REduce
REuse
REcycle

Designing with Salvaged Building Materials

Submitted By: Nilesh Bansal, A/1869/2006

Dissertation Guide: Mrs. Mitra Mitra

Coordinator: Mrs. Jaya Kumar

School of Planning and Architecture, New Delhi
Acknowledgements

Special thanks to everyone who helped me through this dissertation. A big thank you to my guide Mrs. Mitra Mitra for her continuous help and support. I would also like to thank Mr. Ashwini Dutta for his guidance and remarks that helped to the betterment of my dissertation. Thanks also to Didi contractors for they guided me and helped document their projects. A final thank you to our dissertation coordinators Mrs. Jaya Kumar and Dr. Ranjana Mital who were never tired of our requests, enquiries and questions, and who supported us throughout.
List of Figures, Tables and Plates

**Figures**

**Figure 1:** Closed-loop life cycle for materials  
**Figure 2:** The Delft Ladder showing life-cycle material flow  
**Figure 3:** Waste industry view point  
**Figure 4:** Demolition industry view point  
**Figure 5:** Recycling and Manufacturing industry view point.  
**Figure 6:** Salvage industry view point.  
**Figure 7:** Design team and client view point  
**Figure 8:** Design for deconstruction  
**Figure 9:** Fabrication of new glass units from salvaged window  
**Figure 10:** Concrete recycling process  
**Figure 11:** Wood recycling process  
**Figure 12:** Gypsum recycling process  
**Figure 13:** Brick recycling process

**Tables**

**Table 1:** Comparison of High Value and High Volume Salvaged Materials  
**Table 2:** Considerations for Deconstruction during Design Phase
Plates

Plate 1: House made of reused and locally available materials 42
Plate 2: Handmade bricks molded from locally available clayey soil 42
Plate 3: Foundations of previous house reused for new construction 43
Plate 4: Reused wood members used for stilts 46
Plate 5: Lack of resources forces people to live in rickety shacks and cramped living conditions 46
Plate 6: Houses built from used asbestos sheets, torn fabric and straw 47
Plate 7: Structure made from reused glulam beams and metal cables 49
Plate 8: Roof decking done with reused cedar from deconstructed house 51
Plate 9: Refurbished house in Ardencraig 52
Plate 10: Stained glass window made from reused glass 52
Plate 11: Restored garage and house in Ardencraig 54
Plate 12: Existing wood framework 54
Table of contents

Abstract

Introduction

- Research Question
- Need Identification
- Aims and Objectives
- Scope of Study
- Limitations
- Research Methodology

Chapter I  The World Is A Salvage Yard

- Reasons to consider use of salvage materials
- The Delft Ladder
- Reclaiming The Material
- Architects Role
- Salvaged Materials Industry
- Different Perspectives
- Salvaged Materials

Chapter II  Obstacles and Solutions

- Social Factors
- Environmental Factors
- Economic Factors
- Materials Natural Factors
- Participants’ Factors
- Regional Factors
- Strategies for Increasing Building Materials Reuse

Chapter III  Case Studies

- Didi Contractors, Himachal Pradesh
- Urban Slums of India
- Liu Centre, for the Study of Global Issues – University of British Columbia
- Arden Craig

Analysis

Conclusion

Appendix A

- Reusing and Recycling Building/Industrial Wastes
- Materials That Can Be Reused

Appendix B

Technology Behind Reclamation

Bibliography
Abstract

"Vasansi jirnani yatha vihaya navani grihnati naro aparnai,
thata sarirani vihaya jirnanyanyani sanyati navani dehi"

The soul is eternal. Our existence is timeless; we have been here before in the past and will come in the future too. The actions of body, our words, and our thoughts leave imprints on our consciousness. The mind stores imprints in the form of impressions. Our past impressions carry weight and determine how well we can face the present moment and how well we can live life to its full capacity, free from fears and negative emotions.

“The journey of the soul is continuous, just as a man gives up old worn out garments and wears new clothes in the same way the embodied soul "Ataman" gives up old worn out bodies verily accepts the new bodies.” (Bhagwad Gita, Chapter 2, Shloka 22)

This is also true with the resources and energy we use for building our environment. As our buildings worn out over time, we rebuild them with new materials. Instead if we apply the same ideology in the process of re-building our environment and transfer the ENERGY by reusing building materials and changing our design strategies; we would do justice not just to the natural environment but to ourselves also.
Introduction

Sustainability has emerged as a necessary notion to guide all future human endeavors. It has environmental, social and economic dimensions, embraces all facets of human activity. Environmental sustainability will require optimum utilization for all resources before returning them to nature.

Simply improving the performance of new buildings - making them more resource efficient and with increased potential for recyclability and reusability - will be insufficient to realign the built environment towards a sustainable future. Attention must be directed at the use and reuse of existing buildings. Changing attitudes toward resource use will require us to rethink the environmental value of existing buildings and their constituent materials. Indeed, along with developing new skills, knowledge, and attitudes on environmental issues, architects will have to learn to be more “curators” of the built environment rather than “creators.” (N. Levinson, Architectural Record. Vol. 181, no. 8, 1993, p.70)

Buildings over the past 100 years or so have their own materials palette and construction techniques – varying in quality, quantity and accessibility. (P. Kernan, Design Guide, 2002, p.3). Existing buildings that are refurbished or decommissioned represent a vast source of future building material. Although the majority of buildings were created without a view for re-use or recycling of their constituent materials, components and systems, a large portion will be salvaged and reused in new
construction. Indeed, whereas the construction industry has historically considered the harvesting of natural resources, the future will see increasing harvesting of resources from the built environment.

Although the wider use of salvaged material will depend on the development of a used materials “infrastructure” for identifying, locating, accessing and reprocessing quality used materials, the key will be for architects and builders to engage the opportunity. Architects will be required to look creatively at re-using existing buildings, materials and components in combination with a mass of new materials that will become available as the building industry examines innovative ways of turning wastes into useful resources.
Notes and Referencing

Research Question

It is clear that due to the obsolescence, damages and contaminations, the reuse and recycling rate of different materials is quite different and we usually do not reuse certain building materials.

The main purpose of conducting this dissertation is:

- To find out obstacles that we face in reclaiming and reusing building materials.
- To identify the solutions on how to overcome such obstacles and increase the recycling rate.

Need Identification

Technically, it is possible to reuse, recycle nearly everything in a building, but in reality, the building materials’ recycling rate is very low. There are a lot of obstacles for building materials’ reclamation. Some of them are related to the people who are going to use them, while some of them are related to the materials’ characteristics. Some materials may require additional labor before they can be reused. Moreover, in order to be recyclable, materials must be separated from contaminants, such as trash, nails, and broken glass.

There is a serious need of identifying the nature of obstacles before we can continue the reuse and recycling of building materials. After the problems are identified, we can start our work in the right line of direction which helps us save our time and resources.
Aims and Objectives

- What are the causes of such obstacles?
- How can we sort them?
- Who are responsible for these obstacles?
- How can we identify the obstacles?
- Is there a more effective way of recycling and reusing materials?
- What is building design recyclability?

Scope of Study

The study shall focus on the nature of obstacles that we face while working with materials that have been reclaimed from prior construction sites. After identifying the problems faced, all the practical solutions that can be put to use for reclaiming materials would be analyzed.

The work done in the developed countries and in our country would be documented in the form of case studies and would be further analyzed for all the practical possibilities that exist of whom we are unaware of.

The study shall also comprise of a list of materials which have the potential to be reused again and again, it will also look at the techniques that are involved in reusing and recycling such building materials.
**Limitations**

There are infinite methods by which we can conserve energy. Though reusing and recycling building materials forms a major part, there are still many different perspectives of the industries that are involved in recycling and reusing the building materials. The study tries to bring in the problems that are mostly faced by the different industries involved but it is not possible to do an in depth analysis for all of them.

