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A NEW PERSPECTIVE ON ARCHITECTURAL SUSTAINABILITY

The impact of planned obsolescence on the overall sustainability of houses

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Abstract. The research presented in this paper intends to establish a new perspective on architectural sustainability as an effect of good architectural quality. The intention is to show the importance of an actual architectural mindset in the design phase, and whether the conscious architectural material selection based on a balanced cost and aesthetics decision making will prove more sustainable and ensure better maintenance, as a result of architectural appeal, than cheaper standard houses.

Keywords. Sustainability; case-study; Life Cycle Assessment.

1. Introduction

This paper introduces an on-going preliminary study of architectural quality as a parameter for assessing the lifelong sustainability of single-family houses using a combination of the calculations used in Life Cycle Assessments (LCA) and field case studies. At this stage in the study, we present a pilot-project of the methodology, which is intended to be applied on a larger scale. Thus the results of the study can be considered as initial, showing preliminary tendencies from a limited number of the cases, and do not yet contain all the data from a full registration of the cases.

1.1. RESEARCH QUESTIONS

The ambition for an ideal architectural building design combines both low construction cost and low maintenance costs while at the same time adding overall value to the building's lifecycle through architectural aesthetics, since an environment that is architecturally appealing to the users automatically is better taken care of (Nørgaard, Ærø 2004).

Hence we claim that an architectural mind-set must be one of the parameters in the measurement of a building's sustainability. The desire for obtaining high architectural quality in and around a building becomes a sustainability parameter that is worth exploring. We ask: How does an architectural selecting of building materials, with different levels of durability, impact on the building's overall lifelong sustainability?

That kind of 'planned obsolescence' of the entire building is a product of conscious choice of materials resulting from the architect's work on both the aesthetic value and the construction costs as important parameters. How does this affect the actual and perceived obsolescence in relation to the necessary renovation and sustainability of the building?

2. On Architectural Sustainability

Since the construction industry uses around half of all the non-renewable energy resources on Earth (Jørgensen, Lyngsgaard 2013), the discussion of architectural sustainability is as important as ever. The significance of this on a larger scale can be seen also in the use of the sustainability certification for buildings such as the assessment methods in BREEAM, LEED, and DGNB, and the focus on Environmental Product Declarations (EPD) in the European Union.

We embrace the understanding of sustainability as a holistic cross-disciplinary system, with its main drivers being a combination of legislation, materials, scarcity, consumerism, and ethics (Edwards 2010). In this definition we prefer to include the importance of a relation between economic, social, and environmental sustainability of the Cradle to Cradle mind-set (McDonough, Braungart 2002). In addition to this we perform our case study inspired by the notions of 'shearing layers of change' and the calculations performed in a 'lifecycle assessment' and our definition of the term 'planned obsolescence', as explained below.

2.1. SHEARING LAYERS OF CHANGE

The division of buildings into the differently-paced systems of Site, Structure, Skin, Services, Space plan, and Stuff (Brand 1994), and the following understanding of these systems' symbiotic relations, highlights the question of embedding systems and creating dependencies between materials with different lifetimes. While the Site remains and has permanence, the structure last for 50-100 years, the Skin and its components lasts 20-50 years, the Services, technical installations are replaced after 10-30 years, the Space plan can be changed every 5 to 10 years, and finally Stuff, furniture etc. is usually changed every 1-5 years. Thus making a long-lasting component dependent on a shorter lived one, would seemingly degrade its performance to that of the short-lived, e.g. obsolete insulation that can be renovated only by replacing long-lived façade or roof elements. Even though pouring concrete on the ground for an instant foundation looks efficient at first, it is maladaptive when pipes are buried, without space for maintenance and Services access.

2.2. PLANNED OBSOLESCENCE

The above definition of layers and embedded systems corresponds intriguingly with another phenomenon, mainly found in the product industry termed planned obsolescence. Bernard London (London 1932) described already in 1932 his grandiose plan for a way out of the depression by planning the obsolescence of everything from products like shoes and houses to mining and agriculture. When a product reached its predetermined obsolescence, the Government would collect and destroy it, to guarantee a constant flow of new product and an end to unemployment. The term is nowadays used to describing how consumer products are 'made to break' to insure more sale. In this research project we have found it inspiring to use this term to describe an obsolescence which is indeed planned, but not necessarily from an economically devious perspective, to defraud the users, but a necessary way of combining materials to perform as architecture, i.e. aesthetically and economically.

2.3. LCA – LIFE CYCLE ASSESMENT

Life cycle thinking seeks to identify possible (product) improvements to lower environmental impacts and less use of resources throughout a products entire life cycle. It also seeks to avoid burden shifting, which means that, through optimising a product with focus on a certain process, geographic location or environmental impact, another part of the system may become responsible for new, greater impacts. It intends to design or plan all life cycle stages, from raw material extraction to end-of-life, reuse, or recycling of components.

