DESIGN AND RECONSTRUCTION FOR A LONG SUSTAINABLE LIFESPAN OF HOUSING

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ABSTRACT

This work attempts to consider some basic principles of structural design and material properties of bricks and brickwork to carry out the architectural design of a complete building in structural masonry. The paper deals with the architectural conception itself, including design requirements, walls layout, and the simplification of the design. Design and detailing including modular planning, door and window openings, service design, facade and aesthetics are also discussed. It is shown that a clear understanding of the construction process together with the flexibility offered by the material can contribute to a better use of structural masonry.

Key words: Housing, Sustainability, Future value, Labeling, Life span.

Introduction

In this era, to design and to build have to take into account environmental issues. On the extreme is the cradle to cradle approach whereby ‘waste’ will be converted into food or, when translated into the building industry: materials and components will be reused, preferably for the same purpose.
Basically, when merging these principles with the ones followed when designing lifespan-oriented buildings, two different approaches may appear: The first approach is to design buildings for a predetermined (limited) period of time and to, afterwards, deconstruct the building and reuse (most of the) components for another building. The second approach is to build for an unlimited period of time and to cyclically intervene in order to accommodate the newer requirements, without neglecting opportunities to reuse components on each intervention.

Whatever approach will be adopted; the following three items are always of importance to be considered, which. These were investigated last academic year in more detail, by our MSc. students:
1. labeling of a housing unit, regarding health, energy and flexibility,
2. the future (technical, architectonical, etc) value of a house,
3. creating function free buildings through more flexibility,

The research was carried out through interviewing, questionnaires, extensive literature reading and research by design work.

Introduction

Today, the Cradle-to-Cradle approach receives a lot of attention. In the Netherlands, the theorization and implementation of principles to design and to build in an environmental-friendly way has already become a current practice. Thus, the C2C principles were so perfectly well recognized, as how to keep up to standard requirements the existing built environment and as to build new [1].

The Netherlands is facing a limited building capacity and supply of habitable buildings compared to a relatively high demand. This causes much friction on the housing market. Over the last 5 years, an average 64.000 units were added to the housing stock; 80.000 new houses became available, 24.000 units were removed from stock and 7.000 units were converted or split into smaller units. By the end of 2007, the Dutch housing stock covered over 7 million units, which represents the incredible value of 2.3 inhabitants per unit. [2]

As we are able to produce 64.000 units only, the total replacement of the housing stock will take over 100 years. This means that we have to develop appropriate policies to keep up with the demand. Because of this limited capacity it has been advised to rehabilitate and upgrade existing housing and to convert other buildings into housing units. That would compensate the exceeding capacity of office buildings (10% empty). Although this has been advised, practice has shown problems. Meanwhile, also new buildings have to be erected.
The economic lifespan of buildings is very important and often shorter than the technical lifespan. The wishes of the client are changing, which reduces in fact the foreseen economic lifespan of a newly built building or a rehabilitated building. Reasons for shortening economic lifespan are:
1. The client wishes to keep the outlook of a building as modern, to impress the business / society.
2. Architecture developments, new materials, etc. go very fast, so the building may get outdated.
3. New electronic devices are coming on the market, enabling easier communication, which this building may not possess.
4. The organization of the client may change which requires areas with other functions or less spaces than foreseen.
5. The location of a building may get a lower classification forcing clients to move to a ‘higher’ one.
6. Higher costs for cooling/heating may force to move to a more energy efficient building.

In conclusion: from an environmental point of view, it is needed to predict the future and influence the expected economic life span. There are two options (A and B):
Option A can be described as: to design for a predetermined lifespan whereby economic lifespan = technical lifespan. An example is the XX office building of J. Post [3] (Figure 1), which is specifically designed as an office building for a 20 years period. After this period the building is intended to be deconstructed and its components to be re-used. Already from the start the building contains recycled/reused building materials and new materials which can be reused / recycled. LCA calculations have shown that this approach causes a significant lower environmental burden than a conventionally built office building built for a longer life span.

Option B. is: to design for an undetermined lifespan. When we look at historical buildings, like the canal houses in Amsterdam, these old buildings have been there for ages and are even gaining more (economic market) value than ever (Figure 2).
This teaches us that all buildings have intrinsic values (of several kinds), which make them attractive for rehabilitation, after a long period of time without other scales of intervention (Pereira Roders [4]). In fact, in this case the original lifespan of a building is continuously being extended.

