for a beam with $L_b > L_p$, using the equation below (19);

$$M_n = F_{cr} * S_x$$

$$F_{cr} = \frac{C_b * \pi * E}{(\frac{L_b}{R_{ts}})^2} * \sqrt{1 + 0.078 * \frac{J * c}{S_x * h_o} * (\frac{L_b}{R_{ts}})^2}$$

For lateral-torsional buckling. To be conservative C_b was assumed to be 1. The modules of elasticity (E) is a material property for steel. While; R_{ts}, J, c, S_x, and h_o are section properties that vary depending the wide flange selection. From Table 3-10 (19) the beam size was determined, W10x49, using 34.5 feet as the unbraced length (L_b). This process was then repeated, taking into consideration the weight of the W10x49 to find the new maximum moment. The new moment surpasses the capacity for a W10x49; therefore, Table 3-10 (19) was used again to find new beam size of W12x53. When the weight of this new beam were used to find the moment the, W12x53 had a capacity greater than the moment demand. Once the moment strength criterion was met, the shear was checked; the beam was more than capable to hold the maximum shear. Therefore the W12x53 was used for the beams in all canopy structures.

The girders were sized in a similar manner as the beams. The girder with the largest tributary area was analyzed. This girder is the center girder for the end structures because it has the largest tributary area due to its location in the center and due to the end structures having the largest roof area. Using Table 3-10 (19) and the same steps as sizing the beams, the girders were sized to be W14x90, which have adequate capacity for moment and shear.

When sizing columns, connections to existing columns had to be taken into consideration. For ease of connection to existing columns using columns of the same or similar sizes would be best. To do this, W10x39 columns were selected for the exterior columns, and W12x40 for interior columns.

To check if the existing structure's columns could support the added load, the added load to the columns was compared to the capacity of the columns. The added loads for the exterior columns and interior columns are 40.77 kips and 81.54 kips, respectively. The capacity of the existing structure is 512 kips for the W10x49 exterior columns, and 806 kips for the W12x72 interior columns, at the bottom story of the parking deck with an unbraced length of 12 feet. The bottom story columns will be holding the most weight and therefore were the only ones analyzed. The columns sizes for the bottom story stated previously are also the smallest ones on the bottom story to be conservative. The added loads are only 8 percent and 10 percent of the existing exterior and interior capacities respectively. Due to the added load being such a small percentage of the columns' capacities, it can be assumed that the parking deck can support the added load of the canopy structure.

Connections

Steel sections only come in 20 to 40 feet sections; therefore, splice connections are required between girders. The length of the average girder is 60 feet so the span will be broken into a 40 and 20 feet sections to keep the splice connection away from the center of the span, which holds the most moment, along with keeping the connection away from the columns for ease of construction. The typical section for connection can be seen in Figure 2a-c. This connection is designed using A36 steel with thicknesses of 1 inch and 0.75 inches for the flanges and web, respectively. This will give the plates a higher yield strength than the girder, ensuring that it will not fail. Using four bolts for each plate will provide a conservative shear strength.

A shear tab was chosen for connecting girders to columns as well as connecting beams to girders. Tabs were designed and checked for bolt shear, beam web shear yielding, beam web shear rupture, beam bolt bearing, beam block shear, plate shear, plate yield, plate bolt bearing, and plate block shear (19) as shown in Table 2. The shear tab for the girder to column connection is 10 inches long by 6 inches wide with a half inch thick tab connected to the column by a full penetration weld as seen in Figure 3a-c, this weld ensures the weld will handle the shear and moment caused by the girder on the tab. The tab connecting the beams to the girder also uses full penetration welds, however, this tab is 8 inches long by 6 inches wide by half an inch thick, as seen in Figures 4a-d.

Panel Selection

For the sake of this feasibility study research was conducted to determine the best type of panel, between monocrystalline or polycrystalline. Panels of these two types were investigated and selected for this study. 10 panels we've investigated and compared to find the best one. The main qualities were normal operating cell temperature (NOCT) power, cell cost, and investment return period. NOCT is a corrected cell power based on normal temperature; this value is a more realistic power rating. The posted power for panels is a nominal power based on perfect conditions in a lab. Using NOCT values will increase the return on investment period to a more accurate number. Manufacture's were found for all the panels investigated. The panels and all of their specifications are listed in Table 3.

The first step to determine the amount of profit was to fine the number of panels needed to fit the seven canopy structures. Each panel has different dimensions which must be taken into consideration for finding total number of panels, as well as when calculating the power output (kW/yr) and total cost, as shown in Table 4. To find the power generated, in kilowatts per year, the sun exposure for the site location had to be investigated. This value was found to be 1,357 hours of sun per year, which is an average of 3.7 hours per day (20). This sun exposure value of 1,357 hours of sun per year comes from goggles' project sunroof, shown in Figure 5. This project uses the angle of the sun throughout the year, along with weather patterns to give an accurate estimate for the number of sunlight hours a roof receives each year. The total power generated per year was calculated by multiplying the sun exposure by the normal power generated, as shown in Table 5. To find the cost saving the amount of power generated per year was multiplied by 25 years and by 5.17 cents per kilowatt hour; which is the current rate that UA pays for electricity, this amount is from UA's Capital Asset and Planning Department. However, panels do not work at 100 percent efficiency and efficiency decreases over time. This was taken into consideration looking into the manufacturer's warranty.

