Timber structures for cottages in the mountains, Olpererhütte made by cross laminated timber

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ABSTRACT: The architectural design and the construction with cross laminated timber elements harmonise. The cross laminated timber elements connected by screws are suitable for envelope, for forces and for transport and directly erection from helicopter.

KEYWORDS: cottages, cross laminated timber, connection by screws, erection by helicopter, energy

1 INTRODUCTION

In the middle of the nineteenth century the formation of alpine clubs in the european mountains starts. Since 1869 the „Deutsche Alpenverein“ exist. The aim of all this clubs was to make it possible and more easier to visit the mountains.
Ways and cottages ware built with a lot of enthusiasm. Surprising is, that people far away from the mountains ware engaged. The clubs in Austria and Germany worked together and there was the "Deutsch-Österreichische Alpenverein". The club is organised in "sektionen". In general each Town ore region has a section. And so the „Sektion Prag“ par example built the first Stüdlhütte (Figure 1). Mister Johann Stüdl, a businessman in Prag, was also a member of the founder of the alpine club.
The end of the Austrian monarchy changed also the ownership of some cottages, but today the "Deutsche Alpenverein has abut 320 cottages in Germany and Austria.

2 COTTAGES IN THE MOUNTAINS

The first cottages ware very simple refuges, only able to protect against rain and snow. Johann Stüdl gave also rules how to built this cottages. The material for these first cottages was the material fond directly on the place: stones and timber.
Over the intervening years the demands are changing, new cottages are built, so a new Stüdlhütte, a timber structure with modern technical equipment (Figure 2).

Timber structures ware always a good method to built cottages (Figure 3).

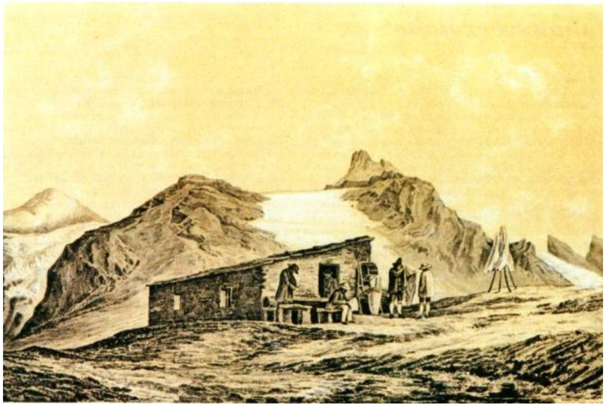

Figure 1: Stüdlhütte, Großglockner 1868

Figure 2: Stüdlhütte, Großglockner 1994

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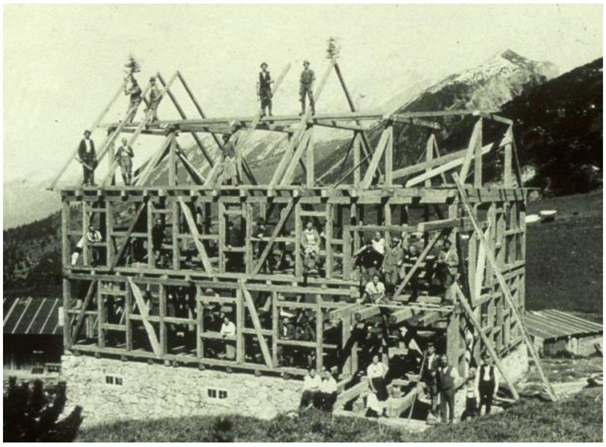

Figure 3: Falkenhütte, Karwendel, 1926

In the year 1882 there was built the Olpererhütte in the Zillertaler mountains, 2400 m over sea level. The owner was the Sektion Berlin.

Figure 4Figure 5): Olpererhütte up to 2006

After changing time the cottage was given to the Setktion Neumarkt and the old cottage does not meet the demands of time it was decided to built a new one.

3 DESIGN, CONSTRUCTION AND ERECTION

3.1 CALLENGE FOR ARCHITECTS

There was organized a callenge for architects. The owner formulated his wishes: the number of sleeping places, the number of seats in the restaurant, no puplic supply .
All the necessary equipment for heating, electric power, drinking water and with electricity, water for drinking and the waste water treatment must be planed. Importend also is the sustainability of all the actins. A own small building for the wintertime is necessary. During the cottage is not in service, there must be a possibility for alpinists to have a lodging. Ten architects were involved to make proposals fort the new cottage

The owner, Sektion Neumarkt, and the management of the Deutschen Alpenverein were conform with the design of the Architekturbüro Kaufmann.

