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Final Report

Passive Cross Laminated Timber Buildings

Cerbof-project no. 76

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Summary

In this project, Stora Enso's newly developed building system has been further developed to allow building to the Swedish passive house standard for the Swedish climate. The building system is based on a building framework of CLT (Cross laminated timber) boards. The concept has been tested on a small test building. The experience gained from this test building has also been used for planning a larger building (two storeys with the option of a third storey) with passive house standard with this building system.

The main conclusions from the project are:

- It is possible to build airtight buildings with this technique without using traditional vapour barriers. Initial measurements show that this can be done without reaching critical humidity levels in the walls and roof, at least where wood fibre insulation is used, as this has a greater capacity for storing and evening out the moisture than mineral wool. However, the test building has so far not been exposed to internal generation of moisture (added moisture from showers, food preparation etc.). This needs to be investigated and this will be done during the winter 2013-14.
- A new fixing method for doors and windows has been tested without traditional fibre filling between them and the CLT panel. The door or window is pressed directly on to the CLT panel instead, with an expandable sealing strip between them. This has been proved to be successful.
- The air tightness between the CLT panels is achieved with expandable sealing strips between the panels. The position of the sealing strips is important, both for the air tightness itself and to allow rational assembly.
- Recurrent air tightness measurements show that the air tightness decreased somewhat during the first six months, but not to such an extent that the passive house criteria were not fulfilled. The reason for the decreased air tightness is not clear, but can be due to small movements in the CLT construction and also to the sealing strips being affected by changing outdoor temperatures.
- Long term measurements (at least two years) have to be carried out before more reliable conclusions can be drawn regarding the long term effect of the construction on air tightness and humidity in the walls.
- An economic analysis comparing using a concrete frame or the studied CLT frame for a three storey building shows that it is probably more expensive to build with CLT. For buildings higher than three floors, the CLT frame has economic advantages, mainly because of the shorter building time compared to using concrete for the frame. In this analysis, no considerations have been taken to differences in the influence on the environment or the global climate between the two construction methods.

1 Background

Passive houses, i.e. buildings without a traditional heating system or buildings with a very small active heat demand, have been pointed out as an important technology for the long term reduction of the building sector's energy consumption.

An important characteristic of passive houses is that they are airtight and thus allow a high level of heat recovery from the ventilation air. Cross Laminated Timber (CLT) wall panels are airtight in themselves, which means the wall and roof elements can be utilised to achieve airtightness in the building, provided that holes are not made in the building envelope for pipes and ducts, and that both the joints between the laminated timber panels and the fixing of doors and windows can be made airtight. If this is successful, glued and taped plastic sheeting is not required to make the building airtight, and this can make the building more robust and reduce the amount of work in the building process.

Timber framed buildings are important both for the environment, as emissions are reduced in the production stage, and for the domestic trade and industry, as the forest-based raw materials can then be utilized better. As the wall panels are airtight, this allows the use of different types of insulation with good environmental qualities, e.g. wood fibre insulation instead of cellular plastic and mineral wool.

2 The project plan and the actors

The project plan has been to further develop and test a building system for building passive houses with a cross laminated timber (CLT) frame as the structural element. This has been carried out through preparatory studies of low energy timber building in Austria and also through the experience of low energy building and testing of air tightness in Sweden. It included further development of Stora Enso's building system, building a test building with the new building system, and also measurement and evaluation of this. The actors in the project, and their main areas of work, were as follows:

Dalarna University: Project management, survey of the building system and the formal requirements for passive building. Architectural design of the demonstration buildings, measurement and evaluation of the test building.

Stora Enso Wood products: Development of an existing framing system into a system for passive houses which fulfill Swedish standards in the Swedish climate, design of the demonstration buildings and delivery of the prefabricated CLT elements for the demonstration building.

HMB Construction: Active participation in the discussions on potential building and demonstration projects, construction of the test building, development of a new method for foundations.

During the project we had some ten joint planning meetings where we discussed solutions for the construction and function, planned the demonstration project and test building, and also evaluated the test results. In addition to this, there have been any number of meetings in smaller groups where details have been discussed.

The project has been financed by the research programme CERBOF (Centre for Energy and Resource Efficiency in the Built Environment), Dalarna University, Stora Enso Wood Products and HMB Construction.

3. The realisation of the project

3.1 Review of building and building services systems

The present project was originally intended to be carried out with other industrial actors and Dalarna University was given the go-ahead to carry out the project before it started. The remaining actors were, however, convinced that they should try to find new partners to be able to carry out the planned project at a later date. Therefore the University group made an originally planned trip to Austria using other resources than the project money. Therefore we include this trip as part of the project, even if we made the trip prior to the formal start of the project.

The trip is summarised in the report "*Träbyggande och energieffektivt byggande i Tyskland, Österrike och Lichtenstein*" (Rönnelid and Wik, 2010), The aim was to give a picture of the situation for modern low energy building in CLT and to study the most important experiences from the regions we visited. During the trip we also attended the conference, Forum Holzbau09, in Garmisch-Partenkirchen, which gave a present day picture of modern and industrial building in timber.

- Important conclusions from this trip were:

- There is very great environmental awareness. This means that natural materials such as wood and wood fibre insulation are most often chosen, and also that the houses have a low energy consumption.
- All the low energy houses/passive houses we visited had controlled ventilation and heat recovery and this was regarded as a guarantee for comfort and good air quality. A CLT framework is regarded as particularly favourable for this as the system itself is airtight.
- There is a great feeling for wood in modern timber building and building is carried out with great precision where, for example, mouldings and door architraves are not needed. The most usual external surface, in a class by itself, was unfinished wood, principally larch, but also, in some cases, silver fir (spruce).

During the winter of 2010-11, an analysis of the present situation was made with the aim of finding out how present day multi-family dwellings of passive house standard are designed and constructed in Sweden. Important questions in the survey included survey of the choice of framework, the air tightness which was achieved and also the design. In total, eight suitable objects were chosen, of which six were multi-family dwellings and two were areas of single-family houses. Of the eight objects visited, seven were passive houses. (Janols and Wik, 2012).

The result of survey clearly shows that, technically, the passive houses were constructed with similar choices of framing and technical details at the time of the visit. Everybody visits all the same objects and studies one another's choices, which means that there are many identical technical solutions. All of the multi-family dwellings were constructed with a concrete frame and, in most cases, the framework is comprised of a flat slab concrete floor, steel columns at the face of the outer wall and also in-situ concrete party walls between apartments. A recurrent argument for the choice of the structural framework is the idea that it is easier to reach and guarantee the required air tightness with in-situ concrete. The air tightness of all the passive houses surveyed was also shown to be good, in an interval between 0.09-0.25 [l/m².s]. However, they have all put a lot of work into making the buildings airtight which has often also required a great deal of hand finishing. It was also shown that the air tightness is measured in different ways in the different projects: sometimes for each apartment and sometimes for the complete building by measuring the stairwell, which in turn affects the measurement result achieved.

With regard to building technology, the conclusion that can be drawn is that the U values for roofs, walls and floors in passive houses in Sweden are relatively uniform. The only project among the passive houses visited which is somewhat different is Pumpkälleghagen in Viskafors where the values are slightly lower for the walls and foundation. Valö lighthouse in Göteborg has slightly higher values than the others, but this is because this project was not planned as a passive house. The average U value for the windows is around 0.9 [W/m².K]. This must be lowered because of FEBY's (Forum for Energy Efficient Buildings) new requirements from 2012 which give a maximum U value for windows of 0.8 [W/m².K]. (FEBY, 2012)

In several cases the design of the objects visited leaves much to be desired. In several cases the design opportunities are not exploited, and in other cases the position and arrangement of the windows is not always suited to use of the building. On the whole, the impression from the survey is that the requirements for air tightness and energy requirements often overshadow other requirements and opportunities, such as the design of the building.

3.2 Model for industrial production

Our work is based on the framework system which was developed by Stora Enso in Finland and which was tested in a small single-family house in Finland, constructed in 2010-11. This framework system includes technical solutions for basic junctions between foundation and wall elements, between wall and roof elements and between internal walls and structural floor elements, and also details for these.

This project has adapted Stora Enso's basic concept to fulfill the requirements for passive houses for the Swedish market. In our test building, which was constructed in December 2011, the details of junctions have been developed to fulfill the air tightness requirement for passive houses.

The most important steps in the development of Stora Enso's building system which this work has contributed to are:

Increased wall thicknesses, to make room for enough insulation to fulfill the passive house requirements. This has led to special ways of forming the wall elements where the CLT panels can handle the loads, and at the same time there is also room for insulation.

Air tightness without plastic sheeting. At present the air tightness in passive houses is normally achieved using a layer of airtight plastic sheeting in the walls and roofs. The air tightness of this layer is crucial for the air tightness of the building, which is why extensive (and expensive) work is carried out to glue or tape the plastic sheets together. One of the goals of the project has been to produce a cost effective building system for passive houses. As CLT panels are airtight in themselves, money can be saved by letting the CLT panels themselves form the basis of the air tightness, and in this way avoid the cost of fitting the plastic sheets. In particular, the CLT panels used by Stora Enso are suitable for this as the panels are glued both between the board layers and also between the individual boards in every layer. Achieving an airtight wall without plastic sheeting also gives the structure an increased robustness as the air tightness is independent of physical influences such as differences in pressure (e.g. in connection with pressure tests), deterioration of tapes and glues, mice or other biological influences, or different types of holes made through the wall during the life of the building which will threaten the air tightness in the long run. At the same time the construction is airtight but can breathe and thus allow a certain moisture diffusion.

The requirement for a climate smart building with low CO₂ loading. This is fulfilled partly by prefabricating wall elements with wood fibre based, renewable insulation. In the test building this

has been carried out in only one wall section, from which we have been able to assess the difference between walls with wood fibre and walls with mineral wool insulation regarding moisture diffusion.

New methods for the junctions with door and window frames to achieve better air tightness and also to retain high production efficiency. In the adapted building system there is no traditional fibre filling between the frames and the wall panels; the air tightness is achieved by direct contact between a rebate in the frame and the CLT panel where they are pressed together with a sealing strip between them. This is possible as the CLT panel is stable in form which means that it is not necessary to have a gap between the wall panel and frame.

Reduced air leakage from the joints between the panels. All of the panels are constructed so that the air, in case of possible leakage, has to follow an s-curve, which increases the resistance to unwanted air movement and reduces leakage, see figure 1. For example the wall panel is fixed to the floor by a shallow rebate being cut in the floor panel into which the wall panel is lowered. This rebating is combined with expandable sealing strips which are fitted together with the assembly of the elements. However, it should be pointed out that the form of the joint to reduce the air leakage has not been preceded by theoretical calculations but is a solution based on the builder's own experience. The rebates also reduce the possible visible gaps between the panels which reduces the need for cover strips to hide the joints later for aesthetic reasons.

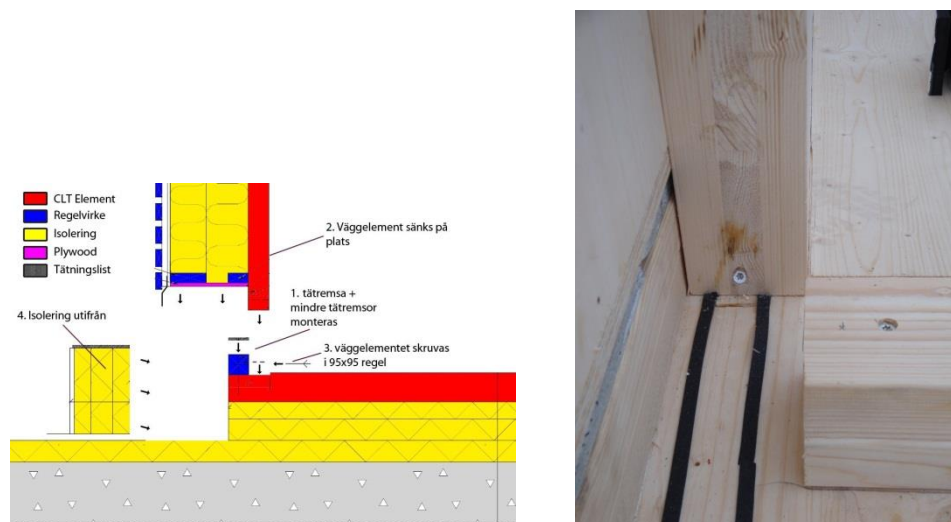


Figure1: On the left: Example of junction between wall panel and floor where the sealing strips and the formation of the junction to give an indirect route for air movement between inside and out reduce the air leakage (Fyhr, 2012). On the right: Junction between wall panel and floor where the wall panel is placed on the sealing strips in a rebate cut out of the floor panel.

