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# Undergraduate Students' Design and Cost Analysis of a 3-Story Building Based in Los Angeles, California

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## ABSTRACT

*A group of undergraduate students of various age groups and ethnicities were given a project to design a three-story, three-unit residential complex with GREEN components that would benefit the surrounding environment. The building should not exceed more than 2000 square feet and has to have a valid location in the Southern California area. The team designed the foundations, columns, beams, connections, LEED design and got an estimated cost analysis of the project. It was concluded that the project will cost around 2 million dollars to construct including labor and GREEN features. The consumer that is acquiring the property is likely to see a return of his LEED investments in the long term. The undergraduate engineers used the necessary resources such as RS means, RAM Steel Design, AutoCad and various other programs to complete this project. The project will also be LEED certified and be given the appropriate Certification based on its impact on the environment. This project tested the knowledge of the group of undergraduate students and prepared them for a real life scenario.*

**Keywords:** *Steel Design, Cost Analysis, LEED Design, Civil Engineering, Residential Building*

## INTRODUCTION

When the project was presented by Dr. Zirakian as our Senior Design Project, the objective as undergraduate students was to implement all our knowledge gained from our educational careers and implement them to all aspects into the building. Students from various backgrounds and ethnicities, designed the building's steel structure, foundations and LEED design. The cost analysis and architectural plans are also presented in the project.

The team of undergraduate students used the various resources available inside and outside of the school grounds. With the limitation placed on no in person meetings these past few months, various group meetings had to be held via zoom in order to work on the project efficiently and safely. Each group member contributed to help complete the project. The students worked productively with each other to overcome any challenges along the way. With many challenges presented the group of undergraduate students were able to produce a three-story three- unit residential GREEN complex.

The project consists of a multi-story residential GREEN complex, with 3 bedrooms, 3 bathrooms, a living room and a kitchen located on each floor, along with additional accessories. The building's location is 2427 Buckingham Rd., Los Angeles, CA., 90038. It is in the Culver City Area right of the Santa Monica Freeway. With the wellbeing of the environment being more of a hot topic around the world [6], it was an important goal to implement the necessary GREEN elements to make the project as environmentally friendly as possible.

After weeks of working together as a team and with help from the mentors of the project, the design project approached it's finishing stages. As a team of undergraduate students, being able to present this project is a milestone and an opening gateway to the foreseeable future as Civil Engineers.

## ARCHITECTURAL FEATURES

The lot size of the proposed property is 50 feet by 190.25 feet. According to CBC (California Building Code), the required minimum 15 feet front and rear setbacks and 6 feet side setbacks has been designed for the complex. The residential complex has a 3-story and 3 bed/ 3 bath unit at each floor. The proposed height for the building is 41 feet that includes 12.5 feet height of each floor and 3.5 feet height of parapet at roof level. At the first floor, the designed planter boxes at front setback will be used for drainage purpose and the bike parking has been designed for each unit. Also the common open space at the rear setback that has been designed, includes landscaping area and wood trellis to make shade for the seating area and provides a small storage and laundry room for each unit at each floor. The design of the second and third floor are the same as the first floor; the only difference is the balcony which is designed instead of a trash/recycle room at the first floor. At the roof, there is an area for the future solar panels and package unit for the third floor and split unit for the first and second floors and also designed an access staircase to connect all floors with the roof level. For the exterior materials of the building, there are horizontal metal siding panels for the first floor and stucco for the rest of the building. Also there is a designed tempered glass in aluminum frame for the windows and proposed 42 inches height solid parapet for the roof area and 42 inches height metal railing for the balconies. Fig. 1 shows a 3D view of the building that has been provided with the Autodesk Revit, Fig. 2 shows the first floor plan, Fig. 3 shows the second and third floor plans and Fig. 4 shows the elevations of the building.

