SINTEF Building and Infrastructure

CECILIE FLYEN ØYEN

Design process challenges – Simple obstacles or complex building defects?

Report from the R&D-programme «Climate 2000»

Project report 1 2007

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Preface

This report discusses the architects' basis of knowledge, application of competence and approach to technical challenges and requirements applied to design and design management. The aim is to identify possible areas or occasions within the course of the design process where building defects are likely to originate, and where preventive measures most likely will be effective. The work has been carried out as part of project 12 *Weather Protection in the Construction Process. Critical Decisions – Causes and Consequences - Protective Actions* within the Norwegian research and development programme *Climate 2000 - Building constructions in a more severe climate*. The discourse will be part of the theoretical foundation of the authors' PhD-project.

The *Climate 2000* programme's principal objectives are to develop principal solutions for building structures resulting in both increased durability and reliability in the face of external climatic impact, and to survey the possible impacts of climate change on the built environment. The intention is to define more accurate criteria and Codes of Practice for the design and construction of critical elements of building envelopes. *Climate 2000* is an important part of the continuous development of the Building Research Design Sheets in the SINTEF Building Research Series, and product documentation in the form of technical approval and certification.

The programme is being managed by SINTEF Building and Infrastructure and carried out in co-operation with the Norwegian Defence Estates Agency, the Research Council of Norway (NFR), the Norwegian State Housing Bank, Norway's Directorate of Public Construction and Property (Statsbygg), the Norwegian Financial Services Association (FNH), National Office of Building Technology and Administration (BE), the Norwegian University of Science and Technology (NTNU) and a large number of key players in the construction industry. The programme was initiated in August 2000, and will continue until the end of 2007.

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Trondheim, June 2007

Tore Kvande
Programme manager
SINTEF Building and Infrastructure

Contents

1 Introduction

1.1 Principle objectives and scope

This paper discusses the architects' basis of knowledge, application of competence and approach to technical challenges and requirements applied to design and design management. The paper presents a discourse based on a theoretical foundation of selected topics. Professionalism and reflective practice, design theory, design practice and design management are seen in relation to a specific technical field where a high degree of building defects seem to emerge from; process induced building defects. The aim is to identify possible areas or occasions within the course of the design process where such defects are likely to originate, and where preventive measures most likely will be effective. The discourse will be part of the theoretical foundation of the authors' PhD-project.

The paper will form a theoretical basis of the principal objectives, in order to reveal possible ways of explanation and thus derive plausible causal connections to the questions asked. The theoretical framework will be seen in relation to a Norwegian setting. Another purpose of the paper is to form the basis of a subsequent qualitative case survey of planning and design practice in the construction industry. Thus it is vital to understand the mechanisms of the design process. In the process, the designer job is to interlace a strict framework of requirements and the architects/designers often multifarious creative shaping of a project. The management of the design process adds another dimension to the designers' challenge; directing interfaces through interaction, cross-disiplinarity, communication with clients and local authorities etc. To enable a deduction of causes and possible measures best adapted to the moisture related challenges of the early stages of the construction process, sorting of the different actors, roles, tasks and responsibilities of the parties involved in the early stages of the process is as important.

1.2 Background

According to several research reports of the SINTEF Building and Infrastructure[1], the present occurrence of process induced building defects[2] in new buildings in Norway is high. More than 75 % of building defects registered in the SINTEF Building & Infrastructure's building defect files (a register of a selection of Norwegian building defects) are induced by climatic strain, moisture being the main source of the defects. A large share of these defects originates in early stages of the construction process. Findings suggest that as much as 40 % of building defects in Norway can be related to mistakes or omissions in the design process, which is in good agreement with corresponding investigations or sources of information in other European countries (Ingvaldsen, 1994, 2001). Experiences and registrations demonstrate an evident need of preventive measures in the planning and design phases of the construction process, to reduce the extent of process induced moisture defects and the impact on building quality, building lifetime and users' health etc. In a recently published analysis of the SINTEF Building and Infrastructures' building defect files, Lisø et al. conclude that the construction industry is not able to learn from past experience and that the exchange of knowledge in construction projects is not satisfactory (Lisø et al., 2006).

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[1] SINTEF Building and Infrastructure is a new department of the SINTEF foundation, as the result of a merge of the former Norwegian Building Research Institute and the construction related parts of SINTEF

[2] Building defects discovered subsequent of the initial employment of the building, traceable to mistakes or omissions in the construction process. This does not apply to defects caused by incorrect use, normal wear and tear etc.

