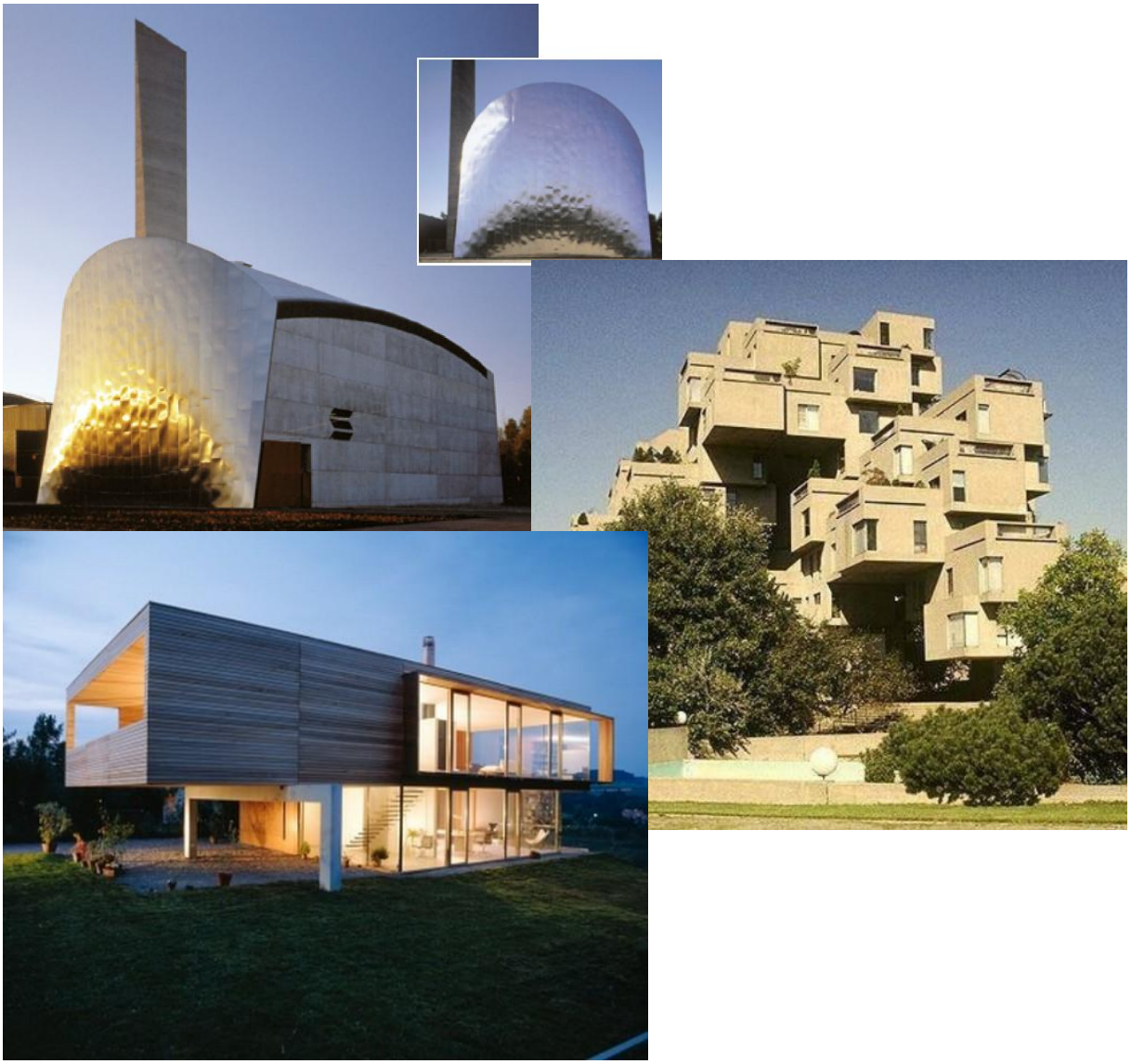
VIA University College, Horsens, Denmark
Bachelor of Architectural Technology and Construction Management
3rd semester Elective subject

October 2011

PREFABRICATED ELEMENTS



Guðmundur Örn Arnarson

Consultant: Leila Kæmsgaard Pagh Schmidt

Prefabricated Elements

28-10-2011

VIA University College, Horsens, Denmark

3rd semester Elective subject

Consultant: Leila Kæmsgaard Pagh Schmidt

1 Copy - Font - Calibri

Number of Pages: 32

32.877 Characters.

Signature:_____

NOTE:

This report was compiled as a compulsory student assignment in the 3rd semester Architectural Technology and Constructing Management degree course - no responsibility is taken for any advice, instruction or conclusion given within!

ACKNOWLEDGEMENT

I would like to thank my teachers Leila Kæmsgaard Pagh Schmidt and Gordon Lindsay Alcock for their assistance in writing this report for 3rd semester elective subject, without them this report would not be as good as it is.

I would also want to thank my father, without him this report would not have been possible. My photos and tables are taken from companies on the internet, I would thank them for that opportunity.

SUMMARY

This report is a documented record of how prefabricated elements are built and what we specifically involve when we talk about prefabricated elements. The report also compare what is the history behind and using prefabricated elements. What is specific advantages and disadvantages when using them. Which kind of components is possible to use, architectural possibilities and the finishes and construction on side behind prefabricated elements.

There is a photographic record of the work behind components and prefabricated elements together with an analysis of the quality of execution with references to the appropriate regulations, legislation and other guidelines.

Key word: Prefabricated elements, Concrete, Timber, Steel, Architecture, Construction, History, Advantage, Disadvantage.

PROBLEM BACKGROUND

This report has been written as a elective subject assignment in the 3rd semester, Constructing Architect degree course.