Our assessment is constrained to a limited number, and the focus is on comparing indicative values from an LCA calculation method. The aim has not been to generate a complete assessment, but to test the method in preliminary study. To make a full LCA assessment of all the cases in this research project would require an amount of work vastly beyond the capacity of this pre-study.

3. Method

Assessing architectural sustainability are not an easy task, since the methods of calculating are continuously debated, and can be very delicate, both politically and in relation to manufacturers, when measuring the performance of building materials. This research project aims at finding a method with a level of detail, which is on one hand not too complex and overwhelming to be usable, but same time is sufficient to actually generate useful results. That is why we have attempted to combine both calculations and field studies in order to assess the buildings.

3.1. IDENTIFICATION OF SUITABLE BUILDINGS

This pre-study research is limited to a number of single family houses that have lasted at least one generation. This makes possible to base evaluation on long term maintenance and renovation. Accordingly, we compare similar sized Danish single-family houses from 1960s in two categories: houses designed by a standard house construction company and architect-designed single-family homes.

3.2. CATALOGUING OF MATERIALS AND OBSOLESCENCE

We have performed cataloguing and calculations of many materials, including an assessment and on-site comparison of the current state of the houses. Using the original architectural and technical drawings, we have defined the materials used at the time of construction. We are only concerned with the actual house materials, since the required labour of construction is a resource that produces growth on the societal level. In a sustainability discussion, that can be considered as renewable energy.

As the main goal of the LCA is to examine the different material profiles of the houses, energy consumption related to usage is excluded from the calculation.

The energy supply for each building can be quite different and may distort or invalidate the assessment results. Moreover, great variability would be added to this comparison, as energy demand is strongly related to user behaviour and will vary in time. The same applies to the current energy sources, which certainly will change within the 50/100 year scope of this assessment.

3.3. COMPARISON OF CASES

The cases are compared both according to the results from the LCA calculations and a comparison of the distribution and size of the rooms.

To make the results easier to understand, the discussion is limited to results for Global Warming Potential (GWP / ‘CO_2-footprint’) and Non-renewable Primary Energy Demand (NPED / ‘Embodied Energy’) that will be discussed in the conclusion of this paper.

All data used for assessment is generic data from the Ökobau.dat databases 2009/2011 or data from material specific Environmental Product Declarations (EPD) sheets. Data for lifetimes of materials or components originates either from a lifetime database (Bundesamt, 2001) or are based on the experience and knowledge of the authors.

The potential environmental impacts are calculated with an excel-tool that integrates both databases and guides the user through the Life Cycle Inventory phase (LCI) and, partly, the Life Cycle Impact Assessment phase (LCIA).

4. Cases

Selection of the cases is based on two main criteria: the prevalence of the type of housing, and the timeframe that covers the renovation of the houses over a period of fifty years or so. These criteria limit the range to single-family detached houses from the 1960s. From 1960 to 1980, 450,000 single-family detached houses were built in Denmark. That equals the same amount built during the preceding 100 years (Lind, Møller et al. 1996). Of the total national housing stock more than a third are single-family detached houses (Danmarks Statistik 2013).

Of the twenty-seven single-family houses in the area of Fortunparken in the Lyngby-Taarbaek municipality in Denmark, fifteen are designed by architects. Twelve of the houses are standard houses, and five of which are standard houses designed by architects and seven are made by construction companies without individual architectural customization.

Standardization and industrialisation have had a serious impact on building technique and building traditions of the single-family house, both technically and aesthetically. New and cheaper methods of creating roof constructions and façade solutions facilitated a faster and more economical building process, which unfortunately, not always improved the quality of the houses.

5. Findings

The findings are from the comparison of houses in the LCA analysis performed at this stage, and from comparing the cases in relation to distribution and size of rooms in the houses.

5.1. BUILDING COMPONENTS

To support and underpin the collected empirical data of the crucial building materials in the cases, a rudimentary examination of the houses is provided here to the parts of the single-family house cases.

The roof can be categorized according to both its cladding and construction. The flat felt roofs, or built-up roofs, are wooden constructions covered with flexible bitumen roofing felt. Pitched or hipped roofs are constructed with wooden trusses which were traditionally collar-beam trusses allowing use of the first floor or giving more headroom. This construction gradually became substituted with the cheaper trussed rafter construction in the standard houses, thus these cost savings often resulted in less headroom. The cladding usually consists of fibre cement board, clay roof tiles, or concrete roof tiles.

