Solar Master Plan

OAKLAND UNIFIED SCHOOL DISTRICT (OUSD)

Chapter 3

Structural Evaluations

Structural Evaluations

Once a school district has identified the buildings that it believes are the best candidates for a PV system, the district will want to consider whether the roofs can support the gravitational, wind and seismic loads of a PV system. In other words, can the PV system meet the strict building code requirements that apply to California's public schools?

The U.S. Department of Energy contracted with Interactive Resources in Richmond, CA to review the "as-built" drawings for a selection of schools identified as good candidates for PV systems. The purpose of the review was to identify any structural conditions that might indicate that the roof of a target building would not meet the building code requirements. The buildings were not physically inspected during this review; the assessment was based on a review of the drawings only.

The reports that follow describe in detail what Interactive Resources considered in its evaluation of several school roofs located in this district. While it is not necessary to conduct this type of evaluation prior to seeking bids on a PV project – a review and inspection can be done at a later point in the process – the district can save itself and interested vendors time and money by doing a preliminary assessment prior to seeking bids.

INTERACTIVE
RESOURCES

Architecture
Engineering
Planning

117 Park Place
Richmond, California
94801
510.236.7435
Fax 510.232.5325
www.intres.com

August 25, 2011

Mr. Dan Olis
National Renewable Energy Laboratories
1617 Cole Blvd.
Golden, CO 80401

Subject: **NREL Structural Evaluation** **2010-004.01**
OUSD – Castlemont High School
Evaluation of Existing Framing

Dear Mr. Olis:

In accordance with the provisions of our agreement, we have completed our preliminary structural investigation of the existing roof framing for select structures of the Castlemont High School Facility located in Oakland, CA. The purpose of the evaluation is to rapidly assess if the existing framing can support a solar array and determine if there are potential structural deficiencies that may preclude the addition of a solar array.

The evaluation is based on an in-house review of the available "as-built" drawings furnished by the Oakland Unified School District. No site visit has been performed as part of this phase of the work; however, should the project move forward, a site visit during a subsequent phase is planned to confirm that the structure, in general, conforms to the "as-built" drawings. At that time the results presented in this rapid evaluation should be reviewed and any refinement prepared as necessary.

This letter summarizes the results of our preliminary evaluation.

Existing Conditions

The existing structure is located at 8601 Macarthur Blvd in Oakland, California. The buildings reviewed for this evaluation are comprised of three buildings: two multiple story Classroom buildings and a single story Cafeteria building. Solar has been identified for potential installation on each of these buildings. The year of construction is approximately 1960. No solar is proposed for the other buildings at this site at this time.

The roof of the classroom buildings is specified as a composition roof over concrete slab over concrete beams. The roof framing is supported by concrete columns and concrete shear walls. Resistance to lateral loads due to wind or earthquake forces is provided by the horizontal concrete diaphragm and the vertical concrete columns and shear walls.

The roof of the cafeteria building is specified as a composition roof over diagonal sheathing over wood rafters and beams. The roof framing is supported by wood shear walls. Resistance to lateral loads due to wind or earthquake forces is provided by the horizontal sheathing diaphragm and the vertical wood shear walls.

Preliminary Structural Evaluation

The evaluation involves investigating two distinct aspects of the framing. First, can the framing support the added gravity loads to be imposed by the proposed solar array and second, can the existing lateral force resisting system support the added wind and/or seismic horizontal forces without triggering a code required upgrade of the structure? The latter is limited to a maximum of 10% of the existing tributary structural dead load as permitted by ASCE 7-05 Section 11B.3 and the California Building Code (CBC) Section 3404A.4, Exception. The analysis assumes that there is only one roof membrane present and that should a re-roof be performed either prior to installation of the solar array or during the life of the array that the existing will be removed and not roofed over. For the purposes of this analysis, a second roof membrane over the existing has been excluded to maximize the potential size of the solar array.

Where the racking system keeps the array close to the roof, wind loads generally do not represent a significant increase in forces to the existing main lateral force resisting elements. There are no parapets to prevent the arrays from sliding off of the roofs, therefore, the proposed arrays used in the analysis are planned to be positively anchored to the structures without the use of any ballast. The design wind speed for this site is 85 MPH (3-second gust), Exposure C. A Suntech STP 260 solar module has been selected for use in the framing evaluations. To support the modules and provide a 20° tilt to the array, a SunLink racking system has been assumed. The use of alternate modules or other racking systems that may produce alternate loadings is beyond the scope of this report. The anticipated weight of the array (module + racking system) use in the analysis is estimated to be 80.5# per module. A breakdown of the design loads used in the evaluation of the existing framing is shown in the Table at the end of this report.

1) Evaluation of Gravity Loads:

The existing roof deck at the classrooms is shown as a 2 ¾" concrete slab over 6.5x17 concrete joists spaced at 31 inches on center. At this time an array layout has not been determined. In order to perform an evaluation of the gravity loads on the existing framing, we used a 4x1 panel arrangement as manufactured by SunLink with the north-south axis parallel to existing concrete joists. This orientation results in the maximum concentration of loads to the least number of concrete joists. Our evaluation shows that the existing framing is adequate to support the anticipated loads and that, therefore, the existing framing is acceptable for any orientation or distribution of modules in the array(s).

At the Cafeteria building, the existing roof deck is shown as 1x diagonal sheathing over 2x joists spaced at 16" on center. The design live load on the original roof is 20 psf; however, per DSA IR 16-8, the design roof live load based on the array racking system selected may be taken as zero (racking system is low to the roof preventing storage beneath it) in the area of the array. Our analysis indicates that the existing framing using a 4x1 panel is acceptable to support the proposed loads. However, it should be noted that the stress rating of the existing 2x framing is not shown on the plans. For this analysis a common lumber grade of No. 1 has been assumed, but this should be confirmed should the project move forward. Attached for your reference are our preliminary calculations.

2) Evaluation of Lateral Loads:

The total existing roof area where placement of arrays has been proposed is approximately 45,955 sq. ft. At Classroom building A, the roof area is 19,890 sq. ft., at Classroom B the area is 16,770 sq. ft. and at the Cafeteria building the area is 9,295 sq. ft. The estimated dead load of the classroom roofs is 80 psf and 17psf for the Cafeteria. The Classroom exterior walls are concrete columns and a curtain wall with an estimated dead load of 20 psf. The Cafeteria exterior walls are wood studs covered with plaster with an estimated dead load of 18 psf. Combined together the total effective existing roof dead load at the @ Classroom A is 1,708,200 lbs., 1,443,000 lbs. at Classroom B and 173,608 lbs. at the Cafeteria building.

In order to avoid triggering a code required upgrade, the weight of any added solar array should not exceed 10% (Total Dead Load) or 170,820# (Classroom A), 144,300# (Classroom B), and 17,361# (Cafeteria). Dividing these weights by the combined weight per module of the proposed array (59.5+21) the maximum number of permissible modules for the array can be determined as 2122, 1793, and 216 respectively. However, checking the available roof area against the plan area of each module, the actual number of modules that can be used at the Classroom buildings are significantly less than that based on 10% of the existing mass. The module count, by area, at Classroom A is 640, and 539 at Classroom B. Please note these module quantities do not account for any setbacks that may be required or aisle ways, shading restrictions or any other roof obstructions that may affect the final array layout.

Conclusions

In conclusion, we believe that positively anchored solar (PV) arrays can be supported on the existing structures. They should not exceed either the Maximum Array Weight or the Maximum Number of Modules shown below. Either the SunLink 4x1 or 3x1 panel system is acceptable for this project.

Design Parameters	
Existing roof dead load	80 psf (Classroom A & B) 17psf (Cafeteria)
Basic Wind Speed (3-second gust)	85 MPH (Exposure C)
Seismic force (Allowable Stress Design)	0.447 $W_p \simeq$ 36# per module
Module	Suntech STP 260
Module weight	Approximately 59.5# each
Module Area	20.9 square feet
Module Mounting System	By SunLink Corporation
System weight	Approximately 21# per module
System tilt angle	20º
Maximum PV Array	
Maximum Array Weight (10% Total Est. Roof DL)	170,820# (Classroom A) 144,300# (Classroom B) 17,361# (Cafeteria)
Maximum Number of Modules	640 (Classroom A) (Limited by the available roof area)

	539 (Classroom B) (Limited by the available roof area) 216 (Cafeteria)

If you have any questions regarding this letter, please call me at (209) 736-2079.