Lack of experience; reuse of materials and recycling goods is a very old and widespread practice but using construction materials is a developing industry, thus the projects are very limited and the work done in this field is also not sufficient to support the questions and problems that are faced during the projects.

The reference material mostly has a strong western influence and is more suited to countries outside India. Therefore, though effort has been made to analyze the available material according to the Indian context, it is mostly not relevant.

**Research Methodology**

Literature will be reviewed to find the obstacles of building materials reclamation and to find the current solutions for increasing recycling rate. Interviewing industry professionals will also help to identify the obstacles. Case studies will be used to testify these obstacles. After having all the above information, a more effective suggestion will be given. The principles of design recyclability and deconstruction will be described by analyzing and summarizing the above information and findings.
The World Is A Salvage Yard

Using salvaged building materials in place of new materials can be an effective means of conserving natural resources, and reducing embodied energy, as well as having tangible economic benefits. The use of salvaged materials is not as easily incorporated into conventional building practices as other green design strategies. Once a decision has been made to build in an environmentally responsible manner most of the challenges are technical in nature. While there are technical issues to be addressed in using salvaged materials, the most significant differences relate to the processes of specifying, locating, and acquiring the materials.

**Reasons to consider use of salvage materials:**

- Demonstrates leadership and innovation.
- The quality of salvaged materials, especially lumber, is often better, resulting in a better building.
- Cost benefits; salvaged materials may be cheaper, definitely won’t cost more.
- May result in unique buildings, and increased employee satisfaction
- Green buildings as marketing tools. Public opinion and awareness about environmental issues is evolving.
- Building can incorporate historical associations.
- Performance equal to that of conventional building can be achieved. (Demolition / Deconstruction, 1999)
The most successful way of handling waste is not to produce it in the first place. Rather than considering goods as waste at the end of their first life cycle, they should be given another chance and should be looked as an opportunity. If we are to avoid production of waste, we should certainly turn towards a closed-loop life cycle of materials that is somewhat similar to what is found in the nature.

**Figure 1**: Closed-loop life cycle for materials. (B. Addis, 2006, p. 13, Figure 1.3)

### The Delft Ladder

It is a way of representing various stages of the life cycle of materials. It has ten stages which ensure that the materials are being exploited at most for as long as possible. Doing this prevents or slows down the movement of waste towards the landfills. The processes of the Delft Ladder are as follows:
1. **Prevention**: waste can be avoided by devising a building system that allows dismantling and reassembly, or by designing a component that allows the materials to be fully recycled.

2. **Object renovation**: avoiding demolition by renovating a building and its components to keep them in continued use.

3. **Element reuse**: elements removed from a building can be improved by maintenance, refurbishment or reconditioning and reused for their original purpose in a new situation.

4. **Material reuse (recycling)**: waste materials from production processes can be collected and improved (for example by cleaning) to make them suitable for returning to the production process.

   Following processes 3 or 4, if the material or element cannot be reused for their original purposes, they can be improved to enable their use in a new application.

5. **Useful new application**: a material, element or component can be used in a different situation, perhaps with a lower performance specification (‘down-cycling’).

6. **Immobilization with useful application**: a potentially harmful material can be rendered harmless when used as a raw material for a new component (e.g. the use of pulverized fuel ash in concrete).

7. **Immobilization**: a potentially harmful material can be rendered before sending to landfill.
8. Incineration with energy recovery: combustible materials are burnt and the energy liberated is collected for use.

9. Incineration: combustible materials are burnt and, though not providing useful energy, are not sent to landfill.

10. Landfill: the final destination for materials if no alternative use can be found. (B. Addis, 2006, p. 15, Box 1.3)

---

**Figure 2**: The Delft Ladder showing life-cycle material flow. (B. Addis, 2006, p. 14, Figure 1.4)
Reclaiming the Material

Technically the use of salvaged materials is similar to construction using new material; the process of obtaining salvaged materials differs significantly from normal industry practice. Some key considerations are:

- The level of salvaged material use proposed.
- The type of materials to be acquired from salvaged sources.
- The time available to research and obtain materials both during design and construction.
- Whether the owner already possesses significant quantities of salvaged materials. For example, buildings those are on site.
- The stage at which materials are to be acquired and the party responsible for locating and acquiring them. (Retrieved on 14/12/2009, http://www.umich.edu/~nppcpub/resources/compendia/architecture.html)

Once the decision has been made to use salvaged materials, and goals have been established, the areas in which these materials are to be used should be studied. At this stage it is useful to draw up a preliminary list of materials and components that may be acquired from salvaged sources.

Once a preliminary list of salvaged materials has been developed, consideration should be given to where they may be obtained. Salvaged materials may be obtained from a number of sources:

- A suitable existing building on site, or on an adjoining site. This is perhaps the best
way to obtain salvage materials. Particularly if the building can be identified and materials measured and an inventory taken prior to design of the new building.

Obtaining materials in this way from a single source also results in greater consistency of material quality and appearance.

• An existing building off-site. If demolition and salvage contractors can be made aware of the project’s material requirements they may be able to assist in identifying a suitable building.
• A salvaged building materials supply yard
• Demolition / Deconstruction contractors - on-site sale

For smaller buildings it may be possible to find suitable structural materials in sufficient quantities at a single salvage materials yard. For larger buildings this is likely to be more difficult unless an entire building scheduled to be demolished, and containing the needed materials, can be identified. (B. Addis, 2006, p. 75)

Architects Role

Architects have a key role to play in the initial decision to use salvaged materials and in helping clients make this decision. Initial reaction of owners, and future building users, is often negative; the image of "building with garbage" often comes to mind. (Thesis: Recycled content. Retrieved from Victor_tvedten_thesis.pdf)
Most clients however, are unlikely to have highly developed environmental agendas for their projects, and in many cases the idea of using salvaged materials, or of incorporating other green strategies, may come from the architect initially. It is important to have the full support of the client, particularly if significant quantities of salvaged materials are to be used. Depending on how, and at what stage, salvaged materials are obtained additional design or construction time may be required. It is also likely that a greater level of involvement, commitment and associated fees will be required, although these may be offset against savings in construction costs. *With certain projects there are opportunities to reduce construction costs, and this is obviously an attractive prospect for owners. However, reusing construction materials does not automatically result in savings, and architects are cautioned against over-estimating the potential, or letting this be the sole driving force behind a decision to use salvaged materials.* (P. Kernan, Design Guide, 2002, p.32)

Whatever the motivation, it is vitally important that owners are fully supportive of the decision to use salvaged materials, and be aware of, and willing to share any associated risks. The decision as to what level of use of salvaged material should be determined based on the following criteria:

- The size of the proposed building. Because of the nature of the supply of salvage materials and the different acquisition process involved salvaged materials are most easily, and cost effectively, obtained in relatively small volumes. Greater and more efficient use can therefore be achieved in smaller buildings.
• Previous experience of the design team and contractor, with the use of salvage materials. Knowing how and where to locate and acquire salvage materials can improve the efficiency and cost effectiveness of the process.

• Time available during both design and/or construction phases, to locate and acquire salvaged materials.

• Type of construction of the building. Wood and wood products represent the largest category of salvaged materials; buildings permitted by code to be of combustible, or heavy timber construction, offer the best opportunities for salvaged materials use.

• The level of implementation of other environmental strategies. (B. Addis, 2006, p. 20)

On small to medium sized projects using combustible construction, up to 25% use of salvaged materials can be easily achieved. Achieving higher percentages will require more effort and time, although goals of 50 or 75% are realistic.

