Prepared by

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Structural Option

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Architectural Engineering

Pennsylvania State University 2012

Southwest Housing, Arizona State University

Thesis Proposal

Table of Contents

Executive Summary

The Southwest Student Housing building is a 20-story residential building for the students of Arizona State University. This building is located in Tempe, Arizona, where there is no snow load and seismic design category B. The unique construction process for this building's design makes it very useful as a generalized building method: it is extremely fast and efficient, with low erection costs. The applicability of this sort of design to other climates, soils, and loading conditions is important to investigate in order to be able to expand construction to any other area within the country. As a result of this importance, the proposed thesis in this document focuses primarily on evaluating and redesigning the structural system for a location with high seismicity, such as St. Louis, Missouri.

Relocating this building to a location with high seismicity would put it into seismic design category D, E, or F. As a result of this increase in design category rating, the concrete cores that comprise the entirety of the lateral and gravity system will need to be redesigned, potentially with a higher strength concrete. The methodology for anchoring the floors to the cores will need to be re-evaluated for higher SDC. The building envelope will also need be examined to accommodate larger lateral drifts induced by strong earthquakes.

The alterations to the structure to resist strong earthquakes will require stiffer and stronger shear walls. Therefore, openings in the concrete shear walls need to be minimized. In addition, the floor plans will need to be re-evaluated and re-arranged to accommodate the new seismic requirements. Rearranging the floor plan will potentially result in a change to the current modules that comprise each floor of the building. Time permitting; the changes to these modules also will need investigation.

There is also potential to apply this building design as a sustainable building design. Sustainability will need to be evaluated, and the changes necessary to bring the building to LEED certification will need to be established.

The cost and schedule impacts of both enhancing the structural system for SDC D or higher and boosting the LEED points of the building to attain LEED certification will also need to be investigated and compared to the existing design. Ultimately, the goal of this proposed thesis is to expand the application of this building design and construction method to different locations and to sustainability, and to be able to quantify this versatility of application by showing cost and schedule adjustments from the existing design.

Introduction

The Southwest (SW) Student Housing building is a 20-story high-rise for students attending Arizona State University. The building site is located in a downtown area, at 1000 Apache Blvd. East in Tempe, Arizona (see Figure 1, the site is highlighted in red[1]). The building plans are designed to accommodate 528 beds in 268 units, with an emphasis on modularity for ease and economy of construction. There is additional potential to include an automated parking facility on the first level of the building, which can be accounted for in the initial building design. A rendering of the potential building design can be observed on the front cover of this report.

Figure 1: Site Location, 1000 Apache Blvd. East, Tempe, AZ

This particular building has a unique structure designed for easy assembly on site to enable extremely fast and efficient construction. The building's gravity and lateral system are one and the same: a series of three 8-inch thick concrete cores, 25' wide and 25' long which can be classified as load-bearing structural shear walls. These cores are constructed using slip-forms to within a 1/8" tolerance. The roof of the building is then assembled on the ground around the cores in two parts and lifted into place using six 75-ton strand jacks. Each subsequent floor is then assembled on the ground, half the floor area at a time (with the joint located at the precise halfway point of the floor plan, as indicated in Figure 2), and lifted into place. The building is essentially constructed from the top, down.

The floors are constructed using metal deck with lightweight concrete and structural steel beams. Each floor has a similar and regular floor plan (and thus, loading), with residential areas for 23' on each side of a 6'-wide corridor running through the center of the building, lengthwise (see Figure 2 below).

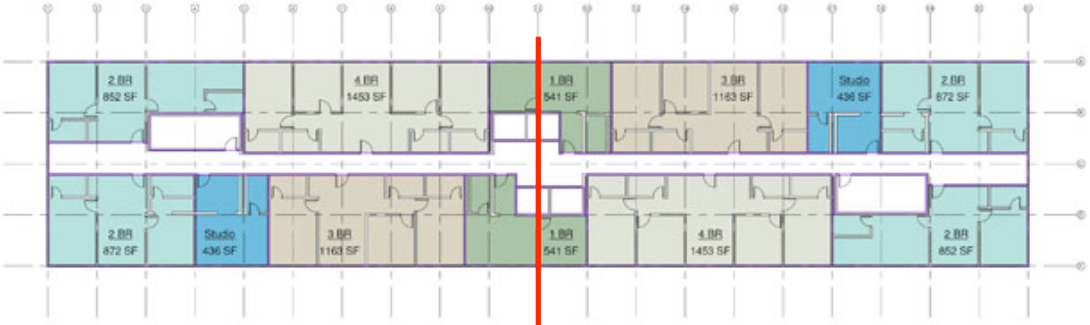

Figure 2: Typical Building Floor Plan

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[1] Taken from http://maps.google.com

Structural Systems

Foundation

The SW Student Housing building will exert significant loads to the foundation elements, according to the geotechnical report for the area. As a result, this building will require a deep foundation system that penetrates through to the second layer of soil on the site to limit settlement. The first layer of the site is Silty Sand and Poorly Graded Sand for a depth range from 10' to 35'. The second layer of soil on the site is Sand Gravel Cobble, from a depth of 35' to 100'.

The geotech report recommends drilled piers, with no pier shaft sized to a diameter of less than 12". Each pier should penetrate at least twice the shaft diameter into the second layer of soil. The calculated settlement for this pier configuration is less than one inch for an isolated pier shaft with a diameter of less than 60". A potential foundation layout is shown in Appendix I, with relevant calculations.

Floor System

The floor system is the same on all floors. This system consists of 3-1/4" lightweight concrete on 3" metal deck, with a minimum gage of 20. The composite deck is supported by a structural steel frame, with wide-flange sizes ranging from W14x22 infill beams to W24x176 interior girders, as indicated by the typical framing shown in Figure 3, and reiterated in the notes included in Appendix A. Both girders span the length of the building (250'), and all typical load beams span the width of the building (52'). Infill beams span either 12'-6" or 24', depending on their location within the building. The typical members are labeled in Figure 3. Every structural steel element in the typical floor framing is cambered. Some members are cambered up to 4 inches at the cantilevered ends (See Appendix A for the project structural engineer's camber diagrams).

