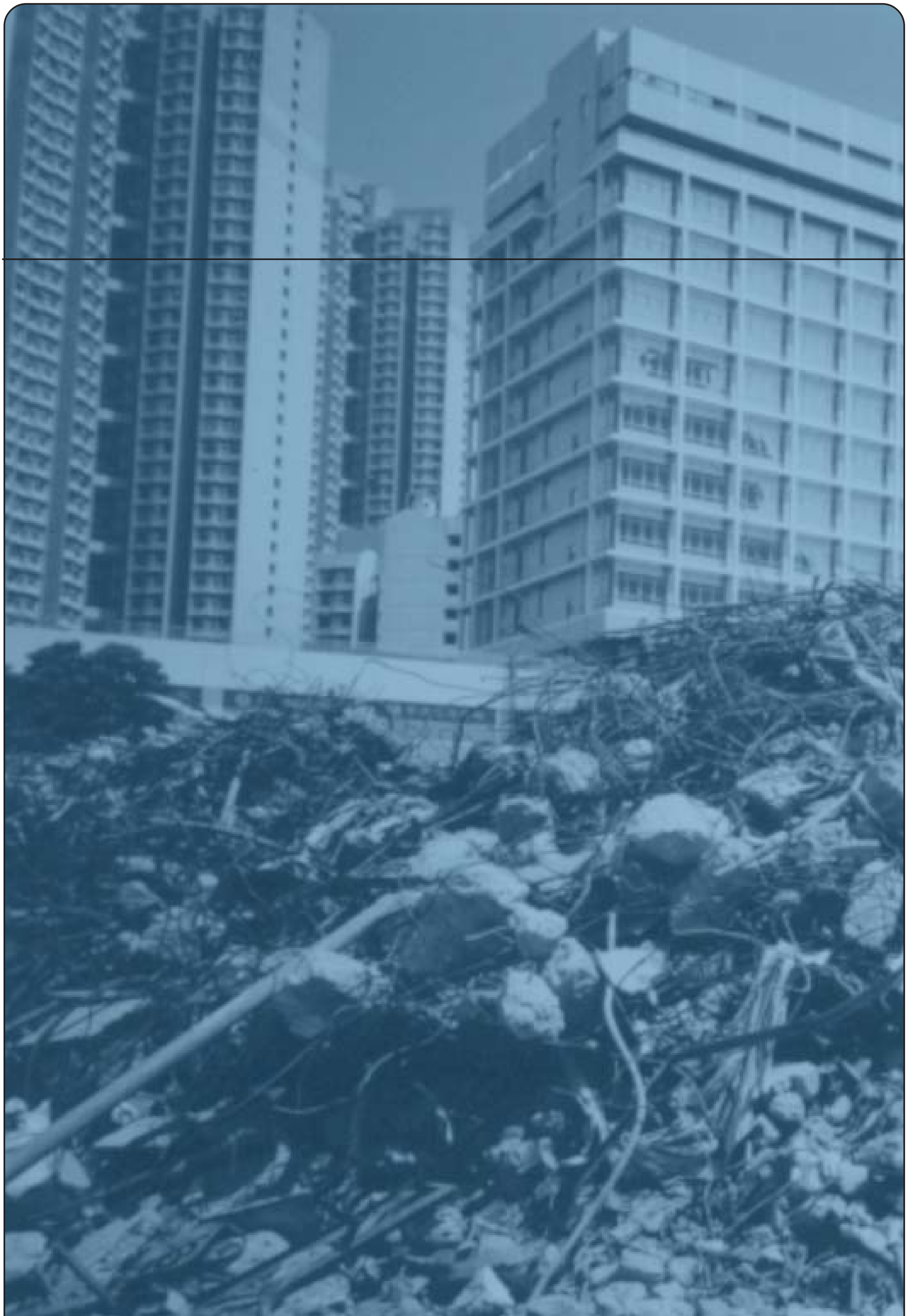
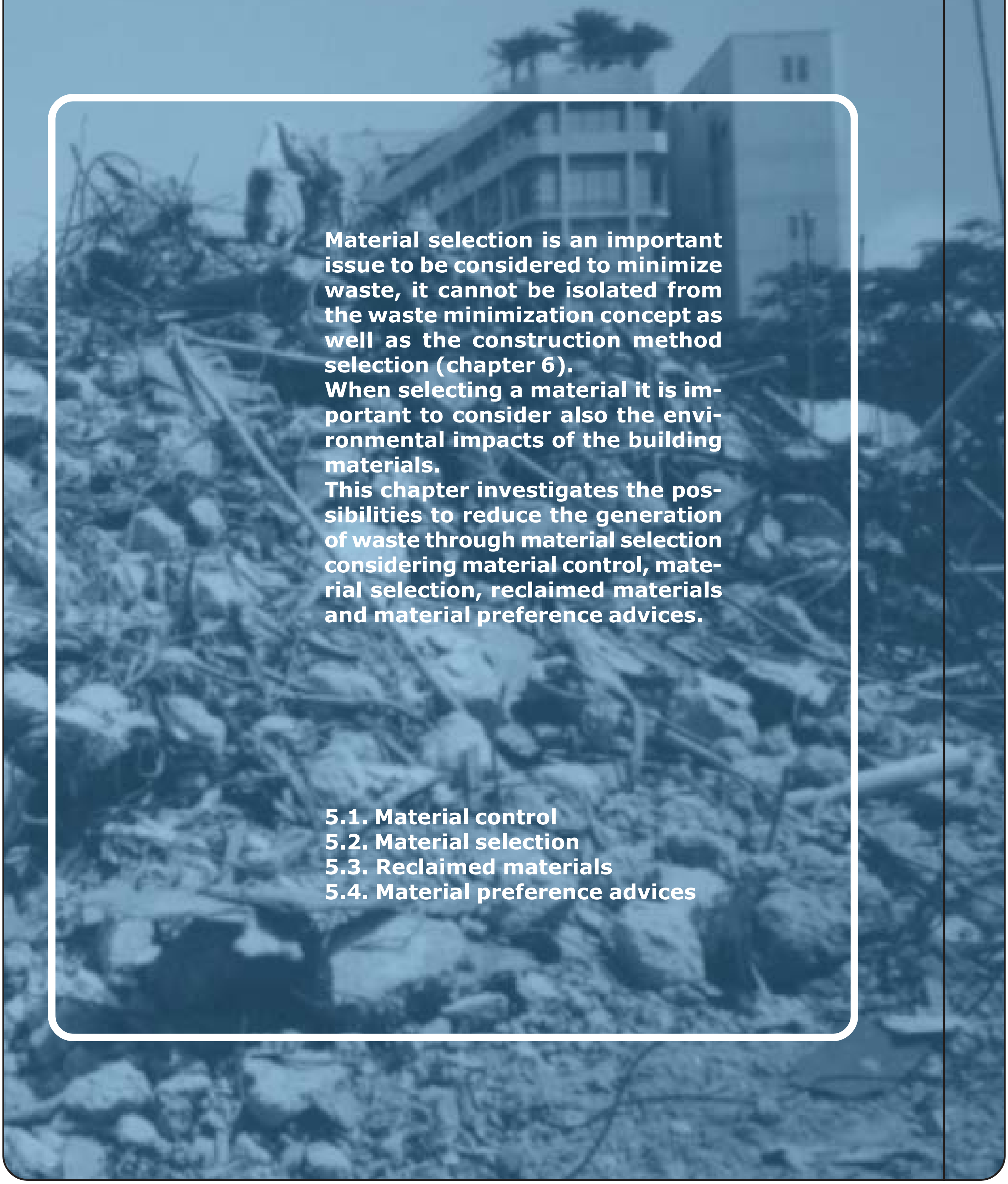