The house with two floors and a basement only in a part of the ground view is 24 m long and 11 m wide. The characteristic of the design is the placement: the long line of the house is situated perpendicular to the hillside. The first level is like a cantilever over the basement (figure 5). A small separate building is for wintertime.

The design and the construction were developed consequently to use elements of cross laminated timber. So the erection by helicopter and also directly using of the surface of the elements for the art of the rooms were possible.

3.2 CROSS LAMINATED TIMBER

First experiences with large elements made by cross laminated laminates were done since 1992. The company was „Holzbau Merk“. After successful projects the application was possible in Germany by a „bauaufsichtliche Zulassung“ in 1998 given by the “Institut für Bautechnik, DIBt” in Berlin. In the “Zulassung” there are rules for fabrication, design and construction with these elements. “Zulassungen” for these products, fabricated in in other countries (Austria, Swiss) were given and it shows the attractiveness of this product. Cross laminated timber is now established in timber engineering.
The different layers of the cross laminated timber are usually glued together. It is also possible to use timber bolts or nails.
The pressure for the gluing process is made by a hydraulic press or in a special case by using the pressure of atmosphere: the layers are situated in an envelope and a vacuum is made. Usually the pressure for gluing is about 0.6 to 0.8 N/mm^2. Using the vacuum there are only less than 0.1 N/mm^2 possible. But also a good quality of the product is possible. To have good products there are rules for the width and the thickness of the laminates.
The configuration of the cross section results in an anisotropic behavior of the plane or plate. There may by forces in the flat or and perpendicular to the flat. The flat is used as a plane or as a plate. The first is the main stress in a wall, the second in a floor. The flat is able to transfer loads in all directions according to its condition of support compact elements under area load
To do computation and dimensioning it is necessary to respect the rolling shear stress and its deformation. Possibilities are given in an annex to the code DIN 1052 [ ] and also presented in [HTO] and [Mestek].

Remembering (Mestek) ,shear deformation should be considered having concentrated loads orcomplicated 3-dimensional systems and shear deformation could be neglected in slim elements under area load (simply supported ($L/t \geq 20$).

prEN 1995-2:2004 (E)

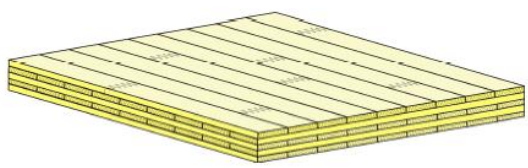

Figure 4: Cross laminated timber prEN 1995-2, EC5-2

The elements made by cross laminated timer are rigid and allows high loads by a small weight. So these elements are useful also for multistoried houses and bridges. (Areo, Japan Rütteltisch)

Figure 5: Cross laminated timber

3.3 CONSTRUCTION

The concept was done using plane elements (Figure 5) of cross laminated timber for the walls, the roof and the floors.
Necessary is a powerful possibility to connect the elements. In then factory building overlapping plywood elements were used (Figure 10) and by erecting only screws (Figure 7)

Figure 5: Olpererhütte

Figure 6:Wall and roof

Figure 7:Connection by screws

Deciding for erection directly from the helicopter is the weight of the elements (Figure 14). No crane on the building site is available. In the inside of the house the elements are visible, there is no sheathing of walls and floors intended (Figure 8).

Figure 8: Inside of the rooms

3.4 DESIGN ROOLES

3.4.1 Loads, special in the high mountains

Besides the self and the traffic loads there are relevant the snow and wind loads. For the situation in the high mountains there are special conditions for:

Ultimate limit state	snow load
	wind load
Serviceability limit states	heat protection
	noise protection

The "Zentralanstalt für Meteorologie und Geodynamik, Regionalstelle für Tirol und Vorarlberg" gives with the following values:

Snow load s_0 = 6,8 kN/m^2
Wind pressure q_0 = 1,65 kN/m^2

The wind pressure belongs to wind velocity of 184 km/h or 51 m/2. The correlation is given by equation 1.

$$q_0 = \frac{1}{2} \cdot \rho \cdot v^2 = \frac{1{,}25 \cdot 10^{-3}\, t/m^3}{2} \cdot v^2 \frac{m^2}{s^2}$$
$$= \frac{v^2}{1600} = \frac{51^2}{1600} = 1{,}65 \frac{kN}{m^2} \qquad (1)$$

In this formula ρ is the mass of the air int/m³ and v the velocity of the wind in m/s. (It is not regarded, that the mass of the air in the altitude of 2.400 m is smaller than at sea level.he snow and wind loads).
In normal regions the comparable value of the wind pressure is about 1,0 kN/m².