**Salvaged Materials Industry**

The demolition and salvaged materials industries are separate, but closely related entities. The disassembly, removal, and disposal of buildings at the end of their useful service life may be accomplished through either demolition or deconstruction.

*Demolition refers to the "rapid destruction of a building with or without prior removal of hazardous materials"*. Deconstruction on the other hand involves "taking a building or structure apart in a manner that achieves safe removal and disposal of hazardous

Full, or partial, deconstruction of buildings provides the material for the salvaged building materials industry. Increased construction industry demand for salvaged materials will encourage more deconstruction and materials recovery.

Individual municipalities regulate building demolition, typically through building and development by-laws. Permits are required before any building may be demolished, and increasingly, municipalities are concerned about the proper disposal of hazardous material. Deconstruction of buildings takes considerably longer than demolition but does allow for the correct removal and disposal of hazardous materials. Removal of useful building material is a labor-intensive process, requiring special skills and tools if materials are to be removed without damage. A number of different types of contractor are involved in demolishing or deconstructing buildings and supplying salvaged materials. Broadly, they can be identified under three categories but their boundaries are somewhat flexible and their practices can vary and change.

**Demolition Contractor**

They work on the ideology of demolition, although they may also carry out some deconstruction, and sell the more valuable materials such as heavy timbers, to salvaged contractors, or specialty sub-contractors. They often sell material on-site when
deconstructing or demolishing buildings. *The term deconstruction is not widely understood, and most contractors use the term demolition, even when large portions of their work may be classified as deconstruction.* (P. Kernan, Design Guide, 2002, p.53)

**Salvage Contractors / Salvage Building Materials Suppliers**

The terms salvage contractor and salvage building materials supplier refer to the two aspects of acquiring and selling materials. *In some cases they may contract to selectively deconstruct portions of the building, and remove particular materials themselves, but usually the demolition contractor removes the material from the building and sells them to the salvage contractors.* (P. Kernan, Design Guide, 2002, p.54)

**Specialty Suppliers / Brokers**

They purchase specific salvaged materials, particularly those with high value, such as heavy timbers. In many cases demolition contractors, and even salvage contractors who have their own yards, will sell directly to these companies. Specialty contractors represent one of the best sources of salvaged materials. *They act as intermediaries between demolition contractors and purchasers. Because they deal in a single material only, they can generally provide a much wider selection than all but the largest salvaged materials yards.* Specialization also allows contractors to have a bigger inventory. (P. Kernan, Design Guide, 2002, p.54)
Different Perspectives

Waste and reclaiming salvaged materials are relative to issues and one's point of view, one man's waste problem is another man’s commercial opportunity. There are different perspectives that exist in the industry. Some of them are stated below:

**Waste industry:** the waste industry sees recycling according to the materials involved, which is very different from the viewpoint of an architect while selecting components to be used in his building.

![Diagram](image)

**Figure 3:** Waste industry viewpoint (B. Addis, 2006, p. 18, Figure 1.5)
Demolition contractor: the demolition contractor always seeks to minimize the quantities of materials being sent to landfills because of the cost factor. As the landfill tax is on a constant increase in most of the countries.

Figure 4: Demolition industry viewpoint (B. Addis, 2006, p. 19, Figure 1.6)
Manufacturers of Recycled Components: their primary task is similar to any manufacturer that is to persuade his buyers.

Salvage Industry: they recognize and purchase goods which are deemed to be waste by their owners knowing that there are potential buyers who value those goods more than their waste value.

Figure 5: Recycling and Manufacturing industry view point.

Figure 6: Salvage industry view point.

(B. Addis, 2006, p. 20, Figure 1.7, 1.8)
**Client and Design Team**: they need to make a number of choices about which components to reuse as it is, which to reuse from some other location and which to be the new items.

**Figure 7**: Design team and client view point (B. Addis, 2006, p. 21, Figure 1.9)
**Building Itself:** buildings should be designed and built in such ways that make them easy to dismantle and facilitate the reuse of components later. The buildings should be designed for deconstruction in the first place.

![Design for deconstruction diagram]

**Figure 8:** Design for deconstruction (B. Addis, 2006, p. 22, Figure 1.10)
Salvaged Materials

Salvaged building materials can be broadly divided into two categories, high value materials and high volume materials.

**Table 1:** Comparison of High Value and High Volume Salvaged Materials

<table>
<thead>
<tr>
<th></th>
<th>High Value Materials</th>
<th>High Volume Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>High demand from contractors and brokers. Often used in high quality timber framed residential projects.</td>
<td>High demand from small contractors and the general public. Typically used in small renovation projects, but also recently on some larger projects</td>
</tr>
<tr>
<td>Supply</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Source</td>
<td>Mainly specialty suppliers and brokers, also salvaged building materials supply yards</td>
<td>Salvaged building materials supply yards.</td>
</tr>
<tr>
<td>Potential for Cost Savings</td>
<td>Heavy timber - relatively small HVAC equipment - large</td>
<td>Significant if obtained in large volume from a single source.</td>
</tr>
<tr>
<td>Examples</td>
<td>Heavy timbers, heavy timber, wood trusses, Architectural antiques, HVAC equipment</td>
<td>Doors and frames, windows, brick, mechanical and electrical components, etc.</td>
</tr>
</tbody>
</table>

Quality

In many cases the quality of salvaged materials is comparable to that of new materials; particularly where some form of refinishing is carried out. With most materials and components, minor imperfections are not significant, and may be expected within a short period of service life, even if new materials are used.

*In the case of other materials, for example dimension lumber and heavy timbers, the functional quality of salvaged material may be superior to comparable new product available today. Other salvaged materials have historical associations providing a physical link to the past. The social and cultural significance of these links should not be underestimated in an age where few artifacts, including buildings, are designed to last for long periods of time. In this context, imperfections in materials can be accepted and even welcomed.* (P. Kernan, Design Guide, 2002, p.57)

Selection

In terms of material selection and availability, a distinction can be made between generic type materials, such as dimension lumber, and more specific components such as doors and frames, or washroom accessories. Non-specific materials are relatively easy to acquire from salvaged sources and selection is less of an issue. One wood stud is much the same as another, and substituting a reused stud is relatively straightforward. In specifying specific components on the other hand, architects are used to choosing from a greater range of products. (Retrieved on 14/12/2009, http://www.umich.edu/~nppc/pub/resources/compendia/architecture.html)
Notes and Referencing

Obstacles and Solutions

Technically, it is possible to recycle nearly everything in a building, but in reality, the building materials’ recycling rate is far from 100%. There are a lot of obstacles for building materials’ recycling and reusing. The major obstacles we face are:

Social Factors

Lack of Education: Many people haven’t realized how necessary reusing is. If we continue consuming and polluting at current rate, our next generation will have to dig the landfill. We cannot live a good life without a healthy global environment. Therefore, we have to draw people’s attention towards reusing and recycling.

People’s Willingness: Reusing materials is usually a voluntary activity. Sometimes, people know that reusing is beneficiary, but they don’t have a strong willingness to do it.

People’s Preference for Fashion: Customers always prefer new and fashionable items to used ones. Sometimes even if we can salvage some components during demolition, we cannot find a market for the used ones.
Environmental Factors

**Hazardous Components**: Throughout the construction industry, we have used and continue to use large quantity of chemical substances and additives in all types of products to enhance technical properties. Hazardous components prevent materials from recycling and reuse.

**Low Tipping Fee**: Construction and demolition landfills generally have lower tipping fees, and a large fraction of debris generated ends up in landfills.

**Site Condition**: The demolition job sites always don’t have enough space for storage of recyclables and on-site sorting. Having separate containers for each type of materials can reduce contamination. Therefore, site condition is also an important factor for building materials recycling.

