Basis of Structural Timber Design
from Research to Standards

8th Workshop in Zurich	Minutes

COST Action FP1402
“Basis of Structural Timber Design – from Research to Standards”

Minutes of the Workshop
“Future challenges and need for research in timber engineering”

Attendance List

Name	**Country**	**Institution**
Robert JOCKWER (Host)	CH	ETH Zurich
Philipp DIETSCH (Chair)	DE	Technical University of Munich
Jochen KÖHLER Vice-Chair)	NO	Norwegian University of Techn., Trondheim
Ishan ABEYSEKARA	UK	Arup, London
Andrii BIDAKOV	UA	O.M.Beketov National University, Kharkiv
Jean-François BOCQUET	FR	Lermab, Épinal
Stefania FORTINO	FI	VTT, Espoo
Massimo FRAGIACOMO	IT	University of L’Aquila
Andrea FRANGI	CH	ETH Zurich
Steffen FRANKE	CH	Bern University of Applied Science
Julien GAMERRO	CH	École polytechnique fédérale de Lausanne
Alfredo GERALDES DIAS	PT	University of Coimbra
Kiril GRAMATIKOV	MK	Ss. Cyril and Methodius University, Skopje
Richard HARRIS	UK	Bath University
Alar JUST	ES	Tallinn University of Technology
Miriam KLEINHENZ	CH	ETH Zurich
Miha KRAMAR	SI	ZAG, Ljubljana
Andrew LAWRENCE	UK	Arup, London
Benjamin KREIS	CH	ETH Zurich
Katharina MÜLLER	CH	ETH Zurich
Pedro PALMA	CH	Empa, Dübendorf
Stephan SCHILLING	CH	ETH Zurich
Joachim SCHMID	CH	ETH Zurich
Erik SERRANO	SE	Lund University
Ivan SOPUSHYNSKYY	UA	Ukrainian National Forestry University, Lviv
Mislav STEPINAC	HR	University of Zagreb
Roberto TOMASI	NO	Norwegian University of Life Sciences
Tomi TORATTI	FI	Federation of the Finnish woodworking ind.
Konstantinos VOULPIOTIS	CH	ETH Zurich

Total: 29

1. Opening and welcome to the participants

Philipp Dietsch welcomes all participants and opens the workshop.

Robert Jockwer briefly presents Structural Engineering at ETH and provides useful information about the workshop.

Philipp Dietsch explains some news and information on the STAR reports, training school documentation, presentations of the final conference and the special issue of “Engineering Structures”. All information is available for download on www.costfp1402.tum.de

2. Presentations by participants on ongoing research activities

Stephan Schilling, Konstantinos Voulpiotis, Benjamin Kreis, Christine Graffé (ETH Zurich)
Presentations on their PhD topics.

Philipp Dietsch (Technical University of Munich)

CLT, in-plane shear, prestressing of CLT walls - horizontal stiffness and reduction of connections, reinforcement vs. free shrinkage, monitoring of environmental effects on wood moisture content, hybrid structures.

Kiril Gramatikov (Ss. Cyril and Methodius University, Skopje)

Architects perception of Engineering Wood Products, Energy Efficiency, Numerical modelling of TCC structure in fire.

Jean-Francois Bocquet (Université de Lorraine)

Dowel type connections with BOF Modell, hardwood structures, recycled materials, quality control.

Julien Gamerro (EPFL)

Digital fabrication and automation, Wood-wood connections, load-deformation behaviour.

Erik Serrano (Lund University)

Materials, components, joints and structures, Numerical methods: reduction methods for dynamics, CLT beams, load-bearing structures exposed to weathering, glued-in rods, material modelling.

Ishan Abeysekara (Arup, London)

TCC, execution, stability, robustness, steel-CLT floors (input from practice), dynamics, modular houses, fire.

Andri Bidakiv (O.M.Beketov National University, Kharkiv)

Glued-in rods.

Mislav Stepinac (University of Zagreb)

Engineered Wood Products, composite structures, seismic design for southern Europe, tall buildings, assessment and repair.

Ivan Sopushynskyy (Ukrainian National Forestry University, Lviv)

Biological decay of timber, grading, connections.

