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Standard Timber Structures for Lean Architectural Design

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Abstract

The Finnish building stock is our most significant national asset and the construction industry an important source of income. By managing building production we affect the performance of this activity. Development is required for timber-building to compete in this market.

Lean culture is one approach to optimized production. Lean construction research has defined lean and industrialized processes, identified the differences between mass-customization and mass-production, and the importance of standardization. Redesign is a recognized cause of inefficiency, typical also for complex timber buildings. Development visions include building system based design automation and modularization. This study explores pre-designed details as a means to reduce work in planning processes.

The article bases on a comparative case study. Six collections of pre-designed details developed for building with timber are presented and compared regarding availability, formats, accessible material and structures. Usability in practice is assessed with one selected intermediate floor structure as a benchmark. Conclusions are that barriers exist for transnational use, in referencing systems and for the direct use of proposed details and structures in a CAD-environment. The amount of material varies greatly. However, the collections successfully act as an overview of solutions compatible with local building regulations, and the similarity of solutions offers an opportunity for European wide competition and implementation.

Research leading to these results is part of the transnational WoodWisdom-Net Research Programme, project Innovative lean processes and cooperation models for planning, production and maintenance of urban timber buildings, leanWOOD.

Introduction

This research is part of the transnational project *Innovative lean processes and cooperation models for planning, production and maintenance of urban timber buildings* (leanWOOD). The project aims to develop timber-building with the design process as focal point.

Detailing is one issue to improve in building practice. For example, it is not uncommon for joints and structures to be first designed by the architect, redrawn by the structural engineer, possibly revised by a sub-contractor, and redrafted on site before final versions are agreed upon. This type of redesign can be characterized as waste of work and resources in the building design process.

The article includes a literature review of lean construction and design research, and a comparative case study of six European collections of timber-building details. The discussion evaluates the usability in architectural practice.

The article bases on a comparative case study. Six collections of pre-designed details for building with timber are presented and compared regarding availability, formats, accessible material and structures. Usability in practice is assessed with one selected intermediate floor structure as a benchmark.

PEER-REVIEWED ARTICLE

This article presents a comparative case study of six European collections of pre-designed details for timber-building. Selection criteria are the familiarity and use in partner countries of project leanWOOD; Finland, France, Germany, and Switzerland. Research material includes additionally two Austrian collections known in both Germany and Switzerland. The availability and usability of presented material in design practice is assessed by comparing the collections regarding user interface, availability, formats and amounts of published material, and suggested solutions. A benchmarking exercise based on one exemplary structure complements the comparison.

Literature review: lean construction and design

Systematization and industrialized construction do not necessarily equal mass-production.

Project leanWOOD aims to develop the timber-building design process by building on the foundations of *lean culture* in the construction industry. Research in lean production and manufacturing started with the *Toyota Production System* (TPS) (Womack et al., 1990) but further development of the construction industry based on lean methodology has gained speed only in the 21st century. Due to the small amount of publications on lean timber construction the discussion below concerns general lean construction and design research.

Among the first to define *Lean construction* was Howell (1999) who concludes that “Essential features of lean construction include a clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent design of product and process, and the application of production control throughout the life of the product from design to delivery”. Later, Lessing et al. (2005), and Bildsten (2011) identified *Industrialized construction processes* as characterized by the planning and control of processes, developed technical systems, off-site manufacturing of building parts, long-term relations between parties, integrated supply chain management, customer focus, the use of information and communication technology, systematic performance measuring and the reuse of experiences.

Systematization and industrialized construction do not necessarily equal mass-production. Bildsten (2011), Lessing et al. (2005), and Rich (2012) underline the difference between “*mass-customization”* and “*mass-production*”. For example, in housing production the aim should be for high customer satisfaction and a bespoke building as end result - expressed in other terms as “/…/ a custom product exactly fit for purpose /…/” (Aziz and Hafez, 2013).

