Proceedings of International Structural Engineering and Construction, 11(2), 2024
Developing Materials and Structures for Sustainable Engineering
Edited by Gribniak, V., Rimkus, A., Holschemacher, K., Quapp, U., Singh, A., and Yazdani, S.

ISSN: 2644-108X
www.doi.org/10.14455/ISEC.2024.11(2).AAE-01

CONCEPTS FOR TIMBER-SPECIFIC MEP INSTALLATIONS AND SEALINGS IN BATHROOMS OF MULTI-STORY RESIDENTIAL BUILDINGS

PETRA FORTMÜLLER[1], GREGOR SILLY[2], DOMINIK MATZLER[2], ALEXANDRA THIEL[2], GERHARD SCHICKHOFER[2, 3], and MICHAEL MONSBERGER[1]

[1]*Institute of Building Physics, Services and Construction, Graz Univ of Technology, Graz, Austria*

[2]*holz.bau forschungs gmbh, Graz, Austria*

[3]*Institute of Timber Engineering and Wood Technology, Graz Univ of Technology, Graz, Austria*

The European market for cross-laminated timber (CLT) is rapidly growing in the field of multi-story residential buildings. However, water leaks repeatedly lead to severe moisture damage in timber buildings. Undetected moisture damage may result in biological degradation of the CLT structure, is difficult to repair, and incurs high costs. Currently, there is a lack of awareness of the fact that timber buildings require different mechanical, electrical and plumbing (MEP) installation methods than buildings made with mineral construction materials. In addition, too little attention is given to protecting the wooden structure by applying appropriate sealing measures that actually work in practice. Lack of planning and uncoordinated construction work exacerbate this problem. Presenting 2D drawings and 3D BIM models, the paper illustrates concepts that can be used to optimally design and safely integrate MEP installations in bathrooms in multi-story residential timber buildings. A special focus is placed on a holistic view of the topics structure, pipe installation, sealing, and fire protection. The concepts presented are based on an analysis and classification of over 1100 bathroom layouts. Therefore, they are applicable to a wide range of bathrooms in practice. The presented results were developed in the research project CLT_Plumbing_Design. They contribute to the development of standardized, timber-specific solutions for pipe installation and sealing in bathrooms, and can help reduce moisture damage in timber construction. In addition, these concepts form a basis for a new automated planning process in the area of bathroom planning, for which a brief outlook is given.

Keywords: Timber construction, CLT, Safe MEP Integration, Prefabrication.

1 INDRODUCTION

Timber construction, and especially cross-laminated timber construction, has experienced strong growth in Europe in recent years. Many multi-story residential buildings are now being constructed in this sustainable way. However, moisture damage occurs repeatedly due to leaking pipes or because water penetrates through improperly installed or damaged sealings (e.g., shower area) (Monsberger *et al.* 2019). In both cases, the wood can be heavily damaged, and reconstruction is associated with great effort and high costs. The risk of water damage is high: In Germany, for example, more than one million claims are reported to insurance companies related to damaged water pipes or other plumbing components (e.g., boilers) each year. Almost 40% of these damages are due to installation errors (Knap *et al.* 2018).

Currently, pipes are often installed in the floor construction and are not visible or accessible. Schickhofer and Schmid (2014) point out that, in many cases, the installation routing is not planned thoroughly when the pipes are installed in the floor construction. Planners and construction companies often lack cross-trade knowledge, and there is only poor coordination at interfaces (Mersch and Rullán Lemke 2016). The needs of workers practicing other construction trades or planners are ignored, resulting in uncoordinated and chaotic construction work that is neither adequate for timber construction nor ensures functional sealing.

Especially small water leaks from inaccessible, hidden pipes often remain undetected for a long time; hence, these have the potential to cause massive damage to the timber structure (Monsberger and Partl 2016). Timber structures, therefore, require different installation concepts than mineral constructions.

In addition to adequate pipe installation concepts, placing a sealing on the raw ceiling is the most important measure for protecting the timber construction. In Austria, this is the state of the art for bathrooms in timber construction (ÖNORM B 3692 2014). However, due to a lack of detailed specifications, it happens that this sealing is installed, but does not work properly due to erroneous planning or construction work. Interfaces between sealing and pipe installations are particularly problematic. Improper pipe penetrations or installation fixings through the sealing pose a major risk. In addition, areas with a high installation density such as shafts or facing shells are usually not sealed, and sealing is only installed in the bathroom itself.

Therefore, there is an urgent need for simple, high-quality, standardized installation and sealing concepts to ensure that plumbing is safely integrated in timber constructions. It is also essential to develop solutions that promote prefabrication to reduce construction time while increasing construction work quality and counteracting effects of the skilled workers shortage. In addition, the planning process must be simplified by using generic designs and automated design methods. Currently, it is both challenging and time-intensive for planners to consider all rules included in standards on different detailed aspects. Critical sticking points and their underlying rules, therefore, must be identified and implemented in automated design methods by using appropriate rulesets that conform with the standards.

