Increased use of ruins through secured masonry and comfortable climate

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Abstract

This paper presents a unique scientific research project, funded by the KK-foundation in Sweden together with several companies participating in the project. A primary goal is to find methods to examine and take care of open masonry constructions thereby enabling an increased use of them in a safe and comfortable way without diminishing their cultural values. A second goal is to establish a long-term cooperation/network of researchers, conservators, engineers, antiquarians and craftsmen that can keep and develop the knowledge. The project takes place in year 2010 and 2011. This paper presents a model of cooperation as well as the ongoing experiment and expected results.

The project is divided into three major parts:1) Description and assessment of historic masonry as load bearing structures. 2) Assessment of stone and mortar in old masonry and finding the methods to secure and preserve them. 3) The climate in the ruin with respect to comfort and preservation.

The goals for the different parts of this research project are to find the best possible solutions of how to: a) Evaluate the construction of complex masonry structures to enable new additions that are appropriate with respect to statics. b) Find efficient methods to evaluate and conserve the status of the materials (stone, mortar) and walls in old masonry to grant safe accessibility. c) Create a comfortable climate in an open masonry structure without closing it.

These three research areas all focus on the historic masonry which at the same time forms the climate shell, the bearer of plaster and the historical setting to the activities that are to take place in the ruin.

Introduction

This paper presents a unique scientific research project taking place at Gotland University in Sweden, funded by the KK-foundation together with Tyréns AB, Gotland Museum, Bygg-nadshyttan på Gotland, WSP Environmental AB and Exners Tegnestue A/S.

A primary goal is to find methods to examine and take care of open masonry constructions thereby enabling an increased use of them in a safe and comfortable way without diminishing their cultural values. A second goal is to establish a long-term cooperation/network of researchers, conservators, engineers, antiquarians and craftsmen that can keep and develop the knowledge.

The ruin of St Nicolas in Visby is serving as the principal case study in this research project. The ruin has been used as a cultural venue for more than 100 years. Severe defects concerning masonry, accessibility and comfort must be dealt with in order to facilitate an extended and sustainable use. The aim is to create opportunities for the ruin to function as a spectacular cultural arena all year around without destroying the historic document in the materials and constructions or the ruin atmosphere and the high cultural values.

In the preliminary study made for the St Nicolai-project it has become clear that there is a lack of experts who can deal with the particular problems of ruins. A cluster of researchers, craftsmen, archaeologists, historians, engineers and antiquarians is needed in order to develop, maintain and distribute the required knowledge. The St Nicolai project is a unique chance to perform scientific research, in situ experiments and collaboration between historians, technical researchers and practitioners. It will create a link between medieval history and modern technology with an increased possibility of using the historic monument. Furthermore it will set an example of how to deal with historic monuments in the need of restoration or modification. In order to make the knowledge available to a broader public St Nicolai will be used as a demonstration object as well as a research object.

The companies involved in this project aim to develop their cultural heritage profile, enabling growth in terms of services and products. Through collaboration, research findings are expected to lead to new knowledge and know-how that can be applied in all kinds of historic buildings.

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The goals for the different parts of this research project are to find the best possible solutions of how to:

- Evaluate the construction of complex masonry structures to enable new additions that are appropriate with respect to statics.
- Find efficient methods to evaluate and conserve the status of the materials (stone, mortar) and walls in old masonry to grant safe accessibility.
- Create a comfortable climate in an open masonry structure without closing it.

2 Methods

In order to secure the future of the ruins and their possibilities there is a need for increased knowledge about historic constructions and their materials in general and how to make those environments more comfortable and safe for visitors in particular.

The research is being carried out in three parallel projects as described in detail below. These projects are being kept together by the project-coordinator who is responsible for the overall issue on how to enable a safe use of ruins without diminishing their cultural values.

2.1 Historic Masonry Structures as Load Bearing Structures

Structural evaluation is one of the determining factors in the preservation and use of the built cultural heritage. It can be related to evident damages that need repair and reinforcement or that the building is about to get a new use with new prerequisites for the structure. In a ruin issues such as strength, durability and safety are put to their head.

There is a need for more research in order to develop a practical and applicable method-logy for analysis of historic masonry structures and buildings that are used and reused.