I am interested to find good information about prefabricated elements. How it is built and produced by factory's and the history behind them. I want to find good information about the constructions and the finishes and compare that with our subjects in this semester which is the main theme. I also want to find nice Architecture buildings made out of prefabrication, but it is not possible to take every building and subject in the world so it will be choosing from many different angels.

The thought behind this report subject is because I want to have good knowledge and information about this building industry part which is just improving in our lives. I want for example to work with prefabrication in the future, both in Architects offices and on building sites as constructing manager, so the main theme is to get some more knowledge about it because this industry is big today.

PROBLEM STATEMENT AND RESEARCH QUESTIONS

What is Specifically involved when we talk about prefabricated element buildings?

1. What is the history and background of using prefabricated element in buildings?
2. What materials and components can be used in the prefabrication of buildings?
3. What are the specific advantage/disadvantage when using prefabricated elements?
4. What examples of prefabricated Architecture are there? Where is it?
5. Prefabricated Construction- How are prefabricated building typically constructed and finished?

COURSE OBJECTIVES

- To get knowledge about what is involved in prefabricated elements.
- To gain experience in prefabrication construction for future work.
- To go into prefabricated Architecture buildings and what is possible to build.
- To develop my report writing skills.

DELIMITATION

Delimitation is always hard to approve but it is not possible to talk about everything. What I will not research and include in my report about prefabricated elements is; production factor, mounting about timber, steel and glass for example. I will talk about the mounting of concrete because I find it interesting and is so heavy material. I will not go to every continent in the world but I will talk about it in the history most. I will talk to constructing managers but not many of them and also try to find some companies on the internet which could take part in my report.

CHOICE OF THEORETICAL BASIS/RESEARCH METHOD/WORKING METHOD

I will use quantitative methods – collecting facts and information mainly through the internet from sites like Palsgaard, BETONELEMENT, Træelement and WIKIPEDIA and from books which I will take from the library in VIA University College. I will also interview some people to find out alternative solutions for prefabricated elements. I will talk with my father which is constructing manager in Iceland.

Table of contents

HISTORY AND BACKGROUND

The use of prefabricated elements have to start somewhere. It is told that prefabrication has been used all the way from ancient times. It is told that around 3800 B.C. there was built the oldest known engineered roadway called Sweet Track constructed in England. It was made out of prefabricated timber sections. I would say because they started to make it out of timber not concrete more architectural. It is held that it was brought to site rather than built there.

Sinhalese kings[1] have used prefabricated buildings technology to erect giant structures, it goes all the way back for 2000 years. It is said that there were some sections prepared separately and then put together in the Kingdom of Anuradhapura[2]. Prefabrication buildings where used a lot in the 20th century in United Kingdom to replace houses which have been destroyed during the World War II. Putting the elements together in factories reduced cost and saved time. But it was found out that the quality was sometimes not as good but that was in old days time and it is different nowadays, I will come to it later in this report. That the house was used for longer time than it was designed made s certain stigma on that time.

Houses have been built on one place and moved to another one throughout history we can say. Possibly the first announced prefabricated house is the Manning Portable Cottage. It is told that the carpenter H. Manning, constructed a house that was built out of components, and then shipped and delivered by British emigrants. This was published in South Australians Records 1837.

We can build small houses and big houses and blocks. The first prefabricated, precast paneled apartment block was made in Liverpool 1906. Those blocks were also very important in making homes for families after the World War II, because it had two bedrooms, separate toilet, living room, bathroom and kitchen. The materials which was used then is told to be timber, steel, aluminum.

The United States used prefabricated housing for troops during the war and for GIs returned homes. Prefab classrooms were popular with UK schools increasing their rolls during the baby boom[3] of the 1950s and 1960s. Many buildings were designed with a five to ten year life span, but have far exceeded this, with a number surviving today.

[1] (The Sinhalese are an Indo-Aryan ethnic group, forming the majority of Sri Lanka, constituting 74% of the Sri Lankan population)

[2] (Anuradhapura, is one of the ancient capitals of Sri Lanka, famous for its well-preserved ruins of ancient Lankan civilization.)

[3] A baby boom is any period marked by a greatly increased birth rate.

Materials and components

ABOUT THE MATERIALS

Prefabricated building materials are used for buildings that are manufactured off site and shipped later to assemble at the final location. Some of the commonly used prefabricated building materials are aluminum, steel, wood, fiberglass and concrete. Like in 3rd semester of Constructing Architect we have to learn about concrete elements and timber elements. Like it is in Iceland, we have started to build with concrete element components a lot more. All the schools which are new in Iceland now a days are built in concrete elements. I worked in two of them the summer of 2010 and my father is a constructing manager over one of them.
Here are examples of those schools:

Figure 1 -Schools in Iceland.

Figure 2

Prefabricated building materials used for small prefabricated buildings are steel, wood, fiberglass, plastic or aluminum materials. These materials are cheaper than regular brick and concrete buildings.

When we use prefabricated metal buildings it is most of the time used galvalume and galvanized steel as the main materials for the buildings. The steel of galvalume is coated with aluminum-zinc to protect the material and the building from fire, corrosion and rust. Metal buildings have almost all the time all their components made out of steel, like frames, columns, walls, roofs and beams. All those materials are very flexible and provide flexibility and are recommended to be used in accessories and structures like for seats in gyms or big stadium.

TIMBER/WOOD

The prefabricated wood components industry includes many products, including premade panels and sections for chicken coops, farm buildings, geodesic domes, marinas, sauna rooms, hotel rooms, and decks. The industry is fragmented and entrepreneurial and is represented by a wide range of companies. By far the largest segments of this industry are modular single-family homes, multifamily units, and institutional buildings including hotels and motels, schools, hospitals, and prisons.