**Fig1.** *3D view*

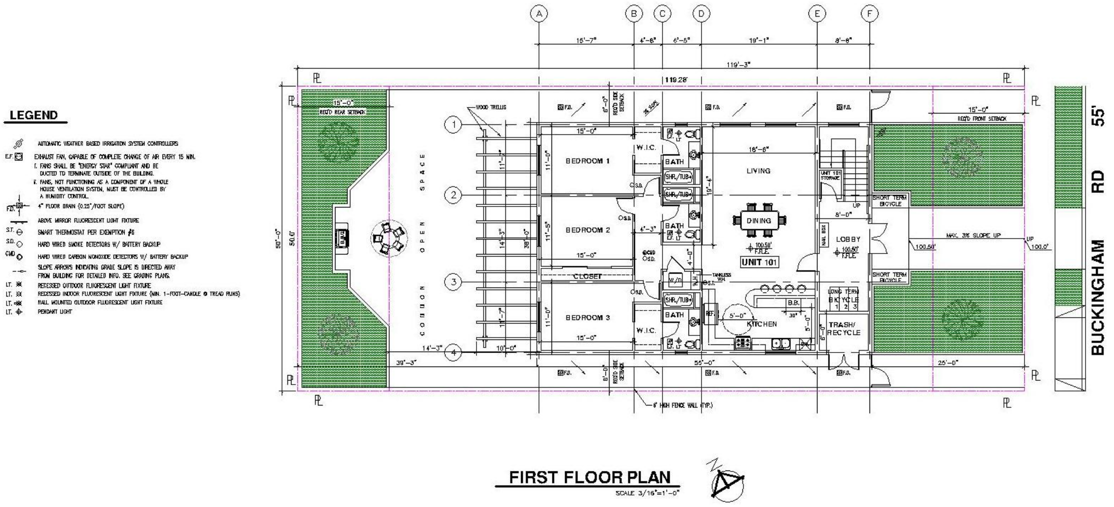


**Fig2.** *First floor plan*

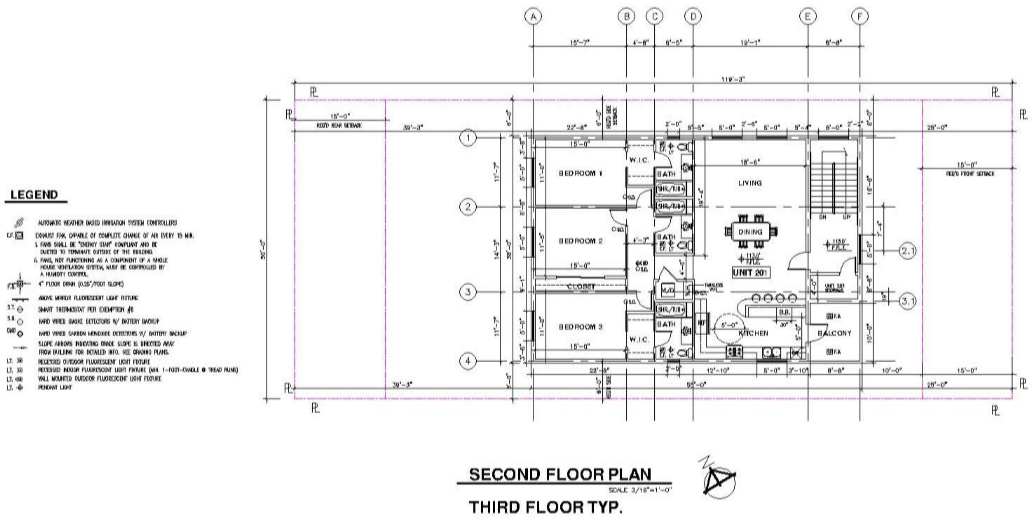


**Fig3.** *2nd/3rd floor plan*


**Fig4.** *Elevations*

## STRUCTURAL DESIGN

As stated before, when the project was given, the objective was to design the building using steel beams and columns throughout the building, which resulted in the use of different connections throughout the building. Some of those include bolts and nuts, welding, connecting plates and connecting angles. With this in mind, the use of the basic codes from various codes books had to be considered. Some of the code books used were the ASCE 7-16 [2] code book and the Steel Manual [3]. These books [4] and manuals gave the undergraduate students the basic formulas and conditions needed to apply in order to figure out what beams and columns were going to be needed. Following the codes and the conditions from these books the calculations needed for the beams, columns and foundations were able to be done. After careful calculations a W8×10, W10×14, W12×14, and W12×19 steel beam were going to be sufficient to carry the loads from our building [4]. Furthermore, the undergraduates were able to determine that a W10×33 column was going to be sufficient enough to carry the loads throughout the building. Once the beams and columns were calculated, the size of the footing and the rebar it would need was able to be calculated [1]. Once again after careful calculations, it was determined that a 4'×4' in length with #3 rebar at 12 inches on center. Table 1summarizes the results for the structural design. A summary of the seismic calculations is also provided in Table 2. After acquiring the hand calculations the Ram Modeling software was used to verify the work. Figs. 5 and 6 show the different beams and columns used in the Ram Modeling software. Figs. 7 and 8 show the beams and columns used in the Ram Modeling software.

**Table1.** *Summary of the results for structural design*

| Structural element | Design results |
|---|---|
