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Supporting Design for Deconstruction through Environmental Assessment Methods

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ABSTRACT

It is important to consider the embodied energy of buildings and not solely the operational energy required to run them. This paper discusses potential ways of reducing the embodied energy of construction projects, utilising strategies such as design for deconstruction and the reuse of materials. However, there are barriers preventing wide use of this approach - these are discussed along with possible strategies for overcoming them. Design for deconstruction and material reuse could be encouraged through environmental assessment methods. Three assessment methods (BREEAM, LEED and Green Star) are analysed and contrasted, investigating the current scope of credits that reward material reuse and design for deconstruction. An analysis is then undertaken of LEED platinum projects, examining how many projects actually achieve material reuse credits, and if this varies depending on the building type or location. This paper proposes that current environmental assessment methods be expanded to more actively encourage the practice of design for deconstruction, with a view to increasing the supply of reused materials.

KEYWORDS：Embodied Energy, Design for Deconstruction, Material Reuse, Environmental Assessment Methods

1 INTRODUCTION

There is increasing pressure on governments to reduce operational carbon emissions in buildings. The UK aims for all new domestic buildings to be zero carbon by 2016 and non-domestic buildings zero carbon by 2019 (CLG, 2008). In designing a zero carbon building, the main issue to be addressed is the operational energy of the building and offsetting energy use by the provision of renewable energy sources. Zero energy buildings may be defined in a number of ways: net zero site energy, net zero source energy, net zero energy costs and net zero energy emissions (Torcellini et al, 2006). Most zero carbon buildings aim to be net zero energy emissions, meaning that they are designed to generate on site at least as much emissions-free energy as they use from emissions producing energy sources. Net zero site energy (i.e. all the energy the building uses in a year must be produced on-site) can be a challenge for many projects. Net zero source energy is generally considered to be more achievable than this, meaning renewable energy can be sourced from off-site. The most difficult of all to achieve is net zero energy costs, this is because the income from exported electricity is generally not enough to offset all the utility charges and energy supplied from the grid (Torcellini, et al, 2006).

However, is it enough to focus solely on operational energy? There are also significant amounts of embodied energy and carbon within buildings that should be considered. The Green Building Council Australia note that ‘buildings need to have zero emissions in their construction, operation and embodied energy to be truly carbon neutral’ (GBCA, 2008). Concern over climate change and the minimisation of green house gases would seem to suggest that once operational carbon emissions have been addressed it will become increasingly important for embodied energy to also be considered. A fact sheet by the Green Building Council Australia states that it should be possible to construct buildings with zero operational emissions by 2020, but ‘truly carbon neutral buildings are a significant challenge’ (GBCA, 2008). Part of that challenge is the consideration of how to minimise embodied energy.

This minimisation could be targeted in a number of ways; the energy efficiency of manufacturing processes could be improved, thus reducing the energy embedded in some components. Durable and adaptable materials could be specified reducing the need to expend further energy in maintenance and repair activities. Local materials could be specified to reduce the energy and emissions associated with transport that can make up large proportions of the embodied energy of materials. Another alternative is the specification of reused materials; this avoids the expenditure of energy to manufacture new materials, and values the embodied energy already in an existing material. A Waste and Resources Action Programme (WRAP) report suggests that there is a ‘96% environmental impact saving by reclaiming and reusing 99 tonnes of steel’ (WRAP, 2008, p.5). Other advantages of this approach are a lessening of the exploitation of natural resources, which Brocklesby (1998) identifies as a key point of environmental concern. Material reuse will also result in the reduction of demolition waste and is an important part of a waste management strategy called the Ladder of Lansink (Dorsthorst & Kowalczyk, 2003). Clearly, the specification of reused materials is a sustainable solution to several construction problems.

2 ENVIRONMENTAL ASSESSMENT METHODS

Environmental assessment methods are widely used to rate the sustainability of buildings. As the construction industry aims to minimise its impact on the environment, these tools are becoming essential to assess and compare design innovations intended to improve sustainability across the sector. In addition, these assessments highlight those buildings that are achieving very high environmental standards, demonstrating how this can be accomplished. There are a number of assessment methods used around the globe, some of which include: BREEAM (Great Britain), EcoProfile (Norway), Environmental Status (Sweden), LEED (USA), GBTool (Canada), HK-BEAM (Hong Kong), CASBEE (Japan), and Green Star (Australia) (Ali & Al Nsairat, 2009 and Lee & Burnett, 2008).