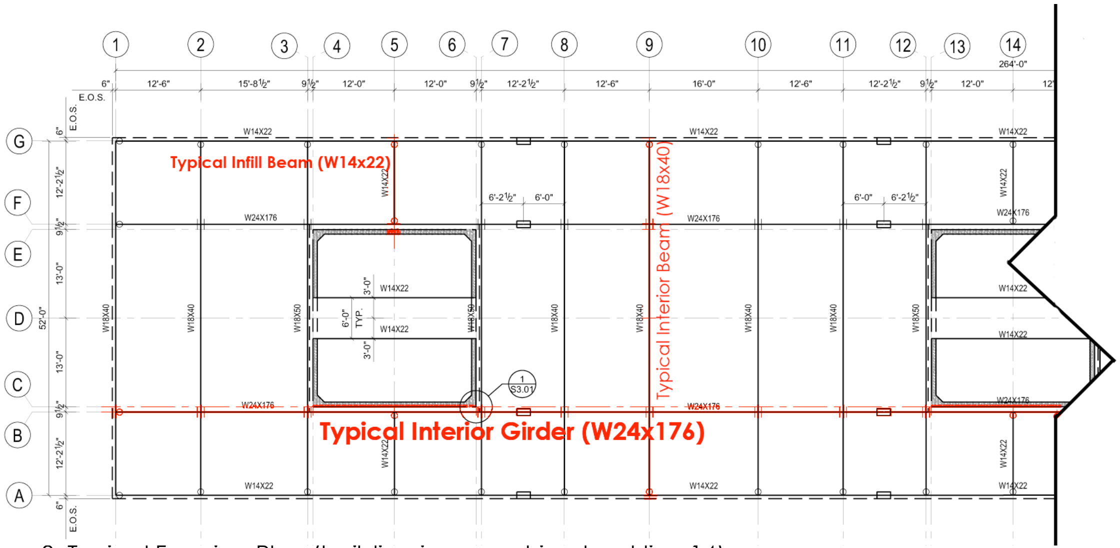
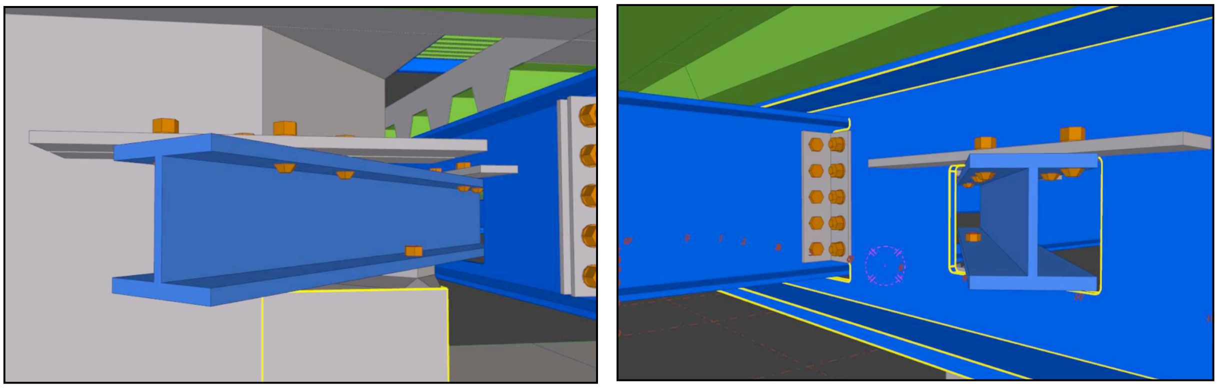


Figure 3: Typical Framing Plan (building is symmetric about line 14)

Gravity and Lateral System

Unlike some conventional construction, this building has no columns. The three 8-inch thick, 25'x25' (at the centerline) concrete cores carry all of the gravity weight of each floor. As a result, the floors are cantilevered off of the cores (spaced at 62'-6" on center), which support the structural steel floor framing via a wide-flange beam inserted through each of the four corners in every core, as illustrated in Figure 4. During construction, half of a floor is lifted via the 75-ton strand jacks and then fitted into place using the aforementioned corner details. The cores are designed as structural walls using ACI 318-05. As a result, each core satisfies the minimum reinforcement amount (one layer of the smallest permitted rebar size by code).



Figures 4a and 4b: Corner detail at every floor, framing into the interior girder to support each level

The concrete cores are also the building's sole lateral system, and provide lateral bracing in both directions in the form of shear walls. For clarity, the core walls are highlighted in green in Figure 4, with the enclosed area filled in red. It can be observed in Figure 6 on the next page that the openings are only present for a minimal height on each floor so that the shear wall segments can be connected via large coupling beams for added rigidity and support.

Figure 5: Typical Building Floor Plan (Core areas are highlighted in red, core walls are highlighted in green)

