Adaptability of Materials in Green Buildings: Australian Case Studies and Review

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\textbf{Abstract.} Globally, more and more buildings are constructed as the basis of green methodology. Green building methodology includes the reduction of energy from the conception through the operation phases. Importantly, the practice of green building is gradually becoming more regulatory compliance rather than optional. Subsequently, this paper will carefully review the adaptability of materials in green buildings. In supporting such aim, this paper will also reviewed five Australian case studies. For these building, as a part of adaptability of green materials, recycled concrete, metal and timber were utilized. It was found that most benefits of adaptability of materials for these buildings were significantly improved with the integration with sustainable design. Such alignment is the key for effective material selection and usage in green buildings. The use of green materials alone may be not be enough to considerably reduce the energy usage. Holistically, the green design together with recycled materials need to be combined to deliver efficient green buildings.

1. Introduction

Universally, green buildings refer to advanced and innovative processes which ultimately lead to less environmental impacts [1-4]. Such processes include all the building design and construction together with operational practices. On the other hand, an important aspect of green buildings are the utilized materials [5-7]. Sodagar et al. [8] argued that, the impact of green buildings can at times be heavily material based. Another words, a more sustainable building approach can be undertaken with the limiting material sources and thus the subsequent build-up of waste in landfills. Nonetheless, the green building methodology includes all the mining and collection of materials, their preparation and production, the transportation and the overwhelming creation of construction waste [9]. Additionally, the practice of green building is gradually becoming more regulatory compliance rather than optional [10-12]. Such outcome is based on universal reduction of global resources to high levels of pollution for the benefits of environment [13-15]. Subsequently, all the entities involved in building and construction field such as architects, manufacturers and so on need to carefully consider the environment conservation [16-18]. Subsequently, this paper will carefully review the adaptability of materials in green buildings. In supporting such aim, this paper will also review five Australian case studies.

2. Literature review

Traditionally, due to renewable focus, the green building materials have nontoxic properties which are made from recycled materials [19-22]. Moreover, these can be recycled and subsequently share the...
characteristics of being both energy and water efficient. For green buildings such materials share distinct benefits: ability to conserve energy; increased adaptability through the design stages and so on [23-25]. Such benefits will ultimately lead to overall reduced costs ie moderate repair costs throughout the building’s lifecycle [26-28].

As far as comparison of such materials in opposition to the traditional i.e. steel, Gunn [29] signified the that complex deterioration can be expected in the form of replacement and repair for the standard building materials, however, for green materials they can be less complex. However, the real advantage of green materials is their overall energy consumption. Green materials such as stone, due to their the natural bases, generally require very little maintenance and rehabilitation. Additionally, stone has far superior water resistance in comparison to concrete. Morel et al. [30] further compared energy consumption of stone opposed to concrete, with their result suggesting that typically a concrete house would consume couple of times more energy. They also noted that transportation of concrete when compared to stone has even more energy consumption. Subsequently, other research have also highlighted stone as a better alternative to concrete, wood and steel. Particularly, when the durability, maintenance, energy usage and environmental impact of such materials are considered.

Nonetheless, Bartlett and Howard [31] deliberated that there is a common misconception with green buildings costing 5% to 15% more to construct when compared to standard buildings. They further expand on their claim by suggesting that cost advisors in the building industry severely over-estimate the central costs of green building and critically under-estimate the possible cost savings. This view is supported by Nalewaik [32] who also claims that green building green benefits from lifecycle cost savings and that some aspects of such design methodology are more cost-efficient. Subsequently, it can be determined that the general conception of green buildings is associated higher costs throughout their life. Gharehbaghi and Rahmani [33] reviewed the concept of green materials, as alignment with recycled substances particularly, concrete, metal and to extent degree timber. While recycled concrete usually consists of crushed materials, it can be used as dry aggregate for many purposes such as new mixes. On the other hand, recycled metal would generally include scraped aluminum, copper, steel, brass, iron and so on. Both recycled concrete and metal can significantly reduce the overall cost of material's cost [3, 34, 35]. At the same time as, recycled timber could also be reprocessed as alternative building material. Subsequently, reusing and recycling concrete, metal and timber would ultimately reduce the material waste and more importantly lessen environmental impacts [36]. Appropriately, further investigate is required to carefully review both positive and negative possibilities of green buildings and their material usages.

3. Research methodology
This research first reviews the most relevant and recent green building and material literature. In supporting such aim, this paper will also review five Australian case studies. The appropriate data was gathered from used various building log-books together with design schematics and reports were accessed and scrutinized. Finally, since this study is a qualitative investigation, an overall finding was then evaluation.

