WORLD CONFERENCE ON TIMBER ENGINEERING 2025
BRISBANE, AUSTRALIA
Advancing Timber for the Future Built Environment

ADRESSING THE CHALLENGES IN THE HOLISTIC DESIGN OF TALLER TIMBER BUILDINGS – COST ACTION HELEN

Robert Jockwer[1], Gerhard Fink[2], José Manuel Cabrero Ballarín[3], Mislav Stepinac[4], Eleni Toumpanaki[5], Pedro Palma[6], Chiara Bedon[7], Daniele Casagrande[8], Steffen Franke[9]

ABSTRACT: Designing multi-storey buildings in timber is often more demanding than in concrete or steel. It is therefore crucial to address taller multi-storey timber buildings from a collaborative and interdisciplinary perspective, considering static, dynamic, fire, acoustic, human health and other aspects simultaneously and not in isolation. Only through interdisciplinary analysis and interaction can a set of holistic design guidelines be developed that will enable safe and economic construction of taller timber buildings, as well as respect comfort and human wellbeing demands. In this paper, the work carried out in COST Action HELEN is presented, and the main activities and outcomes are discussed.

KEYWORDS: COST, holistic design, tall timber buildings, multi-storey timber

1 – INTRODUCTION

The popularity of building with timber has increased over the past decades, and midrise timber buildings up to eight storeys are now common. Multi-storey timber buildings are recognised as a long-term sustainable solution to provide healthier environment and better living quality and therefore present an environmentally friendly alternative to concrete and steel buildings. Taller timber buildings require, however, a holistic approach and highly specialised architecture and engineering teams to address the unique demands and challenges related to structural safety, robustness, deformations, vibrations, accidental loads, as well as sustainability and durability (see also Figure 1). Also, the research for multi-storey timber buildings has to go beyond and combine the individual fields (e.g., connections, vibrations, acoustics, fire, durability).

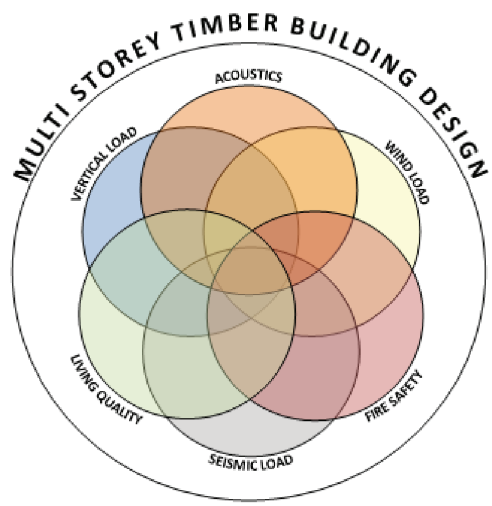

Figure 1: *Illustration of the interaction of some building design fields and their inherent collisions*

[1] Robert Jockwer, TUD Dresden University of Technology, Dresden, Germany, robert.jockwer@tu-dresden.de https://orcid.org/0000-0003-0767-684X

[2] Gerhard Fink, Aalto University, Finland, gerhard.fink@aalto.fi

[3] José Manuel Cabrero Ballarín, Universidad de Navarra, Pamplona, Spain, jcabrero@unav.es

[4] Mislav Stepinac, Faculty of Civil Engineering, University of Zagreb, Croatia, mstepinac@grad.hr

[5] Eleni Toumpanaki, University of Bristol, Bristol, United Kingdom, eleni.toumpanaki@bristol.ac.uk

[6] Pedro Palma, Empa – Swiss Federal Laboratories for Material Science and Technology, Dübendorf, Switzerland, pedro.palma@empa.ch

[7] Chiara Bedon, Department of Engineering and Architecture, University of Trieste, Trieste, Italy, chiara.bedon@dia.units.it

[8] Daniele Casagrande, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy, daniele.casagrande@unitn.it