3.4.2 Computation

With the values for snow and wind loads a computation was done using the rules for construction and design. In Germany the DIN 1052 is used for the timber structure. For the cross laminated elements and the screws there are necessary an European technical Zulassung [4].

Exemplary is shown the computation of the floor over the ground in the cantilever region.

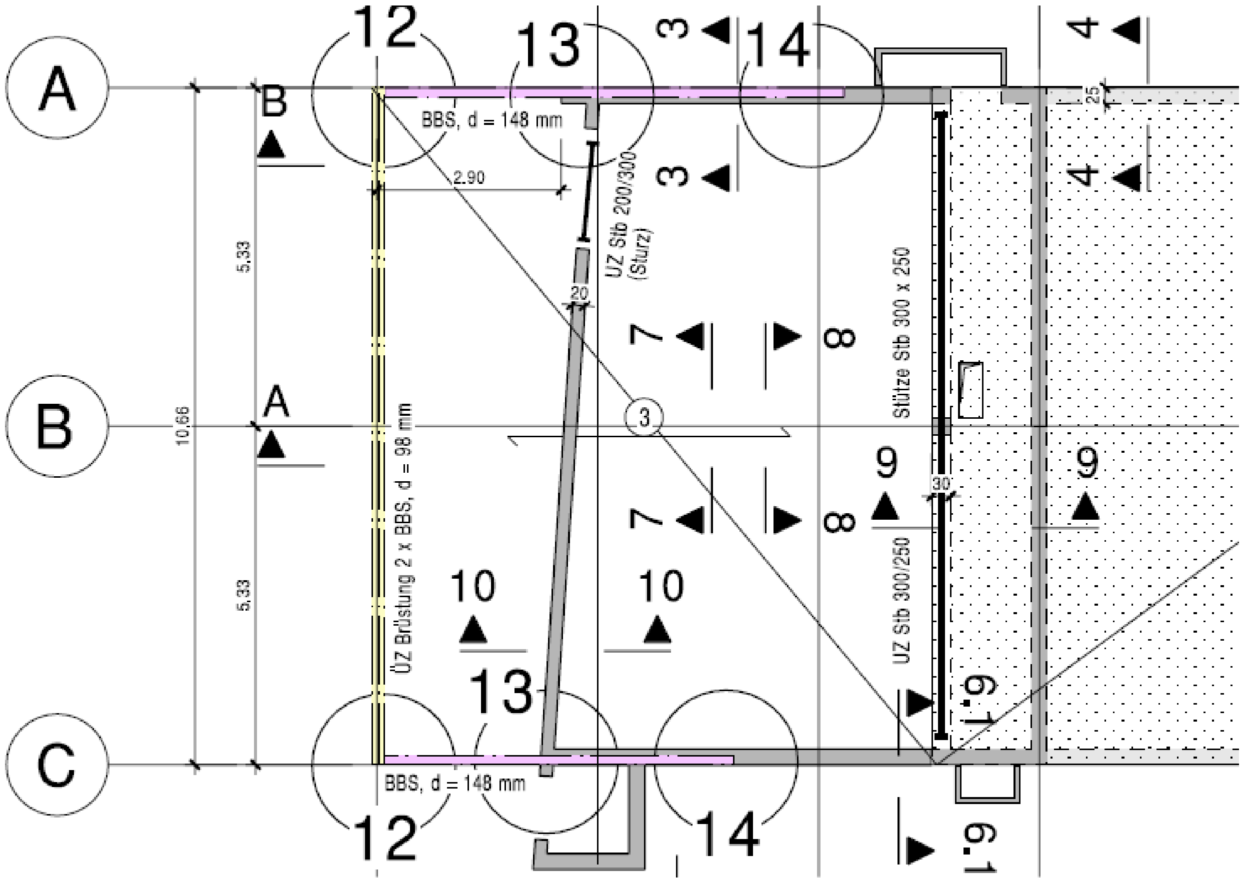

Figure 9 Floor over ground in the cantilever region (Merz, Kaufmann und Partner GmbH)

Figure 9 shows the floor over the basement in the area of the restaurant. The cross laminated timber plate (Pos. 3) is a girder with two fields, elastic supported in the front and rigid supported on the two walls of the basement. The calculation of the ultimate limit state demands a cross laminated timber plate with 5 layers and a total thickness of 126 mm. In respect to the serviceability limit state to reduce deformation and vibration there was decided to use a plat also with 5 layers but a thickness of 166 mm.

