ACTION FP1004

STSM REPORT

Enhancement of timber building connections made with CLT. Development of a good detailing practice of a "SIP" based on screwed CLT timber panels

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Table of Contents

1. Purpose of the STSM

The Department of Structural Mechanics of the University of Mons is developing an innovative SIP technology, based on two CLT panels separated by insulation. The total thickness is defined according to the thermal performance required. Screws (60 cm) ensure strength and stiffness of the composite wall.

This panel should have advantages. In common SIPs, the insulation is not taken into account from the mechanical point of view. Any kind of insulation can be considered, it should increase the energy efficiency of the buildings and the use of sustainable thermal products. Moreover, this SIP made with two thin CLT panels use less timber than traditional CLT construction.

Several studies on SIPs made with CLT are undergoing. Those include the lateral load-carrying capacity of the screwed connection; the analysis of wall diaphragms effect or strengthening techniques. The research works include structural analysis, finite element models, and experimental physic models.

The purpose of this Short Term Scientific Mission at the University of Mons was to work on different design options of the SIP in order to get the optimal performance with ecological insulation. One of the objectives were to study the connection detail between the wall and floor panels, and the ability to provide a robust detail which improve the time of construction and the airtightness..

The energy performance of this innovative SIP system is very important. It will respond the passive houses imposed in 2015 in Belgium. These directives handed down by the European Union (EU) are directly influencing the construction sector in terms of being energy conscious.

2. Work Carried Out

2.1 Review concept of new SIP based on screwed-CLT

The first step of the work was to review the concept of the new SIP with CLT develop at the University of Mons. This innovative solution can solve the disadvantage of the cross-laminated timber concern the insulation and the volume of wood used.

The solution propose a creation of prefabricated sandwich panel, similar to SIP made of two CLT panels and insulation between them. The use of two CLT panels (6 cm thick) allows reducing the wood consumption by thirty percent. Self-tapping screws are used to connect the panels each other. Full threated screws used to reinforce timber structures are to keep the gap between the panels during the screwing. These screws are already used to repair or reinforce structures, i.e. in case of delamination of glulam beams. Their dimensions are available till one meter and the common diameter is thirteen millimeter.

The panels have a mechanical behavior which can be compared with the I-beams. The wood panels have the role of the flanges and the screws have the role of the web. Therefore the flanges are able to resist to bending moment and the web resists shearing.
The new SIP has to be provided with sufficient screws to be enough stiff and strength. The screws can be positioned with different screwing angles, thereby facilitating the load bearing. The screws characteristics (number of screws per square meter, screwing angle and direction, diameter and length of the screws) can be determined thanks to experimental tests and finite element models.
The insulation can be blown or composed of semi-rigid panels, which allow the use of most eco-friendly materials. Assuming a good connection between the panels (local or linear connections independent of the insulation), the mechanical behavior can be improved (reduction of the slenderness, increase of the second moment of area) and therefore the thickness of the CLT panels can be reduced.
The SIP based on screwed-CLT should reduce the cost of the construction, because the panel can be prefabricated, it means reduction of work time, and on the other hand, the lower need of raw material.

2.2 Thermal studies

In order to find the better structural connection between the panels, and to optimize the solution of thermal behavior, the airtightness, and water tightness, a preliminary state of the art was carried out. This activity consisted to realize a comparative table-description of details used in timber frame and CLT constructions.
With those data, the studied focus on resolve the thermal behavior in the connection wall-floor. Several 3d digital models were designed. But only three of them were selected to simulate the thermal behavior using a computational program.

Methods

It was used the COMSOL Multiphysics software. It is a finite element analysis, solver and simulation software package for solving various physics and engineering applications. There are several application-specific modules in COMSOL, in this work the Heat Transfer Module was used in order to solve the relating problems of heat transfer.
The different scenarios were created with the preliminary 3d digital models using common data.

Data known:
Wall thickness L = 344mm panel + 40 mm cavity + 100mm brick = 484 mm
Inner surfaces temperatures T0 = 20°C = 293 K
Outer surfaces temperatures T1= -10 °C = 263 K

Wood wool insulation   thermal conductivity =0.004W/m.K

Scenario 1

At the first scenario the wall panel has continuity over the connection with the intermediate floor, as balloon frame method. This connection allows a homogenous continuation of the panel insulation. The figure 1 shows the conductive heat flux magnitude, and the figure 2 shows the distribution of the temperature through the connection.

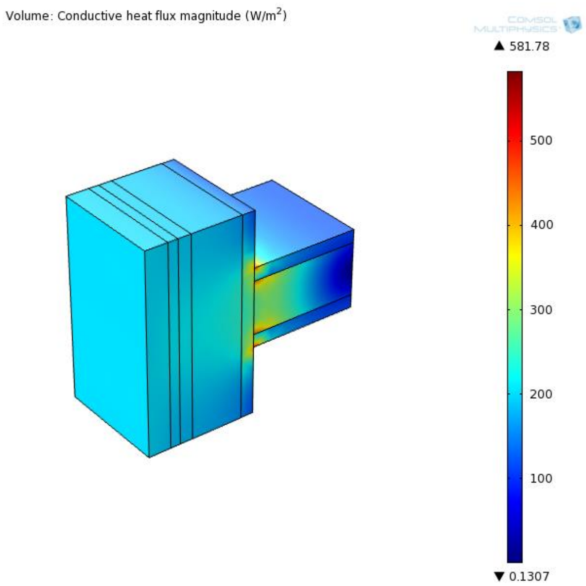


Fig.1 Conductive heat flux magnitude (W/m^2)