However, the application of standardized components aids improving the efficiency of its production. The view is supported by Aapaoja and Haapasalo (2014), who have explored the relationship between standardized products and building processes in the Finnish construction industry. As benefits of standardized components they identify a track record, increased productivity, decreased waste, replicable processes, shorter lead-in times, and a higher quality. Bildsten (2011) and Rich (2012) see standardized components as a means to achieve a continuous improvement of processes.

Design is identified as one barrier for improving construction processes. For example, Aapaoja and Haapasalo (2014) conclude that “(The) current design processes do not support using the standard products and components” and identify an “(The) inability to order (and offer) standardized products and solutions”. (Aapaoja and Haapasalo 2014, Table 3, p 989). Bildsten (2011) sees the cost of development as one barrier. Rich (2012) reports on waste in the design process caused by an ambition to design beyond the limits of know-how or need, and by redesign. He sees potential in pre-developed detailed design and earlier collaboration with suppliers. The notion of redesign as a factor of waste in building processes is supported e.g. by Pasquire and Connolly (2003).

Various strategies to reduce design work have been explored. In the early 1900s architects aimed to lower the costs of housing production by an industrialized approach similar to mass-production. It was also widely applied in the reconstruction era after World War II. Regarding mass-customized building production, Álvaro Siza was an early forerunner of end-user driven design for expandable homes. (Benros and Duarte, 2009)

Current development suggests module-based solutions. For example, Powell et al. (2014) see modularization as the future for producers of engineer-to-order products with little volume but high variety. One recent design-methodology is "*modular design of one-off projects*" introduced by Mohamad et al. in 2013. The strategy builds on the modularization of the building and the standardization of modules. Benros and Duarte (2009) propose a framework integrating architectural design with building construction aiming to speed up repetitive tasks when using a complex building system. Key attributes of their concept include a combination of (1) flexible design, (2) data communication (Computer Aided Design-application, CAD), and (3) industrialized building processes. Similar thinking is proposed by Jensen et al. (2012) discussing building system-based design automation to promote the use of modular standard objects in architectural design. Pasquire and Connolly (2003), developers of the "*design for manufacture and assembly (DFMA)*"-model, support decreasing unnecessary work and argue that designers should emphasize value for the client over detailed design.

Research on lean construction has identified redesign and unnecessary detail work as sources of wasted resources in the building design process. This study seeks to explore the availability of pre-designed details and assess the usability of them as standardized components to aid a more efficient design and production of timber buildings.

The literature review illustrates that research on lean construction has identified redesign and unnecessary detail work as sources of wasted resources in the building design process. Various optimization strategies have been explored including attempts to decrease detailing. This study seeks to examine the availability of pre-designed details and assess the usability of them as standardized components to aid a more efficient design and production of timber buildings.

Research material: pre-designed details for building with timber

This research presents six collections of pre-designed details for timber construction published in Austria, Finland, France, Germany, and Switzerland. The earliest publication is from 1999 and Holzforschung Austria was the first to publish online in 2003. Discussed material is freely and publicly available. Contents are compared regarding availability, offered formats, structures and solutions. The usability in practice and added value of other material is assessed. Table 1 presents selected collections.

Collections: availability and offered formats

RunkoPES 2.0 was published in Finland in 2013 by Finnish Wood Research Oy. It is an open timber element-standard for residential housing production in accordance with the National Building Code of Finland. It gives guidelines for designing multi-storey houses of fire classification P2 and large scale element production. It can also be applied to non-load bearing structures and spatial modules. Detail designs show the principles and are to be further developed by, for example, element manufacturers. All material is free, open-access to the public and downloadable at the website of the Finnish Timber Council (Finnish Wood Research 2013a). Structural solutions are collected into one overview publication in pdf-format and joint details to a separate document. The material can be printed but is copy protected. Additional materials consist of exemplary designs for a model multi-storey apartment building including HVAC- and building permit-drawings. CAD-objects are available in formats ArchiCAD 17, ArchiCAD 16, Revit 2014, and IFC 2x3. The language is Finnish only. Final structures are to be verified by a structural engineer separately for single building projects.