The following research question can be derived from the problems outlined above: How can holistically conceived timber-specific installation systems for bathrooms in multi-story residential buildings look like that, on the one hand, ensure functional protection of the timber structure and, on the other hand, promote standardization, prefabrication, and easy-to-use automated design methods?

The research project CLT_Plumbing_Design investigates this research question, as well as several others. In order to develop installation concepts that can be applied as generically as possible, the first step taken was to examine and classify over 1100 bathroom layouts. The classification process was carried out based on the type and location of the sanitary objects. Subsequently, installation and sealing concepts suitable for timber construction were developed for the most frequent bathroom types identified.

The developed concepts are generically applicable; therefore, they can be transferred to many bathroom and toilet layouts for timber and mineral constructions. The concepts are based on the following design principles: no pipes in the floor construction, compact pipe routing, few pipe joints, permanent access to installation areas, tight sealing wherever necessary (e.g., also in shafts), and integrated measures for water damage detection. In addition, their suitability for standardization and prefabrication, as well as for automated design solutions, were fundamental requirements for the development of these concepts. This paper introduces and describes concrete technical solutions that are applicable to many cases, provide a protective function for the timber construction, and are suitable for prefabrication and automated planning processes. Additional aspects addressed in the CLT_Plumbing_Design project (e.g., classification of bathroom types and automated design solutions) will be addressed in subsequent papers.

2 INSTALLATION CONCEPTS

The developed installation concepts are based on the most frequently identified bathroom types (out of more than 1100 bathroom layouts) and the design principles and concept requirements explained above. Pipes in the floor are particularly problematic, so they are routed outside the floor, as suggested by Schickhofer and Schmid (2014). In the concepts presented, pipes are exclusively located in facing shells and shafts. Each bathroom or bathroom/WC unit has a vertical main shaft behind the WC or washbasin and a separate heating shaft located on the corridor wall next to the heating distributor. This enables the shafts to be positioned as centrally as possible with respect to the end units and allows compact pipe routing. The allocation of all pipes in facing shells and shafts also enables the prefabrication of installation registers. In addition, leakage detection through inspection doors and an emergency drainage can easily be implemented. Fig. 1 shows the installation concepts for two of the most common bathroom types identified in the CLT_Plumbing_Design project. These are a bathroom equipped with a bathtub, a washbasin, and a washing machine (type 1) and the same bathroom but with an adjacent toilet (type 2). The hot water is provided centrally in each case, and a water radiator is included in each bathroom.

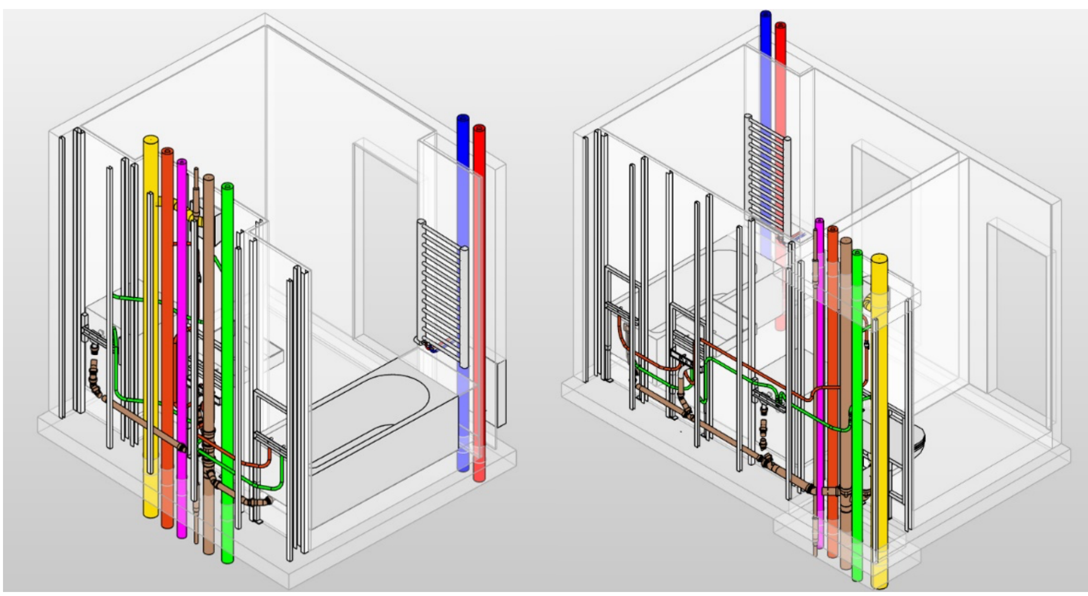

Fig. 1. Installation concept for a bathroom with a bathtub, washbasin, and washing machine - type 1 (left) and with a separate room with a toilet - type 2 (right).