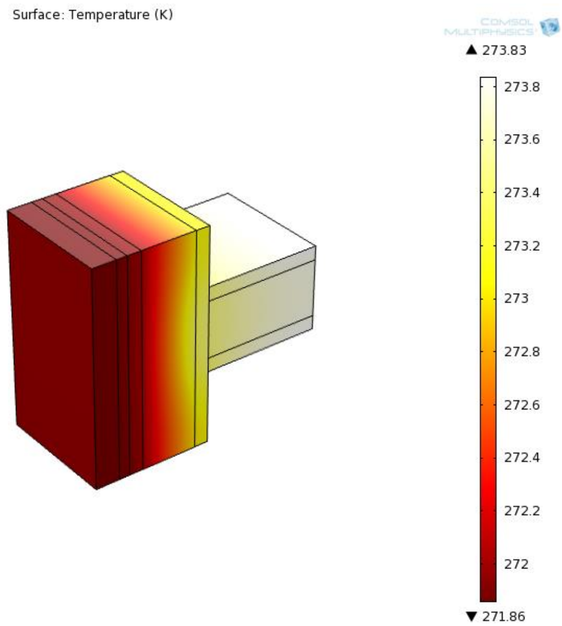


Fig.2 Temperature distribution through the connection

Scenario 2

At the second scenario, it was created a connection between two vertical panels and the horizontal panel. The connection does not allow regular insulation continuity. Horizontals timber pieces in the connection wall-floor could transfer a small heat flux, between the inner surface to the outer surface. The figure 3 shows the conductive heat flux magnitude, and the figure 4 shows the distribution of the temperature through the connection.

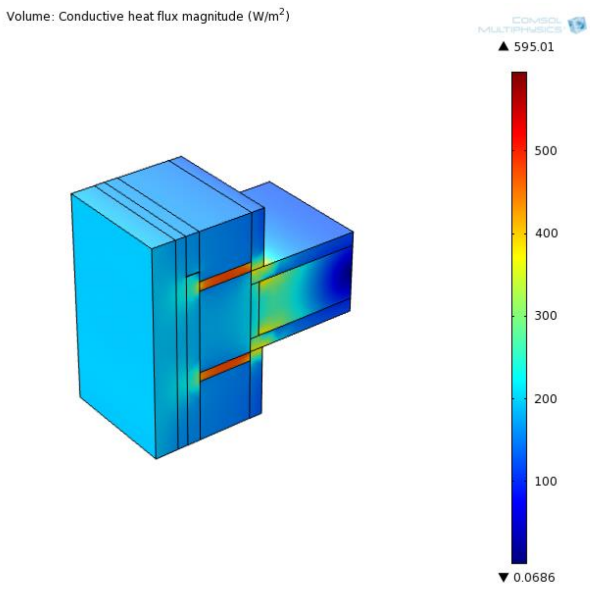


Fig.3 Conductive heat flux magnitude (W/m^2)

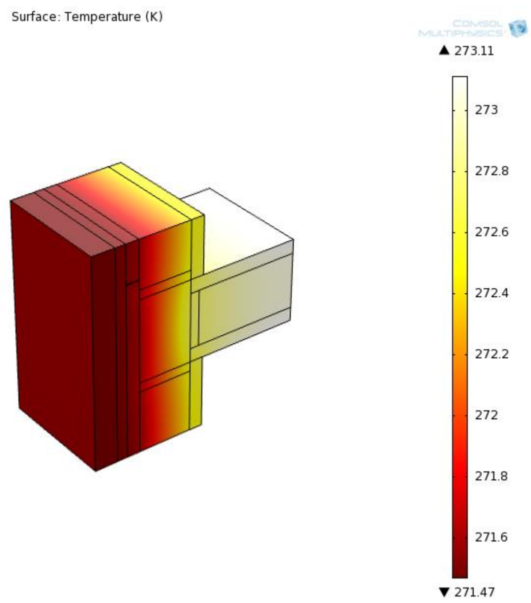


Fig.4 Temperature distribution through the connection

Scenario 3

The third scenario shows the wall panel finishes with intermediate floor, as the platform frame method. The horizontal timber pieces in the connection increased a small heat flux similar at the second scenario. The figure 5 shows the conductive heat flux magnitude, and the figure 6 shows the distribution of the temperature through the connection.

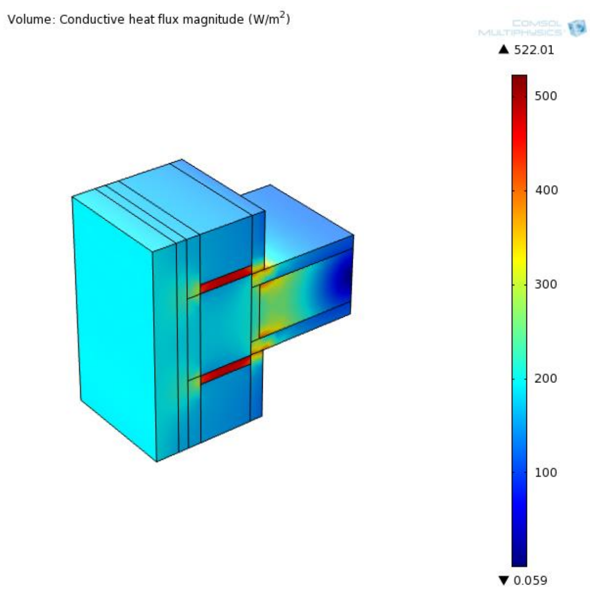


Fig.5 Conductive heat flux magnitude (W/m^2)