1.3 Theoretical approach

The construction process is complex and comprehensive to overview, with a large number of actors, tasks, fields of responsibilities and changing scenarios. Every construction process is different, yet the methods applied and procedural framework is the same. The framework of legal requirements, clients brief, progress of construction process, cross-disciplinary interfaces between actors and the information flow between them, are all challenging circumstances to attend to. Yet the large number of defects poses a mark of interrogation on the attention of technical and building physical issues in quality and accomplishment of basic design and design management.

The deduction that the architect or design team thus perform a poor piece of work is however not implicit. Incorrect design due to lacking experiences and know-how may be among the direct causes of mistakes and thus defects. Nevertheless, other fundamental conditions may also alter the premises and change the outcome of the design process, such as e.g. client economy and alteration of requirements. Derived from this, cause and effect relationships may not be evident, likewise the origin of defects may not be easy to detect. This poses important, basic questions on the nature of building defects, and the search of origin:

- Do the obstacles of the design process prove to be the mere sources of defects?
- Are they solvable challenges in the early stages of the construction process?
- Is it possible to detect the sources of construction process induced moisture defects in the design process?

The construction process is extremely complex, and the sources of defects may be multiple and composed of several actions, conditions and incidents. The following objectives are sought answered in the discourse of the theoretical syllabus:

- Is the architects’ incorporation of provisions in legal framework, technical issues and owner’s requirements in design and design management through the design process adequate?
- Are the inherent, theoretical and experience based skills of the architect optimal in the attention of technical issues such as the moisture challenges?
- Are the demanded requirements on moisture safety and moisture related issues sufficient?

The main focus of the paper is the discourse of issues from the theoretical foundation, relevant to the principle objectives. The discussion will be supplied with a consecutive comparison with aspects of the Norwegian systems and experiences, law, responsibilities and traditions. The final reflections will list a sequence of current fields of the design process where causes of the high rate of moisture related defects induced in the building process may be detected, and thus possible preventive measures are likely to succeed.

2 When do faults emerge?

2.1 The design process – order out of chaos?

"Creativity, it has been said, consists largely of re-arranging what we know in order to find out what we do not know" George Keller[3]

The architects' design process can be characterized by doing the same every time in a different way every time. Every design project is unique, yet the process in making it and the methods used are the same or somewhat similar each time. Architecture emerges through an assembly of several different requirements, consisting of legal provisions and regulations, local authorities brief, clients brief, economy etc. This assembly of requirements envelope the creative processes. Simultaneously with aesthetic, technological, aspects the creative process attend to of each of these requirements and take considerations constantly.

Brian Lawson refers to several authors' maps or sketches as images of the design process. Figure 1 shows a simplified model of three main activities of the design process, as an expression of how the mind of a designer works (Lawson, 1997).

The phases define:

- Analysis - ordering and structuring of the problem
- Synthesis - possible solutions responding to the analysis
- Evaluation - feedback to the proposed solutions

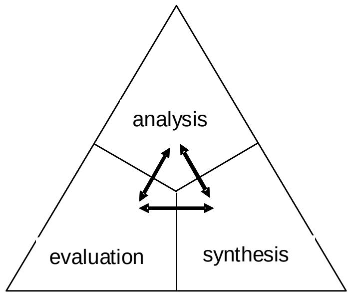

Figure 1
General, graphical representation of the design process (after Lawson, 1997)

The model describes an iterative process, going back and forth in loops, generating a progress of the object of design. Lawson is somewhat doubtful to what extent such maps are in fact useful to the designers. He sees the process as relatively unstructured, in the sense that brief, requirements, standards, solutions, evaluation and testing are interpreted in a non-determined fashion or order, often with overlap. Lawson instead presents a three-dimensional, further developed model of the mental process, seen as a "negotiation between problem and solution through the three activities of analysis, synthesis and evaluation" (Lawson, 1997, p.47). The missing dimension of time, start and closure of the process can seem striking, but may give a perception of a perpetual process and a mental "introverted" stage of the design process. The model is not meant to be too literally understood. A description of a non-sequential, unrestrained process seems to be more agreeable to the comprehension of creativeness as a phenomenon, and thus more likely to resemble the actual mental process of the designer. Lawson states that the design practice is a bidirectional process in which each problem enables the designer to learn from guiding principles. He explains how design is in fact a kind of research, offering the designer a possibility to shape, test, evaluate and reconsider the design through an action-based method of advancing knowledge (Lawson, 1997). Schön concludes in the same direction (Schön, 1991).