| Beams | W8×10, W10×12, W12×14, W12×19 |
| Columns | W10×33 |
| Foundation | 4'×4' Pad Footing w/ #3 Rebar @ 12" O.C |

**Table2.** *Seismic load calculations*

| Building element | Length | Width | Quanity | Height | Total Length | Total area | Deduction | Volume | Unit weight | Deduction | W(lb) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Typ. Floor | | | | | | | | | | | |
| Slab | 55 | 38 | 1 | 0.5 | | 2090 | -138 | 1045 | 150 | -20700 | 146400 |
| Beams | | | | | | | | | | | |
| W 24x76 | 8.66 | | 4 | | 34.64 | | | | 76 | | 2632.64 |
| | 11.08 | | 6 | | 66.48 | | | | 76 | | 5052.48 |
| | 11.58 | | 15 | | 173.7 | | | | 76 | | 13201.2 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Columns | | | | | | | | | | | |
| W 10 x 33 | 6.75 | | 20 | | | | | | 33 | | 4455 |
| | | | | | | | | | | | |
| Floor finish | | | | | | 1740 | | | 16 | | 27840 |
| Exterior walls | 186 | | 1 | 11.5 | | 2139 | -534.75 | | 5 | | 10160.25 |
| interior walls | 197 | | 1 | 11.5 | | 2265.5 | -566.375 | | 3.5 | | 7362.875 |
| Mechanical& electrical | 55 | 38 | 1 | | | 2090 | | | 4 | | 8360 |
| Ceiling | 55 | 38 | 1 | | | 2090 | -409 | | 2.5 | -1022.5 | 4816 |
| Windows &Doors | | | | | | 1101.125 | | | 8 | | 8809 |

Total weight of typ. Floor= 239089.445
Total weight of the building= 717268.335

**Beam Summary**

RAM Steel 17.01.01.05
DataBase: Ram Project Final
Building Code: IBC

04/06/21 15:13:38
Steel Code: AISC 360-16 LRFD

**STEEL BEAM DESIGN SUMMARY:**
Demand/Capacity Limits for: Strength: 1.000 Deflection: 1.000

**Floor Type: ROOF**

| Bm # | Length ft | +Mu kip-ft | -Mu kip-ft | ΦMn kip-ft | Fy ksi | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 1 | 11.58 | 6.4 | 0.0 | 62.2 | 50.0 | W8X10 | 4 |
| 3 | 11.58 | 6.4 | 0.0 | 62.2 | 50.0 | W8X10 | 4 |
| 4 | 11.58 | 13.2 | 0.0 | 62.3 | 50.0 | W8X10 | 6 |
| 5 | 14.25 | 19.9 | 0.0 | 62.4 | 50.0 | W8X10 | 6 |
| 6 | 11.58 | 13.2 | 0.0 | 62.3 | 50.0 | W8X10 | 6 |
| 7 | 11.58 | 13.2 | 0.0 | 62.3 | 50.0 | W8X10 | 6 |
| 8 | 14.25 | 19.9 | 0.0 | 62.4 | 50.0 | W8X10 | 6 |
| 9 | 11.58 | 13.2 | 0.0 | 62.3 | 50.0 | W8X10 | 6 |

