Salvageability; implications for architecture

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Nordic Journal of Architectural Research
Volume 20, No 3, 2008, 14 pages
Nordic Association for Architectural Research
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TOPIC: ARCHITECTURE IN A RESOURCE PERSPECTIVE

Abstract:

In the endeavours of reducing environmental impacts of constructions by facilitating salvage of building components and materials, affiliated design strategies have been identified. These strategies inform the design of building components as well as constructions. In this paper, the challenge of turning the strategies into architecture is discussed. The overriding hypothesis is that the demand for salvageability of building materials may be seen as a positive driver for architectural design. The research uses theory from earlier studies, and also points to building examples from past and present. We ask what the design consequences are if the strategies are strictly followed, and in what ways these strategies may coincide with typical professional approaches of creating architecture. Practical consequences are also considered. Through these discussions it is shown that the criteria for salvageability can be linked to the tectonics of buildings, in the sense that environmental logic can substantiate design concepts. The focus shifts from the restrictions that the demand for salvageability may pose upon construction, and rather points to potentials for creating meaningful architecture for a low-carbon society. A process oriented building practice may challenge the prevailing view on architectural design. However, as a key, the building component is emphasized as an operational and responsible base unit.

Keywords:
Building materials, lifecycle design, closing the loop, tectonics

Six criteria for facilitating reuse and recycling of building materials are explored in an architectural context. The tectonic approach is used in the discussions, which aim at contributing to a debate on environmental design in general.

INTRODUCTION

The aim of this article is to couple the findings from the research of salvageability with the field of architecture. Salvageable constructions aim at resource efficiency of materials through facilitating reuse and recycling of components. This article discusses in what ways the criteria for salvageability, as measures for sustainable construction, can be integrated as an innate part of the design process.

Generally, measures for sustainable construction, such as thermal insulation standards and waste reduction requirements, are implemented through regulations in the building code and through financial incentives. These are important policy instruments in gearing the overall building activity towards more sustainable solutions. However, regulations do not principally aim at a change of mind-set, and are more often perceived as obstacles in achieving good design solutions. An important motive for this study is to bring research results closer to practical design work and to the sphere of interest among architects. As there seem to be significant interactions between the theory of salvageability and some basic elements in architectural design, the overriding hypothesis is that the demand for salvageability of building materials may be seen as a positive driver for architectural design. The core questions are related to the architectural consequences of using the design strategies as "rules" for design, and in what ways these strategies may coincide with various professional approaches.

The discussion is structured according to the criteria for salvageability. The study explores in what ways this field of knowledge may influence building practice and architectural expression, and points to building examples from past and present. The examples are chosen because they display design principles discussed in the text, but are not necessarily designed according to the principles of sustainable construction. For the investigation, the tectonic approach is used as an instrument. Historical developments and practical consequences related to the criteria are considered, and possible approaches to the different challenges they raise are suggested.

Design as reflector of contemporary thinking

The last century may be regarded as an experimental period of construction. Whereas earlier architectural epochs and most vernacular traditions are based on reuse of building material, the last century stands out as a period of unsalvageable structures. Laminated constructions, fixed installations and the use of more than 100 000 different building materials are factors that make salvage prohibitive in current building. A focus on waste sorting and strengthening of landfill taxes has facilitated an increase in the percentual recycling of Norwegian construction waste, but very few building components are actually reused in their original form. The problem derives from the existing building mass which basically reflects a linear resource use. A parallel trend is that buildings generally have a higher turnover than earlier, and these two tendencies amplify each other. The paper is based on an understanding that this experiment did not convincingly succeed, because the environmental impacts have been too high. The consequences are found in both ends of the material flow through the building industry, and include pressure on new raw material as well as large amounts of waste.

The way buildings are constructed may reveal a society's philosophy about nature. And certainly, the prevailing designs of the present correspond to shopaholicism, deforestation and hasty oil production. Future archaeologists may conclude that material resources in this period of evolution were seen as a means to satisfy a small elite within one generation only. This contrasts with earlier layers in the dig site of humanity, where resource use to a greater extent was managed by small scale economy, stable demography and/ or informed by religion. Ironically, as the built environment is the most prominent and also the most expensive cultural expression, it is also here that we find the most striking symbols of a devastating resource use.

Meanwhile, in Norway there is a strong public consensus today that the greenhouse gas (GHG) emissions must be reduced. Regarding buildings, regulations aim at minimizing energy demand as well as reducing landfill waste. In addition to this, a cut in GHG-emissions should be reflected in the choice of materials and in building methods that facilitate recycling and reuse. Although architects in general are more open to include environmental considerations in the design of buildings now, it is not commonly debated how these considerations eventually influence architectural expression. However, since design has the potential of conveying society's aspirations, architecture can be seen as a cultural vehicle for the journey towards a low-carbon society.

Expanding the concept of tectonics

In the field of architecture, the term *tectonic* implies using technological parameters as a source for design. The term can be used to describe the design philosophy of load bearing structures, e.g. of how a column head is shaped. A classic Greek column may be seen to have been designed for not only physically being able to transfer the necessary physical loads, but also to visually demonstrate how these loads were brought down from roof to ground. In the modernist building tradition, designing architecture upon the knowledge of the technical properties of building materials and of how the components are most rationally produced has been labeled a tectonic approach. In the Danish book "Tektoniske visioner i arkitektur", Anne Beim defines *tectonic visions* as: "visionary investigations of new materials, technologies, construction principles and building practice as a means to construct (new) meaning in architecture." (Beim 2004 p.6, translated by author). When steel was still a new material, the struggle to develop a suitable architectural language started. Well in line with the economic framework of the industrialism, the modernist style was later described as a rational answer to the conditions for production.

