SENIOR THESIS FINAL REPORT SANTA ROSA JUNIOR COLLEGE STUDENT CENTER

FINAL THESIS REPORT

Dan Vallimont

4/7/2010

Construction Management Option

Faculty Consultant: Jim Faust

SANTA ROSA JUNIOR COLLEGE

BUILDING STATISTICS

SIZE: 66,646 SF, 3 STORIES PLUS ATTIC

CONSTRUCTION DATES: 12-3-07 – 11-24-09

COST: +/- 30,000,000 Midstate Construction

+/- 20,000,000 Mechanical, Electrical, Geothermal

PROJECT DELIVERY METHOD: Design-Build

PROJECT TEAM

OWNER: Santa Rosa Jr. College

CONSTRUCTION MANAGER: Wright Contracting Inc.

ARCHITECT: BSA Architects

STRUCTURAL ENGINEER: KPFF Consulting Engineers

MEP: AlfaTech Engineers

CIVIL ENGINEER: Brelje & Race

LIGHTING ENGINEER: Horton Lees Brogden

ARCHITECTURE

- 3 750+ SF Classrooms
- 700+ SF Computer Center
- 4000+ SF Student Dining Area
- Numerous Meeting Rooms
- 3 Story Atrium Space at Entrance Lobby
- Grand Staircase around Lobby Atrium
- Student Affairs Offices
- 2100 SF Kitchen

BUILDING ENVELOPE

- Brick Veneer Exterior
- Precast Concrete Panels wrap parts of the building facade
- Concrete Roofing Tiles cover the majority of the roof
- Flexible flashing is used on ridges, penetrations, and elevation changes on roof

STRUCTURAL

- Live Loads
  - FLAT ROOF = 20PSF
  - SLOPED ROOF= 16PSF
  - OFFICES= 80PSF + 20PSF PARTITION LOAD
  - CORRIDORS=100PSF
- Footings to be founded at least 24” below lowest adjacent grade
- Minimum 28-day Concrete Strength
  - FOOTINGS = 3000psi
  - SOG = 3000psi
  - COLUMNS =4000psi
  - WALLS = 4000psi
  - FILL ON METAL DECK =3000psi
- SOG is 5” concrete with #4 rebar at 12”o.c.
- Typical Floor Framing is 3 1/4 “ LW concrete on 3”-18GA composite deck
- Beams and girders are composite with 3/4ϕ” studs at 12” o.c.
- Structural Steel Building

MECHANICAL

- Cooling/heating design: geothermal heat pump loop
  - 8” geothermal vault mains (860GPM @ peak load)
  - 5 geothermal circuit loops
  - 150 geothermal bore loops
- Seismic bracing needed for mechanical equipment and piping
  - Seismic zone 4
  - Importance factor = 1.5
- 376 SF mechanical room on first floor
- Energy Recovery Unit located on second floor

ELECTRICAL

- 12kV Transformer for supply voltage
- Lighting uses 277V
- Main Switchboard runs at 480/277V
- 125kW Emergency Backup Generator
- 24 panel boards located throughout the building
- 6 local transformers step voltage down to 208/120V

LIGHTING

- Dimmable lighting available in leadership center and multiple meeting rooms
- 63 lighting types used throughout
- Rooms with dimmable fluorescent lights must have a LUTRON, HI-LUME or ECO HI-10 dimming ballast rated at 277V
- Interior lighting systems on each floor have separate automatic shut-off controls
- Rooms larger than 100SF and greater than .8 watts per SF of lighting are controlled with bi-level switching for uniform light reduction

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Executive Summary

This Final Report is the result of in depth analyses that were identified in the Fall of 2009 and have been conducted throughout the Spring 2010 semester. The subject of these analyses is the newly constructed, Santa Rosa Junior College, Bertolini Student Center located in Santa Rosa, CA. The student center is the most recent of an ongoing series of new buildings that have replaced outdated structures on the junior college campus in order to provide the best possible opportunities to students and faculty.

This final report includes four major analyses and two short "breadth" analyses. The first is takes a look at a critical industry issue, while the three following took to find ways to reduce the overall cost and schedule of the student center project. The critical industry issue looks at the growing popularity of renewable energy systems and how to implement such a system into the Student Center. This analysis is also supported by two "breadth" analyses which take a brief look into architectural and electrical features of the building.

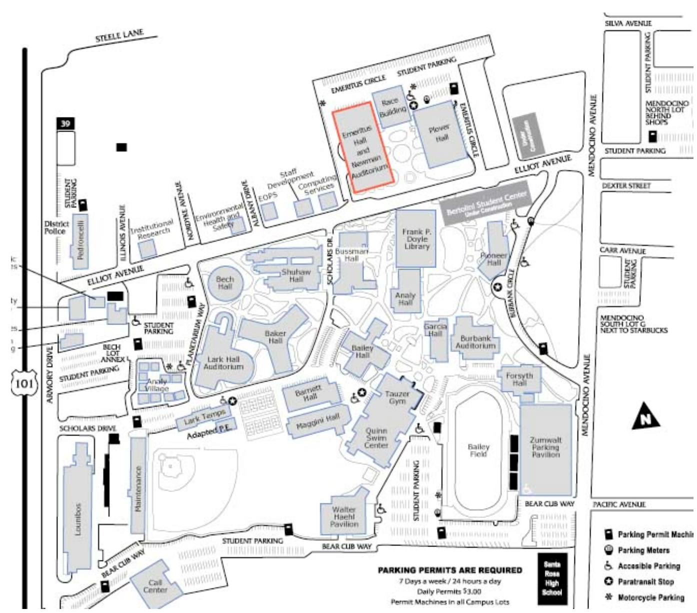
The three technical analyses are aimed at finding ways to decrease the overall cost and schedule of the project. The first looks into the implementation of field welding instead of prefabricated shop welding. This study will look to decrease the schedule through quicker installation time and less rework and to decrease the cost through cheaper labor. The second analysis will look into alternative steel erection methods, particularly multiple cranes instead of the single crane used on the project. This study will aim to decrease the schedule through elimination of delays and to decrease the cost through having the cranes on site for a shorter period of time. The final analysis will focus on the prefabrication of precast concrete panels and will attempt to counter the delays and rework that occurred with the implementation of a design consultant who would be involved from the very beginning design phase. This study will aim to eliminate critical path delays and also costs associated with rework.

The main focus of the analyses above is construction management; however, the architectural and electrical breadth studies will take a look outside of construction management and be carried out in an attempt to provide the best solution for the student center project.

PROJECT BACKGROUND:

CLIENT INFORMATION

Santa Rosa Junior College is located in the Sonoma County Junior College district of Sonoma County California which encompasses roughly 1600 square miles and has a population of 464,568 people (2008 estimate, Economic Modeling Specialists Inc.). The school is designed as a public, two year community college. Santa Rosa has two different campus locations in California: the Santa Rosa campus and the Petaluma campus. The Student Center being constructed is located in the Santa Rosa Campus which is located directly off of route 101 in Sonoma County California which is less than an hour north of San Fransisco. As of 2008, the enrollment between the two campuses was 36,460 students.



Santa Rosa's mission statement is as follows: **Sonoma County Junior College District's Mission is to promote student learning throughout our diverse communities by increasing the knowledge, improving the skills, and enhancing the lives of those who participate in our programs and enroll in our courses,** and the addition of the new student center will help the university to fulfill this statement. The original student center, which was demolished prior to construction of the new, Bertolini Student Center, was very outdated and failed to meet the needs of the students and the college's mission. Upon completion, the nearly 70,000 SF center will give students a place to relax and be social, get administrative advice, and also further their education.

As with all projects, the owner wants the lowest cost, highest quality, and no accidents and the Santa Rosa Junior College Student Center is no exception. Midstate Construction and the construction manager on the project monitor the safety, correct deficiencies, and send out notices when appropriate. The only issue of importance to the owner, dealing with sequencing, is getting the project completed as soon as possible, although the most important part to the college is the cafeteria and student dining area. These areas are the most complicated on the project and will be the last things completed. On the student center project there are no joint, dual, or phased occupancy requirements to meet. The owner does have the right, per specifications, to partially occupy the building when areas have been completed. This would make things a bit more difficult for the tracking punchlist work and finishing the rest of the building if the owner would choose to do so. Some keys that would be important to completing the project to the owner's satisfaction would be finishing the center by December of 2009 so that it is ready to be fully utilized in the spring 2010 semester. As for accommodating students and faculty while they are without a student center, faculty has been spread out in temporary space all over campus until they are able to move in to the new center. As for students, they have had to deal without a student center at all and are most likely excited for the opening of the building in the near future.

PROJECT BACKGROUND:

LOCAL CONDITIONS

Preferred Methods of Construction:

The preferred method of construction on the project is that of most of the pre-existing buildings on campus. The structural steel frame with precast concrete and brick veneer and tile roof is common on many buildings throughout the Santa Rosa Junior College campus and also fits the style of many nearby off campus buildings.

Construction Parking:

Parking for construction workers is located just north of the site. It is directly across Elliot Avenue, which runs directly between the construction site and the lot. The close proximity of the parking lot allows for quick access to the site.

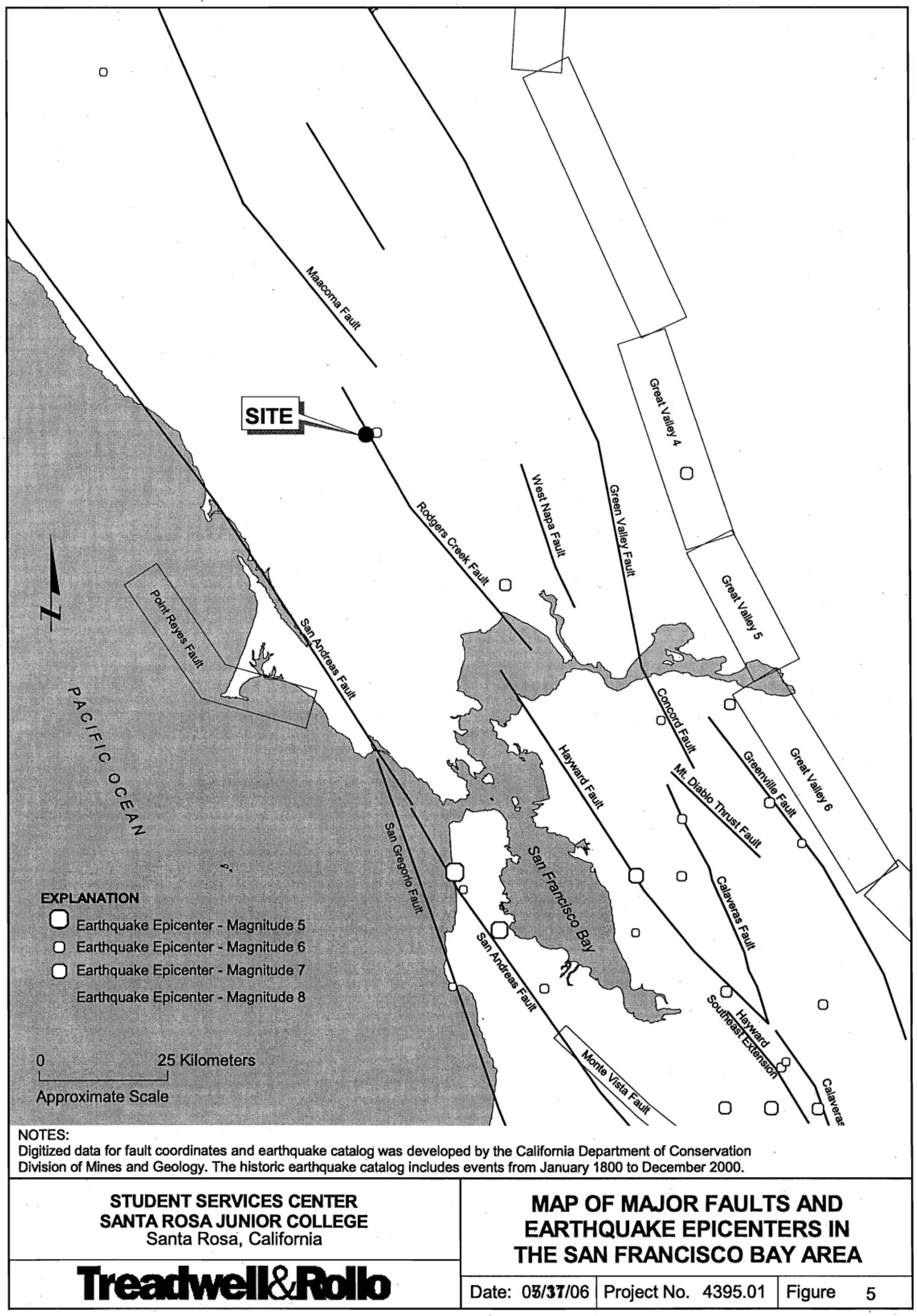
Recycling and Tipping Fees:

Multiple dumpsters are located on site to encourage recycling on the project. The project target goal for recycling is 75% of materials. To make this goal a reality, materials must be sorted out ahead of time.

Soil and Subsurface Water Condition:

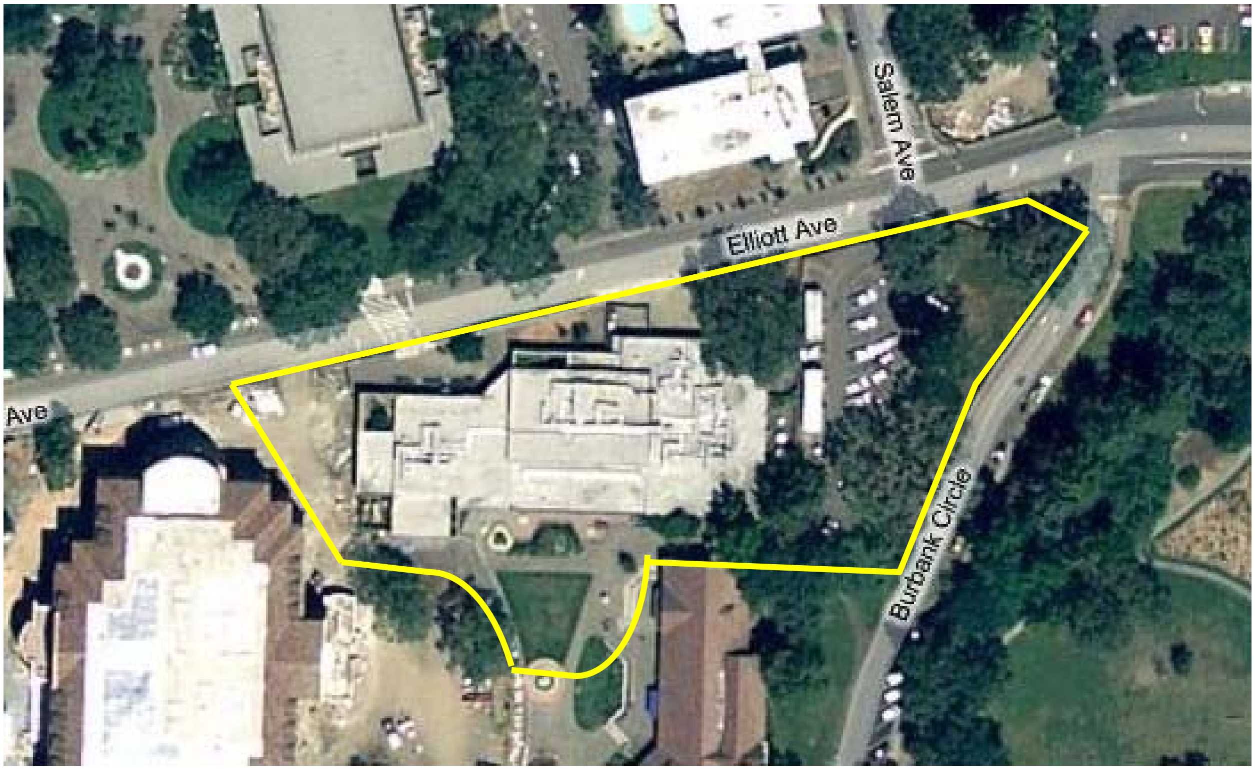
The Student Center construction site is underlain by alluvial soils. The top 25 feet of soil on site consists of a mixture of stiff to very stiff clay along with layers of medium dense to dense sand. The upper portion of the clay is moderately compressible and has a low to moderate potential of expansion. The anticipated high groundwater level is roughly 4 feet below the soil surface. The primary geological hazard that could potentially affect construction is strong ground shaking due to earthquakes due to the fact that the site is located in the seismically active San Francisco Bay Region. Major faults in the area include the San Andreas, Hayward, San Gregorio Rodgers Creek, and Calaveras faults (a map of local epicenters can be found below). Primary geotechnical issues include the presence of clay on the surface that is moderately compressible with low to moderate expansion potential as well as shallow groundwater (Additional seismic maps located in appendix).

Taking into account the soil conditions it has been determined that the student center can be supported on spread footings bearing on at least 3 feet of engineered fill. To reduce the potential of expansion the footings are to be placed at least 24 inches below the adjacent soil sub-grade. If construction of footings is done in the wet season, there is a potential for ground water may be encountered during the three feet of excavation required for the engineered fill below footings.


Maacoma Fault
SITE
Rodgers Creek Fault
West Napa Fault
Green Valley Fault
Great Valley 4
Great Valley 5
Great Valley 6
Point Reyes Fault
San Andreas Fault
PACIFIC OCEAN
Concord Fault
Hayward Fault
Mt. Diablo Thrust Fault
Greenville Fault
San Gregorio Fault
San Francisco Bay
Calaveras Fault
San Andreas Fault
Monte Vista Fault
Hayward Southeast Extension
Calaveras
EXPLANATION
Earthquake Epicenter - Magnitude 5
Earthquake Epicenter - Magnitude 6
Earthquake Epicenter - Magnitude 7
Earthquake Epicenter - Magnitude 8
0
25 Kilometers
Approximate Scale
NOTES:
Digitized data for fault coordinates and earthquake catalog was developed by the California Department of Conservation Division of Mines and Geology. The historic earthquake catalog includes events from January 1800 to December 2000.
STUDENT SERVICES CENTER
SANTA ROSA JUNIOR COLLEGE
Santa Rosa, California
Treadwell&Rollo
MAP OF MAJOR FAULTS AND EARTHQUAKE EPICENTERS IN THE SAN FRANCISCO BAY AREA
Date: 03/37/06
Project No. 4395.01
Figure 5

PROJECT BACKGROUND:

EXISTING SITE PLAN



Existing site prior to the demolition of the old student center (bing.com/maps/)

PROJECT BACKGROUND:

PROJECT DELIVERY METHOD

The project is being delivered using a design-build method with the architect and construction manager contractually bound directly to the owner. Although the project is not entirely a design-build project, several major items were bid that way. The majority of the design-build items include, precast, curtain wall, elevators, and fire sprinkler system for the student center. The project was offered as a lump sum bid because of the fact that it is very difficult to do a public works bid as design-build. Public contracting laws put constraints on it that are difficult to get around. Private owners have more leeway, but design-build always offers a bit of a struggle to control scope vs. price.

The project was bid in 5 different pieces. Sitework landscaping, building construction, mechanical systems, electrical, and geothermal are the 5 different items that were bid on. Each bid was required to be made out on the Bid Proposal Form that was included in the contract documents and must conform and be fully responsive to the plans, specifications, and all other documents included in pertinent contract documents. Also, each bid was required to be accompanied by cash, a cashier's or certified check, or a bidder's bond from an admitted surety insurer. The check or bid bond ensures that the bidder who is awarded the contract will execute the contract documents and provide the required payment, performance bonds, and insurance certificates within 10 days of being notified of being awarded the contract.

On the Santa Rosa Junior College Student Center, the architect works directly for the SRJC. The other design teams on the project work underneath the architect as subcontractors. These design teams include lighting design, civil engineer, structural engineer, graphics, acoustics/audio video, mechanical/electrical/plumbing, landscape architect, and interior design. Since the student center is such a large project, it makes sense to have the design teams contract with the architect instead of the owner so that the architect can have control over everything and avoid any clashing issues. The construction manager on the project, like the architect, holds a contract with the owner. The construction manager's job is to oversee the prime contractors and design team but he does not have a contractual relationship with them.

The organizational hierarchy can be summed up by the chart seen below. The black lines stand for contractual agreements. The CM and the architect are the only people that contract directly with the owner. All other design teams contract directly with the architect and are permitted to subcontract on their own. The blue lines represent the CMs job to oversee design team members. Although he does not have a contractual agreement with them, it is his job to make sure that everything is going ahead smoothly.

