NORDISK ARKITEKTURFORSKNING
NORDIC JOURNAL OF ARCHITECTURAL RESEARCH

2

ISSUE 2 2023

NORDISK ARKITEKTURFORSKNING
Nordic Journal of Architectural Research

2–2023

THEME ISSUE: INDUSTRIAL ARCHITECTURAL RESEARCH – POTENTIAL, PURPOSE, RELEVANCE AND IMPACT

Nordic Journal of Architectural Research
ISSN: 1893–5281

Submitted manuscripts
Manuscripts are to be sent to Marius Fiskevold (marius.fiskevold@nmbu.no), Sten Gromark (sgromark@outlook.com) and Magnus Rönn (magnus.ronn.arch@gmail.com) as a text file in Word, using Times New Roman font. Submitted articles should not exceed 8 000 words exclusive abstract, references and figures. The recommended length of contributions is 5 000–8 000 words. Deviations from this must be agreed with the editors in chief. See Author's Guideline (http://arkitekturforskning.net/na/information/authors) for further information.

Subscription
Students/graduate students
Prize: 27.5 Euro.
Individuals (teachers, researchers, employees, professionals)
Prize: 38.5 Euro.
Institutions (libraries, companies, universities)
Prize: 423 Euro.

Membership for the association
5.5 Euro (for individuals who get access to the journal through institutions).

Students and individual subscribers must inform about their e-mail address in order to get access to the journal. After payment, send the e-mail address to Trond Haug, trond.haug@sintef.no.

Institutional subscribers must inform about their IP-address/IP-range in order to get access to the journal. After payment, send the IP-address/IP-range to Trond Haug, trond.haug@sintef.no.

Payment
Sweden pay to plusgiro: 419 03 25-3
Outside Sweden pay in Euro to Nordea IBAN: SE67 9500 0099 6034 4190 3253 BIC/SWIFT: NDEASESS

Published by SINTEF Academic Press
P O Box 124 Blindern, NO-0314 Oslo, Norway.

CONTENTS

Photo, front cover: Søren Rønholt

NORDISK ARKITEKTURFORSKNING
NORDIC JOURNAL OF ARCHITECTURAL RESEARCH

DEVELOPING A NEW CULTURE OF INDUSTRIAL RESEARCH IN ARCHITECTURE

NINI LEIMAND AND ANNE BEIM

Abstract

A researching architect based in the building industry and affiliated with a PhD program in an architectural school rooted in a Fine Arts tradition is a rather novel phenomenon in Denmark. The first project was in 2005–2008 in a collaboration between CINARK – the Centre for Industrialized Architecture at the Royal Danish Academy of Fine Arts School of Architecture – and the industrial partners, Wienerberger AG (insulating ceramic blocks) and Maxit A/S (mortar/plaster).

As the first of its kind, the terminology, the theoretical framework, the methodologies, the very type of knowledge and the research culture all had to be defined from scratch. And due to the expected commercial output, the contents had to be defined, protected and managed by the PhD student in ways unusual to academic research.

Based on critical analyses of first-hand experiences, notebooks, half-yearly reports and minutes from meetings with supervisors, the article discusses a new culture of industrial research in architecture. Questions asked are: Who defines the research standards in industrial research? How can industrial research lead to original findings when topics are negotiated with the business partners who are driven by commercial logics? How can industrial research enhance academic knowledge production without compromising it?

Keywords:
Industrial research, research culture, block masonry, architecture, tectonics, business collaboration

Introduction

The objective of this article is to unfold and discuss dilemmas and problems built into the industrial PhD framework. The intention is also to discuss and identify the academic benefits of establishing research under this framework, in addition to the financial/commercial ones. Three critical problem areas are identified and discussed in the article:

- Who defines the research standards in industrial research – and why is this important?
- How can industrial research lead to original findings when problems are negotiated with the business partners, who are driven by commercial logics?
- How can industrial research enhance academic knowledge production without compromising it?

As such, the article is an attempt to form a set of critical reflections on research practice that is linked to the Industrial PhD Program, which in the present case of the described PhD project was an attempt to define research as critical reflection.

Methods and selection process

Based on structured, critical analyses of first-hand experiences, revisiting of notebooks and minutes from meetings with academic supervisors and business supervisors, the article will examine the discrepancies between "research in building practice" and "practicing research in/through building practice" (Frayling, 1993). These research approaches are different in nature, but they are often considered as comparable methodologies amongst stakeholders in the building industry. This leads to general confusion; in the worst cases it causes unclear research definitions and a lack of rigor and proper results that can be applied across the disciplines and stakeholders in the field. In one way, the article is a historical account of "the first industrial PhD in architecture" affiliated with the Royal Danish Academy of Fine Arts School of Architecture (KA), but in another way, it also forms a broader reflective study on knowledge production in architecture at doctoral level that brings a series of critical perspectives into account.

The prelude to the first industrial PhD at the Royal

The architect as an industrial researcher based in the building industry and affiliated with a PhD school at an architectural school rooted in the educational tradition of a Fine Arts Academy is a new phenomenon in Denmark. The very first project was executed between 2005–2008. It was set-up as a collaboration between the Centre for Industrialized Architecture (CINARK), at the Royal Danish Academy of Fine Arts School of Architecture (KA) and the companies Wienerberger AG and Maxit A/S, manufacturers of insulating ceramic blocks and mortar / plaster. Crucial to the

mutual interest in establishing such a three-year commitment was that there already existed a dedicated collaboration between the Masonry Information Council (MURO) and architectural researchers at KA, Institute of Building Technology.

Learning from initial research and experiments with block masonry construction

As early as 1990, this collaboration led to the publication "Catalog of ideas: a collection of ideas for development projects to promote masonry construction and the brick industry in Denmark" (Dahl et al., 1990). Subsequently in 1992, a similar but much more focused and elaborated book was published, based on shared interest of the architectural research environment and the professional organization MURO. It carried the title, "The Cavity Wall" and focused on masonry construction, the brick layer profession and brick manufacturing. The objective was to uncover the underlying causes of the existing problems at the time (Dahl et al., 1992).

After thorough analyses of problem areas, such as productivity and economy, building physics, loadbearing capacity, insulation and external surface, five potential paths were pointed out for improving masonry construction that included development of new ceramic products and construction designs. The study showed that there was a strong need to improve and test new products and construction types to expand the architectural design opportunities that were very restricted at the time, and only allowed the designing architect to concentrate on the very surface of the masonry construction and not the construction per se.

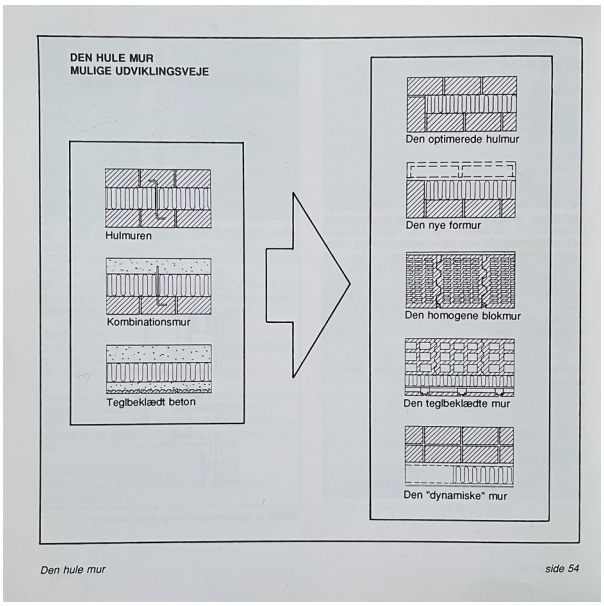


Figure 1
The Cavity Wall – an Innovation Project / Den Hule Mur – et udviklingsprojekt, front cover and page 54.
SOURCE: DAHL ET AL. (1992).