Chapter 5

Material Selection to Minimize Waste



Material selection is an important issue to be considered to minimize waste, it cannot be isolated from the waste minimization concept as well as the construction method selection (chapter 6).
When selecting a material it is important to consider also the environmental impacts of the building materials.
This chapter investigates the possibilities to reduce the generation of waste through material selection considering material control, material selection, reclaimed materials and material preference advices.

Top: left, packaging waste, right, mixed construction waste.
Bottom: Drywall partitions and reusable packaging

5.1. Material control

Material control is more related to material management and waste management. But decisions need to be planned in advance. Therefore it is briefly described in this chapter. (Also refer to the Contractor's checklist in the "Contractor attitude" chapter).

Objectives

- **Reduce the generation of waste through material control, and material management.**
- **Allow "precycling" measures.**

Waste Type

All types of waste arising from:

- Over ordering of materials.
- Wrong ordering.
- Improper unloading and handling.
- Improper storage.
- No on site considerations such as excessive cutting, non sorting of materials...
- No reuse or recycle action.

Strategies

Material management plan

- Decisions should be taken into account at an early stage of the building process (before construction starts).
- Management of materials should be included in the waste management plan.

Waste management plan and materials selection should include the following specifications:

- Specify clearly responsibilities of all members of the building team.
- Estimate types and quantities of waste that should be generated. Each type of material wasted should be detailed.
- Specify types and quantities of materials to be salvaged, reused or recycled.
- Estimate the percentage of total waste to be designated to landfill, public fill and recycler.
- Specify the on site sorting methods.
- Specify the handling methods of waste materials.
- Designate the sorting and storage areas.
- Specify the methods for removing waste from buildings (refuse chutes, ground floor holding area).
- Specify methods to maintain clean site housekeeping to minimize waste.
- See below details for the recycling plan

Top: left, improper stacking, right, Improper storage of tiles.
Bottom: Improper stacking

Recycle and reuse considerations

- Allow the reuse, salvaging and recycling of materials generated at the construction stage.
- Prepare a detailed recycling plan with estimations of quantities, types and destinations of each material (returned to supplier, reused, salvaged, recycled or disposed).
- Check the market for reusing, recycling and salvaging. Materials should not be ordered before the designation of recycling opportunities.
- Consider the packaging destination whether it will be returned to supplier, reused or recycled.
- Saving analysis should consider the cost comparison between normal construction waste disposal and recycling, to envisage feasibility.

Education

- Consider on site education and promotion of material management (careful handling, storage, transportation, sorting, reuse…). (ISO 14000)
- All workers should be aware of the waste management plan and actions to consider on site.

Tasks associated with material management (source: CIRIA SP 56, 1987):

- List materials required: analyze bills of quantity.
- Determine when they are required and the delivery period: consult program.
- Conserve on materials by measuring drawings.
- Obtain quotations: send out enquiries.
- Place order: select from quotations.
- Expedite deliveries.
- Quality inspection: at works, upon delivery, testing.
- Quantity check: inspection upon delivery.
- Site distribution: compatible equipment.
- Fixing: good workplace conditions, quality inspection.
- Prevent damage: protection.
- Monitor waste: materials reconciliation.
- Payment: site measure, client agreement and payment.

Ordering

- Avoid over ordering of materials, or make sure that the surplus can be reused on other projects.
- Prepare good schedule of delivery, and make sure that material delivery matches with the site requirements.

Delivery

- Check both quantity and quality upon delivery.
- Avoid breaking during transportation of materials.
- Allow just in time delivery to avoid material breaking by improper storage, and reduce the need for on-site storage.

On site considerations

- Allow proper storage on site to avoid material damage.
- Allow proper and careful handling of materials to avoid material damage.
- Allow sorting facilities and good schedule for bins (before over filled).
- Check proper sorting of materials.
- Allow reuse of materials on site.
- Check good work practice to avoid abortive works.

Left page: sorted reinforcement bars cutting waste, to be recycled.
Right page: Unsorted construction waste.

Benefits

Cost

· Material control avoids excessive expenses due to over ordering, improper storage and handling…

Environment

· Reduces waste disposed to landfills.
· Less pollution created by transportation of waste to landfill, and less energy used and less noise.

Regulation

Practice Notes for Registered Contractors

· PNRC 25, Submission of Schedule of Building Materials and Products, December 1994.

References

Books

· **The Control of Materials and Waste,** John Illingworth and Kenneth Thain, CIRIA Special Publication SP 56, London, 1987.
· **Waste Minimization and Recycling in Construction, Site Guide**, CIRIA Special Publication 133, London, 1997.

Other references

Inside

· Refer to chapter 3.3 "Contractor's attitude" and chapter 3.4 "Designer's attitude".