**Fig5.** *Beam sizes for the roof level*

**Gravity Column Design Summary**

RAM Steel 17.01.01.05
DataBase: Ram Project Final
Building Code: IBC

04/06/21 15:20:35
Steel Code: AISC360-16 LRFD

**DEMAND/CAPACITY LIMIT FOR STRENGTH : 1.000**

**Column Line A-4**

| Level | Pu | Mux | Muy | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| ROOF | 12.7 | 1.4 | 5.4 | 1 | 0.13 Eq H1-1b | 90.0 | 50 | W10X33 |
| 3RD FLOOR | 27.3 | 0.7 | 3.2 | 1 | 0.11 Eq H1-1b | 90.0 | 50 | W10X33 |
| 2ND FLOOR | 40.7 | 0.0 | 0.0 | 1 | 0.14 Eq Axial | 90.0 | 50 | W10X33 |

**Fig6.** *Column sizes for each floor level*

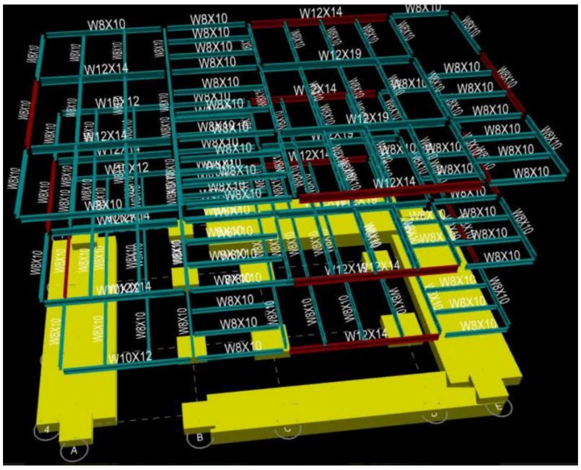


**Fig7.** *Ram modeling program beam sizes*

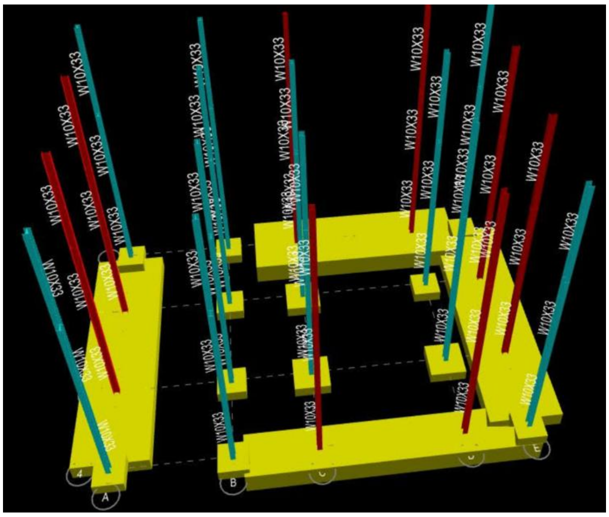


**Fig8.** *Ram modeling program column sizes*

## Design for Sustainability and LEED Certification

With Leadership in Energy and Environmental Design, or LEED, becoming more popular every day, it is important to design a building that would not only help the environment, but also give the building a longer timeline. This project was designed with various environmentally friendly components and with more opportunity to add any additional ones if wanted by the consumer. The design of the building such as the location, is also part of the project's certification success. [5] With a Platinum Certification, this project is set to have a positive impact in the environment and in the consumer's long term investment.