For each manufacturer the warranty of the panels was taken into consideration over a time period of 25 and 30 years. Each manufacturer guaranties the power output of their panels for 25 years. When calculating the total power output the minimum guaranteed efficiency was used to obtain a conservative estimates. A degradation correction term was calculated to adjust for the decreasing efficiency over a period of 25 years. To fine the money generated over this period the power output per year, was multiplied by correction term, and by 5.17 cents per kilowatt hour, as shown in Table 6. Degradation constant for 30 years was calculated using the same process however, degradation rates were assumed to double after the warranty expires for a conservative estimate. The final panel selected based on these criteria is the Polycrystalline Violin Chsm6610P series panel by Astronergy. However, as you increase the payback period the Panasonic HIT Power gives better results. The Astronergy gives better results at 40 years and under and payback period over 40 years are considered unfeasible therefore, the Astroenrgy panel was selected.

Cost Analysis

Federal tax credit

When installing solar panels the owner of the panels is eligible for federal solar tax credit (21). Federal solar tax credit, or the investment tax credit (ITC), allows homeowners or companies installing solar energy systems to deduct 30 percent of the installation cost. The 30 percent deducting lasts until 2019 at which it will be reduced to 26 percent, this deduction comes with no limit. In previous year the deduction couldn’t be claimed until after the solar system was operation. However in 2015 it was changed so that the deduction can be claimed as soon as construction is started, as long as the project is completed by December 31, 2023. The credit can be claimed when filing for federal tax returns (21). The cost analysis of this study shows the total cost and payback period with and without this tax credit, as shown in Tables 7 and 8 respectively.

Construction Cost

The total cost of the project is based on the total cost of the panels, construction materials, labor, and equipment needed to install the panels. The cost of the panels is from the manufactures while the cost of the structure is based on the vales in the 2017 Building Construction Estimator with RSMeans Data (22). The cost of the panel selected in is Table 2, while the cost for the structure can be found in Table 9. The values from the Building Construction Estimator are based on; the structural columns section, structural framing section, sheeting section, and electrical section. For the columns and framing sections the values in the book give a cost for materials, labor and equipment for installation per linear foot. As per the books instructions, the total weight of the project is over 70 tons therefore, a 10% increase was added to the material cost. Sheeting was determined using the same process however, the cost is per square foot; likewise a 10% increase in material cost was added. The material cost for the solar panels was used from the manufacturer instead of the estimator for a more accurate number, however the cost of labor was used from the estimator as a cost per panel. The total end cost for the project is $2,044,633, without the tax credit and $1,431,243 with the tax credit. Taking both into consideration the payback period is too long for each situation making the project unfeasible.

Conclusion

The panel selected in this was the Polycrystalline Violin Chsm6610P series panel by Astronergy. This panel was selected because it has the best payback rate with respect to initial cost. This panel also has the highest output power based on its size. The total cost of installing panels and building the canopy is $2,044,633. Given the current rate that The University of Akron pays for electricity the panels will save $946,650.69, $1,388,990.86, and $1,609,092.49 over a 25, 40, and 50 years period respectively. The savings provided by the panels over a period of 50 years is not enough to offset the cost of the project. If the federal tax credit is taken into consideration the panels will take over 40 years to make a profit. This period is almost double the warranty of the panels, due to this it would be to risky to consider the project as a feasible way to save money. This study has deemed that the installation of solar panels over the Exchange parking deck is not feasible. For future studies it would be recommended to look into areas that do not require a structure be built to support the panels.