From an environmental point of view this extension of lifespan is also preferred over demolition and building new. Figure 3 presents an impression of the difference in total impact over the same period between a building renovated after its first period and the same building rebuilt after the first period.

![Figure 3](image)

**Figure 3.** Environmental impact of a building (A1) which is rehabilitated (A2) or replaced by a new building, (B2) during the same life span. [5]

If we would be able to predict beforehand which strong, stable, favorable, characteristics buildings should have in due course, demolition of buildings could be prevented.

With the previously described options (A and B) in mind, a group of MSc students carried out research on the following three interrelated research questions:

a. In which way can a house / building be labeled for its three main characteristics: health, energy, flexibility which can also be used as an input during the design phase?

b. What is the future value of a house in terms of technical and architectonical value?

c. Can we make buildings, which do not serve a predetermined function only? Does more flexibility in building layouts create more chances for other functions in the future?

**Elaboration of the research themes**

ad a. Labeling an existing house / building for its qualities on health, energy and flexibility. Once these qualities would be known, one could compare them with other houses / buildings for reference purposes and enable to label them. A quick scan could be made for a whole housing area and help stakeholders to determine which housing buildings would be worthwhile of rehabilitation.
ad b. To judge if existing buildings have a certain “future value”, which means: are they worthwhile to be kept? This is not only a matter of feeling attached to the neighborhood or to the building but also valuing spatial qualities and technical qualities.

ad c. To produce new buildings of which the function has not yet to be established/known (function neutrality) there is a greater chance that this building will not become obsolete as it can also facilitate in future the same or a different function; e.g. senior housing – junior housing - small office.

The following paragraphs briefly describe for the three themes the used research methods, the results and discussion.

**Labeling of Housing with Regards to Health/Energy/Flexibility**

**The Housing Stock in the Netherlands**

Of the total housing stock of 7 million housing units, the percentage ownership is 54% and rental 46%. The ownership of housing buildings is increasing. While, the majority of housing buildings owned fall under the category of detached and row housing, the ones rented fall under apartment buildings and only to row housing to a lesser extent.

<table>
<thead>
<tr>
<th>Year</th>
<th>Housing Stock (thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 1945</td>
<td>1,400,000</td>
</tr>
<tr>
<td>1945 – 1970</td>
<td>1,800,000</td>
</tr>
<tr>
<td>1970 - 1995</td>
<td>2,900,000</td>
</tr>
<tr>
<td>1995 -</td>
<td>800,000</td>
</tr>
<tr>
<td>Total</td>
<td>6,900,000</td>
</tr>
</tbody>
</table>

*Figure 4* Housing stock in thousands [2]

The housing stock is of different ages, and one third of the stock is from 1970-1995. There is a shortage of low-income housing, but also people with higher incomes tend to stay in the cheaper housing obstructing any throughput.

When houses are sold, this is mainly done through an estate agent, although nowadays, selling them through Internet is getting common practice. The main attention is given to technical aspects, But, there is also a shift in the market towards other qualities of the house in terms of health, energy and flexibility (reference name, date). Thus, the point is: are we able to present at a glance an overview of these qualities of a house?

The importance of these 3 qualities was checked in interviews, which showed that most people are interested in energy (costs), health aspects (such as ventilation) and possibilities for change / adaptation, here called in this paper as flexibility for future use (e.g. from young families to senior couples) [6].
A checklist, for detailed inventorying: health, energy and flexibility, was found at best as this has a low threshold for people. All stakeholders for an overview of the qualities could use this checklist. For making a quick comparison between more houses, the checklists were reduced to its main items and an extensive explanatory booklet was attached to address potential questions raised during the filling out of the lists.

**Figure 5** Check lists for health, flexibility and energy [7]

The checklist shows 4 categories to indicate to which degree a specific item contributes to either health, flexibility of energy reduction: red (bad), orange (neutral), yellow (positive) and green (excellent). By overlooking the colors one can distinct a profile when comparing the profiles from other housing / buildings. Figure 6 describes an example when valuing the contribution of the roof to the energetic condition of the housing building.