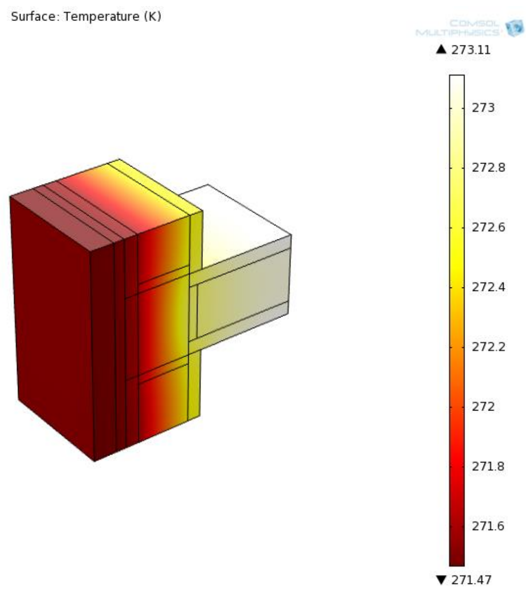


Fig.6 Temperature distribution through the connection

Illustration of good practice to design and construction interface respect to ensuring thermal performance and air barrier

The last activity carried out at the STSM was design good detailing practice to ensuring thermal performance and air barrier. The works choose three kind of possible material on the outsider layer façade: brick, wood, and plaster. The first two systems were defined with cavity ventilated, and the last one without cavity. The illustrations focus thermal and air barrier, in order to assure good performance of the components. Details developed shows four different solutions: the ground bearing floor, the intermediate floor, the wall junction, and the roof. All designs are in the appendix.

3. Main Results

The results of the three scenarios of the thermal simulations with the software COMSOL, shows that a good performance is possible in the different options. The thermal conductivity in the three cases of studies has minimum differences. Though, these first results need to be improved including the performance of the screws and its influence in the thermal behavior. Another geometric model could include the cladding and the air cavity. The studies of the integral component will give more results in order to optimizes their performance

The design of the good detailing practice, as a first approach of the process construction and its complexity, can help to understand, to study and to define the structural connections between the panels.

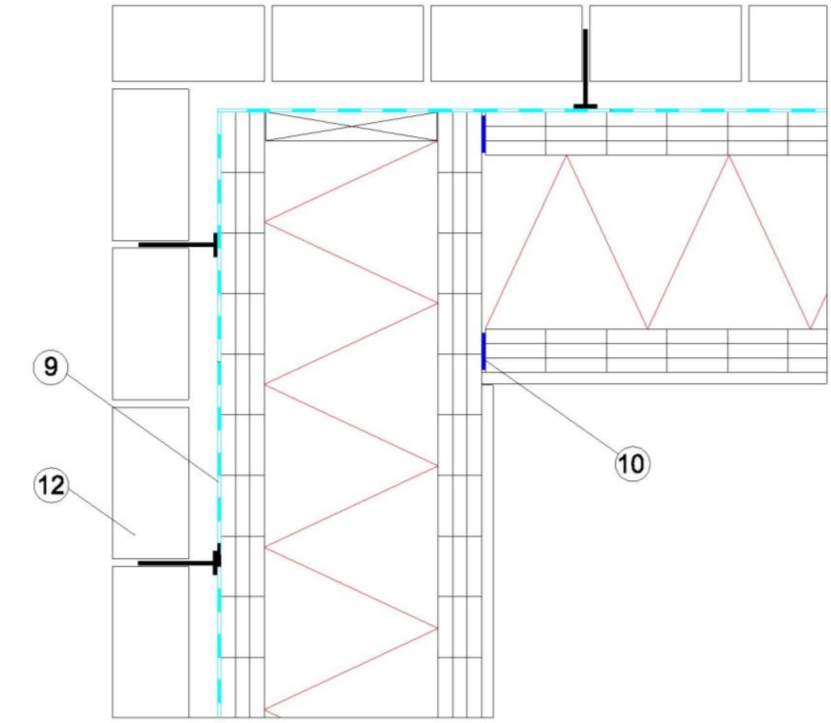
4. Outcomes of the STSM

As a result of this short term scientific mission, the STSM granted is co-author with research group of the host institution of the conference paper entitled "Cross-laminated timber: towards a consistent structural insulated panel for passive buildings in Belgium". This paper will be presented at the World Conference Timber Engineering WCTE 2014 in Quebec City in August 2014. Collaboration with the host institution will continue. The work done during the STSM is the first step of future paper that should be published in a journal about the thermal performance studies of this insulated CLT walls.

5. Acknowledgement

The financial support, provided by COST organization, to this short term scientific research project presented in the report is gratefully acknowledged. Special thanks are here presented to Prof. Thierry Descamps, for hosting and give me the opportunity to collaborate to this research work. I really appreciate the scientific collaboration of Laurant Leskool to help me during my stay in Mons.