Creativity is described as a mental process generating new ideas or concepts, or new associations between existing ideas or concepts. The products of creativity are from a scientific point of view regarded as both original and appropriate (wikipedia references on

[3] Source: Wikipedia at *http://www.reference.com/browse/wiki/Creativity*

the internet). The creativeness of the architect in the design process can thus to be understood as a framework of existing basic knowledge, methods and techniques applied in a "smithy of ideas", confined and shaped by consideration of the constraints and requirements from different generators/actors. The quality of a project is at this dependent on a number of circumstances to fulfil the scientific regards of the concept creativity.

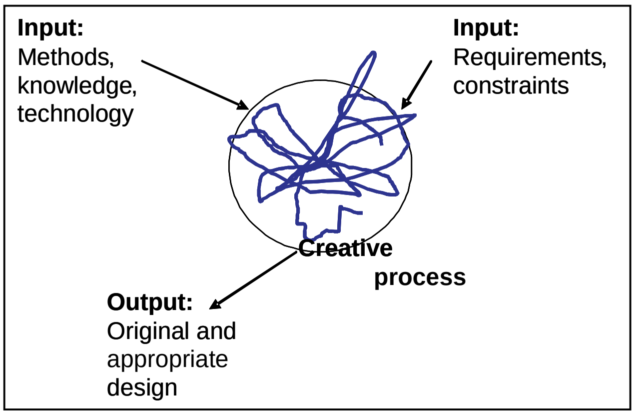

Figure 2
Graphical representation of the three conditions of a successful, creative design process

These circumstances are related to three conditions; the abilities of the generators of constraints and requirements to make appropriate demands, the architects knowledge and skills to apply the framework, and the fulfilment of a creative design process through the application of the two first mentioned.

2.2 The design process – constraints and management

Investigations performed by SINTEF Building and Infrastructure show that as much as 20 % of the construction process induced building defects can arise due to alterations of client requirements or reductions of the budget (Lisø et al., 2006). The perspective of the client represents one of the areas to seek for causal relations for construction defects. The clients' expectations and demands are established in the clients brief as a result of the briefing process. Surveys reveal that the client often have expectations and demands on areas that are "in" and trendy (kitchen design, bathroom tiles etc.), or related to evident qualities such as view, outdoor space etc. To a great extent this counts for the unprofessional builder, who often demands a high degree of unspecified quality, without having the means or knowledge to direct the demands or the economy to pay for it (Øyen et al, 2006). Derived from this, it is an easy assumption to suppose that the professional builders have similar demands to meet the expectations of the market. Does this support the assumption that the "professional" client is not professional enough? Seemingly the lack of requirements addressing moisture issues in the clients brief may be in conflict with the provisions of the Norwegian planning and building legislation, and if not at least contrasting the clients request for high quality.

This view finds support in a report in the evaluation programme of the Norwegian planning and building act of 1997, where it is established that professional builders seem unwilling to pay the cost of substituting competence on technical issues in demanding projects of high complexity and complicacy. A surprisingly low degree of the projects investigated (with a high degree of complication) where supported by professional consultants on building physics (Stenstad, Rollstad, 2004). Sikander and Grantén have an ever stronger indication of lacking requirements in their report on the clients' requirements, management and verification of moisture proof construction. A survey accomplished among builders/clients and construction project managers reveals that two out of three clients or building administers report that moisture safety related requirements are not addressed specifically or not addressed at all in refurbishment projects or new construction projects (Sikander & Grantén, 2003). Sikander and Grantén state clearly that the property developer plays a key role in initializing a minimalization of moisture induced building defects in a construction project. They stress the importance of a close follow-up of preventive measures by careful supervision and control.

The Norwegian system of apportionment of responsibilities was meant to give a distinct division of fields of responsibilities between the actors of the construction process. Unlike e.g. in the Swedish judicial system, the Norwegian client has few legal responsibilities related to the construction process, except from those linked to HSE[4], and of course the procurement engagement of a mere private legal matter. (Øyen, 2005). Even so, it must be in the clients' best interest to require and acquire a dry, healthy building with the best possible obtainable quality within reach. Lawson and Schön agree on an issue dependant on the designers' angle of approach. They both stress that design is as dependent on the selection or identification of problems as on the solving of the problem itself (Lawson, 1997; Schön, 1991). Lawson points out that problems identified are as dependent on the time available. However, there are several factors involved in the identification of problems, e.g. competence and skills, experience, economy in the project, areas of interest, pronounced fields of activity, laws etc. The main focus must be to do a thorough risk evaluation to identify as many *relevant* problems as necessary in order to produce the best project possible.

