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Research, Planning and Interventions Guide for Historic Roof Structures with Baroque Character

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Abstract Historic structures generally and historic timber (roof) structures especially are not included into structural engineering curricula, in Romania. Roof structures and timber structures in general were also for a long time totally absent from all from construction and architecture university and craftsmen tuition curricula. The information gathered by dedicated professionals should be offered to young professionals, or those seeking specialisation in built heritage conservation, in a structured way: guidelines / handbooks, to prevent non-professional approaches. The *Guide* is to be finished in 2010 as integrated part of the PhD thesis of structural engineer D. Makay, supervised by Professor B. Szabó: Transylvanian Baroque Roof Structures.

Keywords: Historic, Baroque roofs, research, conservation practice, conservation, retrofitting, guide

Introduction

The presented premises led to a wide lack of knowledge or experience concerning research, planning and execution of historic (baroque) roof structures' conservation. To proceed against it, parallel action is needed on all training levels, all for undergraduates, practicing specialists and trainers.

Even if circumstances have improved significantly in the last 20 years due to the achievements of built heritage specialists, local NGOs cooperating with British, Hungarian etc specialist organisations, there still is a lot to do. Practical and theoretical tuition in built heritage conservation (for craftsmen: carpenters, renderers, masons and stone masons; engineers, architects and university students) is offered by the BHCT, a training organised yearly since 2001 in The Built Heritage Conservation Training Centre-Bánffy Castle Bontida, Romania (http://www.heritagetraining-banffycastle.org 2004). The Postgraduate Course in Historic Building Conservation, launched in October 1998 at the Faculty of History and Philosophy of the Babes-Bolyai University, Cluj, offers post-graduate tuition to structural engineers, architects, art historians, archaeologists and other graduates interested in built heritage conservation (Szabó 2009).

As leading engineer of an ever-changing (mainly) young designer team in historic structure conservation, and as invited lecturers of the BHCT series, we face the need of a structured Guide (handbook) on research, planning and execution of baroque roof structure intervention.

Target Groups

The *Guide* is to serve mainly professionals with university and technical school background (as well as undergraduates), those who can create or read measured or technical drawings.

It targets all the professionals dealing with historic, baroque roof structures: I) from research (on site measures, assessment): architects, structural engineers, structural experts, to (II) intervention design (structural engineers, structural experts) and (III) execution (carpenters, site managers, technicians, structural engineers), including advice on maintenance after the reception of the conservation – retrofitting works. The first two chapters are designed to inform the larger public, including historic building owners.

Structure and Content

The seven main chapters can be grouped in three major directions **(I)** – Theoretical knowledge, research: (1) Introduction – Definitions of basic terms; (2) Typology and terminology of baroque roof structures in Transylvania; (3) Assessment of historic roof structures with baroque character; (4) Computerised modelling and instrumented testing; the 5th chapter actually can be considered already a transition towards: **(II)** Intervention design – (5) Structural analyses and diagnosis; (6) Interventions design (conservation / retrofitting / reinforcement / recommended engineering and carpentry details), and the last main group: **(III)** (7) Execution technologies and maintenance advice.

Figure 1: (a) Unprofessional interventions on a baroque roof structure, Unitarian church Bădeni, Cluj county; (b) Decay of the tiling – Reformed church, Kogalniceanu street

Although the law requires that all activities of research (assessment), planning and execution involving listed historic buildings (or buildings in protected areas) be carried out by ministry-certified experts, the acute crisis of such specialists leads to situations in which engineers with basic training apply ad literam the norms developed for new buildings to historic load-bearing structures, coming up with technical solutions that many times destroy the roof structure by irreversible over-consolidation, thus destroying historic values.

The other extreme is the lack of the research and planning phase, with “craftsmen” who can deal with almost everything, executing ad hoc “repair works” (Fig. 1)

Chapters on General Information and Research Issues (chapters: 1, 2, 3, 4, 5)

It would be desirable that all “common citizens” possess a general culture enabling them to identify the value (style) of the building they own, as well as to recognise a historic roof structure. The *Guide* is conceived to be a useful tool for this. It is also structured as a manual for undergraduates or professionals, helping them to describe, understand a historic (baroque) roof structure.