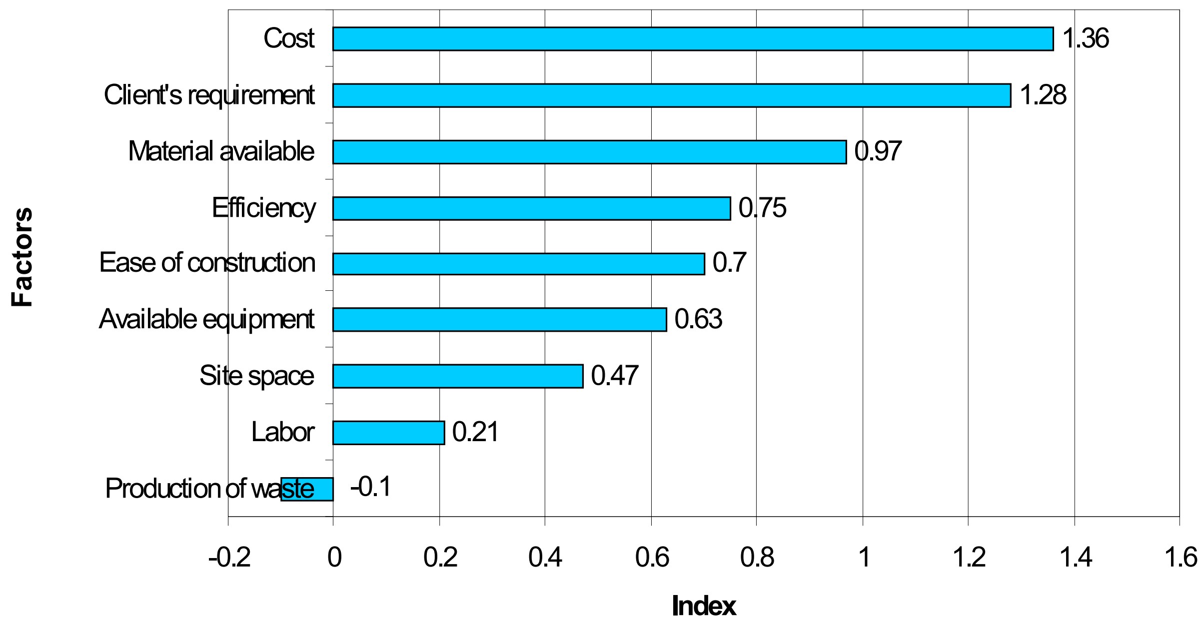


Figure 21: Factors affecting the selection of construction materials and methods. (Source: Hong Kong Polytechnic University Survey, 2001)

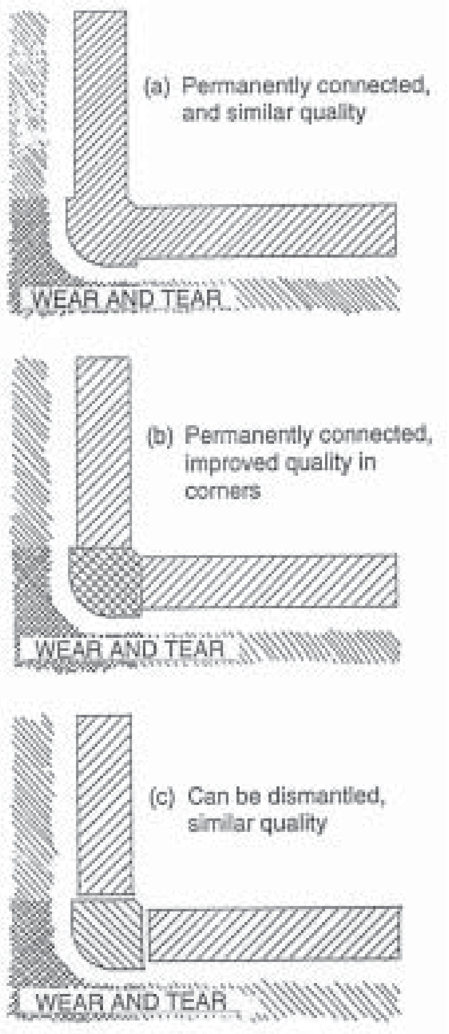
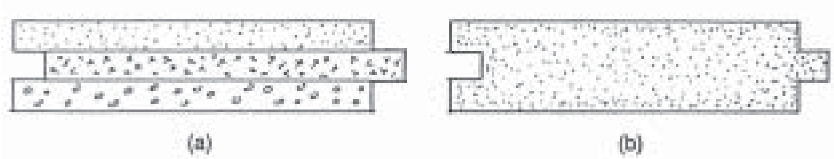


Figure 22: (Left) Three principles for connecting walls.
Figure 23: (Right) (a) Multimaterial component, (b) monomaterial component.
(Source: The Ecology of Building Materials)



The selection of materials is also essential in the waste minimization process. In fact design and material selection are linked and if materials don't fit in with the design concept of reducing waste and waste minimization, it cannot work.
The choice of materials can affect the generation of waste during construction and demolition. In chapter 4 "Design", it shows that efficient designs reduce material usage and waste generation, material selection should follow these concepts.
According to a survey conducted by the department of Civil and Structural Engineering of the Hong Kong Polytechnic University, in 2001, the production of waste is the last factor affecting the selection of construction materials.

Objectives

- **Reduce the generation of waste through material selection process.**

Waste Type

All types of waste arising from improper material selection.

Strategies

When selecting materials, the criteria should include their impact on the natural environment and waste generation. It should complement the usual criteria such as fitness for the purpose, cost, mechanical resistance, stability and safety. Material selection should emphasize durability, maintainability, flexibility and recycled content.

Global process

- Include the material selection process into the waste minimization design process and consider it as a whole global process.
- The action of designing for waste minimization cannot be dissociated with material selection.

Durable materials

- Select durable materials, as they will last longer and therefore stay away from the waste stream through avoiding replacement or demolition.
- Durable materials result in less repair and delay replacement or demolition.
- Durable materials will extend the lifespan of the building.
- Check whether all materials have the same durability in the construction process.
- If materials have inferior quality, they should be easily replaceable.
- Durable materials should be easily dismantled for reuse and recycling.
- Consider also proper maintenance to extend the building lifespan.

"The life span of a material is governed mainly by four factors:
(Source: The Ecology of Building Materials, Bjorn Berge, Architectural Press, 2000)

- The material itself, its physical structure and chemical composition.
- Construction and its execution, where and how the material is fitted into the building.
- The local environment, the climatic and other chemical or physical conditions.
- Maintenance and management."

Climate, humidity:
(Source: The Ecology of Building Materials, Bjorn Berge, Architectural Press, 2000)
" Change of humidity effects deterioration by causing changes in volume and stress within the material. Increased humidity increases deterioration. This is why the manufacture of musical instruments such as pianos and violins can only take place in premises with a stable air moisture content. The same conditions should also be applied to other interiors to reduce the deterioration of cladding materials and improve cleaning."

Materials that can be easily reused or recycled.

- Consider assembly for dismantling process.
- Materials should be easily dismountable for reuse or recycle, throughout the life of a building, during maintenance or renovation, and in the demolition of a building.
- Avoid composite materials whenever possible, and prefer monomaterial components.
- Composite materials have different materials laminated together, which may have different rates of decay within the same component.
- Consider the ease to separate material components to facilitate the recycling process.
- Consider the use of standard materials to facilitate reuse opportunities.
- Standard material dimensions should be compatible with the local standards to get more chance to be reused locally.

"This problem is especially acute in large, prefabricated building elements where cladding, insulation and structure are integrated into a single component."

"For reusable structures only so-called primary and secondary monomaterials are used. A primary monomaterial is a single homogeneous material used in its natural state (e.g. untreated wood) a secondary monomaterial is a mixed material of homogeneous nature (e.g. concrete, glass of cellulose fibre)."

Benefits

Cost

- Cost can be saved by selecting materials to minimize waste and by extending the building life span.

Environment

- It reduces waste disposed to landfills.
- It extends the landfills' life span.
- Less pollution created by transportation of waste to landfills, and less energy used and less noise.

Others

- Materials can represent a marketing advantage due to durability, good quality, reusable and recyclable issues.

References

Books **Materials and Environment**

- **Handbook of Sustainable Building**, An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment. David Anink, Chiel Boonstra and John Mak, James & James Ltd, 1996.