In order to reduce the high degree of construction induced building defects, several changes were incorporated in the Norwegian planning and building act in the late 1990'. Earlier there were no distinct, judicial apportionment of responsibilities according to the planning and building legislation. The changes led to an apparently surveyable system of apportionment of responsibilities; still there were gaps between the fields of responsibilities. Some fields of responsibilities, such as e.g. building physics, have often not been covered with a building physics specialist even if needed. The post has either not been covered, or it has been attended to by the architect. This puts great demands on the basic knowledge of the architects who engages in the role of responsibility of building physics. Gray and Hughes state that the design process is complex and subtle, and that an increasing amount of design is "performed by the specialist contractors who work with the design team to resolve the intricate details of the project. The specialists' involvement usually starts during the initial engineering stage" (Gray & Hughes, 2001). This is contrary to the findings of one of the Norwegian evaluation projects of the legislation reform stating that the application of the specialists' on e.g. building physics is in fact diminishing (Stenstad and Rollstad, 2004).

2.3 The architects knowledge platform

Schön asserts a hierarchic view of professional knowledge, classified into three levels (Schön, 1991). The highest level is the basic science of general principles, of which the profession rests on. The second level consists of the applied science, developed through application of basic knowledge. The third level is the most refined or derived from the basis; diagnostic and problem-solving techniques. Here we find the actual field of activity of which the execution of the profession serves a purpose directed towards the client. The application of scientific theory and technique is performed through the professional activity by operationalized, instrumental problem solving. This description seemingly only applies to the *technical* part of the tasks performed by the professional architect. Still Schön comprises also the creative/artistic side of the performance as instrumental problem solving. In general, each new design project is unique by nature. Yet it is the repeated or similar/comparable sets

[4] Health, Environment and sequrity

of problems that make it possible to apply standard theories or techniques, thus forming a fundamental structure of professional inquiry in the problem solving of the design task.

Schön points out a dilemma when considering the adequacy of the professional practitioner and the task of managing complexity. Technological change has lead to an obsoleteness of methods and techniques. Brian Lawson supports and enhances a similar view, claiming that present designers "no longer can be trained to follow a set of procedures since the rate of change of the world will soon leave them behind" (Lawson, 1997, p.4-5).Thus professionals are expected to solve tasks they are not educated to handle, and need to generate technological change fast enough to "meet the expectations and demands that technology itself has generated" (Schön, 1991, p.15). Schön emphasizes a requirement for adaptability on the professionals, and calls attention to the necessity of a radical alteration of the architect's practice, as a consequence of "new building technologies, new patterns of real estate and land development, and new techniques of information processing in design" (Schön, 1991, p.15). A striking deduction is that a more thorough basic understanding of the fundamental principles of e.g. building physics and statics amongst the architects will enable extended possibilities to adapt to a constantly changing field of technology and material development. The methods and techniques will have to change rapidly and continuously, but the basic technological knowledge will maintain "universal truths".

Lawson focuses on the contemporary debate on the differences rather than the similarities between the different consultants of the construction industry. Yet he maintains that design thinking is a skill that should be performed intuitively, like "golfers and flautists". "They should forget all that they have been taught about technique and just go out and do it!" (Lawson, 1997, p. 12). In this way, Lawson transforms design into a mere artistic performance, cutting the umbilical cord to the tradition of science and technology, in which architecture is deeply rooted. He thus encourages the debate of differences, perhaps to throw the attention on the differences in work methodology rather than on the inherent qualities of the profession itself. Architectural design is artistic in its nature, but the connection to science and technology is undisputable. The quotation is of course drawn out of a context, and should probably not be read literally. Nevertheless, statements like this nourish the traditional opposing debate between engineers and architects on technology vs. art.

Professional expertise is of course not completed by the time of graduation. Professionalism is moulded and acquired through experiences in practice, innovation, implementation of solutions, evaluation of results etc. When looking into educational institutions, Schön is critical to an exclusive case teaching approach. He considers it to be fit for teaching *application of theory and technique*, though leaving little time for the students to master "analytic technique and conceptual material". This reveals an underlying concern for a lacking part of the students' basic knowledge of general principles and methods. Schöns' comprehension is consistent with findings in several surveys carried out by the SINTEF Building and Infrastructure, performed in the building industry. A resent analysis of the SINTEF Building & Infrastructure's building defect files show that lack of knowledge on fundamental principles of building physics is a common problem in building projects in Norway (Lisø *et al.* 2006). Many types of building defect cases are recurring items, which indicate a general lack of knowledge concerning fundamental principles of building physics, but a wide range of classical problems has been recorded. Lisø et al. conclude that the construction industry is not able to learn from past experience and that the exchange of knowledge in construction projects is not satisfactory. These findings are also supported by earlier investigations.