The two shaft designs shown in Fig. 1 can be combined by creating different arrangements of sanitary objects or facing shells (also around the corner), thus offering versatile application possibilities (Fig. 2). In the case of central water heating, the shaft equipment includes the following components: Exhaust air, hot water, hot water circulation, emergency drainage, wastewater downpipe, and cold water. In the case of a decentralized warm water supply (e.g., a boiler), the two hot water pipes are omitted, and the shaft can be accordingly smaller.

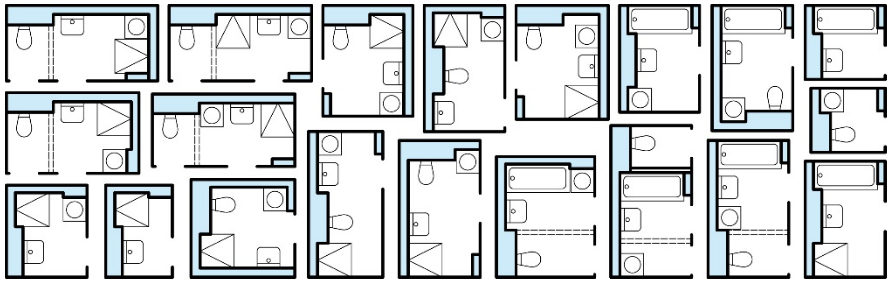

Fig. 2. Examples for the application of the installation concepts in different bathroom layouts.

The wastewater downpipe plays a decisive role when positioning the pipes in the shaft. As only certain pipe branches are available for discharging the wastewater, certain geometric constraints arise. To ensure that the proposed solutions can actually be built, BIM objects with real product dimensions from a manufacturer of installation products were used for 3D modelling. The distance between the pipes arises from the space needed to apply the sealing to the raw ceiling and to the risers. This is explained in more detail in the following section. To use as few joints as possible in the pipes for drinking water, double connection brackets are employed to loop the water through these at the pre-wall installation elements, which are necessarily located behind the sanitary objects. This eliminates the need for additional T-joints (except for the toilet) and reduces the risk of leakage. These installation concepts mainly differ from the current state of the art by the holistic approach taken and their generic applicability. Installation registers currently available on the market do not have timber-specific pipe routing because the dependencies between the pipes and sealing on the timber ceiling are not taken into account.

3 SEALING CONCEPTS

To protect the timber structure in the event of pipe leakage, it is necessary to apply sealing to the timber ceiling in areas with high installation density, such as shafts or facing shells. Up until now, the common practice has been to seal the bathroom itself, but not the adjacent shafts or facing shells. In this case, the pipes that are routed from the bathroom floor construction into the shaft or facing shell penetrate the sealing upstand and normally lead to many pipe penetrations. Pipe penetrations in particular represent a potential risk for untight sealings. Easy-to-apply liquid sealants are often used to seal pipe penetrations. However, these products adhere poorly to some plastic pipe materials or they are not sealed to the pipe itself but only to the surrounding pipe insulation. In addition, pipes are often installed with too little distance between pipes, which makes the application of watertight sealing impossible. When developing the installation concepts as outlined in section 2, particular attention was paid to reducing the number of penetrations and ensuring that the remaining penetrations can actually be built and are waterproof.

In this context, fire protection measures also play an essential role. In Austria, shafts can be divided into stories for fire protection reasons. This is allowed in residential buildings if only one apartment per floor is supplied via this shaft (TRVB 110 B 2015) and if the necessary fire bulkheads are installed in the ceiling area of the shaft. On these fire bulkheads (e.g., core drillings with pipe-specific fire protection measures), the sealing can also be applied in the shaft area. This prevents water from running into the stories below if water damage occurs and from causing further damage there. When sealing the individual pipes, the respective fire protection measures required for the pipe must be considered, as well as a space requirement for sealing of 10 cm around the pipe. Wastewater downpipes can be ideally bulkheaded with a fire protection collar located under the ceiling and not in the sealing area. A sealing collar can then be used to seal the wastewater pipe.

In any case, it must be ensured that the sealing collar is completely fitted to the smooth pipe and not in the area of a pipe socket or a branch. However, pipe branches (through which wastewater from distant showers or bathtubs is emptied into the downpipe) are often on the level of the sealing. In this case, waterproof sealing is not possible. In the CLT_Plumbing_Design project, a solution with a lowered ceiling in the shaft was developed to solve this problem (see Fig. 1, type 2 and Fig. 3). A common fire protection measure, e.g. for water or heating pipes, is a pipe section for fire insulation. This pipe section must be installed up to a certain height above the sealing level in the shaft. In this case, applying a seal to the pipe itself at the sealing level is not possible, because the pipe section insulation must not be interrupted. However, flanged metal pipes can be used in such cases, which allow a tight seal to form (e.g., with liquid sealant). The upper end of the metal pipe should be sealed with a shrink tube to ensure tightness even if leakage originates from one of the risers. Fig. 3 shows the pipe penetrations in the shaft area with sealing and fire protection measures.