Sincerely,
Interactive Resources

Paul M. Westermann, P.E., S.E.
Principal

Enclosure

Design Criteria

Roof Framing

Roof Live Load	20 psf	Slope 1/4:12 Reducible
Live Load at Solar Modules	12	(Special roof load, greenhouse)

Classroom A & B

Roof Dead Load

Roofing	2.0 psf	
Concrete slab	35.0	
Concrete beams	39.0	
Acoustical Tile Ceiling	1.5	
Mech/Elec/Misc	2.2	
	79.7 psf	USE 80 psf

Cafeteria

Roof Dead Load

Comp Roofing	4.0 psf	
1x diagonal sheathing	2.3	
2x6 @ 16" OC	1.7	
Glu lam Beams	4.2	
5/8 GYB ceiling	2.8	
Mech/Elec/Misc	2.0	
	17.0 psf	USE 17 psf

Existing Exterior Walls DL

14'x14" Conc Col & curtain wall 20 psf (Classroom A & B)

Plaster, diagonal sheathing, wood stud wall 18 psf (Cafeteria)

Parapet Height ~ 0.0 ft

Trib Ht. at Classroom A - 6.8' @ Classroom B 6.8' @ Caf - 7.9'

Interior Partitions

USE 5.0 psf for seismic loads at roof at Classrooms only

Determine Allowable Solar Array Size

Determine allowable loads as a percent of the exisitng tributary DL so as not to trigger a Code reqired Seismic Upgrade

Per ASCE 7-05, Section11B.3 & CBC 3403A.2.3 - a seismic upgrade is not required if the addition does not increase the seismic forces by 10%

INTERACTIVE RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD – Castlemont High School

rev.	description	date	by	drawn PMW/JC
				scale
				date

(E) Building Dimensions - Classroom A (larger)

B = 306.00'   D = 65.00'

Existing Roof Area - 19,890 sf   (per original construction documents)

(E) DL = 1,708,200   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 20 psf*min(306, 65')*2*(6.75+0' Parapet)

10% DL = 170820

Prposed Solar Array

Module - Suntech STP260   Titl-angle - 20°
Module Area - 20.9 sf   Plan Area ~ 1.49 * Module Area = 31.1 sf
Module Wt. - 59.5 #   Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{\text{10\% (E) DL}}{\text{Array Wt}} = 2122 \text{ modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 640 \text{ modules}$$

Check (E) Framing

(E) D+L = 1708200+19890*20 psf = 2,106,000
(E) D+L+ array = 1708200+19890*12 psf +640*80.5 = 1,998,400

$$\Delta = \frac{1{,}998{,}400}{2{,}106{,}000} - 1 = -0.051 \quad \underline{\text{Ok}}$$

Change in load on deck

(E) D+L = 100 psf
(E) D+L+ array = 94.6 psf

$$\Delta = \frac{94.6}{100} - 1 = -0.05 \quad \underline{\text{Ok}}$$

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

2010-004-01 OUSD Castlemont Solar Design.xls, (E) Frmg Eval

SUNTECH

Solar powering a green future™

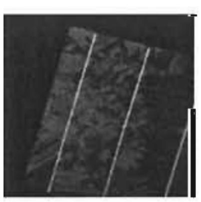
STP280 - 24/Vb-1
STP270 - 24/Vb-1
STP260 - 24/Vb-1

270 Watt
POLY-CRYSTALLINE SOLAR PANEL

Features
- High conversion eff ciency based on innovative photovoltaic technologies
- High reliability with guaranteed +/-3% power output tolerance
- Withstands high wind-pressure and snow load, and extreme temperature variations

Quality and Safety
- Industry-leading, transferable 25-year power output warranty
- Rigorous quality control meeting the highest international standards
- ISO 9001:2000 (Quality Management System) and ISO 14001:2004 (Environmental Management System) certified factories deliver world class products
- UL listing:UL1703, CULus, Class C fire rating, conformity to CE

Recommended Applications
- On-grid utility systems
- On-grid commercial systems
- Off-grid ground mounted systems



Suntech's technology yields improvements to BSF structure and anti-reflective coating to increase conversion efficiency

Unique design on drainage holes and rigid construction prevents frame from deforming or breaking due to freezing weather and other forces

Suntech was named Frost and Sullivan's 2008 Solar Energy Development Company of the Year

The panel provides more field power output through an advanced cell texturing and isolation process, which improves low irradiance performance

3 of A

SUNTECH

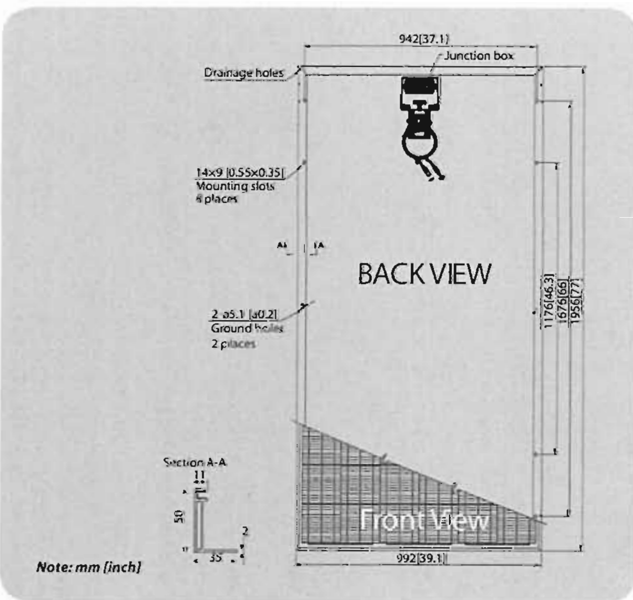
Solar powering a green future™

STP280 - 24/Vb-1
STP270 - 24/Vb-1
STP260 - 24/Vb-1

Electrical Characteristics

Characteristics	STP280-24/Vb-1	STP270-24/Vb-1	STP260-24/Vb-1
Open - Circuit Voltage (Voc)	44.8V	44.5V	44V
Optimum Operating Voltage (Vmp)	35.2V	35V	34.8V
Short - Circuit Current (Isc)	8.33A	8.2A	8.09A
Optimum Operating Current (Imp)	7.95A	7.71A	7.47A
Maximum Power at STC (Pmax)	280Wp	270Wp	260Wp
Operating Temperature	-40°C to +85°C	-40°C to +85°C	-40°C to +85°C
Maximum System Voltage	600V DC	600V DC	600V DC
Maximum Series Fuse Rating	20A	20A	20A
Power Tolerance	±3 %	±3 %	±3 %

STC: Irradiance 1000W/m², Module temperature 25°C, AM=1.5



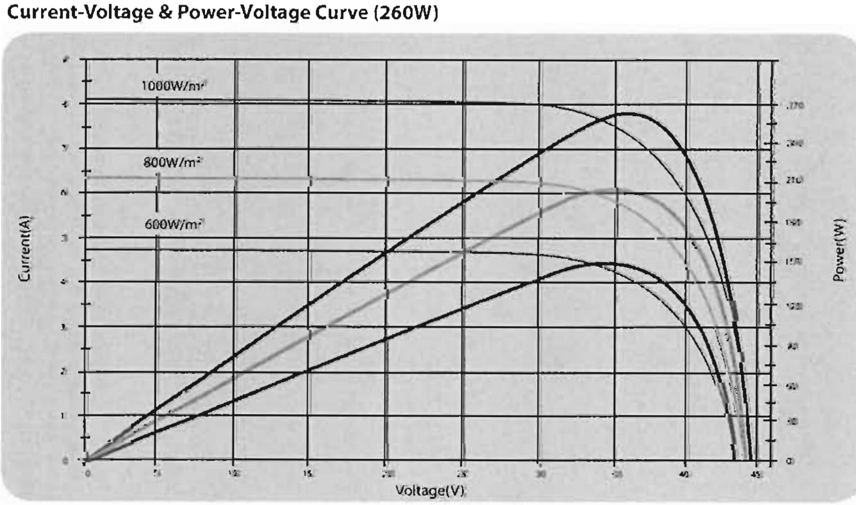
Mechanical Characteristics

Solar Cell	Poly-crystalline 156×156mm (6 inch)
No. of Cells	72 (6×12)
Dimensions	1956×992×50mm (77.0×39.1×2.0 inch)
Weight	27 kg (59.5 lbs.)
Front Glass	4mm(0.16 inch) tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP65 rated
Output Cables	AIW(12AWG), asymmetrical lengths (-) 1200mm (47.2 inch) and (+) 800mm (31.5 inch), MC Plug Type IV connectors

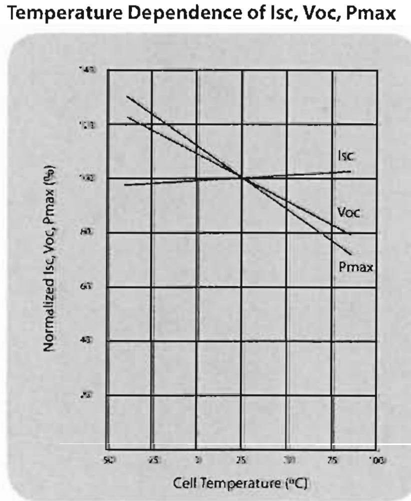
Temperature Coefficients

Nominal Operating Cell Temperature **(NOCT)**	45±2°C
Temperature Coefficient of Pmax	-(0.47 ± 0.05) %/°C
Temperature Coefficient of Voc	-(0.34 ± 0.01) %/°C
Temperature Coefficient of Isc	(0.055 ± 0.01) %/°C

Current-Voltage & Power-Voltage Curve (260W)



Temperature Dependence of Isc, Voc, Pmax



4 of A

(E) Building Dimensions - Classroom B (smaller)

B = 258.00'   D = 65.00'

Existing Roof Area - 16,770 sf   (per original construction documents)

(E) DL = 1,443,000   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 20 psf*min(258, 65')*2*(6.75+0' Parapet)

10% DL = 144300

Prposed Solar Array

Module - Suntech STP260   Titl-angle - 20°
Module Area - 20.9 sf   Plan Area ~ 1.49 * Module Area = 31.1 sf
Module Wt. - 59.5 #   Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{10\%\ \text{(E) DL}}{\text{Array Wt}} = 1793 \text{ modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 539 \text{ modules}$$

Check (E) Framing

(E) D+L = 1443000+16770*20 psf = 1,778,400
(E) D+L+ array = 1443000+16770*12 psf +539*80.5 = 1,687,630

$$\Delta = \frac{1{,}687{,}630}{1{,}778{,}400} - 1 = -0.051 \quad \underline{\text{Ok}}$$