Appendix A

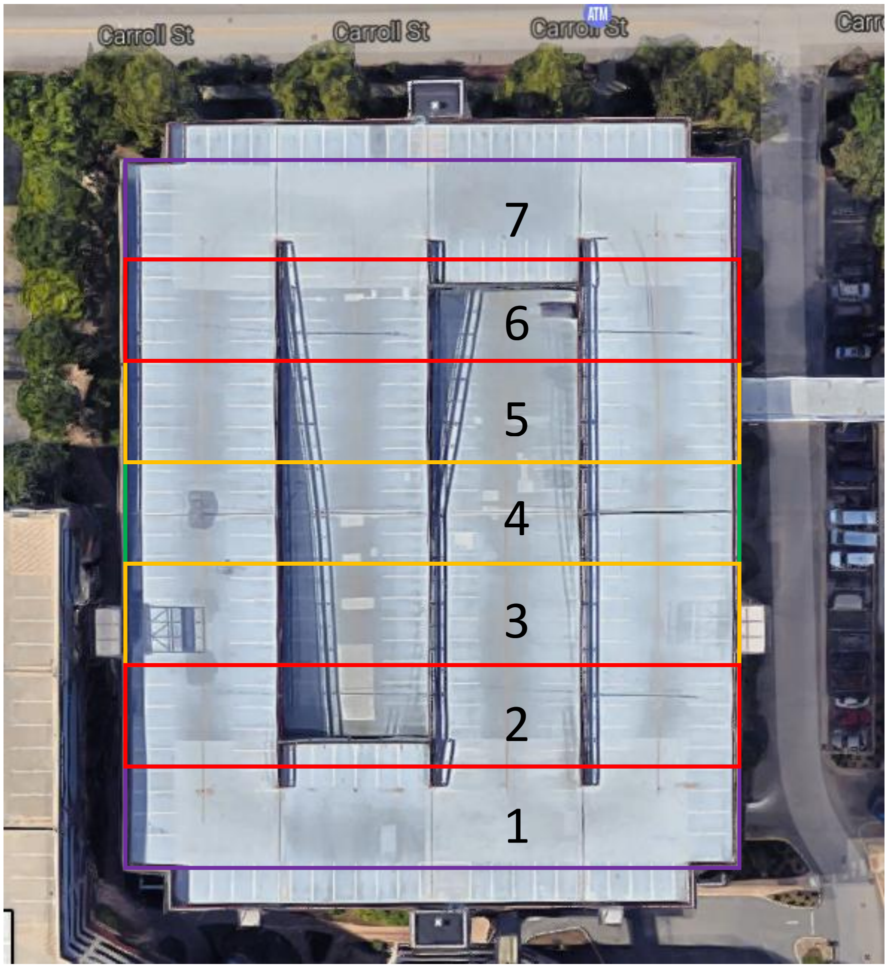


Figure 1a. Ariel view of seven canopy structures, canopies with the same color are the same size.

Figure 1b. Concept for side view of canopy structures.

Table 1. Roof sheeting standard data.

Types	Spacing (ft)	Gauge	Weight (lb/ft)	width (in)	Ridge Length (in)
.5 Corrugated	4.50	18.00	12.50	41.25	2.67
7/8 corrugated	7.00	18.00	12.50	36.00	4.00
Flexbeam	10.50	18.00	12.50	38.80	2.88
Flexrib	6.50	18.00	12.50	39.00	3.00
Box Rib	10.00	16.00	12.17	45.63	2.82

Table 2. Connection capacity check.

	Shear Demand (k)	Shear Yielding Capacity (k)	Shear Rupture Capacity (k)	Bolt Bearing Capacity (k)	Block Shear Capacity (k)
Beam to Girder 1	6.67	102.50	79.85	48.02	77.60
Beam to Girder 2	6.67	96.56	81.34	48.02	77.60
Girder plate	6.67	86.40	52.20	48.02	83.83
Girder to Column	40.00	145.20	115.83	61.25	114.26
Column plate	40.00	108.00	104.40	61.25	96.79

Figure 2.a Flange connection plate detail for W14x90 splice.

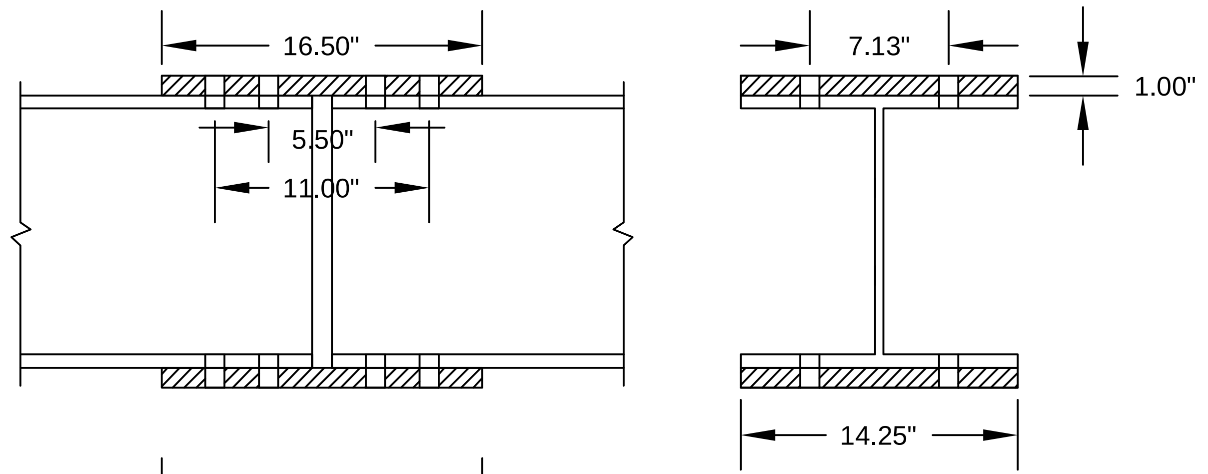


Figure 2.b Web connection plate detail for W14x90 splice.