2.1 An Overview of BREEAM, LEED and Green Star

This paper considers three of these environmental assessment methods: BREEAM, LEED and Green Star; these are used internationally and consider many similar issues. BREEAM (Building Research Establishment Environmental Assessment Method) was the first of these assessment methods, launched in the UK in 1990 (Parker, 2009). It has since grown to encompass a variety of tools for different building types and has also been developed for use in different areas of the world and is now used on an international scale. LEED (Leadership in Energy and Environmental Design) was launched in pilot version in 1998 (USGBC, 2009b), originally for use within the USA, but is now used worldwide with countries developing their own versions of it (CaGBC, 2010). Green Star was launched in 2003, initially for use in Australia, but has now also been adopted in New Zealand and South Africa (GBCA, 2009b).

BREEAM has five different levels of certification (pass, good, very good, excellent and outstanding) depending on how many credits are achieved in total in the assessment. There are ten categories in which credits may be gained, as shown in Table 1, (BRE, 2010). LEED has four levels of achievement (certified, silver, gold and platinum) and like BREEAM the level of certification is dependent on the total credits earned. In the current version of LEED (version 3), there are one hundred and ten points available, divided into seven categories, see Table 1 (USGBC, 2009a). Finally, Green Star has three different rating levels: four star, which represents ‘best practice’, five star, which signifies ‘Australian excellence’ and six stars to demonstrate ‘World Leadership’. The points to achieve these ratings are divided into nine categories. Environmental weighting factors are applied to the percentage score of each category. The weighted category scores are added together to form an overall score, which has a maximum value of one hundred; there are five additional points available for innovation. The weighting factors vary depending on the location of the project, which enables the assessment to take into account local concerns and priorities (GBCA, 2009a). The categories in the different assessment methods are largely comparable, as can be seen in Table 1.

Table 1 Categories in which points can be earned within BREEAM, LEED and Green Star

BREEAM	LEED	Green Star
Management (21*)+		Management (12)+
Health & Wellbeing (18*)+	Indoor Environmental Quality (15)	Indoor Environmental Quality (27)+
Energy (36*)+	Energy & Atmosphere (35)	Energy (29)+
Transport (14*)+		Transport (11)+
Water (8*)+	Water Efficiency (10)	Water (12)+
Materials (15*)+	Materials & Resources (14)	Materials (22)+
Waste (10*)+		
Land use & Ecology (12*)+	Sustainable Sites (26)	Land use & Ecology (8)+
Pollution (12*)+		Emissions (16)+
Innovation (10)	Innovation in Design (6)	Innovation (5)
	Regional Priority (4)	
156 points available	110 points available	142 points available

Key
**Maximum amount of points available in BREEAM education, number of points available is dependant on building type and facilities.*
+Environmental/section weighting factors are applied to these before a total score is calculated.

There have been many discussions about which assessment method is best or fairest (Crawley, & Aho, 1999; Fenner & Ryce, 2008a, 2008b; Julien, 2008; Lee & Burnett, 2008; Parker, 2009; Saunders, 2008; Slavid, 2009). The preferred assessment method is a matter of opinion but the choice of method may also be dependent on the location of the project.

2.2 Materials Credits – those that reward minimisation of embodied energy and design for deconstruction

Green Star is the only one of these three assessment methods that specifically rewards design for deconstruction. Within the materials category (credit MAT 9 – design for disassembly) a single point is available to reward projects that design parts of their building for disassembly. The point is awarded if either 50% and above of the structural framing, roofing and facade cladding systems are designed for deconstruction or if 95% of the facade is designed in this way. The point aims to minimise the impact of the building at the end of life by enabling higher material recovery for reuse, and minimising waste sent to landfill (GBCA, 2010). There are also other credits in Green Star that reward minimising embodied energy e.g. MAT 2, rewards existing building reuse and MAT 3 is available to projects that specify reused materials for 2% of the project's value. Three points are available for the reduction of the embodied energy of concrete (MAT 5) and two points to reward the reuse of steel components or the use of steel with a high recycled content (MAT 6). Finally there are two points that can be achieved through the specification of reused, recycled or FSC (Forest Stewardship Council) certified timber (GBCA, 2010).

LEED has three credits available for existing building reuse, two credits that reward material reuse (one for 5% reuse, the second if levels of 10% are reached) and two credits that can be earned through the use of recycled materials (USGBC, 2009a). Earning points for minimising embodied energy is more complicated in BREEAM. Points are awarded for material specification of major elements, materials are assessed using BRE’s Green Guide, and depending on the assessment a certain number of credits are earned. However, it is difficult to know how reused materials would be rewarded and it is recommended that the assessor seek BRE’s guidance on how to credit the specification of reused materials (BRE, 2010). There are also credits available within BREEAM for reusing existing facades (one credit) or reusing an existing structure on the site (one credit).