In Sweden research on the structural behaviour of historic structures has been carried out at Chalmers university of Technology (Olsson 2005, Thelin 2006). The research has mainly considered historic roof structures but the general methodology is applicable to different types of structures. Little or no research has been done on historic masonry buildings as load bearing structures.

International research on the structural behaviour of historic masonry structures have been carried out on several places. The work by Professor Jaques Heyman is an im-

portant contribution (Heyman 1995). Examples of current research projects are the Masonry at Massachusetts Institute of Technology, the Masonry at Building Materials and Building Technology program at Katholieke Universiteit Leuven and Department of Architecture and Civil Engineering at University of Bath.

The industrial and scientific research problems are:

1. How can specialist in structural engineering make sound assessments on historic masonry structures based on modern analytical methods in a practical and applicable way?
2. How can the complex geometry of historic vaults be described and managed?
3. How can the uncertainties regarding material, material composition, load etc. be handled?
4. What kind of computational models and what type of software is to be used for computations of historic masonry structures?

Description of the scientific approach to the problem addressed:

1. Assessment of historic masonry structures: A survey and summary of present knowledge to identify relevant research and methods used in the analysis and assessment of historic masonry structures. (Block 2009, D'Ayala 2007, Erdogumus 2004, Ochsendorf 2006)
2. Capture geometry: A recurrent problem in the analysis of vault structures is how to describe the geometry. Research and development on the use of laser scanning and photogrammetry (Schueremans and Vangenechten 2008).
3. Building investigation: Defining methods to describe and analyze cracks and deformations of the structure to identify its structural behaviour and to verify computations and other analysis that are carried out. (Fielden 2003, Beckman and Bowles 2004, Forsyth 2008).
4. Accounting for uncertainties: To find a procedure to handle uncertainties regarding materials, geometry, foundations, connections etc. will provide better basis for an objective way to assess the safety. To transfer probabilistic analysis of structures used for advanced modern construction to the analysis of historic masonry structures in order to account for uncertainties. (Schueremans 2001, 2006, Schuereman, Van Gemert and Smars 2001, Schueremans and Verstrynge 2008).
5. Computational models and calculations: To develop the use of advanced 3d-computations with regard to the particular conditions of historic masonry structures with very limited strength in tension. Limit analysis to assess stability and cracking patterns of the structures. Resulting in a geometrical factor of safety and reaction forces which load underlying structures as well as a description of the structural behaviour of the building.

2.2 The materials of stone monuments

In order to preserve the materials of masonry structures the physical properties of existing stones and mortars must be well known. When studying the materials of a ruin both the original materials, old repair materials and future repair materials must be analyzed and studied. The conservation and repair of Swedish lime stone and lime mortars has not yet been evaluated in a scientific way and the methods used are not adjusted to the existing materials.

The latest research in Sweden concerning stone conservation (Myrin 2006) and traditional mortars (Balksten 2007) has shown the importance of understanding both original materials and repair materials in order to find proper conservation measures and correct craftsmanship. Many examples can be shown where the repair methods and materials chosen can cause damage to the construction in the long run and the need for evaluation, new scientific knowledge and the spreading of research are acute.

The international research made on historic mortars and conservation of stone is mainly made in laboratories which seldom reflect actual problems leading to proper restorations. One important factor for success is the collaboration between craftsmen and scientists.

The industrial and scientific research problems to be addressed are:

1. Which methods can be used in order to define the composition and status of stones and mortars in old masonry and which restoration/conservation methods and materials is to be used in order to secure and preserve them?
2. Where new materials must be added, which materials and methods are proper to use in order to prolong the expected lifetime of the construction?
3. How must the craftsmanship be performed in order to create durable solutions for restorations of historic masonry?

Description of the scientific approach to the problem addressed:

1. Conservation methods for ruins: A summary of different methods, materials and techniques used to preserve and maintain ruins, presented in international research. Experiment and evaluations will be made in laboratories and in situ. (Moropoulou et al 2000, Moropoulou et al 2000, Papayianni 2005, Ashurst 2007)
2. Building investigation: Define deterioration problems, identify different materials and their specific needs for conservation.
3. In situ experiments: Application of conservation methods and developing adjusted methods and materials for the case study of St Nicolai. Evaluation of craftsmanship in conservation and restoration methods.
4. New materials for covering masonry: Identify and evaluate the methods and materials used since early 20th century. Identify the need of material properties and try them on the object of St Nicolai, evaluate (Ashurst 2007).