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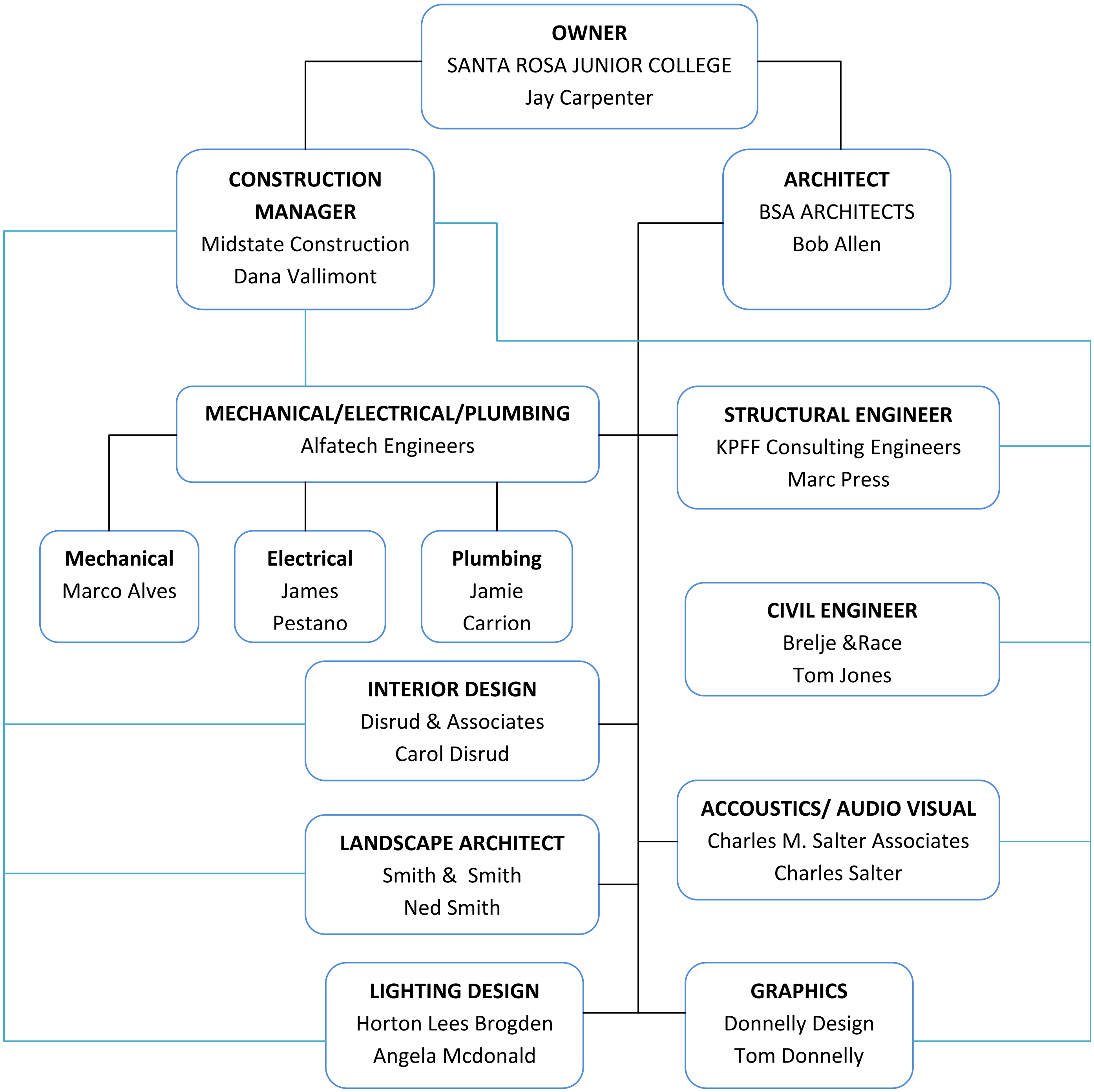
SANTA ROSA JUNIOR COLLEGE STUDENT CENTER
ORGANIZATIONAL CHART



PROJECT BACKGROUND:

PROJECT SCHEDULE SUMMARY

Construction on the Santa Rosa Junior College Student Center began with the Notice to Proceed which was granted on December 7, 2007. Mobilization soon followed on December 13 of 2007. After mobilizing work began on setting structural concrete, steel, SOG's and metal decking. Construction throughout the project was set up in three phases (East Building, Middle Building, West Building). Construction started on the east side of the site and finished up on the west. Work on the building began with excavation for footings and grade beams and was followed by placement of embeds, rebar, anchor bolts and finally inspection before the placement of concrete. Next steel columns and beams were set in place by the use of a mobile crane where they were then plumbed up and welded in place. Following the columns and beams was the erection of stairs and placement of metal decking. After the placement of steel the SOG was formed, reinforced and poured. Construction then moved to the second and finally third floor where concrete slabs were placed on metal decking. This process of setting steel and pouring concrete for the East Building section was completed in June of 2008. The Middle and West sections of construction which started while construction was still being done on the East section would finish in October and September of 2008 respectively.

Once the steel and concrete placement was completed, work then moved on to the exterior envelope of the SRJC student center. The sequence of work would again move in three sections from east to west. Envelope construction began on the second floor and then moved to the third floor before coming back to finish the first floor up last. Exterior envelope construction began in June of 2008 and was completed successfully in December of the same year. Framing/Rough-in was next on the schedule followed by interior finishes, fixtures, and trim. This work is scheduled to be done November 24, 2009 which would allow the student center to open its doors to students and faculty for the first time at the beginning of the 2010 spring semester at SRJC.

This image illustrates the construction sequence of the student center. Work began at the east side of the building and worked across to the middle and finally the west side (right to left on the site plan above).

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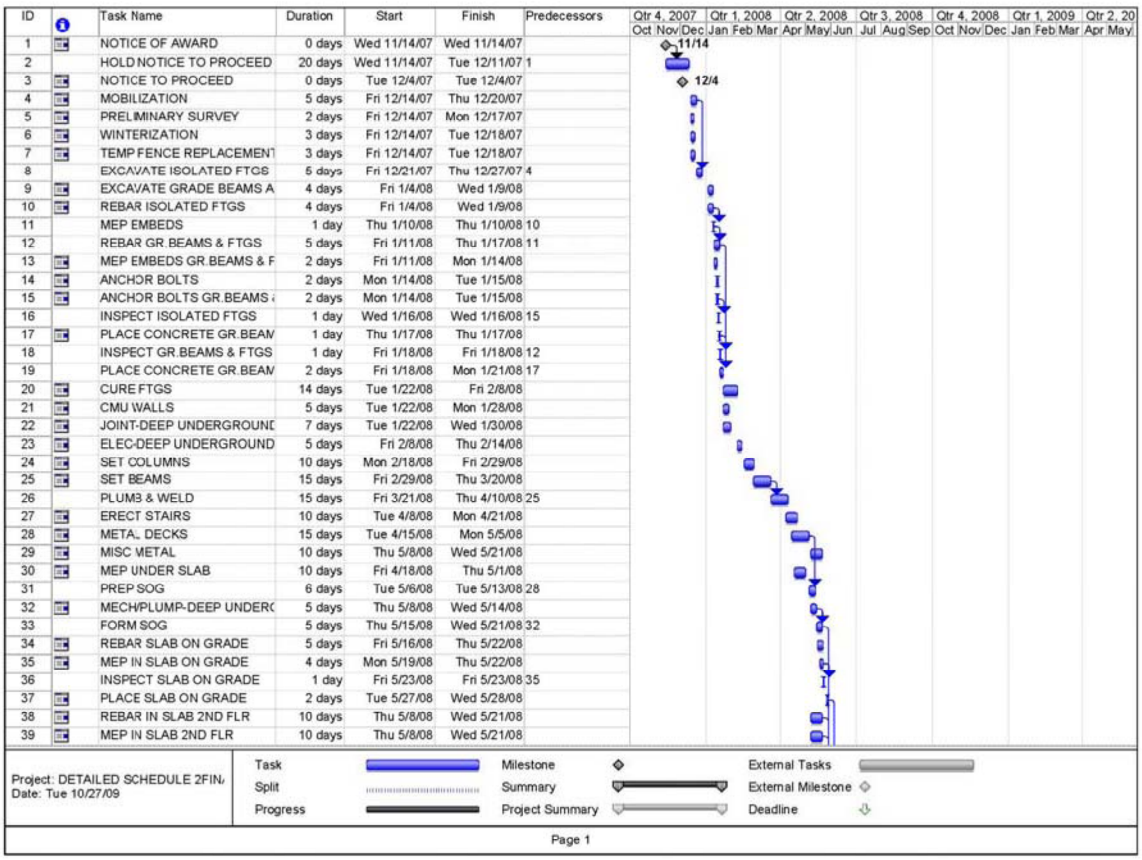
PROJECT BACKGROUND:

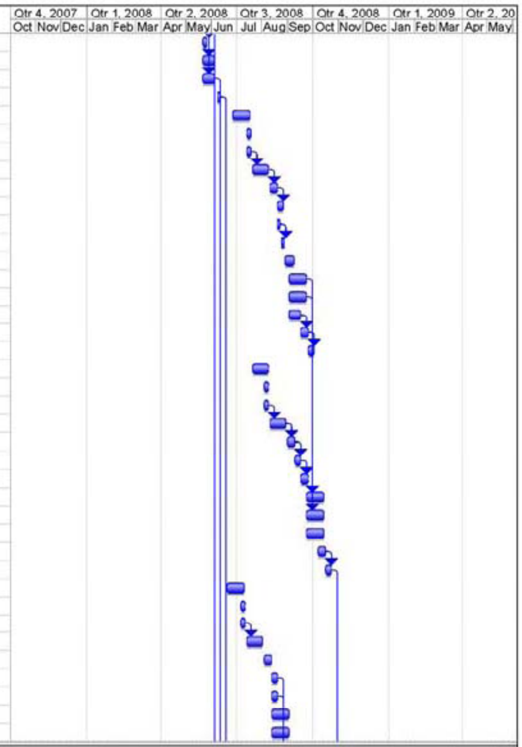
DETAILED PROJECT SCHEDULE

The detailed schedule that I put together for the SRJC Student Center focuses on one of the three sequences of construction on the building. All of the activities and durations are taken from the East Building (section 1) part of the schedule. The middle and west parts of the schedule contain nearly identical activities and are only a few months behind the East Sequence, which was the initial sequence of construction.



ID	Task Name	Duration	Start	Finish	Predecessors
1	NOTICE OF AWARD	0 days	Wed 11/14/07	Wed 11/14/07	
2	HOLD NOTICE TO PROCEED	20 days	Wed 11/14/07	Tue 12/11/07	1
3	NOTICE TO PROCEED	0 days	Tue 12/4/07	Tue 12/4/07	
4	MOBILIZATION	5 days	Fri 12/14/07	Thu 12/20/07	
5	PRELIMINARY SURVEY	2 days	Fri 12/14/07	Mon 12/17/07	
6	WINTERIZATION	3 days	Fri 12/14/07	Tue 12/18/07	
7	TEMP FENCE REPLACEMENT	3 days	Fri 12/14/07	Tue 12/18/07	
8	EXCAVATE ISOLATED FTGS	5 days	Fri 12/21/07	Thu 12/27/07	4
9	EXCAVATE GRADE BEAMS A	4 days	Fri 1/4/08	Wed 1/9/08	
10	REBAR ISOLATED FTGS	4 days	Fri 1/4/08	Wed 1/9/08	
11	MEP EMBEDS	1 day	Thu 1/10/08	Thu 1/10/08	10
12	REBAR GR.BEAMS & FTGS	5 days	Fri 1/11/08	Thu 1/17/08	11
13	MEP EMBEDS GR.BEAMS & F	2 days	Fri 1/11/08	Mon 1/14/08	
14	ANCHOR BOLTS	2 days	Mon 1/14/08	Tue 1/15/08	
15	ANCHOR BOLTS GR.BEAMS &	2 days	Mon 1/14/08	Tue 1/15/08	
16	INSPECT ISOLATED FTGS	1 day	Wed 1/16/08	Wed 1/16/08	15
17	PLACE CONCRETE GR.BEAM	1 day	Thu 1/17/08	Thu 1/17/08	
18	INSPECT GR.BEAMS & FTGS	1 day	Fri 1/18/08	Fri 1/18/08	12
19	PLACE CONCRETE GR.BEAM	2 days	Fri 1/18/08	Mon 1/21/08	17
20	CURE FTGS	14 days	Tue 1/22/08	Fri 2/8/08	
21	CMU WALLS	5 days	Tue 1/22/08	Mon 1/28/08	
22	JOINT-DEEP UNDERGROUND	7 days	Tue 1/22/08	Wed 1/30/08	
23	ELEC-DEEP UNDERGROUND	5 days	Fri 2/8/08	Thu 2/14/08	
24	SET COLUMNS	10 days	Mon 2/18/08	Fri 2/29/08	
25	SET BEAMS	15 days	Fri 2/29/08	Thu 3/20/08	
26	PLUMB & WELD	15 days	Fri 3/21/08	Thu 4/10/08	25
27	ERECT STAIRS	10 days	Tue 4/8/08	Mon 4/21/08	
28	METAL DECKS	15 days	Tue 4/15/08	Mon 5/5/08	
29	MISC METAL	10 days	Thu 5/8/08	Wed 5/21/08	
30	MEP UNDER SLAB	10 days	Fri 4/18/08	Thu 5/1/08	
31	PREP SOG	6 days	Tue 5/6/08	Tue 5/13/08	28
32	MECH/PLUMP-DEEP UNDERG	5 days	Thu 5/8/08	Wed 5/14/08	
33	FORM SOG	5 days	Thu 5/15/08	Wed 5/21/08	32
34	REBAR SLAB ON GRADE	5 days	Fri 5/16/08	Thu 5/22/08	
35	MEP IN SLAB ON GRADE	4 days	Mon 5/19/08	Thu 5/22/08	
36	INSPECT SLAB ON GRADE	1 day	Fri 5/23/08	Fri 5/23/08	35
37	PLACE SLAB ON GRADE	2 days	Tue 5/27/08	Wed 5/28/08	
38	REBAR IN SLAB 2ND FLR	10 days	Thu 5/8/08	Wed 5/21/08	
39	MEP IN SLAB 2ND FLR	10 days	Thu 5/8/08	Wed 5/21/08	

ID	Indicators	Task Name	Duration	Start	Finish	Predecessors
40		CONCRETE SLAB ON DECK	3 days	Thu 5/22/08	Mon 5/26/08	39
41		REBAR IN SLAB 3RD FLR	10 days	Thu 5/22/08	Wed 6/4/08	38
42		MEP IN SLAB 3RD FLR	10 days	Thu 5/22/08	Wed 6/4/08	33
43		CONCRETE SLAB ON DECK 3	3 days	Mon 6/9/08	Wed 6/11/08	
44		EXTERIOR STUDS L2	15 days	Fri 6/27/08	Thu 7/17/08	
45		ROUGH-IN PLUMBING EXT W	5 days	Mon 7/14/08	Fri 7/18/08	
46		ELECTRICAL ROUGH-IN EXT	5 days	Mon 7/14/08	Fri 7/18/08	
47		EXTERIOR GYP SHEETING L2	15 days	Mon 7/21/08	Fri 8/8/08	46
48		WATERPROOF EXT WALLS L	7 days	Mon 8/11/08	Tue 8/19/08	47
49		FLASHING EXT MASONRY L2	5 days	Wed 8/20/08	Tue 8/26/08	48
50		WATERPROOF EXT DECK #2	3 days	Wed 8/20/08	Fri 8/22/08	
51		PAVERS DECK #293 L2	3 days	Mon 8/25/08	Wed 8/27/08	50
52		WINDOWS L2	7 days	Fri 8/29/08	Mon 9/8/08	
53		VENEER MASONRY L2	15 days	Wed 9/3/08	Tue 9/23/08	
54		GFRC PRECAST L2	15 days	Wed 9/3/08	Tue 9/23/08	
55		ALUM WINDOWS L2	10 days	Wed 9/3/08	Tue 9/16/08	
56		CURTAIN WALL L2	7 days	Wed 9/17/08	Thu 9/25/08	55
57		CAULKING WINDOWS L2	5 days	Fri 9/26/08	Thu 10/2/08	56
58		EXTERIOR STUDS L3	15 days	Mon 7/21/08	Fri 8/8/08	
59		ROUGH-IN PLUMBING EXT W	5 days	Mon 8/4/08	Fri 8/8/08	
60		ELECTRICAL ROUGH-IN EXT	5 days	Mon 8/4/08	Fri 8/8/08	
61		EXTERIOR GYP SHEETING L3	15 days	Mon 8/11/08	Fri 8/29/08	60
62		WATERPROOF EXT WALLS L	7 days	Mon 9/1/08	Tue 9/9/08	61
63		FLASHING EXT MASONRY L3	5 days	Wed 9/10/08	Tue 9/16/08	62
64		WINDOWS L3	7 days	Wed 9/17/08	Thu 9/25/08	63
65		ALUM WINDOWS L3	15 days	Wed 9/24/08	Tue 10/14/08	54
66		VENEER MASONRY L3	15 days	Wed 9/24/08	Tue 10/14/08	53
67		GFRC PRECAST L3	15 days	Wed 9/24/08	Tue 10/14/08	
68		CURTAIN WALL L3	7 days	Wed 10/8/08	Thu 10/16/08	
69		CAULKING WINDOWS L3	5 days	Fri 10/17/08	Thu 10/23/08	68
70		EXTERIOR STUDS L1	15 days	Fri 6/20/08	Thu 7/10/08	
71		ROUGH-IN PLUMBING EXT W	5 days	Mon 7/7/08	Fri 7/11/08	
72		ELECTRICAL ROUGH-IN EXT	5 days	Mon 7/7/08	Fri 7/11/08	
73		EXTERIOR GYP SHEETING L1	15 days	Mon 7/14/08	Fri 8/1/08	72
74		WATERPROOF EXT WALLS L	7 days	Mon 8/4/08	Tue 8/12/08	
75		FLASHING EXT MASONRY L1	5 days	Wed 8/13/08	Tue 8/19/08	
76		PLASTER SOFFETS L1	5 days	Wed 8/13/08	Tue 8/19/08	
77		VENEER MASONRY L1	15 days	Wed 8/13/08	Tue 9/2/08	
78		GFRC PRECAST L1	15 days	Wed 8/13/08	Tue 9/2/08	

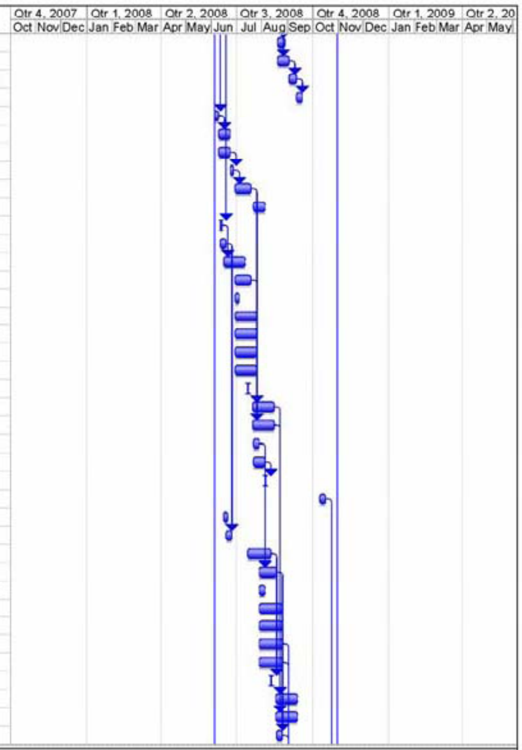


Project: DETAILED SCHEDULE 2FIN/
Date: Tue 10/27/09

Task | Milestone | External Tasks
Split | Summary | External Milestone
Progress | Project Summary | Deadline

Page 2

ID		Task Name	Duration	Start	Finish	Predecessors
79		WINDOWS L1	7 days	Wed 8/20/08	Thu 8/28/08	76
80		ALUM WINDOWS L1	10 days	Wed 8/20/08	Tue 9/2/08	75
81		CURTAIN WALL L1	7 days	Wed 9/3/08	Thu 9/11/08	80
82		CAULKING WINDOWS L1	5 days	Fri 9/12/08	Thu 9/18/08	81
83		ROOF CARPENTRY	3 days	Thu 6/5/08	Mon 6/9/08	42
84		ROOF MASONRY VENEER	10 days	Tue 6/10/08	Mon 6/23/08	83
85		ROOF PRECAST	10 days	Tue 6/10/08	Mon 6/23/08	
86		ROOF MASONRY FLASHING	4 days	Tue 6/24/08	Fri 6/27/08	85
87		ROOF INSULATION	15 days	Mon 6/30/08	Fri 7/18/08	86
88		ROOFING	10 days	Tue 7/22/08	Mon 8/4/08	
89		FIRE PROOFING STEEL L2	2 days	Thu 6/12/08	Fri 6/13/08	43
90		MEP RISERS L2	5 days	Thu 6/12/08	Wed 6/18/08	
91		ROUGH-IN OVERHEAD DUCT	20 days	Mon 6/16/08	Fri 7/11/08	89
92		INTERIOR FRAMING L2	15 days	Mon 6/30/08	Fri 7/18/08	
93		HOLLOW METAL FRAMES IN	5 days	Mon 6/30/08	Fri 7/4/08	
94		ROUGH IN AV/TELECOM/SEC	20 days	Mon 6/30/08	Fri 7/25/08	
95		ROUGH-IN ELECTRICAL/FIRE	20 days	Mon 6/30/08	Fri 7/25/08	
96		ROUGH-IN PLUMBING L2	20 days	Mon 6/30/08	Fri 7/25/08	
97		ROUGH-IN HVAC CONTROLS	20 days	Mon 6/30/08	Fri 7/25/08	
98		CLOSE UP INSPECTION 1/2 L	1 day	Tue 7/15/08	Tue 7/15/08	
99		ROUGH-IN FIRE SPRINKLER	20 days	Mon 7/21/08	Fri 8/15/08	92
100		ROUGH-IN HVAC WET-SIDE L	20 days	Mon 7/21/08	Fri 8/15/08	87
101		ROLL UP GRILLS & DOORS L	5 days	Tue 7/22/08	Mon 7/28/08	
102		MECH. RM.#255- ROUGH-IN/S	10 days	Tue 7/22/08	Mon 8/4/08	
103		CLOSE UP INSPECTION 2/2 L	1 day	Tue 8/5/08	Tue 8/5/08	102
104		BLDG INSULATION L2	5 days	Fri 10/10/08	Thu 10/16/08	
105		FIRE PROOFING STEEL L3	5 days	Mon 6/16/08	Fri 6/20/08	
106		MEP RISERS L3	5 days	Thu 6/19/08	Wed 6/25/08	90
107		ROUGH-IN OVERHEAD DUCT	20 days	Tue 7/15/08	Mon 8/11/08	
108		INTERIOR FRAMING L3	15 days	Tue 7/29/08	Mon 8/18/08	101
109		HOLLOW METAL FRAMES IN	5 days	Tue 7/29/08	Mon 8/4/08	
110		ROUGH-IN AV/TELECOM/SEC	20 days	Tue 7/29/08	Mon 8/25/08	
111		ROUGH-IN ELECTRICAL/FIRE	20 days	Tue 7/29/08	Mon 8/25/08	
112		ROUGH-IN PLUMBING L3	20 days	Tue 7/29/08	Mon 8/25/08	
113		ROUGH-IN HVAC CONTROLS	20 days	Tue 7/29/08	Mon 8/25/08	
114		CLOSE UP INSPECTION 1/2 L	1 day	Tue 8/12/08	Tue 8/12/08	107
115		ROUGH-IN FIRE SPRINKLER	20 days	Mon 8/18/08	Fri 9/12/08	100
116		ROUGH-IN HVAC WET-SIDE L	20 days	Mon 8/18/08	Fri 9/12/08	99
117		ROLL UP GRILLS & DOORS L	5 days	Tue 8/19/08	Mon 8/25/08	108