Introduction – Definitions of Basic Terms – The historic (baroque) roof structures are presented as integrated part of the:

Historic buildings (listed buildings – grade A or B, world heritage sites, buildings with historic character, main architectural styles of buildings that might include baroque roofs); their structural components: (historic) load-bearing structures, historic roof structures; sub-ensembles, main materials, roles within the building.

Definitions concerning the interventions on built heritage in the phases: (I) research (measured drawings, on site assessment, decay-survey, computer modelling, laboratory analyses, building archaeology research, structural expertise etc); (II) design and specifications for various intervention-levels: repair; conservation; retrofitting; consolidation and their background philosophies: the principle of minimum intervention, material and structural compatibility and / or innovative materials/ technologies; and (III) various levels of execution: carpentry repair, specific technologies; material specification and reception; traditional carpentry and engineered joining details; safety and protection measures during the execution; traditional and modern tools.

Historic roof structures with baroque character – definitions: geometry (roofs that can be divided into two plane linear-bar systems, spatial: spire structures), mechanical behaviour, geographic (costal / continental roofs) and time functions (roman, gothic, baroque and eclectic roofs).

Synthesis of legislation and norms concerning historic roof structures – international recommendations; European / Romanian norms, Romanian legislation: given as literature, as well as explaining the steps to follow in order to carry out intervention on historic (baroque) roof structures.

Typology and Terminology of Baroque Roofs in Transylvania – The designations of elements are presented using the example of an ideal, typical baroque roof with 10m span, 50.2º inclination angle (6/5 height / half-span ratio), encompassing the main compounding elements of these roofs organised in: main and secondary trusses and longitudinal bracing system (Makay 2008).

The mechanical behaviour of sub-ensembles and elements of baroque roofs is also explained. Transylvanian baroque roofs are classified according to 6 criteria grouped into three sets of codes (Makay 2008).

Assessment of Historic Roof Structures with Baroque Character Details of on site and auxiliary researches needed for structural assessment of a given baroque roof structure.

All interventions (except regular maintenance) start with the roof's measured drawing. The chapter gives the minimum necessary steps to deliver the measured drawing of a roof structure, as well as the techniques of: (a) traditional survey (hand sketches, techniques and tools); (b) geodesic survey (total station); (c) 3D laser scanning possibilities in roof survey. (Fig. 2) Specifications are given on constructing the ideal (not deformed) trusses, as well as details on deformation survey (3.2. – Survey of the deformed shape). A sub-chapter is dedicated to special techniques of spire survey.

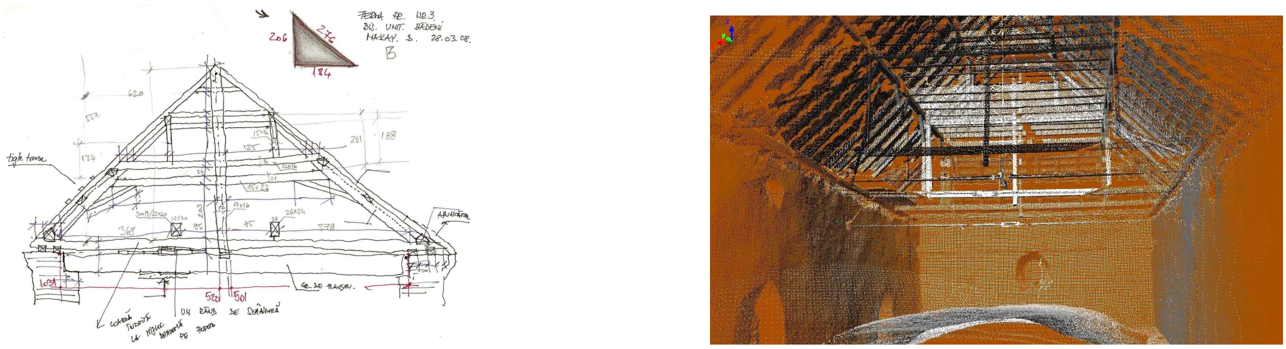

Figure 2: (a) Survey sketch; (b) 3D laser scanning (M & M Design, Leica HDS ScanStation2 owner: The "Gheorghe Asachi" Technical University of Iasi, ARHEOINVEST, Romania)

Special attention is given to the survey of the carpentry details – mortise and tennon joints, pegs / treenails, laps, combined joints (Fig. 3).

