SUSTAINABLE AND ENVIRONMENTALLY RESPONSIBLE DESIGN USING BIM: A CASE STUDY OF A RESIDENTIAL PROJECT

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ABSTRACT: This paper describes the application of the three sustainable design elements for a residential project in the county of Los Angeles, USA. The first design element is the green building design in which a base model will be created using the Autodesk REVIT MEP program for the analysis by Building Information Modeling (BIM) for the energy analysis modeling process to determine the energy savings for each of the recommended design features. The second element is the Low Impact Development design for the site design using specialty material and structural devices for infiltration and recycling of storm water for reuse. The third element is the application of drought tolerant plant species in the site's landscaping design as a means to conserve water. The construction cost associated with the application of these three elements will be reviewed to determine the practicality and effectiveness of this sustainable design approach.

Keywords: Building Information Modeling (BIM), Low Impact Development (LID), Green Building Studio, County of Los Angeles Green Building Program (CGBP)

1. INTRODUCTION

The use of green construction techniques started in California in the early 1980s. At that time, some of the common applications of green construction techniques mainly consisted of the utilization of roof mounted solar energy panels for the heating of water, the use of skylights for natural lighting, and the use of more energy efficient insulation material. These green construction techniques appeared to have some success in energy conservation but had very little effect in protecting our environment, as they were not mandatory.

With the increasing concerns of impacts caused by the global warning, a complete building design approach in a more sustainable and environmentally responsible manner that aims to save our natural and man-made resources is a good first step. In this case study, we will apply the three design elements from the County of Los Angeles Green Building Program (CGBP) for a residential project to determine their practicality and effectiveness in energy savings. These three design elements are specifically geared toward the building design, the site design, and the site landscaping design.

The proposed project is to design an approximately 990 square foot residential dwelling with a conventional type V wood frame construction and a raised foundation. The overall building design will meet the current CGBP requirements. The building design will be evaluated using the Building Information Modeling (BIM)[1] for energy analysis in the preliminary design phase. With the energy modeling using different energy saving alternatives on a simple 3D-CAD model created by the Autodesk REVIT MEP Program [2], we were able to determine the energy savings based on alternative upgrades for this project. The site design will be evaluated with different CGBP recommended BMPs applications [3] for storm water recycling or percolation, groundwater recharge, and water pollution control. The site landscaping design will be evaluated with various types of native plants and landscaping species for conservation of water resources. The final design that incorporates all the energy saving upgrades for this project will be used to determine the energy cost savings to the project. As the CGBP construction cost data is not readily available due to the short implementation time frame since adoption, our cost data is derived from local experienced contractors that are willing to provide estimates.

2. THE PROJECT SITE

The project site is a rectangular shape level lot with a dimension of 62 feet wide by 136 feet long located in the City of La Puente, within the Los Angeles Basin, in Southern California. The Los Angeles Basin has a Mediterranean climate condition that is somewhat wet with generally mild winters, with very dry and warm summers. The normal average annual rainfall is approximately 14-16 inches. The average daytime temperatures are between 65-90 °F, and the average nighttime temperatures are between 50-65 °F.

3. GREEN BUILDING DESIGN ELEMENT

This element requires that any residential development, with four or less units, achieve at least 15% more energy efficiency than the 2005 California Building Code Title 24 Energy Efficiency standards. Utilizing the concept of the whole-house system approach, the design concluded with the application of the following basic design areas:

1) Insulation and air sealing
2) Lighting and daylighting
3) Space heating and cooling
4) Energy Star water heater
5) Low-E Windows, doors and skylights
6) Advanced house framing techniques

The next step is to implement the energy saving techniques of these basic design areas into the final design. Below are the details of the design measures that are considered.

1) Building Envelope Measures:

a. Exterior doors and windows are weather-stripped; all joints and penetrations are caulked and sealed.
b. Insulation in roof framed ceiling should be a minimum of R-30 insulating material.
c. Insulation in a wood framed wall should be a minimum of R-13 insulating material.
d. Insulation in a raised wood framed floor should be a minimum of R-19 insulating material.
e. Install radiant vapor barrier.

2) Space Conditioning, Water Heating, and Plumbing System Measures:
a. An HVAC cooling and heating system with a 13 Seasonal Energy Efficiency Ratio (SEER) that is certified by the Energy Commission.
b. The HVAC air distribution system ducts are sealed and insulated in accordance with the applicable sections of California Mechanical Code (CMC).
c. A water heater certified by the Energy Commission.

3) Residential Lighting Measures:

a. High efficacy lighting, i.e. fluorescent light bulbs used for all interior and exterior lighting needs.
b. All night lights rated to consume no more than five watts of power.