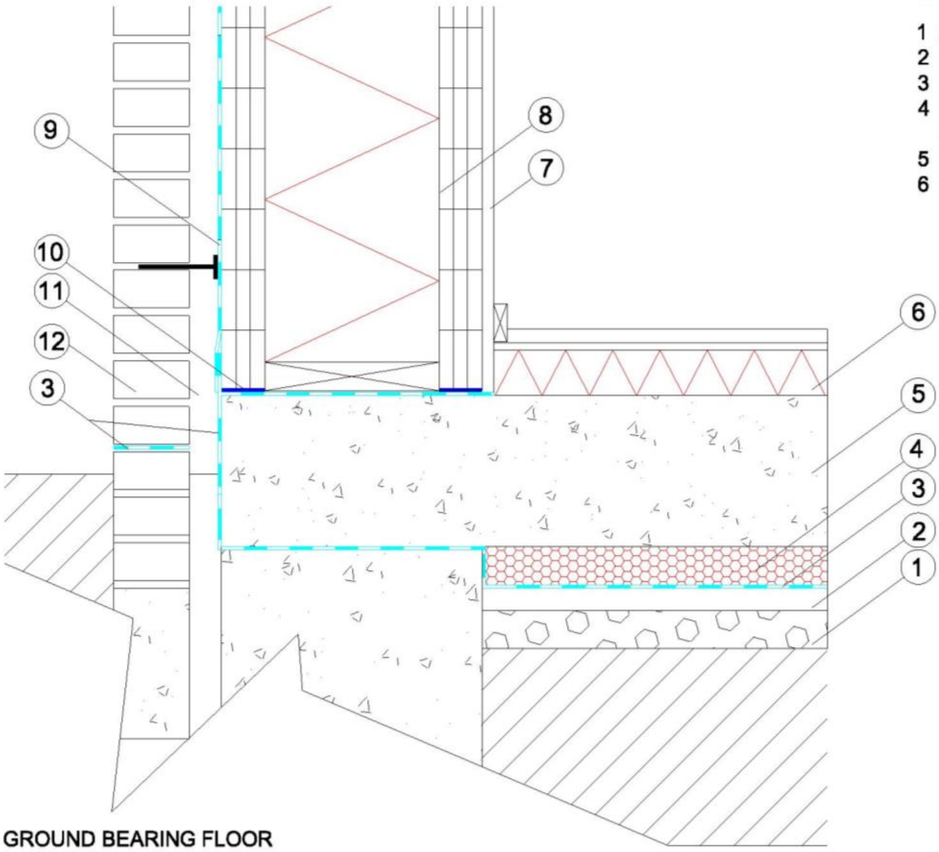
6. Appendix



WALL JUNCTION

7. 15 mm Gypsum fiber board
8. 344 mm prefab structural insulated panel: CLT + Wood Wool + CLT
9. Water - Windproof breathable membrane
10. Butyl airtigh seal
11. 40 mm ventilated cavity
12. 100 mm brick facade

WALL JUNCTION
Horizontal section detail



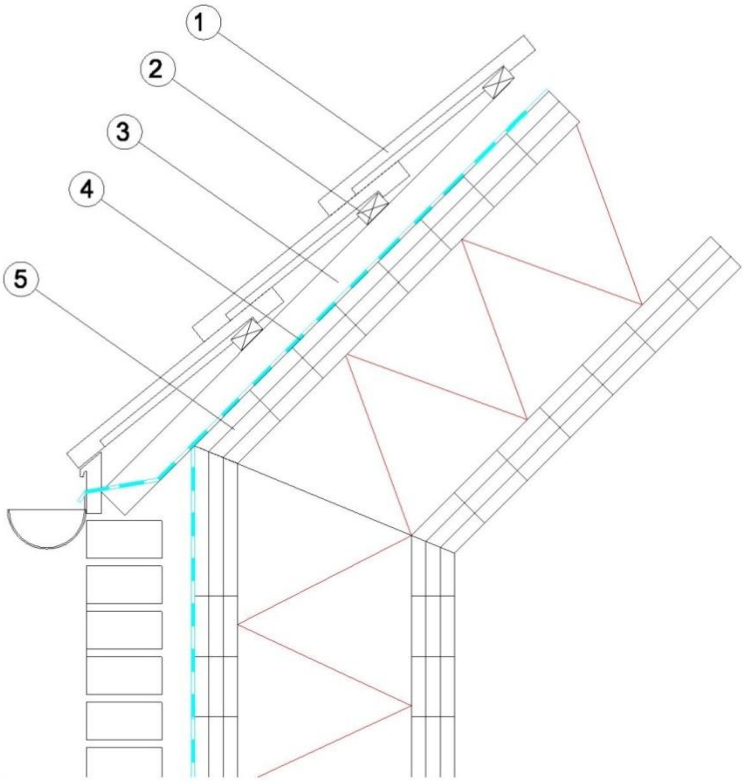
GROUND BEARING FLOOR

1 Hardfill
2 Sand-blinding layer
3 Waterproof membrane
4 Rigid insulation panels expanded polystyrene
5 Concrete slab
6 Thermal insulation

GROUND BEARING FLOOR
In-situ Suspended Ground Floor. Insulation above Slab with timber floor finish
Vertical section detail

BRICK FACADE WITH VENTILATED CAVITY

PREFABRICATED STRUCTURAL INSULATED PANEL. Based on screwed cross-laminated timber and wood wool
Guide to illustrate good practice to design and construction interface only respect to ensuring thermal performance and air barrier