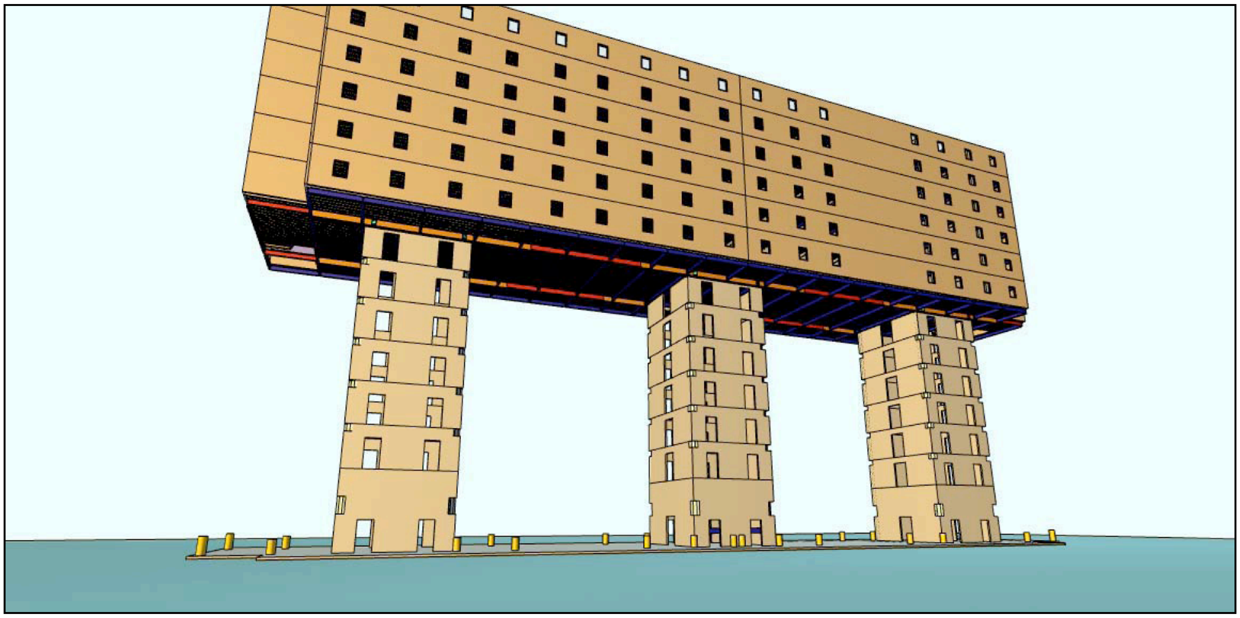


Figure 6: Rendering of visible openings in concrete cores

The theory behind this building design seems to be simplicity: a single set of structural elements to resist combined gravity and lateral loading. The design of these elements was carried out using a combination of hand calculations and computer modeling for more precise answers. Hand calculations were found to be generally with 10% of the computer modeling outputs.

Roof System

The roof system is a simple, long-lasting construction of the typical floor framing (3-1/4" lightweight concrete with 3" metal deck, minimum 20 gage), 3" of rigid insulation and an Ethylene Propylene Diene Terpolymer (EPDM) membrane on top. There is no mechanical equipment on the roof- the major elements of the mechanical system will be located on the ground floor, and will serve each unit in the building via a 2-pipe system.

Problem Statement

The design of the Southwest Student Housing building is very simple, but elegant. The balance of cost vs. speed of construction has been finely tuned, and the structural design is above adequate for the design loads in its location in Tempe, Arizona. Modularity is a key concept within the design. It is used to accelerate the construction process and have each floor equipped with façade walls and MEP systems within the 4 days it takes to pour and finish each floor. The floor system is a reasonable solution for the construction method when compared to other alternatives. Little can be altered in this design that could allow for faster construction or lower construction costs.

An important item to consider is the applicability of this design to other areas of the United States, such as areas with high seismic activity. This design is intended for construction in a wide variety of locations and would benefit from refinement to make it suited to high seismicity areas. Therefore, it is highly pertinent to investigate the functionality and alterations of this building design and construction method for an area such as St. Louis, Missouri. St. Louis was chosen to minimize the number of design parameters that influence the cost of construction. Appendix C shows a comparison of the costs of construction and the seismic design coefficients for several U.S. cities with high seismic activity. The cost of construction in St. Louis, MO is the closest to that of the existing location. In order to bring the building into SDC D, the site class will have to be altered from C to D. To accommodate these changes, the structural design would need to be reexamined (especially the floor-to-core connections), as would the cost for the new system design and any changes to the construction schedule. There is also a great potential need to alter the floor plans and modules to accommodate the structural design changes. The building envelope system might also need to be examined for ability to accommodate seismic drift, if time permits.

Additionally, the current building design is not LEED certified. Sustainability has been an important design aspect of many buildings in the twenty-first century, and should be considered with each new building design. As a result, it is crucial to consider what it would take for the building to achieve, at minimum, LEED certified status. More importantly, any changes or additions to the building design would need to be practical and appropriate for the occupancy, budget and location.

Proposed Solutions

If this building were relocated to and redesigned for St. Louis, MO with site class D, it would need to be designed as a building in Seismic Design Category D. To alter the design of this building for SDC D, the new seismic design loads would need to be calculated and compared to new wind design loads.

The concrete cores would have to increase in cross-sectional area and reinforcing. Potentially, a higher strength concrete might prove useful when changing building locations to SDC D. A careful review of the floor plans would be necessary, in order to change the floor plan to minimize openings in the core walls.

Additionally, the floor-to-core connections would need to be investigated and altered to satisfy special seismic provisions. If time permits, the cladding would need to be investigated and redesigned to accommodate seismic drifts and seismic design forces on nonstructural components.

The solutions to the problem statement would also require analysis and design in several breadths for thoroughness, and to ensure that these redesigns can truly be compared to the original design of the Southwest Student Housing building.

Breadth Studies

To truly be able to compare the original design to the design in an area of high seismicity, it is necessary to take an in-depth look at the construction costs and schedules. The impact of altering the design for high seismic lateral loads would be great: the cost for construction would increase significantly, due in part to increased material cost. It would be necessary to analyze the area prices for different strengths of concrete and compare the costs to the current building design. It would also be important to consider the schedule, which could potentially be prolonged, resulting in the owner (Arizona State University) losing potential profits from opening the building earlier. An analysis of the profit change due to schedule change would also be necessary.

Additionally, the floor plans and modules in the building would need to be redesigned to accommodate the alterations to the structure. Potential streamlining of the module design might accelerate the construction schedule and provide a greater profit that would need to be considered in cost and schedule evaluations. The module design might also have separate changes relating back to initial manufacturing costs, which should be examined if time permits. Additionally, it would also be beneficial to examine the potential for a module design that is applicable to this type of building design in both SDC B and SDC D.