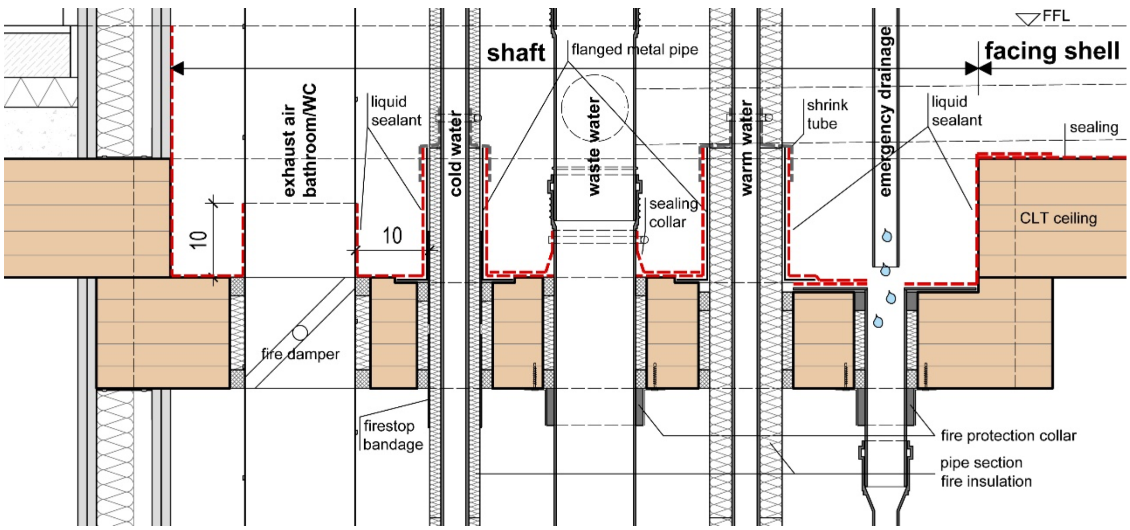

Fig. 3. Pipe penetrations in the shaft area with sealing and fire protection measures.

As shown in Fig. 1 and Fig. 3, an emergency drainage system was also integrated into the shaft area. Large amounts of water can accumulate in a short time if pipes leak. Therefore, it is advisable to position the emergency drainage system in areas with a high installation density to enable rapid drainage and reduce the risk of damage. The shaft/emergency drainage system can be accessed via inspection doors. Moisture sensors can additionally be installed to detect leaks more quickly.

4 CONCLUSION

Undetected moisture damage can cause massive damage to timber constructions. The presented installation and sealing concepts help to significantly improve the protection of the timber construction in bathrooms of multi-storey residential buildings and thus support the sustainable use of timber as a building material. In addition, the consistent routing of pipes in shafts and facing shells supports the prefabrication of installation registers. This results in shorter construction times and an increase in quality. The presented concepts show that it is necessary to take a holistic and detailed approach to develop solutions that can be applied in practice. These solutions are easy to use, accessible at a low level and versatile, ensuring their broad application in practice. The concepts presented in this paper contribute to the standardization and prefabrication of installation solutions suitable for timber construction.

5 OUTLOOK

The developed concepts can be generically applied and are based on a comprehensive set of design rules that can be implemented in software. Therefore, the concepts are a starting point for the development of an urgently needed automated design process for installation solutions suitable for bathrooms for timber buildings. Within the framework of the research project CLT_Plumbing_Design, a new kind of planning process was developed, and a brief outlook for this process is given. The presented installation and sealing concepts form the basis for a configurator called "CLT_Plumbing_Designer", which will be freely accessible from summer 2024 and on. This online tool can be used to easily configure bathrooms and toilets in ways appropriate for timber construction in early planning stages based on the presented concepts. The necessary shaft sizes, facing shell depths, and space requirements of the sanitary objects are implemented as rulesets. This saves time (e.g., for architects) and improves the quality of planning and construction work on the construction site. In addition, the configurator also makes it possible to use a new automated planning process. With just a few clicks, the planner can produce a BIM architecture model of the configured bathroom.

Acknowledgments

This work was done as part of the Basisprogramm/Collective Research project CLT_Plumbing_Design - Computer-aided planning process for automated design of wet rooms for solid timber constructions (Grant No. 885708) funded by the Austrian Research Promotion Agency (FFG).

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