A new method of constructing the foundations. The foundation in the test building consists of packed gravel with 300mm cellular plastic boards and 130mm CLT panels on top, see figure 2. The foundation was raised somewhat to avoid moisture and was clad with edge elements of fibre cement boards glued to cellular plastic. This foundation method has a good level of insulation and the CLT panels spread the load on the ground in the same way as concrete which means that the CLT panel replaces a concrete slab, which thereby makes it an inexpensive solution even if no economic analysis has been made within this project. The system ought to work for modular building units, not only for flat element systems, and can even be a possible solution for more temporary buildings, e.g. temporary schools and health care facilities. This method could also be a way of constructing the foundations for permanent buildings of up to two storeys; buildings higher than this are estimated as being too heavy, but the method must be tested in more detail before it can be proposed for live projects. The evaluation of this foundation method is not included in this project.



Figure 2. The foundation of the test building before the CLT panels have been laid. The cellular plastic boards with fibre cement cladding which are laid over the foundation are to hinder the cellular plastic boards from being blown away.

Several of the ideas which were developed and tested in the test building have been shown to work well and have been implemented in the design of the multi-family dwellings in the Måsen district in Orsa which is described below.

3.3 The search for building projects

In the project we intended to find a larger object where we could test a new building system using CLT on a large scale. If we were not successful in finding this our alternative was to build a smaller test building where we could test the solutions which had been developed for the construction under true conditions.

At an early stage, the proposal was put forward to test the building system in multi-family dwellings with approx 40 apartments on Galgberget, Falun with Kopparstaden, the municipal housing company, as the client. HMB Construction and Stora Enso discussed this carefully and we produced sketch designs for the buildings within the scope of the project. In the end, however, the companies concerned did not tender, mainly because of two factors:

1. The conditions of tender stipulated that the air tightness of the building should be less than $0.15 [l/m^2.s]$, which HMB Constructions did not dare to guarantee and which, furthermore, is twice as high as the requirements of the present day passive house standard. The technology was (and still is) untested on a large scale, and Kopparstaden made the value a requirement that must be fulfilled, not just one that ought to be fulfilled.
2. The requirement for sound insulation could not be guaranteed either, as full scale tests of the floor construction had not been made at this point.

Other possibilities were also discussed, e.g. a two storey building beside Vattenparken south of Teknikdalen in Borlänge. The idea was to build a building which could be dismantled and sold after a few years use, but at the same time was so large that full scale tests could be made both of the floor and the air tightness. To have time to get results within the project period the final choice was, nevertheless, to construct a smaller test building of only one storey to be able to test the air tightness and assembly details and to gain practical experience of the newly developed building system.

3.4 The test building

3.4.1 Design and construction

The design of the test building is designed to meet today's requirements; large windows to the south with generous daylight admission, sliding doors, high rooms and attractive design without giving up the passive house requirements. There was a further wish to test different insulation materials, and for this reason half of the eastern façade was insulated with mineral wool and half with wood fibre. Internally, the building components' fit, detailing and precision in construction have been made use of so that it has been possible to omit cover strips at the floors and ceilings, and door and window architraves (see experiences from Austria, Rönnelid and Wik, 2010).



Figure 3. Test building in the twilight the day after the assembly. The joints between the wall and roof elements remained to be completed as did the external boarding.



Figure 4. The test building with sliding doors on the south when the exterior was complete.



Figure 5. Interior of the test building.

The wall and roof elements are prefabricated in the factory and are delivered with CLT panels, insulation board and exterior plasterboard, and the different elements are lifted into place by mobile crane and assembled. Expandable sealing strips are laid in the joints between the panels to seal them and these are pressed together by the weight of the CLT panels or by the panels being drawn together by screws, e.g. when window and door frames are fitted into a CLT panel. The external boarding is nailed up after the building has been erected. One aim of the test building has been to test how airtight the building is with this production method and no subsequent insulation/sealing with silicon or similar has therefore been applied in the joints or holes in the walls later (with the exception of the holes for the cables to the measuring unit). A detailed description of the assembly and how the sealing strips were fitted is given in Fyhr (2012).

The construction of the foundation was not a traditional concrete slab on the ground. It consists of a lightweight construction where the concrete slab is replaced by a 138 mm thick CLT panel with an underlying layer of cellular plastic which gives an average U value of 0.089 [W/m².K]. The edges of the foundation structure have been fitted with fibre cement clad cellular plastic boards. In view of its light weight the foundation is anchored by four earth anchors to prevent the foundation from moving under high wind loads. The earth anchors are attached to fittings in the CLT foundation panels.

The foundation construction was tested because the test building has a temporary building permit, with a requirement for a mobile foundation construction which can be disassembled quickly and simply. Furthermore, there is also a general need to find energy efficient foundation designs for provisional buildings where there is a requirement for mobility. Figure 6 illustrates the construction of the foundation.

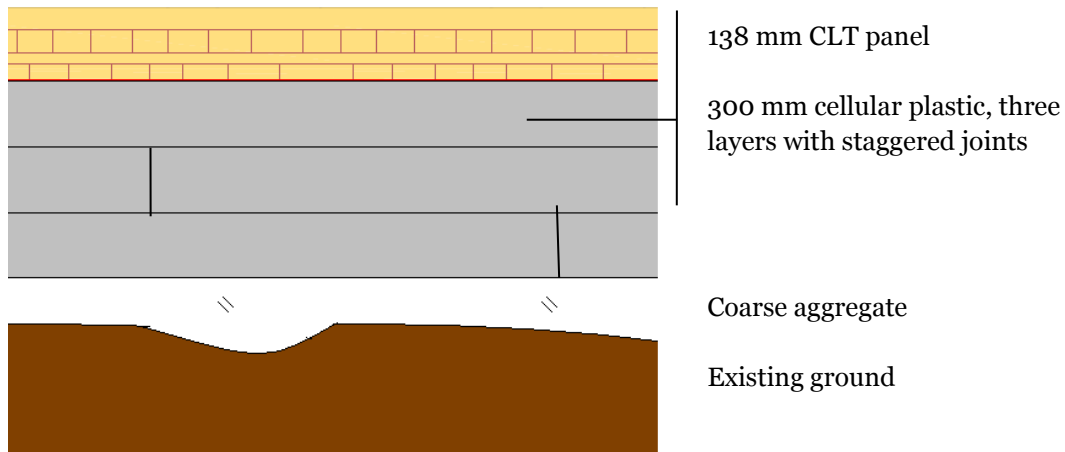


Figure 6: Foundation construction for test building.

The external wall consists of a load bearing CLT panel on the inside. The insulation is placed in an insulation box which is constructed outside the CLT panel to reduce the cold bridge. On the outside of the insulation box there is a layer of studs which in turn supports the exterior plasterboard and the façade material. The external walls and the roof are prefabricated in the factory and lifted into place by a mobile crane. When the building is assembled the façade material is nailed into place. Figure 7 illustrates how the wall is built up.

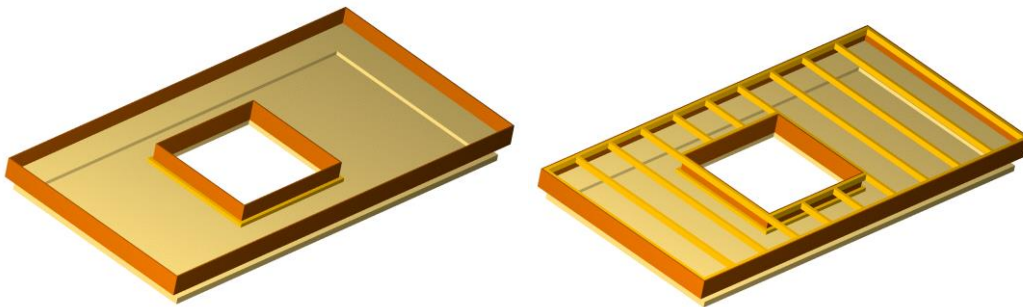
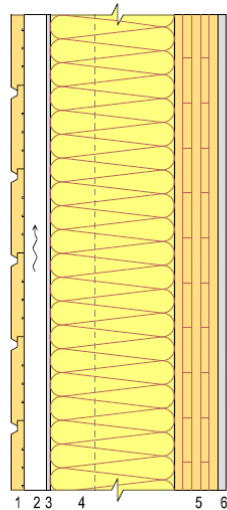


Figure 7. Stora Enso's external wall with insulation box.

Figure 8 illustrates how the wall is built up in section. The walls are approx 50 cm thick and as well as 97 mm CLT panels are comprised of 365 mm insulation boards and have an average U value of 0.093 [W/m².K].

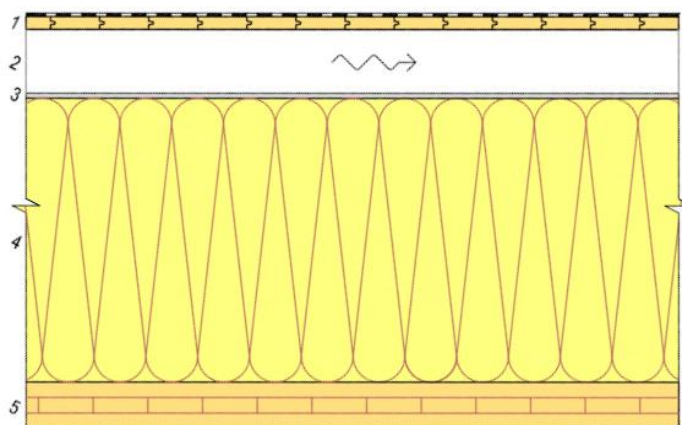


1. Façade
2. Air cavity
3. Wind barrier
4. Insulation
5. CLT panel
6. Plasterboard

Figure 8. Stora Enso's construction of the external wall. There is no internal plasterboard in the test building.

Both the external (entrance) door and the sliding door have U values of 1.0 [W/m².K]. As the glass screen with the sliding door was placed on the outside face of the wall it could not be fitted in the factory because of the difficulty of transport but was fitted on site. The external (entrance) door on the north was, however, inset from the face (about 50 cm from the corner) so that it could be hung in the factory and delivered to the site fixed in the wall panel. The sliding door was chosen as the supplier (Hajom) had recently introduced this product which it was promised would have high level of air tightness to be suitable for passive houses and low energy buildings.

The roof consists of, from the inside, a 138 mm CLT panel, 500 mm insulation in boards, wind barrier and roof covering and has an average U value of 0.075 [W/m².K]. The roof construction is illustrated in figure 9.



1. Roofing, tongued and grooved boarding and roofing felt
2. Air cavity, varying width
3. Wind barrier
4. Insulation with lightweight joists
5. CLT panel

Figur 9: Stora Enso's roof construction

The construction of the different foundation, wall and roof elements is described in more detail by Brindberg (2011).

The test building has been equipped with a heat and recovery ventilation (HRV) unit (Flexit UNI 3RE) to give continual ventilation of the building and give varying humidity inside the building during the measurement period; this follows the outdoor humidity. The HRV unit also means that there is a

slight negative pressure in the building which is preferable if the aim is to create a realistic indoor environment.