- **Ecology of Building Materials**, Bjorn Berge, Architectural Press, 2000.

- **The Green Guide to Specification**, An Environmental Profiling System for Building Materials and Components, Nigel Howard, David Shiers, Mike Sainclair, BRE Report 351, 2001.

- **Environmental Impact of Materials: Volume A, Summary,** CIRIA Special Publication 116, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume B, Mineral Products,** CIRIA Project Report 12, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume C, Metals**, CIRIA Project Report 13, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume D, Plastics and Elastomers,** CIRIA Project Report 14, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume E, Timber and Timber Products,** CIRIA Project Report 15, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume F, Paints and Coatings, Adhesives and Sealants,** CIRIA Project Report 16, London, 1995.

Recycled Materials

- **Waste Minimization and Recycling in Construction, Design Manual**, Stuart Coventry and Peter Guthrie, CIRIA Special Publication 134, 1998.

Journals

- **Salvaged Materials in New Buildings**, Jim Taggart, Old to New, The Canadian Architect.

Web sites

- BRE, http://www.bre.co.uk
- CIRIA, http://www.ciria.org.uk

Other references

Inside

- Refer to chapter 4.2.1 “Optimizing design lives”, and chapter 4.2.3 “Design for reuse and recycle”.

A new guide assists architects and engineers in the specification of salvaged materials for use in new construction.

Salvaged Materials in Mew Buildings **by Jim Taggart**

Over the past decade, through forums such as the recent Maastrich conference and initiatives such as the C-2000 and R-2000 programs, architects and engineers have become more knowledgeable about green design strategies. Organizing plan and section to maximize daylight penetration and natural ventilation, or incorporating technologies such as low emissivity glass and high-efficiency heat pumps, is now common practice in both new buildings and renovations.

At the same time, it is widely recognized that these measures alone will not be sufficient to achieve the desired goal of sustainability in our built environment. External forces such as zoning changes and spiralling land values often conspire to shorten the service life of buildings, even though the building fabric itself may still be in good condition. When one considers the embodied energy in these structures, and the physical implications of materials disposal, these premature losses have a considerable negative impact on the overall environmental equation.

Designing new buildings for flexibility and adaptability will help to address this problem in the future, but there is also a need to change our present attitudes to the demolition and disposal of existing buildings and to extract the full service life from all building materials by reclaiming and re-using them wherever possible. In this way, architects can assume the role of curators, not just creators, of the built environment.

Whereas the challenges in using other green design strategies are largely technical, and their impacts on traditional design practices and contractual arrangements are generally minimal, the same cannot be said when incorporating salvaged materials into new buildings. Architects typically specify materials and products from manufacturerís catalogues, with few concerns about quality, consistency or availability. In contrast, the uncertainties associated with salvaged materials have been sufficient to limit their use in all but heritage conservation or small residential projects.

A new publication from the Greater Vancouver Regional District (GVRD) aims to address thi situation in British Columbia, and has much practical and strategic advice to offer architects across the country.

Old to New - Salvaged Materials in New Construction is the result of a study commissioned by Thomas Mueller, Chair of the GVRDís Demolition and Deconstruction Planning Committee, among whose objectives it is to reduce the volume of solid waste reaching the regionís landfills. The study was undertaken by Paul Kernan, MAIBC, Richard Kadulski, MAIBC and graduate architect Michel Labrie, and it is written and organized to best address the needs and concerns of practitioners.

Old to New draws heavily on the experience gained on three recent Vancouver projects. The C.K. Choi Institute for Asian Research by Matsuzaki Wright Architects, the City of Vancouver Materials Testing Centre by Busby + Associates Architects, and the Liu Centre for the Study of Global Issues by Architectura in collaboration with Arthur Erickson have all successfully incorporated large proportions of salvaged materials. The guide looks at the supply and specification of materials, the effects of salvaged materials on the design process, implications for tendering and contract administration, and the potential foe overall cost savings. In addition, the guide identifies the types of salvaged materials and equipment most readily available, and organizes them in accordance with the 16 divisions of the Masterformat. It also lists the main suppliers of salvaged materials in B.C.

For many years, the architectural salvage market has been geared to the needs of heritage preservationists, the individual homeowner or the small builder. More recently, the increased cost and scarcity of large dimension timber has made it worthwhile for salvage contractors to remove heavy timber and glulam members from industrial buildings and retain them for resale. This has generated interest among architects wishing to incorporate reclaimed materials into their projects, and this increased demand has begun to broaden the range of salvaged materials and products available.

While there is an apparent cost benefit to incorporating salvaged materials, these may well be offset by increased architectural fees, higher front end cash flow for the purchase of materials, and a longer period of uncertainty over final cost of the building. In short, the incorporation of salvaged materials into new buildings needs to be embraced by clients for philosophical rather than purely financial reasons.

The salvaged materials industry is made up of small independent contractors and suppliers who often see themselves in competition with one another. It is prudent to spend some time investigating the situation in your area before embarking on a project of this type. Materials can be obtained either from salvage contractors or suppliers, but the best way to obtain salvaged materials is often to identify and purchase a suitable building already slated for demolition. In the case of the Materials Testing Centre, two suitable buildings already existed on site, and in the case of the Choi Institute and Liu Centre, the client, the University of British Columbia, had redundant buildings nearby. It should be noted that all these buildings were of heavy timber construction, this being, with rare execptions, the only structural system that readily lends itself to re-use in this way.

An inventory of materials from an existing building becomes the starting point for schematic design. For both architect and structural engineer, the size and lengh of available members will determine the spans and spacing possible in the new structure. Any shortfall in materials will need to be made up from other sources. In the Materials Testing Centre, salvaged heavy timber trusses were re-used in their original configuration, and salvaged glulam purlins were reused on the flat to create a suspended floor. In the Choi Institute, the available trusses were not suited to the small program spaces, so they were dismantled and re-used as elements in a post and beam frame structure. In all cases design flexibility and ingenuity are the keys to successful reuse of materials.

Creating a workable structure for a new building using salvaged materials can be the ingle biggest challenge for architects. Many other materials and products are straightforward to use, but may be more difficult to source. The case study buildings variously incorporate salvaged sawn lumber, plywood, insulation, specialty metalwork, washroom fixtures and accessories, doors, windows, and even recycled window glass. Producing all the materials in advance of tender requires money up front and a great deal of research, but enables tender documents to be complete, contractors to view the materials before submitting a bid, and the project to be let as a CCDC-2 Stipulated Price Contract. This was the procedure adopted for both the Choi Institute and the Liu Centre, which achieved approximately 50% recycled content in the completed buildings.

The Materials Testing Centre was also initially set up this way. The schematic design for the project was done based on an inventory of materials from the two adjacent warehouses slated for demolition, but both client and architect wanted to incorporate as many other salvaged materials as possible. Initially, the project was tendered using CCDC-2, with two parallel schedules. The first was to be priced assuming all new materials (except for those supplied by the client), the second assuming substitution of salvaged materials. Bidders responded with only one price, choosing not to assume the risks associated with sourcing and securing salvaged materials. To achieve their goal of 70% recycled content, the architects re-tendered the project as a CCDC-5 Construction Management contract, assigning responsability for sourcing additional recycled materials to the Construction Manager.