More recent interpretations of the tectonic approach include using measures for local climate adaptations as a source for architectural concepts. These measures may originate from vernacular traditions and may include sun shading devices and the use of thermal storage in building mass (Beim 2004). This way of defining the term opens for including measures for a responsible resource use in general. Principles for temperature zoning, solar energy harvesting and for natural ventilation may have strong implications for the overall design of a building. We believe that these strategies could also be included in the tectonic toolbox.

Environmental logic is incorporated in the quality and characteristics of different materials, in their extraction and production terms and in their recycling potential. An investigation into this logic may create a knowledge base for achieving the best possible use of resources in a life cycle perspective. Following the tectonic approach, environmental efficiency may be forwarded into component shape and connection details and subsequently become a premise for construction and deconstruction. Conceptually, environmental logic may inspire the overall design and transform architecture at a larger scale.

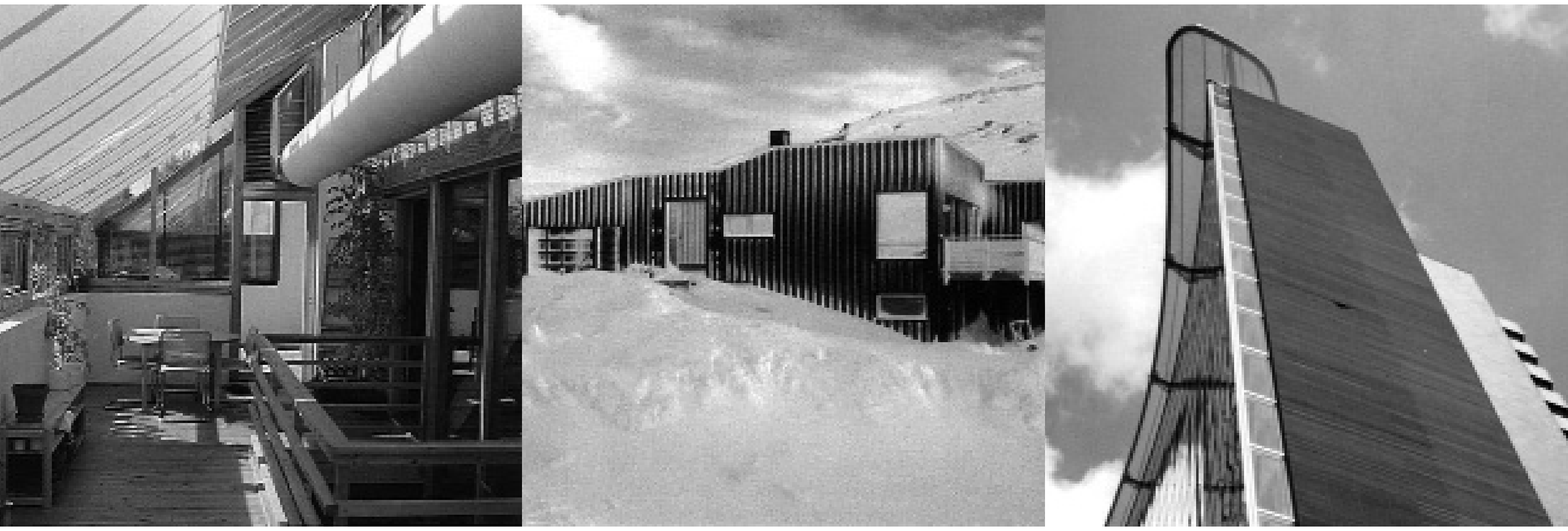

Figure 1:
Measures for climate adaptations have strong implications for the overall design of buildings
a) Norway: Sunroom in passive solar dwelling, Trondheim. Architect: Sintef/ Hestnes 1982. (Photo: F. Østmo)
b) Norway: Wind adapted dwelling reduces snow drifts in Hammerfest. Architect: Børve/ Bjørge 1989 (Photo: O. B. Hansen)
c) Germany: Wind roof facilitating natural ventilation at GSW Headquarters, Berlin. Architect: Sauerbruch Hutton Architects 1999 (Photo: T. Kleiven)

The criteria for salvageability

The overriding hypothesis of this study is that the demand for salvageability of buildings may be seen not as just another restriction, but as a positive driver for creating meaningful architecture. The design strategies for salvageability are collected from research in the fields of both building technology and industrial design (Crowther 2003). Based on theories of Design for Disassembly/ Deconstruction (DfD) (Berge 2000, Fletcher 2001, Thormark 2001, Sassi 2002, Durmisevic 2006), the selection is further substantiated in earlier studies by the authors (Nordby 2007). The focus area is resource efficiency of materials through facilitating reuse and recycling of components. This approach is seen as a supplement to resource efficiency through facilitating a long life of whole buildings. As various traditional building practices show, these two concepts are not at odds with each other, but can be pursued in parallel or with varying strength according to the needs and future scenarios of each project.