Economic Factors

**Materials Markets**: Unfortunately, the markets for reused materials are not enough. If we cannot sell the recycled materials, we have to find a place to store them. Since no one what to buy the reused materials, they will go to landfill eventually.

**Project Timeline**: In order to reuse as many materials as possible, we usually do deconstruction rather than demolition. Deconstruction will take longer time and need more skilled workers than demolition. However, demolition projects always are often on
a tight schedule due to financing arrangements. Thus, the timeline prevent Contractors from reusing materials.

Cost Effectiveness: The feasibility of any recycling and reusing program depends on whether the total cost is less than the sum of cost of labor, tipping, landfill, hauling fees and taxes. If the condition is satisfied, the program becomes cost effective.

Materials Natural Factors

Quantity Too Small: For single-house demolition projects, the quantity of each material is not big enough for a hauling vehicle to go and pick it up.

Size Too Big: Some of the materials like timber are too long to be transported. To solve this problem, designers must know what the size limitation of transport vehicles is and design the buildings using smaller size materials.

Conjunction: The conjunction method of different pieces of materials is very important for deconstruction. The ease with which components can be recovered from a building is greatly affected by how the building was put together in the first place.

Participants’ Factors

Contractors’ Experience: Contractors with knowledge of recovery methods and local markets may be able to recover more materials than contractors unfamiliar with reuse
and recycling issues. Experienced contractors can be more effective in planning, workforce education, and recyclables transportation.

**Labor Capability:** If the deconstruction workforce is familiar with reuse and recycling, it will be easier for the contractor to do his job. With proper education, preplan, and some practice, labors will be capable to do their job.

**Relationships Among Participants:** Owner, designer and contractor should cooperate with each other to make a building recyclable. The owner should understand the process and allow contractor to use enough time to salvage materials for reuse.

**Regional Factors**

**Regional Traditions:** The recycling rates vary from region to region, state to state, city to city. Traditions pertaining to a particular region have a huge impact on the ideologies of the people of that place. Some prefer reusing and recycling materials, for others, used materials are merely waste.

**Regional Capacities:** Regions which lack salvage yards and the recycling abilities, the recyclables will be sent to landfill eventually. Therefore, even though contractors’ participant is important to recycling, it is just one link of the whole chain. Regional capacity for recycling is another vital factor.
**Regional Markets:** Salvaged materials are sorted and processed, then they are sold to manufacturing facilities. Some manufacturing factories even don’t accept recycled materials because virgin materials are cheap and abundant in supply.

**Strategies for Increasing Building Materials Reuse**

After identifying the obstacles, we can try to figure out the ways to break them and increase reuse of salvaged materials.

**Extended Producer’s Responsibility:** Extended producer’s responsibility (EPR) has been used as a policy tool for electronics recycling in some countries for years. EPR requires producers to be financially or physically responsible for their products after their useful life. By placing the end of life burden on the manufacturer, it is expected that he will look for ways to design products to minimize end of life costs such as disassembly and disposal costs through instruments like design for recyclability, reduced material usage, product disassembly, reduced or eliminated use of toxic materials, remanufacturability.

**Deconstruction:** The cost and ease of removal of components from a building at the end of its life are significant factors affecting the amount of reuse and recycling that occurs. The ease with which components can be recovered from a building is greatly affected by how the building was put together in the first place. Designers need to think about not only how materials will be put together but also how components will be separated at the end of life.
### Table 2: Considerations for Deconstruction during Design Phase

<table>
<thead>
<tr>
<th>Factors</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conjunctions</td>
<td>Components with fasteners and connections that are designed to be easy and quick to take apart, such as bolts rather than welds are more likely to be reused and recycled.</td>
</tr>
<tr>
<td>Deconstruction Plan</td>
<td>Whoever is doing reclaiming, whether the manufacturer or a third party, may need instructions, such as disassembly or refurbishment plans, or information, such as specifications for the materials.</td>
</tr>
<tr>
<td>Timeline</td>
<td>Time should be allowed for a building to be disassembled at the end of its useful life.</td>
</tr>
<tr>
<td>Recycling Route</td>
<td>Choosing materials and parts, such as steel and components, that have recognized routes for recycling and reuse will greatly encourage their reuse in future.</td>
</tr>
</tbody>
</table>

(Thesis: Framework For Building Design Recyclability, Retrieved from reusing and sustainability.pdf)

**Benefits of Deconstruction:**
- Significant quantities (up to 90%) of demolition waste can be diverted from landfill disposal.
- Worker and public health and safety is protected through the correct removal, handling, and disposal of a number of hazardous materials commonly found in older buildings.
- Deconstruction is a labor-intensive process and creates jobs, both in dismantling buildings, and in the salvaged building materials industry.
• Deconstruction provides a supply of affordable, and in many cases, high quality used building materials.
• The use of salvaged materials conserves natural resources and protects the environment.
• The use of salvaged materials reduces embodied energy (i.e. the energy required to acquire raw materials, manufacture, and transport new construction materials)


**Alternative Materials:** Considering using more recyclable materials to take place of current materials is another attempt to increase recycling rate. Bamboo is considered to be a highly recyclable material. Another suggestion about alternative materials is using straw. Baled straw can be stacked like bricks for both load bearing and non-load bearing infill walls. Straw fiber can be processed and manufactured as medium density fiberboard, structural stressed skin panels, and non-structural partitions.

**Building Design Recyclability:** Recyclability is a word used to describe characteristics of materials. Characteristic of materials that still have useful physical or chemical properties after serving their original purpose and that can, therefore, be reused or remanufactured into additional products.

Recyclability describes the ability of materials to be recovered at the end of their original service life. Design is not something that can be recycled, but design can make
materials recycling easier. Therefore, we can use recyclability to describe the potential possibility for a design to provide convenience for materials recycling.
Notes and Referencing

Case Studies

Didi Contractors

Plate 1: House made of reused and locally available materials.

Plate 2: Handmade bricks molded from locally available clayey soil.
Didi contractors are a Himachal Pradesh based organization which works with locally available materials and to some extent reuses materials whenever and wherever possible. Reusing and recycling is possible when we work with small scale projects. In small scale projects, the quantity of materials required is less. Since materials available for reuse and recycle are generally found in fewer amounts, this makes it easy to fulfill the requirement of the project. Didi contractors are an organization that deals with small scale residential projects and designs with locally occurring materials.

**The principal materials that are majorly used and salvaged for construction:**

- **Slate:** It is locally available and found in abundance in that region. It is a suitable material for construction in that climate, slate provides with sufficient
insulation and strength to the structure. It is used for raising the superstructure and as roof cladding.

- **Clay**: The soil is clayey in that region which makes it a suitable material for making handmade sundried bricks. Mostly slate is used for constructing the walls but when it becomes hard to transport the material from the quarry to the construction; handmade bricks are preferred over slate for construction. Construction of such kind requires more maintenance and becomes a more costly alternative in the longer run, so they prefer building with slate rather than sundried bricks whenever possible.

- **Insulation**: For insulating the walls of the houses, waste rubber tyres and other rubber based products are used. The tyres and similar waste products which have been discarded; which are ready to go the landfill are cut and turned into small bits and pieces. These are then compressed and used as insulation for the buildings.

- **Foundations**: Foundations of prior construction which have been demolished or deconstructed are used again for new projects. Foundations are the part of the whole project where concrete is used in maximum quantity, by reusing them we save on lot of new materials and energy. By saving on such things, the project becomes very cost efficient and successful.

- **Doors and Windows**: Doors and windows from dismantled houses are reused whenever they are available. In this region, the population is scarce and people generally have fewer funds. Thus, they prefer to renovate their homes rather than building new ones. This becomes a problem as there are very less times
when the doors and windows are available in the right quantity of what they are required.