The three authors and architects, Torben Dahl, Peter Sørensen and Anne Beim immediately afterwards founded the architectural office *BDS Architects*, parallel to their work at KA. Commissioned by KAB, Denmark's largest administrator of non-profit housing, the office was asked to design and realize an experimental housing block, based on one of the 5 concluding development paths, namely the block masonry construction in Poroton. Poroton is the general term for insulating porous blocks in fired clay; manufacturers such as Wienerberger AG have for decades improved the product's technical properties according to northern European standards and building regulations.

Subsequently, a three-story housing block with 24 apartments and a total area of 1.880 m² was realized and became the first of its kind in Denmark constructed by using this insulating masonry block as a homogenous wall construction.

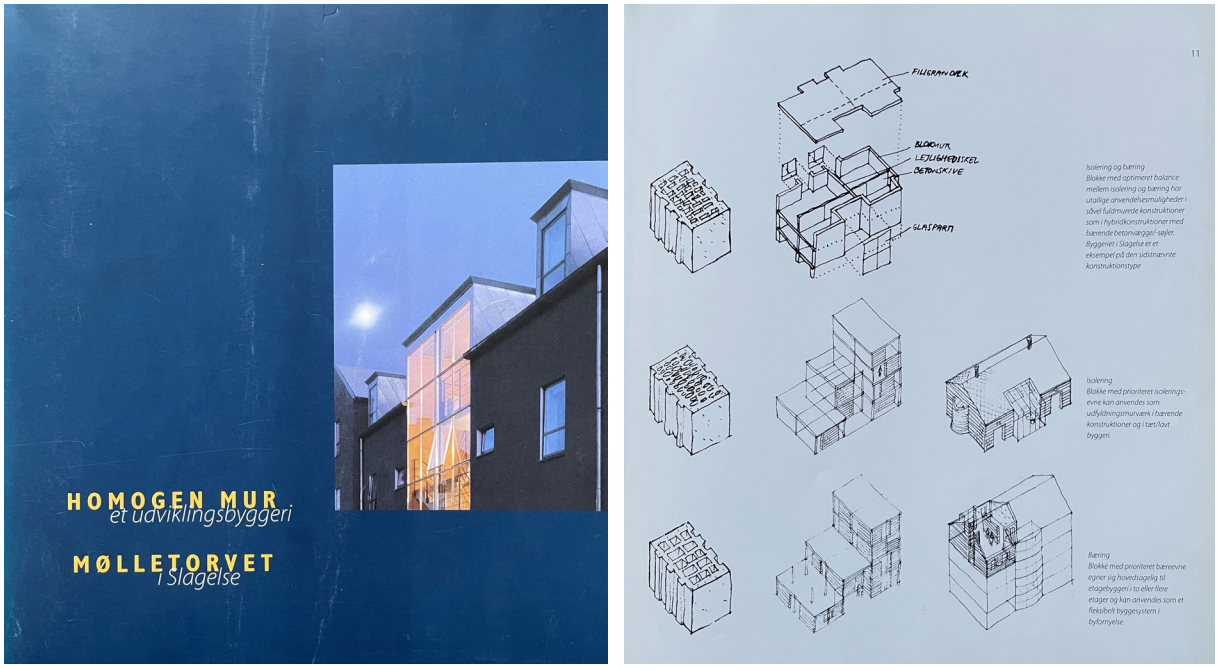


Figure 2
Homogeneous Wall – an Innovation Project: Mølletorvet Slagelse / Homogen Mur – et udviklingsbyggeri: Mølletorvet i Slagelse. Front page & page 11.
SOURCE: DAHL ET AL. (1997).

Supported financially by the Ministry of Housing & Planning and 'MUR', the Masonry Development Council (founded in 1990), the three researchers/practitioners published articles and taught courses based on the publication, *Homogeneous Wall – an Innovation Project*. It presented a review of the various opportunities and challenges when applying block masonry construction principles for multi-story, affordable housing architecture (Dahl et al., 1997).

Formation of a coming PhD researcher and research problem

As a student at KA, Nini Leimand found this coherent experimental approach to building technology and construction very interesting and

implemented these ideas and first test results in her studio work. Five years after graduating in 2003, Nini Leimand and her partner designed and realized their own house as a block masonry construction. Anne Beim learned from the MURO secretariat that a second block masonry house was being built in Denmark. She therefore went to study it to write an article about the potentials of this "novel Danish construction technique" for the journal *TEGL* (Beim, 2003, p. 8-11).

TEGL was a central media for presenting novel masonry products and building techniques to a broader public in the construction industry. *TEGL* was also the oldest construction and trade journal in Denmark, having existed for 116 years, based in the Masonry Information Council/ MURO. *TEGL* presented and analysed masonry constructions, building materials and architecture in both Denmark and internationally through text, drawings and photos. The journal was supplemented by a series of small technical pamphlets focusing on, e.g., brick roofs, joints, maintenance, etc. The target readers were architects, builders, masons, engineers, contractors and laymen interested in architecture and design. *TEGL* was closed in December 2013.

In 2003, Leimand was teaching part time at KA parallel to her employment in an architectural office. She met with Anne Beim, who had just formed CINARK – a research centre for industrialized architecture – at KA. She suggested that Nini Leimand writes a report on the mutual findings regarding the potential of block masonry constructions. At this point, the idea of scientific research into the topic had not yet matured. The report was a fundamental ambition of collecting, analysing and pointing to best practice when building with block masonry.

As a newly educated architect who had limited experience both as a professional practitioner and as a teacher, it was evident that there was a lack of contemporary handbooks about construction for both students, practitioners and teachers within the architectural field (unfortunately, this happens still to be the case). This added to similar experiences Nini Leimand had had earlier. During her studies at KA, Nini Leimand studied one semester at the "constructing architect" program at the Business Academy of Copenhagen (School of Technology, today: *KEA*) to gain insights into the applied literature and technical standards in other related curriculums, and to get to know the academic level, the didactic methods and organization of the scholarly contents applied in this practiced-based education.

Based on her experiences from the different learning and knowledge environments focusing on topics related to building construction, a greater picture emerged. It illustrated the need for a deeper understanding of how knowledge is constituted and can be generated across education,

research and the construction industry – and how knowledge paradigms (educational programs) can be derived from the very practices they feed into (academic as well as professional).

During these early years of close collaboration between the masonry industry and the research environment at the Institute of Building Technology at KA, it became evident that there was not only a lack of research-based literature and general technical analyses but also deeper systemized studies into the construction industry, products and processes, and how knowledge could be developed and shared among the different actors.

