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Integral design workshops for ZEB

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Abstract

Very few designers have the necessary skills or experience to design zero impact buildings and environments. As complexity of the design increases with the efforts to reach the limit of zero impact, it really becomes necessary to involve all building design disciplines in the earlier stage of the NZEB design project.

This is not something done by merely putting the different designers together around one table, but needs more support. Experiences with tools to help with and to support the group design process will be presented. In the last years different design workshops have been held for Zero energy building design, in which more than 100 experienced professionals, architects of BNA and consulting engineers of NL Ingenieurs participated. The steps for further improvement will be presented to stimulate the creation of new concepts to achieve zero impact buildings and environments.

Keywords: Integral Design, Zero Energy Building

1. Introduction

Strong fluctuating and rising energy prices, depletion of fossil fuel and growing awareness of global warming led to planned actions to reduce carbon dioxide emissions. As the built environment is responsible for nearly 40% of CO₂ emissions new approaches are necessary. This led to the development of Zero Emission Building. A Zero Emission Building means a building which emits virtually ‘0 (zero)’ carbon dioxide [Kang et al 2010]. However this new target in building design, ZEB requires totally different approach from conventional building in terms of design, construction and operation [Kang et al 2010, Ritter 2010]. ZEB pursues ‘0 (zero)’ CO₂ emissions during the life cycle of the building including raw material acquisition, building production, building use, and disposal. Which actual means that during the building use stage the building should be producing around 10 to 15% more energy than it consumes. However that goal is too ambitious for the moment as it is already difficult to achieve a net energy building during the building use stage [Opstelten et al 2007]. Furthermore we focus on Net-Zero Energy Buildings which consumes on average over a year net zero, this can be reached more easily and leaves out the difficult discussion about the conversion from different energy sources and their direct and indirect emissions. The study aims to propose a method to support architects within the conceptual phase of a building design process of a Net-Zero Energy Building. This task requires a profound knowledge about energy and technology. This leads to the necessity of an integral design approach not only by the architect but from the structural consultant, building services consultant and building physics consultant. In this context, traditional approaches to organize and plan these complex processes is no longer suffice [van Aken 2005]. First and foremost, a method needs to be developed to allow other, largely engineering, building disciplines to be integrated into the design process of NZEB from the outset in a meaningful way. There are several advanced sustainable building design standards such as Ecohomes (BRE, UK), Passiv Haus (Germany) however these are no specific strategies or design guidelines for achieving zero energy building designs [Wang et al 2009].This re-evaluation of the design process and the individual disciplines within it should facilitate the inclusion of all relevant team members at the outset and give proper recognition to the influence their knowledge and input has on the final design. The standpoint in this research is that a more integral process will not only improve the design process, it will also create the opportunity to introduce a greater variety and amount of design knowledge needed for NZEB design from the outset of the conceptual design phase. The integrated design process has
evolved as a response to the need to improve the traditional design process of buildings, however in low energy building designs it is seldom used [Charron 2008].

2. Methodology

At this point it is useful to state the goals of the research project. Essentially, there are two main goals, one a short term, practical goal, and one more abstract, long term goal. The first goal is to integrate engineering disciplines into a team design process with the view to gaining access to their knowledge at the outset of the conceptual ZEB design process. If the assumptions in this research are correct, then the interventions should lead to a greater amount of aspects and sub solutions than in the status quo.

Starting from the prescriptive model of Methodical design a method, Integral Design, was developed to articulate the relationship between the role of a designer as descriptor or observer within the design team and to reflect on the process [Zeiler and Savanovic 2009]. Methodical design was chosen as a starting point of development because it has exceptional characteristics [Blessing 1994]. The Integral Design model, an adapted model of Methodical Design, allows various design complexity to be separately discussed and generated [sub] solutions to be transparently presented.

A distinguishing feature of Integral Design is the intensive use of morphological charts to support design activities in the design process. Morphological charts were first used by Zwicky [Zwicky 1948]. By using morphological charts each discipline can look for all the necessary functions and aspects decomposed from the program of demands. As the morphological chart allows every designer to immediately see the results, they can discuss aspects that are unclear to them. The morphological charts made by each individual designer can be combined into a [team] morphological overview. The whole process is done in two steps: first the functions and aspects are discussed and then the possible related solutions see Fig. 1.

Figure 1: Building the morphological overview; Step 1; The Morphological overviews show the agreed functions and aspects [1] of the different morphological charts. Step 2: The Morphological Overview with the agreed on sub solutions [2] from the separate morphological charts

A morphological overview is generated [see Fig. 2] by combining the different morphological charts made by each discipline after discussion on and the selection of functions and aspects of importance for the specific design. Such a morphologic overview can be used by the designers to reflect on the results during the different design process stages.