The last step is to further refine the energy savings techniques with the help of a BIM-based energy modeling program, Green Building Studio (GBS). With several runs using higher energy saving alternatives, we concluded that the following design upgrades would provide higher energy savings for this project:

1) Install a HVAC 17 SEER Rating Cooling and Heating Split System.
2) Install High Efficiency Low Emitting Diodes (LED) Light Bulbs with occupancy sensors for all interior lighting control and LED Solar Motion Sensor Lights for exterior.
3) Install Low Emissivity (Low-E) Dual Panel with Argon Gas Insulating Glass Window.
4) Install a Tank-less Electric Water Heater (Energy Star Rated).

The result of this energy savings analysis is shown in Table 1.

Table 1 – Energy Cost Saving Comparison between Different Design Upgrades

	Energy Saving Design Upgrades	Annual Energy Cost (Electricity)	Annual Fuel Cost (Gas)	Total Annual Energy Cost	Annual Energy Savings	Additional Cost to construct
1	Base Design	$2,507	$947	$3,454	--	--
2	HVAC System 17 SEER	$2,517	$915	$3,432	$22	$3,500
3	LED Lighting	$2,154	$1,002	$3,156	$298	$600
4	Low-E Dual Panel with Argon Insulating Glass Window	$2,528	$907	$3,435	$19	$400
5	Tankless Water Heater (Electric)	$2,929	$118	$3,047	$407	$1,500
6	Combined Upgrades 2 thru 5	$2,168	$272	$2,440	$1,014	$6,000

Note: Results are extracted from BIM Base Energy Modeling Process. Construction cost for items 2, 3, and 4 represent equipment cost only, no additional labor cost is required. Item 5 represents equipment and labor cost to have an electrical upgrade for a tankless water heater.

3. THE LOW IMPACT DEVELOPMENT ELEMENT

This element is to manage the rainfall and storm water runoff from the project site to (1) minimize the contamination potential of surface and groundwater quality to rivers, streams, and the ocean, (2) preserve the integrity of ecosystems, and (3) preserve the physical integrity of receiving waters. A successfully designed project should be able to achieve the goal of conserving water through the retention of rainwater onsite and replenish the groundwater through the use of onsite infiltration devices and minimize the pollutants carried by storm water and other urban runoff to the waterways.

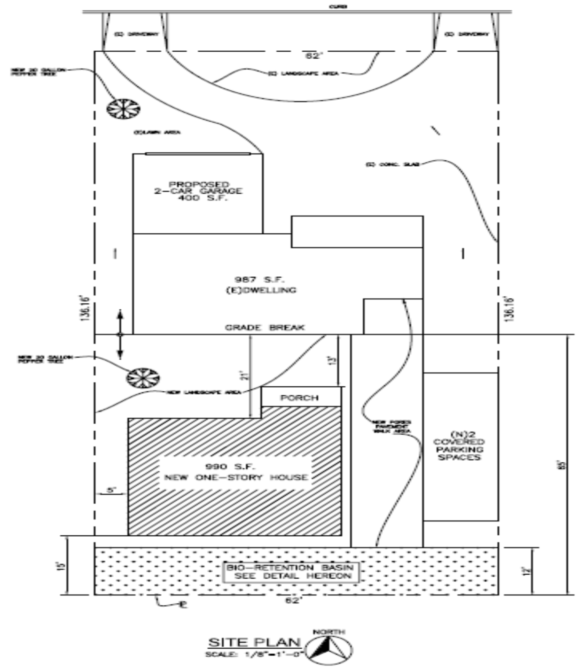

Figure 1. Project Site.