TIMBER ELEMENTS IN ICELAND

Timber elements are very common in Iceland in summerhouses. I worked one summer building summerhouses and we build all our elements in Reykjavík in Iceland and we put the summerhouse together there also. It was not very big houses around 60m2. We put all the

windows and doors into them after we finished them and transfer them with big trucks and crane car followed by the police, it was also in the night because it is not good to have much traffic.

COMPANIES AND PRODUCT

Like here in Denmark we have companies like Palsgaard and Taasinge Wood which manufacture rafters, elements, HQL, dormers and positional joists. They have all kind of rafters from Canopy Types, Scissors Block to Custom Rafters. The main part of it is their manufacture is those timber elements. It´s possible to order Roof Elements, Facade Elements, Floor slabs and Apartment boundary. Those elements are very flexible system and all of them lives up today´s requirements of work quality and good economy. You can order them almost in every span you want and design features.

ROOFS

The roofs you can have is flat roofs and duo pitch roofs for example. From unventilated roofs with moisture draining vapor barrier of Hygrodiode to impermeable roofing. And also Ventilated roof panels with solid underlay of roofing felt on plywood and diffusion or close roofing. Can use the flat roofs on production and storage halls, shops, institutions and schools. They can be from 1.4 ° - 30 ° slope, but the min. is 1:40 and the span can go to 13.6 meters. Fire resistance is possible from REI 30 or REI 60 and it has 3 moisture classes. It is also possible to get it from the u-value 0.25-0.12 and then the thickness of the insulation is from 145-335mm.

Duo pitch roof in timber elements can be used for residential, offices, institutions, schools, and more. You can have it in pitch from 1.4°-45° with tighten eaves, fascia or eaves, ridge. With the roof covering you can put roof tiles on battens or distance strips. Then is usually ceiling made by 22 or 45 mm shuttering of retrofitting with plasterboard. 45 mm battens can advantageously isolated. And 2 layers plasterboard can first layers possible. It is installed from the factory. And it is alternative example with wood wool. When we talk about the span the wingspan can be from 3.6 to 7.8 meters and the deflection is maximum 1/400 . The fire resistance is than from REI 30 and REI 60 and the ceiling have Class 1. The U-value can be from 0.25 to 0.12 depending on the insulation like described in the flat roofs.

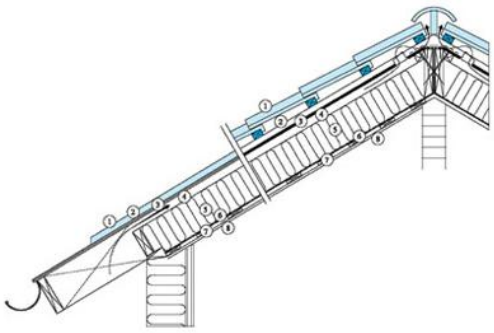


Figure 2 - Duo pitch roof from Palsgaard.

Figure 4 - Flat roof from Palsgaard.

FACADES

Facade elements made out of timber is a product which can be made in factories and then shipped to the location of the buildings and put up there really easy. Paalsgaard and Tassine wood are companies which concentrate on those parts.

Like in Paalsgaard they make many different facades but I am going to talk about few of them. We have different types of elements called F-1, F-2, F-3 and F-4.

F1 is made with Rain Screen and ventilation like F-2 and F-3. F-2 have 9mm wind boards and impr. gipsum plates and timber ribs with mineral wool and DPM on the inside and 45mm battens with 2 layers of gypsum boards. Those walls can be load bearing and non load bearing walls. They are possible from REI 30 to REI60 and the sound and the U value is depending on the thickness of the insulation. It can be from BD 40 to BD 60 and U-values from 0,40-0,12.

The application buildings for those elements are production warehouses, gymnasiums, institutions, schools, offices and more. http://www.palsgaardgruppen.dk/typeoversigt/

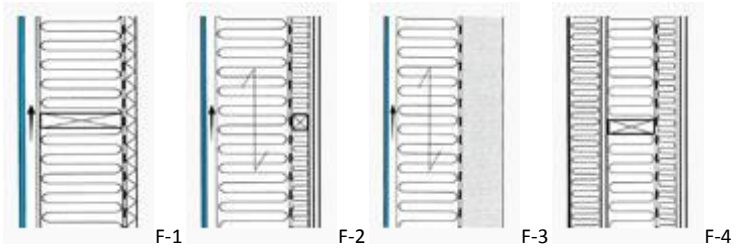


Figure 5 - Different Timber facades.

CONCRETE

Prefabricated elements are also made out of concrete and manufactured like the timber elements, but just totally with other materials and another way. Concrete is much stronger material than the timber and more expensive. Today companies build many different components and elements. We can for example have foundations, facades, walls, construction floors, columns, beams, roofs, balcony elements, stairs, parking garages and bridges. I will show some examples of stairs, construction floors, facades and roofs for concrete elements and components.

External cladding element can be anything from metal through wood, glass to natural stone, brick or ceramic tiles. Flexibility in the number and size or shape of windows and doors, coupled with several cladding alternatives gives almost unlimited options for a façade appealing appearance.

STAIRS

There are many types of stairs like straight stairs, swing stairs, vang stairs , spiral staircases and custom stairs.