Change in load on deck

(E) D+L = 100 psf
(E) D+L+ array = 94.6 psf

$$\Delta = \frac{94.6}{100} - 1 = -0.05 \quad \underline{\text{Ok}}$$

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

INTERACTIVE
RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD - Castlemont High School

rev.	description	date	by	drawn PMW/JC
				scale
				date

job 2010-004.01

(E) Building Dimensions - Cafeteria

B = 169.00'   D = 55.00'

Existing Roof Area - 9,295 sf   (per original construction documents)

(E) DL = 173,608   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 18 psf*min(169, 55')*2*(7.875+0' Parapet)

10% DL = 17361

Prposed Solar Array

Module - Suntech STP260   Titl-angle - 20°
Module Area - 20.9 sf   Plan Area ~ 1.49 * Module Area = 31.1 sf
Module Wt. - 59.5 #   Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{10\%\ (E)\ DL}{\text{Array Wt}} = 216 \text{ modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 299 \text{ modules}$$

Check (E) Framing

(E) D+L = 173608+9295*20 psf = 359,508
(E) D+L+ array = 173608+9295*12 psf +216*80.5 = 302,536

$$\Delta = \frac{302{,}536}{359{,}508} - 1 = -0.158$$ Ok

Change in load on deck

(E) D+L = 37 psf
(E) D+L+ array = 31.6 psf

$$\Delta = \frac{31.6}{37} - 1 = -0.15$$ Ok

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

2010-004-01 OUSD Castlemont Solar Design.xls, (E) Frmg Eval

INTERACTIVE
RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD - Castlemont High School

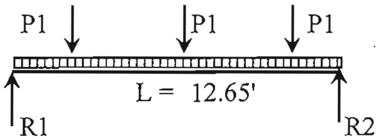
rev.	description	date	by	drawn PMW/JC
				scale
				date

job 2010-004.01

Check (E) Frmg.

Ck. (E) 2x6 @ 16" o.c. Jsts.

Critical loading occurs with N/S array axis parallel to sub-purlins



Support Spcg - 74.0"

P1 = 161

w = (17 - 4.2 + 12) * 16/12 ft = 33

R1 = R2 = 450

M = 1195 (= $wL^2/8 + PL/4 + Pa$) a = 0.16'

Assume (E) Frmg spec'd as DF-L No. 1

V allow = 655

M allow = 1167

See next page

Note: per DSA IR 16-8, the roof live load at the array may be taken as zero

∴ M dead = 876

(E) Joists are Ok

INTERACTIVE
RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD – Castlemont High School

job 2010-004.01

rev.	description	date	by	drawn PMW/JC
				scale
				date

Wood Framing Member Allowable Loads

Beam Size - 2x6 DF-L No. 1

b = 1.50" A = 8.25 in^2

d = 5.50" S_x = 7.56 in^3

I_x = 20.8 in^4

F_v = 95 psi

F_b = 1000 psi

E = 1700000 psi

Beam Span - 12.65'

Adjustment Factors

Wet Service, C_M

F_b - 0.85

F_v - 0.97

E - 0.90

Size Factor, C_F - 1.30

Repetetive Member, C_r - 1.15

Allowable Shear

$F'_v = Fv * C_D * C_M (Fv)$

$V_{allow.} = F'_v * A / 1.5$

Load	C_D	C_M	F'_v	$V_{allow.}$
Floor	1.00	No	95	523 #
		Yes	92	506 #
Roof LL	1.25	No	119	655 #
		Yes	115	633 #
Snow	1.15	No	109	600 #
		Yes	106	583 #

Allowable Flexural Loads

Form Factor C_f - 1.00

$M = F'_b * S$

$F'_b = F_b * C_D * C_M * C_t * (C_V \text{ or } C_L) * C_F * C_r$

L_u	K_L	C_V	Load		Floor			Roof LL			Snow		
					C_D = 1.00	C_t = 1.00		C_D = 1.25	C_t = 1.00		C_D = 1.15	C_t = 1.00	
			C_r	C_M	C_L	F'_b	M	C_L	F'_b	M	C_L	F'_b	M
1	1.00	N/a	No	No	0.99	1292	814	0.993	1613	1016	0.993	1485	936
				Yes	0.99	1099	692	0.993	1372	864	0.994	1263	796
			Yes	No	0.99	1485	936	0.991	1852	1167	0.992	1706	1075
				Yes	0.99	1263	796	0.992	1575	992	0.993	1450	914
2	1.00	N/a	No	No	0.99	1283	808	0.983	1597	1006	0.985	1472	927
				Yes	0.99	1092	688	0.984	1359	856	0.986	1253	789
			Yes	No	0.98	1472	927	0.979	1830	1153	0.982	1688	1063
				Yes	0.99	1253	789	0.981	1558	982	0.983	1436	905
3	1.00	N/a	No	No	0.98	1272	801	0.97	1576	993	0.973	1455	917
				Yes	0.98	1083	682	0.972	1343	846	0.975	1240	781
			Yes	No	0.97	1455	917	0.963	1799	1133	0.967	1663	1048
				Yes	0.98	1240	781	0.966	1534	966	0.97	1417	893
4	1.00	N/a	No	No	0.97	1260	794	0.956	1553	978	0.961	1437	905
				Yes	0.97	1073	676	0.96	1325	835	0.965	1226	772
			Yes	No	0.96	1437	905	0.943	1762	1110	0.951	1635	1030
				Yes	0.96	1226	772	0.949	1507	949	0.956	1397	880
5	1.00	N/a	No	No	0.96	1246	785	0.938	1524	960	0.947	1415	891
				Yes	0.96	1063	670	0.944	1304	822	0.952	1210	762
			Yes	No	0.95	1415	891	0.918	1715	1080	0.931	1600	1008
				Yes	0.95	1210	762	0.927	1472	927	0.938	1370	863
6	1.00	N/a	No	No	0.94	1228	774	0.914	1486	936	0.928	1387	874
				Yes	0.95	1050	662	0.924	1276	804	0.936	1189	749
			Yes	No	0.93	1387	874	0.884	1652	1041	0.904	1553	978
				Yes	0.94	1189	749	0.898	1426	898	0.915	1337	842

2010-004-01 Castlemont Bm allow_loads.xls

INTERACTIVE RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD - Castlemont High School

job 2010-004.01

rev.	description	date	by	drawn
				PMW/JC
				scale
				date

Seismic (IBC / ASCE 7)

Seismic Design Category - E (CBC 1613.5.6 & ASCE 7-05, Sect. 11.6)

Building Category - II (ASCE 7-05 Table 1-1)
Seismic Importance Factor, I - 0.00 (ASCE 7-05 Table 11.5-1)
Soil Site Class - D (ASCE 7-05 Chapter 20)

Site Location		
Latitude	37.759°	N
Longitude	122.164°	W

$S_s = 1.996$
$S_1 = 0.778$
} See next Page

$S_{MS} = F_a S_s =$ 1.996 $F_a = 1$
$S_{M1} = F_v S_1 =$ 1.167 $F_v = 1.5$

$S_{DS} = 2/3\ S_{MS} = 1.331$ $T_0 = 0.2\ S_{D1}/S_{DS} = 0.117$
$S_{D1} = 2/3\ S_{M1} = 0.778$ $T_s = S_{D1}/S_{DS} = 0.585$

for $T < T_0$, $S_a = S_{DS}(0.4 + 0.6\ T/T_0)$

for $T_0 < T < T_s$, $S_a = S_{DS}$

for $T_s < T$, $S_a = S_{D1}/T$

$T = C_t h_n^x =$ 0.21 (ASCE Eq. 12.8-7)
$C_t = 0.020$ (ASCE Table 12.8-2)
$h_n = 23.50$
$x = 0.75$ (ASCE Table 12.8-2)

Component Force (ASCE Section 13.3.1)

ASCE Eq. 13.3-1

$$F_p = \frac{0.4\ a_p S_{DS} W_p}{R_p / I_p}\left(1 + 2\frac{z}{h}\right) = 0.639\ Wp$$ ***Controls*** z = h h = roof elev.

ASCE Eq. 13.3-2

$F_p \max = 1.6\ S_{DS} I_p W_p =$ 2.130 Wp

ASCE Eq. 13.3-3

$F_p \min = 0.3\ S_{DS} I_p W_p =$ 0.399 Wp

$I_p = 1.0$ $a_p = 1.0$ $R_p = 2.5$

$W_p = 81$ # $\therefore F_p = 51$ # for ASD, USE $0.7 * F_p = 36$ #

2010-004-01 OUSD Castlemont Solar Design.xls, ASCE Seis

Oakland Unified School District
Castlemont High School

Conterminous 48 States
2005 ASCE 7 Standard / 2010 California Building Code
Latitude = 37.759
Longitude = -122.164
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B - Fa = 1.0 ,Fv = 1.0
Data are based on a 0.01 deg grid spacing

Period (sec)	Sa (g)
0.2	1.996 (Ss, Site Class B)
1.0	0.778 (S1, Site Class B)

Conterminous 48 States
2005 ASCE 7 Standard / 2010 California Building Code
Latitude = 37.759
Longitude = -122.164
Spectral Response Accelerations SMs and SM1
SMs = Fa x Ss and SM1 = Fv x S1
Site Class D - Fa = 1.0 ,Fv = 1.5

Period (sec)	Sa (g)
0.2	1.996 (SMs, Site Class D)
1.0	1.166 (SM1, Site Class D)

Conterminous 48 States
2005 ASCE 7 Standard / 2010 California Building Code
Latitude = 37.759
Longitude = -122.164
Design Spectral Response Accelerations SDs and SD1
SDs = 2/3 x SMs and SD1 = 2/3 x SM1
Site Class D - Fa = 1.0 ,Fv = 1.5

Period (sec)	Sa (g)
0.2	1.331 (SDs, Site Class D)
1.0	0.778 (SD1, Site Class D)

Reference: "USGS Seismic Hazard Curves and Uniform Hazard Response Spectra", **NSHMP_HazardApp.jar** application

Castlemont High School
8601 MACARTHUR BLVD 94605

Questions for District

1. What are age & condition of roofs?
2. Are there roof structural concerns?

INTERACTIVE
RESOURCES

Architecture
Engineering
Planning

117 Park Place
Richmond, California
94801
510.236.7435
Fax 510.232.5325
www.intres.com

September 22, 2011

Mr. Dan Olis
National Renewable Energy Laboratories
1617 Cole Blvd.
Golden, CO 80401

Subject: **NREL Structural Evaluation** **2010-004.01**
OUSD – Fremont High School
Evaluation of Existing Framing

Dear Mr. Olis:

In accordance with the provisions of our agreement, we have completed our preliminary structural investigation of the existing roof framing for select structures of the Fremont High School Facility located in Oakland, CA. The purpose of the evaluation is to rapidly assess if the existing framing can support a solar array and determine if there are potential structural deficiencies that may preclude the addition of a solar array.