2.3 A comfortable climate in a ruin

Comfort is defined as »that state of mind which expresses satisfaction with the indoor climate«. Thus comfort, as perceived by an individual, is a complicated interaction between the body, the mind and the environment. Providing comfort in a ruin adds yet another element; the preservation and perception of cultural heritage.

The indoor climate in a ruin will, by necessity, be determined as compromise between numbers of conflicting factors. The objective is not only to extend the knowledge on indoor climate and comfort science in general, but to investigate the compromise itself. The research on climatisation of ruins is very limited. Mostly one would have to extrapolate from studies on historic buildings, in particular churches. The European project »Friendly heating« provides an evaluation of different heating systems for churches, where a compromise must be made with respect to comfort, preservation and energy efficiency. The project also proposes a system for radiative heating that will provide comfort with a minimum disturbance of the natural indoor climate and low energy consumption. Schellen (2002) and Limpens (2006) have made similar investigations on church heating systems in general and radiative systems in particular.

The effect of air motions on comfort is extensively covered in the literature, but the conditions in ruins are rather extreme and more research is needed to cover both negative and positive effects of air motions.

The industrial and scientific research problems to be addressed are:

1. What is the preferred/indoor climate (taking into the account the full complexity of this question)
2. How can we achieve no 1 with a minimum intervention and energy consumption?

There is both a scientific and commercial value in addressing these questions.

Description of the scientific approach to the problem addressed:

1. Thermal comfort in ruins: A summary and evaluation of present knowledge in relation to ruins. Experiments in lab and in situ to gain a better understanding of comfort in typical ruins. The present project will deal with a domain of parameters yet not covered in research (Fanger 1970).
2. Tempering the climate by radiation: Radiative heating can be used to temperate a ruin. Simulations end experiments will be carried out in order to develop and evaluate solutions that are energy efficient and inobtrusive, (Camuffo 1998, Schellen 2002)
3. Simulations and experiments on air motions: Air movements due to the wind often have a negative effect on the comfort and they need to be limited. Warm air currents can be used to enhance comfort. By the use of advanced simulations, a number of different schemes can be evaluated. As a complement to the simulations, measurements will be made in situ.
4. Compromise, decisions strategies and risk management: This is the cap stone research task; it uses the input of the other tasks in order to come up with a compromise that is acceptable from all points of view. Rather than working with a continuous, and infinite, spectrum of possible solutions we will start with two extreme cases; minimum intervention and maximum intervention.

3 Results

The goals for the different parts of this research-project are to find best possible solutions. An expected outcome is that the St Nicolas Cultudral in Visby will be designed and built in accordance to the research results emerging from this project and it can be evaluated for a long period of time. It can also set as an example for other similar objects.

Historic Masonry Structures as Load Bearing Structures: The objective is to identify and develop an applicable method for advanced analysis of historic masonry structures in order to be able to describe the structural behaviour and to assess the safety of the buildings. This includes development of applicable methods in order to capture the geometry of historic masonry structures and turn it into usable information for structural analysis as well as to obtain values for the actual reliability of structures.

The materials of stone monuments: The investigations are to define analyse methods that can be used for:

- learning more about the historic materials, building archaeology and craftsmanship
- finding proper conservation methods adjusted to specific materials and structures.

The expected results are deeper knowledge about historic mortars and traditional building stones as well as new methods for conserving ruins. This part of the research is also involving and educating well trained craftsmen skilled in restoring fragile historic masonry and their materials.

A comfortable climate in a ruin: The general objective is to facilitate an extended use of the ruin by providing new knowledge and technical solutions. The expected results are:

- Adding to the knowledge of comfort science.
- Adding to the knowledge of air movements and radiative heating.
- Development, implementation and evaluation of new technical solutions.

These three research areas all focus on the historic masonry which at the same time forms the climate shell, the bearer of plaster and the historical setting to the activities that are to take place in the ruin.

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