In the early 90s, innovative masonry structures and new brick components had been examined mainly from an engineering perspective; the research field was therefore dominated by technical scientific traditions focusing on technical topics. Deeper studies into the culture of construction, tectonic aspects and the wider architectural possibilities that could emerge from combining the technical challenges and the construction design had not yet been conducted. This was mainly because there was no established educational framework at doctoral level that supported this kind of cross-disciplinary knowledge production based on polyvalent exploration, but also partly because there was no adequate public/private research funding to support this sort of research.

The launch of an industrial PhD program – for the humanities

The Industrial PhD program originated from an initiative of the Academy of Technical Sciences (ATV, 2022). At first, it was meant for candidates and businesses that were linked to the natural and technical sciences, but later it was taken over by the *Ministry of Higher Education and Science* that developed the program into having a broader scope. However, the primary intention has always been to fund research projects that could have commercial value for the involved businesses (Innovation Fund Denmark, 2022). The overall introduction of academic thinking and methods to small businesses has also shown to be a long, challenging process:

> *In the beginning, the program was almost exclusively funding large research-intensive companies. Up through the 1980s and the following decade, efforts were made to involve small and medium-sized enterprises (SMEs). The idea was that industrial researchers should establish R&D units in smaller companies (interview, Zeuthen & Ahm, 1981). In 1995, about 45% of the projects took place at companies with fewer than 500 employees and approx. 20% in companies with fewer than 50 employees (Erhvervsfremmestyrelsen, 1996). A well-functioning funding program was of great importance for its spread among the SMEs, as these companies usually do not have a strong research environment* (Knudsen, 2012, p. 89).

In the years 2003-04, the *Ministry of Science, Technology & Development* / VTU (Today: *Ministry of Higher Education & Science,* UFM) held a promotion campaign hosted by the Department of Humanities at the University of Copenhagen to disseminate the industrial PhD program and to push the idea that not only the natural sciences and technical universities could benefit from this business-oriented PhD program (Knudsen, 2012, p. 89). This campaign, and the idea of framing a research project that addressed both the construction industry and architectural knowledge production related to practice, sparked the interest of Nini Leimand and Anne Beim to formulate an industrial PhD project that investigated the potentials of block masonry in architecture. After several meetings with the director of MURO, the Danish CEO of Wienerberger AG and the head of R&D at Maxit, everybody was ready to collaborate to apply for this new industrial research funding.

Research for whom?

The working title of the application was "The Architectural Potential of Block Masonry". However, the research project arose from an overall scepticism concerning the growing complexity of modern construction techniques applied to exterior walls. At the time, this tendency to "technical complexity" was driven by high demands for reducing energy consumption in housing and construction solutions; new requirements were met through technical norms and building regulations and by the accumulation of additional performative layers. Also, the building industry in general did not see the value of a comprehensive (tectonic) approach, which considered the full problem, i.e., the building structure as part of a broader context, including the architectural consequences. These dilemmas were critically addressed in the problem description of the PhD project.

Defining the research project within a suitable scientific framework was another dilemma of the early stages, since design research mainly was oriented towards psychology and the social sciences at the time. *The Reflective Practitioner: How professionals think in action,* by the American philosopher and urbanist Donald Schön, was a popular reference amongst architectural researchers. It dealt with theories concerning feedback loops of experience, learning and practice – also known as "organizational learning" (Schön, 1983). But considering the technical, practical and commercial contents of the PhD project, these sorts of theories appeared difficult to apply as a framework for the intended studies. To situate the industrial PhD project within a scientific tradition, it appeared evident that there was a need for empirically based architectural methods and knowledge creation, where the collection and type of data, analyses through drawing, the assessment methods, the making of syntheses and suggestions through prototyping overlap. This iterative and mixed research process provides a deeper understanding that is built successively and can be assessed from a broader architectural perspective.

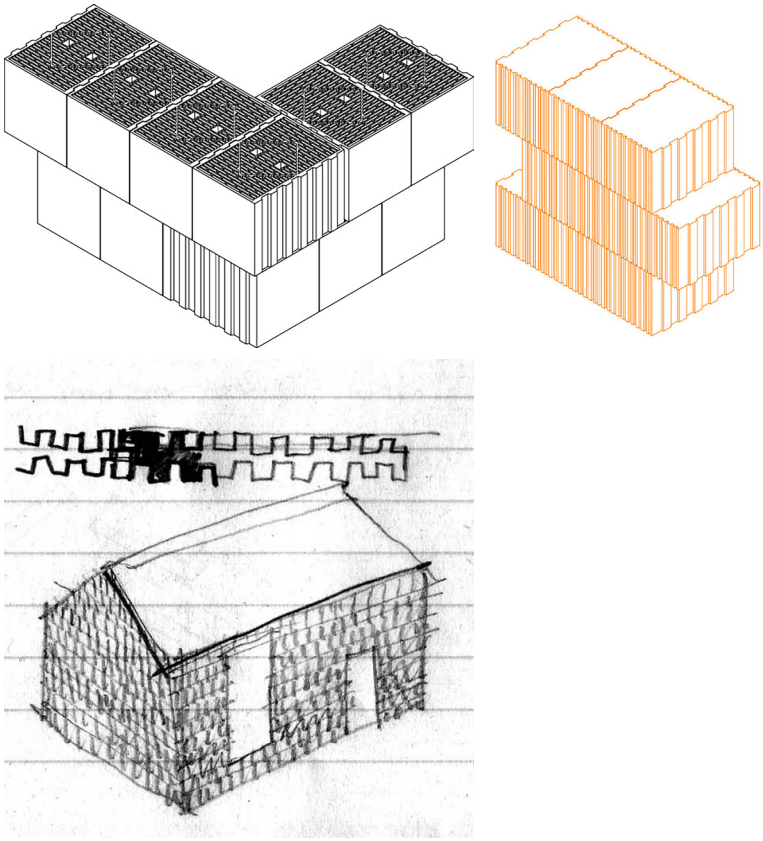


Figure 3
The porous block masonry must be covered with plaster or other windproof surface materials. During the work on the dissertation in question, our optics have changed from a search for the ideal undisguised block to a realization of the fact that if you deprive the block masonry of its cladding and develop its outer shell to be weatherproof, you also deprive it of its inherent freedom and intuitive nature. The homogeneous masonry block offers the ideal body as a basis for a cladding of any observance, and therein lies its force of architectural space-forming.

Formalizing a "new" research typology at an institutional level

Having no comparable models when it came to industrial PhD research rooted in an architectural school within a Fine Arts Academy and having no specific literature that treated similar topics in this new field meant that the theoretical framework, the type of knowledge, the methodology and terminology and the research culture all had to be developed from scratch and accepted within the institution and the professional environment.

At the time, the scientific traditions of civil engineering in Denmark only partly addressed the field of architectural research dealing with design practices and construction. Also, the research approach of civil engineering in building structures was, and still is, primarily based on mathematical models and technical analyses of physical performance, which is a very specialized approach when compared to the polyhistoric approach that characterises the architectural discipline. In addition, there were ongoing discussions about how to define the project within the general framework of R&D, referring to the three types of research activities defined by OECD: basic research, applied research or experimental development project:

> *Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. Applied research is original investigation undertaken to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.* (OECD, 2015).