The evaluation is based on an in-house review of the available "as-built" drawings furnished by the Oakland Unified School District. No site visit has been performed as part of this phase of the work; however, should the project move forward, a site visit during a subsequent phase is planned to confirm that the structure, in general, conforms to the "as-built" drawings. At that time the results presented in this rapid evaluation should be reviewed and any refinement prepared as necessary.

This letter summarizes the results of our preliminary evaluation.

Existing Conditions

The existing structure is located at 4610 Foothill Blvd in Oakland, California. The roofs reviewed for this evaluation are comprised of 3 sections (of various heights and areas) of the Gymnasium building. Solar has been identified for potential installation on each of these roof areas. The year of construction is around 1940. No solar is proposed for the other buildings at this site at this time.

The roof of the existing structure is specified as a composition roof over concrete slab over concrete beams (at the low roofs) or over steel beams and trusses (at the main roofs). The roof framing is supported by concrete walls and concrete columns (at the low roofs) or steel columns (at the main roof). Resistance to lateral loads due to wind or earthquake forces is provided by the horizontal concrete diaphragm and the vertical concrete shear walls.

Preliminary Structural Evaluation

The evaluation involves investigating two distinct aspects of the framing. First, can the framing support the added gravity loads to be imposed by the proposed solar array and second, can the existing lateral force resisting system support the added wind and/or seismic horizontal forces without triggering a code required upgrade of the structure? The latter is limited to a maximum of 10% of the existing tributary structural dead load as permitted by ASCE 7-05 Section 11B.3 and the California Building Code (CBC) Section 3404A.4, Exception. The analysis assumes that there is only one roof membrane present and that should a re-roof be performed either prior to installation of the solar array or during the life of the array that the existing will be removed and not roofed over. For the purposes of this analysis, a second roof membrane over the existing has been excluded to maximize the potential size of the solar array.

Where the racking system keeps the array close to the roof, wind loads generally do not represent a significant increase in forces to the existing main lateral force resisting elements. The proposed array used in the analysis is planned to be positively anchored to the structure without the use of any ballast. The design wind speed for this site is 85 MPH (3-second gust), Exposure C. A Suntech STP 260 solar module has been selected for use in the framing evaluations. To support the modules and provide a 20° tilt to the array, a SunLink racking system has been assumed. The use of alternate modules or other racking systems that may produce alternate loadings is beyond the scope of this report. The anticipated weight of the array (module + racking system) use in the analysis is estimated to be 80.5# per module. A breakdown of the design loads used in the evaluation of the existing framing is shown in the Table at the end of this report.

1) Evaluation of Gravity Loads:

The existing roof deck on the low roofs is shown as a 3 ½" concrete slab over concrete beams with an average size of 12x20 spaced at roughly 7'-6" on center. At this time an array layout has not been determined. In order to perform an evaluation of the gravity loads on the existing framing, we used a 4x1 panel arrangement as manufactured by SunLink. Our evaluation shows that the existing concrete framing is adequate to support the anticipated loads and that, therefore, the existing framing is acceptable for any orientation or distribution of modules in the array(s).

At the main roof, the existing roof deck is shown as a 3 ½" concrete slab over steel purlins spaced at 6'-6" on center. At this time an array layout has not been determined. In order to perform an evaluation of the gravity loads on the existing framing, we used a 4x1 panel arrangement as manufactured by SunLink. Our evaluation shows that the existing concrete & steel framing is adequate to support the anticipated loads and that, therefore, the existing framing is acceptable for any orientation or distribution of modules in the array(s). Attached for your reference are our preliminary calculations.

2) Evaluation of Lateral Loads:

The total existing roof area where placement of arrays has been proposed is approximately 15,516 sq. ft. At the western low roof, the roof area is 3,684 sq. ft., at the eastern low roof the area is 3,057 sq. ft., and at the main roof the area is 8,775 sq. ft. The estimated dead load of the two low roofs is 92 psf and 61 psf at the main roof. The exterior walls are 8"concrete with an estimated dead load of 100 psf. Combined together the total effective existing roof dead load at the western low roof is 459,648 lbs., 398,829 lbs. at the eastern low roof, and 823,875 lbs. at the main roof.

In order to avoid triggering a code required upgrade, the weight of any added solar array should not exceed 10% (Total Dead Load) or 45,965# (western low roof), 39,883# (eastern low roof), and 82,388# (main roof). Dividing these weights by the combined weight per module of the proposed array (59.5+21) the maximum number of permissible modules for the array can be determined as 571+495+1023 respectively. However, checking the available roof area against the plan area of each module, the actual number of modules that can be used at the 3 roof areas is significantly less than that based on 10% of the existing mass. These module counts are 118+98+282 respectively. Additionally, per the client's direction, the usable roof area for the two low roofs further limits the module count. These module counts are 58 for the western low roof and 42 for the eastern low roof. Please note these module quantities do not account for any setbacks that may be required or aisle ways, shading restrictions or any other roof obstructions that may affect the final array layout.

Conclusions

In conclusion, we believe that positively anchored solar (PV) arrays can be supported on the existing structures. They should not exceed either the Maximum Array Weight or the Maximum Number of Modules shown below. Either the SunLink 4x1 or 3x1 panel system is acceptable for this project.

Design Parameters	
Existing roof dead load	92 psf (low roofs) 61 psf (main roof)
Basic Wind Speed (3-second gust)	85 MPH (Exposure C)
Seismic force (Allowable Stress Design)	0.391 $W_p \simeq$ 31# per module
Module	Suntech STP 260
Module weight	Approximately 59.5# each
Module Area	20.9 square feet
Module Mounting System	By SunLink Corporation
System weight	Approximately 21# per module
System tilt angle	20º
Maximum PV Array	
Maximum Array Weight (10% Total Est. Roof DL)	45,965# (western low roof) 39,883# (eastern low roof) 82,388# (main roof)
Maximum Number of Modules (Limited by the available roof area, as specified by client)	58 (western low roof) 42 (eastern low roof) 288 (main roof)

If you have any questions regarding this letter, please call me at (209) 736-2079.

Sincerely,
Interactive Resources

Paul M. Westermann, P.E., S.E.
Principal

Enclosure

Design Criteria

Roof Framing

Roof Live Load	20 psf	Slope 1/4:12 Reducible
Live Load at Solar Modules	12	(Special roof load, greenhouse)

Low Roofs - West & East

Roof Dead Load

Comp Roofing	4.0 psf	
Concrete slab	43.8	
Concrete beams	40.0	
Acoustical Tile Ceiling	1.5	
Mech/Elec/Misc	2.0	
	91.3 psf	USE 92 psf

Main Roof

Roof Dead Load

Comp Roofing	4.0 psf	
Concrete Slab	43.8	
Steel Beams	2.7	
Steel Trusses	7.0	
Accoustical Tile Ceiling	1.5	
Mech/Elec/Misc	2.0	
	61.0 psf	USE 61 psf

Existing Exterior Walls DL

~8" thick conc walls 100 psf (At each roof)

Parapet Height ~ 4.0 ft

Trib Ht. at Low Roofs - 7.0' @ Main Roof - 14.5'

Interior Partitions

USE 5.0 psf for seismic loads at roof at Low Roofs only

Determine Allowable Solar Array Size

Determine allowable loads as a percent of the exisitng tributary DL so as not to trigger a Code reqired Seismic Upgrade

Per ASCE 7-05, Section11B.3 & CBC 3403A.2.3 - a seismic upgrade is not required if the addition does not increase the seismic forces by 10%

2010-004-01 OUSD Fremont Solar Design.xls, (E) Frmg Eval

INTERACTIVE RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD - Fremont High School

rev.	description	date	by	drawn PMW/JC
				scale
				date

job 2010-004.01

(E) Building Dimensions - Low Roof - West

B = 90.20'   D = 46.50'

Existing Roof Area - 3,684 sf   (per original construction documents)

(E) DL = 459,648   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 100 psf*min(90.2, 46.5')*2*(7+4' Parapet)

10% DL = 45965

Prposed Solar Array

Module - Suntech STP260   Titl-angle - 20°
Module Area - 20.9 sf   Plan Area ~ 1.49 * Module Area = 31.1 sf
Module Wt. - 59.5 #   Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{10\%\ (E)\ DL}{\text{Array Wt}} = 571 \text{ modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 118 \text{ modules}$$