Experiments: Workshops for professionals

To test our approach of the morphological overviews and to determine if the approach led to positive effects for the professionals, we arranged workshops as part of a training program for professional architects of BNA Dutch Royal Society of Architects and consulting engineers, NL Ingenieurs (former ONRI) [structural engineers, building services engineers and building physics engineers]. On average these participants had 12 years of professional experience. An essential element of the workshop, besides some introductory lectures, was the design cases, on the basis of which the design teams worked and presented their ideas/design at the end of each session to the whole group. These design exercises were derived from real practice projects and as such were as close to professional practice as possible. In the current configuration [Fig. 2] stepwise changes to the traditional building design
process type, in which the architect starts the process and the other designers join in later in the process, are introduced in the set up of the design sessions. Starting with the traditional sequential approach during the first two design sessions on day 1, which provide reference values for the effectiveness of the method [amount of integral design concepts], the perceived “integral approach” is reached through phased introduction of two major changes: first all disciplines start working simultaneously within a design team setting from the very beginning of the conceptual design phase and secondly the integral design model / morphological overviews are applied. A comparison of settings one, two and will show the impact that a simultaneous approach has on the design task.

![Figure 2. Workshop series 5 set-up; design teams were changed for each of the four design tasks / settings](image)

### 3. Results

The morphological overview was put to use as a recording device in the following way. First, all design teams were video recorded. Then, as a pre-test measure, in order to check whether separate individuals could arrive at the same analysis, two researchers independently reviewed the video recording of one team per design setting and recorded the relevant aspects on the overview. Here, what was considered relevant was limited to the explicitly noted aspects and sub solutions of the design teams.

**1st design setting,’ parasite pavilion sustainable building’ design task**

In design setting 1 each team was given the same design task: to design a ‘parasite’ structure to be placed on the building the workshop was taking place in. For full description of the design task see Savanovic [2009]. In design setting 1 each team was given the same design task: to design a ‘parasite’ structure to be placed on the building that the workshop was taking place in. For full description of the design task see Savanovic [2009]. All teams proceeded with the task in the same way. Initially, in the first design session, which lasted approximately 30 minutes, the architect worked alone on the design. In order to demonstrate what occurred in design setting 1, the work and analysis of one team is presented below, while the work of the other four teams can be found in Savanovic [2009]. After the initial design session I, in which the architect worked alone, all team members met in design session II, to discuss the design. Here, the architect led the discussion. He did so by first explaining the considerations he took into account while working on his design. Through analysis of the session the architect’s explanation of the initial proposal at the beginning of second design session is translated into a table of aspects and sub solutions the architect’s morphological chart. Then, on the basis of a review of the videotaped session, a table of aspects and sub solutions considered by the design team is structured in the design team’s morphological overview. In order to allow comparison between different design teams and settings, these tables were reconfigured into the form of morphological overviews. The analytically derived morphological overview of team 1 is presented in table 1.
### 2nd design setting: ‘energy neutral office’ design task

The task was to design an energy neutral office. The mono-disciplinary team of architects (group of five) focused on spatial arrangement during the first design session. In order to demonstrate what occurred in design setting 2, the work and analysis of one team, team 2, is presented below. Most teams followed a very similar pattern during design session two. First, representatives of the individual disciplines explained the results of their work from the mono-disciplinary team in design session 1. After these individual explanations, team discussion ensued. The focus of this discussion was on fitting sub solutions into a final design. Here, the majority of participants motivated their turns by mentioning personal experience in previous projects. Decisions on how to fit these sun solutions into a final design were made relatively quickly in these four teams. All teams managed to produce a final design sketch accompanied by explanations of specific systems or building elements used. The focus of all teams was largely on building parts rather than on building as a whole.

After accepting the building physics consultant’s argument, the team agreed to use this completed building as a benchmark with which to work out which sub solutions to use and how to fit them into the final design proposal. The team’s table of aspects and sub solutions, and its morphological overview are shown below.

<table>
<thead>
<tr>
<th>Time (design session II)</th>
<th>Who</th>
<th>Aspect or sub solution</th>
<th>Description</th>
<th>Text/sketch or verbally</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h32min</td>
<td>Team</td>
<td>Solution!</td>
<td>Oval building, example Rabobank ‘De Lier’</td>
<td>Verbally</td>
</tr>
<tr>
<td>00h35min</td>
<td>BS</td>
<td>Sub solution (1-1)</td>
<td>Solar tubes for parking garage</td>
<td>Verbally</td>
</tr>
<tr>
<td>00h38min</td>
<td>BP</td>
<td>Sub solution (1-2)</td>
<td>Rainwater for pond in atrium – light reflection + ‘gray water circuit’</td>
<td>Verbally</td>
</tr>
<tr>
<td>00h49min</td>
<td>BS</td>
<td>Sub solution (2-1)</td>
<td>Ventilation with air via ground</td>
<td>Verbally</td>
</tr>
<tr>
<td>00h57min</td>
<td>BP</td>
<td>Sub solution (2-2)</td>
<td>Hybrid ventilation</td>
<td>Verbally</td>
</tr>
<tr>
<td>01h05min</td>
<td>BS</td>
<td>Sub solution (2-3)</td>
<td>Season regulated double façade</td>
<td>Sketch</td>
</tr>
</tbody>
</table>