A provocation to the designer is the cantilever situation. The end wall on the south side is without supporting in the air. All the loads from the roof, the walls and the floors are concentrated in the sidewalls in the axes A and C. Figure 10 shows the side wall of the ground floor in the axis A. The concentrated load for supporting the cantilever was estimated about 350 kN.
The Detail 13 shows the construction where the vertical load of 350 kN is coming from the wall to the concrete wall of foundation. Also at hte end of the wall, in point 14 there are tension forces to transport to the concrete foundation.
The floors over the ground floor in the area of the restaurant have no supporting in the axis B. These loads are hanging on a cantilever beam in the first floor supported by a column in the restaurant.
The end wall in the south side have also the large window, compare figure 14, and the part below the window is the beam from axis A to B to support the floor Pos.3.

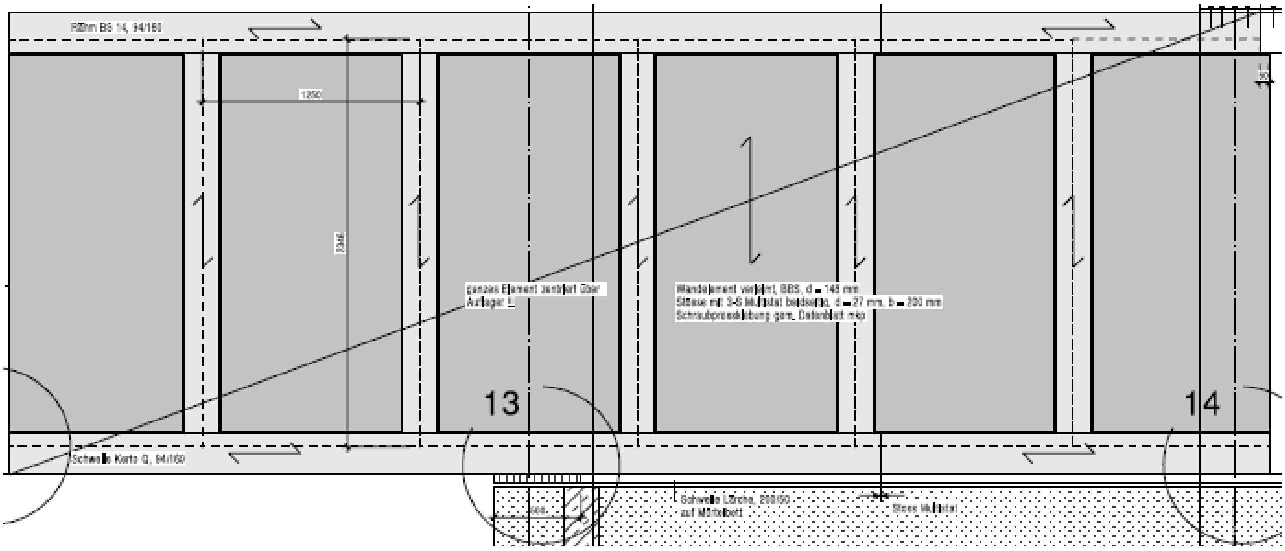

Figure 10: Wall on the south side (Merz, Kaufmann und Partner GmbH) Olpererhütte