3.4.2 Measurement plan

The test building has been followed up by continual measurement of the energy consumption, temperature, humidity and air tightness. The system for temperature and humidity measurements consists of 18 sensors (BaWit) which together measure the two measurement parameters and log the data. The location is shown in figure 11. The location of the sensors is mainly based on two main parameters, partly to study the natural moisture diffusion through a homogeneous section of the wall without plastic sheeting, and partly to study the moisture diffusion and temperature gradient in the different junctions in the building, such as joints in the panels or the window fixings where there is a risk of air leaks. In the east wall, on the left in the figure, half of the wall is insulated with mineral wool (sensors 15-17) and the other half is insulated with wood fibre insulation (6, 18, 14) to show possible differences, not least of the moisture content in the wall, between the two methods of insulation. The sensors are placed in the upper part of the wall, in the junction between the CLT panels and the insulation, in the middle of the insulation layer and also in the junction between the insulation and the plasterboard.

Two sensors (nos. 3 and 13) have been placed in the intersection of the north and east wall elements in order to study possible leaks in the junction between the elements. These sensors are placed in the upper part of the wall, on the inside between the CLT panel and the insulation, and on the outside between the insulation and the exterior plasterboard. In the same way, sensors have also been placed at the fixing of the sliding door screen and the entrance door. Furthermore four sensors have been placed (nos. 8, 9, 2 and 4), see figure 11, in the roof of the building directly over the joint in the elements. This joint is considered to be a critical point with regard to the risk for condensation if the joint does not remain completely airtight. The sensors are placed, from the inside, in the junction between the CLT panel and the insulation, in the middle of the insulating layer, in the upper edge of the insulation and also in the air cavity in the roof construction, see figure 10.



Figure 10. An example of the placing of a sensor, in this case the sensor in the air cavity in the roof.

In addition to the above mentioned sensors, there is also a sensor that measures the indoor climate (no. 5) and a sensor which measures the outdoor climate (no. 1). A list of all the sensors is given in table 1.

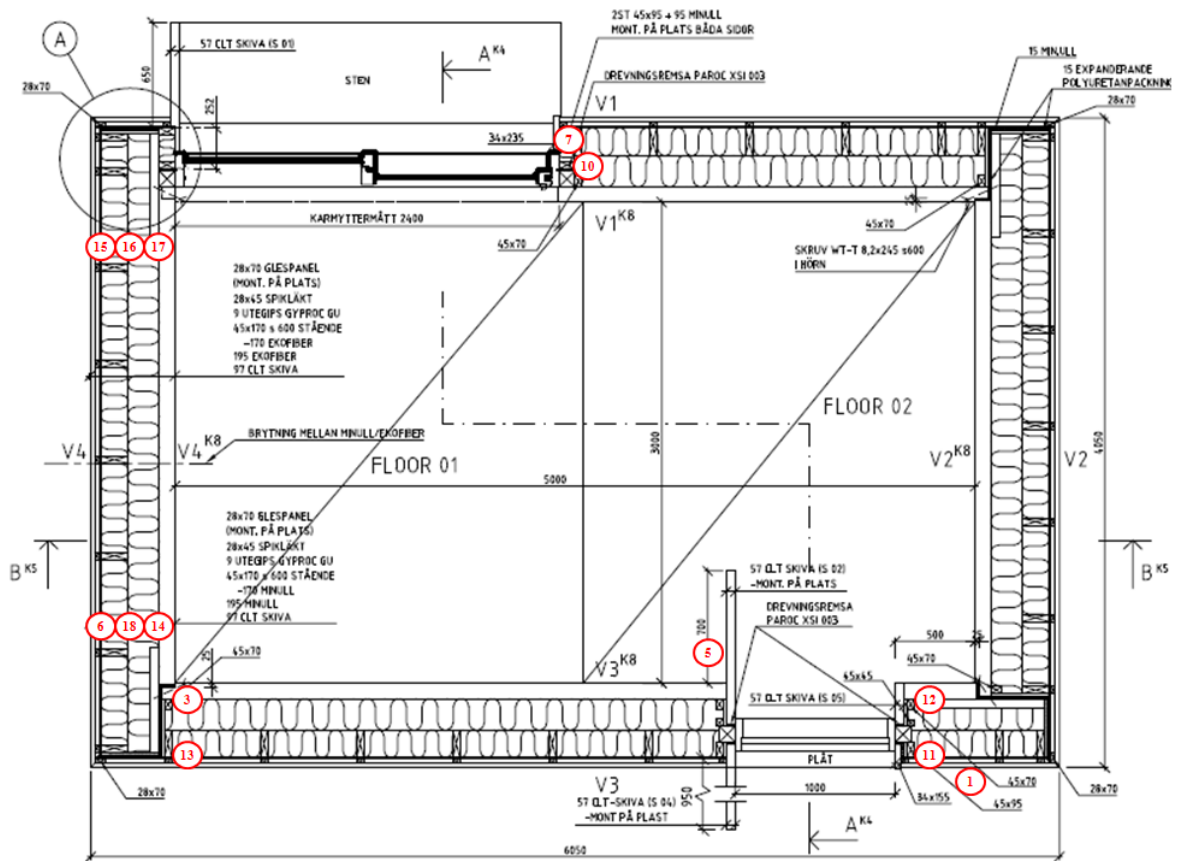


Figure 11. Plan and section of the test building. In the upper drawing, east is on the right and in the lower drawing, south is on the right.

Table 1. Combined sensors for temperature and humidity in the test building

Part of building/ measurement point	Sensor no.
<i>Indoor climate</i>	5
<i>Outdoor climate</i>	1
<i>Roof 1, (inside)</i>	8
<i>Roof 2</i>	9
<i>Roof 3</i>	2
<i>Roof 4, (air cavity)</i>	4
<i>Sliding door, inside</i>	10
<i>Sliding door, outside</i>	7
<i>External door, inside</i>	12
<i>External door, outside</i>	11
<i>Corner, inside</i>	3
<i>Corner, outside</i>	13
<i>Wood fibre 1, (inside)</i>	14
<i>Wood fibre 2</i>	18
<i>Wood fibre 3</i>	6
<i>Mineral wool 1, (inside)</i>	17
<i>Mineral wool 2</i>	16
<i>Mineral wool 3</i>	15

The energy consumption is measured by metering the electricity consumption of the HRV unit, i.e. both electricity to the fan and to the heating unit, as all the energy from the supplied electricity can be presumed to be transferred into the building as heat, directly or indirectly via the ventilating air. At the same time, both the indoor and outdoor temperatures are recorded. The data for temperature and humidity is logged and stored as hourly values by a logger.

The air tightness of the building is measured by a blower door test (Retrotec q56 Blower Door) which is carried out once a month starting in May 2012. Initially, a duplicate measurement was carried out where a consultant in air tightness was engaged to confirm the method of measurement and the equipment. Together with the initial measurement, a search was made for leaks where larger points of leakage were identified. The idea of monthly measurements is to be able to follow possible variations of air tightness in time, e.g. to be able to see the effect if the CLT panels crack as they dry out or if severe cold winter weather causes certain sealing strips to shrink or become rigid which can affect the air tightness. During the first year of measurement, no extra moisture will be supplied to the building, which will probably contribute to exceptionally dry air, and an increased risk for cracking in the building in the winter. If necessary the blower door test will be followed up by measurements with an infrared camera to obtain more specific information on the effect of certain junction details on the total air tightness.



Figure 12. The picture shows cracking in a CLT panel approx. five months after the assembly of the building. However, thermography in connection with pressure testing shows no sign of this cracking causing any extra air leakage, partly because the CLT panel is built up of several layers.

3.4.3 The assembly and the lessons learnt from this

The assembly took place during a somewhat raw and chilly day in December, 16th December 2011. The foundation was completed before assembly took place, and the building envelope took approximately a day to construct. Delivery was made at 07.30. The elements were loaded on a double trailer truck where all the wall elements stood upright on the first trailer and the roof and floor elements lay on the second. Nothing could be placed on top of the roof elements so they lay on top.

After the two floor elements had been laid, the wall elements on the north were erected at 10.55. By 12.15, two walls and also the floor elements had been assembled and the assembly was then broken off for lunch. The third wall element was in place at 14.10. Then the erection of the last element and the glass screen which was to be erected on site was begun, and this was completed by 16.10. At this stage the roof remained and this was in place at 18.00. The erection of the roof took 90 minutes but would have been carried out more quickly if the light had been better.

The following week, additions to the framework were carried out in the form of supplementary insulation of the joints between the elements, leveling of windows and door reveals, screens, metal flashings etc., completion of the foundation with extra fill and edge elements. During January and February the completion of the test building continued with façade boarding and also building services in the form of electricity and ventilation. The extra work took about five working days in total.

The measuring equipment was installed and ready for use by April 1. Since then measurements have been carried out continually, although the equipment was adjusted up to 1 May. From this time there are reliable test results of temperature and air tightness from 18 different points on the structure.

The next two sections summarise the experiences from the assembly of the building. On the whole, the assembly went well, but there were several points where there was potential for improvement, which are detailed in the list below.

Positive experiences of the work of assembly

- In general the results have been very good with flexible assembly and good air tightness
- The junctions between the floor and wall panels were both airtight and looked good although the wall elements were leaning during assembly. The s-bend contributed to the good result.
- Apart from the earth anchors, which are described in more detail in the following section, the foundation was constructed very quickly; one day and the assembly immediately afterwards.
- The sliding door was very airtight, both regarding the joint between the frame and the wall panel and regarding the formation of the sliding door itself.
- Rapid assembly of the walls at the corners due to the quick and simple method of jointing where the corners are diagonally screwed.

Problems which arose during the assembly and the reasons for these

- The adjustment tolerance for the earth anchors was insufficient and the positioning of these was not accurate enough.
- The foundation was presumably not completely level which caused problems in assembly at the corners and when erecting the roof elements. In normal cases the accuracy had probably been sufficient, but in this case the different panels were joined with zero tolerance which makes extra strong demands on the foundation.
- Production of the panels; It was not possible to saw a 90 degree intersection in the corner of an existing panel without it being rounded off. This works in most cases, but in this case it was a problem as there was zero tolerance between the CLT panel and the door frame.
- The position of the lifting loops caused problems in assembling the wall elements as they hung asymmetrically which caused an angle when they were sunk down towards the floor. This meant that it was difficult to lower the panels into the rebate which had been prepared in the foundation panels, see figures 13 and 14.
- The glass screen with the sliding door fitted in the factory would have reduced the assembly time compared with an on-site assembly, due to its size. On the other hand the on-site construction gave better air tightness (see further the results of the measurements) for the sliding door compared with the external door which was fitted in the factory.
- The manufacturer of the elements has not understood the importance of precision when producing the elements which contributed to the following defects:
 - ✓ exchanging the position of the insulation materials
 - ✓ incomplete insulation of the sealed elements
 - ✓ misses in details regarding sealing including those which were seen at the external door
 - ✓ difficulty in shutting the external door due to how it was hung; it was probably in tension.

- The difficulty of making the building envelope airtight around the external door arose partly because of the decision to place it so far out in the wall, which led to difficulty in pressing it against the CLT panel. The detail with the internal screen at the external door was important for the air tightness of the entrance door, but it was shown to be difficult to assemble with the required air tightness.
- The south wall element could not be moved into place as intended due to a miss in the design.
- It took a long time to apply the expandable sealing strips during assembly due to too narrow strips being used. They should have had the same breadth as the wall panels to reduce the time.
- Some "holes" occurred in the junction with the external door, because all the junctions were not checked during design and planning. This is a result of a co-ordination miss.
- The position of the sealing strips should be studied in more detail. This is particularly important in the joint between the wall and roof where the roof had a tendency to fasten in one of the sealing strips and pull it down. See figure 15 below:



Figure 13: During assembly the wall elements got stuck on the edge of the reveal in the foundation element.