Few, if any, salvaged materials suppliers will guarantee the availability of specific materials or products for the duration of the design and tender period. So if pre-purchase is not an option, flexibility must be built into the design. For example, the drawings for the Materials Testing Centre simply identified ìCladdingî, specifying neither metal nor wood, as suitable material had not been sourced at the time of tender. Similarly, to allow some flexibility in procurement, the architects required all doors on any floor to be the same design and height, but permitted variation between those on different floors. With the City of Vancouver as a client, the lack of a definitive specification for exterior materials at development permit stage was not an issue. Similarly, the applicable building codes permitted the use of salvaged materials where these met the required specification. The situation in other areas may be different, and it is important that the municipality endorse the intent of the project from the outset, and understand the design implications.

Clients should also be aware of the potential for delays if a large number of items need to be procured during the contract period. In Vancouver, as more projects go this route, specialist materials procurement consultants are emerging, and their experience can minimize the risks of disruption or delay. They work from an architectís or engineerís ìwish listî of materials, sourcing from a range of suppliers and suggesting substitutes where appropriate, based on availability.

Old to New also lays out a case study of a ìtypicalî project, identifying the key decisions that must be made at each stage. A cost comparion concludes that with 50-70% salvaged material content, overall savings of 5-10% on the cost of new construction are possible. Typically, as a percentage of contract value, the labour content is much higher than for a project using new materials. This can provide tangible benefits to the local construction industry.

It is hope that this guide will encourage architects to incorporate more salvaged materials into their projects, so increasing the overall demand and making it viable to deconstruct, rather than demolish, a greater percentage of our redundant buildings. The case study projects clearly demonstrate that this practice can result in significant benefits to clients, society and the environment, without compromising conventional architectural goals.

Tim Taggart is an Associate of the Architectural Institute of British Columbia. Old to New *is available from Thomas Mueller at the Greater Vancouver Regional District Policy and Planning Department.*
Phone (604) 436-6818,
E-mail: thomas.mueller@gvrd.bc.ca

(Source: Canadian Architect, January 2001)

5.3. Reclaimed materials

Definition of reclaimed material (CIRIA, 1999):
"Material extracted from the waste stream of construction and other industries and used either in its original form (reuse) or following processing (recycling)".
Includes:

- Materials reused from demolition sites (on site or from other sites).
- Materials processed or not.
- By-products from other industries such as PFA.

According to a survey conducted in 2001 in Hong Kong:

- 69% of respondents have either never specified materials from demolition on sites and reused in its original form, or after little processing.
- 68% have never specified materials from demolition on sites for processing to allow for use in another application.
- 77% have never specified materials from other sites, reused it in its original form or after processing.
- 58% have never specified products made from recycled materials.
- And 65% have never specified by-products from other industries used in their original form or after processing.

Objectives

- **Consider the use of reclaimed materials to minimize waste.**

Waste Type

Actions of all types of waste generated from either not having recycled or reused.

Strategies

Considerations for the specification of a reclaimed material:

- Consider cost comparison between a reclaimed material and other alternatives.
- Check if there is local supply (might be difficult for Hong Kong).
- Material should be available in sufficient quantities and follow the time schedule of the project.
- Material should be suitable in terms of performance, durability and compatibility.
- Check if the material requires extra maintenance or extra design decisions.
- Consider the efficiency of using the material compared to its application.

Some problems may occur when specifying a reclaimed material such as:

For Reused materials:

- Quantity of material available for large-scale development.
- Availability at the right time of the project schedule.
- Constant quality.
- Materials would not be standardized if old materials such as bricks or stones were used.
- Time for sourcing materials. The Internet could be a good alternative to source materials on material web sites.
- Storage of the material.

For recycled materials:

- The homogenous supply of the material (unless originated from the same site).
- The quality of the material needs to be tested.

Strategies

The British Standards specify material standards for reclaimed materials, BS6543, The Use of By-Products and Waste Materials in Building and Civil Engineering. It focuses on materials for fill, pavement layers, aggregates, cementitious materials, bricks and blocks. The materials covered include: colliery spoil, spent oil shale, pulverized fuel ash (PFA), furnace bottom ash, china clay waste, slate waste, incinerated refuse, metallurgical slag, demolition wastes.

The Practices notes in Hong Kong mentioned the Pulverized Fuel Ash in Concrete (PNAP 90, PNRC 13).

The choice of reclaimed materials might not always be the best environmental solution. It is important to consider other issues when selecting materials. Guidelines on environmental impacts of materials are available to help understand the whole concept and issues and to select good materials.
Some guidelines to refer to:

- Environmental Impacts of Materials, CIRIA Special Publication SP 116. 1995.

STRUCTURAL MATERIALS

METALS

Steel structures are used in Hong Kong for office high-rise buildings such as the Bank of China, The Center, which can be mixed with concrete for fire protection. Some buildings are constructed using steel structures with reinforcement concrete cores and basements such as the project under construction at the airport express terminal in Central, Lee Gardens Redevelopment…
The steel can be used for foundations, wall, roof and floor structures. It is generally prefabricated and assembled on site, welded with or without the use of both.

Reuse

Reuse of structural steel sections is the best environmental option, although it is not so common. There is a lack of disassembly considerations in the design.
As BRE mentioned (Deconstruction and Reuse of Construction Materials, 2001), "The challenge will be to increase the amount of steel reused rather than recycled. There remains a need to incorporate design for deconstruction for new buildings and to develop new tools and techniques to maximize the reuse of material from existing buildings through deconstruction."
Examples: steel and aluminum formwork.

Recycle

Metals can be recycled by re-smelting, therefore they have a high capacity of recycling and "conserve much of the energy of refining from ore and the natural mineral sources required for new primary metal production" (CIRIA, SP 134).
Most of the time, both structural sections (beams and columns) and reinforcement bars are recycled. Metal formworks are also recycled (e.g. aluminum formworks recycled to produce cans for drinks).

Specifications

There are no specific standards to reuse reclaimed steel components.

- "Appraisal of Existing Iron and Steel Structures" SCI publication gives information on methods of investigation and guidance on calculations to check the structural adequacy.

Strategies

- The existing standards do not encourage the reuse of metal for structural purposes: e.g. BS 5950 Structural use of steelwork in building 2.1.1: " Unless otherwise specified by the engineer, all but rolled structural steel products shall comply with BS 4360, BS EN 10025. For other steels as specified by the engineer the performance must still accord with the standards of 2.1.1."

Constraints

- Need for storage space on site.
- Need for quality assurance testing facilities for suitable components.
- Time and cost spent carry out testing.