[9] Steffen Franke, ETH Zürich, Zürich, Switzerland, steffen.franke@ibk.baug.ethz.ch

https://doi.org/10.52202/080513-0228

2 – AIMS OF AND PROGRESS IN COST ACTION CA20139 (HELEN)

The COST Action CA20139 (HELEN) [www.cahelen.eu] aims at shifting R&D from isolated topics to an integrated interdisciplinary approach, which is critically necessary to safely and economically design and build as well as correctly maintain, adapt, and reuse taller timber buildings. The main objective of COST Action HELEN is to foster international interest and effort in developing a shared understanding and deriving common guidelines for the holistic design of taller timber buildings. This is carried out through the sharing of technical and scientific skills from different research fields within the network. The Action is running from 2021 to 2025 and several outcomes have been already published [1-4]. In the contribution of the COST Action HELEN at the 2023 World Conference on Timber Engineering in Oslo, Norway, the first activities of the Action and the content of the State-of-the-Art report are summarized [5]. In this contribution, the continuous work and further outcomes and results are presented.

The COST Action HELEN has successfully created a network of researchers, educators, and practitioners from Europe and the entire globe (see also Figure 2). COST Action HELEN has more than 400 members from almost 50 countries and is structured in four working groups (WGs), each having more than 150 participants and covering several topics.

1) Design for robustness, adaptability, disassembly and reuse, and repairability of taller timber buildings.
2) Design of taller timber buildings against deformations and vibrations.
3) Design of taller timber buildings subjected to accidental loads.
4) Sustainability and durability of taller timber buildings.

The COST Action HELEN organised conferences, WG meetings, management committee meetings, and focused meetings. During the meetings, the knowledge transfer from fundamental research to industrial applications has been promoted by the participation of practical experts and selected keynote speakers. Already, two training schools were carried out targeted to early career investigators and a third one is planned. The first training school addressed "*Holistic design of connections*" and the second one "*Sustainability of Taller Timber Buildings*". In spring 2025, a third training school on "*Case studies of Taller Timber Buildings*" will be carried out. As a result, almost 70 students received financial support to participate in the training schools. Within the short-term scientific missions, COST Action HELEN supports the exchange of researchers. Until now 35 researchers have used this opportunity, and 8 missions are still ongoing. In addition, 4 researchers from inclusive target countries received conference grants to be able to participate and present their work in international meetings.

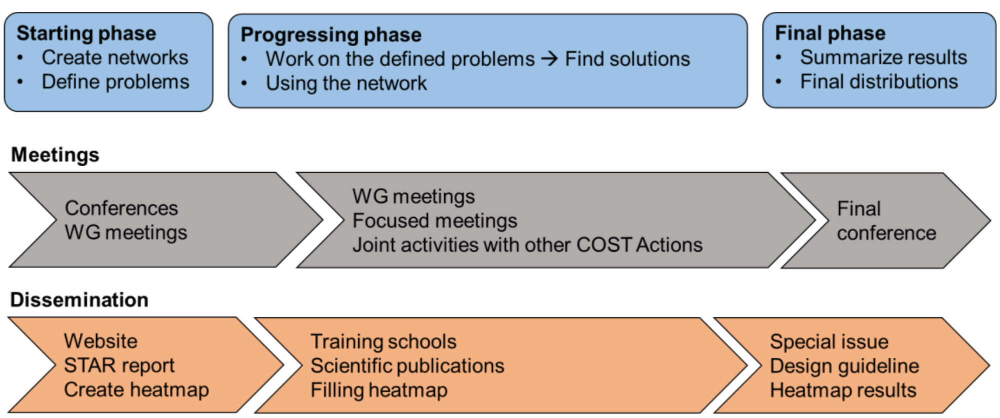

Figure 2: *Overview of aims and activities during the course of the COST Action Helen*

In its activities, COST Action HELEN pursues a holistic research approach with inter- and transdisciplinary collaboration between experts from different working groups in order to expand the field of knowledge. One of the main objectives of the first year was the development of the state-of-the-art report "Holistic design of taller timber buildings (HELEN)" [1], describing various aspects of the topic including drivers and barriers. The state-of-the-art report is published on COST Action HELEN's homepage and can be downloaded as a whole or in its four main parts:

A Diversity, Equity and Inclusion (DEI) Coordinator was established during the second year of COST Action HELEN, in order to coordinate and implement activities that support diversity within the Action, and promote equality benefits to the related fields.