As a result of the need for in-depth cost and schedule evaluation, one of the breadth studies can be classified as a Construction Management breadth. The other breadth study would be with regards to Architecture, and how the floor plan and module design would need to be modified as a result of the changes to the structural system. The Architecture breadth would involve module design and floor plan design, including an evaluation of the locations of openings, stairs and elevators.

A third breadth study to carry out will center on Sustainability. This breadth will require evaluation of LEED points throughout the building, as well as analysis of potential changes that can be made to bring the building to LEED certified status. Ultimately, if LEED certified status can be achieved, a cost and schedule evaluation will follow to gauge the impact of expanding the sustainability of the building design.

Methods

In order to carry out the investigations presented in the Proposed Solutions section of this document, several ETABS models will need to be constructed. Basic dimensions for members in the model will be calculated using excel and hand calculations, satisfying ACI 318-08 for concrete members, and the 13th edition of the Steel Construction Manual by AISC for steel members. These initial dimensions will then be modeled in ETABS under the new design loads for the exercises stated in the Problem Statement section of this document.

The design loads will be calculated with the use of ASCE 7-05. All load calculations will be performed using factored loads, and all members will be designed using Strength Design. Evaluation of strength, drift, cost and timeline will provide comparisons between each proposed solution to the design problems. Ultimately, the outcome of the analysis will lead to a concrete estimate of the changes in cost and schedule for the application of this design in an area with high seismic lateral loads, and for bringing this building design up to LEED certified.

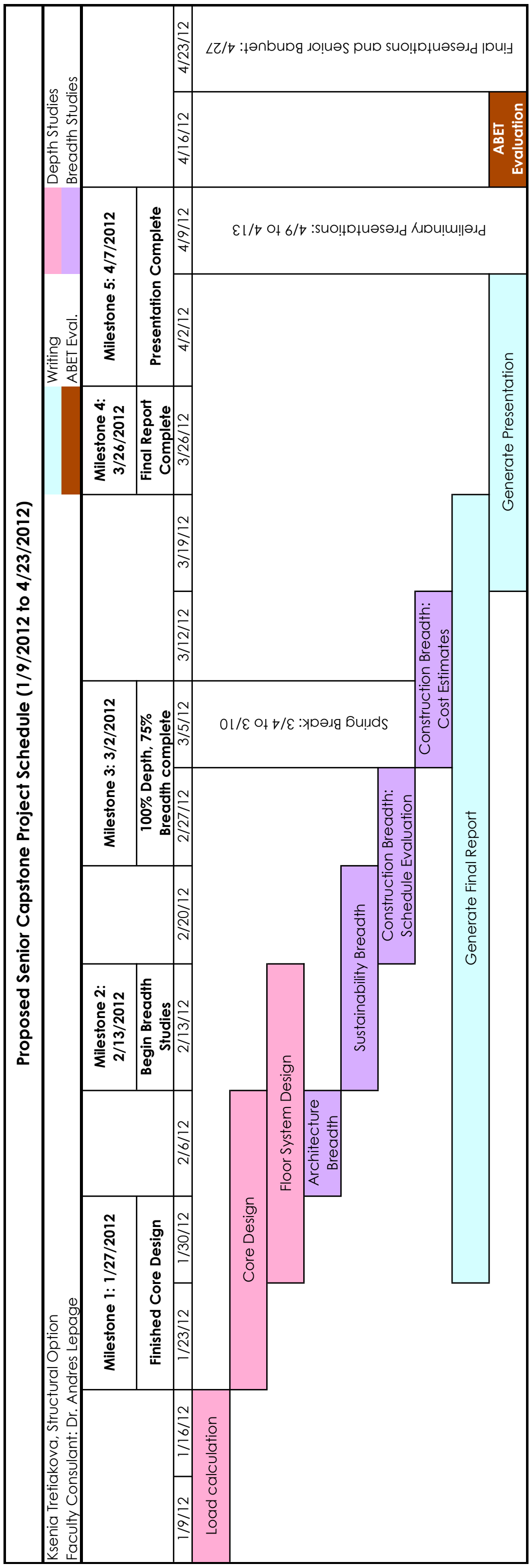
Additionally, all of the design parameters will be checked against IBC 2006 to assure code compliance throughout the project design. Revit Architecture, Google Sketchup, and AutoCAD will be used to create floor plans, and module designs as applicable. Primavera, Microsoft Project, and RS Means will be used for schedule creation and cost estimation. The new schedules and cost estimates will then be compared to the schedule and cost estimates for the existing system

Tasks and Tools

I Relocating the building to SDC D
- Task 1: Re-establish design loads
    i) Lateral loads
    ii) Snow loads
    iii) Estimate gravity loads
- Task 2: Concrete shear wall design
    i) Estimate dimensions and reinforcing
    ii) Model new shear walls in ETABS
    iii) Finalize core sizes
- Task 3: Floor system design
    i) Examine code requirements for floor anchoring to cores
    ii) Design floor system to satisfy code requirements including special seismic requirements for floor diaphragms
    iii) Verify estimated gravity loads
    iv) Model in ETABS
    v) Finalize dimensions and gravity loads

II Breadth Studies
- Task 4: Architecture
    i) Evaluate assumptions about openings from Task 2
    ii) Re-arrange floor plan to streamline traffic and minimize openings in shear walls according to analysis assumptions
    iii) Examine floor modules and redesign as needed
    iv) Evaluate floor module applicability to existing and new designs
- Task 5: Sustainability Study
    i) Evaluate LEED points for the existing building
    ii) Examine potential for new LEED points that could be applied to the building
    iii) Alter the current building design to accommodate identified new LEED points established in part ii
- Task 6: Construction Management
    i) Material takeoffs for structural depth study
    ii) Cost estimation for structural depth study
    iii) Schedule evaluation for structural depth study
    iv) Cost estimation for Sustainability breadth study
    v) Schedule evaluation for Sustainability study