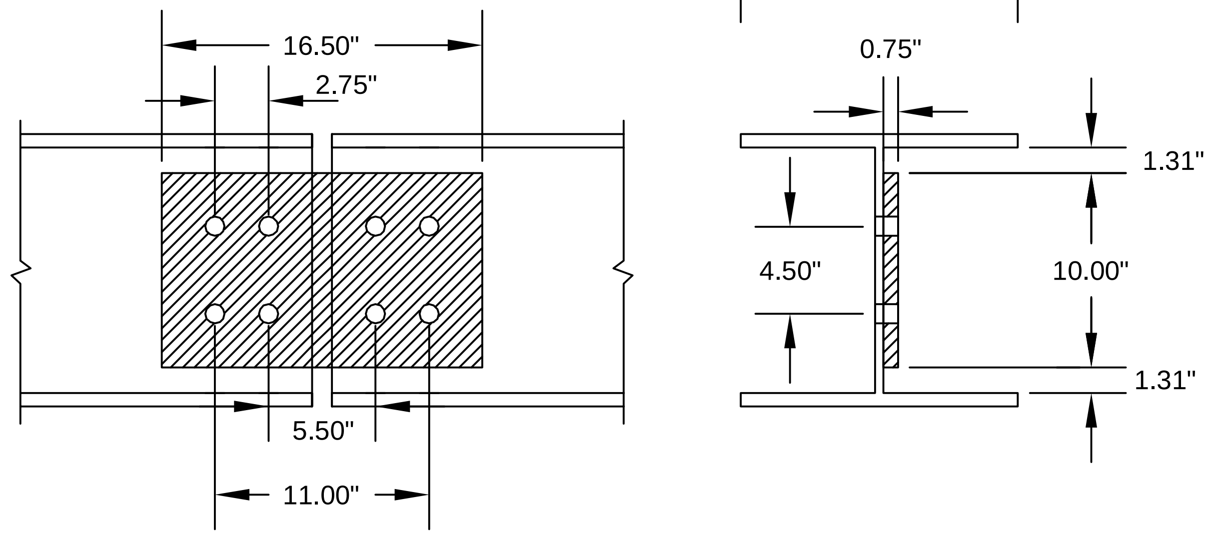
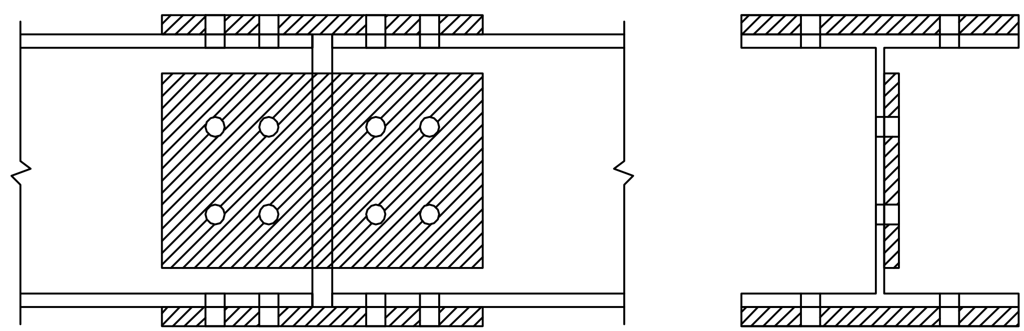


Figure 2.c Full detailed connection for W14x90 splice.



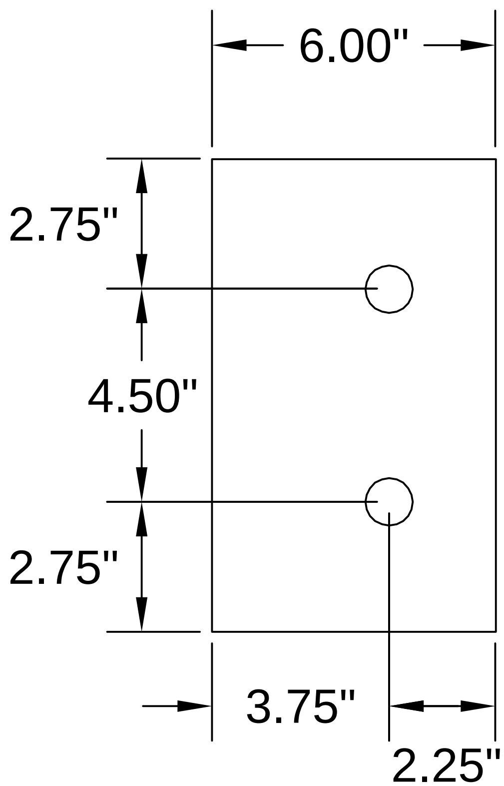


Figure 3.a Typical section for connection plates on column.