Compared online libraries include the Finnish RunkoPES 2.0, the Austrian Dataholz and IBO Passivhaus Bauteilkatalog, the Swiss Lignum Bauteilkatalog Schallschutz, the French Catalogue Construction Bois, and the German book The Erarbeitung weiterführender Konstruktionsregeln /-details für mehrgeschossige Gebäüde in Holzbauweise der Gebäüdeklasse 4.

The *Catalogue of reviewed timber building components for thermal, acoustic, fire performance requirements and ecological drivers* (Dataholz) published in 2003 was developed by the Austrian Association of the wood industry, HolzForschung Austria and proHolz Austria. It includes construction details for residential building in framework and massive timber designs. The material is free, open-access to public and downloadable at the dataholz.com-website (Holzforschung Austria, 2003). It consists of fact sheets and drawings in pdf-format. All can be both copied and printed. Language options include German, English, Spanish and Italian. The material is offered as suitable proof of compliance with Austrian building regulations. However, no liability is accepted.

Swiss timber construction details, *Lignum Bauteilkatalog Schallschutz* (Lignum Bauteilkatalog), were published by LIGNUM Holzwirtschaft Schweiz in 2014. It is a collection of intermediate floor structures only for acoustic design in accordance with standards SIA 181:2006, EN 12354:2000, ISO 717-1, and ISO 717-2 and to reduce low-frequent impact sound (below 100Hz). Framework and massive timber designs are included. The material is free, open-access to public and downloadable at the Lignum Bauteilkatalog-website (Lignum 2014). It consists of structural detail fact sheets and drawings in pdf-format. Documents can be printed and the information copied. It is published in German only.

The Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4 (GHG4) was published in 2014 (Gräfe et al., 2014). It promotes the design of multi-storey timber buildings in Germany up to 13 m height of upper floor level (Gebäudeklasse 4). Structures include framework and massive timber-designs. The publication is free, open-access to public and downloadable at the Fraunhofer IRB-website. It contains background and general information, structural and detail-solutions. Contents can be copied and printed. The book is published in German only.

The Austrian *IBO Passivhaus Bauteilkatalog* (Baubook) collection is published by Österreichisches Institut für Baubiologie und - ökologie (Verein) und IBO GmbH. The contents of 68 pre-designed structures support passive house design. They include framework and massive timber designs in a standard and an ecologically optimized version. The collection is open-access to public and material can be downloaded at the Baubook-website (IBO 2009). Fact sheets are available as separate pdf-documents and structures can be examined as 2D or 3D-images. All material can be copied or exported to pdf-documents. It is available in German only, with small parts translated to English. Materials and structures listed need no separate verification: they are accepted by the authorities and funding institutions as such. The online-version bases on the Passivhaus-Bauteilkatalog – Ökologisch bewertete Konstruktionen first published in 1999 (Passivhaus-Bauteilkatalog 2009). The latest publication from 2009 includes full text in both German and English and can be purchased through the Baubook-website.

L'Institut Technologique Forêt Cellulose Bois-construction Ameublement, FCBA, and the Comité professionnel de développement des industries françaises de l'ameublement et du bois, CODIFAB, have developed the French *Catalogue Construction Bois* (CCB). Wall details were published in 2013 and other in 2014. The collection includes structural and joint details, and guidelines for fire-safety design. It entails structural solutions in framework and massive timber for residential single family homes and multi-storey apartment buildings. The material is free, publicly available and downloadable at the catalogue-construction-bois.fr-website (FCBA 2013). All material is available in pdf-format, partly also in MS Word-format. It can be both copied and printed. Details are available as pdf-documents and in dxf-format (CAD). The material is published in French only.

Table 1. Online collections of pre-designed timber building details evaluated in this research.