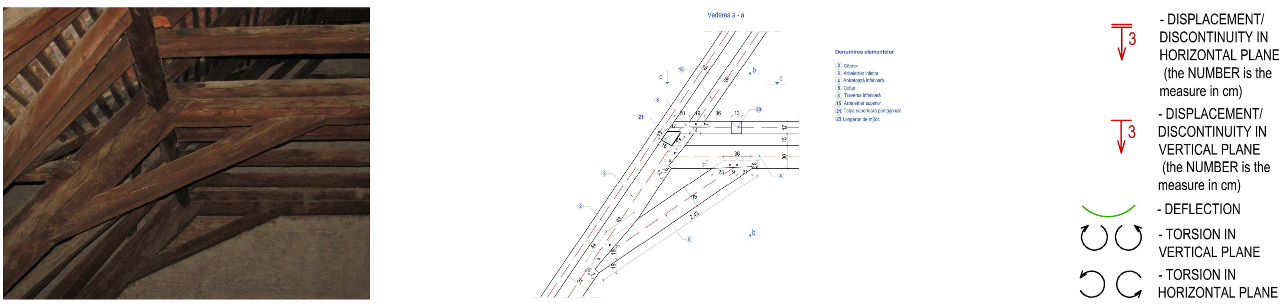

Figure 3: (a) Upper joint of a baroque straining system; (b) Detailed drawing of the same joint (Reformed church Kogalniceanu street, Cluj-N.; (c) Decay representation system

Survey of the decays and material properties. The chapter presents the various mechanical degradations (displacements in horizontal or vertical planes, lack of continuity, torsion, etc) and biological decays, as well as the their representation system. (Fig. 3) Biological decays are surveyed

within the building biology study carried out by a building biologist or timber restorer. For important roof structures, the timber strength and elastic modulus is identified by laboratory analyses.

Attic spaces can be dangerous: generally there are no maintenance platforms on the tie-beam's or the upper levels; the slabs (timber or vaults) are on a lower level. A chapter is dedicated to work and health safety issues (pigeons' guano, dead corpuses, attic dust can be highly contagious).

Building archaeology / art history study, and other auxiliary researches, e.g. timber restorer report for a painted panelled ceiling fixed to the roof structure; dendrochronological survey. In Romania, art historians generally do not deal with roof structures, but their report can offer information on dating, carpenters-guilds etc (Professor Caston).

Computer aided Modelling and Instrumented Testing – A useful tool in checking the overall behaviour of the structure and the safety of the compounding elements (and joints)is the computer aided modelling. The section – on the example of the 15.70m span roof of the Reformed church, Cluj – shows the step by step construction of the geometrical model, load and combination calculus, and offers guidance in obtaining and interpreting the results and checking the elements.

Criteria in choosing the modelling level – the chapter starts with presenting modelling levels (details are given in the author's: "From Simple Roof Structure Calculus Based on 2D Modelling to 3D Models – Case study: Reformed Church in Cluj-N., Romania" prepared for the present forum).

Mechanical models of the described levels – is a chapter presenting the steps in constructing the models (within a given software), including special questions of each level: (a) 2D frame models for secondary trusses, longitudinal bracing systems and main trusses; (b) 3D limited spatial model of roofs made of transversal and longitudinal plane frames; (c) holistic 3D models of the same type of structures (Fig. 4); (d) 3D models of spires, (e) decay modelling on various levels.