3 RESEARCH METHOD

The use of environmental assessment methods is becoming more important and their use as part of the design process is starting to be common practice. Projects that achieve the highest of environmental ratings attract publicity, but there is also criticism that some buildings have sustainable add-ons to gain points (Zimmerman & Kibert, 2007), or concentrate on the easy to gain points, and ignore the harder to achieve, and perhaps more important ones. To investigate this, an analysis of where credits are typically gained, and where they are not, has been undertaken. As LEED has easily accessible data from the USGBC website, whereas BREEAM and Green Star do not, the credit analysis examines only LEED case studies.

In order to try and ascertain which credits are easiest to earn in LEED, data on 61 case studies was collected from the USGBC website. All the case studies chosen have attained LEED platinum certification, when assessed using LEED for New Construction, version 2.0, 2.1, or 2.2. These versions assess the same credits, but the wording has been altered to clarify the aim of certain credits. Version two of LEED does have some differences to the current version of LEED (version 3, which was described earlier in this paper), mainly, there are a different number of credits available, only a total of sixty-nine points can be earned in version two, and there is no regional priority category. The case studies are made up of a number of different building types and are located across the USA.

The data collected identified which credits were gained within each project and was considered in two ways: the total number of credits achieved within individual categories, and the number of projects that obtained each separate credit. From this data it was possible to ascertain which credits the majority of projects were obtaining; these being the easiest credits to achieve, and conversely which credits could be seen as being hardest to achieve, as so few projects were earning them.

The data was broken down into sets to investigate whether the location or the building type influenced which credits were easiest to earn. For the analysis by location, the projects were sorted by the state in which they were located.

To investigate the impact of different building types on the achievement of credits, the projects were grouped into five different building types: educational buildings, office buildings, combined office and public buildings, public buildings and residential buildings. Where projects had multiple uses the main use was chosen for the categorisation.

4 Results and Analysis

Initially, the number of credits achieved within each category was investigated on an individual case study basis. The number of credits obtained in a category was divided by the number of credits available in that category, and converted into a percentage. It was thus possible to compare the level of credit achievement between the different categories on an individual case study basis. Considering all the projects together, an average was taken of the percentage of credits achieved in each category, this allowed further analysis. Figure 1 shows that the category in which the fewest percentage of credits are earned is materials and resources, and the percentage of credits earned is significantly lower than all the other categories. There does however, seem to be a fairly even spread of credits within the other categories. The material and resources category was considered in more detail (see Figure 2) to investigate if there are particular credits in this area that are difficult to obtain.