In the remaining time of the COST Action HELEN in 2025, the outcomes of the work in the past years is summarized in a Special Issue of the scientific journal Wood Science & Technology and in a final book publication which will serve as guidance for engineers, architects, and planners.

https://doi.org/10.52202/080513-0228

It is planned to use the network to promote the development of a joint research roadmap in order to increase the efficiency and efficacy of the innovation process and, therefore, have a direct impact on the development and implementation of new technologies, processes, methodologies and products for taller timber buildings. It is planned to suggest new design approaches, processes and technologies that can build and improve upon existing best practices and ensure optimal holistic design of taller timber buildings.

3 – REPORT FROM THE WORKING GROUPS

3.1 - WORKING GROUP 1: DESIGN FOR ROBUSTNESS, ADAPTABILITY, REUSE AND REPAIR

The Working Group 1 (WG1) deals with aspects related to robustness, adaptability, design for disassembly and reuse, and repairability. Given the broad range and interdisciplinary nature of the topics assigned to WG1, it has members with different backgrounds in both engineering and architecture, as well as in research and industry. WG1 has been reorganised into two Sub-Groups (SG): i) SG Robustness; and ii) SG Design for extended service life.

Robustness

The SG "Robustness" deals with the topics of resistance to disproportionate damages, including structural and non-structural robustness and resistance to progressive collapse. The SG has worked on developing a framework for the design of timber buildings against disproportionate collapse, which includes identifying all stakeholders and their interests and responsibilities. Case studies of structural design for increased robustness have been analysed and the most important strategies have been summarised. The ongoing research projects and exchanges with structural engineers involved in designing timber buildings against progressive collapses have allowed the SG to identify some key issues: guidance to adjust the necessary measures to increase resistance to disproportionate collapse to the risk category of the building; simplified structural analysis models for alternative load-paths (ALPs), e.g., with dynamic amplification factors; behaviour of connections under large deformations, e.g. catenary action; connections as fuse elements in segmentation strategies, which has similarities with capacity design for earthquake resistance; and “power storeys” for vertical segmentation in taller timber buildings.

Design for extended service life

The SG "Design for extended service" results from the merger of previous SGs "Adaptability", "Design for disassembly and re-use" and it dealt with topics related to changes in the functional use of buildings, how the design of tall timber buildings can account for adaptability-related requirements, and with the interactions between these and other requirements (e.g., robustness, acoustics, durability). The SG has focused on the evaluation of the demountability of timber connections and on identifying solutions that facilitate disassembly of timber buildings. Design for disassembly is not only important for increasing the reuse and recyclability potential, but primarily for repairs in case of damage.

Other activities

WG1 participated in the 2023 Training School “*Holistic design of timber connections*”, focusing on robustness and design of connections for disassembly and repair. Focused sessions on various WG1 topics were also held during the working group meeting held in Hasselt (Belgium), in May 2024, and in the working group meeting that took place in Skopje (North Macedonia), in September 2024. The members of WG1 have also contributed with research articles for the special issue of the journal Wood Science & Technology and for the book in the series Springer Tracts in Civil Engineering.

3.2 – WORKING GROUP 2: DEFORMATIONS AND VIBRATIONS

WG2 deals with aspects and design issues that are primarily related to deformations and vibrations in the framework of taller timber structures. WG2 takes advantage from the interaction of scientist and professional engineers (i.e., representative of research institutions, universities and industrial partners) that have different experiences on these themes. The internal organization of WG2 takes form into two major Sub-Groups: SG1 – Deformations and SG2 – Vibrations. Besides, many tasks and sub-topics represent a critical input and vital part of discussion and elaboration in SG1 and SG2, and in most cases, an interconnection of expertise is required.