Straight stairs | Swing stairs | Vang stairs | Spiral stairs

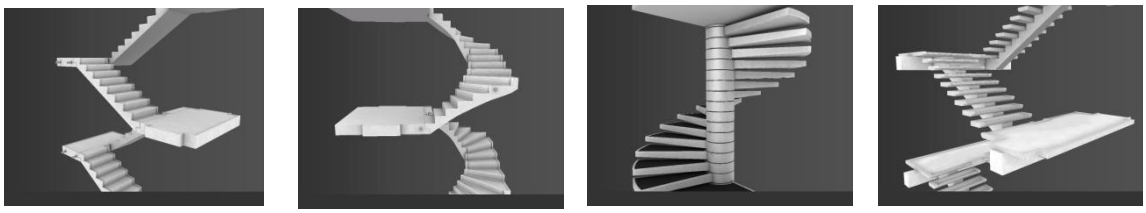


Figure 6 - Types of stairs.

Stairs can be transformed on construction side as hole components and constructed there and finished to the building. I will talk about that later on as well as reinforcement in writing about constructions and finishes.

CONSTRUCTION FLOORS

When we talk about construction floors we have for example cavity plates/hollow core elements and TT plates. Cavity is produces in standard thicknesses of PE 180, ED 215, JE 265, 320 and QE ZE 400 mm. The standard width of them are 1197 mm and the length can be up to 20 meters. Material inside the pre-stressed concrete cavity is carried out in passive environmental class. Armament consist also of pre-stressed reinforcement wires, they are put in the underside of the elements. The cantilevered deck elements can be performed with pre-stressed reinforcement wires in the upper side.

http://www.betonelement.dk/betonelementer/4-d%C3%A6k/4-1-huld%C3%A6k-generelt/4-1-1-huld%C3%A6k-elementgeometri/4-1-1_daek_figur1a_betonelement/

EXAMPLE:

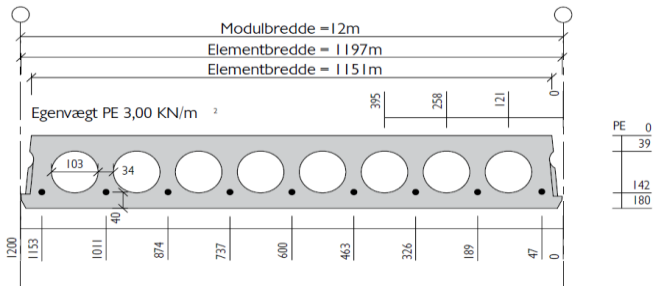


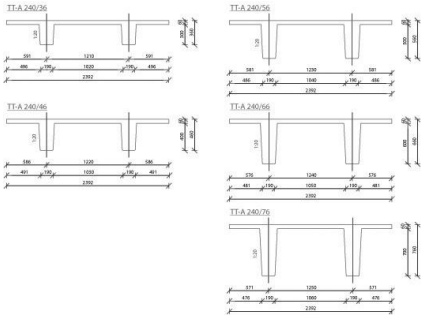
Figure 7- Construction floor.

TT PLATES/ROOFING

Roofing sheets can be used for roof. Roofing is produced in sizes 600, 720, 900 and 1020 mm and 1800 mm rib spacing. Roofing done in concrete 45 and the passive or moderate environmental class. The armament consists of pre-stressed reinforcement wires with dimensions 12.5 mm.

The design of the materials are ribbed slabs with two ribs and 40 or 60 mm thickness of a top plate in TT plates. They are made in 3 types and all of them are pre-stressed concrete. We have type A, B and C.

Type A is supplied in different heights and we have for example 360, 460, 560, 660, 760 and the width distance is greater than 1200 mm between the two ribs on the plates. Standard width for them are 2400. You can order them by doing agreement with companies and get them in 600 to 3000 mm in widths.



Type B is than supplied in heights of 300, 400, 500, 600 mm center distance between fins which are 1194 mm. Standard width for type B is the same as in type A and you can order it in same different widths.

Type C is than supplied in height of 420 only and the center distance between the two bars of it is 600mm and the standard width is only 1200mm.

http://www.betonelement.dk/wp-content/uploads/Rippeplader_TypeA_Betonelement-NY1.jpg

Figure 8 -TT plates.

FACADES

"Facade is the building face". That is totally true. Because when you are seeing buildings the first thing you see is their facades and how they look like and that gives your impression off the company or people how live there. We have many opportunities to choose from when we want to find style for the building.

Facades are used in residential buildings, offices and industrial. You can have them as non load-bearing and load-bearing structure. It is possible to get them performed as plate elements or rib elements. Dimensions are typically 420 or 480 in thickness and then you have the front plate 80mm.

GLASS/STEEL

There are many possibilities of making elements out of steel and also components which are made out of steel frame with glass all around it. There is very popular today for instance to build up houses only with glass walls and many people find it very architectural and fashioner. You can build for example walls just with windows but you always have to have steel beams or steel frames around it. You can have sky lights which are made only with the frame and windows and I will show some architectural examples later on in this report.

I have worked for company which put steel frame windows as skylight in Iceland and that is on a building in Reykjavík which is University of Reykjavík. You always have to think about the construction and finishes so it can work and that the heat loss will not be much inside the rooms you are using those elements and components. It will also be shown and talked about that later on in this report as well what is related to concrete and timber elements.

Glass gives the architects to be as free as possible to their design as they can and with respect. We have many different glasses which can be Anti-reflective, Color, fire rated, mirrored glass, restoration and solar glasses. I want to show one example of color glass, it is a body tinted colored, machine drawn flat glass with a textured surface on one side. It is called Artista glass and is manufactures from SCHOTT company which is about glass made of ideas.
http://www.schott.com/architecture/english/function/facade.html

Building made with Artista glass:

Figure 9 - Artista glass.

COMPONENTS

GLASS COMPONENTS

There are many components available. We can have glass as component. Glass is very strong material but it can be very fragile. Glass brakes very quickly under very sharp loading on it and also big shocks. It is a positive environmental filter and structural filter. It is told to be self cleaning material but it have to be regularly maintained and it can provide color, surface translucency and can transform from day to night. It can be produced as glass facades, skylights, stairs and sometimes houses with the right material properties of glass. It is possible to have safety glass which is toughened glass, heat strengthened glass, laminated glass, drawn glass, studio glass, contemporary cylinder glass, polished plates or fire rated glass.