Project: DETAILED SCHEDULE 2FIN/
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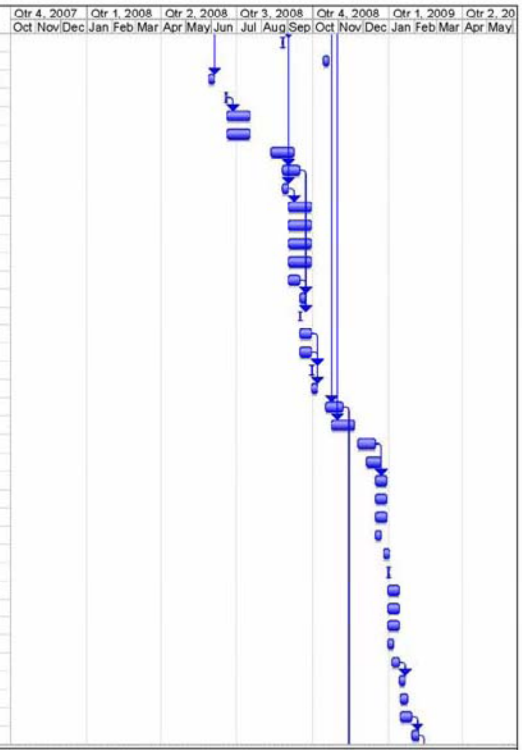
ID	Indicators	Task Name	Duration	Start	Finish	Predecessors
118		CLOSE UP INSPECTION 2/2 L	1 day	Tue 8/26/08	Tue 8/26/08	117
119	▦	BLDG INSULATION L3	5 days	Tue 10/14/08	Mon 10/20/08	
120		MEP RISERS L1	5 days	Thu 5/29/08	Wed 6/4/08	37
121	▦	FIRE PROOFING STEEL L1	2 days	Wed 6/18/08	Thu 6/19/08	
122		ROUGH-IN FIRE SPRINKLER	20 days	Fri 6/20/08	Thu 7/17/08	121
123	▦	ROUGH-IN HVAC WET-SIDE L	20 days	Fri 6/20/08	Thu 7/17/08	
124	▦	ROUGH-IN OVERHEAD DUCT	20 days	Tue 8/12/08	Mon 9/8/08	
125		INTERIOR FRAMING L1	15 days	Tue 8/26/08	Mon 9/15/08	113
126		HOLLOW METAL FRAMES IN	5 days	Tue 8/26/08	Mon 9/1/08	112
127		ROUGH-IN AV/TELECOM/SEC	20 days	Tue 9/2/08	Mon 9/29/08	126
128	▦	ROUGH-IN ELECTRICAL/FIRE	20 days	Tue 9/2/08	Mon 9/29/08	
129	▦	ROUGH-IN PLUMBING L1	20 days	Tue 9/2/08	Mon 9/29/08	
130	▦	ROUGH-IN HVAC CONTROLS	20 days	Tue 9/2/08	Mon 9/29/08	
131	▦	ELECT. RM#125- ROUGH-IN/S	10 days	Tue 9/2/08	Mon 9/15/08	
132		ROLL UP GRILLS & DOORS L	5 days	Tue 9/16/08	Mon 9/22/08	131
133		CLOSE UP INSPECTION 1/2 L	1 day	Tue 9/16/08	Tue 9/16/08	125
134	▦	ELECT. RM#126-ROUGH-IN/S	10 days	Tue 9/16/08	Mon 9/29/08	
135	▦	MECHANICAL ROOM #127 L1	10 days	Tue 9/16/08	Mon 9/29/08	
136		CLOSE UP INSPECTION 2/2 L	1 day	Tue 9/30/08	Tue 9/30/08	135
137		BLDG INSULATION L1	5 days	Tue 9/30/08	Mon 10/6/08	134
138		DRYWALL L2	15 days	Fri 10/17/08	Thu 11/6/08	104
139		TAPE & TEXTURE L2	20 days	Fri 10/24/08	Thu 11/20/08	69
140	▦	PAINT & WALL COVERING L2	15 days	Tue 11/25/08	Mon 12/15/08	
141	▦	CEILING GRID L2	12 days	Fri 12/5/08	Mon 12/22/08	
142		CERAMIC TILE RESTROOM #	10 days	Tue 12/16/08	Mon 12/29/08	140
143	▦	HVAC IN CEILING GRID L2	10 days	Tue 12/16/08	Mon 12/29/08	
144	▦	LIGHTING/DEVICES IN CEILIN	10 days	Tue 12/16/08	Mon 12/29/08	
145	▦	STAINLESS STEEL RAILS & M	5 days	Tue 12/16/08	Mon 12/22/08	
146	▦	PROJECTION SCREENS L2	5 days	Fri 12/26/08	Thu 1/1/09	
147	▦	MILLWORK RESTROOMS #25	2 days	Wed 12/31/08	Thu 1/1/09	
148	▦	HVAC TRIM & FINISH L2	10 days	Wed 12/31/08	Tue 1/13/09	
149	▦	ELECTRICAL TRIM & FINISH I	10 days	Wed 12/31/08	Tue 1/13/09	
150	▦	ACOUSTICAL TILE L2	10 days	Wed 12/31/08	Tue 1/13/09	
151	▦	WINDOW TREATMENT L2	5 days	Wed 12/31/08	Tue 1/6/09	
152	▦	PLUMBING TRIM RESTROOM	7 days	Mon 1/5/09	Tue 1/13/09	
153		TOILET PARTITIONS & ACCE	5 days	Wed 1/14/09	Tue 1/20/09	152
154	▦	INTERIOR GLASS & GLAZING	7 days	Thu 1/15/09	Fri 1/23/09	
155	▦	MILLWORK & CASEWORK L2	10 days	Thu 1/15/09	Wed 1/28/09	
156		CARPET L2	7 days	Thu 1/29/09	Fri 2/6/09	155



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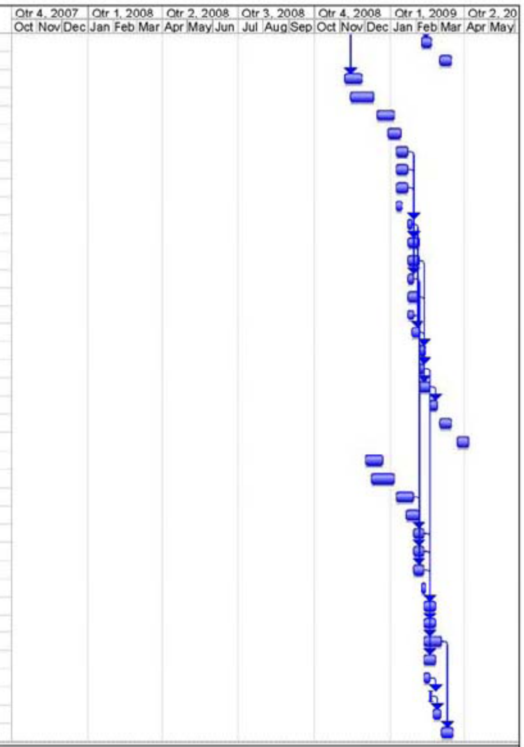
SENIOR THESIS FINAL REPORT
SANTA ROSA JUNIOR COLLEGE STUDENT CENTER

ID	Task Name	Duration	Start	Finish	Predecessors
157	INTERIOR DOORS & HARDW/	10 days	Mon 2/9/09	Fri 2/20/09	156
158	CLEAN & PUNCH L2	10 days	Tue 3/3/09	Mon 3/16/09	
159	DRYWALL L3	15 days	Fri 11/7/08	Thu 11/27/08	138
160	TAPE & TEXTURE L3	20 days	Fri 11/14/08	Thu 12/11/08	
161	PAINT & WALL COVERING L3	15 days	Tue 12/16/08	Mon 1/5/09	
162	CEILING GRID L3	12 days	Mon 12/29/08	Tue 1/13/09	
163	CERAMIC TILE RESTROOM #	10 days	Thu 1/8/09	Wed 1/21/09	
164	HVAC IN CEILING GRID L3	10 days	Thu 1/8/09	Wed 1/21/09	
165	LIGHTING/DEVICES IN CEILIN	10 days	Thu 1/8/09	Wed 1/21/09	
166	STAINLESS STEEL RAILS & M	5 days	Thu 1/8/09	Wed 1/14/09	
167	MILLWORK RESTROOMS #36	3 days	Thu 1/22/09	Mon 1/26/09	165
168	HVAC TRIM & FINISH	10 days	Thu 1/22/09	Wed 2/4/09	164
169	ELECTRICAL TRIM AND FINIS	10 days	Thu 1/22/09	Wed 2/4/09	
170	PROJECTION SCREENS L3	5 days	Thu 1/22/09	Wed 1/28/09	163
171	ACOUSTICAL TILE L3	10 days	Thu 1/22/09	Wed 2/4/09	
172	WINDOW TREATMENT L3	5 days	Thu 1/22/09	Wed 1/28/09	
173	PLUMBING TRIM RESTROOM	7 days	Tue 1/27/09	Wed 2/4/09	167
174	INTERIOR GLASS AND GLAZI	7 days	Thu 2/5/09	Fri 2/13/09	173
175	TOILET PARTITIONS AND AC	5 days	Thu 2/5/09	Wed 2/11/09	171
176	MILLWORK AND CASEWORK	10 days	Thu 2/5/09	Wed 2/18/09	169
177	CARPET L3	7 days	Thu 2/19/09	Fri 2/27/09	176
178	INTERIOR DOORS AND HARD	10 days	Tue 3/3/09	Mon 3/16/09	
179	CLEAN AND PUNCH L3	10 days	Tue 3/24/09	Mon 4/6/09	
180	DRYWALL L1	15 days	Tue 12/2/08	Mon 12/22/08	
181	TAPE AND TEXTURE L1	20 days	Tue 12/9/08	Mon 1/5/09	
182	PAINT AND WALL COVERING	15 days	Thu 1/8/09	Wed 1/28/09	
183	CEILING GRID L1	12 days	Tue 1/20/09	Wed 2/4/09	
184	CERAMIC TILE RESTROOM #	10 days	Thu 1/29/09	Wed 2/11/09	182
185	HVAC IN CEILING GRID L1	10 days	Thu 1/29/09	Wed 2/11/09	172
186	LIGHTING DEVICES IN CEILIN	10 days	Thu 1/29/09	Wed 2/11/09	170
187	PROJECTION SCREENS L1	5 days	Mon 2/9/09	Fri 2/13/09	
188	HVAC TRIM AND FINISH L1	10 days	Thu 2/12/09	Wed 2/25/09	186
189	ELECTRICAL TRIM AND FINIS	10 days	Thu 2/12/09	Wed 2/25/09	185
190	CERAMIC AND QUARRY TILE	15 days	Thu 2/12/09	Wed 3/4/09	184
191	ACOUSTICAL TILE L1	10 days	Thu 2/12/09	Wed 2/25/09	175
192	WINDOW TREATMENT L1	5 days	Thu 2/12/09	Wed 2/18/09	
193	MILLWORK RESTROOMS #13	2 days	Thu 2/19/09	Fri 2/20/09	192
194	PLUMBING TRIM RESTROOM	7 days	Mon 2/23/09	Tue 3/3/09	193
195	TOILET PARTITIONS AND AC	10 days	Thu 3/5/09	Wed 3/18/09	190



Project: DETAILED SCHEDULE 2FIN/
Date: Tue 10/27/09

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ID		Task Name	Duration	Start	Finish	Predecessors
196		INTERIOR GLASS AND GLAZI	5 days	Fri 3/6/09	Thu 3/12/09	
197		MILLWORK AND CASEWORK	3 days	Fri 3/6/09	Tue 3/10/09	
198		CARPET L1	7 days	Fri 3/20/09	Mon 3/30/09	
199		INTERIOR DOORS AND HARD	10 days	Tue 3/31/09	Mon 4/13/09	198
200		CLEAN AND PUNCH L1	10 days	Tue 4/21/09	Mon 5/4/09	

Project: DETAILED SCHEDULE 2FIN
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Task		Milestone		External Tasks	
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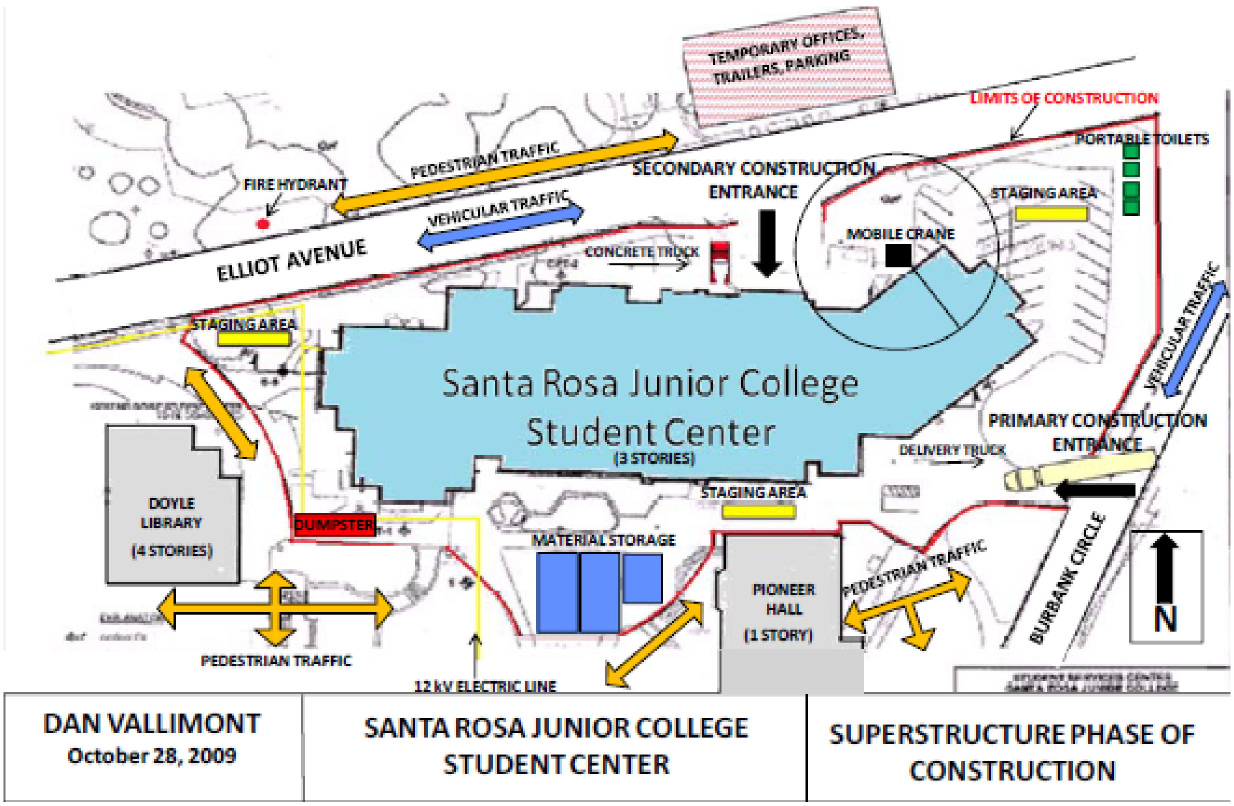
PROJECT BACKGROUND:

SITE LAYOUT PLANNING



The image below was taken during the phase of construction that is illustrated above by the site plan.

PROJECT BACKGROUND:

PROJECT COST EVALUATION

Actual Building Construction Cost (CC):

- $30,000,000 Bid Building Cost
- Roughly $450/SF ($30,000,000/66,646 sq ft)

Total Project Cost:

- $50,000,000 Bid Project Cost (total building cost)
- Roughly $750/SF ($50,000,000/66,646 sq ft)

Building Systems Costs: Cost and Cost/SF		
BUILDING SYSTEMS	**COST**	**COST/SF**
Concrete	$2,000,000	$30.01
Masonry	$5,500,000	$82.53
Structural	$3,500,000	$52.52
HVAC	$8,000,000	$120.04
Electrical/Data	$12,000,000	$180.06
Flooring Finishes	$1,000,000	$15.00
General Conditions	$1,000,000	$15.00

PROJECT BACKGROUND:

Detailed Structural Estimate

Detailed Structural Estimate Summary:

The estimate performed below was done using RS Means Costworks and represents the structural system estimate of the Santa Rosa Junior College Student Center. The estimate includes foundation, footings, Slabs, decking, and structural steel. Although a full takeoff for the structural steel would have been ideal, I was forced to resort to estimating a typical bay in the building which was repeated throughout the entire structure. The reason for this was due to time constraints and the complexity of the project. Upon asking the project estimator for advice on alternatives I was met with the response of:

> “We would never try to do a complete takeoff (going through the plans and counting everything) on a building the size of Bertolini. Especially with steel, the estimates are way too complicated for a general contractor to do accurately in house. You would need to figure in the number of bolted connections (cheaper) vs. welded, all of the miscellaneous bracing, stiffener plates, etc...plus adding up all of the beams, columns, and brace frames.”

Upon receiving this response I decided to go with the typical bay estimate method and then multiplied my findings out through the rest of the building. Although it is not as detailed as a full takeoff it is still a good representation of the structural estimate on the Bertolini Student Center at SRJC.

Cost Estimate Report
CostWorks
RSMeans

Assembly Detail Report

Year 2009

Date: 28-Oct-09

DETAILED STRUCTURAL ESTIMATE

Prepared By:
DAN VALLIMONT
psu

Assembly Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
10 Non-CSI							
10201241255	U		Concrete Reinforcement	40,000.00	L.F.	$0.00	$115,000.00
10 Non-CSI Subtotal							**$115,000.00**
A Substructure							
A10102102200			Spread footings, 3' - 0" square x 12" deep, 3 KSF soil bearing capacity, 25 K load	24.00	Ea.	$199.42	$4,786.08
A10102104800			Spread footings, 9' - 6" square x 24" deep, 3 KSF soil bearing capacity, 250 K load	15.00	Ea.	$2,364.57	$35,468.55
A10102105600			Spread footings, 12' - 0" square x 28" deep, 3 KSF soil bearing capacity, 400 K load	15.00	Ea.	$4,535.30	$68,029.50
A Substructure Subtotal							**$108,284.13**
B Shell							
B10102084600			Steel column, W10, 200 KIPS, 10' unsupported height, 45 PLF	1,200.00	V.L.F.	$108.94	$130,728.00
B10102085000			Steel column, W12, 200 KIPS, 20' unsupported height, 58 PLF	2,995.00	V.L.F.	$118.00	$353,410.00
B10102087000			Steel column, W12, 600 KIPS, 10' unsupported height, 120 PLF	1,130.00	V.L.F.	$271.54	$306,840.20
B10102251500			Floor - ceiling, concrete slab, 4000 PSI, reinforced, 7" thick, no columns	20,000.00	S.F.	$26.00	$520,000.00
B10102411600			W beam and girder, 20'x15' bay, 40 PSF superimposed load, 14" deep, fireproofing .659 SF/SF, 50 PSF total load	29,000.00	S.F.	$8.36	$242,440.00
B10102412650			W beam and girder, 20'x20' bay, 40 PSF superimposed load, 14" deep, fireproofing .746 SF/SF, 50 PSF total load	40,400.00	S.F.	$9.45	$381,780.00
B10102481200			Floor, concrete, slab form, open web bar joist @ 2' OC, on W beam, 15'x20' bay, 17" deep, 40 PSF superimposed load, 83 PSF total load	50,000.00	S.F.	$12.74	$637,000.00
B10102581170			Floor, metal deck, 18 ga, 3" deep, concrete slab, 11' span, 5.5" deep, 150 PSF superimposed load, 194 PSF total load	50,000.00	S.F.	$9.10	$455,000.00
B10201341250			Steel deck, cellular, single span, 14' span, 3" deep, 5 PSF, 30 PSF TL	30,000.00	S.F.	$18.56	$556,800.00
B20101082100			Concrete block (CMU) wall, 12" thick, slump	6,200.00	S.F.	$35.75	$221,650.00
B Shell Subtotal							**$3,805,648.20**

PROJECT BACKGROUND:

GENERAL CONDITIONS ESTIMATE

General Conditions Estimate Summary:

The Conditions Estimate was derived using RS Means Costworks. Going into this estimate I was given very limited data. I was given only an approximate value of the general conditions and a list of a few items that were included, but no specific information. The reason for this is that Midstate Construction considers general conditions to be a very sensitive area. A common belief at Midstate is that winning or losing bids is often a result of how general conditions and fees are priced. They also believe that making some of that information available to the public (through my thesis project) creates a risk that it may also become available to competitors in the market which puts very real jobs and very real money at stake. Due to this I formulated my estimate using all of the data that was available to me while also making some general project assumptions in some areas of the estimate. Having stated all of this, I believe that my estimate of the general conditions on the Santa Rosa Junior College Student Center is as good a representation of the actual estimate as I was able to develop with the information made available to me.