The strategies are ordered in groups, which are labeled by a set of criteria. The criteria summarize the core points of the guidelines, and are expressed as general performance standards. We have focused on the principal criteria informing architecture, which are: *Limited Material Selection, Durable Design, High Generality, Flexible Connections, Suitable Layering* and *Accessible Information*. These criteria form the six headings, under which the discussion is ordered. The various reasons for the strategies are described. Also, the various practical and architectural consequences are discussed in the text.

THE ARCHITECTURAL CHALLENGE

Limited Material Selection

- Minimize the number of types of material, preferably use monomaterial components
- Minimize the number of, and types of, components and connectors
- Avoid toxic and hazardous materials and secondary finishes

A limited material selection is desirable in order to encourage recycling. Simplicity in the material composition for each element, and also for the whole building, gives several advantages in the processes of deconstruction, sorting and reuse. The term monomaterial implies that a component consists of a homogenous material throughout (Berge 2000). Many building products today are laminated and built up of materials with different technical lifetimes. This results in poor resource management because when only one layer wears out, the whole component must be replaced. The use of monomaterials also enables necessary quality-control of components. Another advantage of using fewer material types is that it is possible to sort in fewer fractions when deconstructing the building. This simplifies the sorting job, and in addition it saves space at an often crowded deconstruction site. Furthermore, when the quantity of each material becomes relatively large, the marketing potential after deconstruction becomes more favorable. Toxic and hazardous materials should be avoided as well as secondary finishes because the material then stays clean, both as whole components and as crushed aggregate, and is not subjected to contamination in the form of mixing of material types.

In earlier times, when transport was less widespread and available than today, the industry of construction materials was more decentralized. The local material resources defined the basis for a common building tradition in the region, and this could also give benefits for reuse. In a situation where there are fewer material types to choose from, the market for reuse of materials will correspond more closely to the market for new products, and reuse may therefore be more easily incorporated into new building activity. However, returning to using only materials from the region may seem an awkward measure today. Building materials for specific purposes, also those solving environmental challenges, may be hard to source locally. A practical approach to this dilemma is to separate bulk material from special components and to make sure that the principal materials to be used are locally extracted. For secondary materials, the environmental cost/ benefits based on freight distance/ material weight contra desired performance in the building should be estimated.

A limited material selection for settlements results in a coherent agglomeration of buildings, independent of styles and time epochs. Thus, different cultural layers are woven together. Also, as seen in Figure 2a, the use of local material types may blend the buidings into their natural surroundings (for more examples, see e.g. Oliver 2003). A limited material selection also creates a basis for design simplicity, a well-known approach in the modernist tradition. By restricting the material use and avoiding

Figure 2:
A limited material selection facilitates homogenous architecture and design simplicity
a) Malta: Local sand stone blending centuries of architecture into the landscape. (Photo: E. Grytli)
b) Switzerland: Wood unites prefab elements with traditional logs in Versam. Architect: P. Zumthor 1994. (Photo: A. S. Nordby)
c) Norway: Design simplicity of glass and concrete at the Museum of Architecture, Oslo. Architect: S. Fehn 2007. (Photo: A. S. Nordby)

overloads, the building may gain in refinement. Simplicity calls for an investigation of each building material at its own premises, which may give insights into technical as well as environmental qualities. When this knowledge is put into practice, a sustainable production of building components can take place.

Durable Design

• Design durable components that can withstand repeated use and outlast generations of buildings
• Pay attention to joints and connectors, and provide adequate tolerances for repeated disassembly and reassembly

Durable design aims at reducing environmental impact through extending the useful life of materials. In addition to considerate detailing for the purpose of avoiding climatic abrasion etc., a long life of whole buildings may be facilitated through generality and flexibility of the layout. However, in this study the focus is on the component level. Independent of building turnover, durable and flexible components would result in greater resource efficiency because the same components could be used for generations of buildings. According to the theory of environmentally justifiable lifetime (Nordby 2006), a high environmental input in the production of building materials should be reflected in a correspondingly long component lifetime, or environmental payback time.

Durability must, however, also be seen in connection with the component's lifecycle and final disposal. Materials with low environmental investments and low risk for pollution do not require a long lifetime in the same way as high impact materials. For short-term building purposes, choosing materials that decay locally without contaminating soil or air might be an overall beneficial approach. By combining the right material quality and detailing with expected functional scenario, salvage of building material becomes differentiated and gives opportunities for resource management that takes the original environmental investment into account.

Architectural quality can be incorporated at both the building level and when designing components, and may in its own right be a facilitator for long functional lifetimes. Therefore, in general, more architectural effort could be spent on building components. However, there are many opinions about what is good design. Surely, some people will passionately salvage what others carelessly throw away. The challenge of the designing architect is to both reflect contemporary spirit and at the same time to give buildings and building components classic qualities that can provide for long lasting relationships with the users. Clever design and careful detailing might increase the affection value. Thus, the chances are great that both the whole building and the components themselves will be maintained and reused by the owners so that an environmentally responsible resource use is achieved.