Until the beginning of the 1960s most small houses were built with solid brick walls. To comply with the sudden growing demand for single-family houses, and to minimize construction time, insulated cavity walls with load-bearing inner leaf were introduced. Quickly erected inner leafs from wooden frames or aerated concrete blocks allowed for earlier roof covering, and the house could be clad with brick facing later on.

The separation of the inner leaf and the façade represents not only a technical development, but also a fundamental change in the quality, which has been called an overall impairment of the architecture (Lind, Møller et al. 1996). The problems such as bad indoor climate and cracks in the walls can often be detected only after several years. Light weight inner walls constructed from plaster- or fiberboard on wooden frames may cause undesirable acoustic environments.

Quickly built solutions also characterize new types of floor. The craving for increased construction speed and low costs is seen in the extensive use of the ground slab construction, without a basement to ventilate wooden constructions. Minimal floor height, gained from pouring concrete directly on the ground, allows spatial connection of inside with outside, but, even with the application of floor joist on various layers of concrete and insulation, floor construction, relies on the durability of ultrathin plastic membranes to avoid damp areas.

Most of the doors and windows of the standard house come as prefabricated elements, often of a better quality than the rest of the house. Traditionally, the joints and architraves between walls and doors and the reveal linings of the windows, are made from decoratively crafted wood. In the standard house however, the common solution replaces these parts with industrially manufactured thin wood or plastic pieces, and the joint compound is a silicone sealant instead of the traditional oakum and mortar. This creates a completely closed cavity that could generate conditions for rotting of the wooden window frames.

5.2. RESULTS

The graphs below depict results from a selection of the cases that represents the overall tendency of all the cases. The tendency is shown using three standard houses ‘STAN’ and four architectural individually planned houses ‘ARCH’. The ‘FP’ and numbers refer to the location of the house in the area (Table 1).

Table 1. Square meter / areas and ceiling heights in Fortunparken

House ID	total (m^2)	living area (m^2)	living room (m^2)	%	rooms (m^2)	%	dining room (m^2)	%	room height (m)
STAN (FP02)	121	102	22	22	30	29	0	0	2.30
STAN (FP11)	151	126	30	24	35	28	17	13	2.35
STAN (FP13)	144	116	36	31	28	24	14	12	2.2-3.0
ARCH (FP04)	151	136	35	26	44	32	12	9	2.30
ARCH (FP08)	156	140	32	23	35	25	13	9	2.40
ARCH (FP26)	232	199	44	22	42	21	25	13	2.50-3.10
ARCH (FP42)	138	124	24	19	38	31	13	11	2.13-2.50

The Total Primary Energy Demand TPED can be split into two parts: energy from non-renewable sources NPED and energy from renewable resources RPED (Figure 1). In the case of materials, the non-renewable energy demand is often also referred to as the ‘embodied energy’. The diagrams below show that, where the total energy demand is high, the embodied energy can still be lower. The large share of the renewable primary energy demand in these cases can be explained with the usage of wood for the building construction. Renewable Primary Energy is ‘used’ while the trees have been growing (photosynthesis) and the ratio of NPED to RPED is typical for all wood-based materials.

Not surprisingly, the average energy demand is similar, since the houses are built in the same time period under the same regulations, with largely the same selection of materials. However, the graphs also suggest that the architectural individually designed houses, in the selected cases, do not necessarily have a higher primary energy demand than standard houses.

ARCH (FP04) is the most demanding of the selected cases, because of

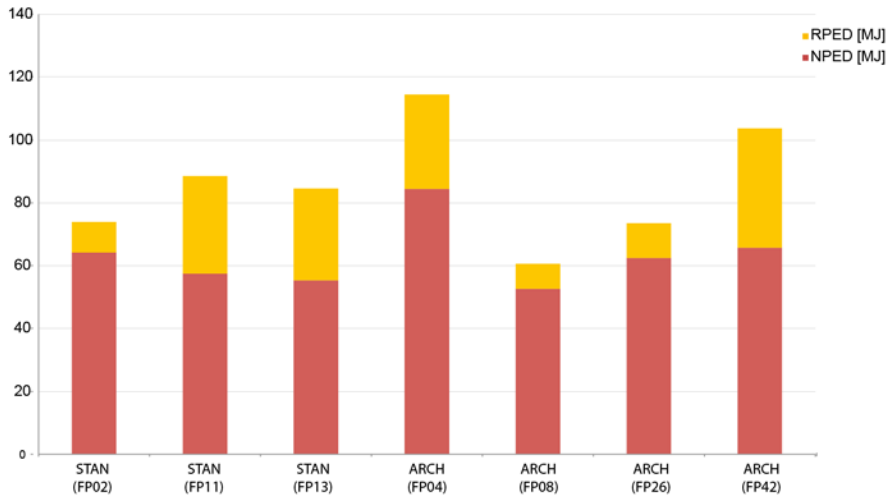

Figure 1. The Primary Energy Demand (Mega Joule) pr. m^2 / 50 years TPED / NPED / RPED

