

Using Prefabricated Building Components to Obtain LEED Credits

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This study intends on investigating the possibility of using prefabricated components to obtain USGBC LEED credit points for the materials and resources section. When implemented efficiently, the use of prefabrication has the ability to reduce different forms of waste. A critical literature review was performed to examine: (1) How material use is optimized in prefabricated components (2) How material use, reuse, and recycling can be more efficient at prefabrication manufacturing plants versus on construction sites (3) How prefabrication can be used to obtain LEED credit points in the material and resources section. It was found that prefabrication reduces material waste significantly in projects in which it is utilized. A survey of construction industry professionals was conducted to help gauge attitudes towards prefabrication. The industry professionals that participated in the survey had prior experience in LEED projects and the use of prefabrication. The survey indicated that eighty percent of the participants believe that prefabrication should be used to obtain LEED credit points. The survey also established that construction professionals thought the benefits of using prefabrication in the construction industry was very beneficial due to a number of reasons and that it would reduce waste in material usage and labor usage.

Key words: Prefabrication, Prefabricated Components, LEED, LEED Certification, Construction Waste

Introduction

The mission of the United States Green Building Council (USGBC) is "*to transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life*." (USGBC n.d.). The USGBC created the Leadership in Energy and Environmental Design (LEED) building rating system, which has become one of the leading green building rating systems domestically and internationally (Kobet 2009). The rating system awards credits for fulfilling certain criteria that weigh the environmental impacts and human benefits (Kobet 2009). Using the LEED rating system as a design tool gives designers and owners the ability to build structures that address issues related to sustainability and add value to projects (Gorgelewski 2009).There are a total of seven different categories that total 110 possible points, and produces four certification levels that can be awarded to a project. The materials and resources category deals with efficient use of material resources, including building, component, and material recycling and reuse (Gorgelewski 2009). This research presents the thesis that prefabricated building components, when implemented correctly, should aid in obtaining the LEED credits that the materials and resources category offers.

The first examples of prefabrication dates back to the 1600s (Haas et al. 2000). In Great Britain, a great example of an early-prefabricated structure is the Crystal Palace. In 1851 the Crystal Palace was constructed for Britain's Great Exhibition. The building was designed in less than two weeks, and was made up entirely of prefabricated glass panels, wood, and cast-iron components. Assembly of the prefabricated components lasted just a few months. Once the Great Exhibition was over, the building was then deconstructed and moved (Haas et al. 2000). In the United States prefabricated components were first utilized by the housing industry. In the early 1900's, the first example of prefabricated structures in the United States came in the form of homes. The Aladdin Company and Sears were the first to sell mail order homes. They could be purchased via a catalog and the pre-cut materials would be delivered to the purchaser. Upon arrival, instructions were provided for the home to be constructed using basic tools (Haas et al. 2000). Unlike European countries, prefabrication never really caught on in the United States. There were periods in which prefabrication was viewed favorably, like during and after World War II when there was a great need for new home construction. During times when an influx of returning veterans increased the need for production of new homes also increased, after the Second World War. However, these periods were short lived as prefabrication became undesirable because of a stigma for being low quality work (Haas et al. 2000).

Although we have seen significant advances in technology since the industrial revolution, building structures continue to be built the way they have been for centuries. Traditional construction methods call for structures to be built up by a number of elements and subassemblies at a construction site (Sandberg 2008). All industries produce some level of waste but construction has an overabundance of waste occurring throughout all of its processes. In America material waste in construction accounts for approximately 30 percent of all materials placed in landfills (The Modular Building Institute 2009). Waste in construction is when an activity displaces value, instead of producing it (Ibrahim et al. 2010). Traditional construction methods are plagued with different forms of waste. Ibrahim et al. (2010) state that some of the main forms of waste come in the form of poor quality work that causes rework, repairs and defects, construction inefficiencies, material waste, schedule delays, down time causing trades to wait, poor material allocation, unnecessary material handling and material waste. Osmani et al. (2008) further referenced waste as the number one action that contributed to last minute changes by clients. The formation of waste in America has been identified as one of the key issues that society must address for future generations (Gorgelewski 2009). V. W. Y. Tam et al. (2007) state that construction waste is one of the main factors that have a negative impact on the environment.