Usable roof area per client - 1,790 sf   (see roof area 'C' on the areal site image attached after calcs)

$$\text{No. Mod. based on client's roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 58 \text{ modules}$$

Check (E) Framing (based on full area)

(E) D+L = 459648+3684*20 psf = 533,328
(E) D+L+ array = 459648+3684*12 psf +118*80.5 = 513,355

$$\Delta = \frac{513{,}355}{533{,}328} - 1 = -0.037$$ Ok

Change in load on deck (based on full area)

(E) D+L = 112 psf
(E) D+L+ array = 106.6 psf

$$\Delta = \frac{106.6}{112} - 1 = -0.05$$ Ok

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

SUNTECH

Solar powering a green future™

STP280 - 24/Vb-1
STP270 - 24/Vb-1
STP260 - 24/Vb-1

270 Watt

POLY-CRYSTALLINE SOLAR PANEL

Features

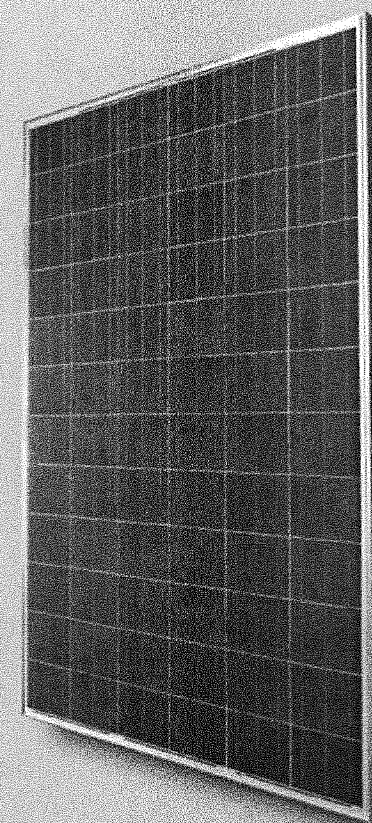
- High conversion eff ciency based on innovative photovoltaic technologies
- High reliability with guaranteed +/-3% power output tolerance
- Withstands high wind-pressure and snow load, and extreme temperature variations

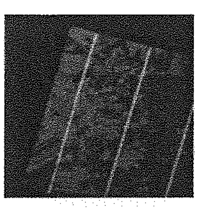
Quality and Safety

- Industry-leading, transferable 25-year power output warranty
- Rigorous quality control meeting the highest international standards
- ISO 9001:2000 (Quality Management System) and ISO 14001:2004 (Environmental Management System) certified factories deliver world class products
- UL listing:UL1703, CULus, Class C fire rating, conformity to CE

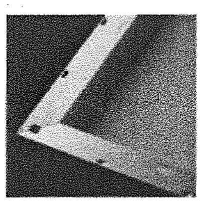
Recommended Applications

- On-grid utility systems
- On-grid commercial systems
- Off-grid ground mounted systems

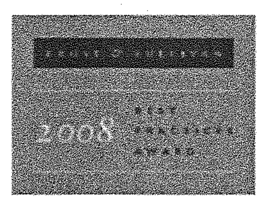




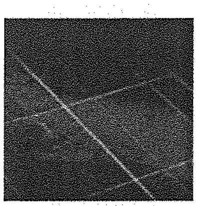
Suntech's technology yields improvements to BSF structure and anti-reflective coating to increase conversion efficiency



Unique design on drainage holes and rigid construction prevents frame from deforming or breaking due to freezing weather and other forces



Suntech was named Frost and Sullivan's 2008 Solar Energy Development Company of the Year



The panel provides more field power output through an advanced cell texturing and isolation process, which improves low irradiance performance

3ofA

SUNTECH

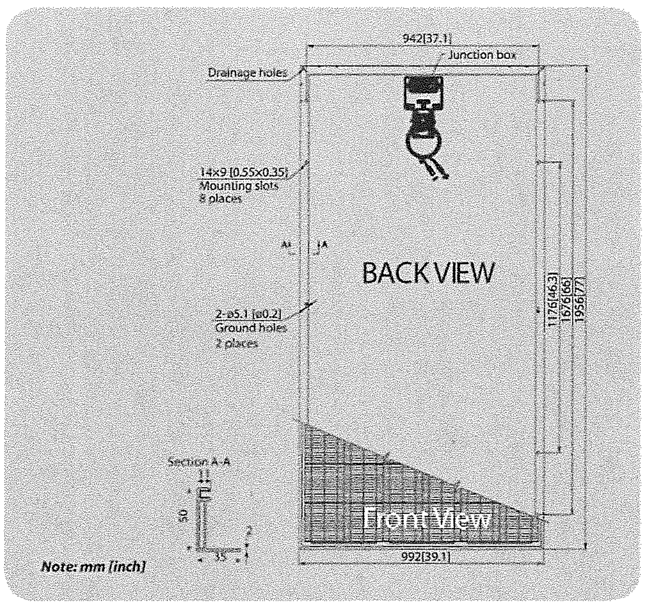
Solar powering a green future™

STP280 - 24/Vb-1
STP270 - 24/Vb-1
STP260 - 24/Vb-1

Electrical Characteristics

Characteristics	STP280-24/Vb-1	STP270-24/Vb-1	STP260-24/Vb-1
Open - Circuit Voltage (Voc)	44.8V	44.5V	44V
Optimum Operating Voltage (Vmp)	35.2V	35V	34.8V
Short - Circuit Current (Isc)	8.33A	8.2A	8.09A
Optimum Operating Current (Imp)	7.95A	7.71A	7.47A
Maximum Power at STC (Pmax)	280Wp	270Wp	260Wp
Operating Temperature	-40°C to +85°C	-40°C to +85°C	-40°C to +85°C
Maximum System Voltage	600V DC	600V DC	600V DC
Maximum Series Fuse Rating	20A	20A	20A
Power Tolerance	±3 %	±3 %	±3 %

STC: Irradiance 1000W/m², Module temperature 25°C, AM=1.5



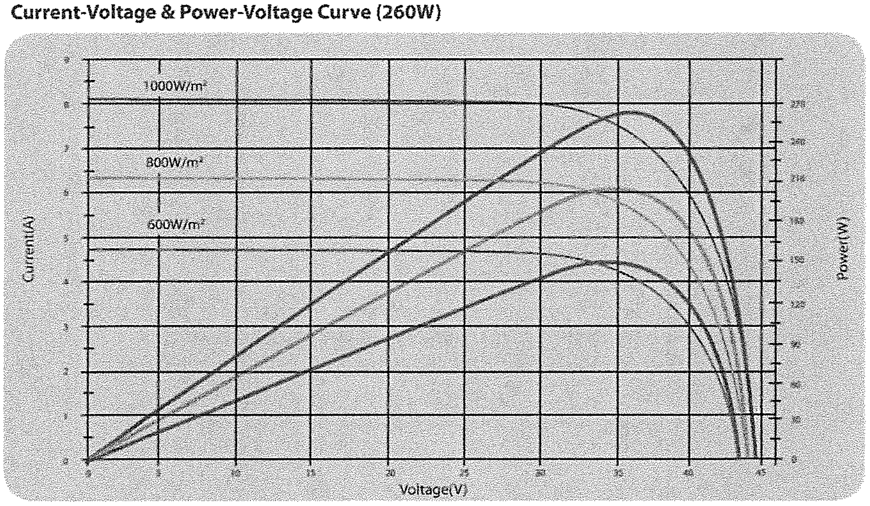
Mechanical Characteristics

Solar Cell	Poly-crystalline 156×156mm (6 inch)
No. of Cells	72 (6×12)
Dimensions	1956x992x50mm (77.0x39.1x2.0 inch)
Weight	27 kg (59.5 lbs.)
Front Glass	4mm(0.16 inch) tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP65 rated
Output Cables	AIW(12AWG), asymmetrical lengths (-) 1200mm (47.2 inch) and (+) 800mm (31.5 inch), MC Plug Type IV connectors

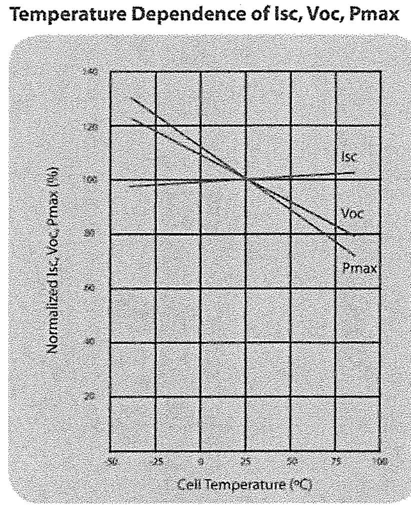
Temperature Coefficients

Nominal Operating Cell Temperature **(NOCT)**	45±2°C
Temperature Coefficient of Pmax	-(0.47 ± 0.05) %/°C
Temperature Coefficient of Voc	-(0.34 ± 0.01) %/°C
Temperature Coefficient of Isc	(0.055 ± 0.01) %/°C

Current-Voltage & Power-Voltage Curve (260W)



Temperature Dependence of Isc, Voc, Pmax



4 of A

(E) Building Dimensions - Low Roof - East

B = 85.50'   D = 46.50'

Existing Roof Area - 3,057 sf   (per original construction documents)

(E) DL = 398,829   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 100 psf*min(85.5, 46.5')*2*(7+4' Parapet)