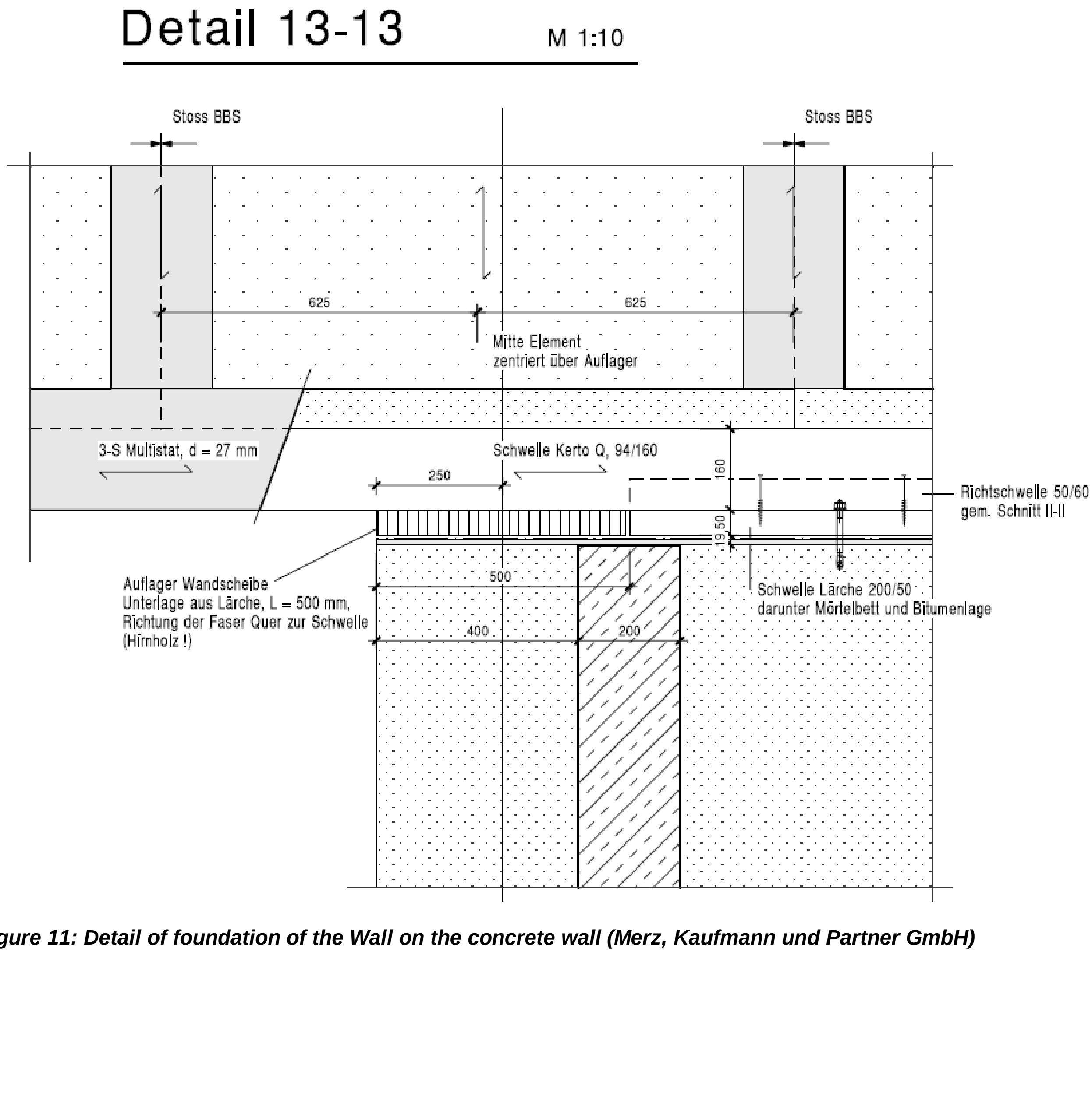

Figure 11: Detail of foundation of the Wall on the concrete wall (Merz, Kaufmann und Partner GmbH)

4 ERECTION

All the material for the cottage, also the concrete for the basement, were transported by helicopter to the building place. The material was transported by truck over a small road to a parking place on the barrier of the Schlegeisspiecher, 1.782 m over sea level (Figure 12). The cottage lies 600 m higher.

Das gesamte Baumaterial, auch der Beton für die Fundamente, die Wände des Kellers und die Fußbodenplatte des Erdgeschosses wurden mit dem Hubschrauber angeliefert. Die Brettsperr-holzelemente für die Kellerdecke, Wände, Decken und Dach sind mit LKW zum Parkplatz am Schlegeisspiecher transportiert worden und dann mit dem Hubschrauber auf die Baustelle. Da auf der Baustelle kein Kran vorhanden war, musste der Hubschrauber die einzelnen Teile direkt an den vorgesehenen Stellen zur Montage absetzen.
Figure 14 shows the coming ot the window side. The elements are rigid enough and robust for the demands of fly and erection.