Prefabrication, preassembly and modularization are contextually linked as being the same. All three of these processes are similar but not the same. Prefabrication is a building manufacturing process that takes place at an offsite facility. At the offsite facility, materials are joined to form a component, not a complete module that is ready for final construction installation. A single trade commonly performs the work. Preassembly involves the joining of various materials at an offsite location immediately followed by installation as a complete unit onsite. This work commonly involves to coordination multiple trades working together. Modularization is the complete construction of a module offsite that is then transported to the project site. More than one trade is also involved in this assembly. These processes are all unique as outlined here, but many commonly mistake all three processes as the same (Haas et al. 2000). The use of prefabrication has varied over time based on need and wartime boom, but never consistent. Nevertheless, the technological advancements that have been made in construction have increased the potential of prefabrication (McGraw-Hill 2011).

The construction industry has not made many improvements when it comes to productivity in the past 40 years; whereas other industries have continuously made advances in productivity (McGraw-Hill 2011). Several factors have contributed to limited advance in productivity in construction industry. Poor site conditions have an effect on laborers and assist in decreasing their productivity. The continuous changing in weather conditions, dust and airborne particles, and high levels of noise are some of the factors that lead to fatigue and injuries. Fatigue leads to laborers slowing down and also injuries, which all attribute to a decline in efficiency and productivity (The Modular Building Institute 2009). When productivity is low, project schedules begin to be of concern. Assaf and Al-hejji (2006) state that poor labor productivity is one of the top factors that cause project delays. Delays can be caused by a plethora of events on a construction projects, which can snowball and contribute to other delays further down the line (Arditi and Pattanakitchamroon 2006). To remedy many of these construction issues, more innovative methods along with new attitudes towards construction need to be established. As well as being open to new construction techniques, construction organizations are now in a position where they need to consider enhanced building methods that will improve productivity, quality, and efficiency to better compete (Ibrahim et al. 2010).

Prefabrication can be used as a means to help reduce many of the forms of waste (Osmani et al. 2008). Prefabrication, if efficiently implemented, can help lower project costs, shorten project schedules, improve quality of work, assist in more efficient use of labor and improves safety (The Modular Building Institute 2009). These positive effects of construction all help alleviate construction waste and help make construction sites more sustainable. Along with reducing construction waste, prefabrication increases recycling and allows for the selection of sustainable materials (McGraw Hill 2011). This means financial, time, and material waste can all be reduced significantly by using the offsite approach, prefabrication, as a construction method.

In a report produced by McGraw-Hill (2011) on prefabrication, it was stated that prefabrication in two-thirds of companies that use prefabrication experienced reduced project schedules. Out of those companies 35% reported decreasing schedules by as much as four or more weeks (McGraw-Hill 2011). This is significant not only because it proves prefabrication reduces project schedules but also because it can yield significant cost savings. Many projects take place on active sites, where business is negatively impacted when construction is occurring. When schedules can be reduced by a month or more, businesses can return to normalcy sooner and help minimize negative impacts to business. A good example of an active site would be a new building being constructed in a hospital complex (McGraw-Hill 2011).

With prefabrication, components are built off site in controlled environments. LEED credits are given for the amount of waste that is diverted from landfills at construction sites. Prefabricated units constructed off-site need to account for the waste that is reduced at the manufacturing facility also, to satisfy LEED requirements. If it can be proven that similar waste management practices are being employed at manufacturing facilities, innovation points may be available (Kobet 2009). The ability to be reuse and recycle makes prefabricated components an ideal choice when looking to obtain LEED credit points. However, it is important to develop a set of guidelines to help in deciding if prefabricated material usage can be implemented on a project. In the LEED rating system for new construction and major renovations, the material and resources category consists of 14 out of 110 possible points. The intention of the materials and resource category is to reduce waste sent to the landfill. Points can be earned by implementing a construction waste management strategy that identifies and separates materials to be diverted from the landfill. It is conceived that prefabrication can be implemented in the materials and resources category of the USGBC's LEED rating system. Although it is known that prefabrication can reduce waste on site, it is necessary for waste to be reduced at the manufacturing plants of the raw materials as well. Also, it is possible to more carefully pick what materials will be used to make up prefabricated components. When owners want to construct a LEED certified building, the highest certification level is the ideal outcome. Thus this research investigates the possible use of prefabricated building components to obtain LEED certification on projects, thereby contributing to innovative construction techniques.

Methodology

The intent of this research project is to investigate the potentiality of USGBC awarding LEED rating credit points for the use of prefabricated components for the materials and resources section of the LEED rating system. When considering the appropriate approach to research, there are many factors to consider (Dilanthi Amaratunga et al. 2002). This topic is does not lend itself to be measured easily with numbers or statistical procedures. The available information made it so the research topic was both exploratory and attitudinal in nature. When looking at the availability of material that could support this subject matter a qualitative approach was determined as the most appropriate technique for data collection.