- **Gutters**: Mild steel is required for casting gutters in the houses. They try to reuse as much as possible but when they do not have the supply, buying scrap metal and molding it into the gutter is preferred over buying new prefabricated sections.

Reusing such materials and features saves lots of resources in turn making the project cost efficient. They prefer to reuse as much as possible and build with naturally occurring locally available materials.
Urban Slums

Plate 4: Reused wood members used for stilts.

Plate 5: Lack of resources forces people to live in rickety shacks and cramped living conditions.
The moment we talk about slums, the picture that forms up in our minds is that of dirty shanties and flooded gullies, highly dense and rickety construction. But this is the only sector in our country that reuses materials for construction at such a large scale. The slum dwellers are constructing and evolving their houses all the time, but they don’t use new materials else make up to their needs with old ones that had been dumped into the landfills by the formal sector; it is these people who are helping reduce the load on our landfills.

Their houses are built with old asbestos sheets, fabric, straw and broken wooden members. Almost 95 percent of the house is made from reused materials and is constructed in such a way that it becomes very easy to deconstruct the house whenever needed and rebuild it somewhere else.

Construction in slums is done in such a manner because the people do not have enough resources but it is our responsibility to understand this instinct of scavenging materials which still have the potential to be used again and apply it to our lifestyles.
This way we can save on our resources and reduce the load on the landfills. The formal sector cannot construct in the same way but they can surely adopt some techniques and develop new ones for the construction sector.
Liu Centre, for the Study of Global Issues – University of British Columbia

Northwest Marine Drive, Vancouver, BC


The Liu Centre continues UBC’s commitment to ‘green’ design. The use of salvaged materials responds to a number of sustainable goals identified by project stakeholders at the beginning of the design process. Many of the glulam beams and most of the cedar decking were obtained from the deconstruction of the Pan Hellenic House on the same site as the new Centre. In keeping with efforts to reduce finish materials, the salvaged beams and decking, which form the roof structure, have been sandblasted and will remain exposed. All surplus glulams and decking have been sold for reuse.

Plate 7: Structure made from reused glulam beams and metal cables.

## Building Type

<table>
<thead>
<tr>
<th>Building Description</th>
<th>Research And Conference Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Floor Area</td>
<td>19,000 sq. ft.</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>$3,000,000 ($158 / Sq. ft.)</td>
</tr>
<tr>
<td>Construction Type</td>
<td>Heavy timber / Non Combustible</td>
</tr>
<tr>
<td>Completion Date</td>
<td>March 2000 - 10 month construction schedule</td>
</tr>
<tr>
<td>Contract Type</td>
<td>CCDC-2 Stipulated Price Contract</td>
</tr>
</tbody>
</table>

## Principal Salvaged Materials

<table>
<thead>
<tr>
<th>Component</th>
<th>Salvaged Material</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Structure</td>
<td>Glulam beams and columns</td>
<td>Deconstruction of Pan Hellenic and Forintek buildings at UBC</td>
</tr>
<tr>
<td>Secondary Structure</td>
<td>Roof decking&lt;br&gt;Rough carpentry (plywood, studs)</td>
<td>Litchfield &amp; Dubreuil Architectural Salvage&lt;br&gt;Reused formwork</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Radiators, copper pipe, valves</td>
<td>Surplus, UBC Forest Science Centre</td>
</tr>
<tr>
<td>Landscaping</td>
<td>Concrete pavers</td>
<td>Residential renovations</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Grab bars, exterior furnishings</td>
<td>Surplus, UBC Forest Science Centre</td>
</tr>
</tbody>
</table>
Glulam beams from the Pan Hellenic House building were identified and measured prior to deconstruction of the building. Design of the heavy timber portions of the Liu Centre was based on these measured sizes. Generally this process worked well although in one case an existing glulam was damaged during removal and did not fit the new structural span. It is important to ensure the salvage contractor is aware of which materials are to be reused, and also in what form they will be used prior to deconstruction. Care must also be taken in deconstructing buildings that materials to be reused are not damaged. Salvage contractors have developed special tools and techniques to carefully remove material.

Plate 8: Roof decking done with reused cedar from deconstructed house.

**Ardencraig**

353 West 11th Avenue, Vancouver, BC


Ardencraig comprises four townhomes designed within the framework of an existing heritage home and garage. The use of salvaged materials is just one of a number of environmental strategies employed in the building and associated site work. Ardencraig is an excellent example of the rehabilitative reuse of an existing structure; over 90% of the wood in the original structure is retained. Additional salvaged materials, obtained from deconstruction of an existing garage, were used to construct a coach house behind the main structure. Salvaged framing members were also used to strengthen the roof trusses and increase the space available for insulation.

**Plate 9:** Refurbished house in Ardencraig.

**Plate 10:** Stained glass window made from reused glass.
Other salvaged materials include granite from the existing foundation walls, and stained glass used in feature windows.

**Building Type**

<table>
<thead>
<tr>
<th>Building Description</th>
<th>VBBL Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Floor Area</td>
<td>4700 sq. ft.</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>$520,000</td>
</tr>
<tr>
<td>Construction Type</td>
<td>Combustible</td>
</tr>
<tr>
<td>Completion Date</td>
<td>August, 2000</td>
</tr>
<tr>
<td>Contract Type</td>
<td>Construction Managed, Fixed Fee</td>
</tr>
</tbody>
</table>

**Principal Salvaged Materials**

<table>
<thead>
<tr>
<th>Component</th>
<th>Salvaged Material</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Structure</td>
<td>Dimension lumber and studs</td>
<td>Existing building and salvaged materials suppliers</td>
</tr>
<tr>
<td></td>
<td>Roof truss strengthening members</td>
<td></td>
</tr>
<tr>
<td>Secondary Structure</td>
<td>Studs</td>
<td>Salvaged material suppliers</td>
</tr>
<tr>
<td>Landscaping</td>
<td>Cobblestones</td>
<td>Private purchase</td>
</tr>
<tr>
<td></td>
<td>Granite rocks</td>
<td>Existing house foundation</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Stained glass</td>
<td>Stained glass artist</td>
</tr>
</tbody>
</table>

Analysis

Didi Contractors

**Project Description:** Didi contractors are a Himachal Pradesh based organization which works with locally available materials and to some extent reuses materials whenever and wherever possible.

**Materials used and reused:** Slate is locally available and found in abundance in that region. It is used for raising the superstructure and as roof cladding. The soil is clayey in that region which makes it a suitable material for making handmade sundried bricks. For insulating the walls of the houses, waste rubber tyres and other rubber based products are used. Foundations of prior construction which have been demolished or deconstructed are used again for new projects. Doors and windows from dismantled houses are reused whenever they are available. Mild steel is required for casting gutters in the houses. They try to reuse as much as possible but when they do not have the supply, buying scrap metal and molding it into the gutter is preferred over buying new prefabricated sections.

**Cost:** Reusing such materials and features saves lots of resources in turn making the project cost efficient. Reuse and recycling in this region is not very effective as the decommissioned buildings are very less and people still demolish their houses rather than dismantling them. This makes it difficult for the firm to work for the cause but they still prefer to reuse as much as possible and build with naturally occurring locally available materials. This saves on the energy required for extracting, processing and transporting materials from the processing yards to the site.
LIU centre

UBC, Vancouver, BC

Project Description: The Liu Centre is a research and conference facility at the University of British Columbia. The decision to use salvaged materials was supported by all project stakeholders.

Salvaged Materials: The principal salvaged materials used at the Liu Centre were Douglas fir glulam beams, and cedar decking material. Concrete pavers used in site landscaping were also obtained from salvaged sources. The majority of salvaged glulam beams and cedar decking came from the deconstruction of the Pan Hellenic House, an existing building on the Liu Centre site. Materials from the UBC buildings were provided by the owner. Additional cedar decking material was required, and was purchased from two local salvaged materials suppliers. Materials from the existing buildings were inventoried by the architects at an early stage in the design phase, and where available to the contractor when required. Additional materials obtained during construction where located by the architect, and purchased by the contractor. The architects provided assistance in locating suitable materials and were available to review and approve the quality of salvaged materials.