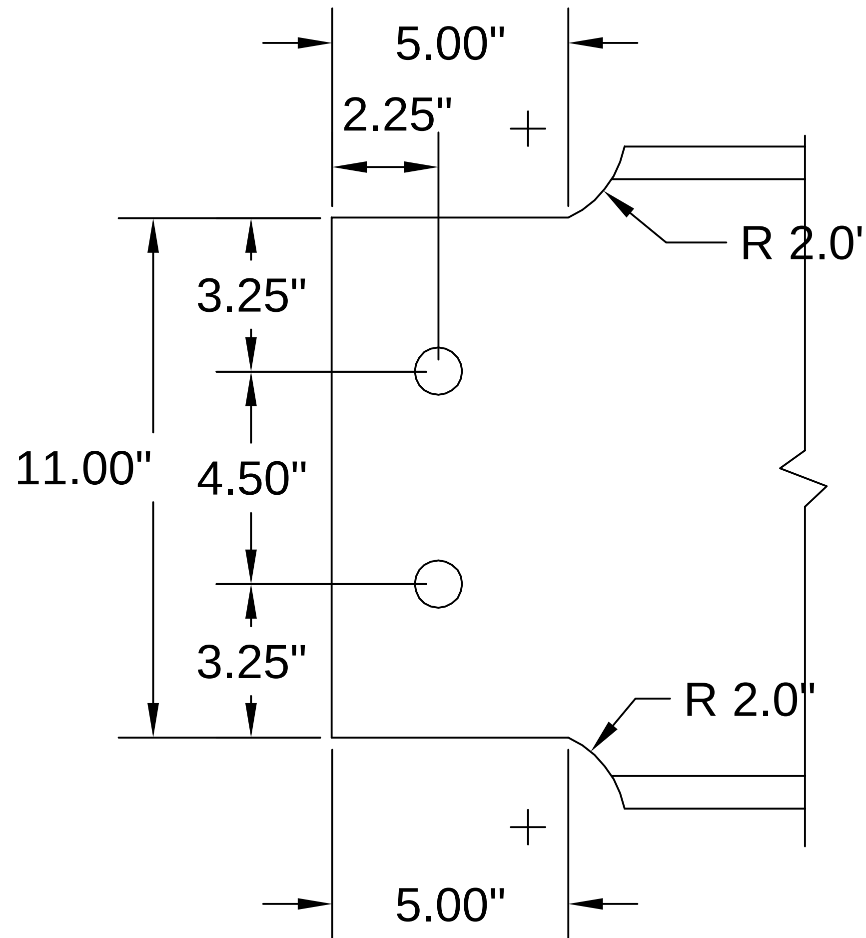


Figure 3.b Typical section for girder to column connection.

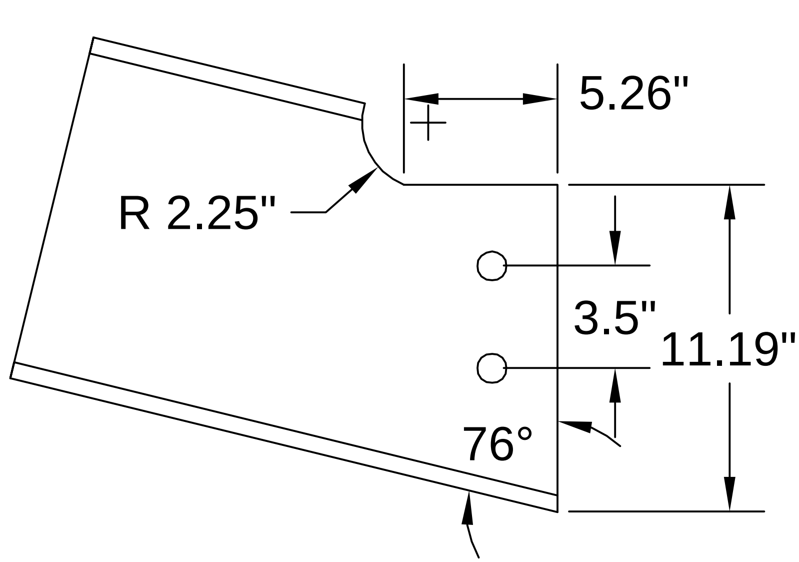


Figure 4.a Typical section for higher end beam to girder connection.