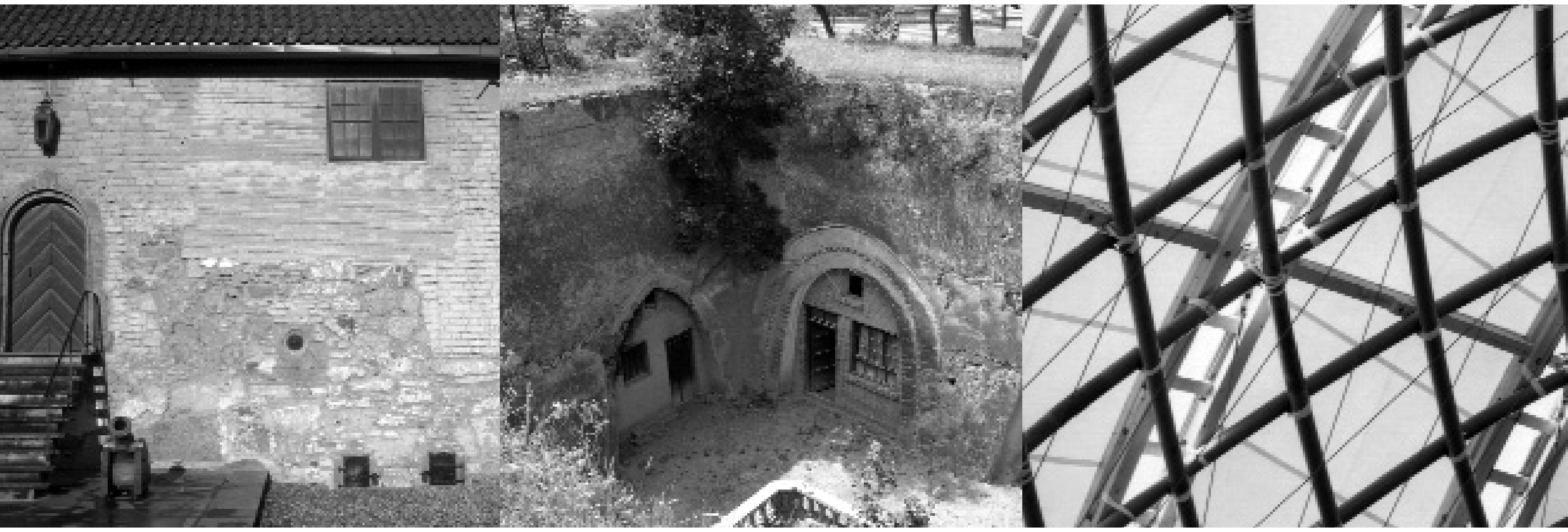

Figure 3:
Lifecycle design facilitates environmental efficiency by combining the right material quality and detailing with expected functional scenario
a) Norway: Multi-restorations at the west wing of the archbishop's court, dating back to the 1300s, Trondheim. The use of weak lime mortar in traditional masonry allows for disassembly and modifications so that the functional lifetime of the durable bricks and stone can be extended (Photo: A. S. Nordby)
b) China: Cave dwellings, Shaanxi province. The use of local, renewable and bio-degradable building material does not require environmental payback in the same way as high impact materials (Photo: A. S. Nordby)
c) Germany: Expo pavilion of paper-tubes and cardboard, designed for short lifetime and easy recycling, Hanover. Architect: S. Ban 2003 (Photo: Hiroyuki Hirai)

High Generality
• Use standard dimensions, modular constructions and a standard structural grid
• Aim for small scale and lightweight components
• Reduce the complexity of components and constructions, and plan for using common tools and equipment

Generality is a term that may be used for characterizing both components and whole buildings. A building that has a high degree of generality has the potential for changing its functionality within existing floor plans and deck-to-ceiling heights. A high generality of building components, on the other hand, will give architectural flexibility also in a second service life. This property is crucial to increasing the likelihood of component reuse. Simple and common construction methods, standard dimensions and small to moderately sized components aim at giving freedom of design and will enable use in different architectural contexts regarding functions, structure, expression and detailing, whereas large and specialized components can only repeat the same building. Furthermore, small scale and lightweight components and the use of simple tools and methods will facilitate do-it-yourself building, which is assumed to also encourage local reuse. Facilitating reuse in the private market as well as through the industry increases flexibility of production.

Reuse of building materials is actualized by two approaches, in which the need for generality differs. Firstly, reuse may be based upon purely economic reasons. When it is more expensive to manufacture and transport new materials, salvage becomes an obvious choice. In the second approach, historic building components may be appreciated for their materiality and for their ability for cultural storytelling. In late antiquity and medieval times, reuse or "spolia" was even performed on a political basis as the use of plundered art treasures and valuable building components signalled command over conquered land. Today, reuse may have another value based effect in the context of "compost-modernism" (term introduced by Helen&Hard Architects in the journal Byggekunst 2006/04), namely to demonstrate environmental concern. In salvage on an economic basis, generality is needed because it gives architectural flexibility and because it betters the chances for reclaimed material to match common standards and practices. Historically interesting components, on the other hand, are highlighted independent of their generality, and the remaining material use is seen more as a backdrop. In the latter approach, generality of components will therefore be less crucial.