Cost and Quality: The principal materials used at the Liu Centre, glulam beams and cedar decking, offer considerable potential for cost savings. Deconstruction of older commercial, industrial, and institutional buildings generates large volumes of both
materials. Because of the relatively high cost of comparable new material, prices for these salvaged materials are low, even when the cost of testing and refinishing is included.

One of the difficulties in comparing costs is the difference in the nature of current building material when compared with materials salvaged from earlier buildings. In many contemporary buildings steel decking material is used in floor and roof assemblies. At the Liu Centre salvaged cedar decking is used in place of steel. Salvaged cedar is less expensive than comparable new material, but the cost savings would be less significant if compared to a more common contemporary material such as steel decking. For the purpose of the analysis new cedar decking is used for comparison.

**Additional Consultant Costs:** The architects did incur additional costs as a result of the use of salvaged materials. During the construction phase of the project the architects assisted the contractor in obtaining additional salvaged materials. As part of this process it was necessary for the project architect to visit various salvaged materials suppliers to review stocks of material and assess quality. Some additional site review and administrative functions were also required. The contractor also incurred some additional costs in obtaining and preparing additional salvaged materials. These costs were included in the contract amount.
Ardencraig

353 west 11th avenue, Vancouver, BC

**Project Description:** The project comprises four townhomes designed within the framework of an existing heritage home and garage. The use of salvaged materials is one of the many environmental strategies employed in the building and associated site work.

**Salvaged Material:** The existing buildings were of wood framed construction, and were originally built using balloon framing. Over 90% of the wood in the original house is retained. Additional salvaged materials, principally dimension lumber, were utilized to construct the in-fill coach house. Salvaged framing members were also used to strengthen the roof trusses and increase the space available for insulation. Other salvaged materials include granite, and stained glass used in feature windows. The developer initiated most of the green design strategies, including the use of salvaged materials, and was responsible for the acquisition of dimension lumber for the project. Approximately 36,000 board feet of framing materials were obtained from Vancouver Timber a local supplier of salvaged building materials. An additional 5,000 board feet of materials were obtained from deconstruction of the existing garage building. Most of the salvaged wood was used in construction of the new coach house and as new infill walls at the base of the main house.

Acquiring salvaged dimension lumber in a cost effective manner can be difficult. New framing material, although not of the same quality as salvaged framing, is inexpensive.
The cost of denailing salvaged dimension lumber pushes the cost of small sized members, such as studs, above the cost of the most commonly used new framing materials. However when compared to the cost of better quality new materials, the comparison is more favorable.

**Cost and Quality:** There are a number of reasons why it is appropriate for comparison in the case of a renovation project such as Ardencraig. Framing material in existing buildings will have dried to relatively low moisture content. The shrinkage associated with this initial drying takes place soon after the original construction of the building, and is uniform through most assemblies. If new green wood is added to existing structures, shrinkage of the new components adjacent to existing framing can create problems. For this reason a better practice is to use kiln dried wood which will have a moisture content in the same range as the existing framing, and will therefore not shrink to any significant extent.

At Ardencraig modest cost savings were achieved as a result of using salvaged dimension lumber. In part this may be attributable to the relatively small quantities of wood required. Local suppliers of salvaged materials are more likely to be able to supply smaller quantities from stock.

**Additional Consultant Costs:** The majority of work with respect to research and acquisition of salvage materials was undertaken by the developer. Associated costs were included with other project overhead costs.
Notes and Referencing


Conclusion

Reusing building materials is an important aspect of sustainable construction, while sustainable construction is a critical issue to fulfill the overall sustainable development. However, the current materials recycling rate for construction industry is far from satisfying.

Reusing and recycling depends upon the development of a used materials “infrastructure” for identifying, locating, accessing and reprocessing quality used materials. Architects will be required to look creatively at re-using existing buildings, materials and components in combination with a mass of new materials that will become available as the building industry examines innovative ways of turning wastes into useful resources.

After conducting and analyzing the case studies, in a broader sense we can come to some conclusions:

1. Regional factors are responsible for most non-recyclable materials, and many non-recyclable materials will become recyclable and can be reused if building’s location changed;

2. There are always multiple obstacles for a single item;

3. Some obstacles are leading ones. If we can break these leading obstacles, non-recyclable materials will become recyclable even though other obstacles still exist;

4. Contamination is another major obstacle which prevents many materials from being recycled;
5. Increasing people’s willingness for recycling can help to conquer most obstacles.

In current construction practice, too many responsibilities of recycling and reusing on site have been put onto contractors, while the designers’ role in reusing has always been omitted. As primary participants in the first stage of a project, designers’ action can change the outcome of recycling tremendously. If designers can deliver a recyclable design, it will be very easy for contractors to do their job and fulfill the goal of reusing. Using more recyclable materials and making building more deconstructable can make designs more reusable and recyclable.
Reusing and Recycling Building/Industrial Wastes

Need for building materials will grow at an alarming rate in future, in order to meet the demand for new buildings. Manufacturing of building materials like bricks/blocks, cement, steel, aggregates, etc. consumed in bulk quantities, puts great pressure on natural resources and energy requirements. As already mentioned, the top 300 mm layer of fertile soil will be used for brick manufacture in due course of time, if we do not use alternative materials for bricks. In order to sustain the construction activity in future, it becomes inevitable to explore the following possibilities:

- Use of energy-efficient alternative building technologies
- Efficient utilization of natural resources/raw materials
- Optimal designs and planning practices
- Recycling of building wastes
- Utilization of industrial/mine wastes for the manufacture of building materials
- Adopting energy-efficient process in manufacturing processes of building materials
- Use of renewable energy sources and technologies.

Majority of the large-scale industries and thermal power plants generate solid wastes in bulk quantities. Red-mud, coal ash, slag, fly ash, etc. represent such wastes unutilized
for several decades. For example, \( > 100 \times 10^6 \) tonnes of fly ash is produced annually in India (from thermal power plants) and only 2–3\% of it is being utilized. Similarly millions of tonnes of red-mud is stored near aluminium manufacturing units (\( \sim 20 \times 10^6 \) tonnes of red-mud is heaped into hillocks at the aluminium manufacturing units. Such huge heaps of wastes concentrated in certain specific localities cause environmental and pollution hazards. Such wastes can be utilized for the manufacture of bricks/blocks, substitute for fine aggregates in concrete, partial replacement of cement in concrete, lime–pozzolana cements, etc.

Reuse and recycling of demolished building wastes is another area/aspect of efficient utilization of materials and resources. Recycling of materials like steel, stone and timber from demolished structures takes place to some extent. But the recycling of bricks, concrete, aggregates, mortar, etc. is still not done in an organized fashion. Such materials can be crushed and processed to utilize them in new constructions.
Materials that can be Reused

The following sections provide information on specific salvaged materials with details of their availability and sources. As with new materials, the characteristics of salvaged materials differ significantly. The use of particular salvaged materials should be carefully researched, and if necessary samples of the materials should be tested to confirm suitability for the proposed application.