Pedro Palma (EMPA, Dübendorf)

Lateral load-resisting systems, GLT from beech, behaviour of connections.

Alfredo Diaz (University of Coimbra)

TCC with cyclic behaviour, structural products with optimized use of wood species, optimized use of structural wood.

Tomi Toratti (Federation of the Finnish woodworking industries)

Main interest from practice: Proof on service life, durability engineering, stability, robustness, BIM.

Miha Kramar (ZAG, Ljubljana)

Wood composites and modification / mineralization of wood, stuctural use of hardwoods, composite structural elements from “waste” material, connections in timber structures, innovative connections in CLT buildings.

Richard Harris (University of Bath)

Montoring/measurements of existing buildings, vibrations, SLS as primary issue with timber.

Stefania Fortino (VTT Finland)

Material life of building products, microstructures, hygro-thermo-mechanical models for wood, wood cell deformation.

Jochen Köhler (NTNU, Trondheim)

Structural Engineering and decision making under uncertainty, code calibration, non-linear limit state functions for codes, over strength factor, seismic design, robustness.

Massimo Fragiacomo (University of l'Aquila)

Seismic design also under uncertainty, Log-house buildings, FEM of composite beams, CLT with mixed wood species, anti-seismic wooden furniture.

Alan Just (TalTech)

Fire resistance of timber, durability, building physics.

Steffen Franke, Bern University of Applied Science)

Press glued connections, quality assurance – moisture loads, Monitoring, FE Modelling – moisture content and moisture induced stresses, use of hardwood – glulam and connections, product and method development, TS3, modular and hybrid structures.

Roberto Tomasi (NMBU)

Bio-based multi-functional construction system, design of engineered timber system, existing/historical buildings retrofit, SENECA, floor vibrations.

3. Discussion of input on future challenges and need for research

The topics noted during the presentations and following discussion were subsequently grouped into three groups with subtopics and main challenges.

1. Prefabrication/Industrialization

- Elements
- Modularity
- Connections
- Logistics in fabrication
- Standardized design vs. company specific solutions
- Missing Standardisation
- Possible precision in factory vs. on site
- Execution quality
- Costs and competitiveness
- Speed in industry vs. academia
- What can we contribute as researchers?

2. Components/Products/Materials

- Use more wood or use the resource wood efficiently?
- More clever use of material (more timber vs. less steel and concrete)
- Timber as high-tech material
- High-tech design for high-tech buildings?
- Unknown material properties (other wood species)

3. Enhanced design methods

- **Considering the behaviour of the whole structure**
- Performance based design
- Early stage design
- System behaviour
- Rules for different levels of structures
- Codes as cookbooks?
- Optimization & updating (reproducing, not single design)
- SLS vs. ULS
- Considering ductility of connections
- FE-Models

4. Prioritization of topics for exemplary structures

Day 2 was structured into two timeslots for discussions in smaller groups. The results of these discussions were subsequently presented to the plenum. The objective was to define important future topics for future applications in timber construction, followed by a prioritization of these topics. The first timeslot was used to define and prioritize topics that are of importance for specific structures (1) complex spatial structures, (2) tall buildings and (3) typical office building.

1. Complex spatial structures

- Structural behaviour → load path
  → system based design
- Member & connection behaviour
  → material behaviour
- Robustness
- → Safety of the structure
- Durability and long-term behaviour
- Wind loads
- Erection forces

2. Tall buildings

- What is a tall building? (30 m – 100 m? above limit of fire brigade?)
- **Stiffness, ductility (local level, connections)**
  - Stiffness vs. deformation capacity (global level)
  - Analysis methods
  - Vibrations
  - Lateral systems
  - Reaction to lateral load
  - Differential settlement

- **Robustness design**

- **Reaction to environment SC1 and SC2**
  - Durability
  - Different climates in different countries
  - Internal environment → User comfort
  - Cooling of buildings (façade systems?)
  - Temperature storage (concrete, special timber elements)

- **Fire safety**

- Erection process

- Prediction vs. full scale testing (not possible at very large scales)
- Size effects, scale effects
- Re-assessment, model updating
- Dismantling, recycling

3. Office buildings

- **Lateral stability**
  - Wind area (location)
  - Seismic area
  - What is the lateral stability system? Shear walls? Braced frames?
  - Core
  - Energy dissipation
- **Building purpose**
  - Residential? Office?
  - Ground floor
    - Parking?
    - Retail zone?
- **Structural system**
  - What level of prefabrication is possible?