Unit Detail Report

Cost Estimate Report
CostWorks
RSMeans

Year 2009
Date: 26-Oct-09

gen conditions

Prepared By:
dennis walter
psu

LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 01 General Requirements							
013113200180			Field Personnel, project manager, minimum	102.00	Week	$2,550.00	$260,100.00
013113200260			Field Personnel, superintendent, average	102.00	Week	$2,750.00	$280,500.00
013113200265	U		Assistant Superintendent	102.00	week	$0.00	$230,000.00
014523500100			Field Testing, for building, costing $10,000,000, minimum	1.00	Project	$37,369.90	$37,369.90
015113200185	U		Construction lay-down areas	1.00	project	$0.00	$95,000.00
015113500140			Temporary electrical power equipment (pro-rated per job), underground feed, 3 uses, 600 amp	1.00	Ea.	$3,496.13	$3,496.13
015113500140	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$349.61	$349.61
015113500140	A		Contingencies, at conceptual design stage	1.00	Project	$699.23	$699.23
015113500560			Temporary electrical power equipment (pro-rated per job), temporary feeder cords, 100 amp, 3 uses, 100' long	1.00	Ea.	$616.46	$616.46
015113500560	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$61.65	$61.65
015113500560	A		Contingencies, at conceptual design stage	1.00	Project	$123.29	$123.29
015113800100			Temporary Heat, per week, 12 hours per day, incl. fuel and operation	700.00	CSF Flr	$36.84	$25,788.00
015113800100	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$3.68	$2,576.00
015113800100	A		Contingencies, at conceptual design stage	1.00	Project	$7.37	$5,159.00
015113800360			Temporary Power, lighting, incl. service lamps, wiring and outlets, max	700.00	CSF Flr	$48.12	$33,684.00
015113800360	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$4.81	$3,367.00
015113800360	A		Contingencies, at conceptual design stage	1.00	Project	$9.62	$6,734.00
015113800700			Temporary Utilities, temporary construction water bill per month, average	51.00	Month	$70.24	$3,582.24
015113800700	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$7.02	$358.02
015113800700	A		Contingencies, at conceptual design stage	1.00	Project	$14.05	$716.55
015213200020			Office Trailer, furnished, buy, 20' x 8', excl. hookups	2.00	Ea.	$10,583.83	$21,167.66

LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
01 521 3200020	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$1,058.38	$2,116.76
01 521 3200020	A		Contingencies, at conceptual design stage	1.00	Project	$2,116.77	$4,233.54
01 521 3201200			Storage Boxes, buy, 20' x 8'	5.00	Ea.	$6,026.11	$30,130.55
01 521 3201200	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$602.61	$3,013.05
01 521 3201200	A		Contingencies, at conceptual design stage	1.00	Project	$1,205.22	$6,026.10
01 521 3400120			Field Office Expense, office supplies, average	23.00	Month	$96.59	$2,221.57
01 521 3400120	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$9.66	$222.18
01 521 3400120	A		Contingencies, at conceptual design stage	1.00	Project	$19.32	$444.36
01 521 3400120	A		Contingencies, at conceptual design stage	1.00	Project	$19.32	$444.36
01 562 6500100			Temporary Fencing, chain link, 6' high, 11 ga	1,500.00	L.F.	$12.12	$18,180.00
01 562 6500100	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$1.21	$1,815.00
01 562 6500100	A		Contingencies, at conceptual design stage	1.00	Project	$2.42	$3,630.00
01 562 6500100	A		Contingencies, at conceptual design stage	1.00	Project	$2.42	$3,630.00
01 741 3200050			Cleaning Up, cleanup of floor area, continuous, per day, during construction	70.00	M.S.F.	$50.21	$3,514.70
01 741 3200050	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$5.02	$351.40
01 741 3200050	A		Contingencies, at conceptual design stage	1.00	Project	$10.04	$702.80
01 741 3200050	A		Contingencies, at conceptual design stage	1.00	Project	$10.04	$702.80
01 741 3200055	U		Progress Cleanup	70.00	day	$0.00	$300,000.00
01 741 3200100			Cleaning Up, cleanup of floor area, final by GC at end of job	70.00	M.S.F.	$104.24	$7,296.80
01 741 3200100	A		Contingencies, for estimate at preliminary working drawings stage (Design Development)	1.00	Project	$10.42	$729.40
01 741 3200100	A		Contingencies, at conceptual design stage	1.00	Project	$20.85	$1,459.50
01 741 3200100	A		Contingencies, at conceptual design stage	1.00	Project	$20.85	$1,459.50
Division 01 Subtotal							**$1,403,773.11**

PROJECT BACKGROUND:

BUILDING SYSTEMS SUMMARY

YES/NO	SCOPE OF WORK (IF YES, ADDRESS)
YES	**Demolition Requirements** Demolition of the pre-existing structure was done under a separate bid. Demolition was considered phase one of the project while phase two encompasses construction.
YES	**Structural Steel Frame** The structural system used for the Santa Rosa Junior College Student Center is structural steel. The floor system that is utilized is a 3 ¼" lightweight concrete on 3" 18 gauge composite decking. The final floor thickness is 6 ¼". The typical reinforcement for the decking is #3 rebar at 18" on center. The roof system is made up of 1 ½", 16 gauge decking on steel beams. Flexible flashing underneath concrete tile covers the steel decking on the roof. Typical exterior columns used are W12x50 and W12x40 members. Typical interior columns used throughout the project are W12x58, W12x53, and W12x40. The braced frame on the Student Center is supported mainly by diagonal W10x68 beams connected to structural beams and columns by gusset plates ranging from 1" to 1 ¼" in size.
YES	**Cast in Place Concrete** As far as cast in place concrete utilized on the Student Center project, the foundation, slab on grade, and concrete fill on metal decking comprise the majority of it. The slab on grade is 5" thick with a vapor barrier, 4" rock course, and 6" of select fill below. Reinforcing for the SOG is comprised of #4 rebar at 12" on center at mid-depth along with staggered 30" lap bars. The 18 gauge 3"decking on the second and third floors uses 3 ¼" concrete with #3 rebar at 18" on center. Shear studs are used to tie the concrete into the metal decking and structural steel. Concrete footings range in size from 3x3 to 10.5x10.5 and are located at depths ranging from 1.5 to 2.5 feet below grade comprising the foundation of the center.
YES	**Precast Concrete** The precast concrete used on the project is architectural in function and creates an elegant and institutional look to the façade of the building. The precast concrete is light in color and complements the red brick on the façade nicely. The concrete is located all around the building at window heads and sills, and also several accent bands that wrap the building. The concrete along with the brick masonry on the façade of the building are tied into the structure through a connection to metal stud framing.
YES	**Mechanical System**

	The mechanical system for the Student Center is a geothermal heat pump loop with 8" geothermal vault mains (860GMP @ peak load), 5 geothermal circuit loops, and 150 geothermal bore loops making up the system. The geothermal system was installed according to IGSHPA and ASHRAE standards and recommendations. Coordination with the landscape architect and civil drawings is used for irrigation and utilities (existing and new). Extra care is also taken when selecting bore drilling locations as to preserve existing trees on campus. The main mechanical room is 376 SF and is located on the first floor of the center. Each room is served by its own geothermal water source heat pump which range in air flow values from 180 to 2260 CFM. Cooling capacities of these heat pumps also have a wide range of 3.5 to 61.5 MBH. A 15,000 pound energy recovery unit is located on the second floor of the building. The unit, which sits atop a 6" concrete pad, has a designed 26,000 CFM supply plan along with a 24,500 CFM exhaust fan. The recovery unit runs at 3 phase power and 460 volts. Two special fans are required in the kitchen/servery areas as exhaust hoods. The units are a combination of fans and grease filtration, which meet exhaust requirements for the kitchen and servery areas of the building on the first floor. Two other fans are used in the kitchen area to provide makeup air. Fans are also located in restrooms, janitor spaces, and the AV room. Fire Alarm System: The fire alarm system is an addressable, non-coded, manual initiating system with supplemental detectors for door holders, fire/smoke dampers, and HVAC shut-down. The devices consist of addressable initiating devices and non-addressable notification appliances. The stand-alone system is supervised by a California state approved supervision station. The next nearest building is over 25 feet away and therefore the center is allowed to have a stand-alone system according to code.
YES	**Electrical System** The Santa Rosa Junior College Student Center gets its power from the 12 kV campus main power service. The power is stepped down from 12kV to 480/277V (power at which the main switchboard runs at) before being stepped down further to 208/120V to be distributed throughout the building by 6 local transformers. The power is further distributed throughout the center by 24 panel boards. The main switchboard is located in the main electrical room on the northeast side of the buildings first floor. Smaller electrical rooms are located on the second and third floors. Along with the electrical rooms, there are also telecommunication rooms on each floor of the building. A 125kW emergency backup generator is located directly outside of the building

	in the service yard (northeast part of site). The generator is diesel powered with NEMA 3R base day tank and NEMA 3R sound attenuated housing mounted on a 6" high, 55x123 inch concrete pad. The 12kV transformer, a fire pump with integral automatic transfer switch, booster pump and cooling tower with control panel are also located in the service yard. The 63 types of lighting used in the building run at 277V. Dimmable lighting is a available in the leadership center and also in multiple meeting rooms. Rooms with dimmable fluorescent lights must have a LUTRON, HI-LUME or ECO HI-10 dimming ballast rated at 277V. Interior lighting systems on each floor have separate automatic shut-off controls. Rooms larger than 100SF and greater than .8 watts per SF of lighting are controlled with bi-level switching for uniform light reduction.
YES	**Masonry** The masonry walls in the Student Center on non-load bearing. The façade of the buildings is comprised mainly of anchored brick veneer that is reddish in color. The bricks are installed over gypsum sheathing and cold-formed metal stud framing, or over CMU or cast in place concrete. Construction conforms to the Masonry Institute of America (MIA) standards. Horizontal reinforcement is provided at 16" on center. In the first joint below top of walls joint reinforcement is continuous. Anchors or ties are located every 16 inches on center horizontally and every 12 inches on center vertically. Self sealing membrane is installed under each anchor, accept ones at concrete level. Along with the elegant image that the brick veneer façade creates, there is also a fair amount of brick pavers used around the building serving as walkways.
YES	**Curtain Wall** The curtain wall system used on this project is most evident at the main entrance where a giant glass entrance way welcomes students and faculty into the Student Center. The three story framed glazing is held in place horizontally by W24 beams and vertically by HSS 10x3x3/8. Other than at the main entrance there is no other significant use of a curtain wall system on this project.
NO	**Support of Excavation** Excavation below grade on this project is held to a minimum. The footings on the project are located only a few feet below grade and therefore support for the needed footing excavation is not needed. If need be, step backs could be used for foundation construction instead of an actual support system.

THESIS THEMES

For this thesis project I will focus on four different areas in an attempt to reduce excess costs and eliminate schedule delays while providing a building that meets or surpasses the owner's standard of quality. The four areas that I will focus on are as follows: The incorporation of a renewable energy system; the use of an alternative façade design; the use of an alternative steel erection process; and finally the use of an alternative precast concrete prefabrication process.

Building Integrated Renewable Energy System

With energy costs continually on the rise, taking advantage of new building integrated renewable energy systems seems like a great solution. In the case of the SRJC student center it makes even more sense since the project is located in a geographic region that receives a large amount of sun annually. Although it would require a steep upfront cost, utilizing some form of renewable energy system would surely benefit the owner with its long term payback.

Alternative Façade Design

Construction of the brick façade proved to be a challenging task due to the fact that the brick supports were attached to metal studs as well as steel members in order to tie the façade into the structure. Having two types of connections caused confusion during construction. Also, the connections of the prefabricated supports to structural steel were very difficult to weld to acceptable tolerances, causing much time and money to be wasted. I believe that the utilizing a single type of support connection involving no prefabricated elements would result in quicker installation while meeting required tolerances.

Alternative Steel Erection Process

The steel erection process used for the student center resulted in nearly three months of delays that resulted in excess spending. A single mobile crane, forklift, and connection crew were used to complete the entire steel frame of the building, resulting in the need for a 72 day deadline extension. I believe that the use of multiple cranes and crews would have resulted in the structural frame being completed on time without a negative cost impact.

Alternative Prefabrication Process

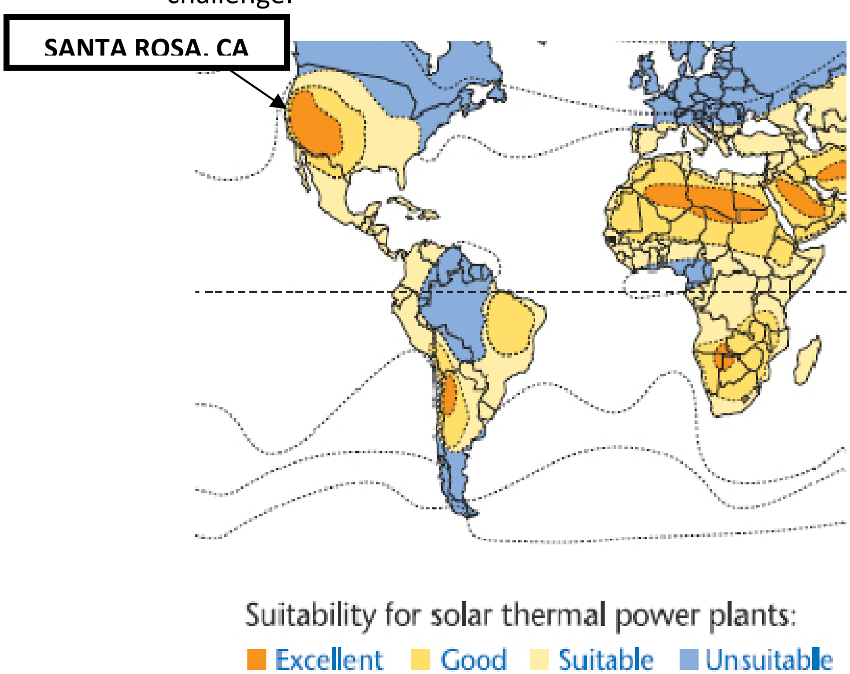
The design-build prefabrication process used for the architectural panels on the student center resulted in incorrectly sized members due to the fact that exact field measurements were never able to be taken. I believe that the use of an alternative option such as design-assist would have resulted in a more efficient process that would lead to simplified installation and furthermore reduced cost and schedule impacts.

BUILDING INTEGRATED RENEWABLE ENERGY SYSTEM

Problem:

Recent issues with energy overconsumption and diminishing resources have caused many people to think differently about how they access and use energy. This crisis has caused the price of energy to go up all over the world. The construction industry is one of many areas that have been affected by this issue that is growing every day. Increased costs of energy, increased greenhouse gasses, and depletion of oil supply are only a few of the numerous negative aspects relating to this issue. This energy problem has caused many people to look into the use of alternative forms of energy as a remedy. The only problem associated with the use of alternative energy sources is that these new technologies are often very expensive which deters many potential buyers who are unwilling to pay the upfront cost or are unaware of the long term potential benefits.

Although the SRJC student center incorporates a geothermal loop, it fails to make use of the increased amount of sunlight that is very common to California. The use of building integrated renewable energy could be very beneficial to the structure, the only problem being that the owner does not wish to sacrifice the architecture of the building. Finding a way to incorporate renewable energy while meeting the owner's standard of approval for the architecture of the project poses a challenge.



Goal:

The goal of this research is to develop a plan that would that would implement building integrated renewable energy technology as a means of reducing overall energy costs for the owner. This research will focus on the implementation of distributed production (using energy where you create it) as it is related to solar thermal technology and the use of absorption chillers and solar cooling, as the SRJC student center is located in a prime geographic location to benefit from the use of this technology.

Analysis Steps:

This analysis focus on the replacement of the geothermal loop that is currently used to provide all of the space heating and cooling for the SRJC Student Center with a system involving the use of a large solar array on the roof of the building in combination with an absorption chiller. This system could potentially save a lot of money while simultaneously providing a reliable renewable energy source for the building. The building demand of 290 Tons of space heating/cooling is met by the geothermal loop and therefore the next step is to perform an in depth analysis to see what kind of savings may be attainable by using this system comprised of solar panels and absorption chillers.

Absorption Chillers:

Absorption refrigeration systems serve as substitute for the commonly used compression energy refrigeration systems which use electric power as an energy source. Instead of using electric power, absorption chillers use heat as the energy system. Absorption chillers have been around for a long time but have just recently began to gain popularity. The first absorption system ever made was developed in France by Ferdinand De Carre' in 1890 but it was not heavily used. The most popular form of domestic refrigeration of the time relied on energy that was generated by small kerosene or gas burners. It was not until the 1950's that compression systems became more popular due to the cheap electric power that was available. Absorption chillers have been gaining popularity slowly since the oil crisis of the 1970's and have become a very common alternative considering our current energy crisis. The switch to absorption refrigeration can be seen best in Japan where nearly 70 percent of its large refrigeration needs are met through the use of absorption chillers. The benefits of absorption refrigeration have helped it to gain popularity and increased use worldwide. The diagram on the following page gives a quick summary of how an absorption chiller system operates. The diagram was taken off of a page from the Thermax's product catalog. Thermax is a company that produces a number of eco-friendly products, including absorption chillers.

OPERATING PRINCIPLE

Basic Principle :

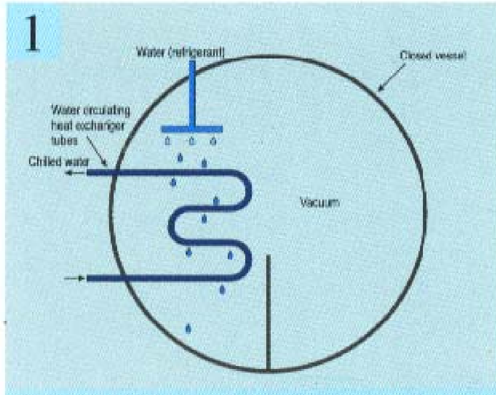
Boiling point of water is a function of pressure. At atmospheric pressure, it boils at 100°C. At lower pressure water boils at lower temperature. The boiling point of water at 6 mm of mercury absolute, is only 3.7°C.

Lithium Bromide (LiBr) salt has the property to absorb water due to its chemical affinity. It is soluble in water. As the concentration of LiBr increases, its affinity towards water increases. Also as the temperature of LiBr increases the affinity decreases.

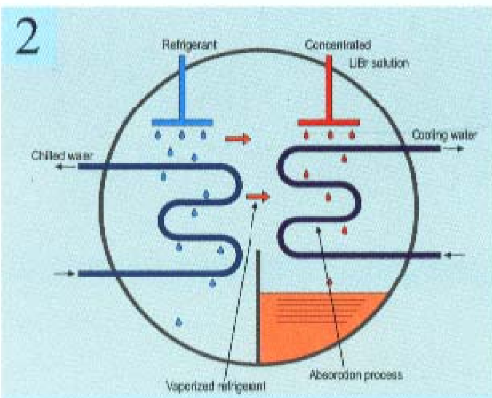
There is a large difference between vapour pressure of LiBr and water.

Operating Principle :

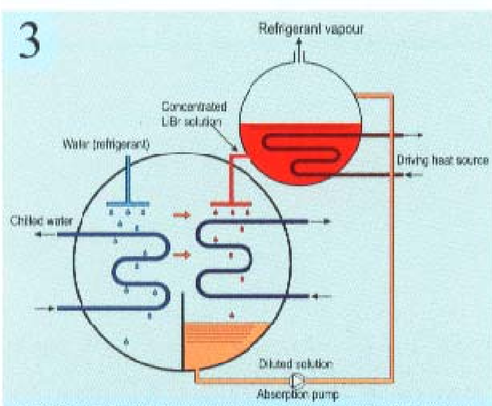
The vapour absorption chiller produces chilled water upto 4.5°C, utilizing steam as the driving source. The absorption chiller utilizes the latent heat released by the refrigerant (water) as it evaporates (in a closed pressure vessel) for cooling. Unlike a compression chiller which uses a compressor to pressurize the vapourized refrigerant (Freon) and condenses it by using cooling water, the absorption chiller uses an absorbent (LiBr) to absorb the vapourized refrigerant (water). The refrigerant is then released from the absorbent when heated by an external source.



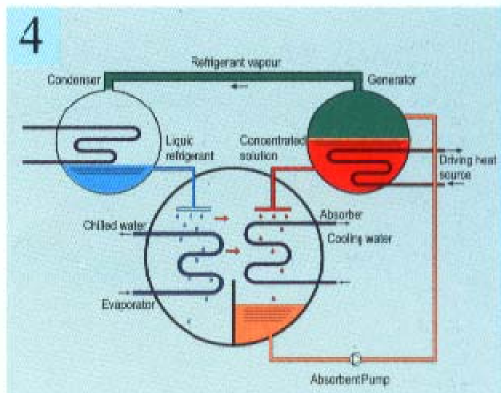
When maintained at high vacuum, water will boil and flash cool itself.



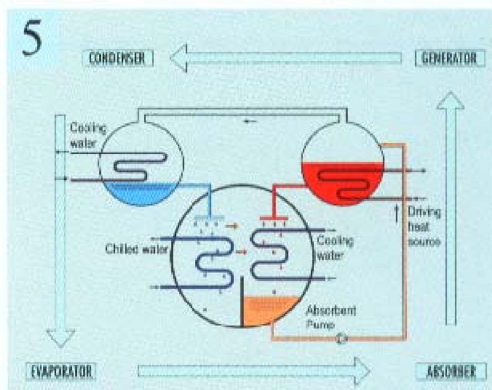
Concentrated Lithium Bromide solution has affinity towards water. The solution absorbs vapourised refrigerant water.



As Lithium Bromide becomes dilute it loses its capacity to absorb water vapour. It thus needs to be reconcentrated using a heat source.



This heat causes the solution to release the absorbed refrigerant in the form of vapour. This vapour is cooled in a separate chamber to become liquid refrigerant.



The basic operation cycle of the single effect vapour absorption chiller.

Selection of an Absorption Chiller

- The chiller required for the SRJC Student Center must be able to meet the 290 Ton heating/cooling demand.

(290 Tons)(12,000BTU/hr) = **3,480,000 BTU/hr**

(3,480,000 BTU/hr)(.29307107w/BTU/hr) = 1,019,887 watts = **1019.9 kW**

- Upon consulting the Thermax absorption chiller catalog I was able to find a chiller to meet the building demands.
- The "Prochill" absorption chiller by Thermax comes in single and double effect models, can supply a range of 50-1400 Tons, and can reach a chilled water temperature of 4.5 degrees.
- The model that is able to meet the SRJC's heating/cooling demands is two "Prochill" A-150 Single Effect Absorption chillers.
  - It is wise to use two smaller chillers as opposed to one bigger one in this type of system. The reason for this is that you must be aware of the low load conditions of the building and must make sure that the chillers are able to unload to that minimum load. Larger chillers are not designed to unload to low loads.
  - Maximum Capacity available =2 Chillers providing 150 Tons each (290 Tons required) *To see the entire list of technical specifications for this model, please refer to the Thermax Catalog information in the appendix at the end of this report.

Solar Analysis:

Santa Rosa, CA is located at 38.44 degrees latitude and -122.78 degrees longitude. Solar systems located in this area can expect a solar exposure value of 5.45 for each kW installed. Solar exposure is measured in kWh/m^2/day.

Annual Yield Calculations

- 1 BTU/hr = .29307107 watts
- 1 Ton = Amount of heat needed to melt 1 Ton of ice in 24 hours
- 1 Ton can remove 12,000 BTUs in 1 hour
- 1 Ton = 12,000 BTU/hr
- 1 kW = 3,413 BTU
- 3 Assumptions:
  1. Inverter inefficiency factor = .95
  2. Factor of soiling, module, and utility inefficiencies = .95

3. Weather impact on inefficiency = .89

- 5.45 Solar Exposure for each kW installed

(365 days/year)(5.45 Solar Exposure)(.95)(.95)(.89) = **1,597 kWh/kW installed**

- California average retail cost of electricity = .14$/kWh

(1,597 kWh/kW installed)(.14$/kWh) = **$223.33 Annually**

- Space heating and cooling demand for entire building = 290 Tons

(290 Tons)(12,000BTU/hr/Ton) = **3,480,000 BTU/hr**

(3,480,000 BTU/hr)(.29307107w/BTU/hr)(1kW/1000w) = **1019.89 kW**

- Total annual demand for building in kWh

(1019.89 kW)(1597 kWh/kW installed in Santa Rosa, CA) = **1,628,764.33 kWh yearly**

- Total current annual savings from geothermal loop

(.14$/kWh)(1,628,764.33 kWh yearly) = **$226,398.24 Annually**

Solar Collector Module Analysis

In order to gather energy to feed the proposed absorption chiller system, a large solar array will be required on the roof of the student center. The following equations will determine how much solar panel area is required to meet the building's annual demand of 290 Tons of heating and cooling. Upon determining the required surface area of panels I will then move into the process of redesigning the architecture of the roof in a way that would provide the flat surface required for the panels.