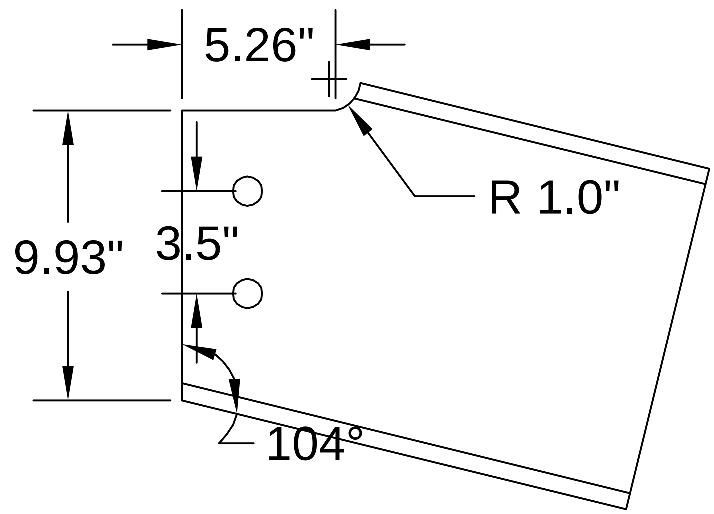


Figure 4.b Typical section for lower end beam to girder connection.

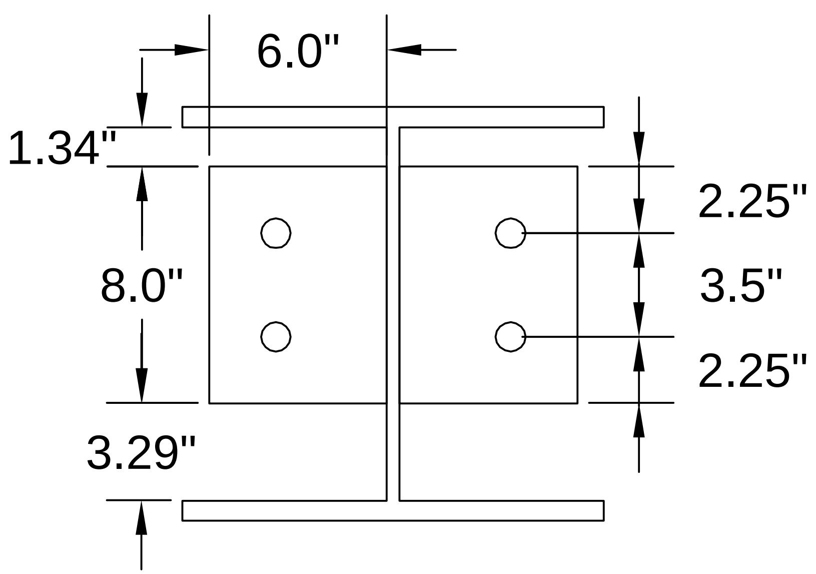


Figure 4.c Typical section for connection plates on girder.

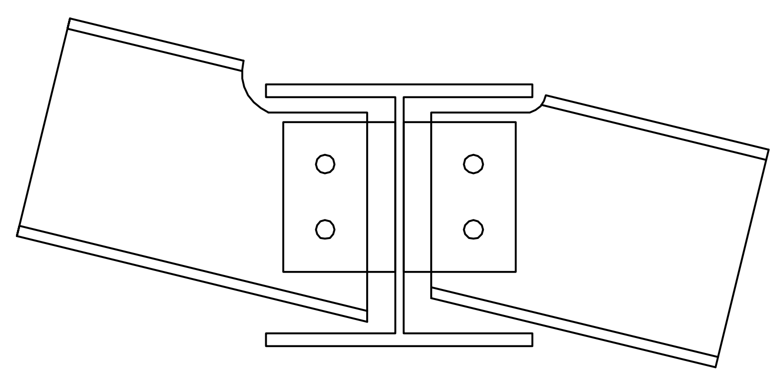


Figure 4.d General overview of beam girder connection.

Table 3. General panel information

Panel	Type of Panel	Max Power (watts)	NOCT max (watts)	Efficiency (%)	Dimensions (in)	Weight (lb)
Sharp 300 watt ND-F4Q300	Polycrystalline	300	218	15.3	39.1 x 77.6 x 1.8	50
Sunmodule SW 340 - 350 Mono	Monocrystalline	340	259.3	17.04-17.54	39.4 x 78.46 x 1.3	39.7
Sunmodule SW285-300 Mono	Monocrystalline	295	220.5	17.3-17.89	37.8 x 65.95 x 1.3	47.4
Sunmodule Plus SW 280-290 Mono Black	Monocrystalline	285	211.1	17.59	37.8 x 65.95 x 1.3	39.7
LG 315N1C Black Mono	Monocrystalline	315	230	19.2	39.37 x 64.57 x 1.57	37.48
LG 305N1K-G4	Monocrystalline	305	225	18.6	39.37 x 64.57 x 1.57	37.48
LG 280S1C Mono	Monocrystalline	280	205	17.1	39.37 x 64.57 x 1.57	37.48
Mitsubishi PV-UD185MF5	Polycrystalline	185	179.5	13.4	32.8 x 65.3 x 1.81	37
Astronergy VIOLIN CHSM6610P-260	Polycrystalline	260	195	15.9	38.98 x 64.88 x 1.57	40.57
Panasonic HIT Power N325SA16	Monocrystalline	325	245	19.4	41.5 x 62.6 x 1.4	40.81