Deformations:

Talking about deformations in tall timber structures, the attention goes to a multitude of aspects and issues that have major effects in research and industrial applications and are often fairly addressed by existing standards and regulations. As a matter of fact, deformations in timber structures are primarily associated to joints and connections. There are however no doubts about the complexity and variability of possible technological solutions in the field of joints and connections for timber structures. Also, the type of load, the boundary conditions and the assessment of their mechanical performance suggests the need of a robust background in support of optimal and safe mechanical design of these systems.

Vibrations:

The issue of vibrations, which is also addressed by WG2 members, is implicitly related to deformations and corresponding gaps in engineering knowledge / design tasks. Starting from the assumption that *vibration* itself is a rather general definition and can cover a multitude of practical / technical aspects in the framework of timber

https://doi.org/10.52202/080513-0228

structures, WG2 members actively contributed to the elaboration of a State-of-the-Art document in which most of engineering terms and problems could be first defined in their context. So far, do we implicitly talk about vibrations in floors or partition walls for timber structures? And which kind of design action should be primarily addressed in terms of vibration serviceability, for the specific solutions in use in tall timber structures?

But indeed, how can we monitor and control, or possibly minimize and mitigate the effect of vibrations in typical load-bearing components for tall timber structures?

The first elaboration from WG2 members, in this sense, resulted in the detection of rather wide and complex tasks in which – under the assumption of a joint primary goal of design – basic engineering knowledge for vibration assessment and mitigation is still represented by the need of standardized operational procedures and guidelines which could be efficiently applied to any type of building component (floors for instance, but not only). This need implicitly recalls the complexity of possible design actions (WG3 topic) and their effect and assessment in terms of vibrations. Human-induced loads on timber floors, for example, are totally different in dynamic and mechanical features (and effects) from wind pressure or seismic actions (and corresponding vibrations). There are no doubts, finally, about the inter-correlation of vibrations and deformations, which again suggest an intrinsic mutual interaction of load-bearing components for tall timber structures and the final user / the design actions

3.3 - WORKING GROUP 3: ACCIDENTAL LOAD SITUATIONS

In the second year of the Action, the activities of Working Group 3 (WG3) aimed to 1) explore the existing limitations in the design process of Tall Timber Buildings (TTBs) under accidental load situations, and 2) describe the interactions and conflicts among different design fields for TTBs involving at least one accidental load (e.g., fire *vs* seismic; seismic *vs* wind).

WG3 members worked to identify potential limitations, interactions, and conflicts in the design of TTBs. First, WG3 members were asked "*how urgent is the need to fill the gap in knowledge?*" for different design situations involving the accidental load categories of WG3 (five situations for seismic, five on fire, and five on blast load). For the seismic design, WG3 members agreed that the need to develop high-performance connections is *very urgent*, whereas, for the fire design, four *urgent* fields to be addressed were identified, namely: the timber's contribution to external fire, the structural robustness, the timber's contribution to internal fire and timber's contribution to fire development. The need for knowledge on the redistribution of internal loads after an element loss and ensuring appropriate redundancy was found to be *very urgent* in the design process for blast load.

WG3 opinions on different potential interactions and collisions involving accidental load situations in TTBs were also collected. More specifically, the WG3 members were asked to define "*how strong is the interaction between accidental load situations involving either seismic & blast, seismic & fire, fire and blast loads?*". Three design situations were considered to be *strong*: pre- and post-blast fires, connections for seismic and blast situations, and fire-resistant blast connections. Regarding potential interactions that involve the design of TTBs under accidental loads and other design fields analysed in other WGs, three *strong* interactions were perceived: design of connections for seismic/fire/blast and robustness, design for seismic and wind loads, and fire design vs architectural features.

To promote a strong holistic approach in the design of TTBs, WG3 organized the inaugural Training School of COST Action HELEN, entitled "*Holistic design of timber connections*" held in October 2023 in Trentino Alto Adige (Italy). The two-day course aimed to offer advanced knowledge about the holistic design of timber connections in TTBs, covering different topics through a strong multi-disciplinary approach. Twelve speakers and 47 trainees from 27 countries attended the course.