The differences of these basic research definitions were all unknown to the business partners and therefore they had to be thoroughly explained. The project description ended up covering all three typologies in different parts of the project, which was considered uncommon from a traditional scientific standpoint.

Formalizing the research project in the business set-up through a built reference

Central to an analysis of industrial research are questions such as: who defines the research standards in industrial research – and why is this important? The mutual expectations to the research elements, results and impact on the business development had to be re-adjusted and aligned, not only in the critical phases of formulating the contents of the project application, but throughout the whole project, so as to secure the rigor of synthesis that emerged sometimes in unforeseen situations where many diverse types of experience and knowledge confronted the research design. For that reason, the "learning curve" of each partner of the project was very steep; this included not only the PhD student, but also the academic supervisor, the business supervisors and the PhD school at KA that represented the institutional framework of the PhD education in architecture.

An important aspect in researching is to ask questions and create transparency; however, it takes some effort to create that kind of culture in commercially driven enterprises. The task becomes very much about defining the contribution of the company and creating a meaningful framework for the collaboration, so that everyone understands their role in a quite diverse set-up.

The single-family house in block masonry designed by Nini Leimand & Kåre Rønne in 2004 represented a straight-forward, built reference that acted as a "platform" for the research design. The house was never meant to be a "development project" but, in this preliminary process of defining the research criteria, it became a helpful common reference. It acted as an existing result of mutual interest in implementing this unknown building technique and material product, seen from a manu-

facturing viewpoint. Also, from a teaching and research perspective, it could be applied for analysing and assigning best practice. The single-family house in block masonry was referred to as an "as built" case and acted as an important lever to formulate the research questions in the multidisciplinary group of stakeholders. But at the end of the research process, the working drawings and photos from this imbedded, tacit case study quite naturally ended up in the appendix of the PhD thesis (Leimand, 2008, Book 3, p. 115)

Industrial PhD in architectural practice compared to architectural development work.

Since the aim of the industrial PhD program is to mediate between theory and practice or academic and business interests, the project took its point of departure in research methods categorized as "architectural development work". These methods were integrated in a series of PhD projects hosted by the two Danish architectural schools (Pedersen, 1998; Jensen, 2001; Abraham, 2002; Nielsen, 2002). This sort of research method operates precisely in the alternation between "the drawn" (designed) or "the built" (the constructed), as well as the conceptual or theoretical / hypothetical. In the early years of 2000, this was a new research category or a sort of explorative research practice unknown to the formal bodies of research at the Royal Danish Academy of Fine Arts School of Architecture, and not comparable to general research traditions linked to the disciplines of building technology. Therefore, it was considered controversial and called for detailed description of research applications in this field.

Research theories and scientific concepts developed in relation to design have their origin in Anglo-Saxon design and art education. They circumscribe knowledge production defined by the characteristics of design methods, the creative act and aesthetic dimensions (Cross, 2001, p. 49-55). "Architectural development work" is associated with research methods such as Research by Design or Research through Design (Frayling, 1993, p. 5). However, when specifying a physical architectural structure or its material properties, fundamental questions can be raised when it comes to how knowledge and methods are defined, how they work and, not least, how knowledge and methods can be shared as common means to establish new theoretical grounds. Schön exemplifies this dilemma (most likely unintendedly), when defining a design-oriented research practice:

> *Reflection-in-action is an effective part of the design process [...] informed by the knowing-in-action and decisions of the designer throughout the process. The researcher is thus no longer constrained by pre-established theories, methods, or techniques, but can construct them anew for each individual case* (Schön, 1983, p. 68).

This definition suggests an open-ended experimental approach, which can be discussed and criticized from a technical, scientific perspective. In the worst case, it could lead to results based entirely on subjective opinions, since the questioning and methods are not "constrained by" any predefined or established "code of conduct". Therefore, Research by/through Design, applied as a methodology in Industrial PhD research that is technically oriented, requires remarkably well-defined standards in terms of transparency, rigor and critical analysis to avoid the pitfalls of subjectivity.

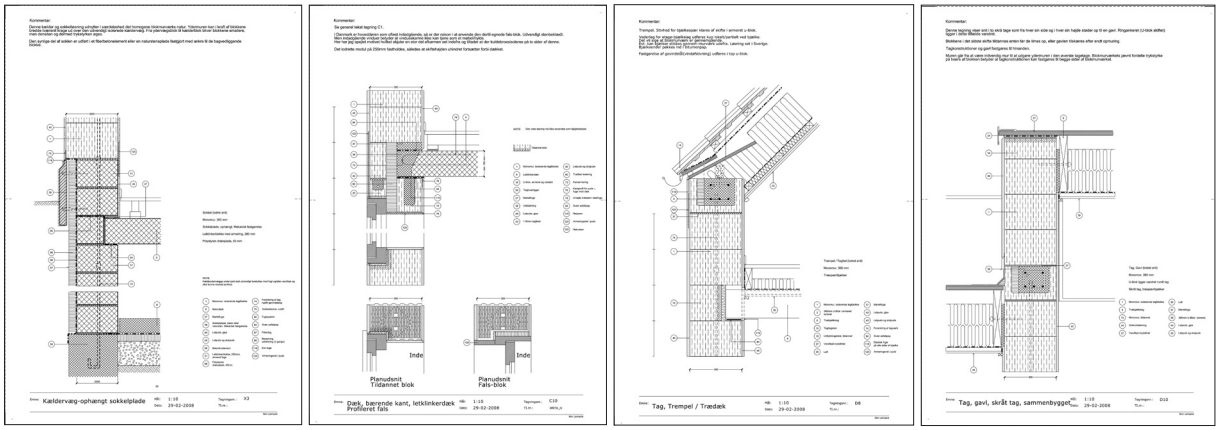
Drawings as tools for research analysis

An important milestone half-way through the project was when Nini Leimand proposed to develop and describe advanced construction details in continuation of general standard-block masonry details. Nini Leimand had served as a consultant helping to qualify these for "MUR-and-TAG" in the beginning of the research process. It gave the dissertation a direct approach and the stakeholders felt satisfactorily addressed, since "MUR-and-TAG" is part of best-practice regarding building technologies, and with which consultants within the building industry are obliged to be acquainted. Part of the MUR & TAG's technical archive concerning block masonry is created by the Lime and Brickwork Association of 1893 (called KT93), in collaboration with the Danish Concrete Industry Association's Block fraction (BIB) and H+H Celcon, and they have made approx. 800 drawings of typical wall and roof details (Mur & TAG, 2021).

Testing ideas, analysing problems and creating an edifice through concept sketches, drawings and technical diagrams is the "disciplinary language" of architects. Architects are trained in using these methodologies during their education and they are also applied in the architectural profession. Therefore, analysing hypotheses through drawing was integrated as a central research tool in the PhD project. The intention was to model the explorative nature found in the practice of architecture, which Nini Leimand had sought for since graduating.

The drawing as a communication tool was an appealing methodology that improved the transparency of the research process to the diverse stakeholders who also included engaged technicians, consultants in the field, engineers, colleagues, students, etc.