Collection	RunkoPES 2.0	Dataholz	Lignum Bauteil-katalog	GHG4	Baubook	CCB
Country of origin	Finland	Austria	Switzerland	Germany	Austria	France
Aim	To create a basis for the commissioning, design and execution of timber buildings in which: 1) a building can be designed without knowing who will execute building works or whose solutions are used, 2) suppliers of different solutions are able to make an offer coherently and cost efficiently, 3) and different manufacturers´ solutions are interchangeable in the design and on site	General construction details to serve as a start for conceptual, initial and detailed design and execution of residential timber buildings	To support the design of ceilings fulfilling impact sound criteria	To create a catalogue with thoroughly designed details and structures for timber building in accordance with the German building regulation code *Musterbauordnung 2002* and the guideline for fire-resistant timber structures from 2004	To offer details for the design and support for the ecological evaluation of passive houses	To aid the design of timber buildings in accordance with RT 2012 (Réglementation Thermique 2012, design for energy efficiency) and requirements set in NF DTU 31.2 (Eurocode compatible timber frames)
Structures	external walls internal walls intermediate floors wet spaces ceilings roofs balconies	wood, wood composites insulation, ligning materials and other external walls internal walls intermediate floors ceilings roofs windows doors other connections and joints	floors	external walls internal walls intermediate floors selected joints including joints between timber and massive wall structures (e.g. concrete or brick) window detailing	external walls internal walls intermediate floors windows roofs	external walls internal walls intermediate floors roofs ductwork integration
Construction types	massive wood framed structures	massive wood framed structures	massive wood framed structures	massive wood framed structures	massive wood framed structures	massive wood framed structures
Other material	Overview catalogue, example designs for a model multi-storey apartment building including HVAC designs, model building permit drawings	NA	NA	extensive guide book on the design for timber construction	Construction calculator (also available in English), Eco2soft calculation tool	General guidelines for the design of timber structure and separately for single family homes and multi-storey housing
Formats	Pdf-documents, objects in ArchiCAD 17, ArchiCAD 16, Revit 2014, and IFC 2x3	Pdf-documents	Pdf-documents	Pdf-book, available as CAD-objects for Dietrichs CAD/CAM	Pdf-documents, book published by Springer (in German and English)	Pdf and MS Word-documents, dxf-objects
Languages	Finnish	German, English, Spanish, Italian	German	German	German, online version only partly in English	French
Availability	Free of charge	Free of charge	Free of charge	Free of charge	Free of charge	Free of charge
Website	www.puuinfo.fi/suunnitteluohjeet/runkopes-20	www.dataholz.com/	bauteilkatalog.lignum.ch/?lang=de&page=home	www.irbnet.de/daten/rswb/14109008377.pdf	www.baubook.at/phbtk/index.php?SW=19	catalogue-construction-bois.fr/

The collections are compared based on suggested structures for intermediate floors as it is the only structure available in all. Floor type VP801KRL from RunkoPES 2.0 is selected as a benchmark.

Structures: case intermediate floor

Within the scope of this research, selected collections are compared based on suggested structures for intermediate floors as it is the only structure available in all.

RunkoPES 2.0 presents structural details in one pdf-document including guidelines for their use (Finnish Wood Research, 2013b). The publication includes ten different types of intermediate floors and eight solutions for bathrooms. Single details are shown on separate fact sheets with drawings in scale 1:10. A table explains structural layers and their task, like ensuring fire performance or sound absorption, material type and thickness of the layer. Performance data of the structure as a whole is also listed. Weight is excluded. To compare different collections, intermediate floor type VP801KRL is selected as a benchmark. It is dimensioned for a span of maximum 6 meters. Structural layers are listed in Table 2 and illustrated in Figure 1.

Table 2. Structural layers of intermediate floor type VP801KRL, RunkoPES 2.0.
Performance characteristics: REI 60, $R_w \geq 55$ dB, $L_{n,w} \leq 53$ dB, U-value not listed.
(Finnish Wood Research 2013b, 146)

Thickness	Layer
15 mm	floor surface, parquet
75 mm	concrete casting
	polypropylene sheet
18 mm	timber board
12 mm	sound absorption
360 mm	timber beam, including 100 mm thermal insulation
	(load bearing structure)
20 mm	gypsum board 2 x 10mm
500 mm	total structural thickness, weight not listed