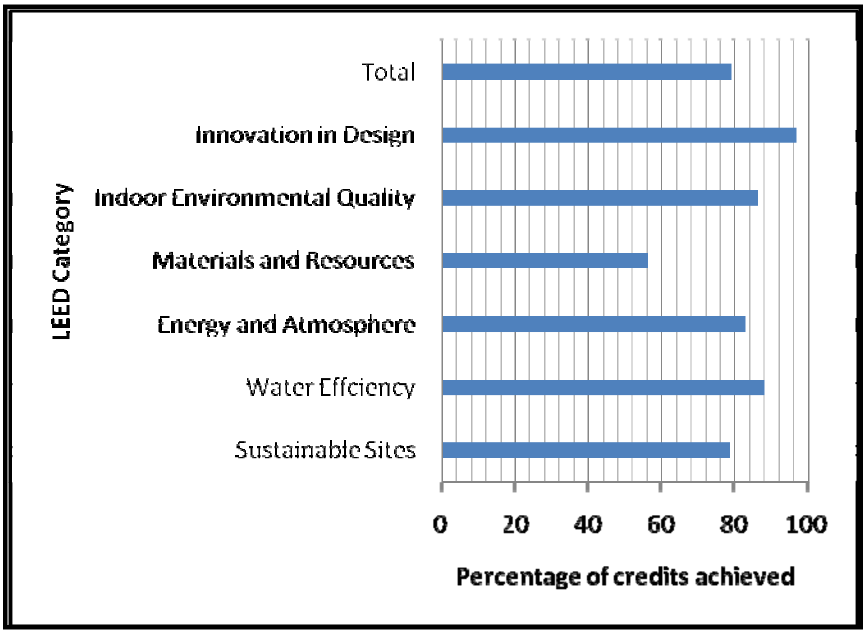

Figure 1 Percentage of credits achieved in each LEED Category

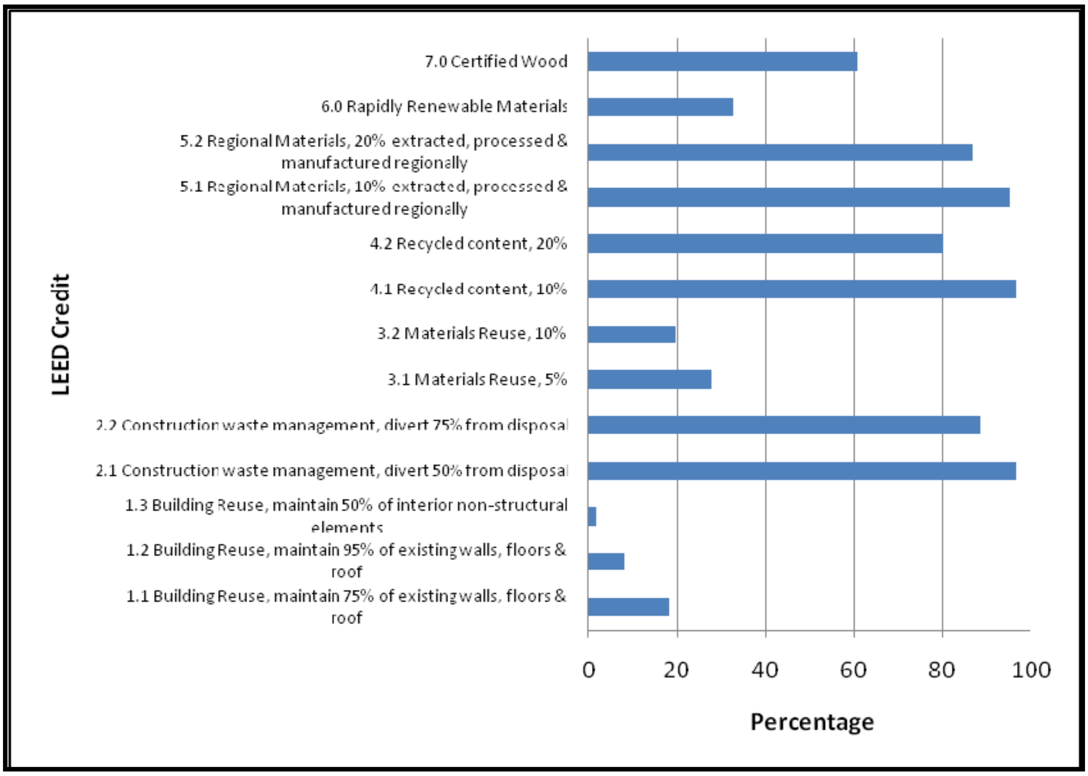

Figure 2 Percentage of projects earning specific credits in Materials & Resources Category

There is a lot of variation as to which credits are earned within the Materials and Resources category. Waste management, specification of recycled and regionally sourced materials are credits that are earned by many projects. Whereas, those credits associated with building reuse or material reuse are obtained by few projects. Greater reuse of materials is an issue that should be encouraged as it would result in lower embodied energy of buildings, minimise demolition waste at end of life, and reduce the extraction of natural resources.

4.1 Credits obtained by all projects

Just two credits were obtained by all 61 case studies; both are found in the water efficiency category, namely *1.1 Water Efficient Landscaping, reduce by 50%,* and *3.1 Water use reduction, 20% reduction.* As all projects obtained these credits it can be inferred that these are the easiest credits to achieve. It could also be argued that these credits should become prerequisites within LEED which would raise the standards of all buildings seeking LEED certification. This has already happened in the case of credit *3.1 Water use reduction, 20% reduction*; in the upgrade to version 3, it has become a prerequisite for all projects. This is an excellent example of how the development of LEED (and other environmental assessment methods) should occur. With each upgrade, higher standards should be sought. In the upgrade to LEED version 3, reduced water use was encouraged awarding up to four points for a 40% reduction in water use (USGBC, 2009a, p.26), up from two points for a 30% reduction in earlier versions of LEED versions (USGBC, 2005). Developing assessment methods in this way promotes higher environmental standards for buildings seeking certification, and demonstrates to the construction industry that these practices can be achieved, hopefully encouraging other building projects to reach for these standards.

4.2 Credits thought to be easy to obtain (achieved by >90% of projects)

Some specific credits were not considered within this assessment, Energy and Atmosphere credits: 1. Optimise energy performance, 2. On-site renewable energy. These were not assessed as there are multiple point options within them and whilst most projects obtained the first credits, few earned all. Innovation credits were also not assessed, as they reward different aspects of building performance and so cannot be directly compared between projects.

