DESIGN OF LOW-DEPTH MODULAR GROUND SOURCE HEAT EXCHANGER

LEED PROJECT DESIGN SUSTAINABILITY AND PERFORMANCE

A Theses Prospectus

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Home heating and cooling account for roughly 50% of annual energy bills with Americans spending more than $100 billion dollars annually. Additionally, residential heating and cooling contributes 441 million tons of carbon annually. Increasing HVAC efficiency is one of the most impactful ways to improve building energy efficiency of new and existing structures. While many innovative technologies in this arena continue to develop, creating sustainable codes and rating systems to regulate designs continues to assist the advancement and implementation of more green systems. This study will focus on the sustainable transitions and social construction of technology through the implementation of the US's most practiced rating system LEED (Leadership in Energy and Environmental Design). From its inception in 1998, this rating system serves a purpose of promoting and expanding usage of green building practices and design features. Emerging patterns in the continuing construction of LEED rated buildings show a lack of emphasis on design implementation and building performance. Currently, the LEED rating system rewards designs checking specific boxes like solar and rainwater reclamation to name a couple. These features are credited towards the building's design, which in turn determines a certification level of silver, gold, or platinum, even before construction begins. This approach poses a problem where real-world performance and behavior over time are not taken into consideration. Improvements on the rating system should take into account suitability of different green features in an authentic manner, as well as assess environmental impacts through life cycle assessments. These adaptations of current LEED practices will keep in mind the mission of transforming building and community sustainability while rooting their intentions in practical applications.

Technical Topic

Ground source heat pumps (GSHP) are an increasingly popular method to reduce carbon emissions from residential buildings due to their superior energy efficiency. GSHP have a coefficient of performance ranging from 3 to 6, meaning that for each unit of heat produced by an electric heater a GSHP can produce 3 to 6 units. For an individual home in the US, this energy savings translates to 10.3 tons of carbon per year. While GSHPs are the most energy efficient and environmentally clean conditioning systems available, their current form requires large upfront investments in equipment and infrastructure, many involving a complex system of pipes buried up to 400 feet below the earth's surface. In an effort to increase availability of these technologies, this study aims to reduce the barrier to entry taking heed of real-world system performance at a smaller scale. This design will bear in mind three main categories of potential improvement; ground loop depth and length, material thermal properties, and ground fluid flow. Pipe burial depth is an important aspect for design constructability, this plan intends to decrease this constraint while taking into account variations in soil temperature at shallower depths. The design also intends to provide a more modular solution for burying pipe lengths given predetermined depth and heating/cooling needs. Geographical location, determines thermal properties of soil, and in turn can hinder or improve heat transfer performance. This investigation will examine feasibility of burying in synthetic soil, as well as varying pipe material. Finally, parameters of the ground fluid flow will be tweaked to maximize heat transfer. Fine-tuning of flow rate, turbulence, and mixture are top considerations from sensitivity analysis. The final ground heat exchanger package is targets efficiency first and foremost while also validating design results with real world construction that is accessible and flexible for a variety of small scale uses.

STS Topic

First created and used in 1998 the Leadership in Energy and Environmental Design (LEED) rating system has shaped knowledge, implementation, and largely the success of green building practices in the United States. To this point their social constructions have incentivized sustainable transitions from several building traditions across the continent. To evaluate the current direction of this regulatory system, this study will first examine how the rating system is developed and adapted over time. An overarching concept used by LEED is an emphasis on iterative development, and continuing to identify opportunities for improvement (Todd, Pyke & Tufts, 2013). Focusing on six main categories; water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in design, groups of volunteer experts work to provide requirements and descriptive language for requirements that are then passed along to another team that reviews market feasibility. Revised versions of the rating system are also released for public comment. Despite establishing an adaptable body for regulating green building projects, development for LEED buildings seems to have stagnated towards building systems designers checking boxes to fulfill LEED accreditation. While being very comprehensive, these designs fail to take into account real world performance metrics. A case study for The University of Texas Health Science Center – Houston School of Nursing provides an excellent example of this lackluster performance (McDermott, 2010). Despite receiving numerous awards for groundbreaking sustainable design, the building was not without major issues. Failing to take into account operation over time, the rainwater collection system saved around $12k per year and cost $1.5m to install. After 6 years of use, its storage tanks were rusting and with a replacement cost of $19k per tank, the intent of the green design was not realized. Additionally, the building's design intended to make use of solar PV panels on the roof at a cost of $1m. Although mounting locations for this feature was constructed on the roof, they remain empty. The engineer's design failed to take into account the insufficient payback for this system and the University opted to pay for green power off the grid. In both cases insufficient analysis of the building system's authentic performance led to LEED credited green designs falling by the wayside. Techniques such as Life Cycle Assessment (LCA) lead important efforts to supplement and increase the effectivity of the LEED system's real-world performance (Dekkiche & Taileb, 2016). The LCA provides one useful outlook tool for analyzing how the building's materials will interact with the environment of a period of 60, 80, and 120 years. Dekkiche and Taileb's study looking at the wall and envelope construction of the Library at Centennial College provides many useful environmental insights. By utilizing a cedar cladding in place of the building's current coper, they estimate a 33% reduction in fossil fuel consumption and a 39% reduction in global warming potential. These show substantial added sustainable value that a LEED assessment would not take into account. Overall, the LEED rating system has done an excellent job of expanding green building knowledge and techniques but must adapt to validating the performance of such buildings after construction. The development of their rating system has already successfully begun adapting buildings to sustainable traditions but must continue to improve well into the future.

Next Steps

An excellent direction would be finding other research looking into adapting or supplementing the LEED rating system to improve present sustainability. In addition, looking into other case studies of LEED rated building performance to assess other areas of weakness. Another important spin on the topic is Global adoption, taking into account how other sustainable building system codes have developed and shaped technologies and traditions especially in other countries. Green Star, EDGE, and BEAM are all other international rating systems affecting not only the US, how do they compare to LEED, what are their advantages and disadvantages? Finally, digging a little deeper into Life Cycle Assessment and other examples than just wall construction. Do other studies take into account things like location, building height/depth, surrounding communities?

References

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