Figure 14. Assembly of the north wall. The position of the lifting loops means that the wall leans somewhat which makes placing it on the floor element more difficult.

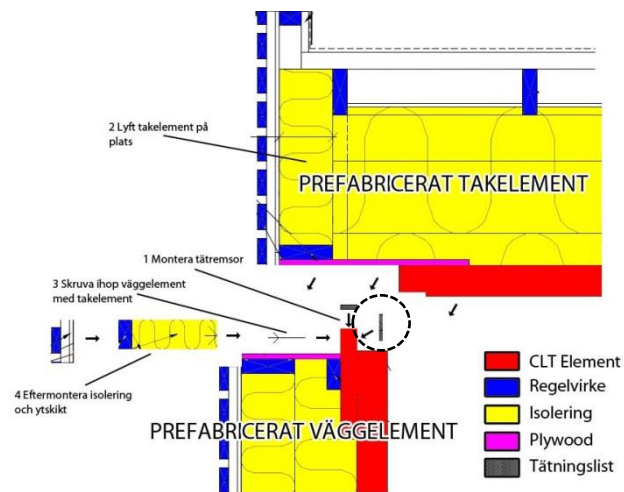


Figure 15: Detail of joint between roof and wall elements. The sealing strip which tended to be in the way and to be damaged when the roof was laid on top is shown by a circle.



Figure 16. Assembly of the west wall.

3.4.4 Results of the measurements – relative humidity

In connection with the design of the test building, two simulations of relative humidity were carried out to estimate theoretically the effect of internal and external humidity on the construction. After the follow-up measurements these will be compared with the measured data. Simulations were carried out with the requirement that that no plastic sheet should be used, and two different sorts of insulation based on wood fibre or mineral wool were also used. The first simulation studied changes in the relative humidity throughout the section of the wall and also how the relative humidity differed depending on the insulation material chosen. Figure 17 shows the relative humidity over time in the section exterior plasterboard/thermal insulation. In this section the results are quite similar regardless of the chosen insulation, but a somewhat larger moisture movement can be noted when the wall is constructed with mineral wool. Furthermore it can be noted that the relative humidity is around 90-95 % during certain periods.

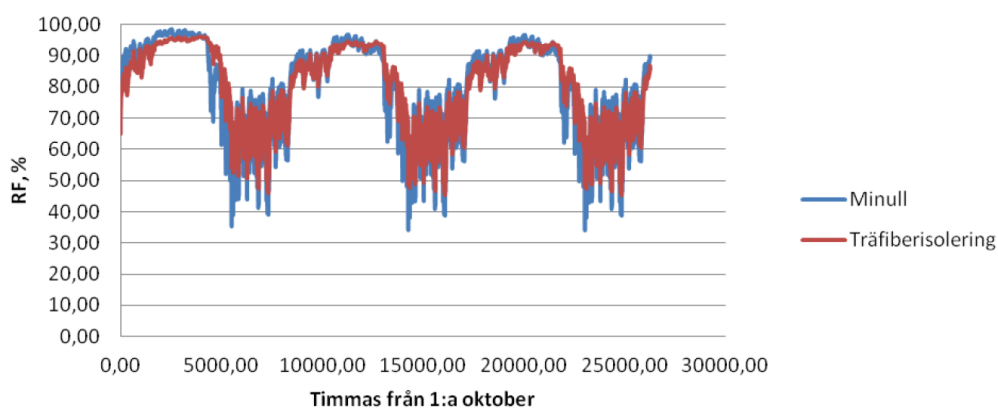


Figure 17: Relative humidity in the junction between the insulation and exterior plasterboard with mineral wool and wood fibre insulation respectively in the wall.

Figure 18 below shows the relative humidity in the thermal insulation 50 mm in from the exterior plasterboard. The simulation shows that the resulting relative humidity in the wood fibre insulation is somewhat delayed compared with the mineral wool and fluctuates somewhat less than in mineral wool.

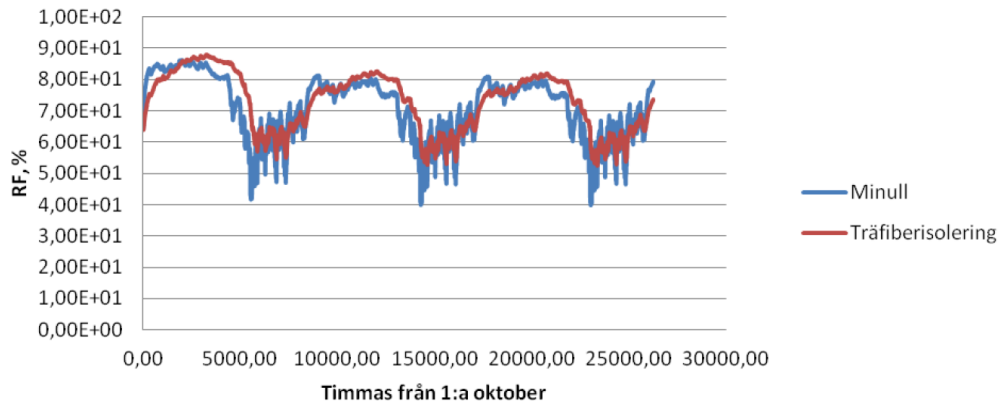


Figure 18: Relative humidity in the thermal insulation, 50 mm in from the exterior plasterboard with mineral wool and wood fibre insulation respectively in the walls.

In the second simulation, which was used as the basis for the decision on the choice of paint for the building, the conditions were changed by a change in the water vapour transmission rate of the paint. Taking into account that the building was constructed without plastic sheeting it is especially important that the coat of paint on the exterior plasterboard has very high water vapour transmission which contributes to the inside of the building continuing to be more airtight than the outside. In figures 19 and 20, the simulations show the effects of humidity and temperature through the wall section over time and with paint on the exterior plasterboard. The result of these simulations shows that the movement of water vapour in the section studied is radically reduced when paint with a water vapour resistance of (Z) 100 000 s/m is applied to the exterior plasterboard. The average annual relative humidity is also markedly raised compared with when the surface is untreated. This emphasizes the importance of using a highly permeable wall paint which was one reason for the choice of paint for the walls of the building. In this case the choice was a silicate paint manufactured by Keim. It is manufactured without additives of plastic components and thus has a low water vapour transmission resistance. The chosen paint was KEIM Granital® and is a water repellent, ready to use, silicate based paint with a water vapour resistance of (Z) of 400 s/m according to data from Keim's technical information sheet.

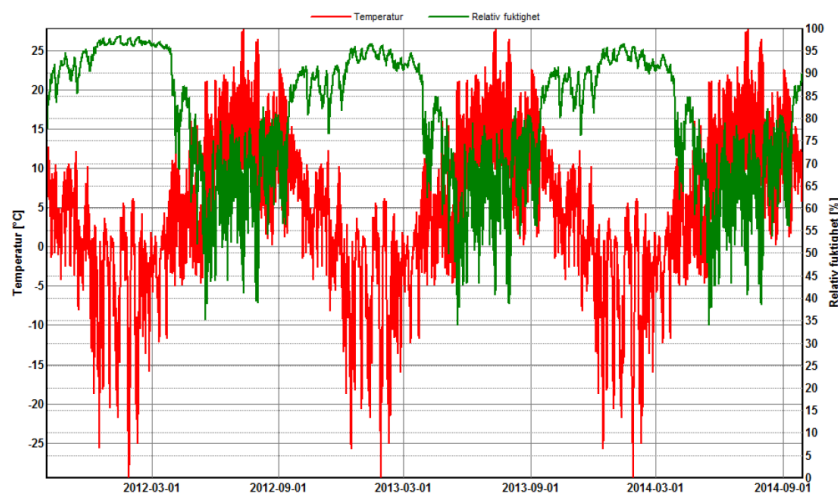


Figure 19: Relative humidity and temperature in the junction between the thermal insulation and exterior plasterboard, wood fibre insulation in the wall, no paint on the outside of the exterior plasterboard.

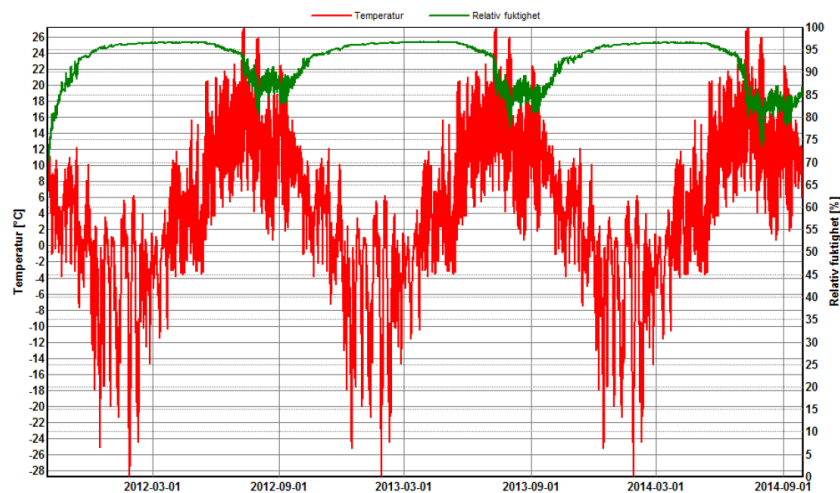


Figure 20: Relative humidity and temperature in the junction between the thermal insulation and the exterior plasterboard, wood fibre insulation in the wall, paint with $Z=100\ 000\ \text{s/m}$.

The figure below, Figure 21, shows the measured values during November 2012 from sensors 6 and 15 which are placed in the insulation layer inside the exterior plasterboard on the east side of the building. The red curve shows the relative humidity 20 mm in from the edge of the wood fibre insulation while the yellow curve shows the humidity 20 mm in from the edge of the mineral wool insulation. This layer is strongly affected by the outdoor climate so that the relative humidity can be rather high at times, and can also vary depending on the outdoor temperature; this can also be seen from the measurements.

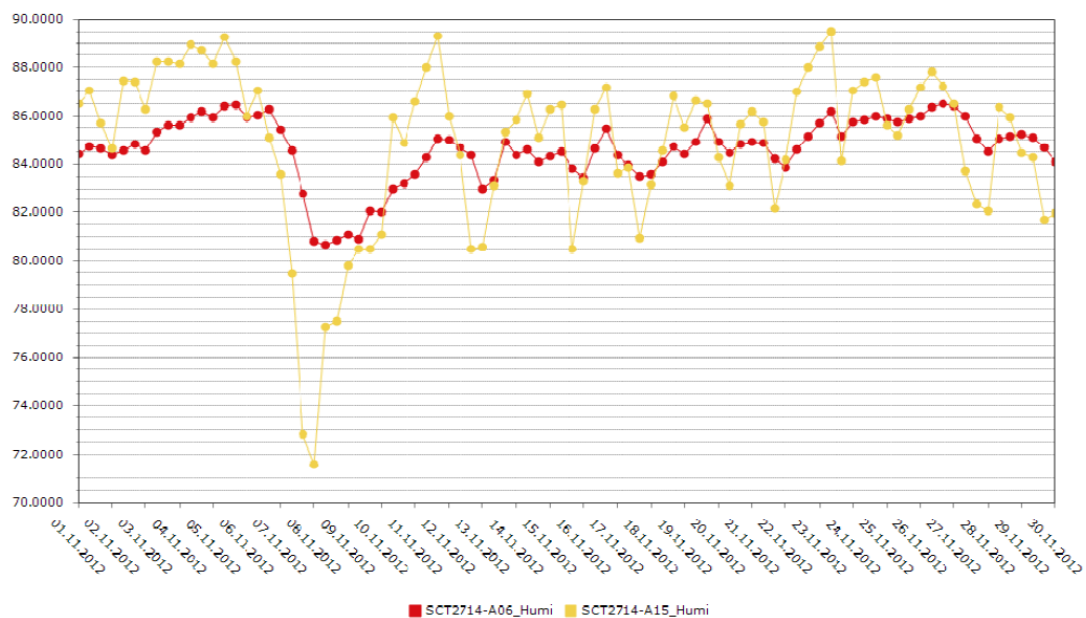


Figure 21: Relative humidity in the insulation in the eastern external wall during November 2012 for wood fibre insulation (red curve) and mineral wool insulation (yellow curve).