Material properties of glass

Property	Value
Density	2793 kg/m^3
Young's modulus	70.3 KN/mm^2
Thermal conductivity	1-1.5 W/mK
Co-effecient of thermal expansion	8.5 X 10^{-6}-9.5 X10^{-6} per K
Corrosion resistance	Excellent
Melting Point	1500°C
Recyclability	Excellent
Primary embodied energy	41 GJ/m^3

Here you can see table with explanation about the glass and how it function, this is shown because glass is much more sensitive than other components so it's necessary to know its properties.

STEEL COMPONENTS

Steel is very strong material. The main components of this material is irons ore, coal, and alloys. It is said that flux can be added to the facilitate purity and many time scrap is melted down and added. Stainless steel is very popular in the building industry because it is very strong and it is very hard for it to get damage.

Steel frames are very popular for internal construction and also for external construction. It is usually in the external construction we talk about vertical steel columns and horizontal I-beams, also known as H-beams and W-beams. Those are most of the time constructed in a rectangular grid which can support roofs, walls and floors of buildings which are connected to the main frame. A column or pillar is a vertical structural element that transmit through compression the weight of the construction to the construction which is underneath itself and is often used as strengthen support. Because of wind and earthquake, columns are always designed so the resist the lateral forces. Columns are frequently used to support beams or arches on which the upper parts of walls or ceilings rest on. In architecture column refers to such a structural element that also has certain proportional and decorative features. A column might also be a decorative element not needed for structural purposes, many columns are engaged with form part of a wall.

As the axial load on a perfectly straight slender column with elastic material properties is increased in magnitude, this ideal column passes through three states stable equilibrium, neutral equilibrium and also instability. When a column is too long to be built or transported in one piece, it has to be extended or spliced at the construction site. A steel column is extended by welding or bolting splice plates on the flanges and webs or walls of the columns to provide a few inches or feet of load transfer from the upper to the lower column section. A steel column, when seated on a concrete foundation, must have a base plate to spread the load over a larger area so it reduce the bearing pressure. The base plate is a thick rectangular steel plate usually welded to the bottom end of the column.
http://en.wikipedia.org/wiki/Columns
http://www.columbia.edu/cu/gsapp/BT/BSI/HISTORY/history.html

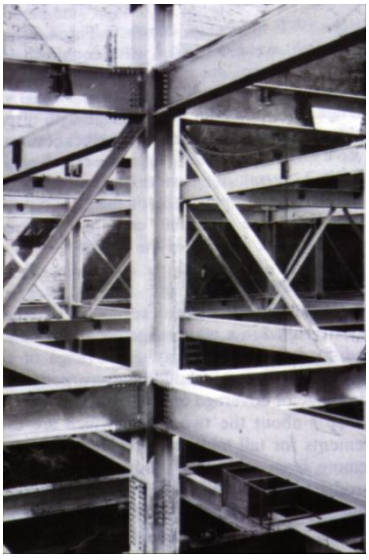


Figure 10 - Skeleton Frame - W14 Steel Column In substructure.

CONCRETE COMPONENTS

Columns, beams and stairs are all very popular concrete components now a days. You can order them well constructed and ready to be placed from factories. Concrete include many different components like; Cement, water which are cement grout and sand, stone Which are aggregate to put in it and you get good concrete with right mixing. When you are making concrete you need to have it reinforced concrete which is the most common type of concrete nowadays or pre-stressed concrete which can span longer, because of bigger capacity of bearing structures. We can have two types of pre-stressed concrete: Pre-tensioned and post tensioned concrete.

Pre-tensioned concrete can increase the tensile strength and stiffness and also counteract the risk of cracking. Pre-tensioned concrete is casted around already tensioned tendons. This method produces a good bond between the tendon and the concrete, which both protects the tendon from corrosion and allow direct transfer of tension.

Post-tensioned concrete is a method where the tendons are tensioned after the concrete is hardened on side. The concrete is casted around a plastic, steel or aluminum curved duct, to follow the area where otherwise tension would occur in the concrete element. Tendons are fished through the duct and the concrete is poured. Once the concrete has hardened, the tendons are tensioned by hydraulic jacks. The tendons can be bonded or unbounded. When the concrete is hardened the tendons will be cut off at the ends of the concrete unit. When we talk about Horizontal post tensioned concrete it enables thinner floors and bigger spans, it is often used for example in bridge construction. Vertical post-tensioned concrete used for example at stair-cores, increases the cores ability to stabilize, and you don´t need so many stabilizing walls, which gives more flexibility. This method is used in around 150 buildings in Denmark.

Concrete components can be used in different systems in the building. For example shear systems, column and beam systems and combination systems. Shear systems are very simple system which can give the owner of the building many different possibilities of arranging the storey's and it is possible to have facade and gable as double wall units. Column and beam system gives the construction wide possibility for wide floor areas and only interrupted by columns in the load bearing lines. They can be very flexible in arrangement of the storey´s.

Combination system is when it is possible to combine the shear system to column and beam system and get the advantage from both of them. There it is possible to get the shear system for facades and gables but using the columns and beams inside the building area, this is often used in parking buildings.

On construction side reinforced concrete column is extended by having the steel reinforcing bars protrude a few inches or feet above the top of the concrete, then placing the next level of reinforcing bars to overlap, and pouring the concrete of the next level. Reinforced concrete and masonry columns are generally built directly on top of concrete foundations.