Fourteen credits (out of fifty-one credits assessed) were obtained by 90+% of projects:

Sustainable Sites:

- 4.4 Alternative transport – parking capacity
- 5.2 Site development, maximise open space
- 7.1 Heat Island effect, roof

Water Efficiency:

- 3.2 Water use reduction, 30% reduction

Energy & Atmosphere:

- 4.0 Enhanced refrigerant management

Materials & Resources:

- 2.1 Construction waste management, divert 50% from disposal
- 4.1 Recycled content, 10%
- 5.1 Regional Materials, 10% extracted, processed and manufactured regionally

Indoor Environmental Quality:

- 1.0 Outdoor air delivery monitoring
- 3.1 Construction IAQ management plan, during construction
- 4.1 Low-emitting materials, adhesives and sealants
- 4.2 Low-emitting materials, paints and coatings
- 4.3 Low-emitting materials, carpet systems
- 7.1 Thermal control, design

As so many LEED projects are obtaining these credits, it is expected that design teams and contractors will become used to considering and achieving these standards. In time, they will start to become integrated into typical design practice, rather than confined to those projects aspiring to a high LEED assessed score. Legislation is planned in California that will require designers to consider some of these issues for all new buildings. The new Green Building Standards Code for California (becoming effective in January 2011) requires all new buildings to achieve a minimum performance, setting standards for practices such as construction waste and specification of low-emitting materials (CALGreen Code, 2010).

4.3 Credits that are considered to be difficult to obtain (achieved in <50% of projects)

There are eight credits that are considered difficult to achieve, five of these are closely linked to site choice, so will generally only be obtained if the site is either specifically chosen to fulfil these credits or simply happens to. In the case of the credits associated with building reuse, there is only a possibility of obtaining these if there is already an existing building on the site and if it is in a condition to be reused. The credits that are not linked to site choice are italicised in the list below. Credits that are considered difficult to obtain are:

Sustainable Sites:

- 2. Development density and community connectivity
- 3. Brownfield development

Materials and Resources:

- 1.1 Building Reuse, maintain 75% existing walls, floors and roof
- 1.2 Building Reuse, maintain 95% existing walls, floors and roof
- 1.3 Building Reuse, maintain 50% of interior non-structural elements
- *3.1 Materials reuse, 5%*
- *3.2 Materials reuse, 10%*
- *6.0 Rapidly renewable materials*

As can be seen from the above list, one credit that few projects achieve is rapidly renewable materials. These materials must make up 2.5% of the total value of the building products specified for the credit to be earned. Examples of these types of materials are: bamboo, wool, cotton insulation and cork. Rapidly renewable materials are generally considered to be those from plants that are harvested in ten-year (or shorter) cycles (USGBC, 2005). These types of materials will not be suitable for all projects and are not commonly used at present.

The difficulties associated with obtaining the two credits to reward material reuse may be partially due to the lack of legislation and design guidance to support the reuse of materials. In some cases reuse of structural materials is discouraged by insurance company policies (Addis & Schouten, 2004). There is also often an absence of a complete supply chain for reused materials (Dolan, Lampo & Dearborn, 1999; Guy & Shell, 2002; Hurley et al., 2002; Storey & Pedersen, 2003), particularly if specific sizes of products are required, and these can be challenging to find. A potential way to overcome this difficulty is to source the reused materials at the start of the project so that specific sizes of components can be designed into the building (Guy & Shell, 2002). Existing buildings can be deconstructed rather than demolished to maximise the materials that can be salvaged for reuse.

An alternative way to increase the supply chain of reused materials is to design new buildings to be deconstructed rather than demolished. This would permit buildings to be taken apart without damage to the majority of the building components, therefore allowing these materials to be reused in later building projects (Addis & Schouten, 2004). Reusing materials is an effective way of decreasing the embodied energy of building projects, as the energy used to manufacture the material can either be associated to the first life of the material, or effectively shared over the two or more lives, depending on the life cycle assessment approach adopted.

Some materials are more suitable than others to design for deconstruction and reuse, this is particularly the case for structural materials. According to Gorgolewski (1999, p.26), 'steel frame buildings are particularly suited to being dismantled, and therefore allow the components and sometimes whole buildings to have further useful life'. Essentially, the components in a steel frame building can be bolted together instead of welded, enabling ease of deconstruction. In addition to this, 'for structural steel sections, the expected performance of reclaimed components can be predicted more easily' (Gorgolewski, 1999, p.26) when compared to other materials. This is not to say that other materials cannot be reused structurally but in cases where there is doubt about their properties testing may be needed before specification.

4.4 Analysis by location

The case studies were also sorted by location, to examine if this had any bearing on the credits earned. There were ten states that had three or more case studies; it was these states that were analysed. California had significantly more projects, a total of thirteen, whereas, all the other states only had three or four case studies each.