The third year of the WG3 activities was aimed at continuing working on topics regarding fire and seismic load situations and establishing a new subgroup on multi-hazard design for accidental load situations (Figure 3). A special session regarding the performance-based multi-hazard design for accidental load situations and robustness was coordinated by WG3 during the COST Action HELEN meeting held in Hasselt (Belgium) in 2024.

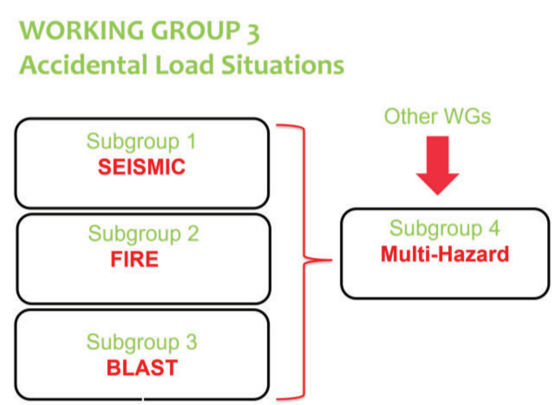

Figure 3: *WG3 subgroups and their interaction with the other WGs*

3.4 - WORKING GROUP 4: SUSTAINABILITY AND DURABILITY

Timber constructions have gained the (rightful) reputation of being a sustainable building option. On the other hand, they also raise questions regarding their durability. They

https://doi.org/10.52202/080513-0228

are more susceptible to damage, either induced by moisture or insects, as well as design mistakes due to their complexity. They are also less forgiving when it comes to construction mistakes, possibly leading to premature failure of their building components. Working group 4 (WG4) looks into the issues dealing with taller timber buildings' environmental footprint and their longevity based on the design details, all assessed through the interdisciplinary prism of the consortium's experts. The results of this Work Group's work are in close correlation to WG1, where the initial design assumptions are considered. As in other WGs, work in this group is also country dependent as, apart from local legislation, local climate properties are also of great importance. The possibility to build safely and effectively in areas with heavy rain and snow differs greatly from dryer places. This, in turn, influences the construction technologies, which, in turn, affects the building erection price, which makes the timber alternatives to concrete or steel more or less viable. For Europe, which strives for an increase in sustainable timber construction, this opens a discussion on state subsidies for timber construction in order to make them more attractive to investors. The interdisciplinary consortium, also including LCC and S-LCA experts, is able to provide answers to such questions.

Working Group 4 is mainly divided into two subgroups: (1) Sustainability, led by Prof. Shady Attia, University of Liège, Belgium, and (2) Durability, led by Prof. ehem. Dr. Steffen Franke, ETH Zurich, Switzerland. The group has more than 200 experts actively working to make progress toward our goals.

The results so far are 17 contributions within the State-of-the-Art Report [4] consisting of 85 pages in Part 1 Sustainability, Part 2 Life Cycle Assessment, Part 3 Durability in relation to Environmental Impact and Circularity and Part 4 Moisture Impact and Management. The purpose of this document was to report on the state of the art in research and practice related to the durability and sustainability of tall wood building systems, to synthesize the existing knowledge in each country, and to develop a common understanding of how to design for moisture safe and robust construction and operation of tall wood buildings. This report reflects parts of the work and discussions within WG4, covers the relevant issues, and reflects the information and studies available worldwide, but especially in Europe, through the active contribution and participation of experts from different countries involved in this Action.

WG4 supported the first Training School of the COST Action HELEN "*Holistic design of timber connections*", held in Trentino-Alto Adige (Italy) in October 2023, with several presentations. WG4 organized the second and very successful 3-day Training School "*Sustainability of Taller Timber Buildings*" in Zagreb (Croatia) in June 2024. The training school explored the issues related to the environmental footprint of taller timber buildings and their longevity based on design details and life cycle assessment perspective. It aimed to educate students about the sustainability of taller timber buildings through the leading international experts in the field. In addition, students had the opportunity to learn more about the durability of timber buildings, environmental performance indicators, timber data evaluation and validation, and to meet fellow researchers from other European universities for networking.