*All information related to solar panels comes from catalog information from Sunda, a large company based out of China who produces many high quality solar products. This information can be found in the appendix of this report.

The specific model of collector that is being looked into is the "Seido 1/5 – 16AS" produced by Sunda. This product is more specifically referred to as a Heat Pipe Vacuum Collector and is commonly used in systems such as the one which was proposed.

Solar Panel Specifics: Seido 1/5 – 16AS

Dimensions	2232x1940x187mm
Gross Collector Area per unit	$4.33m^2$
Net Absorber Area per unit	$2.77m^2$
Weight per unit	100 kg
Inclination Angles Available	15-35 Degrees
Number of Heat Tubes per unit	16 Tubes
Cost per unit (sustainablefuture.biz)	$1,740 per module

- Total Collector Area Required

$(1m^2/1597$ kWh per kW)(1,628,764.33 kWh/year)(1 year) = **$1,019.89m^2$ needed**

- Total Number of Modules Required

$(1,019.89m^2$ needed)(1 module/$2.77m^2$) **=368.19**

=369 Modules Required to Generate All Space Heating and Cooling

- Total Roof Area Needed for Array
  - Exact Area

$(4.33m^2$/module)(369 modules) = $1,597.77m^2$

$(1,597.77m^2)(10.7639$ SF/m^2) = **17,198.24 SF of Space Required**

  - Conservative Area
    - Upon looking into an absorption chiller system installed by Southland Industries I was able to come up with a more conservative surface area. This takes into account that the modules can not fit perfectly together.
    - Southland Industries absorption chiller system utilized a 330 module (Seido 1/5 – 16AS) solar array which took up 18,000 SF

(18,000 SF needed/330 Modules) = 54.545 SF per module

(54.545 SF/Module)(369 Modules) = **20,127.27 SF of Space Required**

Exact Area = 17,198.24 SF

Conservative Area = 20,127.27 SF

*For the remainder of the analysis the conservative area will be used.

- Total Weight of Proposed Solar Array

(369 modules)(100kg/module)(2.2046lb/kg) = **81,349.74 lb of Added Load to Roof**

- Total Cost of Solar Panels

(369 Modules)($1740/module) **= $642,000 for Panels**

- **Solar Panel Conclusions:**
    - Need 369 Seido 1 – 16 Modules at (Inclination of 15 degrees)
    - Need 20,128 SF of space on roof of student center
    - Need to withstand an additional 81,349.74lb of loading
    - Cost of required panels is $642,000

Breadth Topic 1: Architecture

Roof Architecture Redesign Analysis

Now that the absorption chiller has been chosen and the area of solar panels required has been determined, the next step in this analysis is to find a way to flatten areas of the roof so that solar panels can be placed. The problem with redesigning the roof too much is that the owner is very intent on their style of architecture and does not want to "ruin" the building with an ugly solar array. To get around this, I have assumed that I was able to convince that owner that I could flatten the roof of the student center out in certain areas for solar panels while concealing the array with a parapet. I believe that this is a fair assumption considering that another building on the SRJC campus, the new library, uses this method to hide a solar array. This library is directly next to the student center and has the same architectural style.

The above images show the library (circled in yellow) and its solar array located directly next to the student center during construction.

From aerial views it is easy to see the vast solar array on the top of the library. From ground level the solar panels can't be seen at all by the common passerby (see image below). The architectural appeal of the building remains intact and the owner is kept happy. In this part of the analysis I will mimic the technique used on the library to hide the proposed solar array on the roof of the student center. This will require lowering the roof in several locations and flattening it out to provide space for the solar panels.

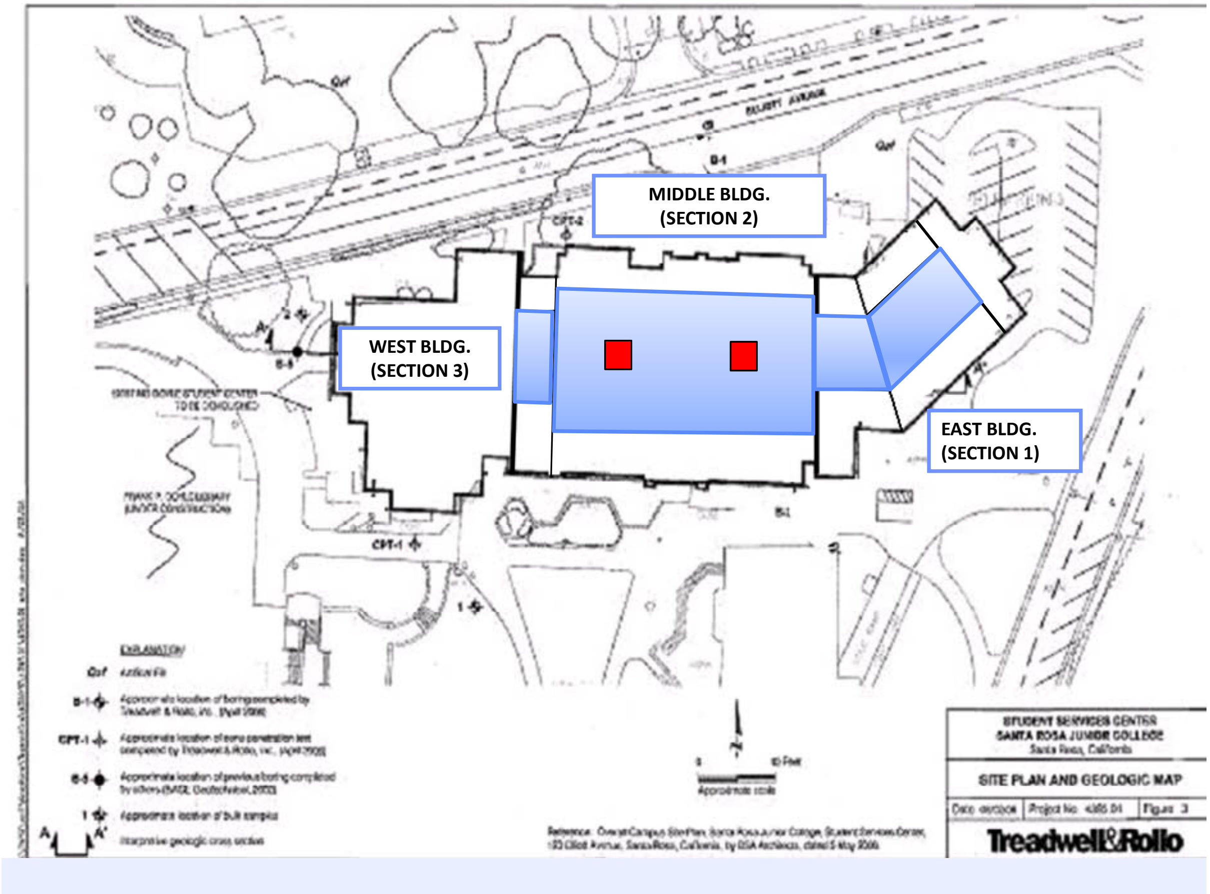
Redesign of Student Center Roof:

The attic of the SRJC Student Center is very spacious and currently has a lot of extra space. This space, although convenient for mechanical workers performing maintenance jobs, is not absolutely necessary. Flattening the top of the roof would cut down on the open work space in the attic, but would still allow enough room for maintenance.

In order to meet the 290 Ton heating/cooling demand of the student center 20,128 SF of roof space must be leveled out for the application of the solar array. Although it has been assumed that the owner will allow this to be done, it must be noted that the West section of the building can not be altered due to the fact that it houses the student dining area which features a vaulted ceiling. This architectural feature is a key component of the building and can therefore not be altered in any way. Therefore, the roof architecture may only be altered in the Center and East Sections.

Upon analyzing the construction drawings I was able to conclude that I would be able to flatten the roof by lowering it in two different areas. On the east side of the building (Section 1) I was able to lower the peak of the roof 8 feet without interfering with any mechanical equipment. On the center section (Section 2) of the student center I was also able to lower the roof 8 feet without any problems with the exception of two 9x13 foot elevator shafts that could not be altered. The middle section of the building's roof is higher than the east or west roof height. That being said I could have lowered it a little more but to keep the height relationship between different levels of the roof I decided to stick with the same 8 feet as used on the east. The following information will explain this in more detail.

The diagram below, while not drawn to scale, gives a very good idea of the areas that I would be able lower and flatten to make room for solar panels. The areas that are shaded in **blue** represent the flattened areas on the east and center sections of the building. The **red** areas indicate the two elevator shafts that can not be altered in any way. The west part of the building remains untouched due to the vaulted ceiling in the café.



Solar Panel Area Analysis:

Through hand measurements and calculations obtained by analyzing the construction documents I was able to determine a very good estimate of attainable roof area for solar panel placement. After determining that the roof could be lowered 8 feet without interfering with any mechanical equipment my next step was to determine how much flat space could be attained by analyzing the slope of the roof and using simple trigonometry along with hand measurements. Through that analysis I was able to determine that have an available width of 40 feet of flat space on the center section of the building, and 26 feet of width on the lower roof sections. By looking at the plans and measuring the corresponding lengths of available space I was then able to multiply the results together to find out surface areas.

- East (Section 1) = 1248 SF of flat space
- Center (Section 2)= (5640 SF)-(2 elevator shafts)(9x13 ft) = 5406 SF

- Total flat surface area available for solar panels:

(1248 SF)+(5640 SF) = **7,476 SF of Flat Surface Area Available**

7,476 << 20,128 SF needed to support the entire system

Through these findings I have concluded that it makes more sense to stick with the geothermal system that was originally used. The geothermal system is very reliable and has a very similar cost to the system that I proposed. In this case the geothermal loops benefits outweigh the costs of an absorption chiller system powered by solar panels.

Breadth Topic 2: Electrical

Having determined that over 7,000 SF of space on the roof can be leveled out for solar panels, my next step is to determine what kind of electrical gains can be attained through the use of solar panels on the roof. Since the heating and cooling loads are taken care of completely by the geothermal loop it makes sense to use the available space on the roof for solar energy in the form of electricity in the student center which could be used for many different things such as computers and lights for example.

How Solar Panels Create Electricity

Solar energy is the ultimate example of renewable energy here on earth. Using the suns energy and converting it directly to electricity through the use of photovoltaic cells allows us to gather energy while not depleting any of the earth's natural resources.

Photovoltaic Cells, also known as PV or solar panels, have been around for roughly 30 years and were initially developed for the space program. Due to the recent rises in energy costs people have began turning heavily towards the use of solar panels to gather energy. The process behind converting the sun's energy into useable electricity begins when the sun's rays strike the PV cell. When this occurs a chemical reaction occurs which releases electrons and thus generates electric current. The small amount of current generated by a single cell is multiplied out according to how many cells are in the solar panel module and even further by how many modules are included in the entire solar array. The generated electricity can be used to power individual homes, large commercial buildings, or can be sent back into a local electrical grid. The diagram below gives a basic idea of how the process of converting sunlight to electricity works.

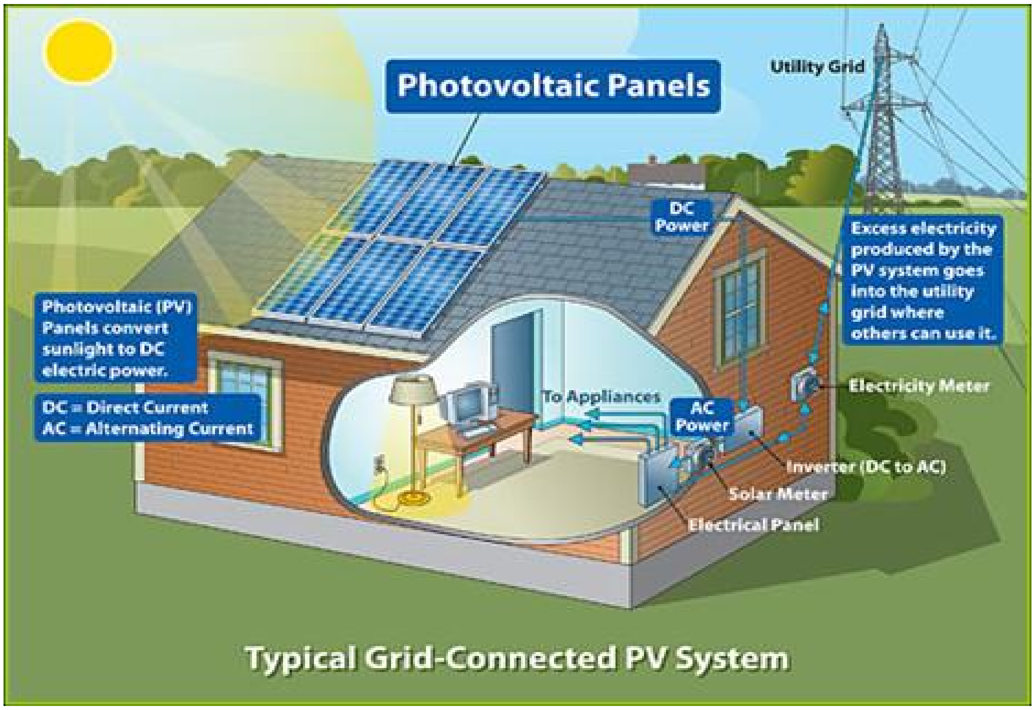


Image from nufranc.com

Environmental Impacts of PV Generated Electricity

Along with being an excellent source of renewable energy, PV technology also offers environmental impacts. Solar panels operate without producing any kind of waste emissions in the forms of air, water, and solid wastes. The fact that there are no emissions makes this a clean energy that will have no negative impact on the surrounding environment. Also, the fact that most solar arrays are incorporated into the structure of the building reduces negative impacts on land. The only negative about PV cells related to the environment comes in the form of minute amounts of hazardous materials that are involved in the manufacturing process of the cells. Appropriate handling and care of the hazardous materials helps to reduce any risk of exposure to humans and the environment.

Available Solar Energy Analysis

Through earlier analysis I was able to determine that 369 solar panels would be needed to meet the 290 ton heating/cooling demand of the SRJC student center. These panels required over 20,000 SF of flat surface area to be placed. Upon completing my architectural analysis I found that only 7,476 SF would be available for this solar array. Originally my plan was to determine structural impacts of the additional dead load due to the solar panels, but after realizing that the added load was very small and would have virtually no impacts I have decided to carry out this electrical analysis to determine how much electricity is attainable through use of a 7,476, SF solar array. The following calculations will further describe this analysis.

Recap of Information Previously Mentioned

- Average Retail Cost of Electricity in California = $.139/kWh
- Santa Rosa, CA Solar Exposure = 5.45 kWh/m^2/day
- Annual Yield = 1,597 kWh/kW installed
  - (365d)(5.45 exposure)(.85)(.95)(.95) = 1,597 kWh/kW installed
  - Assumed Adjustment Factors
    - .85 for weather impact on efficiency
    - .95 for inverter inefficiency
    - .95 factor of soiling, module, utility inefficiencies
- Panel Model = “Seido 1 – 16” by Sunda installed at optimal inclination 15 degrees
  - 1 module
    - Cost = $1,740/module
    - Weight = 100kg/module
    - Collector Area = 2.77m^2/module = 29.82 SF/module
    - Module Area = 4.33m^2/module = 46.61 SF/module
- Total Space Available = 7,476 SF
- Space Required per Module = 54.545 SF/module

Newly Calculated Electrical Analysis Data

These calculations are performed assuming that the owner has decided to go ahead with flattening out the roof in the previously mentioned areas, giving 7,476 SF of space to install a solar array that will provide electricity to the student center.

- Number of Modules Available

(7,476 SF available)(1 module/54.545 SF) = 137.06

=137 Modules Available

- Total Collector Space

(137 modules)(2.77m^2/module) = 379.49

=379.49 m^2 of Collection Area

- Total Annual Electric Yield Attainable

(1597 kWh yearly/m^2 of collection area)(379.49 m^2 of collection area) = 606,045.53

=606,045.53 kWh Annually

- Total Electricity Savings Attainable Annually

(606,045.53 kWh/ 1 year)($.139/ kWh) = $82,240.32

= $82,240.32 of Savings Annually

- Total Weight of System

(137 modules)(100kg/module)(2.2046lb/kg) = 30,203.02 lb

=30,203.02 lb

30,203.02 lb/7,476 SF = 4.03psf

=4.03 PSF of Added Dead Load to Roof

- Total Cost of Panels

(137 modules)($1,740/module) = $238,380

=$238,380 for Solar Panel Array

- Payback Period

($238,380 initial cost)(1 year/ $82,240.32 savings) = 2.9

= 2.9 Years to Payback Initial Cost of Array

Through this electrical analysis I have found that utilizing the 7,476 SF of attainable flat space on the roof for a 137 module solar array would require a $238,000 upfront cost and would be capable of generating up to 606,045 kWh of electricity annually resulting in $82,240.32 of electric savings at the average California retail cost of electricity of $.139 per kWh. The upfront cost may act as a deterrent at first but after a short payback period of less than 3 years the system will be generating over $82,000 worth of electricity annually. This electricity could be used to power items including but not limited to lighting, televisions, and the many computers located throughout the building in labs and offices.

Possible Savings Attainable Through Lifetime

The table below represents the savings that could be attainable for the proposed solar-electric system with the following 3 assumptions.

1. Payback period of system is 3 years
2. Average lifetime of a solar panel is 50 years
3. Most solar-electric systems installed today come with a 20-25 year warranty

*Assumptions 2 and 3 are based off of information obtained from solarcreek.org

Saving After 'X' Years	('X' years – 3 year payback)($82,240/yr)	Total Savings
5 Year Savings	(5-3)($82,240)	$164,480
10 Year Savings	(10-3)($82,240)	$575,680
20 Year Savings	(20-3)($82,240)	$1,398,080
25 Year Savings	(25-3)($82,240)	$1,809,280
50 Year Savings	(50-3)($82,240)	$3,865,280

Overall Summary

- The geothermal loop used with the SRJC student center project provides all space heating and cooling for the entire building (290 Tons). The cost of the geothermal ground exchanger system alone is roughly $1.5 million dollars (Entire mechanical system including geothermal loop is roughly $5 million dollars.)
- The proposed Absorption Chiller System requires 20,127.27 SF of flat space on the roof that is concealed from ground level visibility to meet the 290 Ton output of the geothermal loop.
- The proposed Absorption Chiller System (chillers and solar panels) would cost roughly $4 million dollars (This would make the entire mechanical system including the chillers and solar cost nearly $7.5 million dollars).
- The decision to flatten the roof in allowable areas (due to large amounts of unused attic space) using the same parapet technique that can be observed on the Doyle Library next door to the student center resulted in 7,476 SF of useable area.
- A solar array of 137 modules can fit in the allowable space and can generate roughly 606,045 kWh of electricity which is equal to $82,240 of annual savings according to the average retail cost of electricity in CA of $.139/kWh.

Conclusions and Recommendation:

Based upon the information presented above for this analysis it would seem that the integration of an absorption chiller system as an alternative to the current geothermal loop would not be a worthwhile alternative. One reason for this is that it is simply not possible to generate enough solar energy on the roof of the building to meet let alone surpass the output of the geothermal loop. The geothermal ground exchanger system successfully supplies the 290 Ton space heating and cooling load for the entire student center and offers the benefit of being a maintenance free system. It is basically as simple as burying pipes in the ground. The absorption chiller system requires over 20,000 SF of flat space on the roof to meet the output of the geothermal loop. Upon redesigning the architecture of building by lowering the roof and creating a parapet wall exactly like what was done on the neighboring Doyle Library I was only able to obtain 7,476 SF of concealed flat space on the roof. This alone is enough to make me conclude that the geothermal loop is the best method to provide space heating and cooling. But, even if I were still unsure about which system would be better, the upfront costs of the two systems erased those doubts. The absorption chiller system that would be required to provide the same heating and cooling as the geothermal loop would cost roughly $4,000,000 for the absorption chillers and panels and is fairly maintenance intensive when compared to zero maintenance of the geothermal loop. The geothermal ground exchanger system had a much lower cost of only $1,500,000. These two reasons made it clear to me that the geothermal loop should remain in place.

Having concluded that the absorption chiller system was not a good alternative to the geothermal loop I decided to focus on the 7,476 SF of available solar panel space on the roof in an effort to generate energy in the form of electricity that could be used throughout the student center to power miscellaneous electronics such as lights and computers. Through the analysis I was able to find that a 137 module solar array could be utilized to generate up to 606,045 kWh of electricity which would be equal to about $82,240 in savings annually after a payback period of a little less than 3 years.

The ultimate decision of how to handle this situation would obviously be out of my hands, but having performed this analysis I believe that the best solution is to continue to use the geothermal loop to provide the space heating and cooling since it is very effective. On top of that I would suggest going through with the architectural changes on the roof to create space for the 137 module solar array. I believe that I would be able to convince the owner that this is a worthwhile proposal by first stating the $82,240 annual savings and then stating that the payback period would be less than 3 years. If the system lasted the average lifetime of a solar panel (50 years) it would result in savings of nearly $4,000,000. Seeing that the owner was willing to compromise on the architecture of the Doyle Library I feel that these possible gains throughout the systems lifetime would lead to the owner's decision to apply my proposed system.

ALTERNATIVE FAÇADE DESIGN

Problem:

The current façade system on the SRJC student center is made up of brick veneer and precast concrete panels. The minute tolerances and complicated connections of the brick veneer to the structure created numerous headaches on the job site. The brick is connected to the structure by the use of small ledger angles that are then connected to either metal studs or steel members (WT's). The connections to the metal studs were not too big of an issue but the connections to the steel were a completely different story. The steel connections provided trouble because it is much harder to install structural steel to small tolerances than it is to install metal studs. Also, the fact that the steel sub attached the steel to the bent plates in the shop rather than waiting to do so in the field only added to the problem. The complications created by these issues made it nearly impossible to keep the plates to the required tolerances of ¼" both vertically and horizontally.