Variation in the built environment is a human need. When the words *standardization* and *modularity* are used, it echoes the industrial

Figure 4:
Building components with high generality are architecturally flexible, and can be used in different building contexts
a) Italy: Marble columns of the antiquity were standardized, however handcrafted and thereby subject to variations in finish. The "spoliated style" forwarded reuse of components, often plundering from conquered land. Saint Mark's Basilica, Venice. (Photo: A. S. Nordby)
b) Spain: Bricks are small, "molecular" building units, and flexible for a variety of structural uses and architectural expressions. Vault in the Crypt of the Colonia Güell, Catalonia. Arch: A. Gaudi 1898 1898. (Photo Will Pryce, (c) Thames & Hudson Ltd., London. From 'Brick: A World History' by James W. P. Campbell, Thames & Hudson, 2003)
c) Norway: Valdres Tremiljø´s versatile massive wood components are used for walls, roofs and decks in mountain cabins. Architect: M. Øvergaard 2006 (Photo by the architect)

demands of the 1950s and 60s which ran the risk of producing architecture of monotony and tediousness. However, variation can be enabled in different ways. Vernacular building materials are often based on generality, although the handicraft processes tailor the components according to specific needs and according to specific material qualities. This customization may have environmental benefits as e.g. the varying properties of the wood material in each log can be utilized in a best possible way. Also, handcrafted materials give variations in texture that may add to architectural richness. Certainly, preserving historic buildings while maintaining traditional handcrafting skills contribute to a resource efficient material use. However, if reuse of building material is to be achieved at large scale, it must also be facilitated in the context of industrialized production.

If the possibilities for creating a rich architectural language and at the same time the criteria for salvageability are to be met, the scale of the component is of primary concern. Small components, e.g. bricks, are able to generate responses to various formal situations, whereas larger components to a greater extent will "take control" of the architecture. An example of the latter is typical prefabricated concrete wall elements whose sizes and proportions dominate the visual appearance of a façade. Therefore, the two first strategies of this criterion should be read and pursued together. Following a tectonic approach, the criteria for salvageability may become a basis for design at the "molecular" level of construction.

Flexible Connections
• Use reversible connections for subassemblies, between components and between building parts
• Allow for parallel disassembly and reassembly

Reversible connections are seen as a prerequisite for dismantling. Mechanical fasteners like screws and bolts are preferred to chemical bonding of glues and strong mortars, because they will enable deconstruction without damaging the components. Again, vernacular building types present a variety of solutions like transportable tent structures, lumber joint locks and masonry with weak mortars. In modern architecture, flexible connections are primarily developed for short-term uses like expo-pavilions and temporary barracks.

Connection methods may be designed as integral parts of the components' structure and appearance. As is the case when pursuing other criteria of salvageability like durability and generality, a study of connection methods may lead to a deeper understanding of tectonics. Joints are often refined sections of the

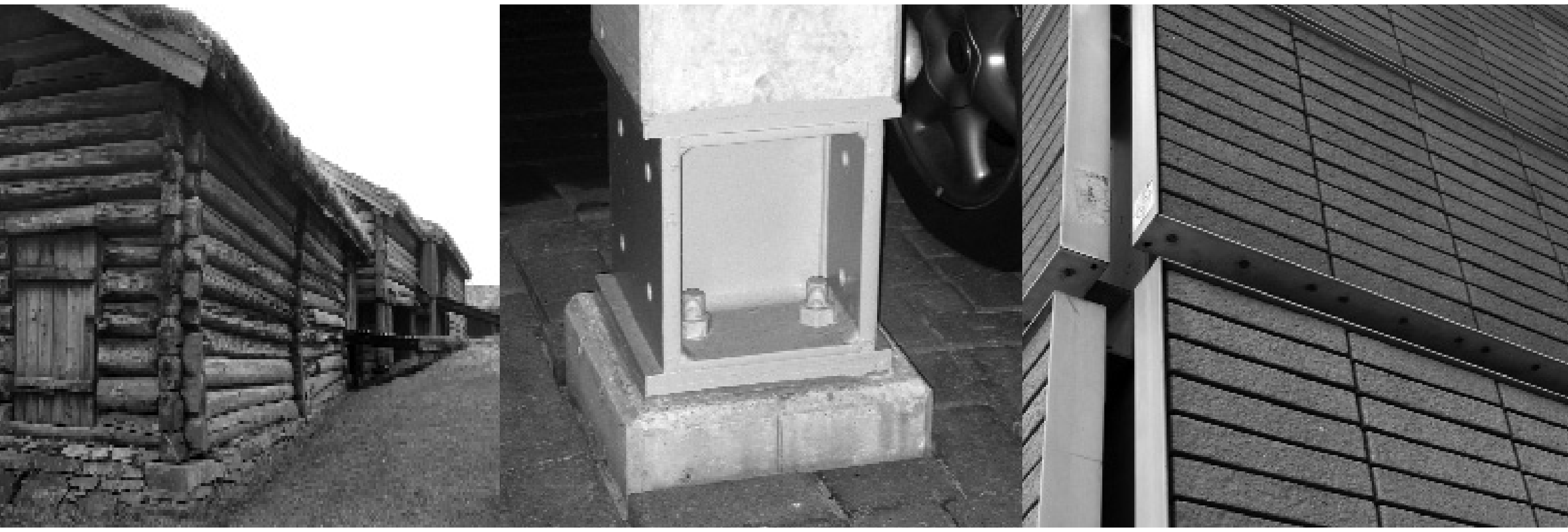

Figure 5:
Reversible connections can take a variety of shapes, and joints are often refined sections of the architecture in both vernacular and modern designs.
a) Norway: Traditional log houses have highly flexible joints that allow for exchanging single components, remodeling and relocating whole buildings. Sverresborg open-air museum, Trondheim (Photo: A. S. Nordby)
b) The Netherlands: Steel segment connecting concrete column to foundation in the XX office-building, designed for a service life of 20-years, Delft. Architect: J. Post 1992. (Photo: A. S. Nordby)
c) France: Demountable system of aluminium frames and bolted bricks also defines the façade expression of the IRCAM-building, Paris. Architect: R. Piano 1988. (Photo: J. Siem)

architecture in both vernacular and modern designs, expressing transfer of loads not only physically but also in a figurative sense. The joining of components can follow different tectonic principles like weaving, stacking and interlocking, and these principles also determine the premises for a possible patterned ornamentation of the surfaces.