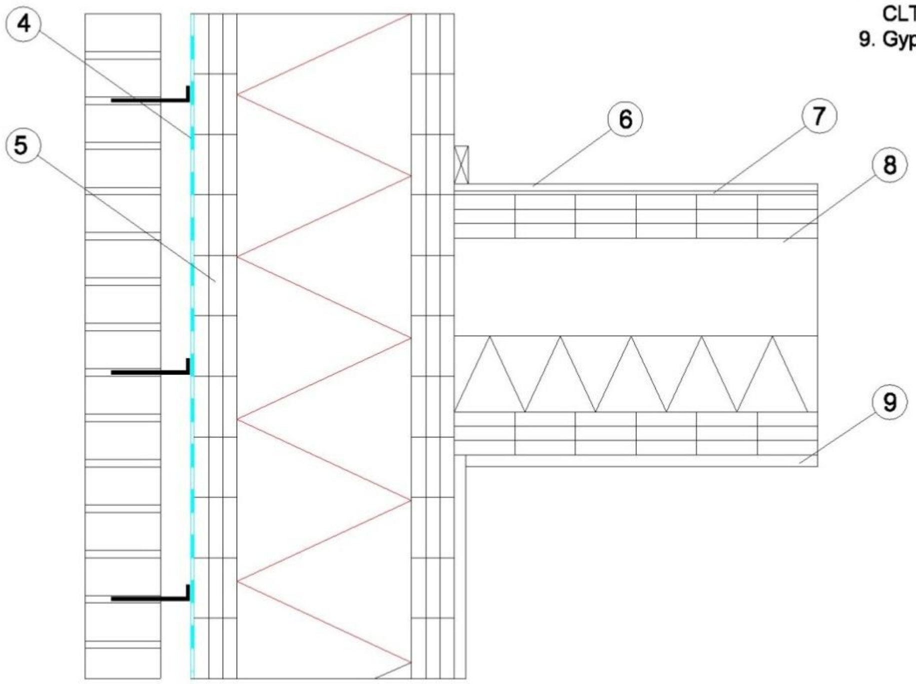
ROOF

1 Tiled roof
2 25x50 mm spruce wood battens
3 50x40 mm spruce wood counter battens
4 Waterproof/windproof membrane
5 344 mm prefab structural insulated panel:
CLT + Wood Wool + CLT

PITCHED ROOF
Vertical section detail

INTERMEDIATE FLOOR

7. Wood paviment
8. Exchangeable layer
9. 344 mm prefab structural insulated panel:
CLT + 100 mm Wood Wool + CLT
9. Gypsum fibre board

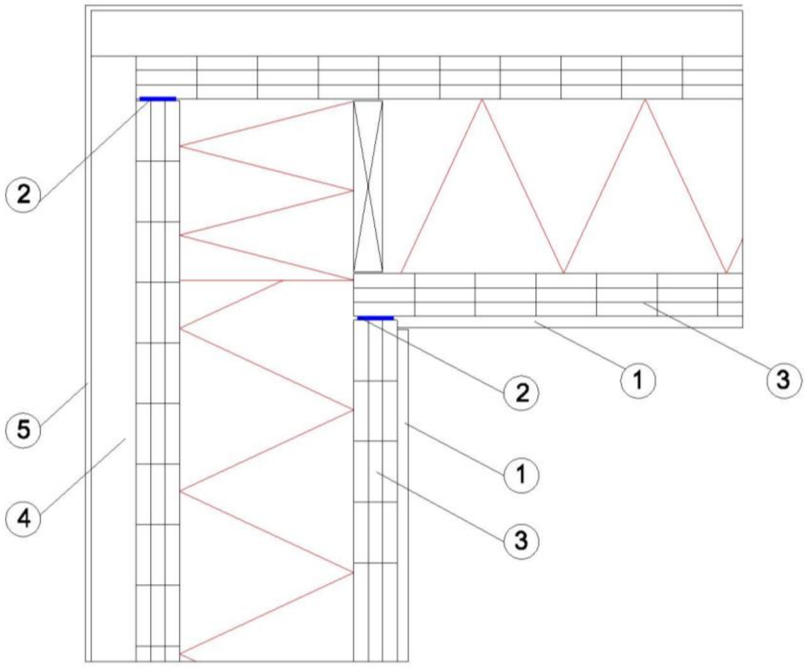


INTERMEDIATE FLOOR
Vertical section

BRICK FACADE WITH VENTILATED CAVITY

PREFABRICATED STRUCTURAL INSULATED PANEL. Based on screwed cross-laminated timber and wood wool

Guide to illustrate good practice to design and construction interface only respect to ensuring thermal performance and air barrier