Figure 22 shows the relative humidity in the east wall 120 mm in from the outside of the insulation for the month of November 2012. As the wall was composed partly of wood fibre insulation (yellow curve) and mineral wool insulation (blue curve) the humidity is shown in both these insulation materials. As the wood fibre insulation stores the moisture this leads to a more even and somewhat lower curve for the relative humidity in the insulation. The values which are registered are on a par with what is expected from the simulations for an external wall with high water vapour transmission.

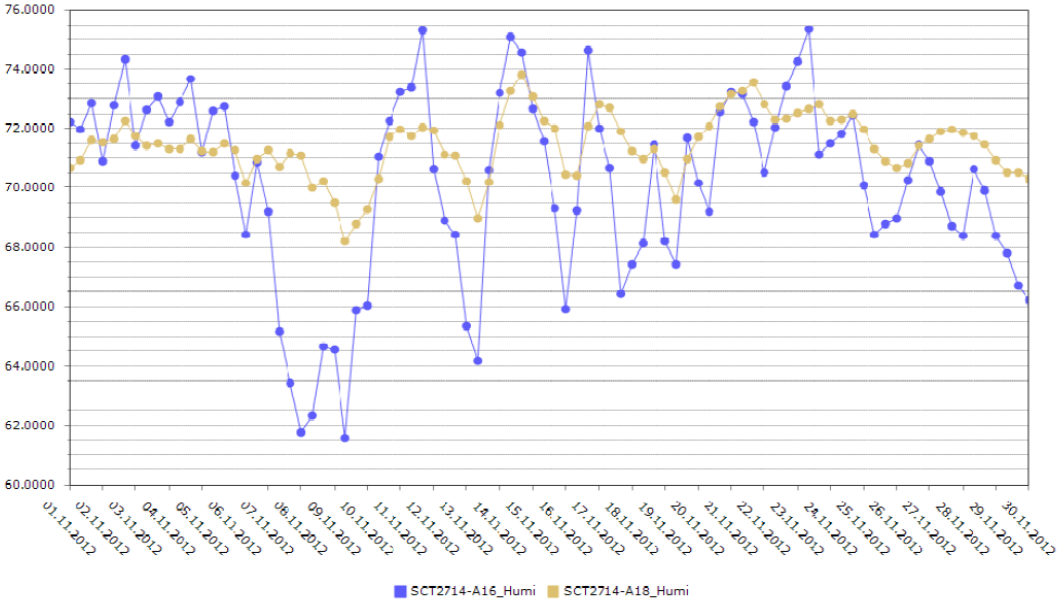


Figure 22. Relative humidity in the insulation in the eastern external wall during November 2012 for wood fibre insulation (yellow curve) and mineral wool insulation (blue curve).

As we have only carried out measurements in the building for six months, it is too early to draw any conclusions regarding the building method and the choice of materials; that is to see if these are the right ones to deal with possible problems of moisture in the building framework without using a condensation barrier, which is indicated by the simulations which have been carried out. The building method chosen seems to work better when wood fibre insulation is chosen rather than mineral wool insulation regarding the moisture levels shown above and, in particular, in the outer layer of the walls. To be able to draw further conclusions, however, the measurements need to be continued for a longer period and also to be supplemented with interior moisture loads, and this is planned for the winter of 2013/2014.

3.4.5 Results of the measurements – temperature and energy consumption

It is too soon to evaluate the measurements of the indoor temperature as the measurements have only been carried out for six months. Figure 23 shows the temperature in the test building during July 2012 when the building is neither heated nor cooled. The black line shows the outdoor temperature and the purple line the indoor temperature. The figure shows that there was an even and relatively constant indoor temperature (21-25.5 °C) although the outdoor temperature varied quite substantially (10-27 °C). Longer series of measurements also made during a longer colder period are needed to be able to evaluate the possible heat storage capacity and how this affects the indoor temperature.

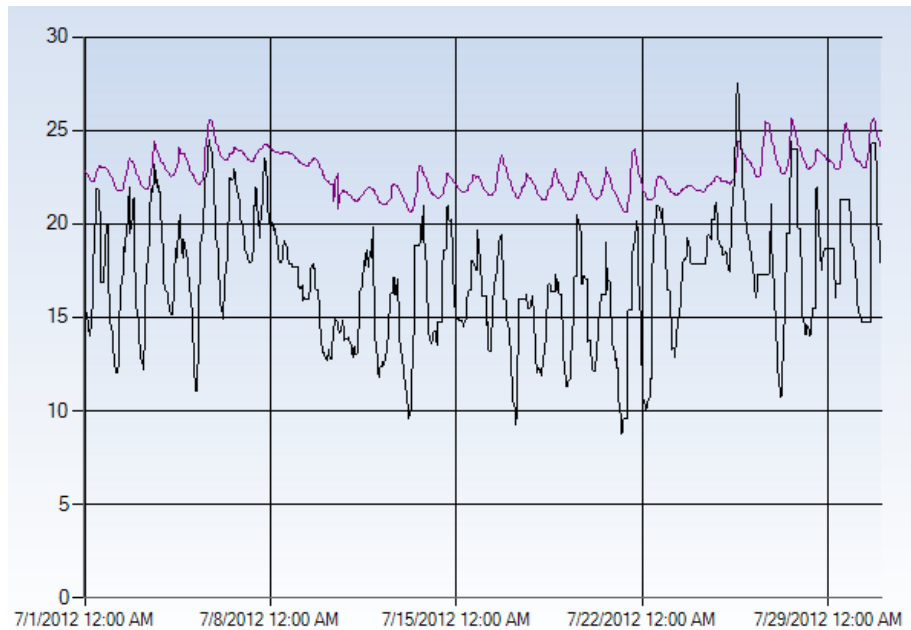


Figure 23. Indoor temperature (purple line) and outdoor temperature (black line) in the test building during July 2012.

The test building has also been equipped with an energy meter to calculate the energy consumption of the HRV unit and the heating unit which will give additional heat when this is needed. However we are not presenting any results from these measurements as the measurements have not been carried out during a complete heating season. Furthermore, the measurements are misleading and the figure given is too low as it has often been difficult to maintain a sufficiently high indoor temperature (20°C) in the test building. The reason for this is not because the heating unit is too small or the thermal loss too great, but is because the building is too small. As the HRV unit is set for ½ air change per hour, it means that slightly over 20 m³ air is changed per hour. This results in such a low air-change rate that the air hardly stirs in the building but is layered with hot air at the ceiling and considerably cooler air lower down. The position of the thermostat which controls the heating unit is therefore crucial and we can see that, up to the time of writing, it has been wrongly positioned which has often resulted in the indoor temperature during cold days not being higher than 10°C, while at the same time the heating unit has been turned off.

We did not discover this until November 2012 when it started to get colder and, when this report was being written we had just installed a special fan which will counteract the layering and thereby make it easier to control the heating unit with a thermostat.

Nor is it particularly relevant to check if the test building fulfills the requirements of the passive house standard as it is very small and has a high shape factor, which gives a large degree of internal surface area per A_{temp} compared with more normal buildings. However, the different parts of the building envelope have U values which are on a par with other recently constructed passive houses (Janols and Wik, 2012) and therefore we consider that there is no doubt that the building system can be used for the construction of larger buildings which can fulfill the passive house standard, on the condition that the airtightness is shown to be sufficient.

3.4.6 Results of the measurement – air tightness

When the framework and the supplementary additions to the framework were completed, an early leakage search was carried out which has been followed later by further air tightness tests every month since July 2012. In connection with the first air tightness test, which was carried out on the

completed building, a certified measurement consultant was also engaged to carry out a control measurement to verify the university's measuring equipment and method. The results of the two air tightness tests were almost identical, with an average value of 0.39 [l/m².s] at 50 Pa pressure. After these control measurements, monthly measurements have been made with the university's equipment and these are shown in figure 24. At the monthly measurements, a leaking joint was discovered in the ventilation system's supply and exhaust air ducts which affected the measurement result and which we had not taken into account in the initial measurements when the duct was sealed on the outside. The monthly measurements were therefore increased to two different procedures where the first measurement was carried out in the same way as the initial measurement while the sealing for the other measurement was moved to the inside of the HRV unit to exclude the above mentioned joint. The measurements were carried out with an air tightness test where the pressure was increased, rising from 15 Pa up to 60 Pa and was repeated with under-pressure and over-pressure respectively.

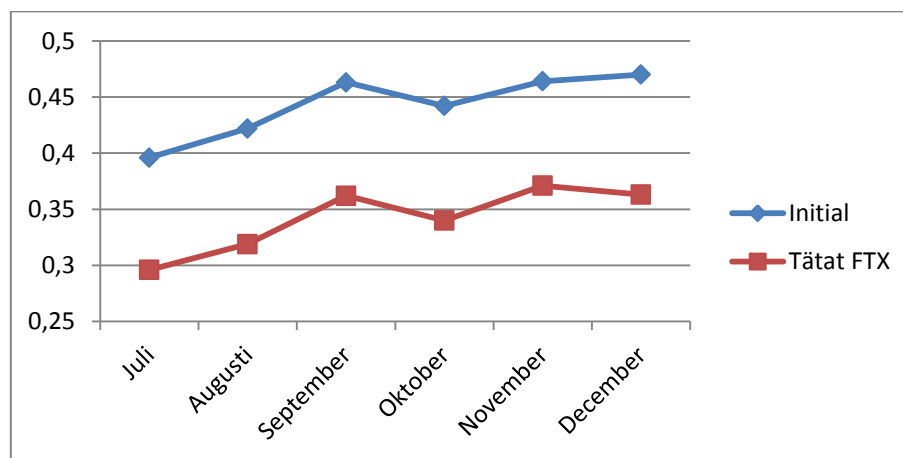


Figure 24: The result of the initial pressure tests with sealing on the outside of the duct and also the result of the pressure tests with sealing on the inside of the HRV unit. Measurements made during 2012.

The results of the measurements show that the leakage from the HRV unit's duct contributed approx. 0.1 [l/m².s], regardless of when the measurement was carried out. There is, however, one exception in the measurement in December where the difference between the measurements was somewhat larger. This is probably due to its being cold when the measurements were carried out with a lot of frost on the outside of the fan duct which contributed to the difficulty of getting the sealing to remain in place during the initial measurement.

The air leakage for the measurement with a sealed HRV unit, which is also the measurement which shall be compared with the present air tightness requirement, was, to begin with, 0.29 [l/m².s], but rose during the autumn to level off later. At present, it is difficult to judge if we have now reached a final level of 0.36 – 0.37 [l/m².s] for the leakage from the building or if it will continue to vary over time. There will probably be continuous variation in the leakage from the building dependant on the effect of humidity and the following drying out/humidifying of the building envelope. However, an important question which remains to be answered is the appearance of these changes over a longer period of time.

In connection with the initial measurements, thermography and a leakage search were carried out on the building envelope of the test building, where the major leakage points were identified. By sealing each of the identified leakage points, the leakage from each point could subsequently be measured at every point. The results of these measurements show that there were two major leakage points in the building envelope which are shown in table 2 below.

Table 2: Identified leakage points

Where	Air leakage
Joints in the panels over the glass screen with sliding door	0.06 l/m ² s
Glass screen with sliding door, including fixings	0.01 l/m ² s
Entrance door including fixings	0.10 l/m ² s

During the autumn of 2012 these leakage points were continually followed up. The result for the joint in the panels over the glass screen with sliding door has not been affected appreciably, but there has been a certain increase for the screen during December. As opposed to the sliding door screen, however, the entrance door has become slightly more airtight. It is difficult to draw any major conclusions, so discussion in the following sections is based on the measured leakage figures given in table 2.