The steel sub was forced to fix his mistake by correcting the placement of his WT steel members both in the horizontal and vertical directions. The challenge of fixing this mistake began by having the building lines surveyed to provide exact locations of where the outside face of the brick needed to be. The next step was to transfer the acquired layout vertically up the building so that the metal studs would be installed perfectly, even thought the structural steel locations varied by significantly more than the ¼" tolerance. The placement of the vertical ledger angles were also laid out by a surveyor so that they would be exactly where they needed to be.

Goal:

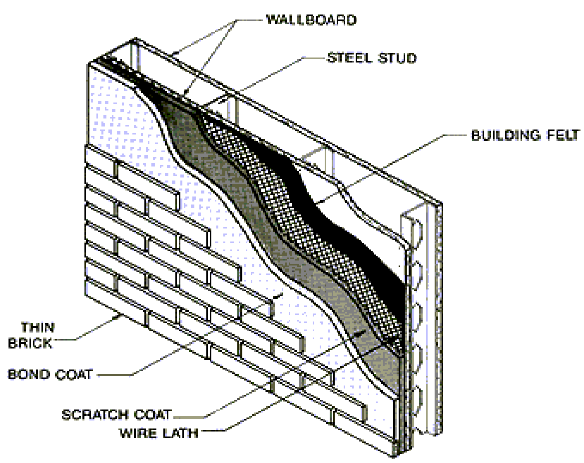
The main focus of this analysis is to investigate the method used for connecting the brick veneer to the student center and then determine whether or not it was the best method that could have been used in that situation. The goal is to find a way to prevent the excess costs and delays caused by rework that had to be done in the field. To perform this analysis I have chosen to investigate the elimination of welds done in the shop and instead perform all welding in the field to better meet tolerances and avoid rework. The next step is to determine and analyze the effects that the new design would have on the schedule and budget to demonstrate any worthwhile improvements.

Analysis Steps:

Method 1

This analysis will be conducted through the investigation of two different alternatives. The first alternative involves the replacement of full size bricks attached to the building's façade with a smaller, thin veneer brick that can be adhered to the structure. After talking to members of the design team it quickly became evident that this was not an ideal alternative for several reasons.

First of all, adhered brick veneer, although lighter and cheaper does not look exactly like real, full size brick. It has a prefabricated look that can come off as looking cheap. The Santa Rosa Junior College is very picky about their architecture and was very specific about wanting the "real deal" when it came to façade design. Many buildings throughout the campus utilize full size brick and therefore the use of anything less on the 66,646 square foot Bertolini Student Center would have been viewed as unacceptable by the college. Along with the school's desire for a high degree of aesthetics comes the need to meet the wishes of the big donors to the college. These people that give money back to the school want to see it going to work in the best way possible and in this case that involves the use of an elegant, full brick and precast concrete façade. Even though the cost of adhered, thin brick veneer is much cheaper and is very easy to install, the cost and schedule benefits of this had to be overlooked to meet the owner's standard of excellence. The next issue is the fact that the current design of the structure was made for full size bricks to be anchored to the frame of the building. The use of a thin veneer requires a very rigid support system. The current steel frame design of the building would not meet those requirements and therefore there would need to be a complete re-design of the support system which would be extremely costly. Keeping these things in mind I still decided to perform this analysis to see what kind of savings were attainable.



LEFT: Sample layout of thin brick veneer system.

Right: Thin brick veneer being installed.

The two images above were taken of the full size brick façade during construction of the SRJC Student Center

Adhered Veneer vs. Full Size Brick

To determine the cost of the full size brick façade installation I utilized both the design team and RS MEANS COSTWORKS. The cost of the thin brick veneer was obtained through the use of cost data from Boral Bricks Inc., the nation's largest brick manufacturer and distributer or masonry products. The material and installation costs are summed up in **TABLE 1** below.

SOURCE	MATERIAL	TOTAL COST
DESIGN TEAM ESTIMATE	Full Size Brick	$1,100,000
RS MEANS COSTWORKS	Full Size Brick	$1,099,659
BORAL BRICKS INC.	½" Adhered Brick Veneer	$499,845

TABLE 1

The information above was calculated using the following methods:

- Price of installed full size brick from RS MEANS = $16.50/SF
- Building size = 66,646 SF

($16.50/SF)(66,646 SF) = $1,099,659

- Price of installed ½" veneer from BORAL BRICK INC. = $7.50/SF
- Building size = 66,646 SF

($7.50/SF)(66,646 SF) = $499,845

- Savings from using thin veneer over full size brick:

$1,099,659 - $499,845 = **$599,814**

After finding these initial savings I was optimistic about this as a viable alternative to the use of full size brick. But, after running my ideas past the design team I was deterred by the fact that they insisted that a redesign of the entire structure would be extremely expensive and would effect much more than just the façade of the building, consequently making the cost higher than originally determined with the use of full size bricks. Also, the fact that the college has been working with this same design team for years comes in to play in this situation. To make sure a good professional relationship continues to exist between the two groups, the design team is better off granting the owner's design wishes even if it would be cheaper and easier to go with a different method. After these findings I decided to stick with the full size brick façade and move on and begin investigation on my second alternative method.

Method 2

The second alternative investigated involves the continued use of the full size brick façade along with the elimination of pre-welded steel ledgers that were welded far too early in the project in the shop. These pre-welded ledgers were not able to meet the strict tolerances required when installed in the field. This resulted in delays of about one month due to rework along with thousands of dollars in excess costs. For the purpose of this analysis all welds will be done in the field, rather than in the shop, to ensure that the level of quality required is attained. Although the cost of field labor is higher than that of shop labor and the fact that more time would have to be taken to do the welds in the field the design team agreed with me in saying that this alternative seems worth the effort to investigate. The time and money that could potentially be saved by getting the welds done correctly the first time will be the focus of this investigation.

SENIOR THESIS FINAL REPORT
SANTA ROSA JUNIOR COLLEGE STUDENT CENTER

Welding in Shop vs. Welding in Field

To determine costs and times associated with welding in the shop and in the field I utilized both the design team and standard rates and values in the Santa Rosa area. The information below sums up the cost per linear foot of welding done both in the shop and in the field. This information will then be used to determine any potential time and cost savings available.

*Detail #16 on sheet S9.1 shows typical weld: Weld symbol shows a 3/16" weld 2" long at 12"o.c. plus a plug weld 2" long at 12"o.c..

- **Shop Welding Estimate**

*Numbers assume welding for a 20' piece

*Assume 3 man crew setting up and welding

-Shop Labor Rate = $55/hr

-Set up = 15 min

-Welds = 40 welds at 2 minutes each = 80 min

-Shop Equipment Rate = $100/day

$$\frac{[(3\text{ men})(80+15\text{min})(1\text{hr}/60\text{min})(\$55/\text{hr})] + [(80+15\text{min})(1\text{hr}/60\text{min})(1\text{day}/24\text{hr})(\$100/\text{day})]}{(20'\text{ piece})}$$

=$14/ft in shop welding

- **Field Welding Estimate**

*Shop labor = $55/hr

*Field labor = $89/hr

-Load separate piece at shop = 5 minutes (2 shop men)

-Unload separate piece in field = 5 minutes (2 field men)

-Stage at field location with forklift = 10 minutes (2 field men)

-Stage welder in field = 15 minutes (2 field men)

-Set in place with forklift/plumb/align = 20 minutes (3 field men)

-Field weld from man lift (move every 8 welds) = [2min/weld] + [5min/8welds] + 15 minutes for special inspector (3 field men)

-Breakdown and cleanup forklift and man lift = 30 minutes per day (3 field men)

- Shop Labor = (5min/piece)(1hr/60min)(2men)($55/hr) = $9.00

=$9.00 shop labor per piece

- Field Labor = (480min/60min)($89/hr) + (30min)(1hr/60min)(3men)(1/3 day)($89/hr)= $756.00

=$756.00 field labor per piece

- Equipment = ($200/day)(2pieces)(1/3 day) = $133.00

=$133.00 equipment costs

- Total Cost = $\frac{(\$9.00)+(\$756.00)+(\$133.00)}{20' \text{ piece}}$ = $45/ft in field

=$45/ft in field welding

From these calculations the fact that in field welding is more expensive than shop welding becomes evident. It is about $45/ft in the field and only about $14/ft in the shop. So, the next step would be to see how these numbers will have an impact on the overall cost and schedule of the façade construction. Next I will use these numbers along with original data to perform a cost and duration estimate for the entire façade using field welding alone. I will then compare those results to what was actually recorded on the project to determine any possible savings.

Cost and Duration of Fully Field Welded Façade Angles

To determine the cost and duration associated with using field welds alone I must first determine how much of the façade relies on the use of shop welded angles opposed to those in the field. After determining the breakdown of the welding I will be able to use data gathered in the previous section to determine a new, final cost. After that, the next step is to find out the time it would take to perform all welds in the field. Through the use of typical welding data gathered in the previous section I will be able to determine a final duration. The information determined below will then be compared against the actual cost and duration from construction.

Ledger Angle Cost Breakdown: Field vs. Shop

Cost of Field Angles

- The total cost of angles welded in the field was found by first determining that 2,800 bolts were used on the student center. 2 bolts were used on each stud and these studs were placed at 16 inches on center.

(2,800 Bolts)(Stud/2 Bolts) = 1,400 Studs Placed at 16" o.c.

(16" between studs/12" per foot)(1,400 studs) = 1,867 Linear Feet of Field Welding

(1,867 linear feet)($45/foot) = **$84,015 for Field Welding**

- The cost above includes performing the welds along with installing the pieces.

Cost of Shop Angles

- Finding the cost of the shop welded angles proved to be a little more difficult since I was unable to get exact information from the design team on this matter. I was forced to perform a takeoff by hand, counting the linear feet of shop welded angles used on the student center.
- Through my takeoff I found the total linear footage of shop welded angles to be roughly 1,180 feet.

(1,180 linear feet)($14/foot) = **$16,520 for Shop Welding**

- Unlike the field weld analysis above, the shop weld number does not include the cost of labor to install the piece on site. Upon consulting the project manager I found $40/ft to be a reasonable estimate

(1,180 linear feet)($40/foot) = **$47,200 for Installation**

- Costs due to rework that needed to be done on the prefabricated angles totaled nearly $50,000

($16,520)+($47,200)+($50,000) = **$113,720 Total**

Total Cost Related to all Angles

(Field Weld Cost)+(Shop Weld Cost)+(Installation Cost)+(Rework Cost) =
($84,015)+($16,520)+($47,200)+($50,000)**= $197,735**
Total Cost = $197,735

Cost Effects of Using all Field Welding

- **New Cost Analysis**
  - 3046 Total Linear Feet
  - $45/ft

(3046ft)($45/ft)=$137,070
Total Cost = **$137,070 Total**

- **Total Savings Possible**
  - Original Cost = $197,735
  - New Cost = $137,070
  - Savings = ($197,735) – ($137,070) = $60,665

Total Cost Savings Available = **$60,665 Total**

Ledger Angle Schedule Breakdown: Field vs. Shop

Time for Field Angles

- Through calculations above I was able to determine that it takes about 180 minutes to complete 20' of welding. Using this data and assuming an 8 hour work day I have concluded that 53' of these angles can be completed daily.

(8hr/workday)(60 min/1 hour)(20'/180 min) = 53' per day

(1 day/53')(1867' total) = 35.2 days

=36 Days of Work

Time for Shop Angles

- Similarly to above I was able to determine that it takes about 95 minutes to complete 20' of welding. Additionally, the welded angles must be transported and installed which adds roughly 55 minutes to the completion of each piece. This brings the total amount of time to 150 minutes to complete a 20' member.

(8hr/workday)(60 min/1 hour)(20'/150 min) = 64' per day

(1 day/64')(1179' total) = 18.4 days

=19 Days of Work

- **Total Time Needed for All Angles**
  - Field Welds = 36 Days =
  - Shop Welds = 19 Days
  - Delays = 30 Days

Total Time for Angles = 55 Days + 30 Days for Rework
=85 Days Total

Schedule Effects of Using all Field Welding

- **Total Time Required to Use Field Welding Entirely**

Rate of Welding = 53.3 linear feet per day
Total Length = 1867 + 1179 = 3046 linear feet

(3046 ft)(1 day/53.3 ft) = 57.11
= 58 Total Days

- **Total Time Savings possible**
  - Original Time = 85 Days
  - New Time = 58 Days
  - Savings = (85 Days) – (58 Days) = 27 Days

Total Time Savings Available **= 27 Days**

Summary: Through the analysis above it can be seen that choosing to perform all of the welding in the field can result in up to 27 days of schedule acceleration at and cost savings of up to $60,665. These results can be summed up by the tables below.

ORIGINAL METHOD

	COST/FT	TOTAL FT	TOTAL COST	FT/DAY	TOTAL DAYS
FIELD WELDS	45	1,867	84,015	53	36
SHOP WELDS	54	1,179	63,720	64	19
REWORK DELAYS			50,000		30
GRAND TOTALS		**3046 Ft.**	**$197,735**		**85 Days**

PROPOSED METHOD

	COST/FT	TOTAL FT	TOTAL COST	FT/DAY	TOTAL DAYS
ALL FIELD WELDS	45	**3046**	**$137,070**	53	**58 Days**

TOTAL SAVINGS

	ORIGNAL METHOD	PROPOSED METHOD	SAVINGS
COST	$197,735	$137,070	**$60,665**
DURATION	85 Days	58 Days	**27 Days**

Conclusions and Recommendation:

Based upon the data presented above through this analysis I believe that the use of field welding alone as opposed to a combination of field welding and shop welding is a viable alternative. Trying to perform prefabricated ledgers with shop welds is simply too difficult to do to meet the required tolerances of the façade construction. The decision to use prefabricated ledger angles resulted in nearly 30 days of rework and extra costs of roughly $50,000.

Obviously the decision of whether or not to carry out my proposed method of performing all of the ledger angle welding in the field would be out of my control but having performed this in depth analysis I believe that the decision to carry out the proposed method would be very beneficial. The attainable savings of up to 27 days of schedule time and $60,665 support this theory.

SENIOR THESIS FINAL REPORT
SANTA ROSA JUNIOR COLLEGE STUDENT CENTER
ALTERNATIVE STEEL ERECTION PROCESS

Problem:

The structural steel frame of the SRJC student center is another problem area on the project. The method of erecting steel on the student center resulted in long delays that held up many other activities on the project which in turn delayed the project completion date by 72 days. Although the steel shop drawings were completed on time, the steel erection process started one month late and the completion of the erection and welding of the steel ended up being almost 3 months late, resulting in the need to be granted a 72 day extension to the original schedule. These problems were in part due to the use of a single mobile crane and welding crew throughout the erection process.

Above: Single crane and crew used during erection process

Goal:

This analysis will involve the investigation and research of the original erection process as well as that of an alternative erection method. The use of multiple cranes and welding crews as opposed to what was used on the project will be investigated along with the cost of using an extra crane and labor. The benefits of an alternative erection process such as schedule acceleration and cost reduction will be analyzed and compared to original data.

Analysis Steps:

This analysis will be performed through the investigation of one alternative method of steel erection. The original method used utilized a single crane and 16-man crew throughout the entire steel erection process. The choice to use a single crane and crew resulted in excess spending and delays. The delays that occurred resulted in the need for a 72 day extension and nearly $400,000 worth or excess spending. This alternative method analysis will look in to the use of two cranes and two crews for the erection, plumbing, and welding of steel. After consulting the design team I was told that they believed that the use of multiple cranes would cause inefficiency due to congestion and would ultimately take longer and cost more because of this. Upon hearing this I have decided to continue on with my analysis with the assumption that two cranes and crews could be utilized to work continuously from start to finish on steel erection with negligible losses due to inefficiencies.

Original Steel Erection Process Details:

The following numbers and statistics were gathered via research and design team interviews. The information includes an approximate steel takeoff for what was erected along with a breakdown of the structural costs, delays, crane, and crew details.

Steel Takeoff Numbers

Equipment	Member Description	Total
1 MOBILE CRANE	• 124 Columns (2 sections = 62 Each) • 762 Beams	**886**
1 FORKLIFT	• 35 Columns (1 section = west end) • 140 “X” Braces (at brace frames) • 159 Beams	**334**
	TOTAL MEMBERS:	**1220**

Table 2

Breakdown of Steel Erection Crew

Responsibility	Number of Men	Rate
Staging steel	3	$89/hr
Helping to set each member	4	$89/hr
Following behind, completing bolting of members	9	$89/hr
TOTAL	**16 men at a rate of $89/hr**	

Table 3

Crane and Forklift Operation Dates

The crane used on the jobsite was an 80 ton Hydraulic Crane which rents for a rate of about $500/hr including an operator. Weekly rates of about $15,000 are what the construction team worked with which saved a significant amount of money compared to an hourly rate. The operator of the crane is assumed to be a union operator. As stated before the steel team was comprised of a 16-man crew during the process, at a rate of about $89/hour.

*Crane data was taken from <u>2010 Current Construction Costs</u>, 47th annual edition, Saylor Publications, Inc.

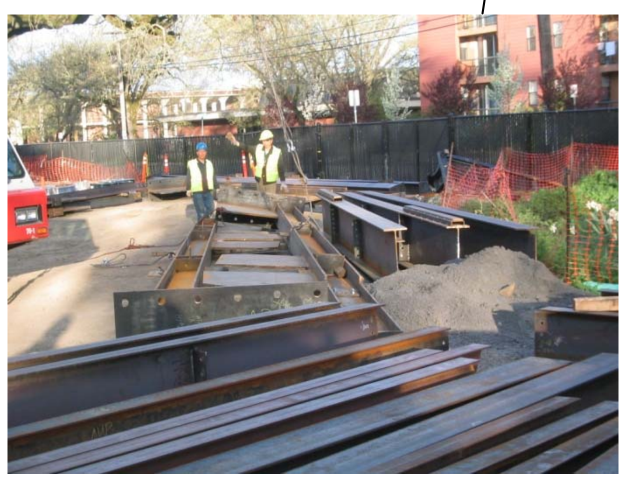
- Section 1 (East Section)
    - First Steel Set: 3-18-08
    - Crane Pulled: 4-16-08
- Section 2 (Center Section)
    - Crane Returned: 5-1-08
    - Crane Pulled for Good: 6-6-08
- Section 3 (West Section)
    - Forklift done setting main steel members: 7-15-08

      * The forklift remained on site throughout entire erection process to help stage material and lift small pieces while crane worked from east to west erecting steel.

The steel sub spent about 8 months beginning in March 2008 on the site. The last three of these months were spent working on miscellaneous braces and small members along with finishing of plumbing and welding.

The contract originally allowed for 24 weeks of steel erection. The first 90% of steel (by weight) was erected pretty much on time. The finishing of the last 10% of steel erection and the plumbing and welding of the first 90% are where delays occurred, ultimately leading to a 72 day extension being granted.

The image below illustrates the sections of the building described above in the steel erection process. The steel work started on section 1 and worked its way from east to west, finishing up with section 3 (right to left on the plan).



Above: Steel being set by crane in section 1

Right: Section 1 steel members ready to be lifted into place by crane

Steel Erection Process Cost Breakdown Including Material, Crane, and Labor

Material: Total steel cost of 1220 members gathered from design team interview and takeoff numbers.

Steel Member Total Cost = $1,800,000

Crane: Total crane cost for 24 week rental at a rate of $15,000 per week

= ($15,000/wk)(24 week rental) = $360,000

Crane Rental=$360,000

Labor:

- Labor performed by 16-man crew, "on time" during 24 week schedule at a rate of $89/man per hour

=(16man crew)($89/hr)(8hr/day)(5day/wk)(24week schedule) = $1,367,040

On Time Labor = $1,367,040

- Labor performed by 9 man crew, "late" during 72 day (estimating using 3 months = 12 weeks)extension period

* Crew is now made up of nine men because erection process has been completed. Only plumbing and welding of steel need to be done at this time. The additional 7 men are not needed.

=(9man crew)($89/hr)(8hr/day)(5day/wk)(12 week extension) = $384,480

Extra Labor Cost = $384,480

*This seems acceptable because the design team estimated extra costs to be around $400,000.

Total Structural Costs Without Delay

= (Material + Crane+ On Time Labor)

= ($1,800,000)+($360,000)+($1,367,040) = $3,527,040

Original Structural Cost (without delay) = $3,527,040

*This seems reasonable because the original estimate given to me by the design team was $3,500,000 for structural costs.

Total Structural Costs With Added 12 Week Extension

= (Material + Crane + On time Labor + Late Labor)

= ($1,800,000)+($360,000)+($1,367,040)+($384,480)=$3,911,520

Final Structural Cost (with delays)=$3,911,520

Alternative Method Analysis Details:

As previously mentioned, the steel erection process involved with the SRJC student center was completed through the use of a single 16 man crew and crane. The decision to erect the steel in this manor ended up resulting in roughly $400,000.00 in excess costs and the need for a 72 day extension because of delays.

The alternative that I have chosen to use for analysis is that of using two cranes and two crews to speed up the erection process helping to avoid the excess costs and delays that occurred. When informing the design team of my alternative method I was told that this idea was never really looked into. The reason that multiple cranes were not considered was due to the fact that they believed that the extra men and machinery on site would not be worthwhile due to inefficiencies in the form of slower work due to congestion. Although the use of two cranes was not thought to be ideal, it was not researched enough to be proved otherwise. Looking back at the delays that occurred, the design team may have looked into ideas such as this a little bit more. For the purpose of this analysis I have assumed that the two cranes and crews would be able to work simultaneously and continuously with negligible impact due to inefficiency.