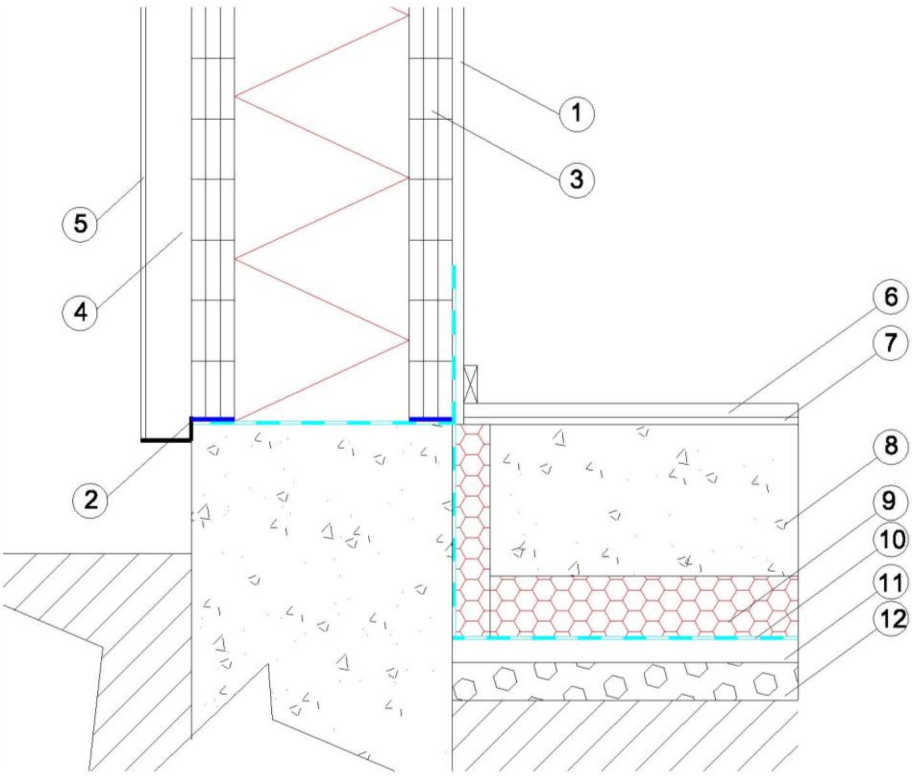
WALL JUNCTION

1. 15 mm Gypsum fiber board
2. Butyl airtigh seal
3. 344 mm prefab structural insulated panel: CLT + Wood Wool + CLT
4. 60 mm wood fiberboard
5. 7 mm Plaster

WALL JUNCTION
Horizontal section detail

GROUND BEARING FLOOR

6. Wood floor
7. Exchangeable layer
8. Concrete slab
9. Rigid insulation panels expanded polystyrene
10. Waterproof membrane
11. Sand-blinding layer
12. Hardfill

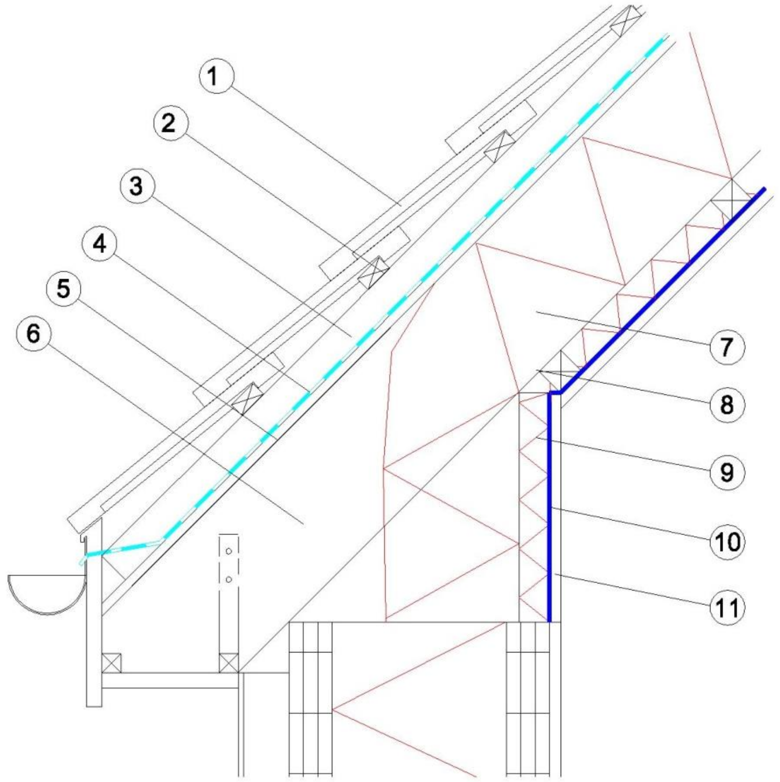


GROUND BEARING FLOOR
In-situ Suspended Ground Floor. Insulation below Slab with timber floor finish

PLASTER FACADE. NOT VENTILATED

PREFABRICATED STRUCTURAL INSULATED PANEL. Based on screwed cross-laminated tmber and wood wool.

Guide to illustrate good practice to design and construction interface only respect to ensuring thermal performance and air barrier



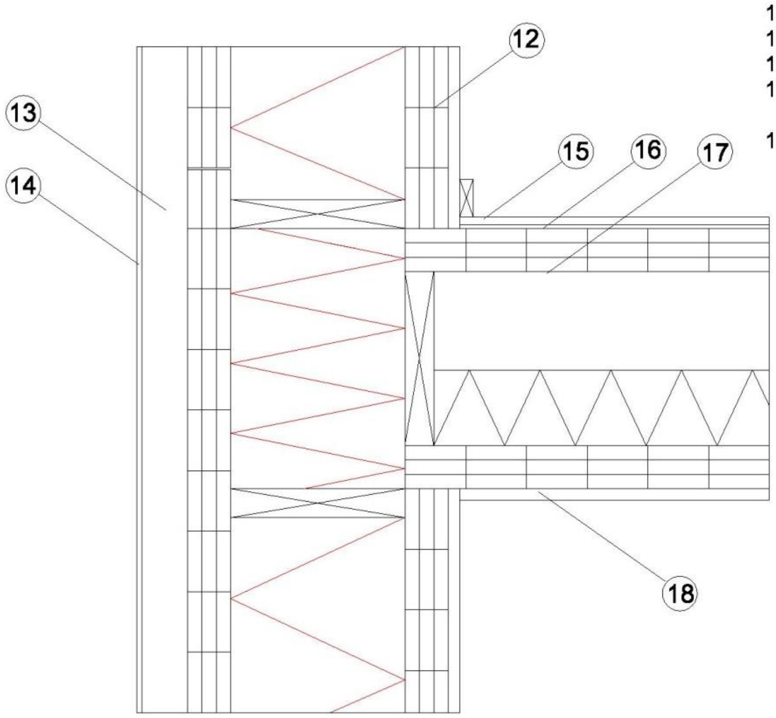
ROOF

1. Tiled roof
2. 25x50 mm spruce wood battens
3. 50x40 mm spruce wood counter battens
4. Waterproof/windproof membrane
5. Fibreboard
6. Rafter
7. Wood wool thermal insulation
8. 50x50 mm spruce wood battensçç
9. Thermal insulation high density
10. Vapour barrier
11. Gypsum fibreboard