TIMBER COMPONENTS

Stairs, windows and doors are possible components made out of wood in building industry. You can have all kind of buildings with different finishes made out of concrete, bricks or steel, but you can always have the windows, doors and stairs made out of wood. The sealants around the components always have to be finished so they don´t leak or make the connection between wood and concrete possible.

You can have stairs which are tailored to suit your particular requirements, you can have all kind of finishes of the wood and construction. Timber windows components have many different finishes and it is available to get them in every type you want and it is finished by your own requirements. We can have door components also in many ways like windows. It is possible to get them in folding door system and also regular door system. Columns and beam components made out of timber are usually extended by the use of a steel tube or wrapped around metal plate bolted between connection storey's.

Components are always made in factories or in small working places. I worked for example one summer building up summerhouses. We did all the walls and the element inside in our working space and built up the floor first outside with floor heating. Than we transferred those elements just outside where we were doing our summerhouse. We put up all the walls and bolted them together and adjusted them so they would function right. After we put them up we built up the roof and put all the layers together. When we were done making the roof and the walls we put the components. Those doors and windows can be made in all kind of ways, you can have them like circle, triangle and square. You can put the glass and make the component 100% ready inside before you place them in the house. We also made small stairs which were transferred into their places later on. You can put them inside the house by crane if they are very big but you can always make them in smaller parts and transfer them like that and put them together inside the house later on.

ADVANTAGES AND DISADVANTAGES OF PREFABRICATION

ADVANTAGES

In construction of prefabricated elements we can have many advantages. We lower the congestion and the construction which is made on side. If we have bad weather like storm or winter which is pretty bad we can minimize the construction time which we lose by doing the elements inside factories. The quality of the elements is controlled much better in factories than on building site, easier to control in a factory assembly line setting than on a construction site. Than we have more experience skilled employees more readily available inside factories and costs of power, materials, space and more is highly reduced. The best advantage at my point of view is the construction time is highly reduced and we can complete the buildings much faster and allowing the capital investors to much quicker return. They may take from one week to three months to build, depending on the amount of customizations.

When we also talk about the timber element advantages we have many same advantages as concrete and also others.

The advantage of prefabricated wood building products is that they save builders money. Because large pieces of the structure come from a factory and are designed for quick and easy assembly on-site, builders reduce on-site costs, such as labor, worker compensation, and insurance. Assembly-line production also allows prefab manufacturers greater quality control. The largest segment of the prefab wood products industry is single-family homes. Homes built using prefab units are called component, or prefabricated housing. Typical prefab housing products include roof trusses, wall frames, and floors. Many builders also use premade wall units complete with plumbing, insulation, systems, ventilation wiring, and doors.

We can have dry construction, good flexibility and personalization. It is possible to do a low energy buildings and having the U-value from 0,25 to 0,08 and also good possibility of doing sustainable construction.

Builders of both detached and attached homes with prefabricating products use a systems approach to building, which is a hybrid of site-built and manufactured housing. The four types of systems-built housing include precut homes, for which all lumber and materials come to

the site already cut and panelized homes, for which the main wall panels are shipped to the site, often with plumbing and wiring already installed in sectional or modular homes, which are 80 to 90 percent complete when they leave the factory and have cabinets and flooring already installed like log homes, which are factory made kit homes.

DISADVANTAGES

There is always some disadvantages which follow things like advantages. Like Prefabricated elements we have to be very careful about the joints for example and that the strength of them are so good that they avoid failure of joining. There has to be very carefully shipping and handling of the components both concrete, glass and steel panels.

Transportation can be very expensive and everything have to be done on site before the element can come so they don't have to wait to be placed on their places. They also need very big and expansive cranes to put them on site and all measurements have to be very precision and also the handling. Large group of local jobs on site is lost and many buildings have the same type of prefabrication which make the environment boring and also tend to look drab and monotonous.

EXAMPLES OF PREFABRICATED ARCHITECTURE

Examples of prefabricated architecture is very big and wide subject, you can find all kind of buildings, from timber, concrete, steel to glass and more. I will tell you about some houses in Iceland and show some pictures of it and the construction. An also from some other countries in the world.

HARPA,REYKJAVIK,ICELAND/ (STEEL/GLASS FRAMES)

First I am going to talk about Harpa concert hall in Reykjavík Iceland. Harpa is used for the Icelandic symphony Orchestra and Icelandic Opera. The facades are build from steel frame elements which was ordered from China. They started to leak at first when they came so they had to take them down again because the sealing wasn´t enough.

Figure 11 - Harpa concert hall.

It was expensive construction and the windows are put inside the frame to deploys light, color, and natural phenomena to test how physical movement, sensual engagement, and the interaction of body and brain influence our perception of our surroundings. Ólafur Elíasson an Icelandic architect born in Copenhagen is the main architect behind those facades. The main designers of the Harpa Reykjavík Concert Hall and Conference Centre are Danish architectural firm

Henning Larsen Architects and Icelandic architectural firm Batteríið Architects. Henning Larsen Architects has gained a reputation for superb design, including the new Opera House in Copenhagen.

ZOLLHOF, DUSSELDORF, GERMANY (STEEL FACADES)

This building is all made out of steel facades and is located in Dusseldorf in Germany. Those are apartments and it is located near harbor pool and river. This is one of three buildings with the same shape but the others are made out of brick facades and buff rendered facades. As we can see the deliberate use of stainless steel is here planned down to the smallest details. I will show how it is constructed and finished in the last chapter about construction and finishes. We can see on the windows form a linking element between all three sections of complex. They are integrated into a box like construction that can accommodate itself to various situations.

Figure 12 - Zollhof.