According to the present passive house requirements (FEBY 2012) the air tightness requirement for smaller passive houses with a shape factor which exceeds 1.7 may not exceed 0.5 [l/m²s]. For buildings with a lower shape factor, which mainly comprise multi-storey buildings, the requirement is 0.3 [l/m²s] instead. If this is compared with the results above it can be seen that the test building fulfils the present requirements for passive houses with a wide margin as the building's shape factor is 4.1. However, it is considered possible to further reduce the measured air leakage by some simple measures. The two largest air leaks which have been located in the test building, the joint over the sliding door screen and the entrance door including fixing, together make up 55 % of the building's total leakage. The joints between the CLT panels over the sliding door are wrongly designed as the rebate in one of the panels is too large compared with the other panel junctions which means that this leakage can certainly be reduced, see figure 25. This miss has later been explained as a miss in the design which was carried out in 2D. We believe that if the design had been made in 3D instead, it would have been discovered more easily as 3D gives a different overview of how the assembly is carried out at angles and joints.



Figure 25: Temporarily sealed joint in the elements above the sliding door screen. This joint has not been sealed during the recurrent air tightness tests.

Regarding the entrance door, which contributed 34 % of the air leakage, it was designed to be further out in the wall compared with the sliding door screen and its fixings, which were shown to be very airtight in the measurements, see figures 26 and 27.

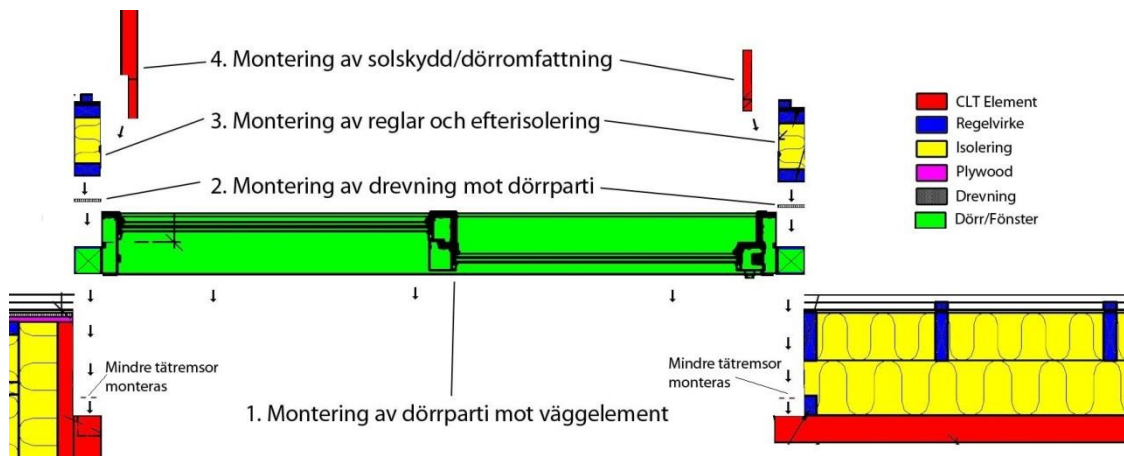


Figure 26: The order of assembly of the sliding door screen in the wall element (Fyhr, 2012)

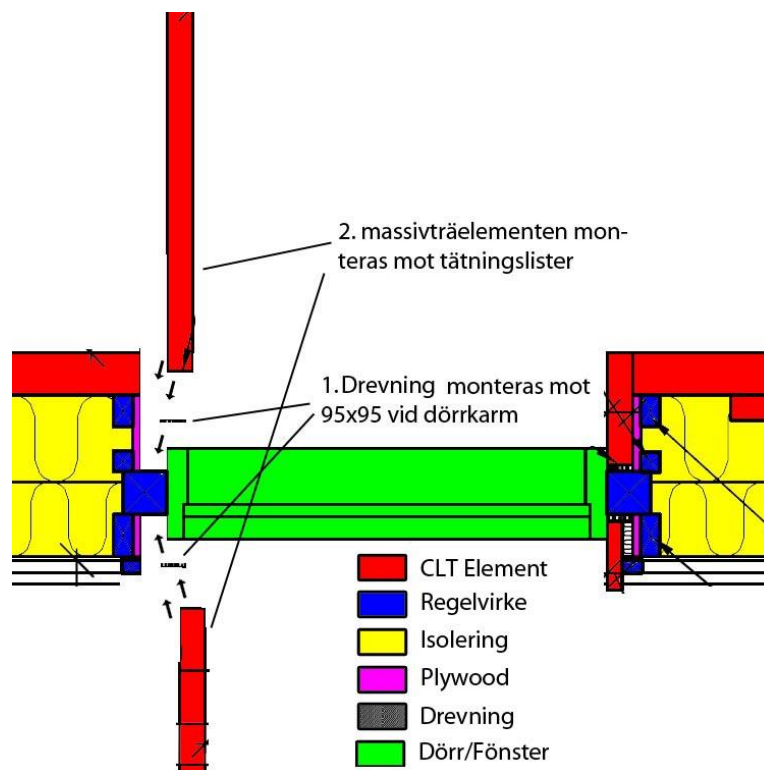


Figure 27: The assembly of the entrance door in the wall element (Fyhr, 2012)

The position of the entrance door towards the outside of the wall was one reason why door linings of CLT had to be added on site, when one of the internal door linings was extended to create a screen in the room. In comparison with the sliding door, the position of the entrance door contributed to several potential leakage points through the junctions between the CLT panel, the door linings and the entrance door. As the CLT screen was assembled on site it was more difficult to move it against the studs in the doorframe and create an airtight joint compared with the fixing of the sliding door.

This, in combination with the additional number of leakage points, is considered to be the main reason for the greater air leakage at the entrance door. By carrying out the fixing of the entrance door in the same way as for the sliding door the same air tightness can probably be achieved for both of them, which according to the repeated measurements was 0.01 [l/m².s]. Furthermore, it is presumed that the wrongly constructed joint in the panels over the sliding door could be made in the same way as the other corner junctions and the leakage would then be approx 0.01 [l/m².s]. Therefore it should be possible for the air tightness of the test building to reach approx. 0.15 [l/m².s] without any major alterations based on the initial measurements, and approx. 0.22 [l/m².s] if the increased leakage which was recorded during the autumn of 2012 is taken into account.

3.5 The design of buildings with passive CLT systems

During the duration of the project, the Måsen district in Orsa was discussed as a possible object to be constructed with CLT frame within the framework of the project Trästad 2012. This was for four two/three storey buildings in two stages, of which the first stage consisted of two buildings. According to the detailed development plan the two storey buildings allow a small superstructure (max 50 m²) on the attic storey. Thus there are 8-9 apartments per building, depending on how the attic storey is utilised. The buildings which were designed, omitted an apartment on the third floor as the cost per square metre was expected to be too high.

In connection with the design and planning of the Måsen district, the Finnish system was adapted for the Swedish market, as the two countries have different noise regulations and fire safety regulations, and also for the passive house standard which is not fulfilled by the present standard solutions. This is expected to be Stora Enso's first project on a large scale. Design drawings, applications for building permit/planning permission and other documents and also simplified working drawings including services have been produced and construction drawings and documents are being planned to fulfill the requirement for standard details for industrial production in the long term.

The design and planning of the Måsen district is partly based on the details of junctions in the test building. New details for the project will be junctions for the intermediate floors, new standard details for wall elements in the stairwells with lower indoor temperatures, details for glazed corner windows and also planning of the production process up to the completed buildings. The bathrooms in the project will be produced as volume elements and be included in Stora Enso's flat element system.

The plans are for apartments with 1, 2 or 3 rooms and kitchen with balconies on the south, east and west where all of them look out over the lake, Orsasjön. The plans are regulated by the detailed development plan which means that it is this which decides the volume of the building rather than what would be optimal for the building system and the apartment plans. The plan has been designed for Stora Enso's module dimensions for the intermediate floor structure, to avoid spill and utilise the panels rationally. The stairwell is not heated and functions as a porch sheltered from the wind.

The design of the building in the Måsen district has, among other things, meant

- the development of Stora Enso's CLT system into a complete passive house building.
- the production of standard details for other conditions than those included in the present system.
- the development of the design of the elements before production in the factory based on the problems which were identified during work with the test building. See earlier description of problems detected including sealing strips, pre-fixed joinery, co-ordination of design and planning.
- adjustment of the position of the lifting loops based on the experience from the test building. Drawings of the buildings in the Måsen district are shown in appendix 3.

3.6 Financial analysis of the building system

Within the framework of the project, thesis work has been carried out by Kristoffer Smedberg, *Kostnadsberäkning av passivhus med avseende på stomval* (Smedberg, 2011). The thesis work is based on the sketches for the Måsen district and he has carried out calculations and produced timetables for the building being constructed in in-situ concrete or alternatively with prefabricated CLT panels. In connection with this comparison, different foundation methods have been assumed as the CLT framework weighs 1/3 of the framework of in-situ concrete. The surface finish has not been included in the calculations, but the erection of the framework and the supplementary additions (balconies, windows, internal walls etc. have been included).

The method used to compare the two types of framework started with interviewing experts about the characteristics of the different types and later by reading relevant literature. Comparisons of cost were made later with the calculation program BidCon and the project planning program PlanCon.

The results of the thesis work showed that building with an in-situ concrete framework in the Måsen district would be approximately 14 percent cheaper than the CLT frame. However, the production time for the in-situ concrete frame was approx 19 weeks longer than for the CLT frame. A longer production period results in loss of income from the rents and increased costs for rented equipment and if this is taken into account the difference will be approx 8%. If the capital costs are taken into account the difference is reduced by a few more percent.

It should be noted that the calculations have been carried out on a two-storey building with a small attic storey. If the building is higher the difference in construction time will increase further which will reduce the differences in cost between the two building systems. In the CLT case the costs also include a certain risk as the technology is, as yet, untried. Neither CO₂ nor other environmental factors have been taken into consideration; these are also advantageous for the CLT framework.

The study can be summarized as that the difference in cost between the two building systems is small but that CLT will be competitive compared with in-situ concrete, principally for larger buildings, in particular for buildings of 4-5 storeys or higher. Further larger objects with a CLT frame must however be constructed and more detailed calculations must be made before more reliable conclusions can be drawn.

4. Departure from the decisions on the project

The project has, on the whole, been carried out as agreed, with the development of a building system for passive houses constructed of CLT panels, building an experimental building and measuring/verification of the performance and also the design of larger buildings as a the most important parts. There is, however, some departure from the agreed project plan.

- In the project plan it was agreed that this project should be co-coordinated with the on-going project being carried out by an industrial PhD student within industrial CLT construction being carried out at Luleå University of Technology. This did not take place as the chosen coordinator was given other fields of responsibility within Stora Enso. However the experiences from this and the current project in Luleå have been coordinated as Mattias Brännström, Stora Enso, is involved in both projects and has seen the current synergy during the duration of the project.
- In the project plan it was agreed that a group of experts within different areas would be formed to support the project. This did not take place, but some of the proposed experts have been engaged as consultants and helped with the analyses of moisture and air tightness, for example. As Stora Enso has an interest of its own in developing a new building system, the company has, itself, engaged different experts who have assisted with the design and the building physics investigations for example.
- We have not written a scientific article, but this is because we do not have a sufficiently long measurement series to be able to present interesting results. We intend to continue with the measurements for at least a year after the formal end of the project and plan to present the results in a scientific context after this. We now believe that there will be a basis for at least two articles; one on the air tightness testing and one on relative humidity in CLT constructions without a water vapour barrier, where we will have comparative measurements from two different insulation materials.