The porous poroton block is manufactured in and imported from Germany. Therefore, the obvious clash between Danish and German building legislation, design practice and culture of construction was a central challenge when BDS Architects and Leimand & Kåre Rønne respectively were to design their multi-story, residential housing project (1997) and the single-family house (2004). These differences were confronted, commented and analysed through drawing (including registrations and written accounts) throughout the research period, forming an amalgam of



development work and action research (Frayling, 1993, p. 5). This work process led to a series of illustrated construction principles that served as architectural reflections (e.g., historical, contextual, aesthetic aspects) on top of the technical observations and theoretical discussions of the thesis. In this way, the illustrated construction principles synthesized the purpose of the thesis, which was to set an example for block masonry in practice. Rather than the study of textual documents, the drawing as a condensed "statement of action" established a common research tool that all the relevant contributors could easily tap into.

Figure 4
Illustrations from the thesis BLOKMUR – MURBLOK showing 4 examples out of 34 technical drawings at the scale 1:10, on construction principles unfolding the architectural potential of block masonry structured into 5 categories: basement, foundation, openings, deck and roof.
SOURCE: LEIMAND (2008).

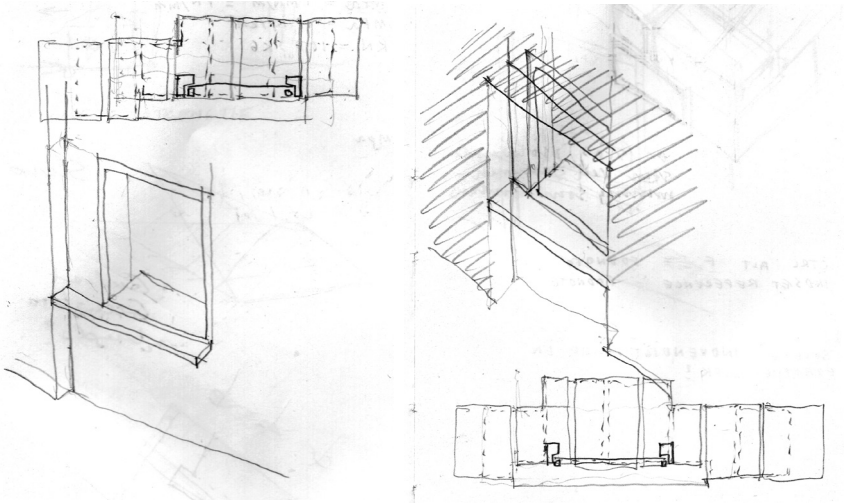


Figure 5
Sketches like these exploring the possible displacement of the block masonry, for example at window openings, reintroduced at meetings with the supervisors the former discipline of structuring parapets, struts, pilasters, etc., naturally imbedded in homogeneous masonry.

How to refine the business perspective in Industrial PhD projects?

Considering the business partners' high expectations to the commercial output of the project, the academic content had to be defined, protected and managed by the PhD student and the academic supervisor in ways that were not commonly applied in academic research practice. The scientific committee of VTU was (and still is?) highly aware of this dilemma, and their critique of the first PhD application regarding the non-academic commercial scope proved particularly important to the common understanding of a higher scientific goal. These circumstances led to the formulation of the second question we address in this article: *How can industrial research lead to original or critical findings, when research problems are "negotiated" with the business partners who are driven by commercial logic?*

The first version of the application for the Industrial PhD scholarship (handed in: 18.10.2004) was only partly accepted by the scientific committee at VTU. The commercial expectations of the industrial partners were criticized for being too narrow and lacking ambition on aspirations for society. Also, the project was regarded as an "industrial development project" instead of a "research project with a clear academic perspective". Furthermore, the proposed supervisors from Wienerberger AG and Maxit in Denmark did not meet the requirements of the academic level since they did not have satisfactory (academic) research qualifications. Therefore, they were not accepted.

In many ways, this was an embarrassing moment since it was a quite idealistic cooperation and represented the first attempt to invite the construction industry into the academic research setting at KA. However, it proved crucial to the common spirit and understanding that came to characterise the progression of the project and which is so important in any untested collaboration. Wienerberger AG and Maxit each had to turn to their hinterland and international parent companies and ask for researchers with a PhD degree who were willing to supervise the candidate in this already formulated project. This meant that most of the relevant capacities within the companies were informed about what was about to be launched and the supervisors were doubled up from the companies now coming from both Denmark, Austria and Germany.

The "missing category"

In many ways, the formal framework of the application process suffered from a "missing category." In the application template from VTU, the only boxes to tick were technology, agriculture/ veterinary, health, natural science, political science, business and humanities. The intended project that bridged the gap between architectural design, building technology and industrial business strategies clearly did not fit into the existing categories. But more importantly, the assessment committee did not

have any reviewers with an architectural (or design) background. These circumstances created several misunderstandings and resulted in submitting a revised application (second version: 21.12.2004) that was finally accepted. Furthermore, the assessment criteria listed in "the guidelines" for Industrial PhD projects (Innovationsfonden, 2019, p. 2) focused primarily on the commercial output:

> *The project can be within any research field if the project is of high research quality and has direct or indirect short or long-term commercial significance and effect. The project must have a clear commercial significance for and effect on the Danish part of the company and will be specifically assessed regarding:*
> - *The results' expected contribution to the company's business foundation and/or revenue*
> - *Plan and probability for implementation and commercial realisation of the results*
>
> *Please note that it is not sufficient that the project promotes or brands the company or serves as a lever for additional projects funds* (Innovationsfonden, 2019, p. 2).

These criteria are far from typical for researchers in the field of architecture. On the contrary, "criteria of success" in architecture and architectural research tend to address potential benefits for users/residents, communities, the natural environment, society, etc.

Longevity of commercial success goals

The section on commercial success goals in the accepted version of the application were not changed, despite the general critique of the first version for being too one-sided in favour of the commercial interests of the partners and lacking ambition regarding aspirations for society as such. Instead, we, the PhD student and the academic supervisor representing the research institution, benefited from the momentum and reformulated the project description including the general objective of the project from being an "industrial development project" to a research project with a clear academic perspective. The commercial success goals stated in the second version of the application were as follows:

> *Sharpen the architect student's "and thus the future architect's" understanding of homogeneous structural forms as well as the necessity and potential of a continued development of new (homogeneous) brick products and the walled tradition.*
>
> *Until now, the tile blocks have been imported from Germany and have therefore been designed in accordance with the German building regulations, German masonry dimensions and lower insulation requirements than is the case in Denmark. The candidate intends to analyse*

the basis for an imminent start-up of a Danish production and to help optimize the brick block for the Danish building tradition.

In addition to the technical and architectural potential of the block wall, this is, after all, a very competitive construction technique. As is well known, new construction in Denmark is disproportionately expensive compared to, for example, our neighbouring countries, which is also a considerable incentive to build a Danish competence within the block wall (Leimand, 2004).

Frequently during the PhD period, we experienced that if the companies had based the spending of this research project on their advertising budget instead of their "new initiatives" budget, it would have provided more focus on the research framework. When situating it within the sales department, or even better the technical department, the project could have helped in answering the questions with which architectural colleagues confronted the companies' salesmen regarding this, in Denmark, unknown poroton block. As former customers of the Danish department of Wienerberger AG, we had in each our own way experienced the lack of systematic and technical knowledge in the Danish sales department regarding block masonry. Their primary focus was to guide customers about the surface quality and colour of bricks and rooftiles; a logical consequence of masonry being reduced to a self-supporting weatherproof surface following the oil crisis in the 1970s. To supply professional support about loadbearing and insulating ceramic block masonry, as introduced in Denmark by *BDS Architects* in 1995-97, called for in-house technical knowledge in the Danish department of Wienerberger AG. The industrial PhD project in question became a temporary platform for this service, but it also acted as in-house knowledge. To conclude, it was not a very robust business strategy.