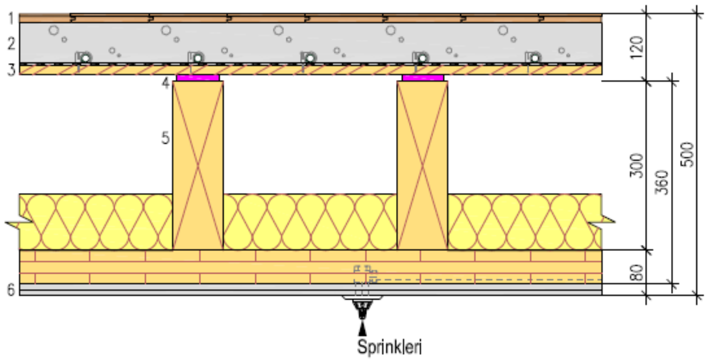

Figure 1. Build-up of intermediate floor type VP801KRL, RunkoPES 2.0.
Authors note: The structural detail drawing includes a sprinkler. According to the National Building Code of Finland sprinklers are mandatory in timber framed buildings from two stories upwards.
(Finnish Wood Research 2013b)

The *Dataholz* shows a list of structural types and details on first page. After selecting intermediate floors, a new page opens up with the possibility to select and organize solutions according to characteristics including fire, acoustic and thermal performance. Construction, floor assembly and type can also be selected. Detailed descriptions are examined directly on the website or as separate pdf-documents. Additional data include an extensive overview of sustainability impacts with calculated values for the Global Warming Potential (GWP, Equivalent kg CO_2), Acidification Potential (AP, Equivalent kg SO_2), primary non-renewable energy content (PEI ne, MJ), primary renewable energy content (PEI e, MJ), the Euthropication Potential (EP, Equivalent kg PO_4), and Photo-oxidants (POCP, Equivalent kg C_2H_4).

Based on the characteristics of RunkoPES 2.0 intermediate floor type VP801KRL, two alternative structural types are suggested. Type gdrnxn04b is similar to type VP801KRL. After selecting this type, the site lists in this case 10 different alternatives with small variations in single components. Intermediate floor type gdrnxn04b-08 is closest to the benchmark. It is dimensioned for a maximum span of 5 meters. The structure is presented in Table 3.

Table 3. Structural layers of intermediate floor type gdrnxn04b-08, Dataholz.
Performance characteristics: REI 60, R_w = 55 dB, $L_{n,w}$ = 66 dB, U-value 0.28 W/m^{2}K. (Holzforschung Austria 2003). Authors note: The online-version lists glass-wool as thermal insulation throughout the layers (both German and English version). However, glass-wool is generally not used in Austria in this type of structure due to fire precaution.

Thickness	Layer
50 mm	cement or anhydrite screed
	plastic separation layer
30 mm	impact sound absorbing subflooring MW-T
19 mm	particle board
220 mm	timber, including 100mm rock/or mineral-wool thermal insulation (online: glass-wool) (load bearing structure)
24 mm	cladding, spruce
25mm	gypsum plasterboards with improved properties at high temperatures (fire), 2x12,5 mm) or 25 mm gypsum fibre board 2x12.5mm
368 mm	total structural thickness, weight 161.8 kg/m^2

Intermediate floor structures of the *Lignum Bauteilkatalog* total 323 alternatives. Selection criteria for structures consist of acoustic performance, load bearing structure, filling finish, floor surface for dry or wet installation, fastening system of ceiling (intermediate floor), total mass, and building part identification number. Information of each item comprises a drawing of the detail itself, basic data of acoustic performance, thickness of the structure in millimeters and weight in kilograms per square meter. Single structural layers are described in a table including name of the suggested material, thickness of the layer in millimeters, weight when relevant, the manufacturer for selected components and possible other specifications. Fire performance is not listed. Several details can be selected simultaneously. However, this function did not work at the time of testing. Of each structure, a fact sheet in pdf-format can be generated. The intermediate floor type closest to type VP801KRL of RunkoPES 2.0 is type number A.2.01-01a-10-00a-01-110a-aa, identification number 298. Maximum span for the structure is not mentioned. Structural layers are listed in Table 4.