These issues all contribute to the perception of the need of a thorough examination of the academic educational system of professional architects, in order to meet the sets of problems demonstrated.

3 The way forward

Several important areas are not mentioned or only merely touched in this paper, such as the attention of information flow between actors of the construction process, and of the interfaces between the actors, communication and re-allocation of experiences, systems of supervision and control. Further the values of risk assessment, assessment of weather-protection systems, data management systems with databases allowing for eased access to experience data and empirical evaluation, IFC/IFD-related systems with rigid incorporation of e.g. local requirements, projects evaluation etc. The paper is not meant to be exhaustive, but merely point out directions of possible fields of further investigation. The complexity of the scope is also a matter of importance in this respect. It is of great importance to stress the fact that this paper merely reflects on a few of several possible areas and sets of problems that needs to be further investigated and reflected upon, there may be a considerable number of additional subjects not mentioned.

Further work will consist of a qualitative case survey, built on the theoretical basis offered by this paper, with a deeper research into a bundle of main issues considered to be of principal importance. Process induced, moisture related building defects would be the main area of investigation.

4 Concluding remarks

However superficial, the Norwegian planning and building act clearly states that moisture problems in buildings are undesirable, and should be avoided. Yet it is seldom a big issue in the requirements of the local authorities' or taken into consideration in the handling of planning- and building applications. Since the requirements of the client also are absent, requirements of moisture related issues seem to be a key factor.

- Through the creative work of the design process, the architect combines basic knowledge, use of methods and technology and the requirements of the generators of such (clients, local authorities, standards, laws and provisions, guidelines etc.).
- Three conditions that may define successful projects have derived:
  - ✓ The abilities of the generators of requirements and constraints are in question: Presently they seem to be lacking.
  - ✓ The knowledge and skills of the architect in order to apply the framework: Good skills on case approach and application of methods, possibly lacking skills on basic technological and scientific level.
  - ✓ Fulfilment of the creative process, with a successful incorporation of the two just mentioned. Require good creative skills of the architect.
- Clients do not demand moisture safety, building physicists etc. in their requirements
- Low degree of involvement of specialists on basic knowledge in building physics must be challenged and altered
- Risk evaluation is necessary in the task of identification of relevant problems to solve
- The technological changes push forward a need for a new focus in the educational system: adaptations to change; thus need of enhanced focus on basic technological and scientific skills. Several matters points to this conclusion, and demonstrates the possible need of a in-depth examination of the academic educational system of architects
- The construction industry as a whole must enable learning from experiences and faults, and prepare for new systems, new possibilities, and new openness in the construction industry

The later years trends push towards the use of untested solutions and details in the construction industry, possibly resulting in a series of building defects. The traditional use of tested solutions assures secure, tested details based on well-incorporated knowledge and experiences. May the architects' creativity in fact be a threat towards good building quality? When considering the use of earlier non-tested solutions, it is of great importance to substitute the lacking incorporated knowledge with the use of extended competence on the specific field of knowledge. Another possible preventive measure is to evaluate and reduce the number of variations of different solutions used on similar details (e.g. different types of external walls), to a minimum and. The present functional regulations in the Norwegian planning and building act require the use of guidelines to a much higher extent than earlier. Still guidelines such as e.g. the SINTEF Building and Infrastructures' Building sheets have had a decrease in use the later years. Rationally one would expect an increased use, somewhat of a paradox.

Schön describes the design process as a dialogue between the designer and the task, where the designer is constantly alternating between the two approaches of technical rational thinking and the creative, intuitive and experience based thinking; reflection-in-action. Assuming (from the previous discussion on the architect's competence) that the architect is lacking in-depth knowledge on fundamental principles of building physics, it is probable to presume that the approach of creativity and intuition will be predominant in the design process. This assumption is a common statement in the habitual/traditional “conflict” between engineers and architects, that needs to be substantiated; *architects are artists without technical skills, engineers are scientists without creative abilities.*

As internationally, the Norwegian schools of architecture have different approaches to the education of architects, of which this paper will not discuss. However, to the knowledge of a third party (without in-depth knowledge on the academic educational system), the distinction in the requirements and tuition of technical fundamental principles on building physics, statics etc. is a field of great distinction between the universities, as of the amount of teaching spent on the domain and the distribution of lessons through the study as a whole.

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Climate 2000 (2000–2007) has been one of the largest research programmes within the Norwegian construction industry for the last decade.The programme's principal objectives have been to survey the likely impacts of climate change on building performance and how society can best adapt to these changes, and further to develop methods, tools and solutions in principal for the planning and design of buildings in severe climates.

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