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An Educational Approach to Implementing the U.S. Green Building Council Certification to a Steel Framed Residential Structure

Gevo Abcarian, Zainab Algharib, Omran Hussain, Ana Martin, Abraham Villa, Francisco Villalobos, Tadeh Zirakian*, and David Boyajian

Department of Civil Engineering and Construction Management, California State University, Northridge, CA, USA

***Corresponding Author;** Phone: +1-818-677-7718, E-mail: tadeh.zirakian@csun.edu (T. Zirakian)

Abstract: *In the construction industry, Civil Engineers focus on sustainability as a key aspect to redress the state of affairs in human society with climate change and urbanization. In professional practice, engineers are dedicated to improving the quality of life of society, without reducing quantity, integrity, and the availability of natural, economic, and social resources. Civil Engineering students at California State University, Northridge (CSUN) explore sustainability design process of a 3,620 ft^2, two-story steel frame, residential home. Implementation of the Leadership in Energy and Environmental Design (LEED) Certification Scorecard was utilized to explore alternative methods for energy consumption and waste-water management. The project has value as an educational opportunity for team building and leadership because it encompasses a collaborative approach to design a 'green building' which includes seismic analysis and the designing of structural members such as girders, beams, columns, and foundation footings. Group members reinforced their knowledge in structural analysis, and the design of concrete and steel members upon the development of architectural and structural plans, inclusive of calculated construction costs for the residential structure. During collaborative team discussions, it was decided to use the 1700 ft^2 for the design of a green flat roof system for vegetation, energy, and natural lighting. Through great efforts, the project has scored Silver for LEED certification, and increased the construction cost by 52%. With the advent of alternative energies, design of any structure must include sustainable practices and innovation.*

Keywords: *Green building; Structural design; Sustainability; LEED certification; Engineering education*

INTRODUCTION

Steel moment frames have been in use for more than one hundred years even though the concept of a special moment frame (SMF) is a recent development. A notable example of this type of construction in the United States is the Home Insurance Building in Chicago. This is a 10-story structure constructed in 1884 and it is often credited with being the first skyscraper. In a SMF, the connections are very strong and are designed to withstand powerful inelastic deformation in both members and connections when lateral forces hit them. These structures are designed and used in regions with high-seismic activity like California. The main advantage of moment frame structures is that they do not have diagonal braces therefore providing architectural freedom in design. Another benefit of moment frame is that they impose smaller forces on foundations which result in foundation design cost savings. These benefits in freedom of design come with a price since moment frame structures can be more costly to construct. The added cost results from the use of larger and heavier sections in moment frames which is why structural engineers tend to use moment frames as a last resort. The column and beam sizes can be significantly heavier per linear foot than in braced frames due to the mechanics of force transfer and resistance in the system. The heavier the sections, the higher the overall costs of the material. Since moment frames require welding, this leads to higher building costs as well **[1]**.

The objective of this project is to gain an understanding on how applying LEED features to a building is beneficial. Maximizing a building's positive impacts on nature and minimizing its negative impacts is important to restore and preserve the environment for the benefit of all life **[2]**. Buildings use resources, generate waste, and are costly to maintain and operate. The purpose of a green building is to use fewer resources and reduce waste that negatively affects the environment and decrease life cycle cost. LEED can be applied to any building type including new constructions, interior fit outs, neighborhood developments or homes **[3]**.

STRUCTURAL DESIGN

A serious concern when designing a steel structure is analyzing if the structure has the internal capacity to resist lateral movement. To combat this, structural engineers can design a structure as a rigid moment-resistant frame. This type of framework uses a series of columns and beams in which the connections are attached through the use of welding; these connections are known as moment connections. Depending on the geometry of the connection, loads are resisted by flexure in the beams and columns. By virtue of the rigid beam-column connections, a moment frame cannot displace laterally without bending the beams or columns therefore making the members the main

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source of lateral stiffness and strength for the entire frame **[4]**.

The architectural plans for the first and second floors of the considered building are shown in Figure 1. During the process of structural design, the team decided to opt for simple results. The beams were designed after calculating the maximum moment and computing M_u to then solve for the design moment, ϕM_n for two different girders and two different beams. The beam sizes were calculated to be W8×13 and the size of the girders were calculated to be W10×12. Calculations for the columns were conducted for an interior column, an edge column and a corner column. The size of the columns were concluded to be W10×33 **[5, 6]**. The footing was concluded to be 5 ft by 5 ft with a depth of 5ft. The rebar size determined was 5-#8 rebars at 10 inches on center. The seismic analysis was conducted using the ASCE 7-10 reference manual and the 2012 IBC manual. The seismic design category for the building was concluded to be B **[7, 8]**.