CONCRETE

Most of the buildings in Hong Kong are made of concrete structure (about 95%) and are mainly cast in in-situ concrete. This represents a large proportion of C&D waste in Hong Kong.
Concrete is made of a hardened mixture of cement, sand, stone and water. Concrete waste is produced in the construction, renovation and demolition of roads, sidewalks, building foundations and structural elements.

Reuse

- Prefabricated elements such as beams, columns, staircases… are simpler to dismantle for reuse if the joints are simply supported. There are no standards for jointing systems, and joints are not designed for deconstruction. As mentioned BRE 2001, "However, these joints are frequently cast in place, usually with concrete or mortar that is stronger than the actual beams".
- Precast flooring systems are easier to disassemble and reuse.
- On the other hand, cast in-situ concrete cannot be reused in its original form.

Recycled

- Concrete is usually crushed and used as aggregates in bases and in-fill, and rarely used as high-grade applications.
- Applications in Hong Kong: aggregates for filling reclamation and site formation…
- Separation of concrete and reinforcement bars is required. See demolition techniques in "A Guide for Managing and Minimizing Building and Demolition Waste" (The Hong Kong Polytechnic University, 2001).
- Purchase of concrete and cement should specify fly ash or slag aggregate content, depending on their intended use.
- The use of secondary crushed concrete aggregate should always meet specified structural requirements.
- They require testing.

Specifications

There are no standards for deconstruction and reuse of concrete structures but there are on the use of reclaimed materials in construction materials, products and structures.
(Source CIRIA SP 134)

- There are opportunities to use reclaimed materials according to **BS 6543** or **BS 5328: 1991** Guide to Specifying Concrete, to use aggregates outside BS if adequate performance can be demonstrated.
- **BS 8110: 1985**, Structural Use of Concrete, defines the inclusion of materials such as pulverized fuel ash (PFA) and ground granulated blast-furnace slag (GGBS) in terms of acceptable quantities.
- **BS 3892: 1993**, Pulverized Fuel Ash, defines the use of PFA in cementitious components.
- **BS 6588: 1991**, Specification for Portland PFA Cements, specifies the use of PFA in cement.

- **BS 12: 1996**, Specification for Portland Cement, allows inclusion of blast-furnace slag and PFA as minor constituents in cement.
- **BS 146: 1991**, Specification for Portland Blast Furnace Cement, specifies inclusion of granulated blast furnace slag and allows PFA as a minor constituent in cement.
- **BS 1047: 1983**, Specification for Air-cooled Blast Furnace Slag for Use in Construction, includes aggregate for use in construction.
- **BS 3797: 1990**, Specification for Lightweight Aggregates for Masonry Units and Structural Concrete, provides guidance on reclaimed materials for use as lightweight aggregate.
- **BS 4246: 1991**, Specification for High Slag Blat Furnace Cement.
- The Department of Transport's **Manual of Contract Documents for Highway Works**, Volume 1: Specification for Highway Works (1994) allows crushed concrete to be used in new concrete paving.

In Hong Kong:

- **PNAP 90, PNRC 13**, Pulverized Fuel Ash in Concrete, May 1994.

Guidance:

- BRE Digest 433, Recycled Aggregates, Garston, CRC, 1998.
- DETR, Quality Control for the Production of Recycled Aggregates, London, Stationery Office, 2000.
- DETR, Protocol for the Use of Reclaimed Production in Precast Concrete, DETR Client Report, 2000, unpublished.

Constraints

- Contamination risks must be controlled.
- Need for quality assurance testing facilities for suitable components.
- Guaranty of homogenous material supply.
- Need for centralized recycling facilities.

References

- The Use of Recycled Aggregates in Concrete, Collins, R J, Information paper IP5/94, BRE, 1994.
- Recycled Concrete and Masonry, Collins, R J, Information paper PD327/93, BRE, 1993.
- Recycled Aggregates: Properties and Performance, Mulheron, M and O'Mahony, M, Institute of Demolition Engineers, 1987.
- Use of Waste and Recycled Materials as Aggregates: Standards and Specifications, Collins, RJ and Sherwood, P T, HMSO, 1995.

MASONRY

Reuse

- Bricks and blocks can be reused but must satisfy the standards.
- Applications for renovation of historical buildings, and also new buildings such as the Wetland Park Museum.

Recycling

- Bricks can be grounded into granular material and used as an aggregate for secondary use, e.g. road base, backfill material…
- It can also be used as aggregates for future construction.

Specifications

- BS 3921: 1985 (1995) is the standard for bricks and blocks.

Constraints

- No official standard that controls the quality of reclaimed bricks and blocks.
- Reuse requires careful demolition and dismantling. It can be difficult with cement-based mortars (rather than lime-based mortars) to avoid block damages because mortar is more difficult to remove than bricks.

- Need to clean bricks and blocks. It is labour intensive and might be more expensive than new materials.
- Low temperature fired bricks are unsuitable for external use. Require tests.

Benefits

Cost
- Benefits can be achieved through selling materials for reuse and recycle,
- Reuse minimizes the purchase of new materials.

Environment
- It reduces the amount of waste disposed at landfills.
- It extends landfills' life span.
- It reduces pollution, energy used and noise generated by transportation of disposal waste.

Others
- The purchase of reused materials add "character" to construction project, e.g. used bricks…
- It can enhance the marketing advantage.
- It can enhance the image of the project and the company.

Regulation

Practice notes for authorized person:
- PNAP 90, Pulverized Fuel Ash In Concrete, May 1994.

Practice notes for registered contractors:
- PNRC 13, Pulverized Fuel Ash In Concrete, May 1994.

British Standards:
- BS 6543, The Use of Industrial By-Products and Waste Materials in Building and Civil Engineering.

References

Books

Materials and environment

- **Handbook of Sustainable Building**, An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment. David Anink, Chiel Boonstra and John Mak, James & James Ltd, London, 1996.
- **Green Building Materials, A Guide to Product Selection and Specification,** R. Spiegel, D. Meadows, John Wiley & Sons, Inc., 1999.
- **Ecology of Building Materials**, Bjorn Berge, Architectural Press, 2000.
- **The Green Guide to Specification**, An Environmental Profiling System for Building Materials and Components, Nigel Howard, David Shiers, Mike Sainclair, BRE Report 351, 2001.

Recycled materials

- Works Bureau of HKSAR, **Works Bureau Technical Circular No. 31/2000 – Specification Allowing the Use of Recycled Inert Construction and Demolition Material**, WB(W) 209/32/105, 6 January 2001.
- **Waste Minimization and Recycling in Construction, Design Manual**, Stuart Coventry and Peter Guthrie, CIRIA Special Publication 134, 1998.
- **Waste Minimization and Recycling in Construction, a Review**, CIRIA Special Publication 122.