Special sessions to define a common understanding of lifecycle assessment and durability were coordinated by WG4 during the COST Action HELEN meetings at the conference in Lisbon (Portugal) in May 2023 and in Hasselt (Belgium) in May 2024. A further working group meeting was held in Skopje in September 2024 to specify and continue work on contributions to the final publication on the design process of TTBs.

4 – OTHER INITIATIVES IN THE ACTION

4.1 – DIVERSITY, EQUITY, AND INCLUSION (DEI)

The COST Action HELEN has set specific goals to strengthen diversity, equity, and inclusion (DEI), facilitating an open network of knowledge among a diverse community of researchers, professionals, and manufacturers that reflects the wide range of skills required for the design, construction, and research of taller timber buildings.

To foster collaboration among our members, it is essential to recognise personality differences, improve group dynamics, and establish a safe environment for open dialogue where individuals can share their perspectives and experiences. Therefore, a DEI session was organized during our fourth working group meeting in Hasselt, Belgium, in May 2024. The session titled, 'Dismantling Barriers in Engineering to Foster a Welcoming and Collaborative Working Environment', comprised four parts designed to enhance participation and encourage discussion among group members. Initially, an ice-breaking session based on 'Two Truths and a Lie' and 'Introducing your Neighbour' was introduced in pairs to facilitate networking, foster communication, and active listening. In the second part of the session, two members with diverse profiles in terms of gender, career paths, and cultural disposition were invited to share their experiences on how their social identities have affected their careers, insights into how our sector has evolved over the years regarding diversity and inclusion, and what steps should be taken to enhance diversity in engineering. The panel discussion aimed to engage the audience and encourage dynamic participation and conversation, allowing members to share their views either live or anonymously on an electronic platform. Most members identified that cultural differences can impact careers in the sector. This reflects either the general mobility of researchers to different universities and countries, where they face challenges related to language skills and career

https://doi.org/10.52202/080513-0228

advancement or that growing up in countries with no forestry industry or limited seismic activity may create an initial disadvantage when entering the timber or earthquake engineering sector concerning background knowledge. The gender gap and the lack of open-mindedness towards the LGBTQ community in the sector, particularly concerning career promotion opportunities and macho behaviours, were also raised. The positive aspects of research mobility by getting exposure to different cultures and broadening horizons were highlighted by one participant. There were also some participants who identified no influence of their background in their career. Some identified slow, positive steps toward inclusivity, while others emphasized the need for interdisciplinary collaboration, fairer working conditions, and broader employee participation in the decision-making process as essential steps toward enhancing diversity engineering. The final part of the session included an introduction to the four personality types (Red, Green, Blue, and Yellow) based on colour personality profiling. The members of the COST Action HELEN were asked to complete a short colour profiling test in their subgroups and discuss their commonalities and uniqueness. The goal was to raise self-awareness, acknowledge personality differences, build empathy for others, and foster effective communication and collaboration in light of future collaborative projects within the COST Action HELEN. It is well known that team diversity and inclusivity are linked to higher motivation, effective teamwork and collaboration, and greater overall performance.

Additionally, the successful completion of the two training schools on "Sustainability of Taller Timber Buildings" and "Holistic Design of Timber Connections" supported PhD students and Early Career Investigators by providing industry-relevant skills and networking opportunities with like-minded researchers.

4.2 – SHORT TERM SCIENTIFIC MISSION (STSM)

Short Term Scientific Missions (STSMs) aim to support individual mobility, strengthen existing networks, and foster new collaborations by enabling researchers to visit institutions or laboratories in other Participating COST Countries or approved institutions. These missions are designed to contribute directly to the scientific objectives of the COST Action HELEN while allowing applicants to learn new techniques or gain access to instruments and methodologies unavailable at their home institutions. STSMs are particularly beneficial for young researchers, helping them build and expand their professional networks. Through these exchanges, the COST Action HELEN also supports diversity and inclusivity in the research community.