Final discussion

Due to the uncertain circumstances that framed the Industrial PhD project, the third question to highlight was evident when discussing the background of the article: *How can industrial research enhance academic knowledge production without compromising it?*

The early years of the Industrial PhD program included a special Industrial PhD business course organized by the Danish Ministry of Science, Technology and Innovation. The research fellows would automatically be invited to participate in the course in their second project year. The course covered areas such as: project management, organization, cooperation, business economy and entrepreneurship. Furthermore, the course prepared the PhD fellow for writing a business report, which was a mandatory part of the Industrial PhD Program. According to the formal guidelines, the business report formed an integrated part of the

Industrial PhD Program and constituted a part of the research fellow's obligation to disseminate knowledge.

> *The purpose of the business report is to document the Industrial PhD fellow's perception of the commercial aspects of the completed project and his/her ability to link practice with theoretical issues. Thus, the business report accounts for the potential applications and development opportunities that the PhD dissertation represents to the enterprise. The business report must be submitted six months prior to finishing the programme* (VTU, 2004, p. 9).

Nini Leimand remembers finding it hard to commit to this research task at that time. But looking back, it worked well to get a deeper insight into the host companies and a formalized reason to ask for their business strategies regarding future focus. Furthermore, how was their business strategy going to be aligned with the adjusted ambition concerning the initiated Industrial Ph.D. study and its expected impact etc.? The business report also worked as an internal adjustment of expectations and represented a clear platform for dealing with potential commercial issues and, not least, securing that these did not interfere with the academic contents of the dissertation. For a limited period, it forced the academic "bridge-builder" (Nini Leimand) to use an unknown language and to study methods familiar to the business partner.

Dissemination of knowledge

To disseminate the project results to the business partners throughout the PhD period was a cornerstone in the Industrial PhD program and still is today. In VTU's official guidelines, Chapter 6.4 "Communication Commitment", it states:

> *The obligation to disseminate knowledge imposed upon all PhD fellows is fulfilled by, e.g., project supervision of university students, participation in conferences by contribution of discussion papers, publication of research articles and enterprise briefings* (VTU, 2004, p. 7).

> *In a Danish PhD program, the student must gain experience in the dissemination of knowledge related to the PhD project, cf. the PhD Order, Chapter 3, § 7. The dissemination may consist of articles, lectures, teaching and other knowledge exchange in the company, university or elsewhere. The extent, nature and content of the dissemination of knowledge are agreed between the company, the student and the university. Industrial PhD students are not employed at the university and therefore have no agreement-based teaching obligation. However, if all project partners agree, teaching at the university may be part of the dissemination of knowledge. All dissemination activities should be agreed upon in the project* (VTU, 2004, p. 9).

Why is it not required to give lectures at the university (KA) while conducting an Industrial PhD was a question that occurred during the PhD study? Amongst other dissemination channels it is extremely important at an academy/Architectural School to share your findings and doubts in truly diverse forums among teaching professors, professors, students, etc. To ensure the research quality and the aspect of "transparency" are key factors to be understood and accepted by the industrial partner. As such, the supervisor at the research institution has a great obligation to manifest this agreement before signing the application and research plan to ensure this sort of dissemination and quality check can take place.

Figure 6
PhD Thesis – 3 volumes (2008) – Block Wall – Wall Block: The simple nature and architectural potentials of the clad block wall. (BLOKMUR – MURBLOK: Det beklædte blokmurværks enkle natur og arkitektoniske potentiale). Front pages of the 3 books.
SOURCE: LEIMAND (2008).

The question of language – who's the audience?

The Danish Industrial PhD program requires that the hosting "business enterprise" must be situated in Denmark. However, if the company language is Danish, it might be an obstacle for the staff to read/engage with English that is the preferred language in research and science. The fact that international research language is English, but Danish companies in general prefer Danish, is a difficult dilemma imbedded in the Industrial PhD framework.

The target group might also be diverse. In the PhD thesis that ended up with the title: BLOCK WALL – WALL BLOCK, this circumstance resulted in three individual parts/booklets, each directed towards a different audience: academia, manufacturers, practicing architects and engineers. Thus, at the highest level, Part 1 (The simple nature and architectural potential of the cladded block masonry) holds a description and discussion of block masonry and many ways of understanding its limitations and its potentials. Part 2 (Type of blocks and surface treatments) has historical and technical information on the various block types, their structural and physical advantages and disadvantages. Part 3 (Construc-

tion principles of block masonry) aims at evaluating block masonry with respect to gravity, the climate and the residents, unfolding 34 drawings at the scale of 1:10, structured into 5 categories: basement, foundation, openings, deck and roof.

As stated above, the highest goal within the Industrial PhD initiative is to mediate and transfer knowledge between theory and practice. This ought to be addressed throughout the project period. The intention was to make the three parts of the thesis mutually independent to make sure that this type of industrial research could supplement and enhance the academic knowledge production without compromising it. At the same time, the intention was also to tempt the reader, regardless of his/her practical or theoretical interests, to examine all three of them.

The importance of physical presence

The work schedule of the Industrial PhD fellow should involve alternate presence at the enterprise and at the university/research institute. The parties must agree to divide the student's time in a way that fits the project and creates a relation with both the company and the university (Innovationsfonden, 2019, p. 9). It may come across as a practical and simple problem, but it had significant mental implications. Also, it requires great integrity and professional confidence of the PhD student to balance this. In many companies, employers are measured by their efficiency and presence. As a researcher at a university, it is legitimate to go 'into exile' to get concentrated peace for one's work. In other words, the two cultures can be vastly different. It is also an expense for both the company and the research institution to have vacant workplaces.

As an architect in the role of as an Industrial PhD fellow hired in a company within the construction industry, you are likely to be the first one! As such, you will typically have to prove the relevance of the project from the very beginning. The work process showed it advisable to report continuously in a logbook to the parties involved on how you have spent your research time during the past week. However, we believe it is a general recommendation to PhD fellows to acknowledge the fact that doing research is never ending! It meant that every Monday, Nini Leimand submitted the status of the past week. A project group meeting as well as individual supervisor meetings were held every third month. The benefit of being part of "the real world", as an Industrial PhD student, is that it is difficult to get lost in an isolated research cell, forgetting the purpose of the project.

Conclusion

Since the founding of CINARK in 2004, the research centre has strived to conduct industrial research of various sorts: Leimand (2008), Jerl Jensen (2011), Manelius (2012), Greisen (2012), Johansson (2017), Sundahl (2019), Munch-Petersen (2020), Thorup (not yet completed), Nielsen (not completed). The Industrial PhD Program has been a formal framework and shaped core activities through which CINARK has developed important insights into organizational, professional and cross-disciplinary aspects of the construction industry. These activities have pushed the architectural research perspective and have inspired the testing of new collaborative formats, topic definitions and clarifying of potentials.