Table 4. Panel cost and savings breakdown

Panel	Cost (US$)	# Panels wide	# Panels length	# Panels	Power Generated (KW/hr)	Total Panel Cost (US$)
Sharp 300 watt ND-F4Q300	329.16	71	37	2627	571.9	$864,699
Sunmodule SW 340 - 350 Mono	385	70	36	2520	653.44	$970,200
Sunmodule SW285-300 Mono	320	73	43	3139	692.15	$1,004,480
Sunmodule Plus SW 280-290 Mono Black	335	73	43	3139	662.64	$1,051,565
LG 315N1C Black Mono	392	70	44	3080	708.4	$1,207,360
LG 305N1K-G4	384	70	44	3080	693	$1,182,720
LG 280S1C Mono	300	70	44	3080	631.4	$924,000
Mitsubishi PV-UD185MF5	350	83	44	3652	655.53	$1,278,200
Astronergy VIOLIN CHSM6610P-260	225	71	44	3124	609.18	$702,900
Panasonic HIT Power N325SA16	373.75	67	46	3082	755.09	$1,151,898

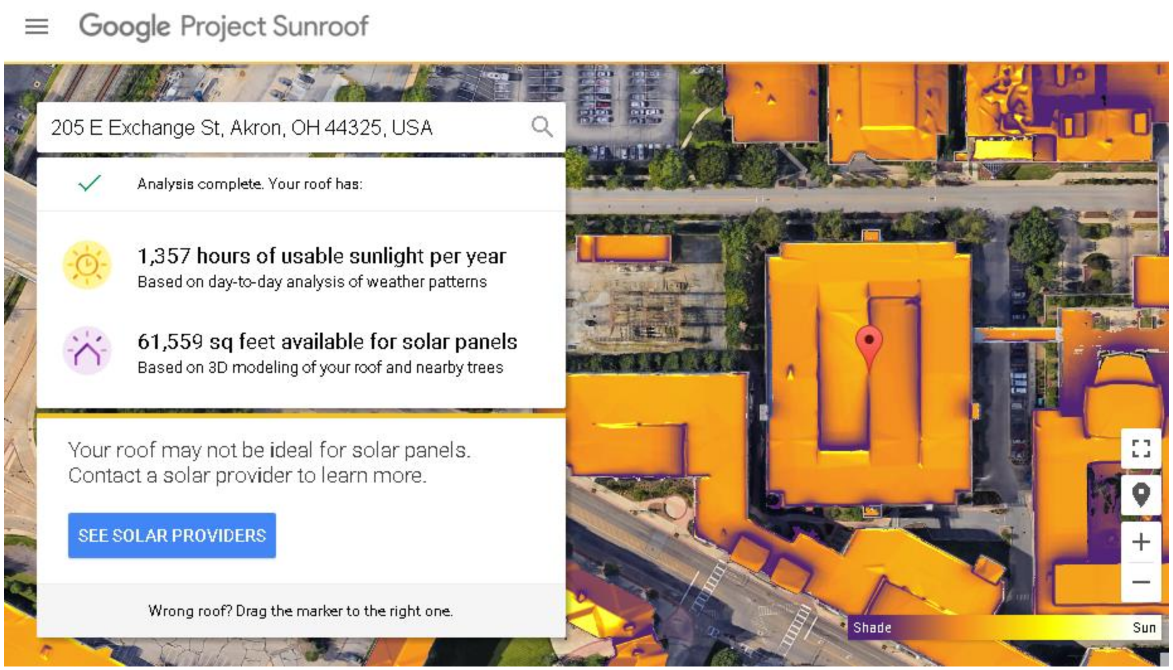


Figure 4. Project sunroof sun exposure for Exchange Parking Deck (24).

Table 5. Total power generated by panels

Panel	Power Generated (KW/hr)	Sun exposure per year (hr)	Power Generated per year (KW/hr)
Sharp 300 watt ND-F4Q300	571.9	1,357	776,068
Sunmodule SW 340 - 350 Mono	653.44	1,357	886,718
Sunmodule SW285-300 Mono	692.15	1,357	939,248
Sunmodule Plus SW 280-290 Mono Black	662.64	1,357	899,202
LG 315N1C Black Mono	708.4	1,357	961,299
LG 305N1K-G4	693	1,357	940,401
LG 280S1C Mono	631.4	1,357	856,810
Mitsubishi PV-UD185MF5	655.53	1,357	889,554
Astronergy VIOLIN CHSM6610P-260	609.18	1,357	826,657
Panasonic HIT Power N325SA16	755.09	1,357	1,024,657