5. Continuing work

We intend to continue the project after the formal end of the project. The test building is built on a site owned by one of the project participants (HMB Constructions) and unless something unforeseen occurs it may remain there for a further 1-2 years. In the first stage we will continue with pressure testing every month so that we have at least a year's continuous measurements. The purpose of this is to see how CLT structures behave regarding air tightness with different climates and during conditions as the wood dries (over time and because of different humidity during the year). Furthermore we want to test how the construction with sealing strips and a good fit instead of airtight plastic sheeting reacts to different conditions of temperature and humidity. These measurements are carried out without any input of moisture into the building; the humidity being completely determined by the outside air which is continually supplied to the indoor air through the HRV unit.

If the measurements are successful we want to continue them for a further year, but to add moisture through a humidifier which will simulate people in the building. Depending on the results of the measurements we can further stress the building by raising the indoor humidity. The aim is to see how the CLT wall and the insulation react to moist air and to see if we can identify any risk for water damage and problems of condensation in the walls without plastic film. Our hypothesis is that the CLT panels will retain their air tightness even if the temperatures and humidity are changed during the year, partly due to the way in which the component layers are glued in Stora Enso's panels. This should, in any case, be substantiated or refuted by these experimental measurements.

It is intended to make a comparison with similar research which is being carried out at the Aalto University in Helsinki led by Professor Stefan Winther. In this way the result can be corroborated based on two research projects which are independent of one other.

Regarding the construction, this can be improved and further development work would be desirable; this can be carried out both by research co-operation or through internal development work at the participating companies. This includes the problem of cold bridges at the window and door junctions which we think can be further improved, and also working out the best way of fixing the doors and windows, both regarding economy and energy performance. The fixing we chose for the doors and windows can be developed for larger elements and higher loads than those present in the test building.

In addition the placing of the lifting loops can be further studied to achieve the fastest possible assembly and required air tightness.

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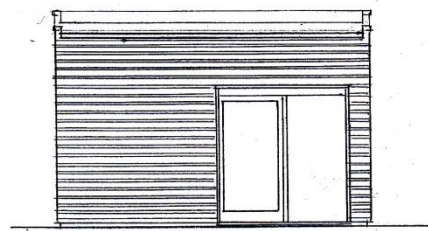
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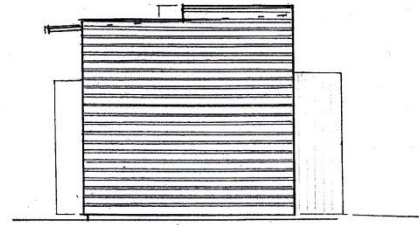
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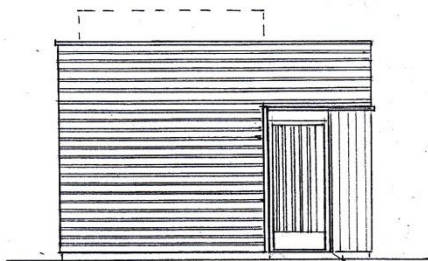
Appendix 1. Drawings of the test building



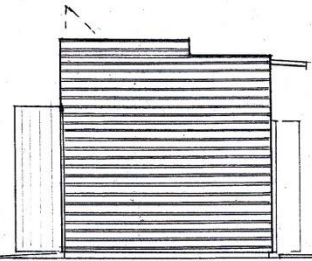
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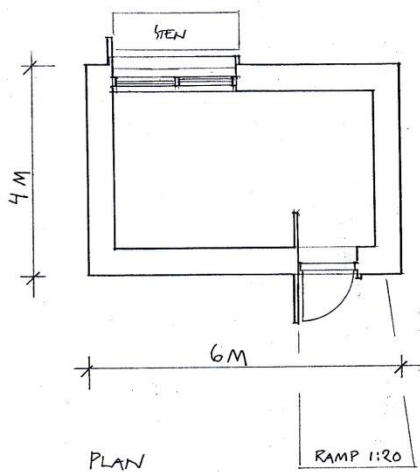
GAVEL MOT ÖSTER



ENTRÉFASAD

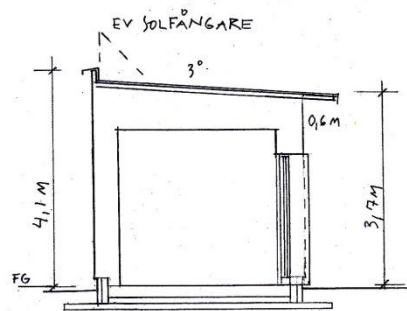


GAVEL MOT GATA



PLAN

RAMP 1:20



TVÄRSEKTION

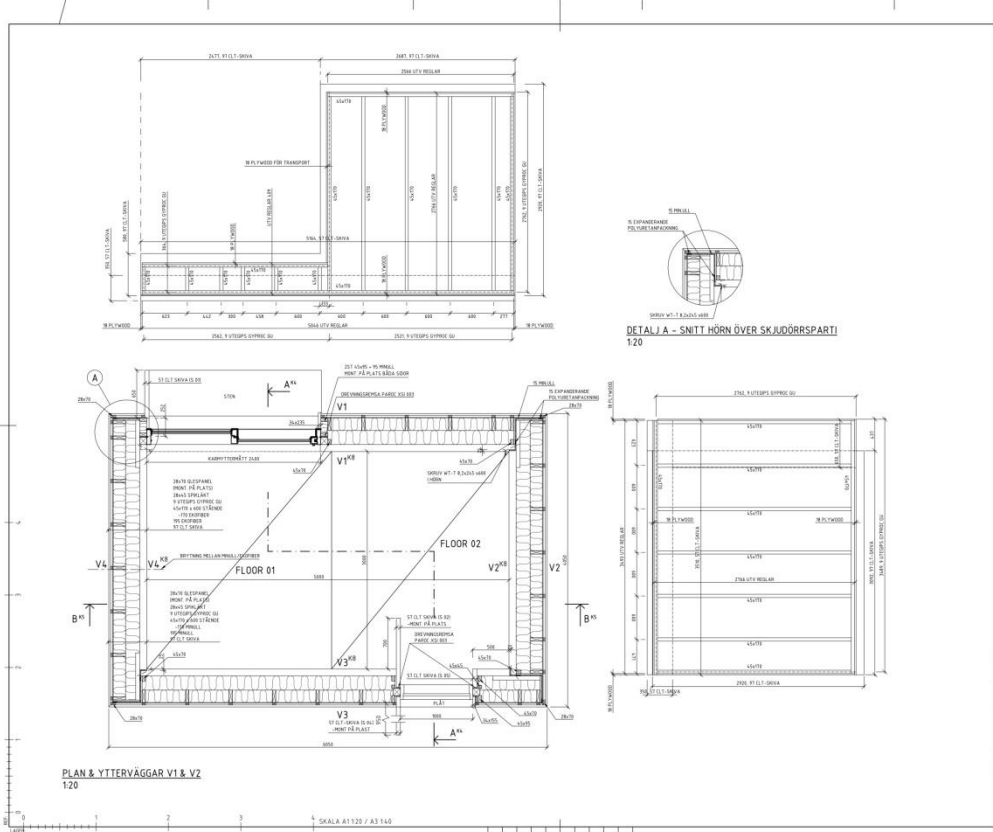
TESTKUB BORLÄNGE

Plan, Sektion, Fasader

Tina Wik Arkitekter, Bondegatan 74 A, 116 33 Stockholm, Tel/Fax 08 6429291
E-mail tina@tinawikarkitekter.se

BYGGLOVSHANDLING

Skala 1:100
20110428



FÖRKÄRLNINGAR

VÄGGAR: BOMBA-LYFVÄGG
YTTERVÄGG: MONTERAD PÅ PLÅT

FÖRESKRIFTER

HÄNVISNINGAR

LÖFTAVGIFNING: TILL VÄGGLÄMNING OCH LEVERANTÖR

BYGGHANDLING

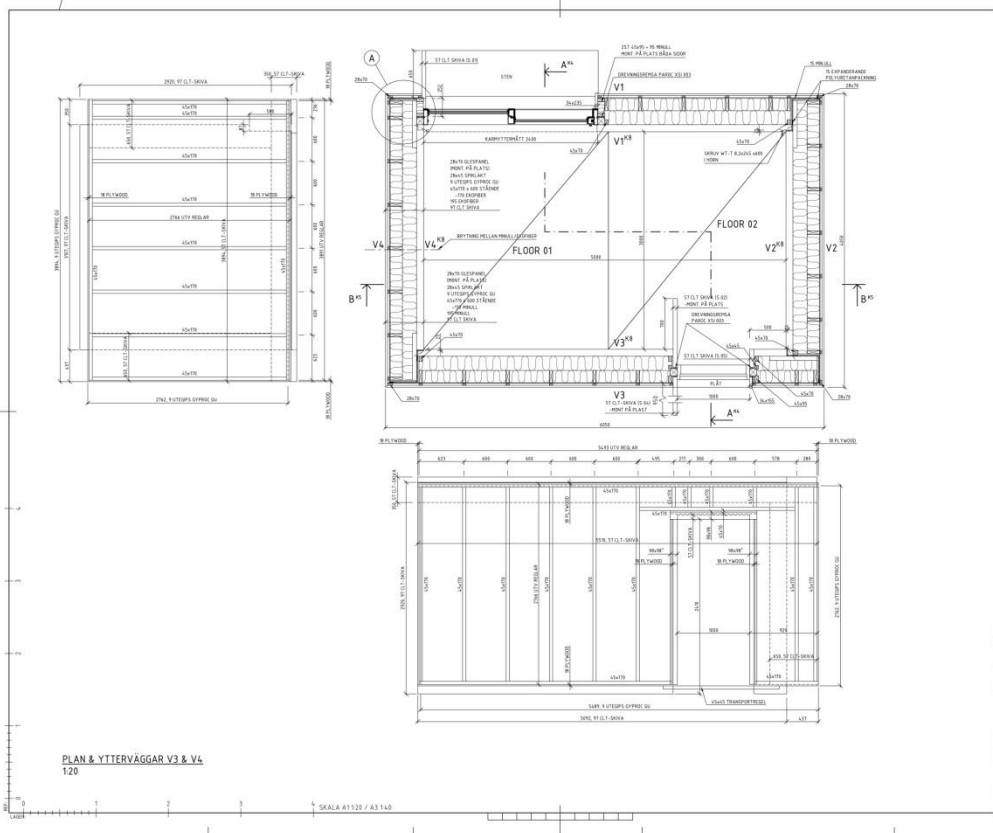
Proj. nr	Proj. namn	Rev.	Datum

RAMBÖLL

Projektledare: Lena Hellberg
Arkitekt: Lena Hellberg
Bygghandling: STORAENGS FÄSTKUB BOKPLÅN

PLÅN: 120/140

1:01



FÖRKÄRLNINGAR

VÄGGAR: BOMBA-LYFVÄGG
YTTERVÄGG: MONTERAD PÅ PLÅT

FÖRESKRIFTER

HÄNVISNINGAR

LÖFTAVGIFNING: TILL VÄGGLÄMNING OCH LEVERANTÖR

DETALJ: A OCH B PÅ VÄGG
TÖRMÄNTAR: PÅ KÄNN

BYGGHANDLING

Proj. nr	Proj. namn	Rev.	Datum

RAMBÖLL

Projektledare: Lena Hellberg
Arkitekt: Lena Hellberg
Bygghandling: STORAENGS FÄSTKUB BOKPLÅN