In 2014, KA was totally reorganized, and the architectural school is still under "dimensioning" (38% reductions during the period from 2016-2023). Despite this tumultuous period, seven Industrial PhDs have been defended positively since 2004, two stipendiums are still active and two are presently being negotiated. Up until now, KA has been involved in altogether 31 Industrial PhDs, of which 11 are still active. 21 of the total 31 are affiliated with the School of Architecture (which eventually means that CINARK has been responsible of 1/3 of all the Industrial PhD candidates at KA).

In addition, CINARK has hosted a series of collaborative PhD projects together with industrial partners. They have been arranged in diverse organizational set-ups and with financial models partly supported by private funds. In these set-ups, the industrial partners have played a comparable role to the formal, national Industrial PhD Program. However, due to the character of their funding sources, the industrial partners have not had a similar decisive influence on the contents or the process of the PhD study or, more importantly, the priorities of the PhD student. Also, these PhD students could move more freely between academic environments, studies abroad and decide in which way they should engage with their collaborative partners. The diverse but still related types of business-oriented PhD projects in the research centre have nurtured one another content-wise and broadened the notion and culture of practice-based research in architecture, e.g., Sattrup (2012), Vibæk (2012), Schipull Kauschen (2014) and Thyregod (2022).

As a part of a pioneering research environment and responsible for KA's outreach to the construction industry, these business-oriented PhDs have dealt with central problems in the building sector and have acted as essential research activities in the centre. In a broader perspective, the industrial research activities were challenged by the fact that they had to include general elements of KA's strategic research plan that was agreed upon at the time with the Ministry of Culture.

It was a challenge that these collaborative set-ups also represented new grounds in terms of institutionalized professional collaboration, ways to create knowledge and formal standards defined by VTU. For that reason, there was no existing experience to draw upon in the KA administration, but more importantly there were no specific PhD courses for industrial PhDs in architecture to attend (Nini Leimand was involved in planning the PhD course: "Videnskabelighed på Arkitekturens gebet – grundlæggende PhD-kursus" (KA, 4 ECTS) / "Science in the practice field of Architecture – basic PhD course").

In that sense, both the PhD students and the supervisors that pioneered the first couple of Industrial PhD projects in the field of architecture / building construction at KA had to define the scientific framing of the projects and find ways to formalize the collaboration, while referring to the directions of VTU. The directions included detailed specifications of time spent in the companies or with the university, specific milestones, results, academic PhD courses, business-oriented courses and finally the *Pilot Business Report*.

Half-year reports that documented the progression of the project according to specified benchmarks also had to be approved by VTU. However, what felt disturbing and intimidating in the beginning of the 3-year framework proved to create a reassuring backbone and approval of the research standard. A backdrop from which uncertain research questions could be posed without causing unproductive resistance from the business stakeholders.

Today, architectural researchers are expected to constantly broaden our professional network and bridge the so-called "gap between theory and practice". As academics, we are expected to be oriented towards the business world more than ever. This understanding clashes with classical academic definitions about knowledge production and higher education, where students are trained to improve their intellectual skills that equip them to think and act critically. To address and handle this sort of clash, in the very beginning of the cooperation between the stakeholders involved in an industrial PhD, is crucial to enhance academic knowledge production without compromising it. The mandatory business report, which was taken out of the Industrial PhD Program after 2008, was time-consuming; but seen in retrospective it was worthwhile. Some other form of formal calibration of expectations should stay but should achieve the best framework for a mutual understanding and an open-minded and trusting workflow.

Today, teaching activities at KA must include the following three measures: *Science, Art* and *Practice*. In a recent survey, the researchers and practitioners teaching at KA define their work as follows: 33% research, 17% research-by-design and 50% practice. In 2019, KA conducted an

Education Statement asking employees how they define their work. It showed that many define themselves as both practitioners and scientific researchers. Regarding this situation, Industrial PhD candidates have the advantage of being able to continue either within the academic environment or within the business area in which the research project has been rooted. This opens opportunities for new collaborations, since four of the Industrial PhD projects affiliated with CINARK have been hosted by architectural firms, two by manufacturers and two by an Approved Technological Service Institute (GTS).

Two weeks after Leimand had defended her PhD thesis on block masonry, Wienerberger AG in Denmark closed their technical consulting division, which she had been part of as a PhD student. Subsequently, without technical in-house knowledge on block masonry, this still unconventional building technique was set back to square one in the context of the Danish construction industry. The decision was made by the international parent group in Vienna. It was a big disappointment to all the parties involved in the PhD project. The year 2008 was marked by the worldwide fiscal crisis, and many external collaborations had to be paused or stopped during this period. Inevitably, the crisis also had profound impact on consulting companies, such as architectural firms and engineering firms in the construction industry, which meant that the newly hatched industrial PhD candidate gave up on resuming a career in practice and instead devoted herself entirely to an academic career. Since June 2008 when the portrayed dissertation was defended, Nini Leimand has given several lectures at KA on "block masonry" and has supervised students in courses and studios on the topic. The material topic, with the focus on applied building technology and tectonics, appealed very much to the students. She was therefore asked to take part in the planning of the technical courses (TEK1, TEK2, TEK3 and TEK4) offered by the department of Architecture and Technology (IBT).

Graduates familiar with especially the instructive "third book" of the thesis, *Construction principles of block masonry*, introduced the construction drawings (scale 1:10) to architectural firms as they started their professional career. This third book of the thesis synthesizes the original findings of this industrial research. They challenge, but also complement the approved standards of MUR-and-TAG (Mur & TAG, 2021) and make use of the same well-known graphics and signatures.

In 2010, the Danish National Broadcasting (DR) made a tv-series titled: *The Architect's Own House* (DR.DK, 2011). At first, Nini Leimand did not want to take part in the tv-series that appeared to be framed as a lifestyle program. But, when the producer realized it was an unknown building technique investigated in a single-family house in a Danish context and, not least, that it had resulted in an Industrial PhD, he insisted on bringing the reportage. "A Sober Way of Building" became the title of

the housing reportage, which also formed the core element of the interview and the presentation of the house. The industrial research project certainly became public overnight and resulted in clients writing to get advice about "block masonry" at least once a month. This paradoxical situation was not foreseen.

On the one hand, the industrial partners, who had invested in the project and who had gained direct expertise about the research project by educating the PhD student, did not have the resources to continue to build up and support their R&D department and technical consulting department in Denmark. Even though the companies did not have a defined research plan at the beginning of the arrangement, they had expressed clear aspirations in terms of using the accommodated knowledge. Also, they showed interest in continuing some sort of collaboration with the PhD candidate as well as the research environment CINARK / KA. But this was not formalized due to the disruption created by the fiscal crisis.

On the other hand, the tv-broadcast of the single-family house in block masonry and thesis' research findings that were directly accessible through the 1:10 construction drawings had sparked the interest of the public, as well as professionals in the construction industry. They all wanted more information. It is of course disappointing that just before the companies involved reached momentum of getting commercial benefits of their "research-investment" they dropped the very platform that could have consolidated the use of block masonry. In this case, it ended up with no discrepancies between the academic "duty" to create original findings and the business interest in framing commercial benefits.