HERRINGBONE HOUSES IN LONDON BY ALISON BROOKS ARCHITECTS. (TIMBER FACADES)

This design get their name from their herringbone pattern timber cladding. This are typical Prefabricated element houses. They are made exactly the same and the construction is just duplicated from one to another building.

They are 400 cm2 houses and have recently been completed in Wands-worth, London. Each open-plan house is composed of two surfaces of herringbone timber and graphite render that extend from exterior to interior to form walls, floors, external decking and fences. These planes interlock and fold inward at the centre of the house to create a double height entrance hall open to the sky. The ground floor living spaces open directly onto series of terraces and decks.

Figure 13 - Herringbone Houses.

Elements of the timber cladding were prefabricated so that the installation cost was equivalent to standard weatherboarding. Elements of the timber cladding were prefabricated so that the installation cost was equivalent to standard weatherboarding.

BUNKER HOUSE, MADE OUT OF PREFABRICATED CONCRETE BLOCKS(CONCRETE ELEMENT)

This house which looks like some kind of bunker is a private residence designed by Thomas Bendel. It's made of prefabricated concrete blocks besides its front and back which are done in glass and black anodized aluminum. Behind house entrance is a ten meters long staircase with a steel handrail. The living area is a large space which hides kitchen behind high gloss maple walls with black oak joints. Other walls are made of raw concrete which are in contrast with pure black floors. Through the windows around the house a lot of landscape views are captured. Even the bathroom has such views but couldn't be viewed from the outside.

Figure 14 - Bunker house.

HABITAT 67: MONTREAL'S PREFAB PIXEL CITY (CONCRETE ELEMENT)

Canadian architect Moshe Safdie designed and built this extraordinary experimental housing complex made up of modular concrete units for the 1967 World Expo in Montreal. It´s named Habitat 67, the apartment complex was Safdie's attempt to redesign urban living, provide affordable housing and create a community complete with shops and a school. All of the units were prefabricated on-site, and each has its own rooftop garden space located on the roof of the neighbor below.

In order to make the complex affordable, Safdie devised a plan for on-site mass production of the concrete blocks. Safdie felt that prefab construction was much more efficient, so he created a factory on the peninsula to construct the housing units. There were four large molds to form the basic shape of each standardized unit. A reinforcing wire cage was dropped into the mold and concrete was then poured around it. After the unit cured it was removed from the mold and moved to the assembly line where a wooden sub-floor was installed with electrical and mechanical services below it. Windows and insulation came next, and then prefabricated bathrooms and kitchen modules were installed. Finally the unit was lifted by crane into position on the building site.

Figure 15 - Habitat 67.

CONSTRUCTION AND FINISHES

STAINLESS STEEL FACADE ELEMENT

I talked about the Zollhof a building in Dusseldorf in Germany and I would like to talk a little bit a about how its constructed and finished.

It is a steel construction in the facade and it is constructed from outside to inside as following:

1. 0.4 MM STAINLESS STEEL SHEET PANEL CLADDING WITH STAINLESS STEEL FIXING TACKS.
2. 0.88 MM GALVALUME SHEETING
3. 100/25/0.88 MM STAINLESS STEEL
4. 250/3 MM ALUMINUM STRAP ON SEPARATING STRIP
5. 63/45/1.5 MM GALVALUME ANGLE BEARER
6. 120 MM THERMAL INSULATION
7. WALL BRACKET WITH DISTANCE PIECE
8. 180 MM PRECAST CONCRETE UNIT.

Steel facade elements are not as common as concrete and timber facade elements.

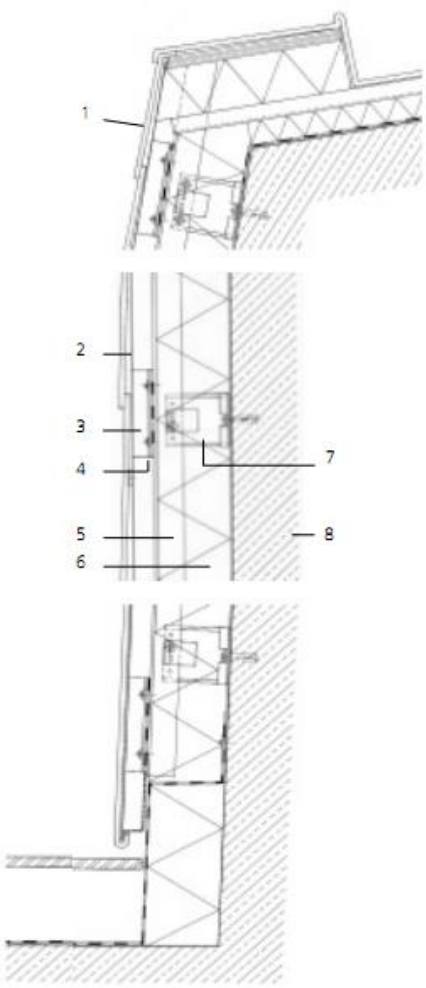


Figure 16 - Zollhof construction.

CONCRETE ELEMENTS

Concrete element walls can be separate in two types, one is load-bearing typical walls and also the double wall panels or in another name sandwich wall.

The double wall process has been in use in Europe for many years. The walls consist of 2 layers of concrete separated by insulation. The double-wall panels can be easily designed to handle both the structural requirements for strength, as well as the design requirements. The double-wall system reduces the construction time on-site considerable.