This component-bound ornamentation is related to the logic of the component, and subsequently differs from the *free* ornamentation that is added to the building independent of the technological context (Selmer 2003). The latter approach includes the use of surface treatments and signs, and may result in a more superficial architectural language. The free ornamentation is more easily influenced by short-lived fashions, and may in the end reduce architecture to mere scenography. If, on the other hand, the aesthetic expression is rooted in the patterns that are determined by the joints' detailing, a tectonic relation between the tactile material qualities and the outward architectural expression is enabled.

A challenge, however, in the broader environmental context regards the carbon footprint of the materials used when the connectors are included. As seen in some newer projects pursuing demountability, such as the IRCAM-building in Paris, a high amount of resource intensive materials like steel and aluminum is used to construct the walls. Although the total environmental load is not calculated here, there is reason to believe that the support system including connectors counts for a higher environmental investment than the primary construction materials themselves. Since salvageability is only one aspect of environmental building measures, there will always be the risk of sub-optimization when working on solving one problem and unconsciously creating others on the way. A holistic perspective must therefore be regarded as a prerequisite in environmental design.

Suitable Layering

- Design the layers of the construction as structurally independent systems
- Arrange the layers according to the expected functional and technical life-cycles of the components

A frequently recommended principle in life cycle planning is the need for layered constructions. The theory is based upon the observation that different parts or layers of a building are changed at different time rates (figure 6b). Therefore, an adaptive building should allow slippage between differently paced systems. When each layer is made structurally independent and each component is exchangeable, the challenges of mismatch between the often long technical lifetime of components and the often short service life of a building or of a building layer are met. These layers should, moreover, be arranged according to the expected functional and technical lifecycles of the components so that the components which are likely to be replaced first are provided access to (Durmisevic 2006). This will reduce damage to components when only some parts of a building are being replaced or removed.

The multi-layered wall mirrors the philosophy of industrialism; to increase the efficiency of the production process through a division of labour (Selmer 2003). One layer is for load-bearing, one for insulation, one as vapour barrier etc. This strategy has evident benefits in creating "intelligent" buildings, where advanced façade structures and HVAC systems capable of regulating climatic conditions aim at lower energy use as well as at increased indoor comfort. Benefits are also gained for maintenance and remodelling when the construction is designed so that each component is individually accessible and exchangeable.

Historically, there is a tendency that the exterior walls of buildings have developed from being integrated, where all functions are attended to in one layer, to differentiated, where separate layers serve different purposes. A contemporary exterior wall generally consists of a number of component types that meet different constructional and climate regulation demands. Also, a need for increasing energy performance has involved the use of thicker layers of insulation. These improvements have, however, resulted in more complex and material consuming constructions. On its way towards optimization, the exterior wall may become an arduous engineering task as a number of joining details are to be worked out both structurally and aesthetically. The situation results in vulnerability because there are many locations where the performance might fail, caused by flaws either in design or in craftsmanship.

Whereas most other criteria for salvageability point to simplifications of building practices, the principle of building layers supports increased complexity. In the perspective of maintenance and remodelling this principle definitely represents an important measure. On the other hand; for the purpose of facilitating reuse after terminated functional lifetime, limited material selection and simplicity of construction methods may be seen as equally important strategies. Components that can meet a number of challenges of the exterior skin may therefore be preferred to specialized components that can carry out only one task. Examples of this difference are shown in Figure 6; pictures a and c.

As a result of these discussions, we have rewritten the heading criterion from earlier studies. Instead of *Layered Construction* we now propose *Suitable Layering*. This stresses the point that in achieving salvageability, a layered con-