Figure 12:The elements on the parking place

Figure 13:During erection

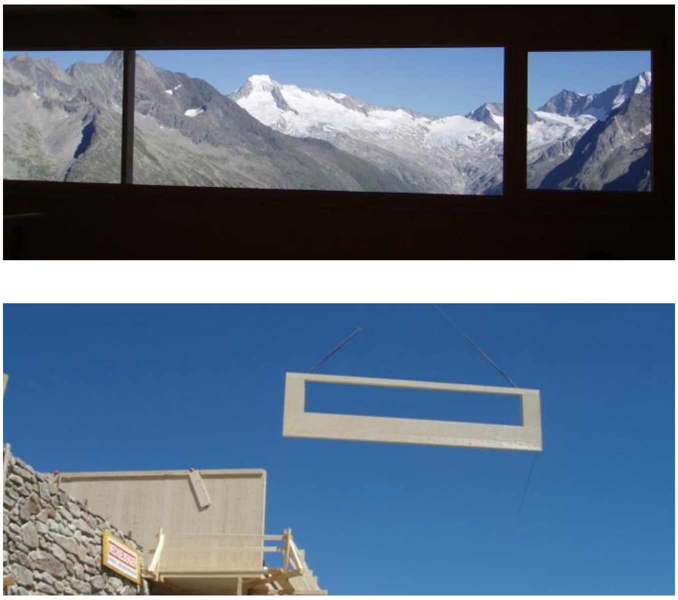

Figure 14: The window coming by helicopter and the view from inside

The use of helicopter is expensive. One flight from the parking place to the building area needs about 4 minutes and one hour cost about 2000 € an the helicopter can transport up to 800 kg. The elements are coming by helicopter to the place where they are needed and must be fixed rapidly so that the helicopter can fly the next round. The cost for transport by helicopter is in this case 18% of the building cost.

'The possibility of erection with helicopter depends extremely from the weather situation: good sight, nearly no wind. The whole structure was erected within one week. The moisture of the timber was about 15 %.

Also the necessary energy for transport with helicopter is high, 200 litre gasoline each hour! This energy must of course bee regarded, when the energy balance of the whole building is done.

The cost are 830 € per m^3 all including (without technical equipment 700 € per m^3).The whole cottage has a wooden surface of 650 m^2 and a volume of rd 2100 m^3 and so the total cost is 1.75 106 € for the cottage.

5 ENERGY AND ENVIROMENT PROTECTION

The DAV with his „Referat für Hütten und Wege" tried since a lot of years to have cottages with good contribution to the environment protection. This includes the service of the cottage and also the waste water treatment. It also includes the sustainability by the used materials for maintenance an in special cases for new buildings.
It is not surprising, the material timber has a good place in this field and so there are in the last years built new cottages in timber structure an with high technical

equipment: Stüdlhütte, Schiestlhaus, Monte Rosa Hütte and Olpererhütte. With different architectural means the aim is the same: to have exemplar cottages in the nature.

As result of the following consideration there was no thermal insulation of the wall and the roof installed. The cottage shall be open three month during summertime in the year. Therefore the investment for a thermal insulation of envelope of the cottage seems not to be reasonable. The wall mode of 16 cm cross laminated timber is so alone good enough for thermal insulation.

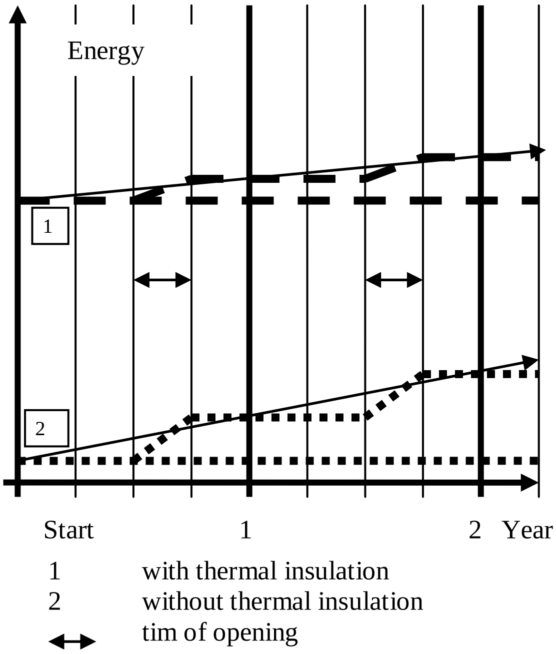

Figure 15: Energyballance with and without termal insulation

The total energy in n years starts with the energy for erection and continues with the necessary energy for service. Two possibilities are regarded:

Cottage with termal insulation:
EG1 energy for erection with termal insulation
eB1 annual energy
En1 Total energy in n years

Cottage without termal insulation:
EG2 energy for erection with termal insulation
eB2 annual energy
En2 Total energy in n years
The differences of this two possibilities are:
$\Delta EG = EG1 - EG2$
$\Delta eB = eB2 - eB1$

The total used energy is in n years the same.

$$EG1 + n \cdot eB1 = EG2 + n \cdot eB2$$

$$n = \frac{EG1 - EG2}{eB2 - eB1} = \frac{\Delta EG}{\Delta eB} \quad (2)$$

The values are estimated [6]:

$\Delta EG = EG1 - EG2 = 90.000$ kWh
$\Delta eB = eB2 - eB1 = 8.000$ kWh/a

In about 11 Years the two versions had dissipated the same total energy. Even 11 years are not so much, the dicision was done to built no termal insulaten.
An additional reason for this decision is the availabele energy for heating by producing electric power with the co-generator.

Cross laminated timber has about 13 kg adhesive per m^3 CLS. (33 m^2 area adhesive / m^3 CLS, 400 g / m^2, 33 mal 400 = 13200 g / m^3 CLS). Not all like this material in their environment. An alternative is cross laminated timber connected with timber dowels or aluminium nails.

6 TECHNICAL EQUIPMENT

For the service of the cottage energy is necessary for: heating, cooking, warm water, waste water treatment. Installed are photovoltaics (two times 560 Wp), bateris (48V, 800 Ah), a co-generator (using rape oil, 11 KVA electric power at a level of 2500 m over sea), a gas stove for the kitchen and a wood stove for the lounge.

Electric power is also necessary for the waste water treatment. The co-generator gives not only electric power but also heating energy. One third is electric, two thirds are heating power. This is a important point for the decision to built no thermal insulation to the envelope.

Rape oil is used because of the CO2 neutrality and more important is that rape oil is not dangerous for the environment.

All the technical equipment: co generator, tank for oil, batteries, electronic equipment to connect electric power with 230 V ac and 48 V dc, boiler and waste water treatment is situated in the basement. The range of energy for one visitor day and night is about one litre rape oil. The cottage is no hotel, the sleeping rooms are not heated.
The cottage has in the summer months more visitors as estimated because of the architecture and the beautiful surrounding. The way from the parking place to the cottage needs about one and a halve hour.

Figure 16:Installing the equipment in the basement

7 INVOLVED PERSONS AND COMPANIES

Owner Sektion Neumarkt DAV (Unterstützung durch die Abteilung Hütten und Wege des DAV)
Architect Hermann Kaufmann, Schwarzach
Computation merz kaufmann partner Gmbh, Dornbir
Timber Structure Sohm Holzbautechnik, Vorarlberg
Cross Laminated Timber Binder, Zillertal

8 CONCLUSIONS

The design of the new Olpererhütte and the construction with cross laminated timber used for static and envelope function gives a consequent unity. The cantilever form of the house could be solved in static and constructive way wit the cross laminated timber elements. The prefabrication allowed the erection with helicopter. The mainly connection during erection was done with screws. The erection without a crane was possible.

To built cottages with timber has a long tradition and the use of cross laminated timber elements is a good contribution to this tradition.

Cottages with difficult architectural design, but one mutuality: timber structures are shown in the following pictures.

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SOME ADDITIONAL PICTURES OF COTTAGES IN THE MOUNTAINS

A lot of cottages in the mountains are made by timber structures. So timber structures are a competitive way. Some pictures of new cottages will show this.

Figure 17: Viopz Hütte, südlicher Ortler

Figure 18: Schiestlhaus, Hochschwab

Figure 19: Monte Rosa Hütte, Matterhorn

Figure 21: Stüdlhütte am Großglockner

Figure 20:Velanhütte

Figure22 :Olpererhütte