![Figure 6](image)

**Figure 6** Sample of the checklist ‘Energy’ [7].

The checklist was based on the row-housing category, but it can be easily adapted for other types of housing buildings [7]. After developed, the checklist was tested in the field, amongst the public. This resulted in a number of suggestions for improvements and a short list of the main items to generate a quick scan. The moment one wants to know more in detail the extensive checklist can be used.
Building for Future Value of Housing, Indicators for Adaptability

For establishing the future value of a building it is of importance to find out the possibilities for extending the lifespan, upgrading of energetic performance and lowering of the exploitation costs (Jorritsma [8]). The results of this research can also be applied to design new buildings with awareness for its “future value”. Two aspects performance and adaptability are derived from the PhD study of Pereira [4] who developed indicators.

But, how can one create buildings for a longer life span in order to prevent demolition? Although demolition will take place because of unforeseen altered circumstances (e.g. cultural values) and ease of demounting and change it is still of importance research: how can one create buildings for a longer life span? Some solutions can be found by incorporating future values ‘timeless’ architecture; which lasts longer, has much more comfort, a higher energetic performance or a large spatial plan. But, also includes the incorporation of flexibility and adaptability. The latter is the topic for this research. “Adaptability” is defined as the possibility to adapt a building physically to changing requirements and wishes through a minimum of building technical measurements”.

Adaptability can be distinguished in:
- Intrinsic adaptability: the building contains already options for adaptation.
- Potential adaptability: the building can be made adaptable but it depends on the available finances if it will really be done.
- Desired adaptability: the adaptations wanted in view of future requirements.

Gulpen [9] distinguishes the following types of adaptations: (Figure 7):
- layout - hereby the volume remains the same but the variation is in the number, size form and position of the rooms.
- volume - means extensibility horizontally, vertically, and to join buildings
- perception value - means change of façade pattern or of interior.

![Figure 7 Types of adaptation [8]](image)
**Judgment of Adaptability**

The degree of adaptability has to be established of existing buildings and also new buildings. This can be done through a set of indicators. The next step is the development of a methodology to evaluate these indicators. The last phase is testing and improving of the methodology through case studies.

**Development of Indicators**

An extensive literature review, studies of existing tools (such as GPR) [10] and interviews revealed a set of indicators related with adaptability. Three main levels of indicators can be defined: spatial (a) capacity (b) and demountable (c).

a) **Spatial**: The research distinguishes typological aspects, such as aspects of forms and structure, dimension, such as width, depth, height and positions of zones, such as ducts, elevator shafts.

b) **Capacities**: are defined as bearing capacity and possibilities for changing the capacity of installations.

   - independency of access, installations, level of separation between façade and structure.
   - exchangeability, the possibility of putting internal walls at other locations.

![Figure 8](image-url) **Figure 8** Indicators grouped by building layers and levels [8].
For distinguishing the adaptations, the building can be divided into building ‘layers’ based on Duffy and Brand [12], and adapted to a certain extent by Leupen [13], Durnisevic [11] and Blok [14]. This results in: Site, Structure, Access, Skin, Services, Space and Stuff (infill). The following figure (Figure 8) presents the indicators ordered by building layers and main levels: spatial, capacity, demountable.

Further practical studies into these indicators lead for each cell in the matrix to two extreme differing forms of adaptation.

The next step is establishing indicators of interest and valuing, to which extent, each indicator enables or just blocks an adaptation. This part of the research is still under development, so no results can yet be presented.

**Analysis Method to Measure Function Neutrality of Buildings**

Many buildings in the Netherlands are designed for just one function. If the stakeholders are willing to change the function one often sees that the building is demolished to give space for another building or target of an heavy rehabilitation where most components are demolished [15].

Both measures are costing much money, materials and capital waste, moreover, affecting the environment through noise, dust and pollution. Therefore the question arises: is it possible to design buildings already programmed for a changing function? What about the concept of function neutral construction? This 3rd MSc. study was aimed at the development of a method to measure the degree of function neutrality of a building.

Here, function neutrality is defined as: the ability to accommodate more than one function, without having to considerably change a building. In this research, the different functions used to verify such function neutrality is housing, office and elderly care housing buildings.