During the second and third Grant Periods of the COST Action HELEN (2023–2024), 29 STSMs were successfully conducted, bringing the total number to 35. The missions covered a wide range of topics aligned with the Action's objectives. Applicants came from various countries, and gender balance was taken into careful consideration during the selection process. Notably, 86% of all grantees were Early Career Investigators (ECIs).

Thanks to the high number of successful applications and inspiring outcomes, the COST Action HELEN is proud of the progress made, and we are confident that these experiences will provide lasting benefits to the participating young researchers.

In support of promoting excellence from Inclusive Target Countries (ITCs), four ITC Conference Grants were awarded. In the past year alone, eight additional STSMs are either ongoing or about to begin, and two more ITC Conference Grants have already been granted.

The COST Action HELEN remains committed to fostering the development of innovative research and will continue to allocate resources toward novel scientific initiatives.

Figure 4: *Overview of countries of host and visitor institutions in the STSMs through COST Action HELEN*

5 – COMMUNICATION

The final book publication of the COST Action HELEN provides in depth knowledge and insights into the complexities of the designing, planning, assessing and construction of multi-storey timber buildings. The book goes beyond traditional design codes, which often focus on isolated aspects of building design. It integrates a spectrum of engineering topics alongside architects, builders, and other key stakeholders, such as investors, municipalities, and policymakers. Structured in four distinct parts, the book addresses a wide range of contemporary challenges in multistorey timber buildings. Ultimately, this book provides timber construction professionals, building investors, and users with valuable guidelines to create safer, more robust, and more comfortable multi-storey timber buildings.

https://doi.org/10.52202/080513-0228

6 – CONCLUSION

The very essence and key to the successful COST Action HELEN is intense interdisciplinary work with in-depth discussions and debate over a series of hypothetical and real case studies, followed by focused research work.

Contrary to common building research work done in the past, where individual topics were assessed in depth by specialised teams working on isolated topics (i.e., just timber connections or just vibration of floor plates), research within COST Action HELEN is intensely collaborative and integrated.

ACKNOWLEDGEMENT

This publication is based upon work from COST Action CA20139 - Holistic design of taller timber buildings (HELEN), supported by COST (European Cooperation in Science and Technology).

For further information please consult also the COST website https://www.cost.eu/actions/CA20139/ and the Actions website: https://cahelen.eu/

The authors thank all members of the COST Action CA20139 HELEN, for the discussions, presentations, and contributions.

REFERENCES

[1] Palma P., Fink G., (Eds.). Design for robustness, adaptability, disassembly and reuse, and repairability of taller timber buildings: a state of the art report. COST Action CA20139 Holistic design of taller timber buildings (HELEN). 2022. https://cahelen.eu/resources-downloads/

[2] Bedon C., Reynolds T., Aloisio A., (Eds.). Design of taller timber buildings against deformations and vibrations: a state-of-the-art review. COST Action CA20139 Holistic design of taller timber buildings (HELEN). 2022. https://cahelen.eu/resources-downloads/

[3] Casagrande, D., Brandon, D., D'Arenzo, G., & Viau, C., (Eds.). Design of taller timber buildings subjected to accidental loads: a state-of-the-art review. COST Action CA20139 Holistic design of taller timber buildings (HELEN). 2022. https://cahelen.eu/resources-downloads/

[4] Franke, S., (Ed.). Sustainability and Durability of Taller Timber Buildings: A state-of-the-art report. COST Action CA20139 Holistic design of taller timber buildings (HELEN). 2022. https://cahelen.eu/resources-downloads/

[5] Fink G., Jockwer J., Šušteršič I., Stepinac M., Palma P., Bedon C., Casagrande D., Franke S., D'Arenzo G., Brandon D., Viau C., (2023). Holistic design of taller timber buildings–cost action helen (CA20139). World Conference on Timber Engineering, Oslo, Norway.

https://doi.org/10.52202/080513-0228