Schedule


Proposed Senior Capstone Project Schedule (1/9/2012 to 4/23/2012)
Ksenia Tretiakova, Structural Option
Faculty Consultant: Dr. Andres Lepage
Writing
ABET Eval.
Depth Studies
Breadth Studies
Milestone 1: 1/27/2012
Finished Core Design
Milestone 2: 2/13/2012
Begin Breadth Studies
Milestone 3: 3/2/2012
100% Depth, 75% Breadth complete
Milestone 4: 3/26/2012
Final Report Complete
Milestone 5: 4/7/2012
Presentation Complete
1/9/12
1/16/12
1/23/12
1/30/12
2/6/12
2/13/12
2/20/12
2/27/12
3/5/12
3/12/12
3/19/12
3/26/12
4/2/12
4/9/12
4/16/12
4/23/12
Load calculation
Core Design
Floor System Design
Architecture Breadth
Sustainability Breadth
Construction Breadth: Schedule Evaluation
Construction Breadth: Cost Estimates
Generate Final Report
Generate Presentation
ABET Evaluation
Spring Break: 3/4 to 3/10
Preliminary Presentations: 4/9 to 4/13
Final Presentations and Senior Banquet: 4/27

Conclusion

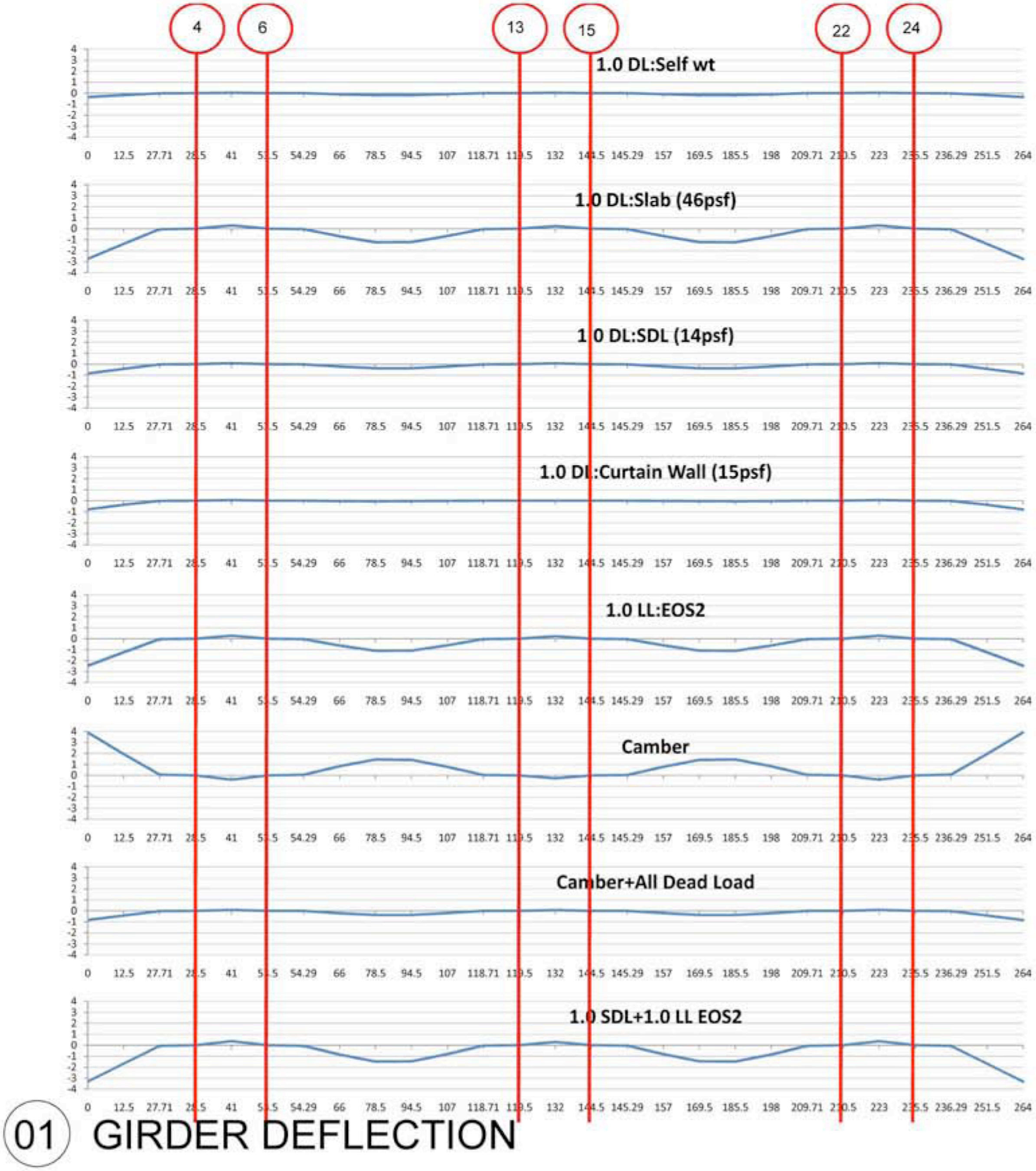
Due to the speed and cost-effectiveness of the current building design and construction methods, it would prove beneficial to understand how this methodology can be applied to other locations and sustainability standards across the United States. The diversity of this methodology makes it ideal for future construction. Having an idea of the cost and schedule separation between designs in different locations, or designs for different LEED standards, is essential toward applying and expanding on the inherent diversity.

The existing building design will be relocated to St. Louis, MO and given a site class of D, for evaluation of the design under new, very different lateral loads. This design will have to be altered to account for the higher seismic lateral loads that would be encountered in those areas, which coincide with SDC D. The cores will need to have their geometry and materials altered. Openings will need to be minimized, which will result in a rearrangement of the floor plan to accommodate the new shear wall design in the cores. In response to the rearranged floor plan, the modules that comprise portions of each floor of the building will need to be reevaluated. The building cladding will also need to be examined and redesigned for ability to accommodate seismic lateral drifts. Once the building design itself is finalized, the schedule of construction will need to be generated, and the cost of the building will need to be examined.