10% DL = 39883

Prposed Solar Array

Module - Suntech STP260
Module Area - 20.9 sf
Module Wt. - 59.5 #

Titl-angle - 20°
Plan Area ~ 1.49 * Module Area = 31.1 sf
Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{10\%\ (E)\ DL}{\text{Array Wt}} = 495 \text{ modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 98 \text{ modules}$$

Usable roof area per client - 1,294 sf   (see roof area 'B' on the areal site image attached after calcs)

$$\text{No. Mod. based on client's roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 42 \text{ modules}$$

Check (E) Framing (based on full area)

(E) D+L = 398829+3057*20 psf = 459,969
(E) D+L+ array = 398829+3057*12 psf +98*80.5 = 443,402

$$\Delta = \frac{443,402}{459,969} - 1 = -0.036 \quad \underline{\text{Ok}}$$

Change in load on deck (based on full area)

(E) D+L = 112 psf
(E) D+L+ array = 106.6 psf

$$\Delta = \frac{106.6}{112} - 1 = -0.05 \quad \underline{\text{Ok}}$$

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

(E) Building Dimensions - Main Roof

B = 112.50' D = 78.00'

Existing Roof Area - 8,775 sf (per original construction documents)

(E) DL = 823,875 (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 100 psf*min(112.5, 78')*2*(14.5+4' Parapet)

10% DL = 82388

Prposed Solar Array

Module - Suntech STP260
Module Area - 20.9 sf
Module Wt. - 59.5 #

Titl-angle - 20°
Plan Area ~ 1.49 * Module Area = 31.1 sf
Frmg per Module -. 21

Basic Wind Speed = 85 mph
Exposure - C (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{\text{10\% (E) DL}}{\text{Array Wt}} = \text{1023 modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = \text{282 modules}$$

Check (E) Framing

(E) D+L = 823875+8775*20 psf = 999,375
(E) D+L+ array = 823875+8775*12 psf +282*80.5 = 951,876

$$\Delta = \frac{951{,}876}{999{,}375} - 1 = \quad -0.048 \quad \underline{\text{Ok}}$$

Change in load on deck

(E) D+L = 81 psf
(E) D+L+ array = 75.6 psf

$$\Delta = \frac{75.6}{81} - 1 = \quad -0.07 \quad \underline{\text{Ok}}$$

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

2010-004-01 OUSD Fremont Solar Design.xls, (E) Frmg Eval

INTERACTIVE RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD - Fremont High School

rev.	description	date	by	drawn PMW/JC
				scale
				date

job 2010-004.01

Seismic (IBC / ASCE 7)

Seismic Design Category - D (CBC 1613.5.6 & ASCE 7-05, Sect. 11.6)

Building Category - II (ASCE 7-05 Table 1-1)
Seismic Importance Factor, I - 1.0 (ASCE 7-05 Table 11.5-1)
Soil Site Class - D (ASCE 7-05 Chapter 20)

Site Location		
Latitude	37.774°	N
Longitude	122.210°	W

S_s = 1.748
S_1 = 0.645 } See next Page

$S_{MS} = F_a S_s =$ 1.748 $F_a = 1$
$S_{M1} = F_v S_1 =$ 0.968 $F_v = 1.5$

$S_{DS} = 2/3\ S_{MS} = 1.165$ $T_0 = 0.2\ S_{D1}/S_{DS} = 0.111$
$S_{D1} = 2/3\ S_{M1} = 0.645$ $T_s = S_{D1}/S_{DS} = 0.554$

for $T < T_0$, $S_a = S_{DS}(0.4 + 0.6\ T/T_0)$

for $T_0 < T < T_s$, $S_a = S_{DS}$

for $T_s < T$, $S_a = S_{D1}/T$

$T = C_t h_n^x =$ 0.34 (ASCE Eq. 12.8-7)

C_t = 0.020 (ASCE Table 12.8-2)
h_n = 43.00
x = 0.75 (ASCE Table 12.8-2)

Component Force (ASCE Section 13.3.1)

ASCE Eq. 13.3-1

$$F_p = \frac{0.4\ a_p S_{DS} W_p}{R_p / I_p}\left(1 + 2\frac{z}{h}\right) = 0.559\ Wp$$

Controls   z = h   h = roof elev.

ASCE Eq. 13.3-2

$F_p \max = 1.6\ S_{DS} I_p W_p =$ 1.864 Wp

ASCE Eq. 13.3-3

$F_p \min = 0.3\ S_{DS} I_p W_p =$ 0.350 Wp

I_p = 1.0 a_p = 1.0 R_p = 2.5

W_p = 81 # $\therefore F_p$ = 45 #   for ASD, USE 0.7 * F_p = 31 #

2010-004-01 OUSD Fremont Solar Design.xls, ASCE Seis

INTERACTIVE RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD – Fremont High School

rev.	description	date	by	drawn PMW/JC
				scale
				date

job 2010-004.01

Oakland Unified School District
Fremont High School

Conterminous 48 States
2005 ASCE 7 Standard / 2010 California Building Code
Latitude = 37.774
Longitude = -122.21000000000001
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B - Fa = 1.0 ,Fv = 1.0
Data are based on a 0.01 deg grid spacing

Period (sec)	Sa (g)
0.2	1.748 (Ss, Site Class B)
1.0	0.645 (S1, Site Class B)

Conterminous 48 States
2005 ASCE 7 Standard / 2010 California Building Code
Latitude = 37.774
Longitude = -122.21000000000001
Spectral Response Accelerations SMs and SM1
SMs = Fa x Ss and SM1 = Fv x S1
Site Class D - Fa = 1.0 ,Fv = 1.5

Period (sec)	Sa (g)
0.2	1.748 (SMs, Site Class D)
1.0	0.967 (SM1, Site Class D)

Conterminous 48 States
2005 ASCE 7 Standard / 2010 California Building Code
Latitude = 37.774
Longitude = -122.21000000000001
Design Spectral Response Accelerations SDs and SD1
SDs = 2/3 x SMs and SD1 = 2/3 x SM1
Site Class D - Fa = 1.0 ,Fv = 1.5

Period (sec)	Sa (g)
0.2	1.165 (SDs, Site Class D)
1.0	0.645 (SD1, Site Class D)

Reference: "USGS Seismic Hazard Curves and Uniform Hazard Response Spectra", **NSHMP_HazardApp.jar** application

INTERACTIVE RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD – Fremont High School

rev.	description	date	by	drawn PMW/JC	job 2010-004.01
				scale	page 8 of A
				date	

Fremont High School
4610 FOOTHILL BLVD, OAKLAND, CA 94601

Questions for District

1. What are age & condition of roofs?
2. Are there roof structural concerns?

INTERACTIVE
RESOURCES

Architecture
Engineering
Planning

117 Park Place
Richmond, California
94801
510.236.7435
Fax 510.232.5325
www.intres.com

August 25, 2011

Mr. Dan Olis
National Renewable Energy Laboratories
1617 Cole Blvd.
Golden, CO 80401

Subject: **NREL Structural Evaluation** **2010-004.01**
OUSD – McClymonds High School
Evaluation of Existing Framing

Dear Mr. Olis:

In accordance with the provisions of our agreement, we have completed our preliminary structural investigation of the existing roof framing for select structures of the McClymonds High School Facility located in Oakland, CA. The purpose of the evaluation is to rapidly assess if the existing framing can support a solar array and determine if there are potential structural deficiencies that may preclude the addition of a solar array.

The evaluation is based on an in-house review of the available "as-built" drawings furnished by the Oakland Unified School District. No site visit has been performed as part of this phase of the work; however, should the project move forward, a site visit during a subsequent phase is planned to confirm that the structure, in general, conforms to the "as-built" drawings. At that time the results presented in this rapid evaluation should be reviewed and any refinement prepared as necessary.

This letter summarizes the results of our preliminary evaluation.

Existing Conditions

The existing structure is located at 2607 Myrtle St in Oakland, California. The buildings reviewed for this evaluation are comprised of: an Auditorium, a Band Room (w/ other rooms), and a Cafeteria – all at different heights. Solar has been identified for potential installation on each of these buildings. The year of construction is early 1950s. No solar is proposed for the other buildings at this site at this time.

The roof of the existing structures is specified as a gypsum roof (similar to lightweight concrete) over steel purlins and trusses. The roof framing is supported by steel columns and concrete walls. Resistance to lateral loads due to wind or earthquake forces is provided by the horizontal gypsum diaphragm and the vertical concrete shear walls.

Preliminary Structural Evaluation

The evaluation involves investigating two distinct aspects of the framing. First, can the framing support the added gravity loads to be imposed by the proposed solar array and second, can the existing lateral force resisting system support the added wind and/or seismic horizontal forces without triggering a code required upgrade of the structure? The latter is limited to a maximum of 10% of the existing tributary structural dead load as permitted by ASCE 7-05 Section 11B.3 and the California Building Code (CBC) Section 3404A.4, Exception. The analysis assumes that there is only one roof membrane present and that should a re-roof be performed either prior to installation of the solar array or during the life of the array that the existing will be removed and not roofed over. For the purposes of this analysis, a second roof membrane over the existing has been excluded to maximize the potential size of the solar array.

Where the racking system keeps the array close to the roof, wind loads generally do not represent a significant increase in forces to the existing main lateral force resisting elements. The proposed array used in the analysis is planned to be positively anchored to the structure without the use of any ballast. The design wind speed for this site is 85 MPH (3-second gust), Exposure C. A Suntech STP 260 solar module has been selected for use in the framing evaluations. To support the modules and provide a 20° tilt to the array, a SunLink racking system has been assumed. The use of alternate modules or other racking systems that may produce alternate loadings is beyond the scope of this report. The anticipated weight of the array (module + racking system) use in the analysis is estimated to be 80.5# per module. A breakdown of the design loads used in the evaluation of the existing framing is shown in the Table at the end of this report.