PITCHED ROOF.
Insulation between & under rafter

INTERMEDIATE FLOOR

12. 344 mm prefab structural insulated panel: CLT + Wood Wool + CLT
13. 60 mmWood fiberboard
14. Plaster
15. Wood floor
16. Exchangeable layer
17. 344 mm prefab structural insulated panel: CLT + 100 mm Wood Wool + CLT
18. Gypsum fibre board



INTERMEDIATE FLOOR
Vertical section detail

PLASTER FACADE. NOT VENTILATED

PREFABRICATED STRUCTURAL INSULATED PANEL. Based on screwed cross-laminated tmber and wood wool.

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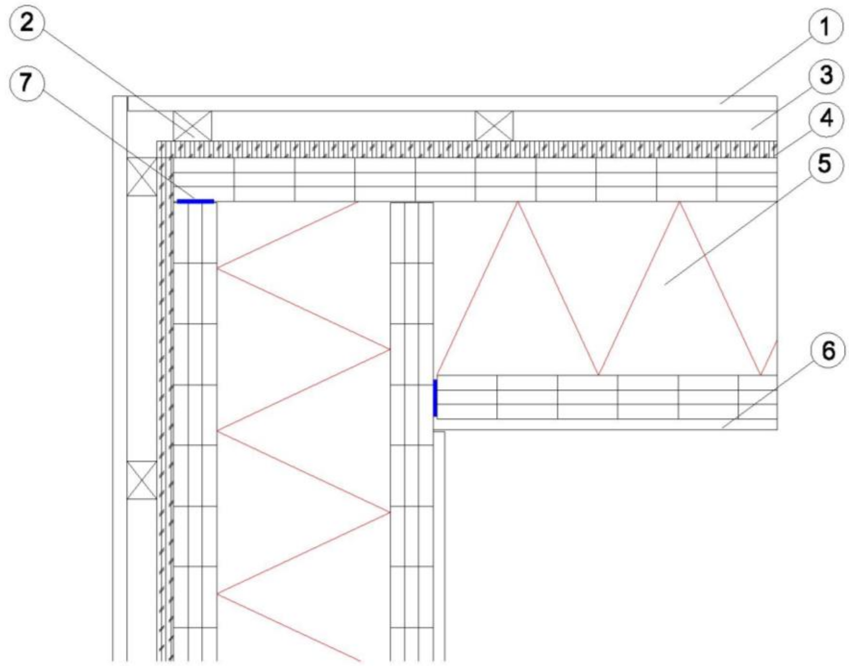
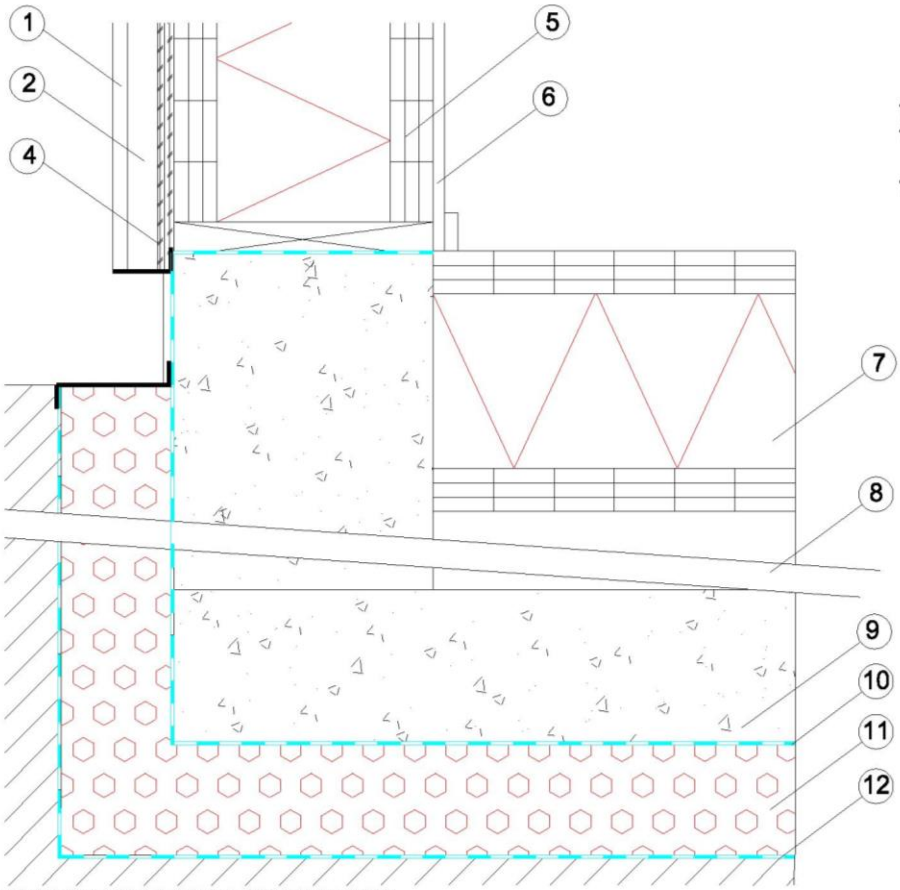