- Vibration analysis
- Hysteretic analysis
- Interaction between (concrete) cores and structural timber elements (vertical and lateral)
- Fire: timber exposed? sprinklers? Reliability compared to other materials?
- Is the standard fire applicable?
- Better or equal to steel / concrete?
- Acoustics? → often helps fire safety but potentially negative for seismic behaviour
- Durability – keeping wood dry

5. Prioritization of sub-topics for principal topics

The second timeslot was used to define and prioritize sub-topics that are important for the following three principal topics: (1) system behaviour, (2) long-term behaviour, (3) serviceability

1. System behaviour / system effects

- Different scales → multiscale modelling and corresponding in-between
- Uncertainty propagation has to be take into account
- Look at stiffness (due to central theorem of probability a system with many connections would depend on mean values, but we have systematic errors and not only uncertainties). We have to look from small to large (from single nail to structure).
- System effects for strength.
- Load-deformation behaviour from members and connections.
    - Different simplifications for different interests. General?
- Effect of non-structural elements
- System effects under fire
- Robustness is the property that connects the different system levels. Load-effects? Unknown-scenarios?

2. Long term behaviour

- SC1: Use of advanced knowledge; SC2: Implementation in codes; SC3: use in advanced methods
- **Creep effects**
    - Redistribution due to time, creep in connections
    - Diversity of load level in structures, even more in use
    - Use of K_{def} – different elements, different loadings
    - Composite elements, interaction between the materials
    - K_{mod}?

- **Definition of building use**
  - Challenges for different Service Classes: SC 1: Dry climate (heated, non-heated), SC 2: detailing of climate, SC 3: durability, direct water impact, detailing of connections
  - Planning for accidental events (water)
  - Signaling, second line of defense

- **Environmentally induced stresses (moisture, temperature)**
  - Benchmarking of models, evaluation with real measurements from structures
  - Size effects
  - Cracks, k_{crack}, different for stress
  - Composite elements, interaction between the materials

3. Serviceability

- Quality related vs. usage related criteria
- Limits for criteria? Quality classes rather than absolutes limits
- Prediction of the structural behaviour is the biggest issue.
- System effects?
- Connection stiffness (elastic), slip in connections

Annex:

Sorted answers given in online-questionnaire to the question “What are the three most prominent future challenges in Timber Engineering?”

- **Prefabrication**
  - Multifunctional prefabricated elements/components
  - Maximise the benefits of prefabrication: in the Trump scenario where climate change is a hoax, timber should still be the construction material of choice due to its world leading prefabrication benefits. That said, the construction industry is still very old fashioned and using timber we can take huge leaps forward.
  - Clarity in calculations of multi-storey timber buildings and modular systems
  - Efficient use of timber / modular systems
  - The use of modern technology and automation in timber engineering
  - To produce a large variety of linear and two-dimensional building elements with desired characteristics for timber bridges and multi-storey framework buildings

- **Tall timber**
  - Tall timber / multistorey buildings
  - Structural behaviour of mid- and high-rise timber buildings under lateral loads (wind and seismic actions, including regions with low-to-moderate seismicity)
  - Enhance the performance of TTB and better understanding of the system effects.
  - Clarity in calculations of multi-storey timber buildings and modular systems
  - How to build safe and efficient multi-storey timber buildings (seismic design, serviceability)
  - Long term performance of tall timber based buildings

- **BIM/design chain/Production**
  - Efficient "from design to building" process (BIM: M=modelling & management)
  - Efficiency of the timber building process and use of BIM
  - Computational design of timber structures
  - Digitalization in the wooden construction field (including numerical models for wood, BIM and LCA methodologies)

- **Material behaviour**
  - Basic research on wood materials (DOL for longitudinal shear, advanced characterisation techniques e.g. X-ray tomography methods)
  - To develop CLT panels made of local wood (hardwood and softwood)
  - CLT and EWPs, composite structures & their long-term behavior