1) Evaluation of Gravity Loads:

The existing roof deck on the existing structures is shown as a 3” gypsum roof over steel purlins spaced at 6’-9’ on center. At this time an array layout has not been determined. In order to perform an evaluation of the gravity loads on the existing framing, we used a 4x1 panel arrangement as manufactured by SunLink. Our evaluation shows that the existing gypsum roof and supporting framing are adequate to support the anticipated gravity loads and that, therefore, the existing framing is acceptable for any orientation or distribution of modules in the array(s). Attached for your reference are our preliminary calculations.

2) Evaluation of Lateral Loads:

The total existing roof area where placement of arrays has been proposed is approximately 22,292 sq. ft. At the Auditorium, the roof area is 13,398 sq. ft.; at the Band Room the area is 3806 sq. ft. and at the Cafeteria the area is 5088 sq. ft. The estimated dead load of each roof is approximately 22 psf. The exterior walls are 8” concrete with an estimated dead load of 100 psf. Combined together the total effective existing roof dead load at the @ Auditorium is 681,156 lbs., 212,357 lbs. at the Band Room and 246,336 lbs. @ the Cafeteria building.

In order to avoid triggering a code required upgrade, the weight of any added solar array should not exceed 10% (Total Dead Load) or 68,116# (Auditorium), 21,236# (Band Room) and 24,634# (Cafeteria). Dividing these weights by the combined weight per module of the proposed array (59.5+21) the maximum number of permissible modules for the array can be determined as 846+264+306 respectively. However, checking the available roof area against the plan area of each module, the actual number of modules that can be used is significantly less than that based on 10% of the existing mass. These module counts are 431+122+164 respectively. Please note these module quantities do not account for any setbacks that may be required or aisle ways, shading restrictions or any other roof obstructions that may affect the final array layout.

Conclusions

In conclusion, we believe that positively anchored solar (PV) arrays can be supported on the existing structures. They should not exceed either the Maximum Array Weight or the Maximum Number of Modules shown below. Either the SunLink 4x1 or 3x1 panel system is acceptable for this project.

Design Parameters	
Existing roof dead load	22 psf (Auditorium, Band Room, & Cafeteria)
Basic Wind Speed (3-second gust)	85 MPH (Exposure C)
Seismic force (Allowable Stress Design)	0.336 $W_p \simeq$ 27# per module
Module	Suntech STP 260
Module weight	Approximately 59.5# each
Module Area	20.9 square feet
Module Mounting System	By SunLink Corporation
System weight	Approximately 21# per module
System tilt angle	20º

Maximum PV Array	
Maximum Array Weight (10% Total Est. Roof DL)	68,116# (Auditorium) 21,236# (Band Room) 24,634# (Cafeteria)
Maximum Number of Modules (Limited by the available roof area)	431 (Auditorium) 122 (Band Room) 164 (Cafeteria)

If you have any questions regarding this letter, please call me at (209) 736-2079.

Sincerely,
Interactive Resources

Paul M. Westermann, P.E., S.E.
Principal

Enclosure

Design Criteria

Roof Framing

Roof Live Load	20 psf	Slope 1/4:12 Reducible
Live Load at Solar Modules	12	(Special roof load, greenhouse)

Auditorium, Band Room, & Cafeteria

Roof Dead Load

Roofing	2.0 psf	
Gypsum Roof	11.0	
Steel Purlins/Trusses	5.0	
Acoustical Tile Ceiling	1.5	
Mech/Elec/Misc	2.2	
	21.7 psf	USE 22 psf

Existing Exterior Walls DL

8" Conc Wall 100 psf

Parapet Height ~ 3.0 ft

Trib Ht. at Auditorium - 20' @ Band Room 9.3' @ Caf - 7.5'

Determine Allowable Solar Array Size

Determine allowable loads as a percent of the exisitng tributary DL so as not to trigger a Code reqired Seismic Upgrade

Per ASCE 7-05, Section11B.3 & CBC 3403A.2.3 - a seismic upgrade is not required if the addition does not increase the seismic forces by 10%

(E) Building Dimensions - Auditorium

B = 159.50'   D = 84.00'

Existing Roof Area - 13,398 sf   (per original construction documents)

(E) DL = 681,156   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 100 psf*min(159.5, 84')*2*(20+3' Parapet)

10% DL = 68116

Prposed Solar Array

Module - Suntech STP260   Titl-angle - 20°
Module Area - 20.9 sf   Plan Area ~ 1.49 * Module Area = 31.1 sf
Module Wt. - 59.5 #   Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{10\%\ (E)\ DL}{\text{Array Wt}} = 846 \text{ modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 431 \text{ modules}$$

Check (E) Framing

(E) D+L = 681156+13398*20 psf = 949,116
(E) D+L+ array = 681156+13398*12 psf +431*80.5 = 876,628

$$\Delta = \frac{876{,}628}{949{,}116} - 1 = \quad -0.076 \quad \underline{\text{Ok}}$$

Change in load on deck

(E) D+L = 42 psf
(E) D+L+ array = 36.6 psf

$$\Delta = \frac{36.6}{42} - 1 = \quad -0.13 \quad \underline{\text{Ok}}$$

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

2010-004-01 OUSD McClymonds Solar Design.xls, (E) Frmg Eval

SUNTECH

Solar powering a green future™

STP280 - 24/Vb-1
STP270 - 24/Vb-1
STP260 - 24/Vb-1

270 Watt

POLY-CRYSTALLINE SOLAR PANEL

Features

- High conversion eff ciency based on innovative photovoltaic technologies
- High reliability with guaranteed +/-3% power output tolerance
- Withstands high wind-pressure and snow load, and extreme temperature variations

Quality and Safety

- Industry-leading, transferable 25-year power output warranty
- Rigorous quality control meeting the highest international standards
- ISO 9001:2000 (Quality Management System) and ISO 14001:2004 (Environmental Management System) certified factories deliver world class products
- UL listing:UL1703, CULus, Class C fire rating, conformity to CE

Recommended Applications

- On-grid utility systems
- On-grid commercial systems
- Off-grid ground mounted systems

Suntech's technology yields improvements to BSF structure and anti-reflective coating to increase conversion efficiency

Unique design on drainage holes and rigid construction prevents frame from deforming or breaking due to freezing weather and other forces

Suntech was named Frost and Sullivan's 2008 Solar Energy Development Company of the Year

The panel provides more field power output through an advanced cell texturing and isolation process, which improves low irradiance performance

3 of A

SUNTECH

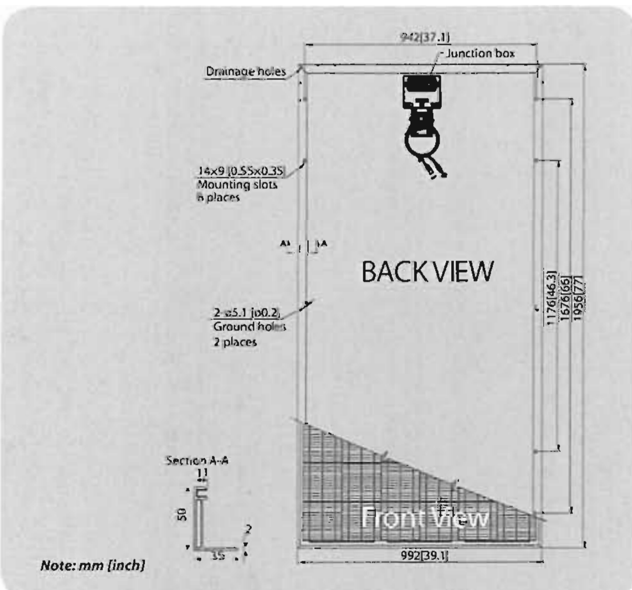
Solar powering a green future™

STP280 - 24/Vb-1
STP270 - 24/Vb-1
STP260 - 24/Vb-1

Electrical Characteristics

Characteristics	STP280-24/Vb-1	STP270-24/Vb-1	STP260-24/Vb-1
Open - Circuit Voltage (Voc)	44.8V	44.5V	44V
Optimum Operating Voltage (Vmp)	35.2V	35V	34.8V
Short - Circuit Current (Isc)	8.33A	8.2A	8.09A
Optimum Operating Current (Imp)	7.95A	7.71A	7.47A
Maximum Power at STC (Pmax)	280Wp	270Wp	260Wp
Operating Temperature	-40°C to +85°C	-40°C to +85°C	-40°C to +85°C
Maximum System Voltage	600V DC	600V DC	600V DC
Maximum Series Fuse Rating	20A	20A	20A
Power Tolerance	±3 %	±3 %	±3 %