Site work

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete paving slabs</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Foundation drainage pipes</td>
<td>Rarely</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Storm and sanitary drainage pipes</td>
<td>Rarely</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Chain link fencing</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
</tr>
</tbody>
</table>

Concrete

Because of the monolithic nature of cast-in-place material, little opportunity exists for salvage and reuse. Concrete from existing buildings and structures is commonly crushed and reused as road base material in place of new gravel or rock. Reinforcing steel is removed and recycled. In theory, precast concrete components, both structural and non-structural could be salvaged and reused although the local supply of these materials is limited.
Masonry

There is a long history of reuse of brick and masonry units, and the supply of salvaged bricks is reasonably consistent and reliable. Demolition of old warehouse and commercial buildings results in large quantities of brick; in some cases up to 10 bricks per square foot of floor area. Reclaiming and cleaning salvaged bricks is a time consuming activity.

Salvaged bricks vary considerably in quality. In part this is due to significant variation in the quality of the original brick. Older methods of manufacturing bricks resulted in uneven firing temperatures within kilns. Many of the resulting bricks were not fired at the correct temperature. Over-burnt bricks were hard and durable, but others were soft and of low strength. These units are referred to as salmon bricks. In deconstructing masonry buildings it is not economical to identify and sort bricks. Mortar and dust also make correct identification difficult. Salvaged bricks are therefore a mixture of high quality face bricks and poorer quality salmon bricks.

All salvaged bricks should be tested and be suitable for the particular proposed application. For exterior applications, in addition to visual examination, an absorption test may be appropriate. Generally salvaged bricks and especially salmon bricks should only be used in interior location or in low exposure exterior areas where wetting is unlikely.

It is difficult to salvage bricks, or concrete blocks, from recent buildings because of the strength of the portland cement mortar bonding them. In earlier constructions bricks were laid with hydraulic lime mortar. Lime mortar is soft, crumbles easily and is readily separated from the bricks making cleaning relatively easy. Although use of lime mortar
in new construction would allow future reuse of bricks, it is difficult to obtain sufficient lateral strength in construction without the use of harder mortar.

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick</td>
<td>Always</td>
<td>Salvaged building materials suppliers, Masonry suppliers</td>
<td>Range is limited but large quantities are often available</td>
</tr>
<tr>
<td>Concrete block</td>
<td>Rarely</td>
<td>Salvaged building materials suppliers, Masonry suppliers</td>
<td>Difficult to remove Portland cement mortar.</td>
</tr>
<tr>
<td>Glass unit masonry</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers, Masonry suppliers</td>
<td>Quantities are often limited</td>
</tr>
<tr>
<td>Exterior stonework</td>
<td>Occasionally</td>
<td>Specialty materials suppliers</td>
<td>Individual stone components, usually granite are often salvaged from brick buildings.</td>
</tr>
</tbody>
</table>

**Steel**

Although wood beams and trusses are more common, structural steel components occasionally become available. However the existence of an established market for salvaged steel to supply the recycling industry, coupled with the difficulty in disassembling steel structures, particularly where welded connections are used, often results in steel structural components being sold for their scrap value. Smaller steel components, which can be removed intact, are sometimes available.
**Material / Component** | **Availability** | **Sources** | **Notes** |
---|---|---|---|
Structural steel | Occasionally | Demolition and salvage contractors, Salvaged building materials suppliers | Will typically be dismantled to remove from original building |
Steel joists and girders | Occasionally | Demolition and salvage contractors, Salvaged building materials suppliers | |
Pipe and tube railings | Always | Salvaged building materials suppliers | |
Prefabricated metal stairs | Occasionally | Demolition and salvage contractors, Salvaged building materials suppliers | |

**Wood and plastics**

Wood has historically been the most common building material, and has been used in structural and non-structural applications for over 100 years. It is the most commonly reused building material. Deconstruction of buildings yields large quantities of wood of all sizes, much of it of high quality, and in some cases superior to comparable new product. Much of the higher quality salvaged wood is valued for its aesthetic values and historic associations as much as its purely utilitarian qualities. Most salvaged materials suppliers will de-nail wood and specialty suppliers will also recut dimension lumber and heavy timbers.
<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension lumber</td>
<td>Always</td>
<td>Salvaged building materials suppliers, Specialty suppliers</td>
<td>Large range of products and sizes</td>
</tr>
<tr>
<td>Heavy Timbers</td>
<td>Always</td>
<td>Specialty suppliers, Salvaged building materials suppliers</td>
<td>Large range of products and sizes</td>
</tr>
<tr>
<td>Glulams</td>
<td>Always</td>
<td>Specialty suppliers, Salvaged building materials suppliers</td>
<td>Can be re-sawn and re-milled</td>
</tr>
<tr>
<td>Wood trusses</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers, Demolition contractors, Specialty suppliers</td>
<td></td>
</tr>
<tr>
<td>Plywood</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td>Quantities may be limited as there is a consistent demand from home renovators</td>
</tr>
<tr>
<td>Wood mouldings</td>
<td>Always</td>
<td>Salvaged building materials suppliers, Architectural antiques suppliers</td>
<td></td>
</tr>
<tr>
<td>Finish flooring</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
</tbody>
</table>
Thermal and Moisture Protection

Insulation material, both rigid and fibreglass batt, is easily reused and is available at many salvaged materials yards. There is little potential for reusing most roofing and waterproofing membranes. These components typically have relatively short service lives and their method of installation makes removal difficult or impossible. Clay or concrete roofing tiles may be reused although the supply is limited. Profiled metal roofing and cladding panels are sometimes available at salvaged materials yards.

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet-metal cladding</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
<td>Existing fastener holes in the material may present problems and may need to be filled</td>
</tr>
<tr>
<td>Sheet metal roofing</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
<td>Existing fastener holes in the material may present problems and may need to be filled</td>
</tr>
</tbody>
</table>

Doors and windows

Doors

Large numbers of interior hollow core doors are available from salvaged materials suppliers. Frames are usually sold with doors. Architectural antique stores can provide older panel doors. Door hardware is also available.
**Windows**

Most salvaged materials supply yards have large numbers of residential quality aluminum framed windows. Frames are typically non-thermally broken and are no longer permitted by building codes. Vinyl frames are less common but are also available. Many yards also sell new windows, which have been returned to the manufacturer because of some defect.

Glass from salvaged windows may be reused. Sealed units from salvaged windows will need to be disassembled, and the salvaged glass cut to new sizes, and reassembled in new units.

![Figure 9](image-url): Fabrication of new glass units from salvaged window. (P. Kernan, Design Guide, 2002, pg. 80)

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel doors and frames</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td>Rated doors and frames are usually available</td>
</tr>
<tr>
<td>Flush wood doors</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td></td>
</tr>
<tr>
<td>Panel wood doors</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Availability</td>
<td>Source</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------</td>
<td>---------------------------------</td>
<td></td>
</tr>
<tr>
<td>Aluminum sliding glass doors</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td></td>
</tr>
<tr>
<td>Overhead doors</td>
<td>Occasionally</td>
<td>Salvaged building material suppliers</td>
<td></td>
</tr>
<tr>
<td>Aluminum windows</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td></td>
</tr>
<tr>
<td>Wood windows</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td>Usually single glazed, residential type</td>
</tr>
<tr>
<td>Vinyl windows</td>
<td>Occasionally</td>
<td>Salvaged Material suppliers</td>
<td></td>
</tr>
<tr>
<td>Glass</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td></td>
</tr>
<tr>
<td>Sealed glazing units</td>
<td>Always</td>
<td>Specialty suppliers</td>
<td></td>
</tr>
<tr>
<td>Mirrors</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td>Architectural antiques stores</td>
</tr>
<tr>
<td>Door hardware</td>
<td>Always</td>
<td>Salvaged building material suppliers</td>
<td>Architectural antiques stores</td>
</tr>
</tbody>
</table>

**Finishes**

Many finish materials, because of their method of installation or application, are difficult to remove from existing buildings during deconstruction. Finishes that are not bonded to substrate material and are not tightly fastened can sometimes be salvaged. Wood trim and paneling, particularly from older buildings, is available as is wood flooring material.
### Designing with Salvaged Building Material

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood flooring</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specialty wood suppliers</td>
</tr>
<tr>
<td>Wood paneling and trim</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Architectural antiques stores</td>
</tr>
<tr>
<td>Carpet</td>
<td>Always</td>
<td></td>
</tr>
</tbody>
</table>

**Specialties, Equipment, Furnishings**

**Office Furniture**

The quality of the material, desks, divider panels, filing cabinets, and storage bins, is high and considerable savings can be achieved as a result of the high cost of comparable new products.