- Create and understand better wood-based advanced materials, like densified wood. They can address many structural and durability problems of current timber products in construction.
- Fundamental research challenges associated to the characterization of new engineered timber products
- To develop new building materials
- Performance of timber structures under variable climates (considering also the effects of climate change)
- Long term behavior, changing climate conditions

- **Materials and components**
  - Design approaches for materials/components (modified wood in load bearing applications, GiR for CLT, CLT as beam/lintel beam/wall with openings)
  - To develop CLT panels made of local wood (hardwood and softwood)
  - How to integrate timber with other materials: now that we can compete with steel and concrete, we also have to work better together: composite and hybrid structures can solve most problems that single material structures can't
  - Structures in hardwood
  - New timber based products
  - To develop high bending strength of timber

- **Composites**
  - Hybrid solutions, composites with timber
  - To investigate the seismic performance of hybrid buildings (CLT with concrete elevator shafts).
  - Composite structures & their long-term behaviour
  - New hybrid structures
  - To develop new connectors between timber and steel components and wood-concrete composites.

- **Connections**
  - Performance-based design of timber connections (specifying connections so that they reliably exhibit a target load-displacement behaviour)
  - Understanding of load-deformation behavior, modelling of connections.
  - Design of timber connections must be simple and strength parameters easily found and test methods must ensure repeatable results
  - To develop new connectors between timber and steel components and wood-concrete composites
  - Modeling of actual behavior of connections

- **Reliability and Robustness**
  - Robustness of structures

  - Measures for robustness
  - Reliability based design
  - How to increase the performance of timber structures to match the technological advances we have seen in our products. Specifically dealing with new issues due to the new scale of timber structures (large, tall, etc), and understanding better the system effects.
  - Load carrying capacities should be safe, but not excessively
  - Analysis of timber structures
  - Making non timber engineers aware of the problems
  - Combined probabilistic and mechanical FE-modelling in research
  - Moving from a fragmented, component based design towards systems-design, assessing structural performance criteria in the context of structural systems.

- **Mechanics**
  - Development of EC5, e.g.: fracture mechanics concepts.
  - Develop reliable analytical methods for practice, able to predict stiffness, strength and ductility

- **FE**
  - FE Modelling: Development of EC5, e.g. Design (assisted) by numerical modelling.

- **Vibrations**
  - Dynamic behaviour of light weight structures (floor vibration, traffic induced vibrations, wind induced vibrations).

- **Seismic**
  - Seismic behaviour of timber and timber composites
  - Structural behaviour of mid- and high-rise timber buildings under lateral loads (wind and seismic actions, including regions with low-to-moderate seismicity)
  - To rewrite the chapter of timber in the Eurocode 8 on seismic resistance
  - To investigate the seismic performance of hybrid buildings (CLT with concrete elevator shafts)

- **Durability**
  - Moisture safety during the building process and during the lifetime
  - Moisture impact
  - Prediction of Durability
  - To use timber for a long service life
  - Performance of timber structures under variable climates (considering also the effects of climate change)
  - Durability of timber bridges by avoiding creosote

- **Fire**
  - Structural fire design (behaviour of members and connections under longer fire exposures and under fire curves with a cooling phase).

- **Sustainability**
  - Effective use of timber as a natural resource. Push sustainability indicators even further away from ""heavy"" materials. Challenges arise from different perspectives: follow and characterize timber material from the forest towards the structure (knowing more about the material facilitates for more effective use), address durability issues, issues of reuse and recycling.
  - Introduction of technology in the entire life cycle of these structures
  - Pressure in the natural resource wood

- **Execution**
  - Quality assurance

- **Retrofitting**
  - Retrofitting existing structures with light timber based elements
  - Assessment of existing structures

- **Codes**
  - Cost competitiveness with other materials. Clear and easy to understand design guides for safe (seismic) design. Uniform code approaches across countries, including test methods (e.g. embedment)
  - Harmonization of design standards (EC), product standards (EN) and test test standards (EN)

- **Publicity/awareness**
  - Increased awareness of possibilities with timber among architects, developers, real-estate owners
  - Increasing the use of timber structures, especially use of CLT and EWPs in buildings, energy efficiency of timber buildings, made of CLT and EWPs
  - The advantages of using wood compared to concrete and steel must continuously be highlighted, but only with statements that are correct
  - The acceptance of timber as a mainstream engineering material

Sorted answers given in online-questionnaire to the question "What has to be done to tackle this challenges?"