The analysis method was developed in steps:

a. A building can be decomposed in to a number of layers of change, (or building layers) based on the theory of Duffy and Brand [12] and others [13]. The following layers were considered of importance: structure, skin, services, stuff, access in the building and spatial plan. The study was focused at one building floor.

b. Then, the degree of which a change of any layer is influencing the other layers was measured. This was done through the coupling indices (CI-R and CI-S) derived from the Design for Variety Method, which is used for product development [16].
The coupling index-receiving: (CI-R) indicates the impact of the coupling and flexibility of other layers on a specific layer. The coupling index-supplying (CI-S) indicates the impact of the coupling and flexibility of a specific layer.

c. The layers have all specific characteristics, which may influence the other layers. The degree of coupling and flexibility can be given a value at a 4 point scale (Table 1). The stronger the coupling between the layers, the more likely a change in one will require a change in the other.

<table>
<thead>
<tr>
<th>Value</th>
<th>Degree of coupling</th>
<th>Degree of flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>1</td>
<td>Strong</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>Highly</td>
</tr>
</tbody>
</table>

d. The degree of flexibility of layers with a longer life span exercises more influence on the other layers than the degree of flexibility of layers with a shorter life span. This resulted in the following weighing table (Table 2).

e. The layers have a different number of specifications. So the totals of the weighed values within a layer have to be divided by the number of specifications. Then this normalized weighed value shows the degree of function neutrality of that layer. This value can be compared with the same layer of other buildings.

<table>
<thead>
<tr>
<th>Layers</th>
<th>Lifespan (yrs)</th>
<th>Weighing factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>60-200</td>
<td>4</td>
</tr>
<tr>
<td>Access</td>
<td>60-200</td>
<td>4</td>
</tr>
<tr>
<td>Skin</td>
<td>30-60</td>
<td>3</td>
</tr>
<tr>
<td>Services</td>
<td>5-30</td>
<td>2</td>
</tr>
<tr>
<td>Stuff (in fill)</td>
<td>5-30</td>
<td>2</td>
</tr>
<tr>
<td>Spatial plan</td>
<td>5-20</td>
<td>1</td>
</tr>
</tbody>
</table>

f. A real function neutral building does no exist, so we defined a band-width of functions which can be considered as one group: living, offices, and elderly care housing. A (theoretical) reference building for function neutrality can be described as follows:
- structure: columns and floors, access, ducts and construction are combined
- access, gallery or a corridor is ideal
- the skin has to be disconnected from the structure
- services have to be independent of the other layers
- stuff, by choosing flexible walls, lowered ceilings, etc. all services remain accessible
-spatial plan, no specifications; just the space is composed by the other layers. This reference building was given the index of 100.

g. The developed analysis method was checked against 7 Dutch so-called function neutral buildings (Figure 9). Compared to a scale of 100, the following can be seen. Some buildings scored around 100 for some layers, while others didn’t. The Martini Hospital scored the best of all. It shows that most neutrality can be achieved at the layers of structure, access, services and stuff. The least neutrality is in the façade. So, that layer has to be given special attention in order to achieve more neutrality. A new design for that façade was developed, which reached the 100 index.

![Figure 9](image)

**Figure 9** Graphical overview CI-S (in %) of the analyzed projects (different colors) compared with the function neutral building (in red) and the average of the fictitious contemporary built buildings (blue). The red marked area is of importance for drawing conclusions on function neutrality [15].

**Conclusion**

1. MSc. and PhD. research give an important contribution to the research capabilities of a university. As such, TU/e is very much motivating the inclusion of such research effort into the both research staff and students.
2. The presented researches gave a clear indication that research on building and technology is open for new views regarding monitoring / reducing the environmental impact.
3. The studies also show that during design, construction and use; the performance of a building and its life span can be effectively influenced as long as one is willing to invest time and money on future changes.
4. Labeling of buildings (in terms of flexibility, health and energy) is a simple way of showing the characteristics of a building.
5. Adaptability can be created at more layers. If this is taken into account already in the design stage, future value of a building (expressed in terms of adaptability) can be created.
6. It is possible to measure the degree of function neutrality of a building. However, more case studies are needed to fine tune the developed analysis method.

References
2. CBS Statistics 2006. Annual yearbook, CBS