STC: Irradiance 1000W/m², Module temperature 25°C, AM=1.5



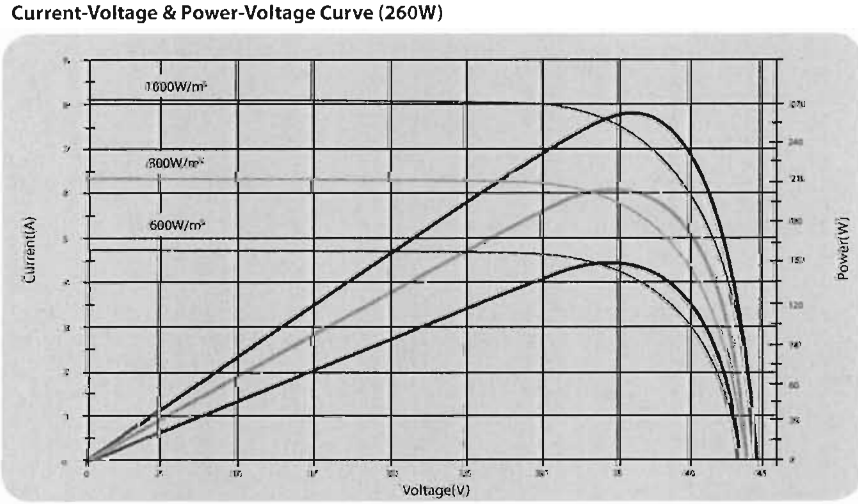
Mechanical Characteristics

Solar Cell	Poly-crystalline 156×156mm (6 inch)
No. of Cells	72 (6×12)
Dimensions	1956x992x50mm (77.0x39.1x2.0 inch)
Weight	27 kg (59.5 lbs.)
Front Glass	4mm(0.16 inch) tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP65 rated
Output Cables	AIW(12AWG), asymmetrical lengths (-) 1200mm (47.2 inch) and (+) 800mm (31.5 inch), MC Plug Type IV connectors

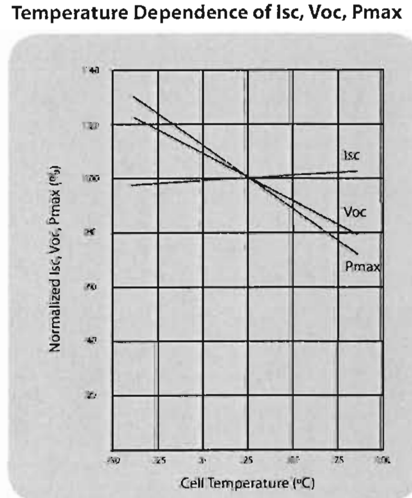
Temperature Coefficients

Nominal Operating Cell Temperature (**NOCT**)	45±2°C
Temperature Coefficient of Pmax	-(0.47 ± 0.05) %/°C
Temperature Coefficient of Voc	-(0.34 ± 0.01) %/°C
Temperature Coefficient of Isc	(0.055 ± 0.01) %/°C

Current-Voltage & Power-Voltage Curve (260W)



Temperature Dependence of Isc, Voc, Pmax



(E) Building Dimensions - Band Room

B = 72.50'   D = 52.50'

Existing Roof Area - 3,806 sf   (per original construction documents)

(E) DL = 212,357   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 100 psf*min(72.5, 52.5')*2*(9.25+3' Parapet)

10% DL = 21236

Prposed Solar Array

Module - Suntech STP260   Titl-angle - 20°
Module Area - 20.9 sf   Plan Area ~ 1.49 * Module Area = 31.1 sf
Module Wt. - 59.5 #   Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{\text{10\% (E) DL}}{\text{Array Wt}} = \text{264 modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = \text{122 modules}$$

Check (E) Framing

(E) D+L = 212357+3806*20 psf = 288,477
(E) D+L+ array = 212357+3806*12 psf +122*80.5 = 267,850

$$\Delta = \frac{267{,}850}{288{,}477} - 1 = -0.072$$ Ok

Change in load on deck

(E) D+L = 42 psf
(E) D+L+ array = 36.6 psf

$$\Delta = \frac{36.6}{42} - 1 = -0.13$$ Ok

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

2010-004-01 OUSD McClymonds Solar Design.xls, (E) Frmg Eval

(E) Building Dimensions - Cafeteria

B = 79.50'   D = 64.00'

Existing Roof Area - 5,088 sf   (per original construction documents)

(E) DL = 246,336   (= Roof Area * DL + Trib Wall DL * Trib Wall Area)
Trib Wall DL = 100 psf*min(79.5, 64')*2*(7.5+3' Parapet)

10% DL = 24634

Prposed Solar Array

Module - Suntech STP260   Titl-angle - 20°
Module Area - 20.9 sf   Plan Area ~ 1.49 * Module Area = 31.1 sf
Module Wt. - 59.5 #   Frmg per Module - 21

Basic Wind Speed = 85 mph
Exposure - C   (ASCE 7-05 Section 6.5.6.2)

Allowable number of Modules

$$\text{No. Modules Allowed} = \frac{10\%\ (E)\ DL}{\text{Array Wt}} = 306 \text{ modules}$$

Array Wt = 80.5 #/module

$$\text{No. Mod. based on roof area} = \frac{\text{Roof Area}}{\text{Plan Area}} = 164 \text{ modules}$$

Check (E) Framing

(E) D+L = 246336+5088*20 psf = 348,096
(E) D+L+ array = 246336+5088*12 psf +164*80.5 = 320,594

$$\Delta = \frac{320,594}{348,096} - 1 = -0.079 \quad \underline{Ok}$$

Change in load on deck

(E) D+L = 42 psf
(E) D+L+ array = 36.6 psf

$$\Delta = \frac{36.6}{42} - 1 = -0.13 \quad \underline{Ok}$$

Racking Point Loads

for SunlLink System

No. Modules per Support ~ 2

P = 2 * (59.5+21) = 161

2010-004-01 OUSD McClymonds Solar Design.xls, (E) Frmg Eval

INTERACTIVE RESOURCES
ARCHITECTURE • PLANNING • ENGINEERING
Structural Engineers
117 Park Place
Point Richmond, CA 94801
510.236.7435
510.232.5325 (FAX)

NREL Structural Evaluation
OUSD - McClymonds High School

rev.	description	date	by	drawn PMW/JC	job 2010-004.01
				scale	page 6 of A
				date	

Seismic (IBC / ASCE 7)

Seismic Design Category - D (CBC 1613.5.6 & ASCE 7-05, Sect. 11.6)

Building Category - II (ASCE 7-05 Table 1-1)
Seismic Importance Factor, I - 0.00 (ASCE 7-05 Table 11.5-1)
Soil Site Class - D (ASCE 7-05 Chapter 20)

Site Location		
Latitude	37.819°	N
Longitude	122.280°	W

$S_s = 1.500$
$S_1 = 0.600$
} See next Page

$S_{MS} = F_a S_s =$ 1.5 $F_a = 1$
$S_{M1} = F_v S_1 =$ 0.900 $F_v = 1.5$

$S_{DS} = 2/3\ S_{MS} = 1.000$ $T_0 = 0.2\ S_{D1}/S_{DS} = 0.12$
$S_{D1} = 2/3\ S_{M1} = 0.600$ $T_s = S_{D1}/S_{DS} = 0.6$

for $T < T_0$, $S_a = S_{DS}\ (0.4 + 0.6\ T/T_0)$

for $T_0 < T < T_s$, $S_a = S_{DS}$

for $T_s < T$, $S_a = S_{D1}/T$

$T = C_t h_n^x =$ 0.32 (ASCE Eq. 12.8-7)
$C_t = 0.020$ (ASCE Table 12.8-2)
$h_n = 40.00$
$x = 0.75$ (ASCE Table 12.8-2)

Component Force (ASCE Section 13.3.1)

ASCE Eq. 13.3-1

$$F_p = \frac{0.4\ a_p S_{DS} W_p}{R_p / I_p}\left(1 + 2\ \frac{z}{h}\right) = 0.480\ Wp$$

Controls $z = h$ $h =$ roof elev.

ASCE Eq. 13.3-2

$F_p\ max = 1.6\ S_{DS} I_p W_p =$ 1.600 Wp

ASCE Eq. 13.3-3

$F_p\ min = 0.3\ S_{DS} I_p W_p =$ 0.300 Wp

$I_p = 1.0$ $a_p = 1.0$ $R_p = 2.5$

$W_p = 81$ # $\therefore F_p = 39$ # for ASD, USE $0.7 * F_p = 27$ #

2010-004-01 OUSD McClymonds Solar Design.xls, ASCE Seis

Oakland Unified School District
McClymonds High School

Conterminous 48 States
2005 ASCE 7 Standard / 2010 California Building Code
Latitude = 37.819
Longitude = -122.28
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B - Fa = 1.0 ,Fv = 1.0
Data are based on a 0.01 deg grid spacing

Period (sec)	Sa (g)
0.2	1.500 (Ss, Site Class B)
1.0	0.600 (S1, Site Class B)

Conterminous 48 States
2005 ASCE 7 Standard
Latitude = 37.819
Longitude = -122.28
Spectral Response Accelerations SMs and SM1
SMs = Fa x Ss and SM1 = Fv x S1
Site Class D - Fa = 1.0 ,Fv = 1.5

Period (sec)	Sa (g)
0.2	1.500 (SMs, Site Class D)
1.0	0.900 (SM1, Site Class D)

Conterminous 48 States
2005 ASCE 7 Standard
Latitude = 37.819
Longitude = -122.28
Design Spectral Response Accelerations SDs and SD1
SDs = 2/3 x SMs and SD1 = 2/3 x SM1
Site Class D - Fa = 1.0 ,Fv = 1.5

Period (sec)	Sa (g)
0.2	1.000 (SDs, Site Class D)
1.0	0.600 (SD1, Site Class D)

Reference: "USGS Seismic Hazard Curves and Uniform Hazard Response Spectra", **NSHMP_HazardApp.jar** application

McClymonds High School
2607 MYRTLE ST, OAKLAND, CA 94607

Questions for District

1. What are age & condition of roofs?
2. Are there roof structural concerns?

Drawings not available in documents furnished

"As-built" drawings available