- **Collaboration between academia and industry**
  - Enlarge the scientific community
  - Increased collaboration and cooperation = stronger together. Encourage research exchange between Universities
  - Establish new research consortiums including academia and industry
  - More collaboration between industry and academia to get advanced/complex structures built and understood
  - Interdisciplinary design and collaboration with producers and practitioners
  - More collaboration with experts in concrete and steel
  - To foster agreement at the EU level by promoting meetings among national seismic experts specialized in timber

- **Data collection & Monitoring**
  - Gathering the data from different projects
  - Comprehensive database of real behavior of connections. Until now, we do not have a common database, and maybe it is not that easy to put together all the info. Often you don't have all the info
  - Not only more research projects, but also combining existing knowledge from previous and ongoing projects, e.g. through a new COST Action
  - Extensive research (in particular data processing of previous tests) on the behaviour of connections to calculate the overstrength factors
  - Adopt/Adapt technologies (e.g. include sensors from the products production/grading) to this sector combining them with the existing knowledge and modelling (e.g. structural optimization, BIM)
  - New monitoring techniques and provision of data
  - Improved performance through advanced monitoring and digitalization
  - Can we get actual information of the behavior of real buildings (monitoring)?
  - Big Data methods. Could we somehow simplify things using Artificial Intelligence?

- **Basic and applied research.**
  - First of all, the timber industry should recognize the importance of the research and development in the field of timber engineering (and we should do our best to demonstrate this importance to them). When investments in research and development will increase, this will also mean more resources for research institutions. In the next phase, an effective cooperation between industry and researchers should be established
  - More research on advanced/complex timber structures

- More research in advanced hybrid systems or composite components (already ongoing, but we can do better). Cure the timber fetish
- Full understanding of moisture impact, good simulations

- **Enhanced testing**
  - Coordinated research
  - Research and tests
  - Research on connections in systems
  - Many future test on ductile connections
  - Perform experimental investigations with focus on load-deformation behaviour and good statistical evaluations
  - Large scale testing projects (whole buildings)
  - Experimental testing of composite structures, long-term behavior of timber- to-concrete beams, serviceability limit state under bending
  - To perform extensive non-linear dynamic analyses on archetypes CLT, lightframe and hybrid CLT with concrete core buildings under earthquake ground motions to calculate the behaviour factors

- **Calculation and design**
  - Develop "a modular approach" in calculations
  - The wood related industry has to cooperate in order to make timber design simple, rather than competing on 'best' ETAs, realizing that the bigger competitor is concrete and steel.
  - Better deformation values for any kind of connections
  - Proposals of numerical models, accounting for material properties, contact, fracture of the timber...
  - Probability-based modelling, include variability in the model in a straight-forward way, not by making many, many models.
  - How do we deal with uncertainty (we never know the actual resistance of timber, there will be human errors during erection)?

- **Durability**
  - Develop and adopt techniques and solutions that assure an adequate long term performance. These can be related to diferent aspects such as for example: design for durability, innovative products, maintenance solutions, quality control.

- **Product development**
  - Develop new optimized products and solutions with equivalent performance, in the various regards, but always with a lower use of wood.

- **Digitalization**
    - Development of digitalization by collecting and assessing several tools and creating platforms at the national and European level, also considering the results of the COST Actions of the recent years
    - Suggestions from the recent COST Actions and focused digitalization can also help in the development of multi-storey buildings

- **Demonstrators**
    - Research, testing and demonstration projects

- **Evaluation of existing experience and practice**
    - Studies on current use of EC5. Approach software companies.
    - Collect state of the art and identify needs for research and/or administrative measures on CEN level. A COST action would be a valuable tool.
    - How do we deal with uncertainty (we never know the actual resistance of timber, there will be human errors during erection)
    - Parametric studies related to the energy efficiency of timber buildings (CLT systems)

- **Education**
    - Have more timber course at University master level
    - Dissemination of the existing knowledge, involvement and further education of designers, architects, engineers, producers
    - Train timber-researchers on reliability issues