brick walls in the area outside the house, but this also makes it architecturally interesting by comparison to the other houses. There sleeps up to five, which places its statistics in the middle of the cases, when based on persons per household. A calculation based on area (shown figures) places the house as the most challenging on mass, CO_2, and energy demand. The construction of the house shows potential for adaptability, and when looking at the floor plan it is the most flexible of the cases. Every inner wall can be moved, since they do not support the roof. The ceilings though, have been covered with compressed asbestos paneling, which is of course highly problematic from a modern viewpoint on materials. This house shows both the largest potential, but, at the same, time very costsly renovation, without changing its architectural appearance. The house has relatively large amounts of insulation on the roof and walls, compared to the standard houses. The total area of glass façade is 56%, while it is only 20-30% for the standard houses. This can lead to high solar gains or losses, depending on orientation.

ARCH (FP26) is the largest building, but with only four beds. This makes it the worst case in a calculation based on persons/household. But in a calculation based on area, it is average. This house could be the most specialised to the first owner's requirements, which could make it harder to adapt to new needs.

STAN (FP11) seems quite flexible as well, and is furthermore the one using least materials by mass, and thus has relatively small impact on the environment.

The GWP-diagram (Figure 2) shows a pattern similar to the primary energy demand, as usually the CO_2 footprint is strongly linked to the usage of non-renewable energy sources.

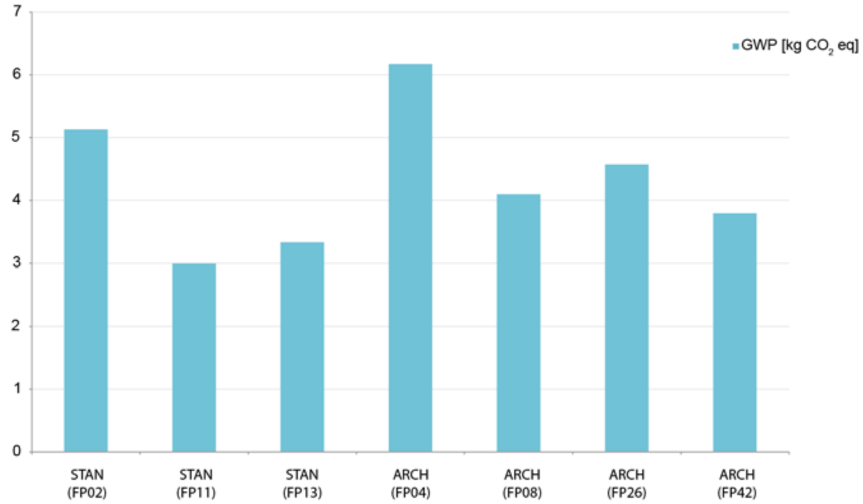

Figure 2. Global Warming Potential per unit area per 50 years (GWP / CO_2-footprint). The unit, CO_2 equivalent, is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale.

6. Conclusions

The overall tendencies that can be discerned from these initial case studies points to, that the standard houses use less material because they have smaller dimensions on building materials. For all buildings, brickwork contributes most to the CO_2 footprint and the energy demand. The statistics of the standard houses are relatively similar, while those of the individually designed houses are spread more widely. This, however, may not relate directly to a standardized production and construction.

There is also a tendency that the architecturally designed houses are being renovated and restored according to, and with respect to, the initial architectural idea, while the standard houses are just being renovated.

These tendencies must of course be solidified through a denser volume of data collection and processing in the next phase of the research.

Generally speaking the materials used in the foundation seem better in the architectural individually customized houses. The dimensions are heavier grade, and sand and gravel are widely used, sometimes with embedded vapor barriers. The standard houses all uses slag concrete and a very thin slab, which will eventually become problematic and require maintenance.

Architecturally designed houses do show a higher quality because of their interior adaptability. The results also indicate a freedom to renovate, though a more architectural design results in a less neutral floor plan, renovation can prove difficult. However there seems to be a higher quality in the materials in these houses compared to the standard houses. This suggests that the architectural individually customized houses are better preserved in the future, while in some standard house cases it will be cheaper to demolish and build again, instead of renovating. All the houses with large glass façades or lightweight façade elements hold better LCA profiles, generally speaking. In order to be more specific about this, a measure of the daily energy consumption would be necessary in the calculation.

The approach taken, provides initial results showing only tendencies, but nevertheless, points out a direction for our research. In the next phase of the research, the energy consumption will be crucial in the assessment, since this often has a high impact on the total values. We will correspondingly use 3D models to simulate the energy consumption. These results will be addressed in a future paper.

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