- **Waste Minimization and Recycling in Construction, Boardroom Handbook**, CIRIA Special Publication 135.
- **Waste Minimization and Recycling in Construction, Technical Review**, Stuart Coventry and Peter Guthrie, CIRIA PR 028.
- **The Reclaimed and Recycled Construction Materials Handbook,** CIRIA, C 513.
- **Recycled Content Building Materials Products Guide**, King County Solid Waste Division, June 2001, USA.
- **Use if Waste Materials in Building Products,** C. Atkinson, R.J. Collins and J. West, Paper for Building and Environment Conference, May 1994.
- **Recycling of Demolition Materials**, R.J. Collins, BRE: Garston, 1993.
- **Recycled Concrete and Masonry**, R.J. Collins, Information Paper PD 327/93, BRE: Garston, 1994.
- **Reuse of Demolition Materials in Relation to Specifications in the UK'**, R.J. Collins, in Lauritzen, E.K. (ed) Demolition and Reuse of Concrete and Masonry (Proceedings of the third International RILEM Symposium on Demolition and Reuse of Concrete and Masonry), Chapman Hall, 1993.
- **Use of Waste and Recycled Materials as Aggregates: Standards and Specifications**, R.J. Collins and P.T. Sherwood, HMSO: London, 1995.
- **Concrete Recycled, Crushed Concrete as Aggregate,** P. De Vries, Concrete May/jun 1993, pp 9-13.
- **Recycled Aggregates: Properties and Performance**, M. Mulheron and M. O'Mahony, Institute of Demolition Engineers: Cleckheaton, 1987.
- **Recycling Waste from Construction Sites**, Snook K., Turner A., Ribout R., CIOB, 1995.
- **Demonstration of Reuse and Recycling of Materials**, IP3/97, BRE, 1997.
- **Plastics Recycling in the Construction Industry,** IP12/97, BRE, 1997.
- **Blocks with Recycled Aggregates: Beam and Block Flooring,** Collins R.J., Harris D.J., Sparkes W. (Kingsway Technology Ltd), IP14/98, BRE, 1998.
- **Reclamation and Recycling of Building Materials,** IP7/00, BRE, 2000.

Journals

- "Recycle, Recycle, Recycle…", Smart Architecture, http://www.smartarch.nl/o2columns/smartarch699.html

Web sites

- CIRIA http://www.ciria.org.uk
- BRE http://www.bre.co.uk

Other references

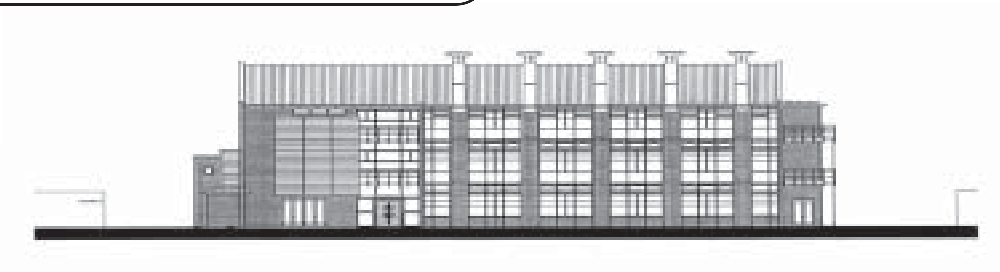
Inside

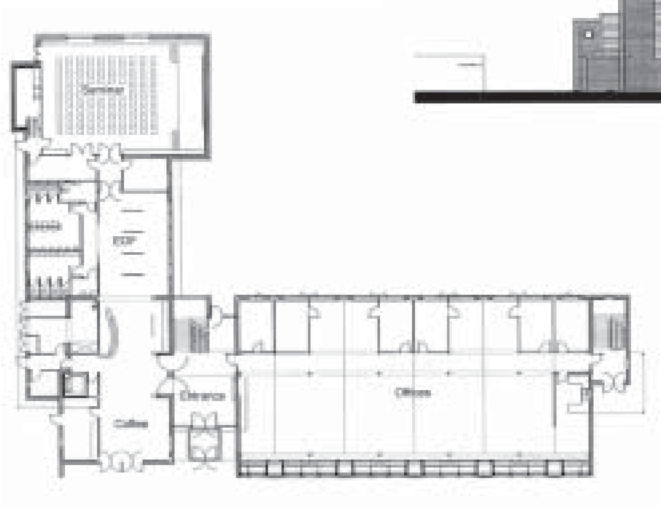
- Refer to chapter 4.2.3 "Design for reuse and recycle".
- Refer to chapter 4.1.2 "Reuse building structure".

Outside

- Refer to case studies:
- King County Solid Waste Division, The Microsoft Data Center.
- King County Solid Waste Division, Carpet Reuse and Recycling.
- King County Solid Waste Division, Team Approach Saves $186,000.
- Waste Minimization in Housing Construction, CIRIA RP582/1. "Langley Park".

Project: BRE, Building Research Establishment.
Location: Garston, UK.
Project Manager: Bernard Williams and Associates
Architects: Feilden Clegg Architects
Services Engineers: Max Fordham and Partners
Structural Engineers: Buro Happold
Quantity Surveyors: Turner and Townsend
Landscape Architects: Nicolas Pearson Associates
Space Planning: DEGW
Planning Supervisor: Symonds Travers Morgan
Main Contractor: John Sisk





South elevation and ground floor plan. (Source: Green Buildings Pay).

This project is a demonstration project for BRE research demonstrating techniques, which could be adopted in the design of future office. It includes 1300 m2 of offices for about 100 staff and 800m2 for seminar and associated facilities.Beside other environmental issues, waste minimization is considered in this project by reusing and recycling materials from the existing building as well as other buildings in London, and by selecting environmentally friendly materials. In fact, 96% of the old building was reclaimed or reused (see extracts for detailed information) and less waste was disposed at landfills.

"It has been built as a demonstration building for the Energy Office of the Future (EoF) performance specifications…"
"Green features in the environmental Building.
As well as designing an energy efficiency building, every effort has been made to include environmentally friendly products and materials. The "green" elements in the building are:

- *80 000 reclaimed bricks.*
- *96% of the old building was reclaimed or recycled.*
- *Reclaimed mahogany parquet flooring.*
- *90% of in-situ concrete used recycled aggregate.*
- *Ground granulated blast furnace slag used in the cement mix.*
- *Timber sourced from sustainable resources.*
- *Environmentally friendly paints and varnishes.*

Extract from the web site: http://projects.bre.co.uk/envbuild/index.html

"The EB provided an opportunity to examine what the construction industry could do if more attention were paid to sustainability.
Firstly, the existing building on the site had to be demolished and every attempt was made to recycle as much of the material as possible – this amounted to 96% by volume, with the remaining 4% going to landfill. Brickwork and concrete were crushed and used as hardcore under the new building. Timber was sent to a firm in Cornwall, which specializes in making furniture with recycled wood. Steel roof trusses were cut up and sent off for melting down and recycling. The electrical accessories and items of mechanical plant were given to a charity, which uses such equipment for community projects.
Secondly, in constructing the new building, careful consideration was given to the choice of materials. Thus, the renewable resource of a timber ceiling was used on the top floor as a compromise between a structural criterion to keep the weight low and an environmental one to keep the thermal mass up. The roof itself is aluminum sheet on the basis that aluminum is an easily recyclable material. Recycled aggregates replaced coarse aggregate in over 1500 m3 of concrete foundations, floor slabs, structural columns and intermediate floors. The recycled aggregates came from a building in London that was being demolished and crushing occurred at a plant in the London area; thus transportation costs associated with recycling were reduced.
In place of 100% cement in the concrete, a mixture of 40% cement and 60% ground granulated blast furnace slag, a by-product of the steel industry, was used.
To clad the building approximately 80 000 yellow stock bricks over 100 years old were used. Their visual contrast with he gleaming stainless steel stack tops and the glazing strikes an attractive and symbolic note for future construction.
Extracts form "Environmental Design: an introduction for architects and engineers, 1999".