WALL JUNCTION

1. 20 mm larch wood external cladding
2. 50 x 40 mm spruce wood battens
3. 40 mm ventilated cavity
4. 22 mm softboard
5. 344 mm prefab structural insulated panel: CLT + Wood Wool + CLT
6. Gypsum fibre board
7. Butyl airtigh seal

WALL JUNCTION
Horizontal section detail



GROUND FLOOR

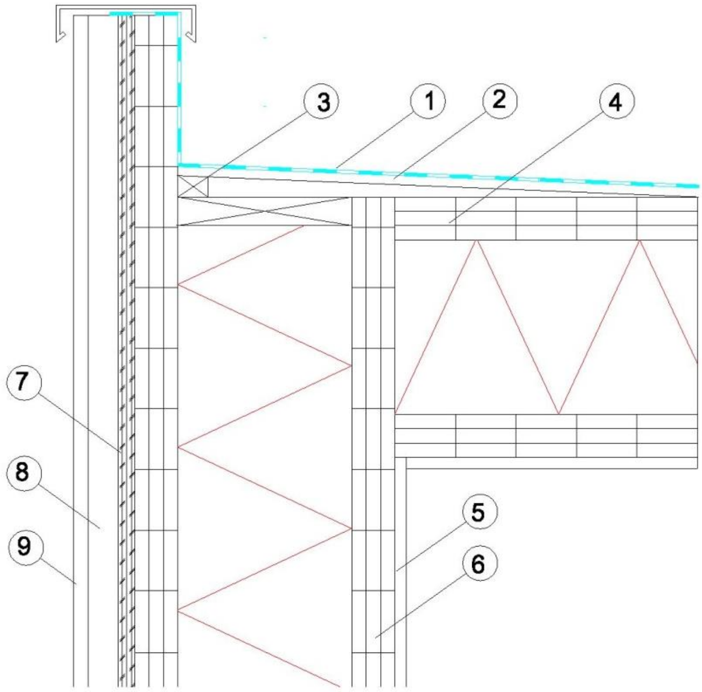
8. Ventilated sub-floor
9. Concrete slab
10. Waterproof membrane
11. Rigid insulation panels expanded polystyrene
12. Polyethylene membrane

TIMBER SUSPENDED GROUND FLOOR
Insulation outside concrete foundation
Vertical section detail

WOOD CLADDING FACADE WITH VENTILATED CAVITY

PREFABRICATED STRUCTURAL INSULATED PANEL. Based on screwed cross-laminated tmber and wood wool.

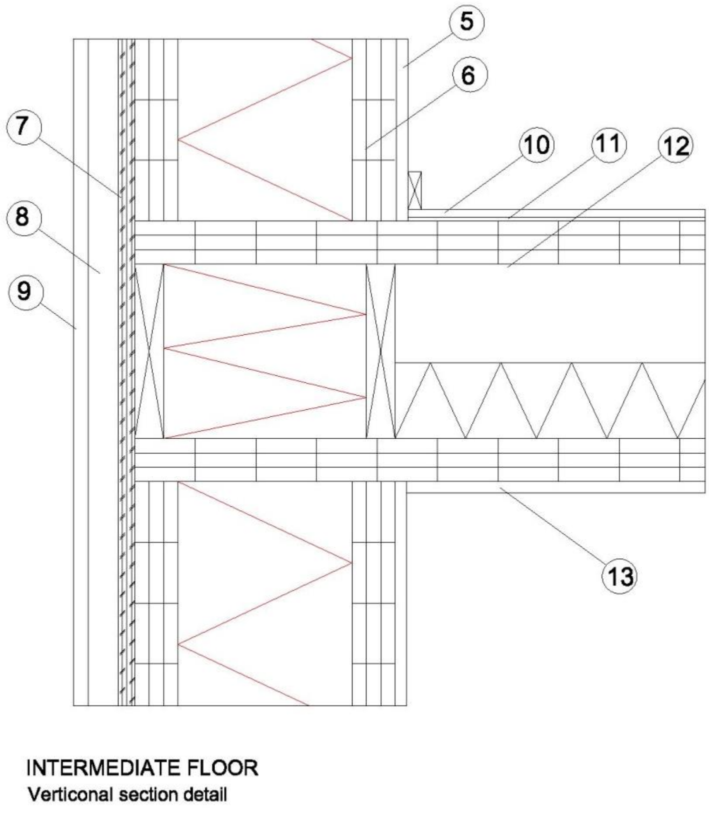
Guide to illustrate good practice to design and construction interface only respect to ensuring thermal performance and air barrier



TIMBER FLAT ROOF WITH PARAPET
Vertical section detail

TIMBER FLAT ROOF

1. Waterproof membrane
2. 22 mm softboard
3. Spruce wood battens
4. 344 mm prefab structural insulated panel: CLT + Wood Wool + CLT
5. Gypsum fibre board
6. 344 mm prefab structural insulated panel: CLT + 100 mm Wood Wool + CLTPlaster
7. 22 mm softboard
8. 40 mm ventilated cavity
9. 20 mm larch wood external cladding



INTERMEDIATE FLOOR
Verticonal section detail

INTERMEDIATE FLOOR

10. Wood floor
11. Exchangeable layer
12. 344 mm prefab structural insulated panel CLT + Wood Wool + CLT
13. Gypsum fibre board

WOOD CLADDING FACADE WITH VENTILATED CAVITY

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