The primary data collection in this research project was online surveys that were sent out to construction professionals that included subcontractors, general contractors, specialty contractors, architects, engineer, and prefabrication manufacturers. Initially it was thought that phone interviews would be the choice of data collection. Phone interviews as a form of data collection was decided upon because it was believed that the phone interviews would provide a better view of how professionals feel about prefabrication, USGBC LEED certification, and how both could be used to improve the construction industry. The interview questions were framed with an open-ended structure, which allowed for various answers from different interviewees. Professionals in the industry were difficult to contact due to scheduling constraints. The use of an online survey for data collection was adopted due to a lack of participation with phone interviews. The survey followed the format for a descriptive survey. In a descriptive survey, the number of respondents with certain opinions or attitudes towards a specific topic is counted. The results can later be analyzed to compare or illustrate reality and trends (Naoum 2011). The survey was available to respondents for thirty days. Upon completion of collecting data from the surveys, certain results and trends can be compared after analyzing the surveys. This will either support or refute the objective of the research study.

Two types of data are available to be collected by a qualitative researcher, namely, primary data and secondary data. Primary data consist of three types of approaches: surveys, case studies, and the problem solving approach (Naoum 2011). Secondary data is information that is obtained from other sources that the researcher was not involved in the collection process (Naoum 2011). For this project, the primary data approach was chosen as the form of data collection. To collect this data, a pilot study was initially conducted which lead up to a creation of an online survey. Initially a recorded phone interview with an industry professional that was well versed in the practice of prefabrication and LEED projects was conducted, as a form of pilot study. Naoum (2011) states that a pilot study is a form of trial run that allows for wording to be tested, establishment of the length of questions, avoidance of confusing questions, data analysis suggestions and a way to test the technique of collecting data (Naoum 2011). The pilot study did exactly what it was designed to do. By conducting the pilot study, lead to the refinement of the questions further, thus improving the survey instrument.

Results and Analysis

The survey was sent to building construction and design professionals. Thirty-nine responses were received as part of the survey. Participants were presented with a statement of ethical standards for conducting this research. Once participants agreed to the terms, they were able to proceed with answering the survey. Participants were then asked for demographical information identifying them with a certain sector within the industry. The results for this question are presented in Figure 1.

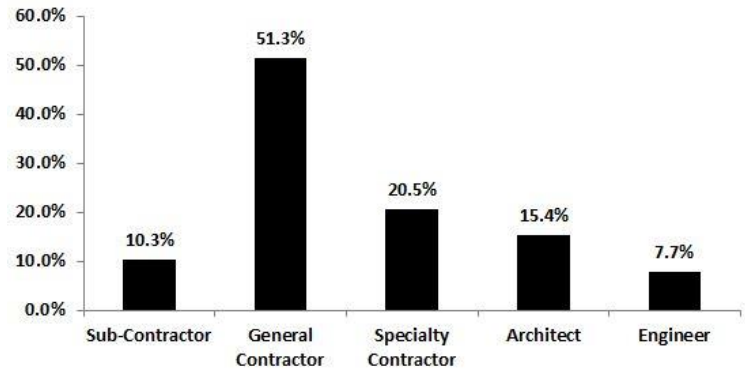

Figure 1: Profile of Survey Participants.

Participants were then asked if they had worked on projects that involved prefabricated components, to which thirty participants replied with a 'Yes' choice. These thirty participants were then asked if they had worked on LEED certified projects, to which nineteen responded with the 'Yes' choice. The survey was designed so that the remaining questions were administered to only the nineteen participants that had experience in projects that used prefabricated components and worked on LEED certified projects. The remaining twenty participants were thanked for their participation and exited the survey. Therefore the results of this survey are only from respondents that have indicated that they had prior experience with prefabricated components and LEED certified projects. Of the nineteen participants that responded, each of the categories from Figure 1 had at least one respondent that completed the survey.

The nineteen participants were asked to rate their knowledge of prefabrication practices in the construction industry on a likert scale with '1' representing low level of knowledge and '5' representing a high level of knowledge. The average for the responses to this question was 3.75, indicating a relatively good level of understanding of prefabrication concepts. The participants were also asked to rate themselves similarly on their understanding of the LEED rating system on a likert scale with '1' representing low level of knowledge and '5' representing a high level of knowledge. The average for the responses to this question was 3.65. The results to these two questions indicate that the participants of this survey are reasonably well versed in the concepts of the LEED rating system and pre-fabrication.