Starting off with the outside of the building, there are 4 inch flood drains that are placed around the perimeter of the building. The drains will collect rainwater not only to prevent flooding but also so it can be recycled. The water will be filtered through a planter box so it can be reused for the building necessities.

East of the drainage system, a smart irrigation system will be in place. The smart irrigation controls will be located near the front entrance allowing it to be accessed easily if needed. The smart irrigation system will save about 30%-35% of water usage throughout the complex due to its ability to adapt to water patterns. The irrigation system will also help prevent any runoff water that will result in water and money saved [6].

Located in the interior of the building a trash and recycling room that will help regulate waste properly. Of Course, any type of plastic, paper or any other recyclable material will be sent to the recycling room to be recycled properly [7].Also inside of the complex will be smoke and carbon monoxide detectors to help regulate smoke and any bad fumes throughout the building. Between the bottom two bedrooms a smart thermostat will be placed on the wall. The thermostat will be able to regulate the temperature of the building making it a more comfortable place to be in. Less energy will be consumed from the heating system, thus resulting in less greenhouse gasses released into the atmosphere. This is the interior LEED design.

On the roof of the building designed solar panels that will help provide solar energy. This will help save energy throughout the entire building. The roof will also be composed of a Glass "A" Roofing that will allow natural sunlight to enter the building. Doing this will help save energy as well.

From the Certified, Silver, Gold and Platinum certifications the building was placed into the Platinum category. With a total of 84 out 110 possible points, the different GREEN features included in the project were enough to get the needed 80+ points to land on this certification level.

Along with the GREEN elements included in the project, there are other aspects of the building that help its overall total score. The project site is conveniently located next to the Santa Monica Freeway making it easier and faster to get to and from the site. The regional area of the project, the Culver City area, also impacts the regional priority of the project. The points earned on the Regional Priority Section are based on the United States Green Building Council Regional Priority Credit Lookup Website.

The Earth has been on an ongoing battle with climate change, but with LEED becoming a more popular implementation to the design of structures, that can help the environment drastically. The goal for this project was to not only create a multi story, multi room complex, but to also implement ways that will help make homes and Earth, better places to reside in.

## Cost Analysis

For the Cost Analysis portion, The team found that the Green Building would cost about 2.2 Million Dollars. The features of the Leed Building would include of course the solar panels, the LID irrigation system, the exhaust fan, and the smart thermostat. This price includes all material and labor. The non-leed building would cost about 1.9 Million Dollars. After careful review, the most expensive feature of the project would be the Solar Panels of course. The cost difference would be about a 16% increase in cost. However, with this LEED building you would save about $32,000 dollars on utility bills per year. Table 3 shows the cost for the individual items in the LEED Building.