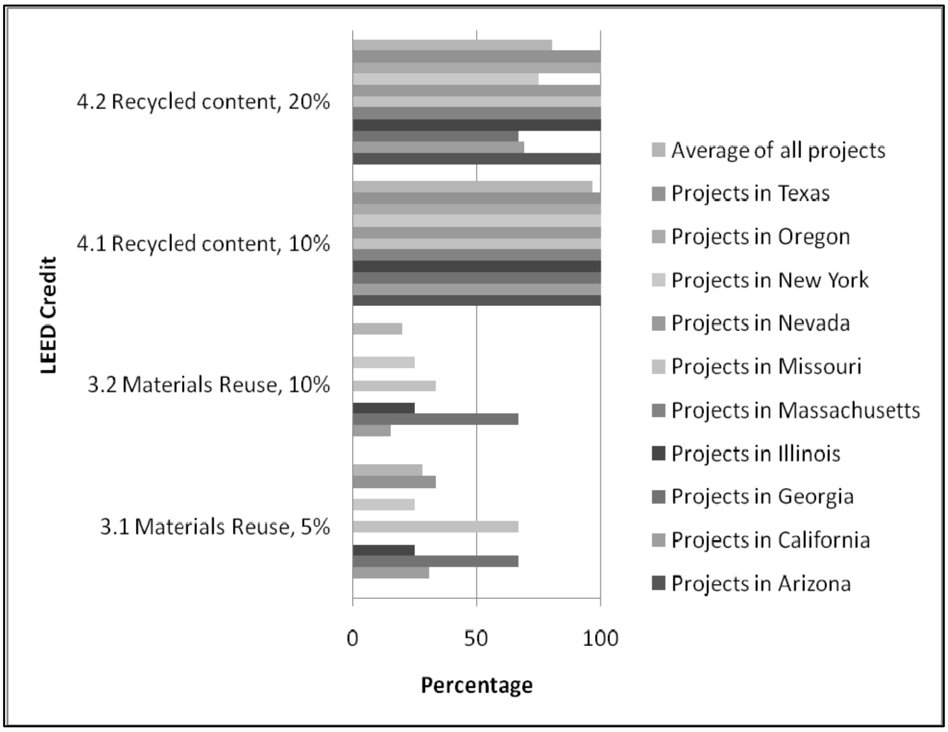

Figure 3 Percentage of projects within different US States obtaining reuse and recycling credits

The material reuse and recycled content credits were investigated to determine if the uptake of these varies depending on the location. No definitive conclusions can be drawn from the data, but the results in Figure 3 show that the percentage of projects obtaining reuse credits are highest within Georgia. It may be that there is a good reused material market within Georgia, or these projects specifically targeted these credits. As this data is derived from only three projects, more data would be required to draw firm conclusions.

4.5 Analysis by building type

The reuse and recycling credits were also analysed to test whether different building types are more likely to earn these credits than others. The results can be seen in Figure 4. It appears that office buildings may be slightly more likely to obtain the first credit, which may be due to some of these case studies being renovation projects and so they may have good access to existing materials. Generally, however, building type does not seem to make a large difference to the uptake of these credits. Once again, it may be that a larger data set would provide more definitive results.