Breakdown of Time to Set Individual Steel Member

Total Steel Members Set:

- Crane = (124 Columns)+(762 Beams) = 886 Members
- Forklift = (35 Columns)+(140 "X" Braces)+(159 Beams) = 334 Members

Total Members Set = 886 + 334 = 1220 Members

1220 Total Members

Approximate Time per Member:

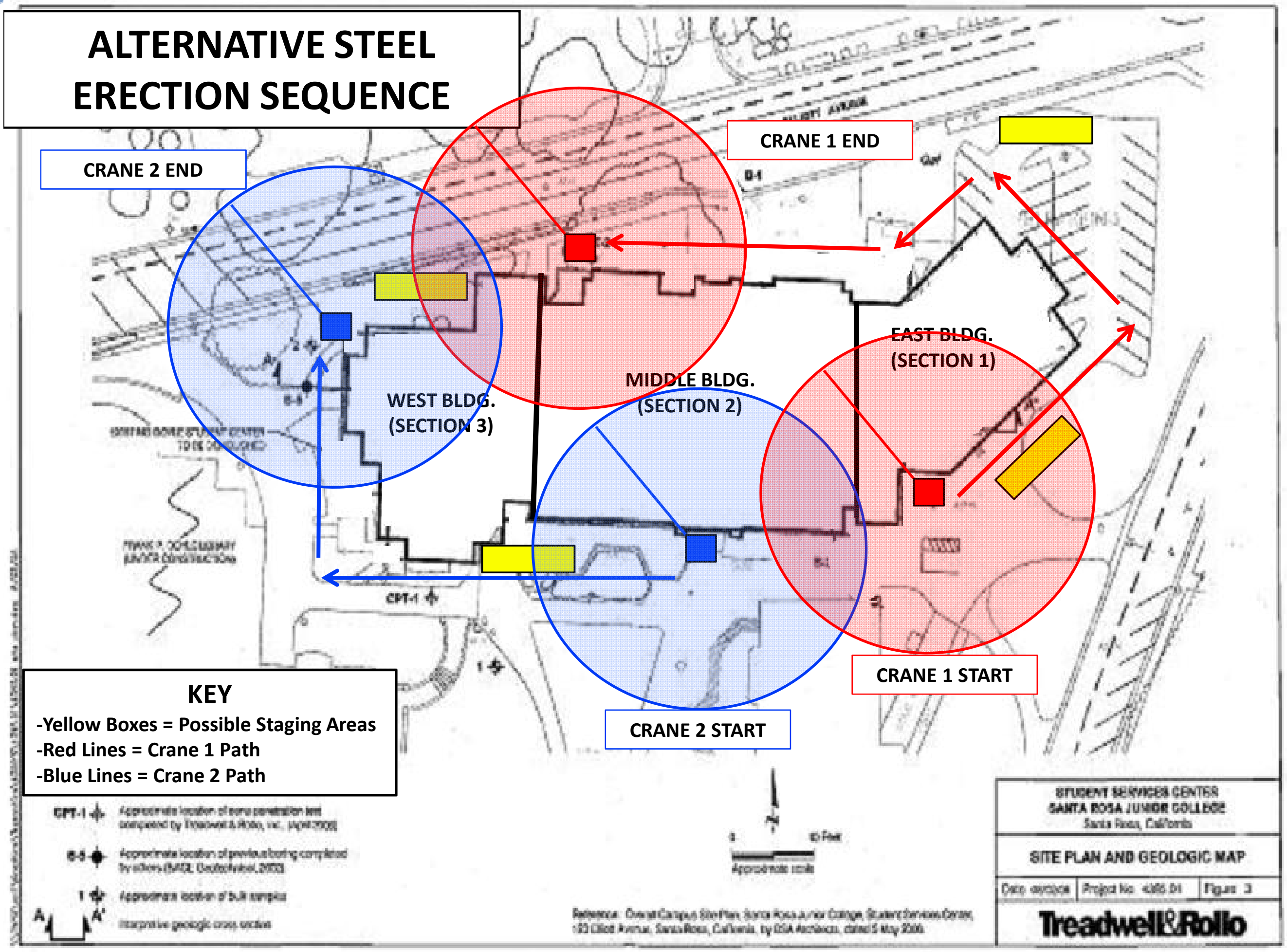
(24weeks)(5days/wk)(8hours/day)(60min/hr) = 57,600 minutes total

(57,600 min)/(1220 members) = 47.2 minutes per member

47.2 Minutes per Member

Alternative Analysis Plan

For this analysis, the plan is to split the steel erection process evenly between two mobile cranes that will be working simultaneously and continuously from the beginning until the end of steel erection. The plan is to start both cranes at the lower east corner of the building and then work in opposite directions. Crane 1 will work starting on the east side of the building and work up and then west around (counterclockwise) the building as far as is possible due to site constraints. Crane 2 will start to the left of Crane 1 and will work westward and then eventually up and around the western corner of the building (clockwise). By splitting the amount of work in half, the goal is to minimize the steel erection time while saving money. The site plan below illustrates the proposed alternative.



Alternative Method Cost and Schedule Breakdown

Time required for two cranes to complete erection process:

- (1220 Members)/(2 Cranes) = 610 Members Each at a rate of 47.2 min. per member (as determined before)
- (610 Members)(47.2minutes/member)(1hr/60min)(1d/8hrs)(1wk/5d) = 11.99 weeks

=12 weeks of work per crane

Total cost required for 12 week rental of two cranes:

- (12 week rental)(2 cranes)($15,000/week) = $360,000

=$360,000 for 12 weeks with two cranes

*The costs related to crane use end up being equal to that of the costs in the original method ($360,000). The positive part about the alternative method is that It only takes 12 weeks with 2 cranes working simultaneously as opposed to the original 24 weeks with one crane working alone.

Total cost required for 12 weeks of labor from two 16-man crews:

- (2 crews)(16 men/crew)($89/hr)(8hr/day)(5days/week)(12week schedule) = $1,367,040

=$1,367,040 for 12 weeks of labor

*The costs related to labor end up being equal to that of the costs in the original method ($1,367,040). Again, like with the crane use, the gain comes in the form of time being made up. Instead of taking 24 weeks, the same amount of work can be accomplished within 12 weeks.

Total Impact on Structural Cost and Schedule Using Two Cranes:

- 12 week rental of two cranes at a rate of $15,000 per week

=$360,000

- 12 week wage rates for 2 crews of 16 men working at a rate of $89/hr

=$1,367,040

- 1220 steel members

=$1,800,000

- Total Cost of Alternative Method = ($360,000)+($1,367,040)+($1,800,000)

Total Cost=$3,527,040

Total Duration = 12 Weeks

Overall the total cost would remain the same, but the work would be able to be completed within 12 weeks instead of 24. During construction of the student center, the steel erection process resulted in about 12 extra weeks of work which was spent almost entirely on plumbing and welding of steel, bringing the total amount of time spent on the steel erection to 36 weeks from start to finish. The cost of the extra labor resulted in an extra $384,480 of spending. Even if an extra 12 weeks of labor was needed for plumbing and welding, the process still would have been completed within the original 24 weeks. Below is a summary of the costs and durations of the original and the alternative methods of steel erection. I have included a best and worst case scenario for the alternative method to show that it is still the best option in either case.

Original Method: Duration Breakdown

= (24 weeks for erection) + (12 weeks extra for plumb and weld)

= 36 weeks

Alternative Method: Best Case Scenario Duration Breakdown

= (12 weeks for complete process)

Alternative Method: Worst Case Scenario Duration Breakdown

= (12 weeks for erection) + (12 weeks for plumb and weld)

= 24 weeks

Original Method: Cost Breakdown

= ($360,000 for crane)+($1,367,040 on time labor)+($384,480 extra labor)+($1,800,000 steel)

= $3,911,520

Alternative Method: Best Case Scenario Breakdown

= ($360,000 for crane)+($1,367,040 on time labor)+($1,800,000 steel)

=$3,527,040

Alternative Method: Worst Case Scenario Breakdown

= ($360,000 for cranes)+($1,367,040 on time labor)+($384,480 extra labor)+($1,800,000 steel)

= $3,911,520

Total Savings from Alternative Method

Best Case:

- Original Duration = 24 + 12 weeks = 36 weeks
- Alternative Duration = 12 weeks
- TOTAL SAVINGS = 36 weeks – 12 weeks = 24 weeks saved

=24 Weeks Saved in Total

- Original Cost = $3,527,040 + $384,480 extra labor = $3,911,520
- Alternative Cost = $3,527,040
- TOTAL SAVINGS = $3,911,520 - $3,527,040 = $384,480 saved

=$384,480 Saved in Total

Summary: In the best case scenario, in which plumbing and welding takes no extra time, the steel erection process would take 12 weeks in total at a cost of $3,527,040.

Worst Case:

- Original Duration = 24 + 12 weeks = 36 weeks
- Alternative Duration = 24 weeks
- TOTAL SAVINGS = 36 weeks – 24 weeks = 12 weeks saved

=12 Weeks Saved in Total

- Original Cost = $3,527,040 + $384,480 extra labor = $3,911,520
- Alternative Cost = $3,527,040 + $384,480 extra labor = $3,911,520
- TOTAL SAVINGS = $3,911,520 - $3,911,520 = 0

= $0 Saved in Total

Summary: **In the worst case scenario, in which plumbing and welding takes a full 12 weeks extra, the steel erection process would take 24 weeks in total at a cost of $3,911,520.**

The best and worst case scenarios are being used to create a range of savings that could be attainable. The actual savings earned would almost certainly fall somewhere between these two cases and would be determined by the ability of the crews to stay caught up with the plumbing and welding of the steel.

The table below summarizes all of the information gathered above for the original method and the proposed alternative method.

METHOD	TOTAL COST	TOTAL DURATION	TOTAL MONEY SAVED	TOTAL TIME SAVED
Original Method	$3,911,520	36 weeks	-	-
Alternative Method: Best Case	$3,527,040	12 weeks	$384,000	24 weeks
Alternative Method: Worst Case	$3,911,520	24 weeks	$0	12 weeks

*Original Method = 1 crane, 1 16-man crew
*Alt. Method Best Case = 2 cranes, 2 16-man crews
*Alt. Method Worst Case = 2 cranes, 2 16-man crews

Conclusions and Recommendation:

Based upon the information presented above for this analysis it becomes evident that using two cranes and two erection crews is a logical alternative to using a single crane for steel erection. This alternative can result in time savings of up to 24 weeks and cost savings of up to $384,000. These factors become very important when looking back at the problems that occurred with the original method. These savings could help to prevent the need for a 72 day extension which delayed the entire project. Even in a worst case scenario, savings of up to 12 weeks are possible, putting the duration at 24 weeks total, which would be on par with what the design team originally aimed for.

The ultimate decision of whether or not to pursue this alternative would obviously be out of my control, but my suggestion however would be to follow through with the use of multiple cranes and crews. The time savings that are attainable through this method are hard to overlook, especially when you see how much of a problem it was to get the steel erection done with the original method. At a minimum I would suggest the use of a second set of laborers to work on plumbing and welding since that is what seemed to put the process behind schedule the most. Ideally though, the use of the extra labor and the extra crane seem to provide the greatest opportunity for savings.

ALTERNATIVE PREFABRICATION PROCESS

Above: Precast concrete panel being lowered into position

Problem:

The prefabricated concrete panels that wrap the perimeter of the student center created yet another problem area on the project. The panels were prefabricated very early on in the project at a location very far away (Mexico) which resulted in installation issues and schedule delays. The reason that this occurred was that the precast concrete was made a design-build element on the project. The early prefabrication took place long before the building had been constructed to the point that field measurements could be taken to verify exact sizes. This led to the installation problems and schedule delays mentioned earlier.

Goal:

The main focus of this study would be to investigate the design-build process used for the prefabrication and compare the results to alternative options such as design-assist. The goal is to find a more efficient prefabrication process that would result in simplified installation and therefore reduced cost and schedule impacts.

Analysis Steps:

This analysis will be performed by looking into the hiring of design consultant in the design phase of the student center project. The original concrete panel prefabrication process began very early on in the project which resulted in pieces not fitting into place correctly and the inability of them to be installed to the required tolerances. The costs due to rework caused from the lack of adequately sized precast panels totaled roughly $200,000. The delays caused by additional work needed were the initial problem on the project which ended up having a lot to do with the delay associated with the steel erection and the 72 day contract extension. This 72 day contract extension was granted due to the fact that the bad prefabrication work began a critical path delay of about 72 days that could be proven and an at least another two weeks of delays that could not be proven and thus were not granted as a part of the extension. Having spoken to the design team they agreed that the hiring of a design consultant during the design stage of the project would have resulted in the delivery of a much smoother and cheaper project. Upon hearing this I have decided to carry out my analysis to determine the benefits of hiring such a consultant early on in the project.

Original Prefabrication Process Background and Details:

The following information was gathered via research and design team interviews. The supply and installation of precast is an extremely complicated matter and this was evident on the SRJC Student Center project. The bidders needed to be certified through the Precast/Pre-stressed Concrete Institute (PCI) plant certification program. This pre-certification set the bar so high that basically only 2 contractors in all of California were qualified for the project.

The precast process is one that needs to begin during the fabrication process so early on because it takes a lot of time to set up molds, get ready for pours, pour, and finish. The pieces must then be allowed to cure before they can be shipped. Because there were so many precast pieces on this job, to delay the start of this process would surely extend the overall schedule by ridiculous amounts, as can be seen through the need for extensions.

The precast contractor that was used on the SRJC project is a very skilled sub according to the design team. The company is based in Monterey, CA, but their plant is in Mexico. The reason for having the plant so far away is because it costs much less to fabricate in Mexico. The cost of labor in Mexico is a fraction of what it is in the U.S. and I was assured that shipping costs are a minimal when compared to the savings obtained through Mexican labor. As a side note to this, the material would have had to be shipped anyway. Even if the work was done in the United

States, it would not have been able to have been done anywhere near Santa Rosa (or more broadly the Bay Area of San Francisco) for the simple fact that nobody manufactures in that area due to extreme labor costs. Most in-state fabrication is done in the Central Valley area of CA where labor is cheaper, but still not competitive with the rates in Mexico. Also, to fabricate the material on site would have required that labor rates comply with "prevailing wage" rates which are estimated at roughly 10x as much as those in Mexico.

The precast drawings proved to provide the biggest initial problem. Many of the details on the structural plans physically did not work. The fact that the details were not adequate enough resulted in a lot of inaccurate work which consequently hindered the installation of the precast panels. The tolerances that needed to be met for the precast to be accurate provided no room for error and the fact that the drawings were not very informative made it impossible to meet those tolerances during installation.

Alternative Method Analysis Details:

One issue that I came across while performing this analysis occurred due to the fact that the design team was unable to provide me with very much information. This occurred because they were currently in the middle of intense change order negotiations with the architect regarding this matter. Because of this I have been very limited on my analysis details relating to money issues. That being said I will continue to carry out this analysis.

The delays caused by the flawed prefabrication process and the rework that was required because of it, could have, in my opinion been avoided with the simple solution of hiring a precast subcontractor as design consultant early on in the design stage to assist the process. The precast subcontractor that the SRJC decided to go with was not the cause of the problem. The problem occurred due miscommunication and poor drawing details. Hiring a design consultant and having them involved with the design from the very beginning of the project would entail an extra cost, but being able to prevent the beginning of a 72 day critical path delay along with two additional weeks of delays would surely make the extra costs early on more than worth it. Being able to catch all of the mistakes long before they occur would eliminate all delays related to poorly detailed drawings.

The hiring of a design consultant would result in the changes having been made before the time of the bid and therefore the work would have been granted at bid prices when contractors are "hungry for work". This is opposed to change order prices, when the owner is able to negotiate but really doesn't have the power to reduce the prices as much as he would like. Again, since it is hard to predict exactly how accurate or helpful this design consultant would be it is hard to quantify exactly how much time and money he would be able to save to overall project.

Assuming that the use of a design consultant eliminates all of the delays and rework I would conclude savings of the following amounts:

- **Time Savings:** The amount of time that could be saved through the successful use of a design consultant would be directly related to the critical path delays. Being able to pick out all of the problems and fix them before they occur could theoretically prevent the need for a 72 day extension due to critical path delays as well as the two weeks (10 days) not related to the critical path. If the precast work had been done right the first time, the steel erection process would have been able to move ahead of schedule instead or at least have stayed on schedule as opposed to falling way behind.
- **Cost Savings:** Knowing literally only that the original cost was over exceeded by roughly $200,000 it is hard to say exactly how much money could have been saved. The fact that I have been given very limited information on this matter has made it difficult to find exact savings that could be obtained. That being said I believe that even though it would cost more for a design consultant to be involved early on in the project, being able to avoid the $200,000 of extra costs would be worth it.

Summary: Making a huge assumption and saying that the design consultant could eliminate all rework that had to be done through catching mistakes before they occurred, the delays that initiated the need for a 72 day critical path extension along with 10 days not on the critical path could have been eliminated, thus resulting in cost savings of up to $200,000 and the completion of the entire project on time.

Conclusion and Recommendation:

Based upon the limited amount of information that I was able to be given regarding this analysis it is hard to determine exactly how much I would be able to theoretically reduce the schedule or save money. That being said, having made some large assumptions I have concluded that through the use of a design consultant early on in the design stage of construction could have resulted in the avoidance of falling behind on the critical path schedule which caused the need for a 72 day extension which the design team was able to prove to be needed along the critical path. Along with the prevention of these delays would come the cost savings related to the rework that had to be done adding up to $200,000. Although extra upfront payments would have been required for the design consultant's services, it is impossible to determine exactly how much that would have been with the information that I was permitted to have related to this subject.

The ultimate decision of whether or not to hire a design consultant would not be in my control, but having discussed my plan with members of the design team and being reassured that it was a good idea leads me to believe that it is the best alternative to avoid the delays and excess spending that occurred. My proposed idea was further supported upon hearing that the newly planned culinary arts building for the SRJC which utilizes the same design team and architectural style as the student center, was bid using a style almost identical to the one that I have mentioned above.

Final Conclusions and Recommendations:

Through the course of the three main analyses of this final thesis report, several proposed methods of how to reduce the schedule and cost of the SRJC Student Center project were investigated. Had these proposed methods been used during the construction of the Bertolini Student Center the impact of the cost and schedule savings would have become evident and would have helped to get the project finished on schedule without the need for excess spending.

The main focus of my first analysis was to investigate the method used for connecting the brick veneer to the student center and then determine whether or not it was the best method that could have been used in that situation. The goal was to find a way to prevent the excess costs and delays caused by rework that had to be done in the field. To perform this analysis I chose to investigate the elimination of welds done in the shop and instead perform all welding in the field to better meet tolerances and avoid rework. The next step was to determine and analyze the effects that the new design had on the schedule and budget to demonstrate any worthwhile improvements.

Based upon the data presented in this report regarding this analysis, I believe that the use of field welding alone as opposed to a combination of field welding and shop welding is a viable alternative. Trying to perform prefabricated ledgers with shop welds is simply too difficult to do to meet the required tolerances of the façade construction. The decision to use prefabricated ledger angles resulted in nearly 30 days of rework and extra costs of roughly $50,000.

Obviously the decision of whether or not to carry out my proposed method of performing all of the ledger angle welding in the field would be out of my control but having performed this in depth analysis I believe that the decision to carry out the proposed method would be very beneficial. The attainable savings of up to 27 days of schedule time and $60,665 support this theory.

The second that was performed involved the investigation of one alternative method of steel erection. The original method used utilized a single crane and 16-man crew throughout the entire steel erection process. The choice to use a single crane and crew resulted in excess spending and delays. The delays that occurred resulted in the need for a 72 day extension and nearly $400,000 worth or excess spending. This alternative method analysis looked into the use of two cranes and two crews for the erection, plumbing, and welding of steel. After consulting the design team I was told that they believed that the use of multiple cranes would cause inefficiency due to congestion and would ultimately take longer and cost more because of this. Upon hearing this I still decided to continue on with my analysis with the assumption that two cranes and crews could be utilized to work continuously from start to finish on steel erection with negligible losses due to inefficiencies.

Based upon the information presented in this report related to this analysis it becomes evident that using two cranes and two erection crews is a logical alternative to using a single crane for steel erection. This alternative can result in time savings of up to 24 weeks and cost savings of up to $384,000. These factors become very important when looking back at the problems that occurred with the original method. These savings could help to prevent the need for a 72 day extension which delayed the entire project. Even in a worst case scenario, savings of up to 12 weeks are possible, putting the duration at 24 weeks total, which would be on par with what the design team originally aimed for.

The ultimate decision of whether or not to pursue this alternative would obviously be out of my control, but my suggestion however would be to follow through with the use of multiple cranes and crews. The time savings that are attainable through this method are hard to overlook, especially when you see how much of a problem it was to get the steel erection done with the original method. At a minimum I would suggest the use of a second set of laborers to work on plumbing and welding since that is what seemed to put the process behind schedule the most. Ideally though, the use of the extra labor and the extra crane seem to provide the greatest opportunity for savings.

My third and final analysis was performed by looking into the hiring of design consultant in the design phase of the student center project. The original concrete panel prefabrication process began very early on in the project which resulted in pieces not fitting into place correctly and the inability of them to be installed to the required tolerances. The costs due to rework caused from the lack of adequately sized precast panels totaled roughly $200,000. The delays caused by additional work needed were the initial problem on the project which ended up having a lot to do with the delay associated with the steel erection and the 72 day contract extension. This 72 day contract extension was granted due to the fact that the bad prefabrication work began a critical path delay of about 72 days that could be proven and an at least another two weeks of delays that could not be proven and thus were not granted as a part of the extension. Having spoken to the design team, they agreed that the hiring of a design consultant during the design stage of the project would have resulted in the overall delivery of a much smoother and cheaper project. Upon hearing this I decided to carry out my analysis to determine the benefits of hiring such a consultant early on in the project.

Based upon the limited amount of information that I was able to be given regarding this analysis it is hard to determine exactly how much I would be able to theoretically reduce the schedule or save money. That being said, having made some large assumptions I have concluded that through the use of a design consultant early on in the design stage of construction could have resulted in the avoidance of falling behind on the critical path schedule which caused the need for a 72 day extension which the design team was able to prove to be needed along the critical path. Along with the prevention of these delays would come the cost savings related to the rework that had to be done adding up to $200,000. Although extra upfront payments would have been required for the design consultant's services, it is impossible to determine exactly how much that would have been with the information that I was permitted to have related to this subject.

The ultimate decision of whether or not to hire a design consultant would not be in my control, but having discussed my plan with members of the design team and being reassured that it was a good idea leads me to believe that it is the best alternative to avoid the delays and excess spending that occurred. My proposed idea was further supported upon hearing that the newly planned culinary arts building for the SRJC which utilizes the same design team and architectural style as the student center, was bid using a style almost identical to the one that I have mentioned above.

Overall I believe that my findings related to these three analyses would prove to be beneficial to the SRJC Student Center budget and schedule. The façade changes, alternative steel erection process, and hiring of a design consultant all have the potential to generate both cost and schedule savings which would be very appealing to the Santa Rosa Junior College and the construction of its new, Bertolini Student Center.