Participants were asked to provide reasons why they thought the use of prefabrication was important. They were presented with several options, which were the result of a conducting a critical analysis of the literature. The results to this question are listed in Figure 2. The responses indicate over seventy percent of the participants agreed that improvement to project schedules, waste reduction and improved productivity were important reasons for using prefabricated components. At least half of the participants also thought that improved quality of work, cleaner work environment, improved safety and increased profits were also important considerations in using prefabricated components.

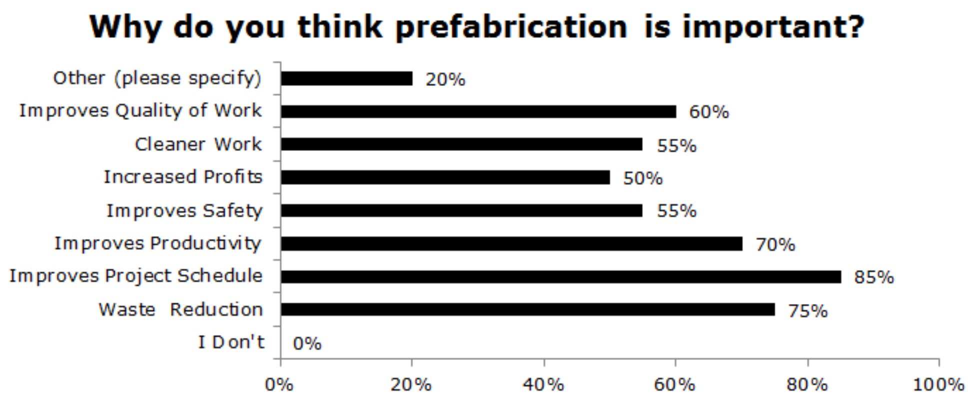

Figure 2: Factors contributing to the importance of prefabrication.

The focus of this research is to increase the use of prefabrication practices within the construction industry. Therefore the participants were further probed about their opinions regarding reduction in waste by using prefabricated components versus traditional construction methods. Specifically they were asked if prefabrication reduces waste in the construction industry, the results for which are shown in Figure 3. The overwhelming majority of participants agreed that prefabrication practices resulted in lower waste, as compared to traditional methods of construction. Participants were given an opportunity to provide written comments, to which two responses were received and both were supportive of the notion that prefabrication reduces waste as compared to onsite construction.

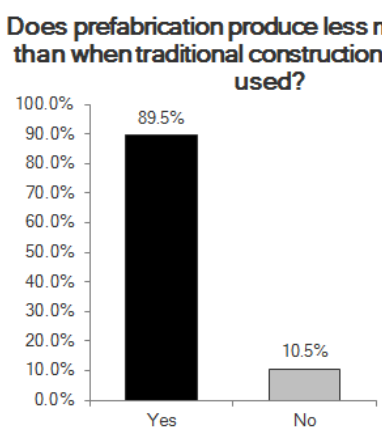

Figure 3: Less waste due to prefabrication versus traditional construction

Participants were asked if they supported the idea of giving LEED credits to construction projects where prefabrication practices were used. The results to this question are presented in Figure 4.

The results indicate that almost 80% of the participants agree that LEED credits should be awarded to projects that use prefabricated components. Six participants also chose to comment further on this question. The responses indicate that four comments were supportive with two of them indicating that they had already received LEED credits in the innovation category of the LEED rating system. Two of the comments suggested a more cautious approach and suggested stringent criteria for basing the decision of whether to award LEED credits for the use of prefabricated components.

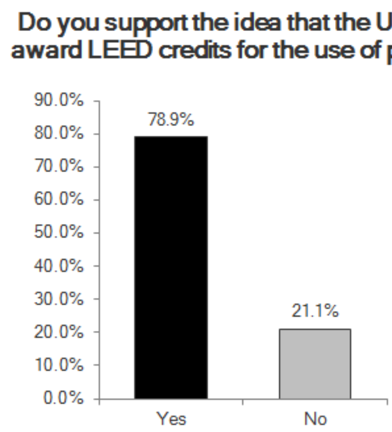

Figure 4: Support for awarding LEED credits for prefabricated materials.