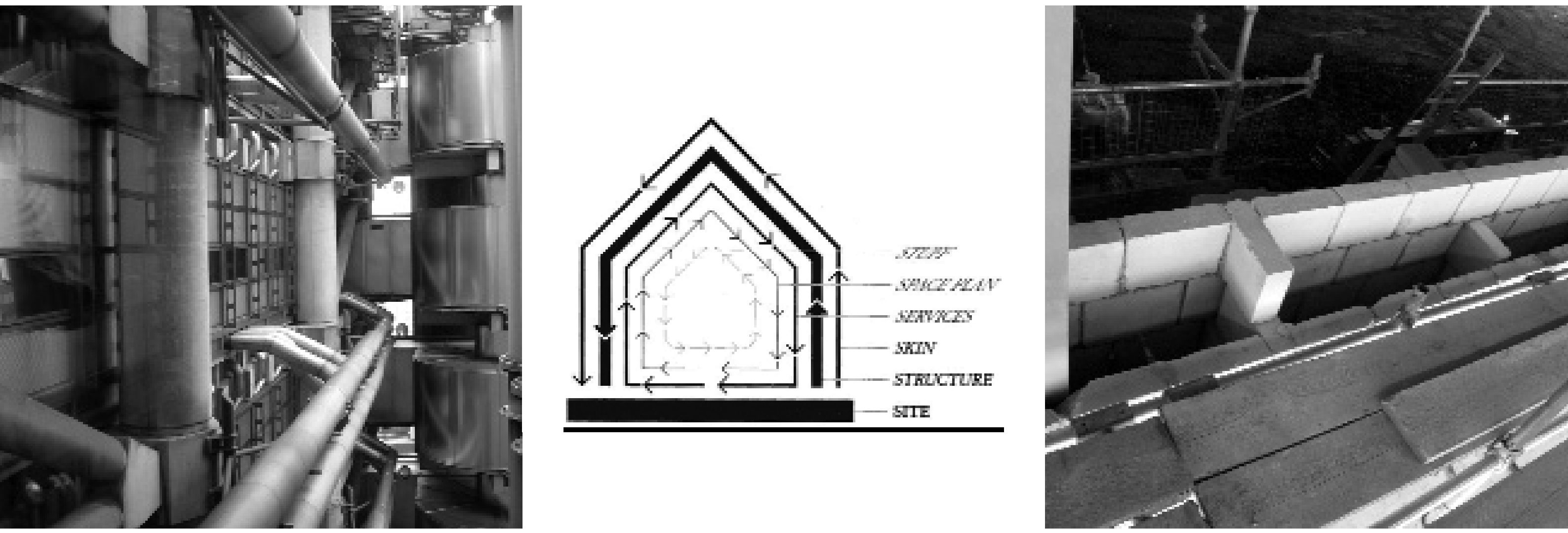

Figure 6:
The two approaches of differentiated and integrated constructions have different consequences for salvageability as well as for design.
a) UK: Functionally differentiated exterior wall of the high-tech icon Lloyds, London. Architect: R. Rogers 1989. (Photo: A. S. Nordby)
b) Principal diagram of time related building layers (S. Brand 1994)
c) UK: Functionally integrated hemp/ lime construction in low-tech warehouse for Adnams Brewery, Suffolk. Architect: A. Fitzroy Robinson 2006. (Photo: N. Magdani)

struction may not be a goal in itself. However, *if* the construction is layered, the layers should be structurally independent and also preferably organized in correct order regarding expected lifetime.

The two approaches have different consequences for design. Both imply a focus on the building units and their connections, but in different ways. The layered, functionally differentiated construction tends to define the units as mechanical parts with many detailing opportunities, but also challenges. Here, only the exterior layer is architecturally communicative, which offers a framework suitable for free ornamentation. In the functionally integrated construction, on the other hand, the structure and joints of the units may offer a tectonic detailing that can communicate constructional coherence and contribute to a component-bound ornamentation.

Accessible Information
• Provide identification of material and component types
• Provide updated as-built drawings, log of materials used and guidance for deconstruction
• Identify and provide access to connection points
This criterion is recognized as an important measure in industrial design. In the manufacture of e.g. cars and electronic devices, recycling has been implemented with great rigour. In facilitating reuse, it is an advantage to have product information tagged or printed directly on the components so that material types and qualities are easily separated and sorted after their first service life. Valuable information about the components may in this way be directly forwarded to coming generations and become a basis of assessment for possible further use. Product information may indicate raw material types and qualities as well as company name, production site and year. Other sources of building information like "as built"-drawings, material-logs and guidance for deconstruction are also of great value for future users and should be updated in connection with renovations. Furthermore, access to connection points should be clearly identified.

There are different practices regarding tagging depending on material type. The Romans started the tradition of making stamped bricks indicating production site or brick-maker, a measure that has made it more interesting for archaeologists to investigate dig sites. More contemporary examples from manufacturing cars and electronic devices include imprints on metal and plastic parts. For storing detailed information that may also be updated later, bar-coded identification or electronic identification chips may be used. However, these methods depend on the existence of similar equipment for future reading (Addis/ Schouten 2004). Therefore, direct tagging is seen as a more robust measure.

In addition to purely technical advantages, tagging of information also has the potential to

Figure 7:
Useful information regarding salvageability can be carried along with the components as well as along with the architectural language
a) Norway: Carved marks on traditional log construction defines the placement of each log in the system. (Photo: A. S. Nordby)
b) Hungary: Old, reclaimed stamped bricks are popular as decorative reuse-objects. (http://forum.index.hu)
c) Denmark: The readability of the architectural language gives access to information about material components and their reuse potentials. Half-timbered house in Holbæk. (Photo: F. Hakonsen)

create decorative effects. Components may be designed so that the surfaces containing information give added value of texture/ relief that may contribute to distinctive architectural expression. Symbols can be standardized so that a simple code language suitable for building components can be developed. Codes and brand-images may in this way give future users and demolition contractors a glimpse of the construction methods and philosophy at production time, as well as the necessary information for reuse.

At the building level, the architectural language may also function as a conveyor of useful information regarding salvageability. This more tacit knowledge is related to the readability of constructions, and is often seen in vernacular traditions. Simple construction methods, integrated functionality of components and the use of monomaterials facilitate this readability. Some building traditions of the past, like the half-timbered house, exhibit the materials as if they were on display. Information about the reuse potentials of the components is thereby made highly accessible to the users of the buildings.