Acknowledgments

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BULL STOCKWELL ALLEN

KPFF Consulting Engineers: Structural Engineer

ALFATECH

MIDSTATE CONSTRUCTION
Building Relationships

Southland Industries
Design • Build • Maintain

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Marco Alves: AlfaTech Engineers – Geothermal Loop

Don Harrisberger: Southland Industries – Absorption Chillers

Family and Friends

Fellow AE Students

PENNSTATE
1855

Appendix

Thermax Catalog Information

Technical Specifications for Single-Effect A-150 Absorption Chillers

TECHNICAL SPECIFICATIONS - SINGLE EFFECT
steam driven absorption chillers
ProChill™

MODEL NUMBERS		UNITS	A 100	A 120	A 150	A 180	B 210	B 240	B 280	C 320	C 360	C 400
NOMINAL REFRIGERATION CAPACITY		NTR	100	120	150	180	210	240	280	320	360	400
		kW	351	421	527	632	737	842	983	1123	1264	1404
CHILLED WATER CIRCUIT	Flow Rate	m^3/hr	55	66	83	99	116	132	154	176	198	220
	Inlet / Outlet Temperature	°C	12.2 / 6.7									
	Friction Loss	mWC	5.5	6.2	5.1	5.7	5.4	5.5	4.1	4.0	3.9	4.1
	Connection Diameter	mm NB	100				125			150		
	No. of Passes (Evaporator)	nos.	6		4				3			
COOLING WATER CIRCUIT	Flow Rate	m^3/hr	90.7	109	136	163	190	218	254	290	327	363
	Inlet / Outlet Temperature	°C	29.4 / 37.8									
	Friction Loss	mWC	3.1	3.6	4.8	5.6	4.6	5.4	7.8	5.6	6.0	6.6
	Connection Diameter	mm NB	125				150			200		
	No. of Passes (Absorber)	nos.	3		2							
	No. of Passes (Condenser)	nos.	1									
STEAM CIRCUIT	Steam Consumption	kg/hr	630	1000	1250	1500	1750	2000	2330	2660	2990	3320
	Connection Diameter (steam)	mm NB	125				150			200		
	Connection Diameter (drain)	mm NB	40							50		
ELECTRICAL DATA	Absorbent Pump	kW (A)	1.5 (5.0)							3.0 (9.5)		
	Refrigerant Pump	kW (A)	0.3 (1.4)									
	Purge Pump	kW (A)	0.37 (1.1)									
	Total Electric Input	kVA	5.9							9.25		
	Power Supply		415 V (± 10%), 50 Hz (± 3%), 3 Phase+N									

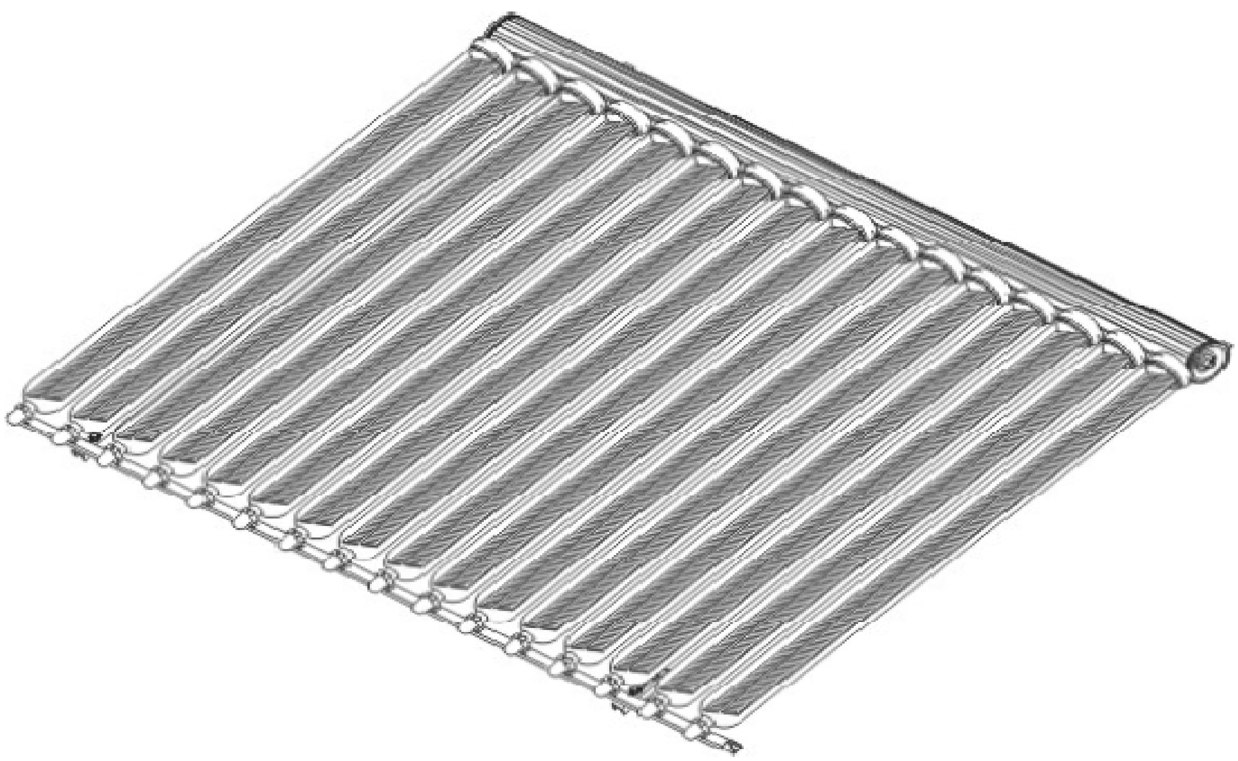
SENIOR THESIS FINAL REPORT
SANTA ROSA JUNIOR COLLEGE STUDENT CENTER

Sunda Catalog Information

Technical Specifications for Seido 1-16As Solar Collector

SUNDA
HIGHTECH SOLAR TECHNOLOGY

Mounting Instruction of Heat Pipe Vacuum Tube Collector
Seido 1/5-8/16AS



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General safety requirement

All installations should be accomplished by professional people, especially should pay attention to the following points:

- Construction conditions
- Local government regulations
- Technical regulations (especially DIN 4757 Items1 and 3)
- In hand available roof construction
- Safety regulation for working on roof
- Safety regulation for safe devices
- Installation instructions of collector
- Safety regulation of VDE and DVGW

Safety regulations for collector

The vacuum tubes can be heated by diffuse solar irradiation, the temperature of which condenser can be very high (over 200 °C). Therefore, please don't directly expose tubes under the sun without shade.
Moreover, please pay attention to the safe operation pressure of system: 6 bar.

Transportation

The collector should be transported to roof part by, and then every part is assembled together on roof.

Snow and ice load

In region, where is rich of snow in winter, man should note the regulation of local construction bureau about the collector installation angle of inclination roof.
Considering stacking of snow, moving of snow by wind and freezing of snow, the load of snow will increase, so it is necessary to take measures to avoid this situation happening.

Lighting protection

One lighting rod should be considered to install. If there is ready- made lighting protection device, please connect it with collector.

1

Inclination angle of collector

In order to avoid unnecessary problems of utilization of collectors, a minimum inclination angle must be ensured: 15°for Seido10. If the tilt angle of roof isn't enough, please build necessary support.

Data

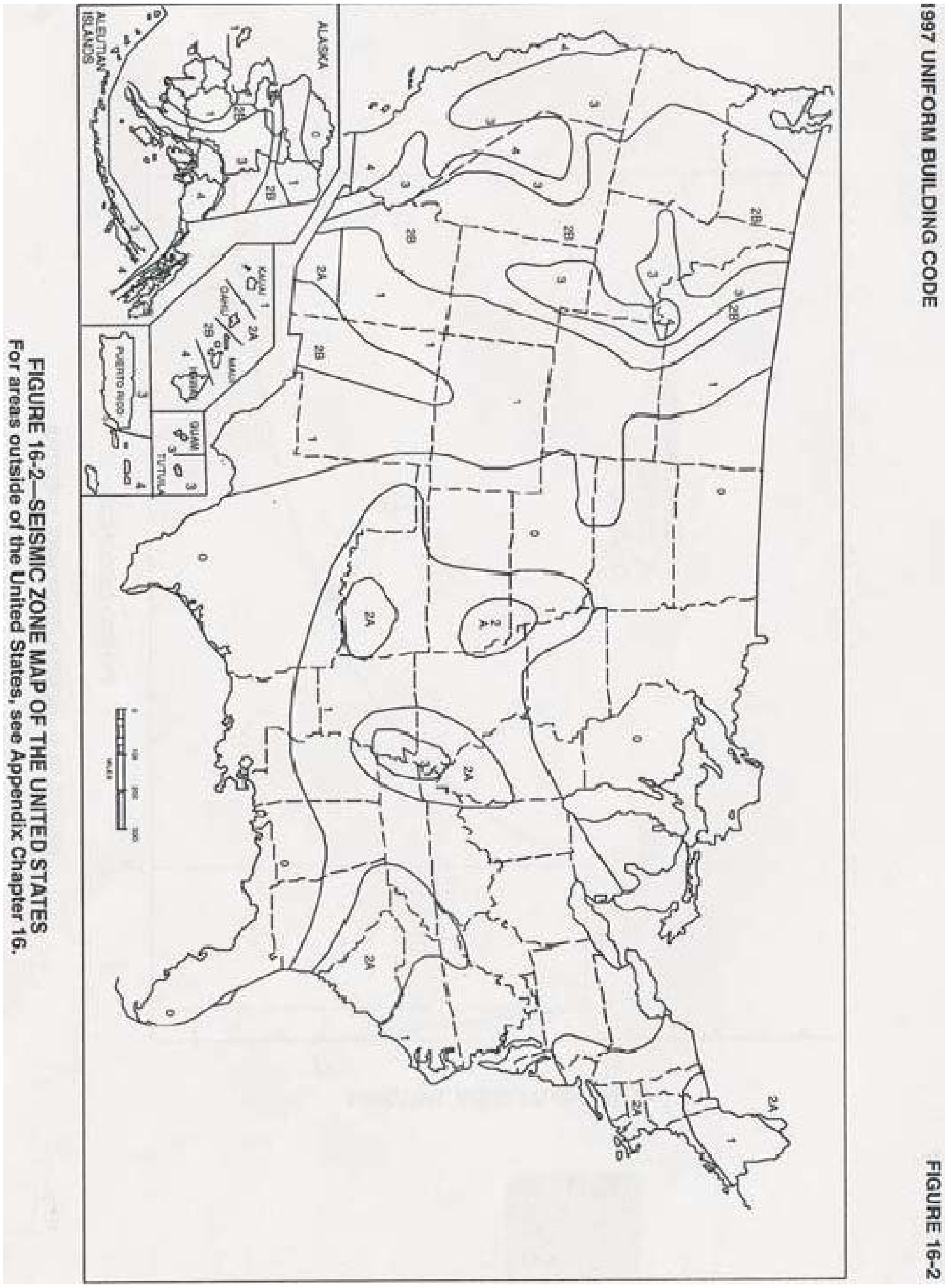
Dimension:
2232 x 980 x 187 mm (Seido1/5-8AS)
2232 x 1940 x 187 mm (Seido1/5-16AS)
Tube: 8/16
Gross collector area: 2.19 m^2 / 4.33 m^2
Net absorber area: 1.39 m^2 / 2.77 m^2
Inclination angle: 15°(Seido1)/35°(Seido5)
Aluminum nitride Absorber
Vacuum grade: 10^{-5} mbar
Gross weight: 50kg / 100 kg
Connection: Dn22 mm fitting
Stagnation temperature: 190°C
Prossure dropper module at 120l/h: 5 mbar

Recycling

We are responsible to use environment friendly materials in our products and to gather these materials for recycling.

Sunda is constantly improving its products; therefore specifications are subject to change without prior notice.

1997 UBC Seismic Zone Map

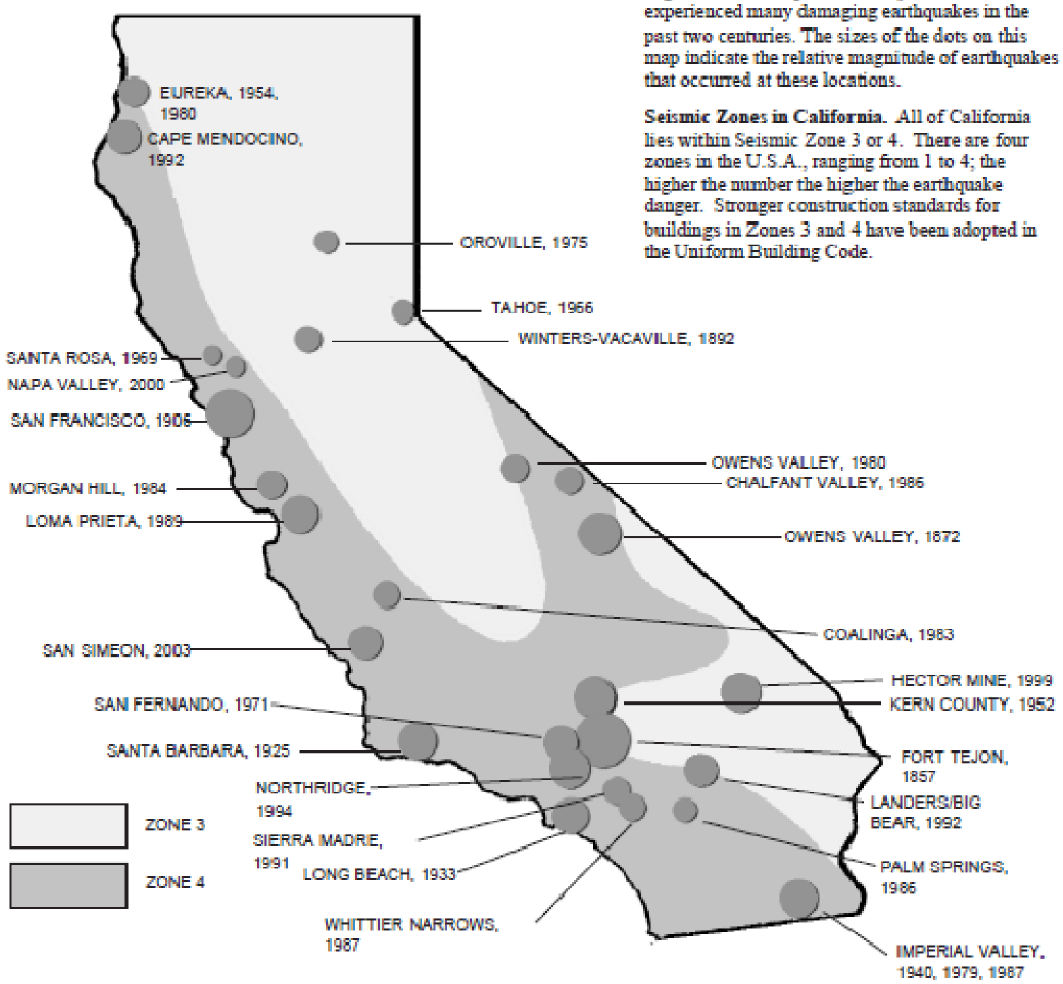


EARTHQUAKE MAPS OF CALIFORNIA

DAMAGING EARTHQUAKES IN CALIFORNIA

Figure 7—Earthquake history. California has experienced many damaging earthquakes in the past two centuries. The sizes of the dots on this map indicate the relative magnitude of earthquakes that occurred at these locations.

Seismic Zones in California. All of California lies within Seismic Zone 3 or 4. There are four zones in the U.S.A., ranging from 1 to 4; the higher the number the higher the earthquake danger. Stronger construction standards for buildings in Zones 3 and 4 have been adopted in the Uniform Building Code.



Source: California Geological Survey, 1986; Earthquake History of the U.S., U.S. Department of Commerce and Interior, 1982; Records of California Office of Emergency Services; compiled and revised by California Seismic Safety Commission, 2004; International Code Council, Uniform Building Code 1997 Edition.

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MAJOR EARTHQUAKE FAULTS IN CALIFORNIA

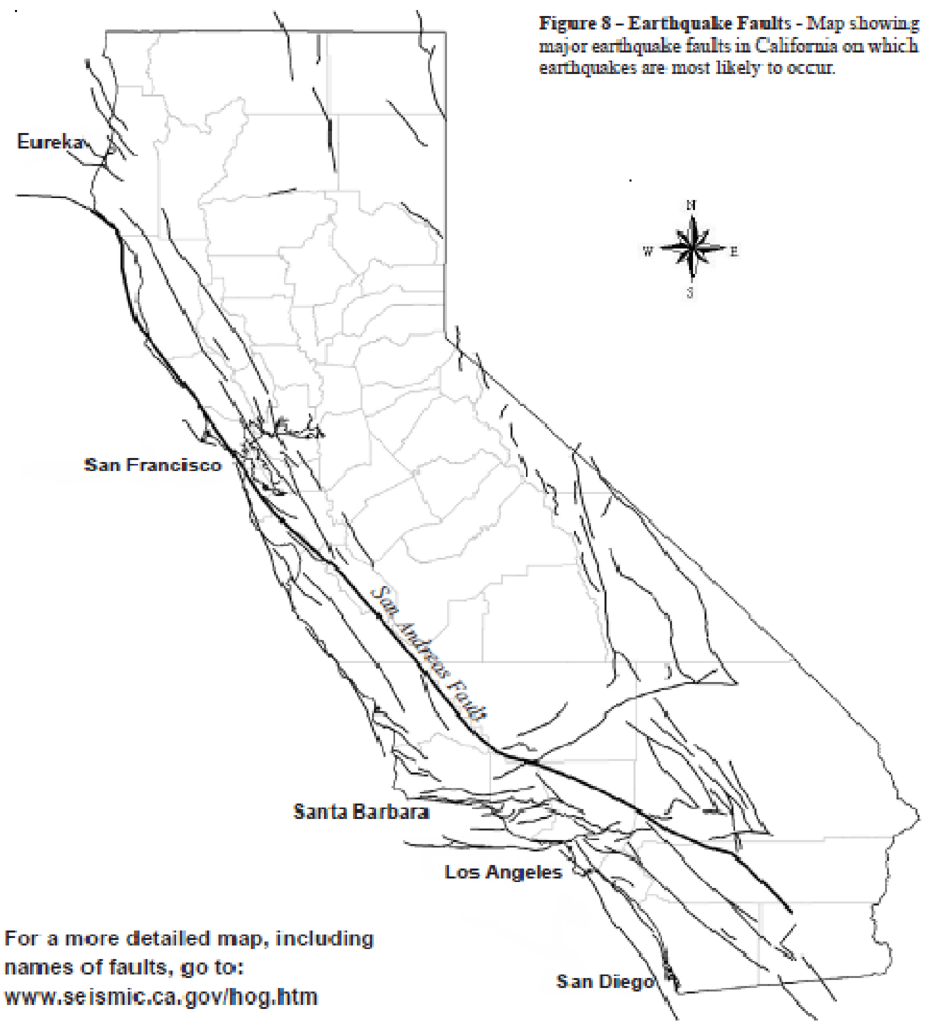

Figure 8 – Earthquake Faults - Map showing major earthquake faults in California on which earthquakes are most likely to occur.

For a more detailed map, including names of faults, go to: www.seismic.ca.gov/hog.htm

Map courtesy of California Geological Survey. Fault locations modified from seismic sources used in Revised 2002 California Probabilistic Seismic Hazard Maps.

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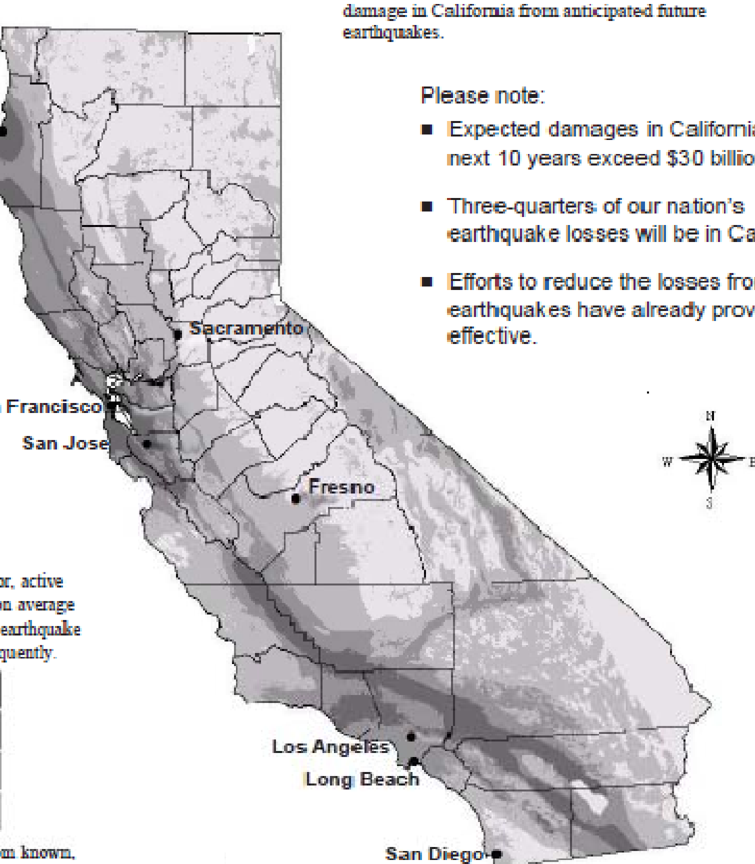
SIMPLIFIED EARTHQUAKE SHAKING POTENTIAL MAP FOR CALIFORNIA

Figure 9 - Earthquake Shaking Potential Map - This map shows the relative intensity of ground shaking and damage in California from anticipated future earthquakes.



Please note:

- Expected damages in California in the next 10 years exceed $30 billion.
- Three-quarters of our nation's earthquake losses will be in California.
- Efforts to reduce the losses from earthquakes have already proven effective.

Regions near major, active faults. These will on average experience stronger earthquake shaking more frequently.

Regions distant from known, active faults. These will experience lower levels of shaking less frequently.

For a full color version go to: www.seismic.ca.gov/hog.htm

Data source: California Seismic Safety Commission, California Geological Survey, Governor's Office of Emergency Services, and United States Geological Survey, April, 2003, Earthquake Shaking Potential for California, California Seismic Safety Commission Publication No. 03-02.

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