Participants were then asked if they thought the use of prefabrication would increase as a result of giving LEED credits to projects using prefabricated components. The results to this question are presented in Figure 5. Almost seventy percent of the respondents agreed that the use of prefabrication in the construction industry would increase as a result of giving LEED credits to projects that use prefabricated components.

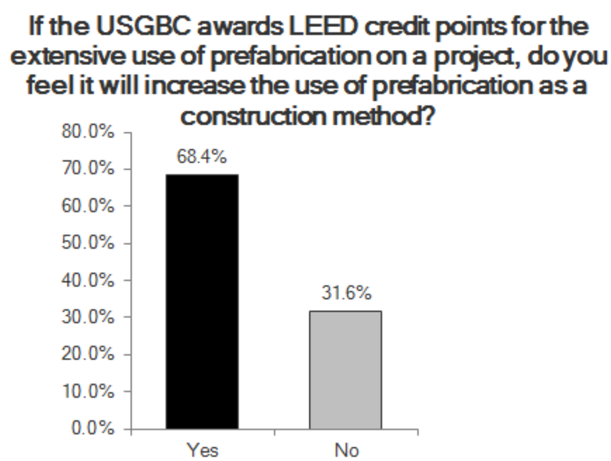

Figure 5: Increased adoption of prefabrication practices as a result of awarding LEED credits.

The final question asked an open ended question, where they were asked to comment about why they thought it was important for USGBC to give LEED credits for projects using pre-fabricated components. They were also asked to comment on how they saw the construction industry would be impacted by that decision. The results for this question resulted in sixteen responses from the nineteen participants. The response rate to this question also indicates a high level of interest by the participants to this topic. The results indicate that two respondents were not in favor of giving LEED credits for the use of prefabricated components in construction projects, whereas the remaining fourteen respondents were supportive of the idea. Among the supportive comments, one theme that was seen in more than half the responses was the idea that prefabrication reduces waste and would fir naturally with the USGBC's mission of building structures in a environmentally responsible way.

Another interesting idea spelled out by three participants for the last questions was that prefabrication tries to replicate manufacturing processes and the current trend in the manufacturing sector is identify and reduce material and labor waste. Hence by the construction industry adopting prefabrication, it would naturally require companies to look at reducing material and labor waste. In order to provide a better understanding of the results to this question, three typical comments from the participants are presented below:

"*By making material use more efficient, the impact on the earth's resources will be reduced. Construction sites do not make the best manufacturing sites, yet everything happening there is about production. Anything that can improve that production without just transferring the problems and waste should be recognized by USGBC."*

"If they were to award credits, more subcontractors would become savvy in this form of construction and in essence a new construction standard might be developed."

"Prefabrication typically brings manufacturing insight to the building process which identifies and eliminates wasted material and labor. Prefabrication will continue to gain ground among top tier contractors regardless of LEED recognition due to cost savings."

Conclusions

It is hoped that this study will help facilitate change within the construction industry. The information derived from the literature review and the data collected from the online surveys was intended to investigate the possibility of using prefabricated components to obtain LEED credit points for the materials and resources section. Through the literature review, it was hoped that that information would support the following objectives:

To investigate how material use is optimized in prefabricated components.
To examine how material use, reuse, and recycling can be more efficient at prefabrication manufacturing plants versus on construction sites.
To propose that prefabrication can be used to obtain LEED credit points in the material and resources section.

The information taken from the literature review did not reveal any specific information that supported the first objective. However, the literature did prove that prefabrication does help in reducing material waste. It also exposed advantages of using offsite facilities to construct prefabricated components. The controlled environment helps in encouraging greater material reuse, and recycling. Information was found that gave some merit to the belief that prefabrication can successfully be used to obtain certification through the use of the USGBC LEED rating system. Future research should seek some way of adding substance, like a case study, to the claims made about using prefabrication to obtain LEED credit point. A limitation with the literature review was that not a lot of information was available on the research topic. A survey was used in place of a case study to help reveal any how professionals would respond to the use of prefabrication for the LEED rating system.

The intent of the waste management strategy in LEED credits is to minimize the amount of waste that is sent to landfills and reprocess that material back to the manufacturing process. This research has shown that experts agree that the use of prefabrication reduces waste and that it should be recognized by awarding LEED credits. The analyzed data produced by the survey aligned with much of the information that was presented in the literature review. The research has shown that many industry professionals shared the same beliefs about the benefits of prefabrication. It also demonstrated how most construction professionals believed that prefabrication use would increase in the future.

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