PLÅN: 120/140

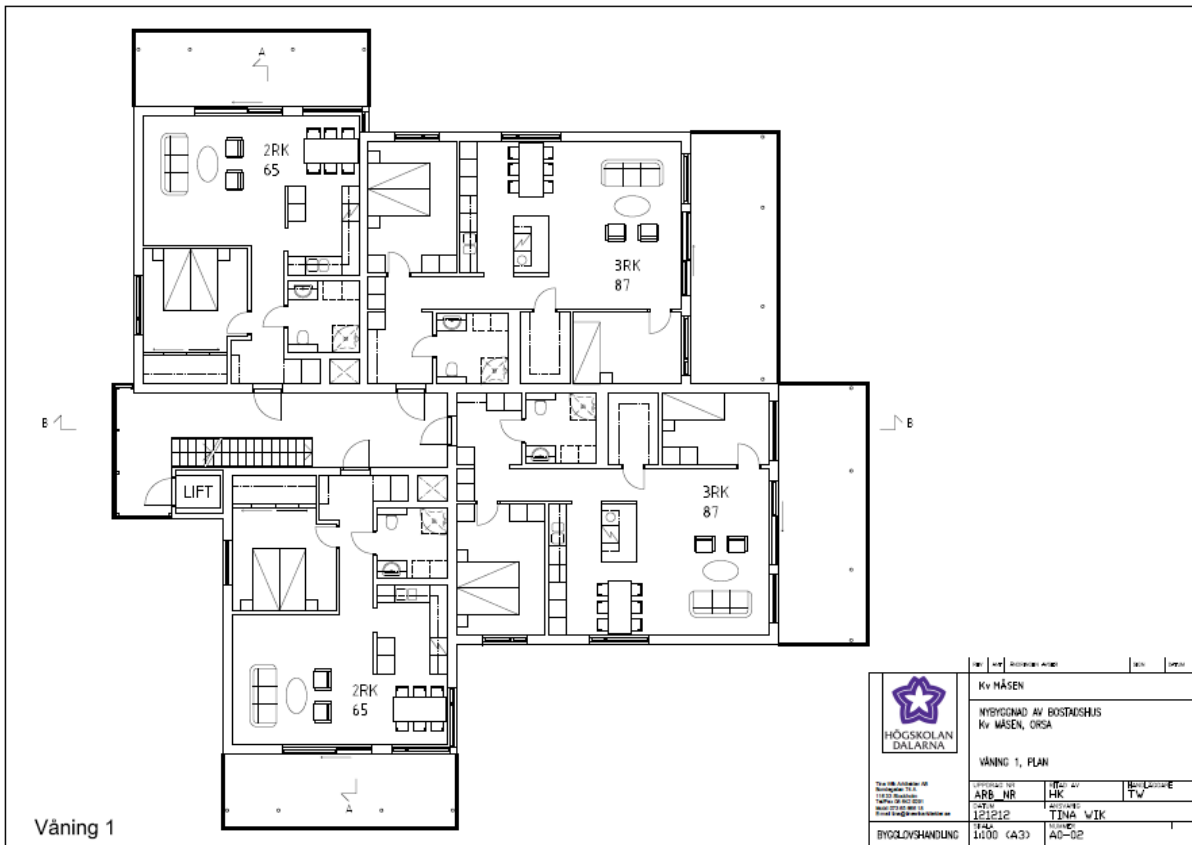
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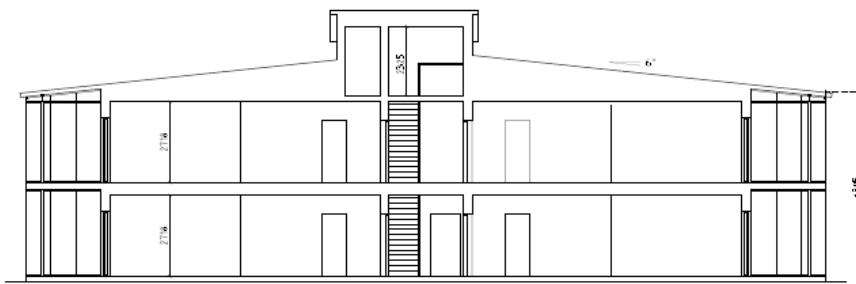
Montage testkub 2011-12-16






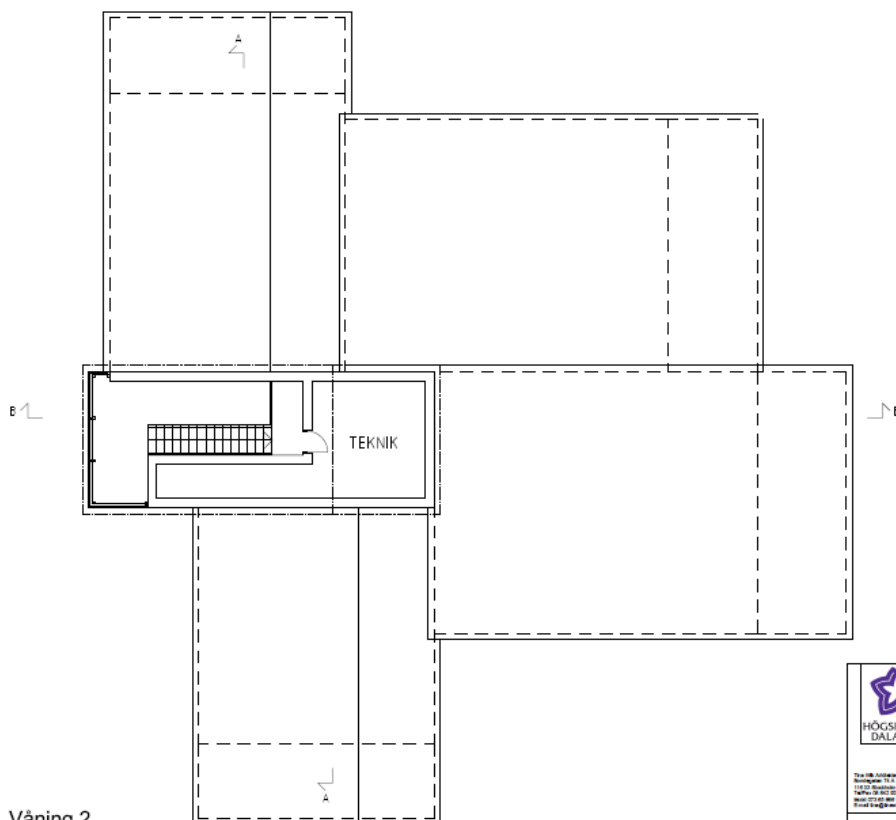
Appendix 3. Drawings of the proposed apartments in the Måsen district, Orsa






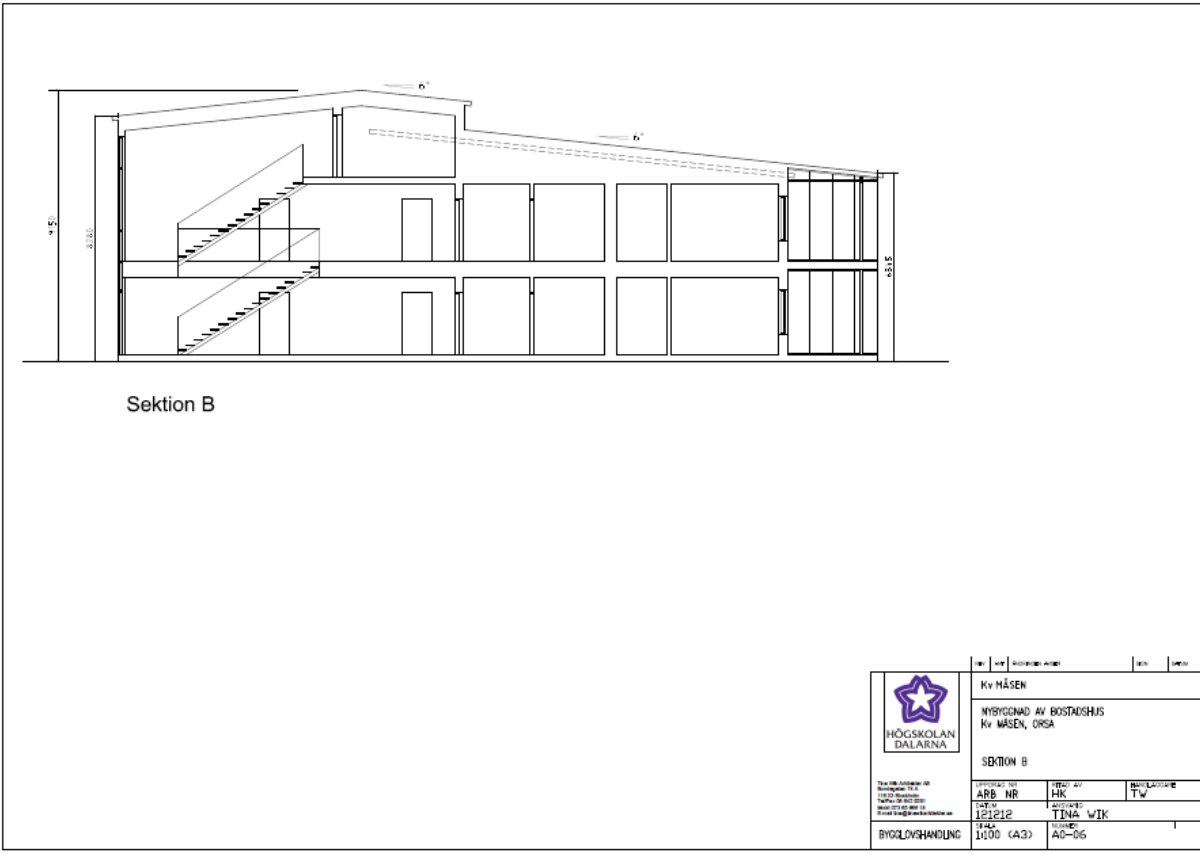
Sektion A

 <small>Högskolan Dalarna</small>	Kv. HÅSEN		
	BYGGNAD AV BOSTADSHUS Kv. HÅSEN, OKSA		
	SEKTION A		
	<small>UPPLAGS NR</small> ARB. NR <small>BYGGLOVSHANDLING</small>	<small>BYGG. ANS.</small> HK	<small>BYGGLOVSH.</small> TW
121212	TINA WIK		
1100 (A3)	AG-05		



Våning 2

 <small>Högskolan Dalarna</small>	Kv. HÅSEN		
	BYGGNAD AV BOSTADSHUS Kv. HÅSEN, OKSA		
	VÅNING 2, PLAN		
	<small>UPPLAGS NR</small> ARB. NR <small>BYGGLOVSHANDLING</small>	<small>BYGG. ANS.</small> HK	<small>BYGGLOVSH.</small> TW
121212	TINA WIK		
1100 (A3)	AG-03		



Sektion B

 HÖGSKOLAN DALARNA	Kv MÅSEN		
	BYGGNAD AV BOSTADSHUS Kv MÅSEN, ÖRSA		
	SEKTION B		
	OFFISIAL NR ARB NR 121212	FASAD AV HK TINA WIK	BYGGLOPP TW
BYGGLOVSHANDLING	1000 (A3)	A0-06	



Fasad mot Norr

Fasad mot Öster


 HÖGSKOLAN DALARNA	Kv MÅSEN		
	BYGGNAD AV BOSTADSHUS Kv MÅSEN, ÖRSA		
	FASAD NORR, ÖSTER		
	OFFISIAL NR ARB NR 121212	FASAD AV HK TINA WIK	BYGGLOPP TW
BYGGLOVSHANDLING	1000 (A3)	A0-07	



Fasad mot Söder



Fasad mot Väster

 HÖGSKOLAN DALARNA		Kv MÅSEN NYBYGGNAD AV BOSTADSBUS Kv MÅSEN, ÖRSÄ	
The 988 Architecture AB Skellefteå, Sweden 0920 22 22 22 0920 22 22 22 0920 22 22 22		FASAD SÖDER, VÄSTER	
ÖPPNINGS-ÅR 2014	ARB. NR 121212	BYGG-ÅR HK 2014	BYGGKONSTRUKTÖR TW
BYGGLOVSHANDLING 3100 (A3)		BYGGKONSTRUKTÖR TINA WJK 40-08	