Table 2. Aspects and (sub) solutions explicated by design team 2 (session II)

The design team essentially recombined the successfully applied systems of the existing building in order to arrive at the following sketch representing their solution to the design task, Fig. 4.

Table 3 contains the aspects and sub solutions from each individual team in setting II.
3th design setting, ‘renovation roof apartments’ design task

The task was to design a zero energy apartments on the top floor of the building (roof). Design setting 3 represented a learning-by-doing opportunity for the individual disciplines and the design teams. The ideal outcome would be that each team could clearly demonstrate successful use of the design tools during the design process. However, as a key part of learning is feedback, after the teams completed tasks set in setting 3, time was given to compare and appraise the teams’ work and to answer any questions that arose. The results of this learning session are discussed in Savanovic [2009] but are not relevant in the context of this article.

4th design setting, ‘energy neutral school’ design task

The task was to design a school with healthy and sustainable environment for children. The same location and overall demands as for ‘zero energy office’ design task was used. Design setting 4 represents the very last stage in the cycle of research in this research project. All of the individual interventions that were used in the earlier research stages are combined so that in setting 4 the ID-method can be tested. To be explicit, the elements that have been combined are: design team, design model, design tool and design setting. The analysis of the fourth workshop design setting, in which 5 design teams participated, of team 1 is here presented. Design team 1 consisted of: A, BS, SE: 3 members from 3 disciplines. In this setting, all of the design teams’ proposed sub solutions were recorded directly on morphological overview, see Fig. 5 & 6. The end result for presentation is Fig. 7.

### Table 3: Aspects addressed and [sub] solutions produced by design teams [setting II]

<table>
<thead>
<tr>
<th>Team 1</th>
<th>Team 2</th>
<th>Team 3</th>
<th>Team 4</th>
<th>Team 5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of aspects</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>No. of sub solutions</td>
<td>13</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

---

**Figure 5: Design team 1 morphological overview [design setting 4]**

**Figure 6: The morphological overview presented by design team 1, with clearly marked chosen sub solutions. Figure 7. The end proposal of design team 1**
Table 4 contains information on the number of aspects and sub solutions generated by the teams in the setting four.

<table>
<thead>
<tr>
<th>Team</th>
<th>Team 1</th>
<th>Team 2</th>
<th>Team 3</th>
<th>Team 4</th>
<th>Team 5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of aspects</td>
<td>5</td>
<td>11</td>
<td>11</td>
<td>5</td>
<td>10</td>
<td>8.4</td>
</tr>
<tr>
<td>No. of sub solutions</td>
<td>24</td>
<td>26</td>
<td>39</td>
<td>20</td>
<td>46</td>
<td>31.0</td>
</tr>
</tbody>
</table>

Table 4: Aspects addressed and [sub] solutions produced by design teams [setting IV]

4. Conclusions

The comparison of design setting 1 and 2 presents the effect of introducing all the different designers from the start without using support. This led to a decrease of the number of aspects and subsolutions, indicating a less effective design process. From the analysis of the workshops it could be concluded that the solution space, resulting from the number of functions and aspects considered, was significantly increased by applying the Morphological Overviews. A good example of this increase can be seen from the results from session 1 [without morphological charts and morphological overview] compared with the results of session 4 [with use of morphological charts and morphological overview]. Figure 8 clearly show that, as expected, more aspects and sub solutions were generated in setting 4 than in any previous setting 1 and 2. The increase of the number of considered functions and aspects leads to a larger number of partial solutions for NZEB, see Fig. 8.

![Figure 8: Comparison of the number of aspects/functions and partial solutions being generated by the design teams in design session 1, 2 & 4.](image)

The primary goal of this research was to find a way to integrate engineering disciplines into the NZEB design process from the outset and to provide a means to integrate engineers at the outset of the design process in a meaningful way. The results show that the ID (Integral Design)-model is relevant for focussing design teams on creation of new NZEB-concepts. Applying the ID model is therefore an important step to stimulate the creation of new concepts to achieve 0 impact buildings and environments.

Acknowledgements

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