Table 4. Structural layers of intermediate floor type 298, Lignum Bauteilkatalog.
Performance characteristics: Fire performance not listed, R_w = 62 dB, $L_{n,w}$ = 53 dB, U-value not listed. (Lignum 2014)

Thickness	Layer
80 mm	cement screed (not the final surface)
30 mm	impact sound absorbing subflooring (impact sound insulation board)
27 mm	paneling/ planking with three-ply panels
240 mm	timber beam, including 160 mm thermal insulation (load bearing structure)
27 mm	paneling/ planking with three-ply panels
15 mm	gypsum board filled
419 mm	total structural thickness, weight 247 kg/m^2

The *Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4* (GHG4) detail catalogue is an all-inclusive publication. The amount of details is limited with only three types of structures for intermediate floors and showing principles and layer types only. Two intermediate floor types use solid wood as a load bearing structure, whereas the basic type TD1 is similar to type VP801KRL of RunkoPES 2.0. Maximum span for the structure is not mentioned. Structural layers are presented in Table 5.

Table 5. Structural layers of intermediate floor type TD1, GHG4. Performance characteristics: REI60, R_w = 60 dB, $L_{n,w}$ = 48 dB, U-value not listed. (Gräfe et al. 2014, 155)

Thickness	Layer
	floor surface
≥ 30 mm	cement screed or anhydrite screed
≥ 20 mm	impact sound absorbing subflooring
≥ 19 mm	timber
	timber, including thermal insulation (load bearing structure)
	air-tight layer if required
	Timber
36 mm	gypsum or gypsum fibre board 2x18mm
	total structural thickness, weight not listed

The *Baubook*-website introduces the collection on first page and structural groups on the next. After selecting floor structures, a new page opens with a list of solutions. Detail information includes the thickness of structural layers, information of thermal insulation capacity and performance, weight, primary renewable energy content (PEI e) and reference values for GWP ($kgCO_2/m^2$) and AP ($kgSO_2/m^2$). Fire or acoustic performance is not listed. Of the six available intermediate floors type GDI 01, version a, is closest to the benchmark VP801KRL of RunkoPES 2.0. Maximum span is not listed. Structural layers are listed in Table 6.

Table 6. Structural layers of intermediate floor type GDI 01a, Baubook. Performance characteristics: Fire performance or acoustic properties not listed, U-value 0.232 W/m^2K. (IBO 2009) Authors note: The online-version lists glass-wool as thermal insulation throughout the layers. However, glass-wool is generally not used in Austria in this type of structure due to fire precaution.

Thickness	Layer
10 mm	floor surface, parquet
50 mm	cement screed or anhydrite screed
0.2 mm	polyethylene (PE)
30 mm	impact sound absorbing subflooring, rock-wool or mineral-wool (online: glass-wool)
50 mm	bonded chippings
0.2 mm	polyethylene foil (PE)
22 mm	OSB-board
220 mm	timber, including 80mm thermal insulation and air-tight layer (load bearing structure)
22 mm	OSB-board
50 mm	rock/or mineral-wool 40 mm + air gap 10 mm (online: glass-wool)
30 mm	gypsum or gypsum fibre board 2x15mm
484.4 mm	total structural thickness, weight 266.6 kg/m^2

The website of *CCB* allows for selecting the type of structure on front page. After selecting intermediate floors, available types are listed on the following page. Four types of intermediate floors are included: (1) timber frame, (2) prefabricated element-structure, (3) double timber frame and (4) solid timber frame. For type 1 the following page shows several alternatives with joint details. One is similar to type VP801KRL of RunkoPES 2.0. Maximum span is not listed. The structure is presented in Table 7 and illustrated in Figure 2.