References

Abraham, A. (2002). *En ny natur – 9 arkitektoniske tilstande mellem flydende og fast* [PhD thesis]. Kunstakademiets Arkitektskole, København.

ATV (2022) *Om ATV* [Online]. Available at: https://www.atv.dk/om-atv (Accessed: 1 September 2022)

Beim, A. (2003). Tag over hovedet på 5½ uge! *Tegl*, (4), 8-11.

Cross, N. (2001). Designerly ways of knowing: design discipline versus design science. *Design Issues, 17*(3), 49-55 [Online]. Available at: http://oro.open.ac.uk/3281/1/Designerly-_DisciplinevScience.pdf (Accessed: 8 March 2020)

Dahl, T., Lundgaard, B., Sørensen, P., & Villaume, R. D. (1990). *Idekatalog – en samling af udviklingsprojekter til fremme af det murede byggeri i Danmark: 20 projektbeskrivelser til MURO's projekt "Murværk år 2000"*. København: Kunstakademiets Arkitektskole.

Dahl, T., Sørensen, P., & Beim, A. (1992). *Den hule mur: et udviklingsprojekt*. København: Kunstakademiets Arkitektskole.

Dahl, T., Beim, A., Sørensen, P., Nørbak, C., & Nicolaisen, O. (1997). *Homogen mur – et udviklingsprojekt: Mølletorvet i Slagelse*. København: Eget Forlag.

DR.DK. (2011). *Arkitektens hjem: Nini Leimand: Ny nøgternhed* [DR_K, TV-series episode, 01.12.2011]. Producer Jan Haugaard.

Frayling, C. (1993). *Research in art and design*. London: Royal College of Art. [Online]. Available at: https://researchonline.rca.ac.uk/384/3/frayling_research_in_art_and_design_1993.pdf (Accessed: 8 March 2020)

Greisen, J. R. (2012). *Arkitektoniske muligheder ved robotfabrikerede støbeforme i betonbyggeri* [PhD Thesis]. Kunstakademiets Arkitektskole, København.

Innovationsfonden. (2019). Retningslinier for Erhvervs-ph.d. Retrieved from: https://ufm.dk/en 28.05.2020

Innovation Fund Denmark. (2022). *Viden om Erhvervsforskerprogrammet*. [Online]. Available at: https://innovationsfonden.dk/da/programmer/erhvervsforsker#accordion3224 (Accessed: 1 September 2022)

Jerl Jensen, M. (2011). *Revitalisering af teglmuren* [PhD Thesis]. Kunstakademiets Arkitektskole, København.

Jensen, T. B. (2001). *Murstenens ornamentale vilje* [PhD Thesis]. Kunstakademiets Arkitektskole, København.

Johansson, J. (2017). *Bæredygtighed i danske almene boliger: Med et brugerfokus* [PhD Thesis]. Det Kongelige Danske Kunstakademis Skoler for Arkitektur, Design og Konservering, København.

Knudsen, H. (2012). *Visioner, viden og værdiskabelse: En historie om Akademiet for de Tekniske Videnskaber*. København: ATV – Akademiet for de Tekniske Videnskaber. http://www.atv.dk/da/publikationer/projekter/75-ars-jubilaeum

Leimand, N. (2004). *Ph.D. application,* Second version, 21.12.2004, The Royal Danish Academy of Fine Arts, School of Architecture. (Not a public document)

Leimand N. (2008). *Blokmur – Murblok, det beklædte blokmurværks enkle natur og arkitektoniske potentiale* [PhD Thesis]. Kunstakademiets Arkitektskole, København.

Manelius, A-M. (2012). *Fabric formwork: Investigations into formwork tectonics and stereogeneity in architectural constructions* [PhD Thesis]. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Copenhagen.

Munch-Petersen, P. (2020). *Circular facade design: The tectonics of circular economy* [PhD Thesis]. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Copenhagen.

Mur & tag. (2021) *Om mur- tagdetaljerne* [Online]. Available at: https://www.mur-tag.dk/mur-og-tagdetaljer/om-mur-tagdetaljerne/ (Accessed: 16 October 2019)

Nielsen, A. G. (2002). *Materialeæstetik – en undersøgelse af krydsfiners æstetiske potentialer* [PhD Thesis]. Arkitektskolen i Aarhus.

OECD (2015) "Concepts and definitions for identifying R&D". In *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development*. Paris: OECD Publishing. [Online]. Available at: DOI: https://doi.org/10.1787/9789264239012-4-en. (Accessed 16 October 2019)

Pedersen, C. P. (1998). *Arkitekturens dynamiske formdannelser* [PhD Thesis]. Arkitektskolen i Aarhus.

Sattrup, P. A. (2012). *Sustainablity, energy optimization, daylight and solar gains* [PhD thesis]. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Copenhagen.

Schipul Kauschen, J. (2014). *Bæredygtige systemleverancer ved renovering: Ressourcer. Økologi. Nødvendighed* [PhD Thesis]. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Copenhagen.

Schön, D. (1983). *The reflective practitioner: How professionals think in action*. London: Temple Smith.

Sundahl, S. (2019). *Materialeadfærd* [PhD thesis]. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Copenhagen.

Thyregod, T. (2022). *Concept of façade: With daylight at heart* [PhD Thesis]. The Royal Danish Academy, Copenhagen.

Vibæk, K. S. (2012). *System structures in architecture: constituent elements of a contemporary industrialised architecture* [PhD thesis]. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Copenhagen.

VTU. (2004). *Chapter 6.4 "Communication Commitment"* [Online]. Available at: https://ufm.dk/en (Accessed: 10 October 2019)

Biographical information

Anne Beim, Architect MAA
MA in Architecture, PhD in Architecture
Professor, Head of CINARK – Center for Industrialized Architecture,
Head of Candidate Program: Settlements, Ecology & Tectonics, SET
Institute of Architecture and Technology, IBT
Royal Danish Academy, Architecture
Institute of Architecture and Technology, (IBT)
Address: Philip de Langes Allé 10, 1435 Copenhagen, Denmark
Phone: +45 6013 1506
E-mail: anne.beim@kglakademi.dk

Anne Beim (b. 1964) is MArch and PhD in Architecture and Professor at The Royal Danish Academy. Since 2004 she has been Head of CINARK – Centre for Industrialized Architecture. Primary research topics are Tectonics, Industrialized Building Culture and Ecology, and her book, Tectonic Visions in Architecture (2000) now form part of curriculum in Scandinavian architectural programs. Since 2014 she has been Co-Head of IBT's candidate program: Settlements, Ecology & Tectonics..

Biographical information

Nini Leimand
MArch. in Architecture, Industrial PhD in Architecture, Associate Professor
Head of Bachelor Program: Architecture's Anatomy and Fabrication, AAF
Royal Danish Academy, Architecture Institute of Architecture and Technology, (IBT)
Address: Philip de Langes Allé 10, 1435 Copenhagen, Denmark
Phone: +45 41701748
E-mail: nleim@kglakademi.dk

Nini Leimand (b.1970) is MArch and Industrial PhD in Architecture and Associate Professor at the Royal Danish Academy. Since 2008 she has been part of CINARK – Centre for Industrialized Architecture. Her main topic is applied construction.

Since 2014 she has been Head of IBTs Bachelor Program: Architecture's Anatomy and Fabrication, AAF.