4. Case studies
The five buildings were all randomly selected, from different Australian estates and were based on two classifications - retrofitting and new buildings. The first three homes were built with standard building design and then retrofitted with green building initiatives. The remaining two homes were built as brand new and utilized green building design. Table 1 summarizes the five case studies.
Table 1. Overview of the case studies.

| Building location                  | Main green building features                                                                                                                                                                                                 | Main green materials                      |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| Building 1: Birkenhead, South Australia. Retrofitting | The renovation of a single-story home that focused on making the structure energy efficient with limited area and spending. Its improvements were: Increasing thermal mass, improving windows and glazing, SIPs wall construction, sealed building fabric, solar hot water and solar photovoltaic systems, energy-efficient lighting and water saving. Each improvement is detailed in the section of the case study and identifies how each of the improvements can be incorporated into future construction builds. | Recycled concrete, metal and timber       |
| Building 2: Curtin, Australian Capital Territory. Retrofitting | The renovation of a two-story home that focused on improving temperature control during colder periods and increasing the availability of natural lighting. Its improvements were based on: Solar hot water and solar photovoltaic systems, passive heating and cooling, active heating and cooling, green building materials and insulation, energy-efficient lighting, recyclable materials and water saving. Each improvement is detailed in the section of the case study and identifies how each of the improvements can be incorporated into future construction builds. | Recycled concrete and timber             |
| Building 3: Fitzroy North, Victoria. Retrofitting | The renovation of a two-story home that utilised the following green building initiatives: Passive heating and cooling, sustainable material use, improved windows and glazing features, water saving, energy-efficient lighting, energy saving, solar hot water and solar photovoltaic systems and insulation. Each improvement is detailed in the section of the case study and identifies how each of the improvements can be incorporated into future construction builds. | Recycled concrete, metal and timber       |
| Building 4: Caloundra, Queensland. New building | The development of a new display home that focused on displaying the potential of construction with green building initiatives. Its inclusions were: Reverse brick veneer, lightweight material construction, insulation, glazed windows, solar photovoltaic system, energy-efficient appliances and water saving. Each inclusion is detailed in the section of the case study and identifies how each of the inclusions can be incorporated into future construction builds. | Recycled concrete, metal and timber       |
| Building 5: Darwin River, Northern Territory. New | The development of a two-story home that focused on passive cooling and water saving. Its green building inclusions were: Water saving, embodied energy reductions, greenhouse gas reductions and renewable sources of energy. Each inclusion is | Recycled concrete, metal and timber       |
Importantly, all the five buildings utilized range of cooling and heating initiatives including, solar hot water systems, solar photovoltaic systems. These initiatives were together used with green materials as a part of the renewable energy production and greenhouse gas reduction strategies. As a part of such materials selection recycled concrete, steel and timber were utilized. As a concept of adaptability of materials in green buildings, this arrangement included lightweight construction with utilization of excess materials from a different demolition while using recycled timber. Foundation slab: 60% recycled materials and 30% cement substitute. Removal of bricks at various sections of the structure and replaced with restored timber weatherboards in the form of cladding. Change to the existing walls insulation that included R3 recycled polystyrene, R2 polyester batts and R5 wool cells. For the existing homes, materials used generally that had lower impact on the environment while having reductions in embodied energy. In addition, the renovation included facade alterations including change to the existing walls insulation that included R3 recycled polystyrene, R2 polyester batts and R5 wool cells. These changes restricted the flow of heat during winter to maintain warmth within the home, whereas the old design lacked the insulation required to do so. Generally, the use of the green processes and materials saved the buildings over a tonne of CO$_2$.

Further, all the five buildings utilized three main green materials, recycled concrete, steel and timber. The overall percentile of materials in the five green buildings in presented in figure 1.

The adaptability of the "overall" materials in the five green buildings in represented in Figure 1. For these five buildings, it seems that recycled concrete is the most dominate green material. The reason for such usage, could be due to more alternatives to use recycled concrete. Particularly for pre-case panels together with low-load bearing walls recycled concrete is an ideal material. Nonetheless, both recycled metal and timber were comparably used in these five buildings. However, the adaptability of materials in these structures were also further supported by green building design. Another words, to reduce energy usage, the materials in these buildings were cooperated with green design. Such green design included, improving the natural lighting through better orientation and new design windows. Moreover, as a part of energy self-efficiency, these buildings sealed off penetrations to greatly improve passive heating and cooling. These buildings use such strategies to provide a passively heat and cool which in-turn reduce the amount of necessary active heating and cooling. The use of green materials along with other energy reductions plans such as rainwater tanks significantly reduced the energy usage for these buildings. The lesson which can be learned, is that the use of green materials alone may be not
environmental benefits of green design together with recycled materials go together to deliver efficient green buildings.

5. Conclusion
This paper aimed to review the adaptability of materials in green buildings, to improve the overall understanding of green building construction methods and materials. Subsequently, other considerations such as the general benefits of using standard green building materials and methods were also researched. To further strengthen the research aim, five Australian case studies were identified and analyzed. Aptly, each study demonstrated how the different regions and climates can ultimately adapt the structures and their materials. Nonetheless, as the basis of adaptability of materials in green buildings the findings of the research can be summarized as: a) generally, there are several small changes which can be made to produce a structure which is home environmentally friendly and energy exertion, and b) such initiatives can be significantly cost efficient. As the findings of the case studies showed, most of the cost effectiveness does not only occur with the material selection but rather the mutually of sustainable design to support the green building adoptability.

6. References
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