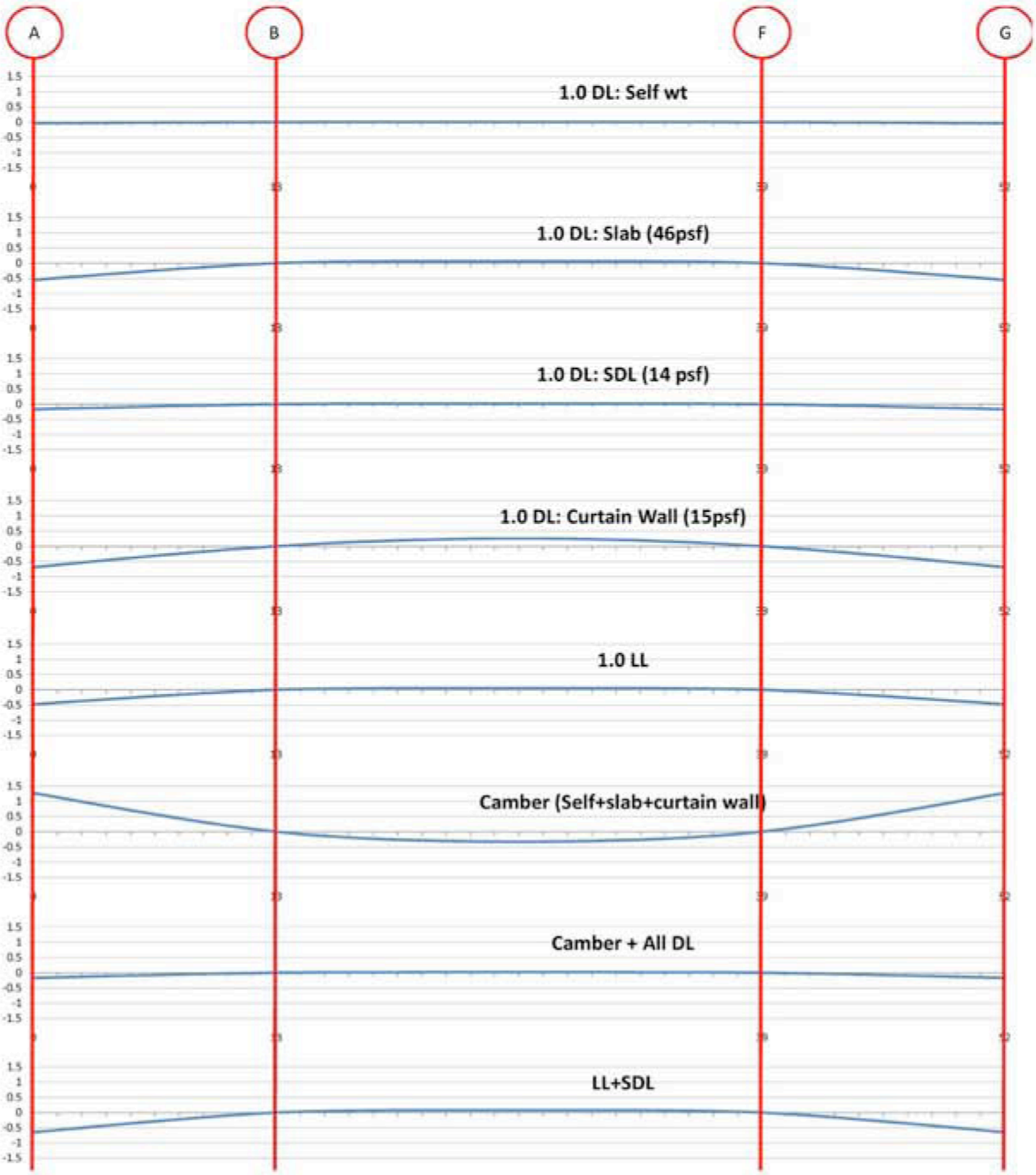
The existing building design will additionally be evaluated for sustainability via accruement of LEED points. Additions and alterations to bring the building to LEED certified status will be examined and estimated, with pragmatism in mind. The cost of building this design at a LEED certified level of sustainability will be compared to the existing design to understand the fiscal impact of sustainable design.

Appendices

Appendix A – Building Information Notes



01 GIRDER DEFLECTION



02 BEAM DEFLECTION

TECH 1

APPENDICES - APPENDIX A
SOUTHWEST STUDENT HOUSING

2

BUILDING INFORMATION

- MODEL CODE: IBC 2006 AS AMENDED BY THE CITY OF TEMPE, ARIZONA
- DESIGN CODES: AISC "SPEC FOR STRUCTURAL STL BLDGS" AISC 360-05
  ACI "BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONC" ACI 318-05
- STRUCTURAL STANDARDS: ASCE 7-05

I WILL USE
ASCE 7-05, AISC 13TH ED, ACI 318-05, IBC 06

- DEFLECTION CRITERIA
  ↳ STRUCTURAL STEEL IS ALL CAMBERED TO DEAL W/ HIGH DEFLECTIONS.
  OUT OF CURIOSITY - HOW DOES ONE ASSEMBLE A CAMBERED STRUCTURAL STEEL FLOOR IF THE METHOD IS TO SLIDE BEAMS THROUGH PLASMA-CUT HOLES ON HYDRAULIC ROLLERS?
  CHARLIE'S NOTES: $\frac{L}{360}$ FOR LIVE $\frac{L}{240}$ FOR TOTAL $\frac{H}{400}$ FOR DRIFT

- STRUCTURAL OVERVIEW:
  - FOUNDATIONS - ~~MAT~~ SPREAD FOOTING ACCORDING TO CHARLIE ←
    ACCORDING TO SOILS REPORT RECOMMENDATIONS -
    BLDG WILL EXERT SIGNIFICANT LOADS TO FOUNDATION ELEMENTS.
    ↳ EMPLOY DEEP FOUNDATION SYSTEM TO LIMIT SETTLEMENTS
    - DRILLED PIERS + MAT