Case Study 20 — Wetland Park Museum, Phase 1, Tin Shui Wai, Hong Kong

Project:	Wetland Park Museum.
Location:	Tin Shui Wai, Hong Kong.
Project team leader:	Raymond Fung
Architects:	Michael Li
Landscape Architects:	Tony Mui
Architect and overseer of the exhibition:	Kevin Li
Year:	December 2000
Site area:	64 ha and the building occupies 0.6 ha. (230 m2 single story building).
Project Cost:	9.9M

This project considers waste minimization as well as other environmental issues. It reduces waste from construction and reuses building materials and uses recycled materials. The main issues regarding waste minimization are the following:

Construction Waste Management

Permanent formwork
- Steel roof beams and metal decking as permanent formwork for the roof slab

Reduce the use of timber
- No timber props to beam/slab soffit.
- Use of second hand formwork from other building sites.

Use of precast units
- Use of precast foting for all fence wall construction

Prefabricated BS installations
- Prefabricated air duct works

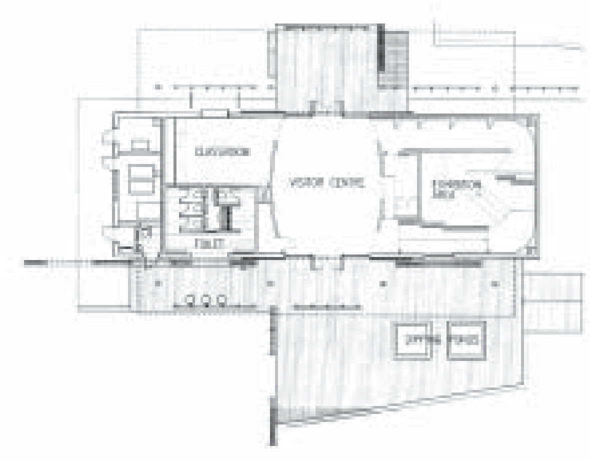
Material Use

Material with recycled content
- Pulverized fuel ash (PFA) as cement replacement for all structural concrete.

Material reused
- Brick wall built from old bricks from China.
- Paving of granite block from old boundary wall of Wanchai Police Headquarter.
- Gabion wall infill made from oyster shells from Lau Fau Shan coastline.
- Boundary fence using the dismantled timber formwork from concreting.

Timber from sustainable source
Timber screens, platforms and horizontal louvers are from sustainable timber sources.

Left page: (top) Access with reused pavement. (Bottom) left, Detail entrance, right, entrance.
Right page: (top) North east elevation. (Middle) left, oyster wall detail, right floor plan. (Bottom) Brick wall detail.



Extract from Hinge magazine Vol. 73, 2000:

"The landscape is designed to imitate the surrounding wetland habitat, and incorporates native wetland species found locally within the Ramsar area…
In the entrance courtyard the team created a dense envelope of foliage to shield the site from surrounding construction activity, while leaving it possible to catch glimpses of the larger wetland site from the western boundary of phase one. The boundary wall is constructed from reused dismantled timber from site's formwork. Also salvaged is the material for the path that runs from the courtyard to the western entrance of the building. It has been paved in the granite from the old boundary wall of the Wanchai Police Headquarters.
A decked path leads visitors past flocks of ducks and around gabion walls filled with reused shucked oyster shells that are farmed at nearly Lau Fau Shan. The designers were looking for a material that could be sourced locally, was freely available, and had relevance to the setting. Above the deck and towards the rear, vertical wooden screens and horizontal louvers are constructed from sustainable timber sources to shade the building from direct sunlight. Recycled bricks from China on the south wall also mitigate the effects of solar gain to the building.
When construction began in March 2000, the contents of the building were undecided. This, the architects admitted, was an advantage in terms of influencing its pure form. The 230 sq m, single story rectangular box is extremely adaptive and remarkably unobtrusive. In addition, the minimal dimensions of the structure negated the requirement for bulky extras such as sprinklers, a transformer room and generators."

5.4. Material preference advices

It is important to consider environmental issues as well as waste minimization, in the selection of materials.
Books and guidelines to refer to:

Materials and environment

- **Handbook of Sustainable Building**, An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment. David Anink, Chiel Boonstra and John Mak, James & James Ltd, 1996.

The Environmental Preference Method was developed in 1991.
"It compares materials and products currently on the market and ranks them according to their environmental impact… Considerations such as cost or aesthetics are not involved in this assessment… The result is not an absolute assessment but a relative ranking based on environmental preference… When preparing a specification, the architect, engineer or contractor can quickly refer to this manual for the preferred environmental solution."

- **Ecology of Building Materials**, Bjorn Berge, Architectural Press, 2000.

- **The Green Guide to Specification**, An Environmental Profiling System for Building Materials and Components, Nigel Howard, David Shiers, Mike Sainclair, BRE Report 351, 2001.

- **Environmental Impact of Materials: Volume A, Summary,** CIRIA Special Publication 116, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume B, Mineral Products,** CIRIA Project Report 12, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume C, Metals**, CIRIA Project Report 13, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume D, Plastics and Elastomers**, CIRIA Project Report 14, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume E, Timber and Timber Products,** CIRIA Project Report 15, London, 1995.

- **Environmental Impact of Building and Construction Materials: Volume F, Paints and Coatings, Adhesives and Sealants,** CIRIA Project Report 16, London, 1995.

Recycled materials

- **Waste Minimization and Recycling in Construction, Design Manual**, Stuart Coventry and Peter Guthrie, CIRIA Special Publication 134, 1998.
- **Waste Minimization and Recycling in Construction, a Review**, CIRIA Special Publication 122.
- **Waste Minimization and Recycling in Construction, Boardroom Handbook**, CIRIA Special Publication 135.
- **Waste Minimization and Recycling in Construction, Technical Review**, Stuart Coventry and Peter Guthrie, CIRIA PR 028.
- **The Reclaimed and Recycled Construction Materials Handbook,** CIRIA, C 513.
- **Demonstration of Reuse and Recycling of Materials**, BRE,IP3/97, 1997.
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- **Reclamation and Recycling of Building Materials**, BRE, IP7/00, 2000.