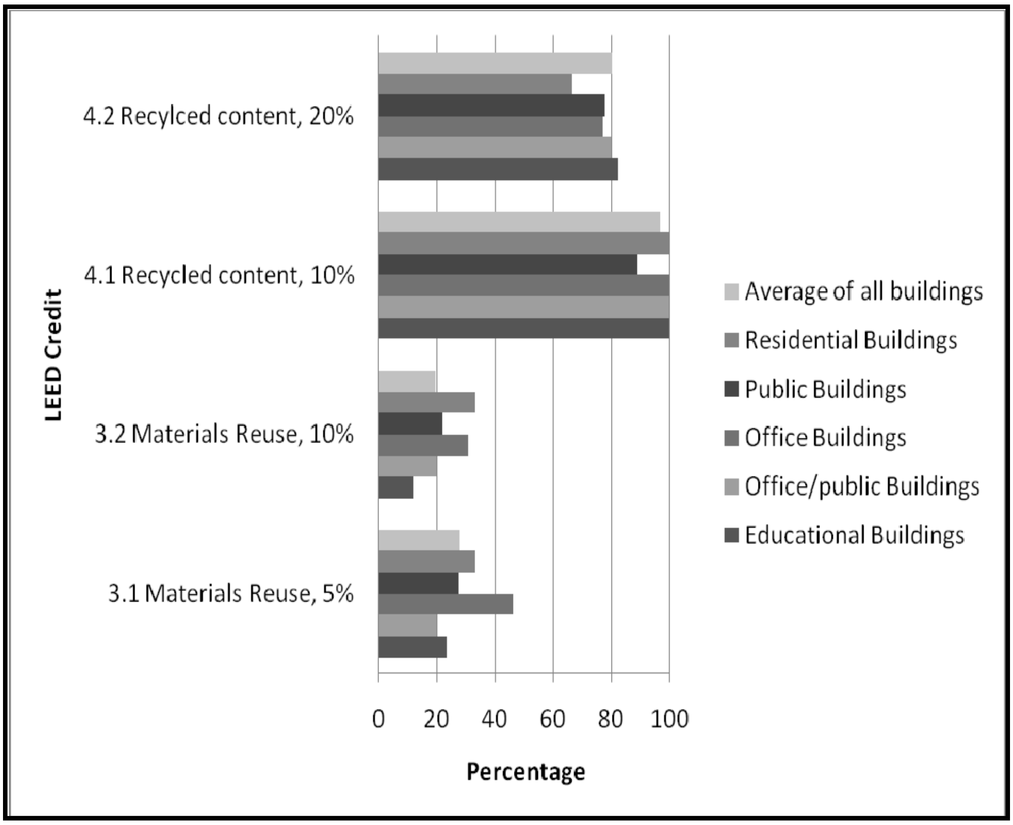

Figure 4 Percentage of different building types obtaining reuse and recycling credits

5 BARRIERS TO MATERIAL REUSE AND DESIGN FOR DECONSTRUCTION AND HOW TO ENCOURAGE THESE PRACTICES

The reuse of materials has been identified as reducing the embodied energy of buildings and combined with design for deconstruction (to increase the future supply chain of reused materials) is a way to minimise waste from demolition, and reduce the exploitation of natural resources. Essentially, a cradle to cradle design approach should be adopted in preference to the current cradle to grave methodology (Braungart & McDonough, 2008). There are a number of barriers to this approach, some of which have already been discussed within this paper but others include: the existing perception of reused materials as sub-standard, economic considerations, the lack of re-certification of materials for structural reuse, and a lack of incentives to deconstruct buildings.

The last of these could be addressed by environmental assessment methods. BREEAM and LEED could award greater credit for the minimisation of embodied energy and include a specific point to reward design for deconstruction to encourage this type of design practice. Design for deconstruction may be included in some capacity in the next updates of these assessments, the Environmental Protection Agency (EPA) are in discussions with the US Green Building Council about this (EPA, 2009), and design for deconstruction is mentioned as a waste reduction strategy in discussions about the proposed 2011 BREEAM update (UKGBC, 2010). An alternative option is to make design for deconstruction a prerequisite within the assessment methods, so that all buildings seeking certification have to consider end of life disassembly. This could start as a low percentage of the building (for example 50% of building structure should be designed for deconstruction) and be increased later as designing in this way becomes more common practice and therefore easier. There is also the possibility of introducing negative marking to the assessment methods, i.e. projects could lose marks if they do not have a certain minimum percentage of reused materials within them, or if a specified amount of the building is not designed to be deconstructed, the project could also lose marks.

6 USING ENVIRONMENTAL ASSESSMENT METHODS

The efficacy of environmental assessment methods in promoting sustainable design largely depends on when they are used. They are generally considered to be most useful when employed at an early stage in the design process, as it is then that environmental issues can be most easily incorporated (Ding, 2008). For example, if at the conceptual design stage the chosen assessment method was consulted and design for deconstruction was sufficiently well rewarded, then it would be possible for the design team to incorporate this within their design and decisions about material choice and construction techniques made accordingly.

One criticism of the use of assessment methods is that they are often used as a template for sustainability and approached in a tick box fashion rather than as an assessment tool to evaluate the sustainability of a well thought through design (Ding, 2008). Projects should be designed to be inherently sustainable, integrating all aspects that designers identify as important not just those areas that they will gain points for. However, as assessment methods are often used in this way then perhaps they should be developed to be more comprehensive and push projects towards more holistic design.

Environmental assessment methods may be approached and viewed differently depending on the legislative context in which they are used. For example, when BREEAM is used within the UK, it is in a much stricter legislative environment than when LEED is used in the USA and Green Star used in Australia. Companies in Australia may be more likely to seek Green Star certification to promote themselves as ‘green’, and to achieve lower operational costs as a quantifiable benefit for the client. By contrast, in the UK new buildings are legally required to meet high energy standards as specified within Building Regulations. In addition to this, some building types are required by the government to achieve certain minimum BREEAM ratings, for example all new build government funded schools must achieve a ‘very good’ BREEAM rating (BRE, 2009). This means that BREEAM rated buildings may carry less kudos as they become increasingly common.