**Table3**. *Shows the cost for the individual items in the LEED building*

| Activity | Yards/Feet/Sft | Rate (USD) | Cost (USD) | Cost (Non LID) |
|---|---|---|---|---|
| Excavation | 20 yards | 125 | 2500 | 2500 |
| Concrete Decking | 13 yards | 126 | 1638 | 1638 |
| Backfill | 20 yards | 12 | 240 | 240 |
| Form Slabs | 2090 sft | 8 | 50160 | 50160 |
| Steel Decking | 2090 sft | 55 | 344850 | 344850 |
| Concrete Foundation Pour | 110 yards | 126 | 13860 | 13860 |
| Form Footings | 610 ft | 10 | 6100 | 6100 |
| Rough Grade | | 2,000 | 2,000 | 2,000 |
| Rough HVAC | | 3,000 | 3,000 | 3,000 |
| Finish Grade | | 3,000 | 3,000 | 3,000 |
| Rough Plumbing | | 30,000 | 30,000 | 30,000 |
| Rough Electrical | | 35,000 | 35,000 | 35,000 |
| Blocked Wall | 338.5 ft | 15 | 5100 | 5100 |
| Install Steel Beams | 1215 ft | 400 | 486000 | 486000 |
| Install Steel Columns | 750 ft | 400 | 300000 | 300000 |
| Install Stud Walls/Framing | 14000 sft | 6 | 84000 | 84000 |
| Insulation | 30 Rooms | 650 | 19500 | 19500 |
| Drywall Tape and Finish | | 40,000 | 40,000 | 40,000 |
| Outside Stucco | | 30,000 | 30,000 | 30,000 |
| Interior and Exterior Paint | | 10,000 | 10,000 | 10,000 |
| Flooring | 2090 sft | 12 | 75240 | 75240 |
| Finish Plumbing | | 30,000 | 30,000 | 30,000 |
| Finish Electrical | | 35,000 | 35,000 | 35,000 |
| Kitchen Cabinets and CounterTops | | 60,000 | 180,000 | 180,000 |
| Appliances | | 25,000 | 25,000 | 25,000 |
| Appliance Installation | | 3,000 | 3,000 | 3,000 |
| Exterior Trim | | 4,000 | 4,000 | 4,000 |
| Irrigation System | | 3,000 | 3,000 | 3,000 |
| Landscaping (LID) | | 20,000 | 20,000 | 10,000 |
| Smart Thermostat | | 250 | 250 | |
| Exhaust Fan | | 150 | 150 | |
| Solar Panels | 21 | 17,000 | 357000 | |
| Subtotal | | | 2199588 | 1832188 |

## Educational Objectives

This undergraduate project research opportunity helped many of the team members in our group spark their creativity, leadership skills, LEED knowledge, and teamwork skills. As team members the students learned how to communicate efficiently and effectively. During these difficult times, the team of students managed to meet frequently with no problems. Engineering in general is more than a discipline, it is a team effort. Engineering problems were easier to solve, when all the efforts and overall knowledge were combined.

The purpose of this project was not only to apply our knowledge, as a group, to design a residential building, but to also gain experience for future projects. This assignment, when given to the group of undergraduate students, tested the various skills of each group member. Being in such a diverse group, many different ideas were offered from each member. This gave the project a wide variety of possibilities.

## Conclusion

The undergraduate civil engineering research team was able to apply the knowledge gained throughout their academic career. Using the ASCE 7-16 and 2014 ACI building codes, the research team calculated and designed the sizes of the beams and columns for the residential building. Seismic calculations were calculated by hand and then checked using ATC hazards by location for the specific address where the residential building is going to be built to see if the steel structure can withstand an earthquake. Implementation LEED features [7] would benefit the project as the team calculated how much they would save over the course of twelve years. The design for the residential building scored 84 in the LEED scorecard and is ultimately LEED platinum. A student-scholar model was successfully implemented in the civil engineering senior design course at CSUN in which a diverse body of undergraduate students completed the architectural, structural, and environmental design of a green building made of steel material and could share their technical results and effective educational experiences with the international engineering community.

## Acknowledgement

The student research team would like to express their sincere appreciation for the support provided by Dr. Tadeh Zirakian and Dr. David Boyajian, Professors of Civil Engineering in the Department of Civil Engineering and Construction Management at California State University, Northridge, U.S.A.

## References


[1] McCormac, Jack C. and Russell H. Brown. Design of Reinforced Concrete. Wiley. 2016.

[2] ASCE 7-16, American Society of Civil Engineers.

[3] AISC 316-16 Specification for Structural Steel Buildings.

[4] Segui, William T. (2018) - Steel Design - Cengage Learning.

[5] Michael R. Lindeburg, PE Civil Reference Manual.

[6] LEED Study of Green Lightweight Aggregates in Construction Fahad K. Alqahtani,Ibrahim S. Abotaleb and Sara Harb.

[7] JianZue and Zhen Yu Zhoa (2013), Renewable and sustainable energyreviews-ELSEVIER.


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