Table 7. Structural layers of intermediate floor type 1 with two layers of gypsum board, CCB. Performance characteristics: REI60, R_w = 63 dB, $L_{n,w}$ = 49 dB, U-value not listed. The structural principle is shown in the detail-document and dimensions listed separately. Structural layer descriptions refer to separate standard documents. (FCBA 2013)

Thickness	Layer
14 mm	surface layer, parquet
50 mm	concrete casting on polyethylene
18 mm	timber board
	timber, including thermal insulation (load bearing structure)
	impact sound absorbents
36 mm	gypsum board 2 x 18 mm
	total structural thickness or weight not listed

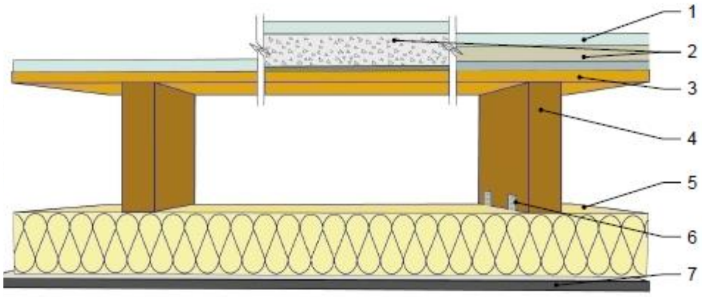

Figure 2. Build-up of intermediate floor type 1, CCB. (FCBA 2013)

Supporting material

In addition to pre-designed solutions, four of the discussed collections offer additional material like general guidelines for timber-building design. Exceptions include Dataholz and Lignum Bauteilkatalog offering fact sheets only. This chapter presents supporting material with information relevant for the application of intermediate floor structures discussed in the previous chapter.

Intermediate floor structures are part of the structural type catalogue of *RunkoPES 2.0*. (Finnish Wood Research, 2013b) The publication consists of a short introduction, tables with basic data of all structures and separate fact sheets of each. The table offers an overview enabling comparison of structures according to fire and acoustic performance, maximum span, U-value and thickness. CAD-objects are downloadable at the same website-page. The selected benchmark, intermediate floor structure type VP801KRL, does not as such exist as an ArchiCAD or Revit-object. However, a general intermediate floor object of same dimensions is available. Software for the dimensioning of intermediate floors is found on the website. Fire-safety design solutions for integrating e.g. ventilation ducts are shown in separate documents. Other joint details are collected into an own publication. Exemplary building permit drawings illustrate the design of a complete building.

The *GHG4* consists of one publication including an overview of building regulations, and solutions for e.g. integrating building technology. Fire performance, testing and recommendations are discussed in an own chapter. About one third of the publication is dedicated to suggested structures and details which are listed in overview tables according to type, description and index number. Separate fact sheets for each structure include a detail drawing, list of layers, and values on fire and acoustic performance. No additional software, calculation tool or material is offered.

In addition to timber building details, the *BauBook* online-collection does not include any other material. However, complementary software is available. Eco2soft-software aids in calculating the environmental footprint of a whole building. Attributes include U-values, GWP 100, PEI and AP. The Bauteilrechner offers an opportunity to compare, edit and save selected structures after a separate login (free of charge).

Supplementary information of the *CCB*-website includes information on design and dimensioning principles for attributes like thermal insulation, acoustic and fire performance, load bearing capacity, accessibility and durability. Documents on regulations, norms, and environmental impacts are available. The link to Eurocodes is highlighted. Principle designs are shown for a multi-storey residential building and single family homes including structural dimensions.

Discussion: usability in practice

Published European collections of pre-designed details could potentially support building system based architectural design. However, the comparison of available material in six detail collections for timber-building and the benchmarking exercise based on one selected structure revealed both barriers and opportunities for the applicability and usability of them in practice.

European collections of pre-designed details could potentially support building system based architectural design. However, the comparison of six libraries for timber-building and the benchmarking exercise based on one selected structure revealed both barriers and opportunities for the applicability and usability of them in practice.

Language is one obstacle. Only Dataholz is entirely available in several languages and the online version of Baubook has some material in English. The other four publish material in native language only. Increased language options would lower the barrier for implementation.