ACCORDING TO TG PACKAGE:
(5) 350 YD3 CORE MATS,
PERIMETER GRADE BEAMS,
SLAB ON GRADE ON TOP

AXIAL CAPACITY = SKIN FRICTION OF SHAFT + END BEARING AT TIP

SOILS:	DEPTH	FRICTION	END BEARING
I SILTY SAND + POORLY GRADED SAND	10-35'	0.4 KSF	—
II SAND GRAVEL COBBLE	35-100'	2.5 KSF	30 KSF

PIER SHAFTS SHOULD PENETRATE AT LEAST 2.5 × PIER ϕ INTO II LAYER & NO PIER ϕ < 12"

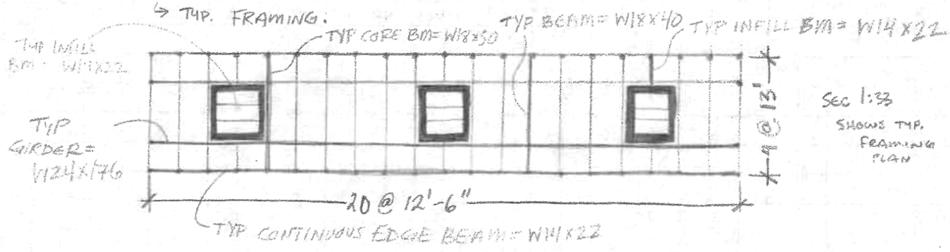
MIN CLEAR SPACING = 3 × BIGGEST ADJACENT PIER ϕ

PREDICTION: FOR ISOLATED PIER, ϕ < 60", SETTLEMENT ≤ 1"

CHARLIE'S NOTES: BLDG DOESN'T HAVE LOCAL? SETTLING B/C SPANS ARE LONGER → NO DIFFERENTIAL SETTLING

- FLOOR SYSTEM - TYP. FOR ALL FLOORS - 3.25" LIGHTWEIGHT CONCRETE ON 3" DECK
  FOR HAND CALCS, CHARLIE ASSUMED 4.5" LIGHTWEIGHT CONCRETE
  ~~WHEELING CORRUGATED 3.0 SB LW.C.~~
  (P 14 IN PDF) 20 GAGE
  GO W/ VULCRAFT

  SUPPORTED BY STRUCTURAL STEEL FRAME
  ↳ TYP. FRAMING:



SEC 1:33 SHOWS TYP. FRAMING PLAN

- FRAMING SYSTEM - SEE ABOVE FOR FLOOR FRAMING SYSTEM
  SEE BELOW FOR GRAVITY FRAMING SYSTEM
- LATERAL SYSTEM - (3) CONCRETE CORES: 8" THICK, 25' × 25' ON CENTER (KIND OF)
  SPACED 62'-6" APART (STARTING AT CENTER)

Appendix B – Gravity Load Calculations

CALCULATED LOADS

★GRAVITY

- CONSTRUCTION DEAD LOAD

• DECK - 3.0 VLI (VULCRAFT COMPOSITE DECK) 20 GAGE
3.25" LIGHTWEIGHT CONCRETE
DECK WEIGHT = 2.14 PSF
CONCRETE WEIGHT = 46 PSF
TOTAL = 48.14 PSF

ADDITIONAL NOTES FOR LATER
MAX UNSHORED SPAN
1 SPAN = 10'-6"
2 SPAN = 12'-10"
3 SPAN = 13'-3"
MAX SPAN ON PLAN? 12'-6"
(ASSUME BELOW DECK ORIENTATION)

MAX SUPERIMPOSED LIVE LOAD ON MAX SPAN? 73 PSF
↑ VERIFY THAT THIS IS LL ONLY
(P55 OF NUCOR DECK MAN.)

• STRUCTURAL STEEL - ASSUME ≈ ~~8 PSF~~
CHECK CURRENT SIZES:

SIZE	LENGTH	#	WT (K)
W18X50	52	6	15.6 K
W18X40	52	12	25 K
W14X22	13	6	1.7 K
W24X176	262.5	2	42.4 K
W14X22	262.5	2	11.6 K
			146.3 K

TYP FLOOR DIMENSIONS:
250' × 52' = 13 000 SF

APPROX. WEIGHT OF STRUCTURAL STL:

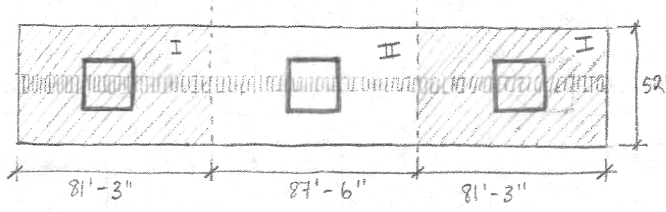
$$\frac{146.3 \times 10^3}{1300} = 11.25 \text{ PSF}$$

STRUCTURAL STEEL - ASSUME $\boxed{11 \text{ PSF}}$ ✓
→ TOTAL CONSTRUCTION DEAD LOAD = 48.14 + 11 = 59.14 → 59 PSF

- SUPERIMPOSED DEAD LOAD
→ ASSUME SDL OF 15 PSF ← ASSUMPTION BY ENGINEERS. SHOULD HAVE CONFIRMED - PARTITIONS NOT INCLUDED.