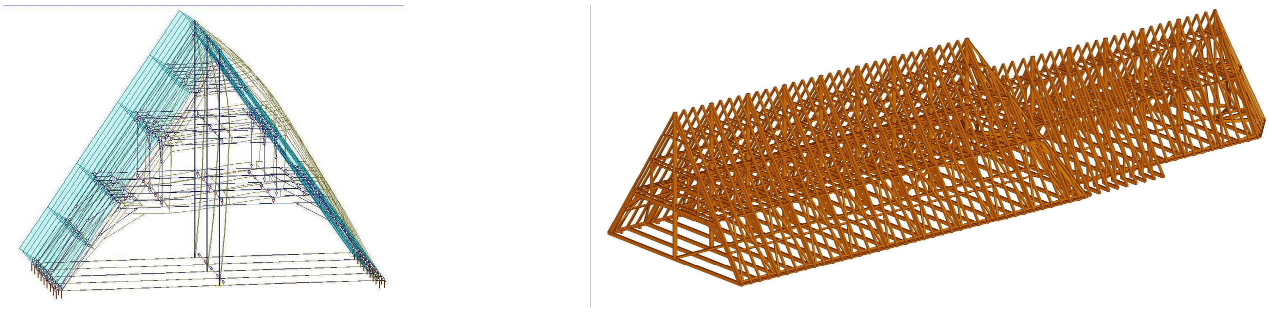

Figure 4: (a) 3D limited model (Axis VM 9) deformation under wind loads; (b) 3D holistic model both of the reformed church, Kogalniceanu street Cluj, Romania

Loads and combinations – Calculation is given step by step for the case study, according to Romanian (European) codes.

Result interpretation – The overall behaviour is analysed through deformation; each element is checked (according to Romanian / European) codes for combined strains (M, N, T). The chapter comments the most common errors in interpreting results. Checking is carried out both in (a) ultimate limit state (ULS) and (b) serviceability limit state (SLS).

(On site) instrumented testing – is generally not available for common roof-interventions, but a number of simple tests are described within this chapter.

Structural Assessment/Diagnosis and Therapy (Structural Expertise) – formulates recommendations on the minimum content of a structural expertise (state assessment report): (a) description of baroque roof structures; (b) decay description; (c) interpretation of the auxiliary reports modelling, testing; (d) identifying decay-causes; creating the:

Structural diagnosis of the baroque roof structure; a separate chapter is dedicated to the most common misinterpretations of historic timber's behaviour. Guidelines are formulated for the acceptability of modelling / calculus results. A roof structure existing without major deformations, even if a high number of joints / elements / trusses are biologically degraded has to be confirmed as a

safe structure also through mathematical / computer aided modelling. If the computer model shows that the structure or some elements are overloaded, mistakes might be in the calculus.

Common mistakes in interpreting a historic roof structure (for example: longitudinal surface drying cracks considered axial over-load cracks; or props or supports introduced later beneath suspension elements seen as necessary intervention to be extended for all trusses, etc.)

Structural therapy – according to Romanian legislation, a qualified structural engineer (expert) is assigned to report on an existing structure's state of decay and to formulate the recommended therapy (repair, minimum intervention, removal of unnecessary, later additions or insertion of missing original elements; or to advise on consolidation / reinforcement / retrofitting of the structure, sub-ensembles, elements or joint). The designer structural engineer, when detailing the solutions, has to take into consideration the assessment report's recommendations.

Intervention Design and Specification (Chapter 6)

Presents the recommended content of the design documentation (drawings, presentation scales) and written specifications for different levels of intervention (Fig. 5):

Regular (tiling) repair (insertion of a maintenance platforms);

Conservation – including mainly replacement of biologically decayed elements – level of detailing is governed by the complexity of the roof and the extent of decay. (In the case of a simple roof with reduced decayed areas / elements a "characteristic main / secondary truss" and the layout may be enough to identify interventions, and a set of "typical intervention joints" may be sufficient). When a limited number of joints need only reinforcement (carpentry joint modification, plating, or engineered solutions) the intervention can be considered of "conservation" level.