Environmental assessment methods assess how the building has been designed, and in some cases how it has been built (BREEAM assessments have an assessment at design stage and a post-construction assessment (BRE, 2010)), but do not consider how the building is used. ‘Post occupancy studies repeatedly show that buildings do not perform to their design criteria’ (Innovation and Growth Team, 2010, p.20) and in many cases this is because they are not used as they were designed to be. This perhaps implies that an increased emphasis should be placed on designing buildings that are easy to use and on putting systems in place to educate the building users. The use of Energy Performance Certificates (EPCs) and Display Energy Certificates (DECs) will help show how efficiently buildings are being used. Energy Performance Certificates model ‘the theoretical, as designed, energy efficiency of a particular building, based on performance potential of the building itself (the fabric) and its services (such as heating, ventilation and lighting), compared to a benchmark.’ (Carbon Trust, 2009, p.14). Display Energy Certificates are a record of the operational energy of the building which is benchmarked against other buildings of a similar type (Carbon Trust, 2009) and will be used to demonstrate building energy consumption and will show where improvements have been made.

In addition to assessment methods, other tools could be developed to help designers assess the sustainable aspects of their conceptual design, considering issues such as embodied energy, potential operational energy and predicted end of life scenarios for the materials chosen. This would help influence designers to include design for deconstruction in their schemes. As more emphasis is being placed on considering the whole life carbon of buildings, tools that rigorously assess this could be very useful. The recent UK Low Carbon Construction report recommends that the industry and Government should agree upon a standardised way of measuring embodied carbon and that this should be incorporated into a whole life carbon appraisal method that can be used in feasibility studies and as a design tool (Innovation and Growth Team, 2010).

7 CONCLUSION

The embodied carbon of buildings is an important issue that needs to be considered and minimised during the design process; this should be done in conjunction with designing buildings to have low-zero operational emissions. It is recognised that this approach presents significant challenges for the construction industry but it is vital to aspire to this in order to minimise carbon emissions. This paper presents material reuse as a way to reduce embodied carbon, acknowledging that the lack of a supply chain of reused materials is a significant barrier. Designing buildings for deconstruction will make it significantly easier for materials to be salvaged at end of life, minimal damage should occur to the components, maximising the potential for material reuse. Designing in this way now will increase the future supply chains of reused materials although even some existing buildings may be suitable for deconstruction rather than demolition which would also increase current supply chains. Whilst material reuse is promoted in the three assessment methods explored, when these credits were investigated in further detail within LEED, few projects were seen to gain them. It is recommended that LEED and BREEAM are revised to include and promote design for deconstruction as a strategy to increase future reused material supply chains, as well as being a method to reduce construction and demolition waste.

The effectiveness of environmental assessment methods in encouraging truly sustainable design has been discussed, and it is suggested that they should be used early in the design process for maximum integration. They should not be used as tick box criteria but rather as schemes to reward and recognise those buildings that are truly sustainable and reward innovation. Minimising embodied carbon through design for deconstruction and material reuse is only one component of this, but a significant one, that is often overlooked. Whilst the lack of a supply chain is a significant barrier to material reuse and will not be changed in the short term, there are other barriers that should be addressed and would lead to more immediate benefits. In order to facilitate maximum material reuse, changes to legislation and practice need to occur. The development of re-certification procedures for reused structural materials would encourage structural engineers to specify such materials, and would also help to overcome insurance related problems that can arise for these materials. Another important issue to be tackled are attitudes towards reused or second-hand materials; they are often considered to be inferior, low quality or sub-standard and a lack of clear information about them may prevent their reuse. This requires informing clients, designers and contractors of the benefits of deconstruction and material reuse, potentially through the use of case studies. Further research to explicitly demonstrate the environmental benefits of material reuse may persuade designers of the advantages of this approach.

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透過環境評估方法之解構支援設計

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摘 要

顧慮到建築物蘊藏能源而不僅是用於建築物之所需運作能源相當重要。本文乃在探討減少建築計畫之蘊藏能源，使用策略如解構與物料再使用等設計。

然而，本方法之使用還是有多重阻礙-這邊會提出可能之因應策略。解構與物質再利用設計可透過環境評估方法來得到依據。運用這些評估方法 (BREEAM、LEED 與綠色之星)來進行分析與評估，調查現行獎勵材料再利用與解構設計等範圍。

接著以一項分析來檢驗 LEED 之白金獎項案例，若此改變乃端視建築物之類型與地點，檢視究竟有多少計畫實際達成物料再利用。本文建議，現行之環境評估方法可以擴大物料再利用之供給，並以此概念來延伸啓發解構設計之實行。

關鍵字：蘊藏能源，解構設計，物料再利用，環境評估方法