- LIVE LOAD
• RESIDENTIAL = 40 PSF
• PARKING = 40 PSF
• CORRIDORS = $\boxed{80}$ ON FLOORS ABOVE GROUND (PSF)
= 100 ON GROUND FLOOR (PSF)
(THERE IS A 6' WIDE CORRIDOR RUNNING THRU THE CENTER OF THE BUILDING IN THE LONG DIRECTION)
*ENGINEERS JUST TOOK LL TO BE 40 PSF

LIVE LOAD REDUCTION:



CALCULATED LOADS (CONTINUED)

REDUCTION FACTORS:

SECTION	AREA/FLOOR	# FLOORS	FACTOR
I	~4390 SF	1	0.5
		>1	@2, 0.41 @>2, 0.4
II	4725 SF	1	0.5
		>1	0.4

} WILL JUST ROUND TO 0.4

$$L = L_0\underbrace{\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right)}_{\substack{\geq 0.5 \ (1\text{ FLR}) \\ \geq 0.4 \ (>1\text{ FLR})}} \qquad K_{LL} = 1$$

SAMPLE CALCULATIONS

SECTION I, 1 FLOOR:

$$0.25 + \frac{15}{\sqrt{1 \times 4390}} = 0.476 \to 0.5$$

>1 FLOOR:

$$2? \quad 0.25 + \frac{15}{\sqrt{1 \times 4390 \times 2}} = 0.41$$

$$3? \quad 0.25 + \frac{15}{\sqrt{1 + 4390 \times 3}} = 0.38 \to 0.4$$

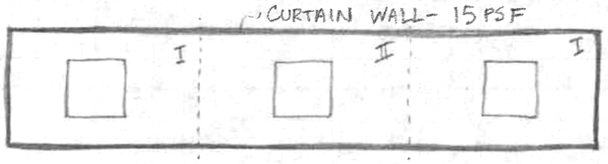
$$\boxed{80\text{ PSF}} \times 0.5 = \underline{\underline{40\text{ PSF}}}$$ (FOR CORE CALCULATIONS)

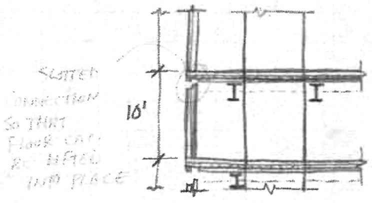
— MECHANICAL EQUIPMENT

ON GROUND FLOOR, W/ 2-PIPE SYSTEM FOR HEATING/COOLING ROOMS

CHILLER, PUMPS, ETC. ON GROUND FLOOR

— WALL LOADS





EACH FLOOR SUPPORTS ITS RESPECTIVE "CURTAIN WALL"
∴ FLOORS 2-19 HAVE 10' PERIMETER CURTAIN WALLS @ 15 PSF

— SNOW LOADS

$$p_f = 0.7\, C_e C_t I p_g \to 0$$

(FLAT ROOF)

$$p_f = 0$$

FIGURE 7-1 (ASCE 7-05)

$$p_g = \begin{matrix} (5000) & 10 \\ (4600) & 5 \\ (3500) & \text{ZERO} \end{matrix}$$

TEMPE, AZ IS @ AN ELEVATION OF... 1140 - 1495 FEET

$$1495 < 3500 \to p_g = 0$$

Appendix C - Cost Estimates and Seismic Design Coefficients for Cities

Material	**Properties**	**Existing Tempe, AZ Material Cost**	**Seattle, WA Material Cost**	**Anchorage, AK Material Cost**	**St Louis, MO Material Cost**	**Units**
Steel Floor Deck						
	Non-Cellular 3" Composite Deck, Galvanized					
	20 Gauge	**1.77**	2.06	2.53	**1.98**	ft^2
	18 Gauge	**2.16**	2.51	3.09	**2.41**	ft^2
	Open Deck, Wide Rib					
	3", 16 Gauge	**4.2**	4.88	5.99	**4.68**	ft^2
	6", 14 Gauge	**6.98**	8.11	9.96	**7.79**	ft^2
Structural Steel Members						
	W14x26	**30.46**	34.88	37.73	**34.59**	ft
	W14x74	**87.11**	99.74	107.88	**98.91**	ft
	W18x40	**47.12**	53.96	58.36	**53.51**	ft
	W18x46	**54.26**	62.13	67.2	**61.62**	ft
	W18x50	**59.02**	67.58	73.1	**67.02**	ft
	W24x146	**172.31**	113.36	213.4	**195.66**	ft
	W27x114	**134.23**	153.69	166.24	**152.42**	ft
Reinforcing Steel						
	#3 to #18	**955.89**	1065.33	1358.6	**859.28**	ton
Concrete						
	Normal Weight					
	3000 psi	**82.76**	101.48	139.29	**89.5**	yd^3
	4000 psi	**86.11**	105.58	144.92	**93.11**	yd^3
	8000 psi	**172.22**	211.15	289.4	**186.22**	yd^3
	Light Weight					
	3000 psi	**111.19**	136.33	187.13	**120.23**	yd^3
	4000 psi	**117.88**	144.53	198.39	**127.46**	yd^3

	If existing site class (C)			
	Tempe, AZ	**Seattle, WA**	**Anchorage, AK**	**St Louis, MO**
Ss	**0.30**	1.25	1.50	**0.60**
Fa	**1.20**	1.00	1.00	**1.16**
Sms	**0.36**	1.25	1.50	**0.70**
Sds	**0.24**	0.83	1.00	**0.46**
S1	**0.08**	0.70	0.60	**0.15**
Fv	**1.70**	1.30	1.30	**1.65**
Sm1	**0.14**	0.91	0.78	**0.25**
Sd1	**0.09**	0.61	0.52	**0.17**
SDC	**B**	**D**	**D**	**C**

	If site class D			
	Tempe, AZ	**Seattle, WA**	**Anchorage, AK**	**St Louis, MO**
Ss	**0.30**	1.25	1.50	**0.60**
Fa	**1.56**	1.00	1.00	**1.32**
Sms	**0.47**	1.25	1.50	**0.79**
Sds	**0.31**	0.83	1.00	**0.53**
S1	**0.08**	0.70	0.60	**0.15**
Fv	**2.40**	1.50	1.50	**2.20**
Sm1	**0.19**	1.05	0.90	**0.33**
Sd1	**0.13**	0.70	0.60	**0.22**
SDC	**B**	**D**	**D**	**D**