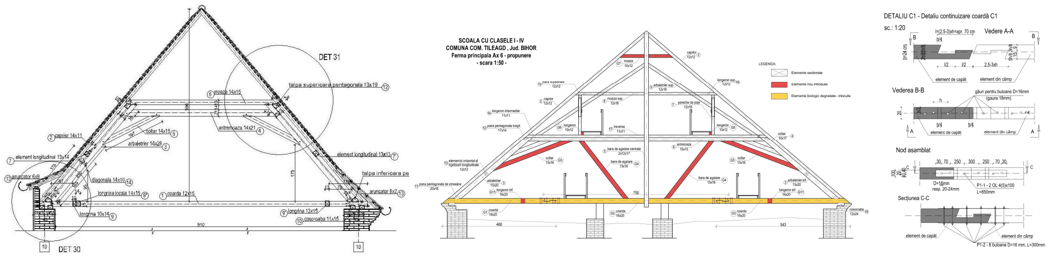

Figure 5: (a) Conservation (Reformed College, Cluj, 2006); (b) Retrofitting / consolidation (Elementary school, Tileagd, 2006), Typical continuity / repair joints

Retrofitting / reinforcement / consolidation – examples are given of roofs that needed important intervention, generally due errors of the original structural concept – when joints, elements, sub-ensembles are modified. In other cases new functions (use of the attic as a mansard space) determine structural interventions (extra timber / metal elements).

Reconstruction of baroque roof structures – identifies the situations when reconstruction is recommended or acceptable, gives examples of conceptual, full or partial reconstructions.

Examples of engineered and carpentry joints – are also given for the case study. (Fig. 5)

Specifications – The chapter gives description examples on technologies, materials, tools, quality assurance, presents the role of the designer and work safety issues during execution.

Execution and Maintenance Issues (Chapter 7)

This chapter describes all steps and special issues to be followed throughout the interventions, from site management and organisation issues to the actual phases of execution.

Site management issues: Includes recommendation on using scaffolding and temporary cover, on work and material supply schedules (problems of quality timber supply), list and specification of tools and equipment. Typical decays of new timber are exemplified in order to avoid inserting infected timber into a historic roof. Work and health safety issues are also detailed.

Execution technologies and details – describes the steps of joint-dismantling, where partial element replacement is needed, including solutions for temporary, local propping and lifting of elements, sub-ensembles. Needed accuracy-level, order of re-assembling the joints, etc are given. The typical mistakes and bad practices are also exemplified in order to avoid their repeated use. (Fig. 6)

Figure 6: (a) Consolidation with element insertion – Tileagd 2008; (b) Minimum intervention – conservation Nusfalau 2010; (c) bad quality lap-joint under execution; (d) good quality lap-joint

The examples present different levels of practices coexisting in Romanian conservation industry: (a) the sub-contractor was not specialised in carpentry-repair, after a high number of site visits offered by the designer, finally an acceptable overall quality for the retrofitting work was achieved, but (d) bad quality carpentry joints had to be replaced by engineering ones. (c) A craftsmen team specialised within the BHCT 2002 programme assures a constant high quality of work, site visit is needed only in unforeseen situations; (b) in some cases, good quality can be achieved with a small number of site visits and good quality craftsmen, even if not specialised in specific training courses.

Legislation concerning quality-checking – The phases when the designing structural engineer or expert has to be invited for site supervision are exemplified.

Maintenance advice – addresses mainly the historic building owners, describing regular and extraordinary checking and maintenance situations.

Conclusions

The end result of any intervention has to be a – repaired, conserved or retrofitted – baroque roof, the life of which should be assured for minimum another century. The quality depends on all factors to the same extent: good craftsmen can execute non-professional designs with wrong results, which can be the outcome of recommendations by a non-specialised expert. The reverse similarly leads to destroyed historic values, so all factors have to assure high quality. Therefore the *Guide* has to reach as many practitioners as possible, contributing to quality interventions on baroque roof structures.

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