Table 6. Panel warranties, degradation rates, and factored savings

Panel	First year efficiency (%)	Degradation Rate (%/yr)	Efficiency for 25th yr (%)	Workmanship warranty length (yr)	Degradation correction
Sharp 300 watt ND-F4Q300	90 for first 10 yr	NA	80 for last 15 yr	10	21
Sunmodule SW 340 - 350 Mono	97	0.7	80.2	10	22.15
Sunmodule SW285-300 Mono	97	0.7	80.2	20	22.15
Sunmodule Plus SW 280-290 Mono Black	97	0.7	80.2	10	22.15
LG 315N1C Black Mono	98	0.6	83.6	12	22.7
LG 305N1K-G4	98	0.6	83.6	12	22.7
LG 280S1C Mono	98	0.6	83.6	12	22.7
Mitsubishi PV-UD185MF5	NA	NA	NA	NA	NA
Astronergy VIOLIN CHSM6610P-260	97	0.7	80.2	10	22.15
Panasonic HIT Power N325SA16	95	0.6	80.6	15	21.95

* Cost based on an energy rate of 5.17 Cents/KW*hr

Table 7. Panel savings over 25, 40 and 50 years.

Panel	Total Panel Cost (US$)	25 year profit after panel cost (US$)*	40 year profit after panel cost (US$)*	50 year profit after panel cost (US$)*
Sharp 300 watt ND-F4Q300	$864,699	-$22,121.71	NA	NA
Sunmodule SW 340 - 350 Mono	$970,200	$45,229.64	$519,708.05	$755,801.18
Sunmodule SW285-300 Mono	$1,004,480	$71,104.03	$573,690.70	$823,770.05
Sunmodule Plus SW 280-290 Mono Black	$1,051,565	-$21,838.78	$459,319.97	$698,737.12
LG 315N1C Black Mono	$1,207,360	-$79,189.34	$472,471.20	$765,696.17
LG 305N1K-G4	$1,182,720	-$79,074.79	$460,593.13	$747,443.65
LG 280S1C Mono	$924,000	$81,543.41	$573,240.85	$834,593.55
Mitsubishi PV-UD185MF5	$1,278,200	NA	NA	NA
Astronergy VIOLIN CHSM6610P-260	$702,900	$243,750.69	$686,090.86	$906,192.49
Panasonic HIT Power N325SA16	$1,151,898	$10,898.78	$575,080.12	$866,441.37

* Cost based on an energy rate of 5.17 Cents/KW*hr

Table 8. Panel cost savings with Federal tax credit

Panel	Panel Cost (US$)	Structure cost (US$)	Total Cost (US$)	Cost after Federal tax Credit	Revenue over 50 year (US$)*	Profit after 50 years (US$)*
Sharp 300 watt ND-F4Q300	$864,699	$1,341,733	$2,206,432	$1,544,502	NA	NA
Sunmodule SW 340 - 350 Mono	$970,200	$1,341,733	$2,311,933	$1,618,353	$1,726,001.18	$107,648.08
Sunmodule SW285-300 Mono	$1,004,480	$1,341,733	$2,346,213	$1,642,349	$1,828,250.05	$185,900.95
Sunmodule Plus SW 280-290 Mono Black	$1,051,565	$1,341,733	$2,393,298	$1,675,309	$1,750,302.12	$74,993.52
LG 315N1C Black Mono	$1,207,360	$1,341,733	$2,549,093	$1,784,365	$1,973,056.17	$188,691.07
LG 305N1K-G4	$1,182,720	$1,341,733	$2,524,453	$1,767,117	$1,930,163.65	$163,046.55
LG 280S1C Mono	$924,000	$1,341,733	$2,265,733	$1,586,013	$1,758,593.55	$172,580.45
Mitsubishi PV-UD185MF5	$1,278,200	$1,341,733	$2,619,933	$1,833,953	NA	NA
Astronergy VIOLIN CHSM6610P-260	$702,900	$1,341,733	$2,044,633	$1,431,243	$1,609,092.49	$177,849.39
Panasonic HIT Power N325SA16	$1,151,898	$1,341,733	$2,493,631	$1,745,541	$2,018,338.87	$272,797.52

* Cost based on an energy rate of 5.17 Cents/KW*hr

Table 9. Cost for installation of canopy by section from RS means book.

Section	Material Cost	Labor Cost	Equipment Cost	Total Cost	Quantity	Cost
W10x39	$61.05 / LF	$2.57 / LF	$1.57 / LF	$65.19 / LF	434 LF	$28,292
W12x40	$68.20 / LF	$2.57 / LF	$1.57 / LF	$72.34 / LF	434 LF	$31,396
W12x53	$61.10 / LF	$3.48 / LF	$2.13 / LF	$66.70 / LF	6970 LF	$464,870
W14x90	$92.26 / LF	$3.43 / LF	$2.10 / LF	$97.78 / LF	5040 LF	$492,811
Sheeting	$2.09 / SF	$0.37 / SF	$0.03 / SF	$2.49 / SF	66908 SF	$166,602
Panels	Varies	$50.50 EA	$0.00 EA	$50.50 EA	3124 EA	$157,762
					Total Cost:	$1,341,733

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