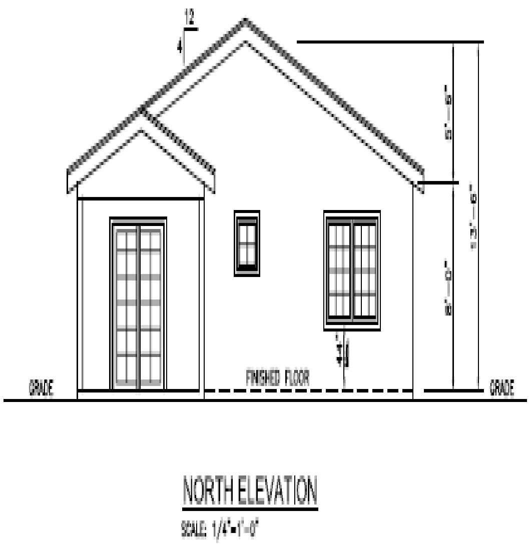

Figure 2. North Elevation

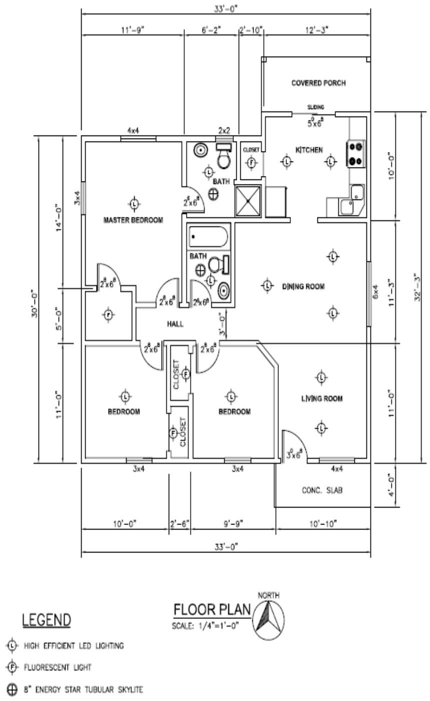

Figure 3. Building Plan

Since the County's recommended LID element emphasizes the implementation of Best Management Practices (BMPs) to mimic the undeveloped site hydrology using site design techniques that store, infiltrate, and detain runoff, it will be necessary to follow the site's existing natural systems to determine the adequate design for this project. To effectively manage the additional storm water runoff that is caused by the construction of this house, our design utilized the southerly half of the lot as a bio-retention basin to provide a natural pervious surface to allow for percolation of storm water. The remaining area between the existing garage and the house will be paved with porous pavement material to allow for the infiltration of storm water to the ground as a supplement to the bio-retention basin.

Using the Rational Formula, the calculated increase in volume of storm water runoff is approximately 0.083 cfs for a design storm frequency. This increase in storm water runoff volume, generated by this project will be mitigated by the use of a bio-retention basin to be built in the rear of the site, and by the new porous pavement BMPs as a method to allow infiltration of storm water runoff. The soil type has a medium infiltration rate that is suitable for handling the volume generated by the project. Additionally, there will be an overflow pipe that serves as emergency relief during extreme weather conditions to minimize potential flooding.

Figure 4 below shows a design of the project's bio-retention basin:

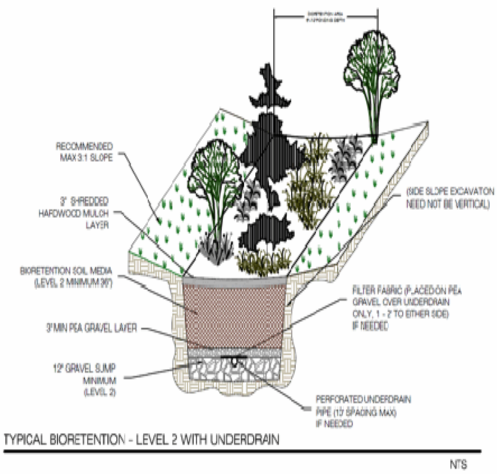

Figure 4. Bio-Retention Basin

4. THE DROUGHT-TOLERANT LANDSCAPING ELEMENT

This element is to specify the use of drought-tolerant and native plants that require minimal water for maintenance in Los Angeles County weather conditions. This requirement will achieve the goal of conserving water. Specially selected plants and drought-tolerant shrubs are chosen to be planted in the area where the Bio-retention Basin is to be constructed. Below are photos of some of the selected drought-tolerant plants and native shrubs that are used for this project.

Figure 2. Drought tolerant shrubs

Table 1. Construction Cost Comparison between Base Design Vs CGBP

Design Element	Estimate Construction Cost	Water Consumption and Storm Water Runoff	Operation and maintenance
Typical Grass Lawn and Portland Cement Pavement	$3,500	High (plus a high potential of discharging pollutants to the river	High
Walkway		system)	
Drought-Tolerant Landscaping Design	$6,500	Low	Low

Note: Construction cost is based on estimates provided by local experienced contractors

5. SUMMARY AND CONCLUSIONS

In this case, our energy modeling process confirms that several energy saving alternatives are cost effective on implementation, and they demonstrated an annual energy cost savings to the project. The cost estimates received from local contractors revealed that the construction of these energy saving alternatives would have a slightly higher cost in material, equipment and/or labor to install. The calculated total increase in cost for this project is approximately $9.10 per square foot or approximately 9% increase in total cost, based on the construction of a 990 square foot house. These design upgrades tend to justify the application of a sustainable design methodology as a way to preserve our environment, resources, and ecology

It is quite common to see government assisted housing projects that incorporate the green building techniques because they received federal and/or state grants to offset the increase in cost. Unfortunately, it is quite a challenge to justify the real financial benefits of building a green single family home to an individual home owner. In the past two years, we have seen a great deal of effort from the federal government, offering home owner incentives to implement different energy saving techniques to either renovate existing homes with energy efficient material or construct new homes with similar techniques. These are indeed positive signs to promote the green building concept to save our environment, if one can follow the complicated federal funding procedures and complete all the forms. A better approach is to start educating our children about the importance of a sustainable design

6. ACKNOWLEDGEMENT

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