THE ARCHITECTURE OF THE COMPONENT

Current production of architecture has two serious, and related, pitfalls. On one hand; rapidly changing fashions may turn architecture into mere sceneography, and on the other hand, the demand for high performance may turn buildings into technological challenges that only engineers can solve. Architects tend to work more and more with purely aesthetical questions, leaving the technical considerations to consultants. Possible design influences of technical issues are thereby marginalized.

Lifecycle design may challenge the prevailing view on architecture. Popularly pursued as original and artistic expressions influenced by changing fashions, the dominant contemporary approaches to architectural design are actually reminiscences from the Modern movement. In the 1920s and 30s, the demand of contemporariness was manifested, and also the demand of originality. Although criticisms of the modernist style have been addressed over the past decades, the attitudes that followed with it remain rather unquestioned (Hvattum 2006). Recurringly, new design ideas are materialized at a large scale, whereas building components subordinate under the dominating visual appearance. However, these characteristics do not fit well with the criteria for salvageability. On the contrary, process-oriented building practices challenge the view of buildings as art objects. The prototypes for flexible design are rather available in vernacular traditions, and consist of building *patterns*. Here, the cultural framework and physical properties of the materials inform architecture. As pointed out earlier, the criteria of salvageability are often included in this vernacular logic. Stewart Brand (Brand 1994), theorist and advocate for lifecycle design, recommends starting out by building in a conservative manner, respectful of regional traditions and the existing urban fabric. During use, each building's uniqueness will come into being.

Physical properties inherent in building components can meet various technical needs. Besides structural strength, weather tightening and thermal insulation, challenges are related to facilitating a healthy indoor environment. Building units may be used as active and operational members of interiors. The ability of heavy materials to store heat can reduce daily heat fluctuations, and sometimes also reduce energy use for heating or cooling. Porous materials with the capacity to regulate humidity may reduce the importance of HVAC installations. Furthermore, acoustic control is managed by building components whose surfaces modify or absorb noise. These measures are integrated with the architecture, and the logic is based on a holistic approach. Although high-tech installations may improve building performance, they may also add complexity and vulnerability to constructions. A focus on the physical and chemical potentials embedded in materials can instead result in more robust solutions. Also, as seen in figure 8, this focus may provide a potential for tectonic relationships.

Leaving the question of whether or not "green" architecture should manifest itself in a certain style, the tectonic approach may be conceived as a more practical concept. Viewing the component as a merger of technological and aesthetical challenges, the tectonic approach acknowledges the logic of the materials as a premise for architectural design. Technical properties like material quality, component shape and connection details may become informative for construction and may inspire a transformation of architecture at a larger scale. As this study tries to argue, environmental considerations should be an integral part of this logic.

Figure 8:
Physical properties of building components can meet constructional and environmental challenges, and at the same time substantiate tectonic relationships.
a) Norway: Acoustic regulation in the grand foyer is facilitated by the use of panelling in oak that also add texture. Opera House, Oslo. Architect: Snøhetta. (Photo: A. S. Nordby)
b) Norway: Moisture resistance and moisture capacity of bricks with different surface treatments are combined in a bathroom in Bærum. Architect: K. Hjeltnes. (Photo: A. S. Nordby)
c) UK: Cloth cladding designed for a possible short-term life, and a more durable exterior skin of sand/ lime/ cement-bags are used in a combined office/ dwelling intended to change over time, London.
Architect: S. Wigglesworth. (Photo: E. Wenn)

The different issues regarding sustainable building practice have various influences on design (see e.g. Larsen et al. 2006). Since the environmental impacts associated with the manufacturing processes cannot be made visible in the finished components, the energy- or CO2 -content of materials, or their pollution profile can not be linked to architectural expression in the same way as measures for climate adaption and energy harvest. The issue of salvageability, however, has strong implications for architectural design, and the criteria are to varying degrees related to tectonic thinking. A salvageable component design is based on environmental logic at a "molecular" level, and underpins the importance of operational qualities of components. When this usefulness is brought forward and expressed in the aesthetics of a building, it may contribute to give meaning in architecture.

Conclusions

The discussions generally support the overriding hypothesis that the demand for salvageability of building materials provides a potential for architectural design. The findings are, however, varying in substance and in strength for the different criteria. The design strategies with the greatest consequences for the building's tectonics were mainly found within the criteria; *Limited Material Selection, Flexible Connections* and *Accessible Information.*

An additional finding is that historical construction methods usually are good examples of salvageable design. This is not only due to *Reversible Connections,* but fits all the criteria regarding salvageability. This leads to the reflection that the investigation of design guidelines for salvageability may be seen as a way of mapping tacit knowledge embedded in traditional building methods. Resource optimization is often an implicit quality of vernacular architecture, but this knowledge is not often explicitly forwarded. The criteria for salvageability may thereby describe and substantiate vernacular logic.

The tectonic approach was found to be useful in the context of salvageability, and in exploring the implications for architecture. Tectonic visions may help bridging the gap between conventional architectural theory and the evident contemporary need to manifest sustainable thinking in the construction of buildings. Thoughtful and up-to-date architecture representing a culture aiming for a low-carbon society is operational and responsible as well as sensuously inspiring. Starting with ingenious building units, the architecture is in the details!

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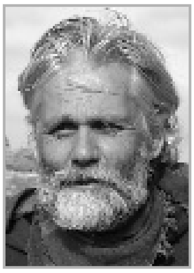

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