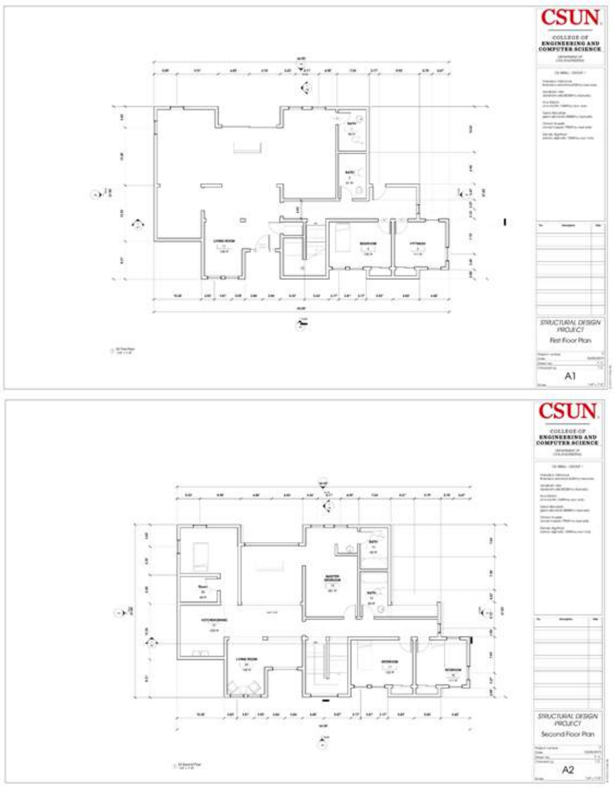

Figure 1: *Architectural plans for the first and second floors*

SUSTAINABILITY DESIGN AND COST ANALYSIS

As of now, a real hot topic in the engineering community is sustainability. The reason for trying to achieve this goal is to reduce or completely avoid the depletion of sources such as energy, water and raw materials. Also, people can save money in time, by treating it as an investment that pays itself off in the future. Today our world needs attention and care, that's why there's a need for sustainability. Hopefully engineers find new ideas in the near future that will allow for more natural resources to be conserved. To design a sustainable structure, components such as solar panels, green-flat roof, a skylight and a greywater system were adopted. Solar panels are a great sustainable choice because it will help conserve energy by absorbing the sun's rays to produce electricity. In time the cost of the solar panels will pay for itself, benefiting from saving money and also being sustainable. As far as green-flat roofs are concerned, the design is most efficient because the energy from the sun will be absorbed by plants and green vegetation to help create a rainwater buffer, purify the air and reduce the indoor ambient temperature of the home; an example of a green-flat roof is shown in Figure 2. A skylight was also included to minimize the usage of electricity and enhance the architectural aesthetics of the house. The Greywater system is fairly new. In the last 20 years it was developed to recycle laundry and toilet water to use for gardening purposes which in turn helps plant life grow, conserves water and saves money, see Figure 3 for this feature **[9]**.

After the addition of the above-mentioned LEED features to the structure, there was a 52 percent increase in sustainability cost to the whole scope of the project. As for the cost of having LEED features, it's about one third of the whole cost of the building, which amounts to $113,912.78. This cost would be paid off after ten years saving money afterwards. The most costly feature are the solar panels, due to the amount of energy this house is going to be utilizing. Just having these solar panels is half the cost of all the LEED features. The greywater system and the flat roof cost $10,000 each to install; the green roof costs more due to having more work needed to be built and maintained yearly. In comparison, the interior lighting of the home and the skylight were inexpensive. The cost of both these features is about $13,000 and gives more of an aesthetic feature to the house, while being energy efficient.

Figure 2: *Example of a green flat roof with landscaping and skylights* ***[10]***

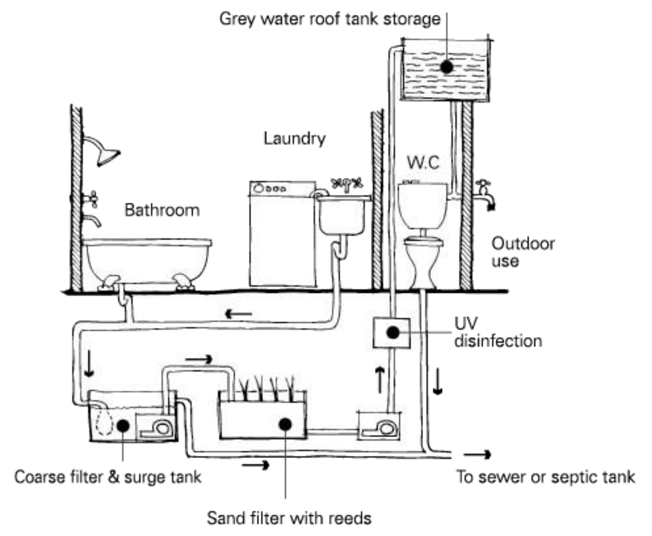

Figure 3: *Diagram of a grey-water system* ***[11]***

EDUCATIONAL OBJECTIVES

From this educational research, the students were able to learn, communicate and work together as a group to conduct and complete the task at hand. Students from different genders and cultures worked together as a team to analyze the best design of a house. The students extended their knowledge in civil engineering by participating in this project and were able to apply their knowledge of Steel Design and Construction Management in completing this research work. Since LEED features were applied to the steel moment frame design, the group researched, analyzed and decided the best and most cost-efficient LEED features for the house. The students were also able to learn and appreciate the benefits of LEED design to the occupants, energy resources and to the environment. This knowledge is very important to the students as future civil engineers, as many consumers are interested in owning LEED-certified buildings.

Research and writing skills were developed from the completion of this paper. The engineering knowledge gained through this project will help the students to further advance their careers as civil engineers. For the purpose of Senior Design module, LEED implementation on the double-story residential unit design is highly focused into enlightening civil engineering students on energy conservation and pollutant reduction. The students are motivated to design more sustainable and safe buildings in the future, through their research on LEED features.

CONCLUSION

The research team was able to apply their knowledge on steel design and construction management in this study. The students managed to improve their designing skills by referencing design codes from the ASCE 7-10 manual and the 2012 IBC manual. By considering lowering the cost while maintaining the requirements of the building and steel codes, the students calculated, analyzed and chose the best fit sizes of beams and columns for the design. Foundation design and basic seismic calculations were done to ensure the building is safe to build at the specific location.

LEED features were considered in the design of the building. The students researched, analyzed and implemented the best fit LEED features for the design of the double-story house. The students managed to determine a 52% increase of LEED features in the building compared to a more conservative design, based on CostWorks calculations. After ten years these features would pay off themselves and the homeowner would save lots of capital thereafter. The high change in cost would justify the efficiency of the LEED features used on the design. People should be more encouraged in considering LEED certified buildings due to the ability of conserving energy and reducing pollutants.

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