User interfaces and the path to find a specific detail vary. Dataholz and Lignum Bauteilkatalog proved practical as a result of the limitation options according to attributes like fire performance. The smaller amount of details in the four other collections made the task fairly simple as well. However, to find a detail or structure matching requirements set demanded work.

The conclusiveness of presented material varies. For example, Dataholz lists a vast variety of alternatives for each separate structural type, whereas GHG4 only contains a few principle solutions. The only collection clearly focused on large structures for multi-storey buildings is RunkoPES 2.0, whereas the other mainly introduce structures of less load bearing capacity, smaller spans, and very few alternatives developed for prefabrication. Then again, RunkoPES 2.0 contains solutions and principles for multi-storey housing only.

Some collections emphasize the aspect of general advice. For example, GHG4 contains advice for multi-storey timber housing and CCB works as an introduction to timber building with an informative overview of selected structures and details for single family homes and multi-storey residential buildings. RunkoPES 2.0 includes the largest variety of material from general guidelines to principles of detailing, exemplary building permit documents and CAD-objects. Dataholz and Lignum Bauteilkatalog do not contain any guidelines, but the variety and amount of details and structures is significant. RunkoPES 2.0 and the webpage of the Finnish Timber Council offer additional support for the dimensioning of structures and large amounts of information. A holistic ecological calculation tool is published only by Baubook.

All collections implement identification numbers. The numbering acts as an internal indexing system. Usability could be improved by referring to external sources like building regulations.

The vision of this study is for pre-designed details to enable reducing waste in architectural timber-building design processes caused by unnecessary work and redesign. For pre-designed details to be used it would require a complete, compatible, and established set of standard structural and joint drawings. Among discussed collections and in terms of extensiveness Dataholz responds best to this requirement whereas RunkoPES 2.0 offers the most holistic approach.

Another characteristic of lean culture is the use of information and communication technology to enhance efficiency, and CAD-software is an essential tool for planners. However, only a few of the collections offer CAD-objects. The most versatile collection in this respect is RunkoPES 2.0.

Selected collections are developed by the wood based products and timber-building industry in collaboration with research institutes. The aim is to aid and promote building with timber. However, this study revealed a vast amount of incoherent material. An efficient use would require more established solutions and easy-to-use interfaces.

However, the comparison based on one selected benchmark shows that suggested structures for building with timber are alike throughout Europe. Fire and acoustic performance is solved similarly. For example, fire performance is mainly ensured by structural encapsulation in gypsum boards. Due to the dimensioning for different spans beam heights of discussed structures vary and the only clearly different structure, designed for passive houses, is presented in the Baubook. These findings are significant as they illustrate a common basis for standardized timber building-design.

For a practicing architect the collections offer an overview of optional solutions and a means to verify the compatibility of designs with local building regulations. Additionally, similar structures can be found in all collections. This is an opportunity for the construction industry in the terms of European wide competition. Based on this study timber buildings in the countries of Austria, Finland, France, Germany and Switzerland could be designed and constructed with same structural solutions.

Conclusions

Research on lean construction has identified redesign and unnecessary detailing as sources of waste in the building design process. The vision of this study is that timber-building could be optimized by using pre-designed details, thus supporting reduced work and leaner processes.

To assess this option, six European free online-collections of pre-designed timber-building details were examined. The usability in practice was explored by identifying and comparing a similar intermediate floor structure and supporting material in all collections. Identified barriers include limited language options, the user interface, the variety of amounts and types among published material, and the identification systems. CAD-objects are absent in several collections, hence failing to efficiently support the use of information and communication technology, and automated architectural design processes. Based on studied material, some collections serve more as an introduction to timber construction and others as a direct design tool.

For a practicing architect the collections offer an overview of optional solutions and a means to verify the compatibility of designs with local building regulations. The discussed exercise also illustrates a minimal variation. Similar structures can be found in all collections. This finding supports the thought of limiting building specific detailing in the design process.

The similarity of structures is an opportunity for the construction industry in the terms of European wide competition. Based on this study timber buildings in the countries of Austria, Finland, France, Germany and Switzerland could be designed and constructed with same structural solutions.

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