**Architectural Antiques**

Architectural antiques stores serve the residential renovation market, and also provide building supplies for heritage building restoration. In addition to furniture, panel doors, wood framed windows, fireplace surrounds, wood paneling and trim are available. Occasionally dressed stone pieces may also be found. Although a wide range of
equipment and furnishings are available the selection within most categories of these specialized components is limited. There are however a number of exceptions.

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toilet compartments</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Louvers and vents</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Metal lockers</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Fire extinguishers and cabinets</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Folding partitions</td>
<td>Rarely</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Washroom accessories</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td>Limited selection compared to new.</td>
</tr>
<tr>
<td>Residential appliances</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Laboratory fume hoods</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Office systems furniture</td>
<td>Always</td>
<td>Specialty suppliers</td>
<td></td>
</tr>
<tr>
<td>Kitchen casework</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
</tbody>
</table>

**Mechanical**

Where environmental issues form part of the design brief in new construction, the focus of mechanical and electrical design is typically on energy efficiency. Systems are
designed to minimize energy use, and often incorporate newer energy efficient technologies. Within this context there is less opportunity to use salvaged materials. Salvaged plumbing fixtures are readily available; the benefits of using salvaged materials must be weighed against the disadvantages of higher water consumption over the life of the building. However as low flush toilets become more common and begin to enter the salvaged materials stream this difficulty will be overcome.

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plumbing fixtures</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td>Most commonly of residential quality</td>
</tr>
<tr>
<td>(toilets, bath tubs, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric baseboard heaters</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>Unit air Conditioners</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
<tr>
<td>HVAC units</td>
<td>Occasionally</td>
<td>Salvaged building materials suppliers</td>
<td></td>
</tr>
</tbody>
</table>

**Electrical**

Light fixtures are almost always available from salvaged materials suppliers. Both residential and commercial fixtures can be found, often in relatively large quantities. In many cases at the time electrical equipment is removed from buildings, power has been disconnected and it is not always possible to confirm proper functioning of components.
<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Availability</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent lighting</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Industrial lighting</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Pot lights</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Switches</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Fuse switches</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Panel boxes</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Smoke detectors</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Transformers</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
<tr>
<td>Wiring / Cable / Conduit</td>
<td>Always</td>
<td>Salvaged building materials suppliers</td>
</tr>
</tbody>
</table>
Technology Behind Reclamation

Technology feasibility is the foundation of building materials recycling. Fortunately, current technologies can support most of the materials recycling. Some components can be reused with proper treatment, while some must be remanufactured. Sometimes the remanufacturing process is complicated due to the contaminations.

Concrete

Concrete is the most commonly used material in construction. Concrete is environmentally friendly in a variety of ways.

- First of all, the ingredients of concrete, water, aggregate, and cement, are abundant in supply and take a less toll in their extraction than other construction materials.
- As a nearly inert material, concrete is ideal for recycling. Moreover, many materials that would end up in landfills can be used to make concrete. Blast furnace slag, recycled polystyrene, and fly ash are among materials that can be included.
- Since the materials for concrete are so readily available, concrete products and ready-mixed concrete can be made from local resources and processed near a jobsite. Local shipping minimizes fuel requirements for handling and transportation. So it becomes energy efficient.
Concrete is a durable material that actually gains strength over time, conserving resources by reducing maintenance and the need for reconstruction. Concrete debris can be recovered using the following two strategies:

1. Crushing onsite and reusing it as compacted base or drain material;
2. Hauling it to a recycling facility

Concrete aggregate collected from demolition sites is put through a crushing machine, often along with asphalt, bricks, dirt, and rocks. Crushing facilities accept only uncontaminated concrete, which must be free of trash, wood, paper and other such materials. Metals such as rebar are accepted, since they can be removed with magnets and other sorting devices and melted down for recycling elsewhere. The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again.

Figure 9: Concrete recycling process. (Thesis: Framework For Building Design Recyclability, Retrieved from reusing and sustainability.pdf)
Generally, recycling concrete is possible and the process is not complicated. But if we cannot make the performance of recycled concrete satisfy the need, there won’t be a big market for it. Therefore, we still need to develop better technology to increase its properties.

**Wood**

Demolition generates timbers, trusses, framing lumber, flooring, decking, and millwork, doors, and window frames suitable for reuse or recycling depending on their condition. The recycled wood must be free of chemicals, including paint, strain, waterproofing, creosote, pentachlorophenol, petroleum distillates, and pressurizing treatments. Recovered wood can be used to manufacturer value-added products such as medium density fiberboard and particleboard.
Figure 10: Wood recycling process. (Retrieved on 22/12/2009, http://www.umich.edu/~nppcppub/resources/compendia/architecture.html)
Drywall

Drywall, also known as gypsum wallboard, is manufactured from gypsum, which is a low-value, plentiful mineral that exists in large natural deposits. Recycled gypsum can be used to manufacture new drywall. It can also be used to improve soil drainage and plant growth. Although recycled gypsum has so many usages, it is seldom recycled because of contaminants in the form of wall-coverings and paints.

Figure 11: Gypsum recycling process. (Thesis: Framework For Building Design Recyclability, Retrieved from reusing and sustainability.pdf)

Scrap generated during the construction process are clean, while those generated during demolition usually contain paints and fasteners. In recent years, the concept of recycling gypsum drywall at the construction site has been proposed. In this approach, scrap drywall from new construction is separated and processed using a mobile grinder and then size-reduced material is land applied as a soil amendment or a plant nutrient.
This recycling technique offers a potential economic benefit when the cost to process and land apply the ground drywall at the construction site is less than the cost to store, haul and dispose of the drywall.

**Metals**

Structure steel, the dominating member of all metals in construction, has been recycled for over 150 years, and it always been called “a green material”. The rebar in reinforcing concrete is always made from recycled steel and will be recycled during demolition, so it is a true green product. More than 7 million tons of steel is recycled into reinforcing bars every year, which is the entire feedstock. After demolition, most of the contractors extract and sell the rebars as ferrous scrap. The rebars are melted down to create new steel products. Metals are always recycled, but seldom reused. If we can reuse metals instead of recycling them, a large amount of energy will be saved.
Bricks

The most common way is crushing them and using the remaining material as a hardcore fill. A large force is needed in order to crush bricks, which means that heavy machinery is required. These machines are expensive and require a lot of room to operate, so they are only appropriate at sites there is a large amount of appropriate material that is available to be crushed.

The crushing process is simple, and any masonry chunks can be put through the crusher without the need to separate the mortar and bricks. After crushing, the material will be uniformly graded and much easier to transport than demolition rubble. However, hardcore is not a valuable material, and the cost of running a crushing machine is considerable.

The second method of recycling bricks is removing the whole brick by hands. If the building was constructed using a modern hard cement, it is very difficult to remove the cement from the bricks without causing damage. A demolition contractor will only consider the value of the whole bricks if it was built using a soft lime mortar, which can be easily removed because it is old and weak.
Nowadays, used brick is becoming more and more popular because of its unique and antique look. In some areas of the country, old bricks actually have a higher price than new ones.
Notes and Referencing

BIBLIOGRAPHY

Books


Thesis


**Report**


**Journal Article**


**Websites**