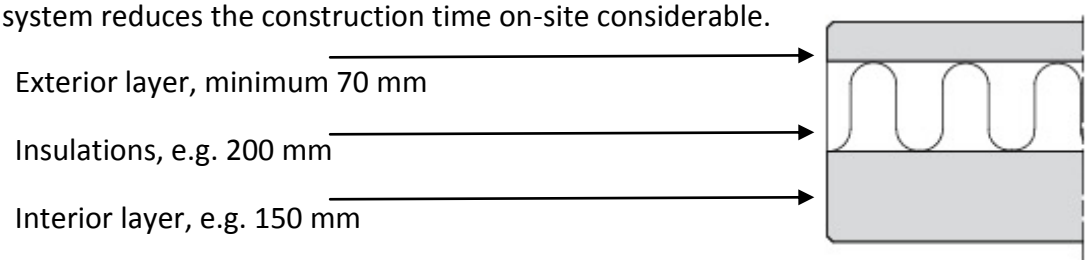


Figure 17 - Double wall panel.

The thickness is defined by the calculations for load-bearing walls, you can find the minimum thickness by dividing the height of the wall with 45.

The interior and exterior concrete layers in a sandwich panel are connected with special anchors or brackets made for sandwich panels as you can see here:

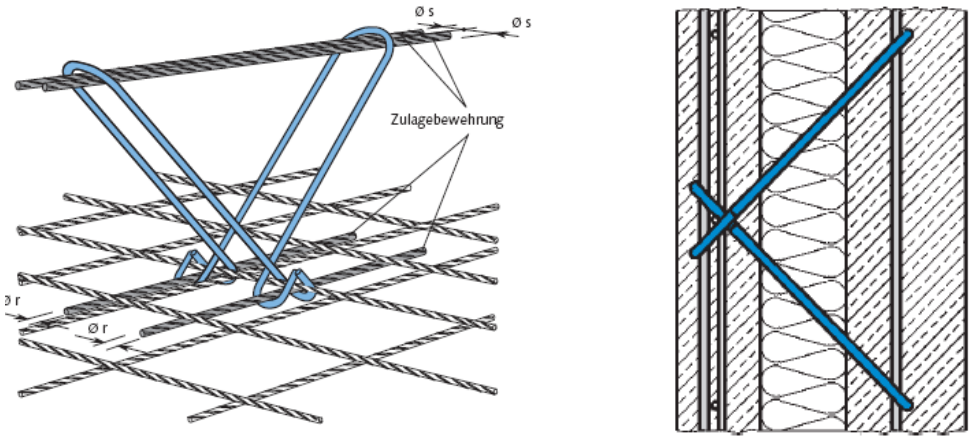


Figure 18 - Anchors/brackets.

You can choose between many different surfaces of the exterior concrete layer. You can have them pure concrete and also what is called visual concrete. You can have it colored, exposed, structured and also a graphic concrete.

Here are some examples for color, exposed and structured finishes:

Figure 19 - Wall finishes.

And there is also possible to have it in graphic concrete which is more modern:

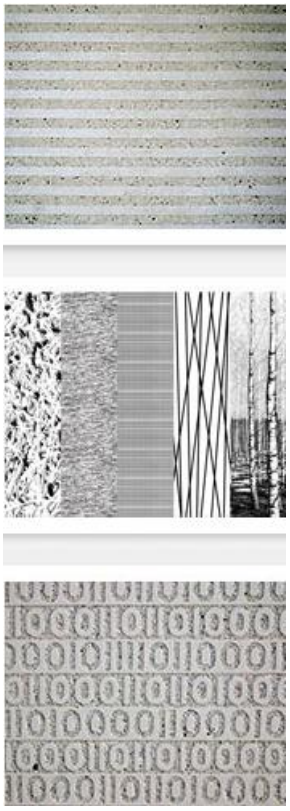
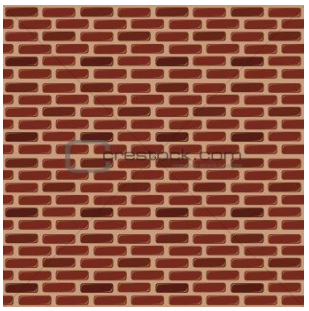


Figure 20 - Graphic concrete finishes.

It is also possible to make the exterior layer look like bricks:



When you are starting to do the construction and place elements on site, first of all you need a mounting plan and mounting instructions, given by the component factory. It is also very important to do all the finishes right and here I will talk about how to handle them.

MOUNTING THE PANELS

When the element is raised, by help from the crane, the crane driver lets the element stand on chocks on the foundation, but still controlling the element with the crane. The element will be supported by rakers before the crane leave it. After that its ready for supporting with mortar under the element. Joints between wall and horizontal elements can be reinforced with metal bars. The reinforcement secure the connection in the finished construction system.

Unloading sandwich panels:

For unloading and mounting the sandwich panels a crane is required. It's possible to choose between different types of cranes, for example tower crane and mobile crane.

The use of rakers when mounting:

Normally 2 rakers for 1 element. It´s not allowed to remove the rakers before the whole building or section is stable itself. Also the supporting mortar must be hardened.

Supporting wall panels and Joints between walls:

The joints under the wall element shall be filled up with a rather dry cement mortar. Joints between wall panels shall be filled up with a liquid mortar.

Horizontal joints:

Joints between horizontal structural floor units shall be reinforced and filled up with liquid concrete.

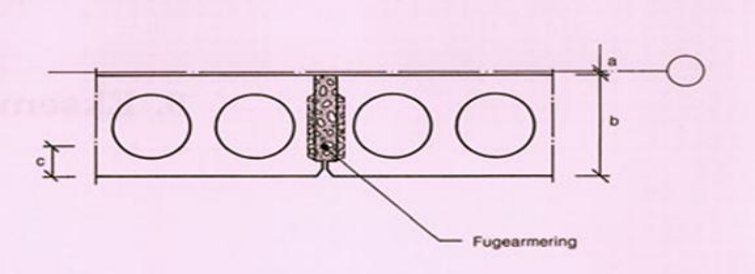
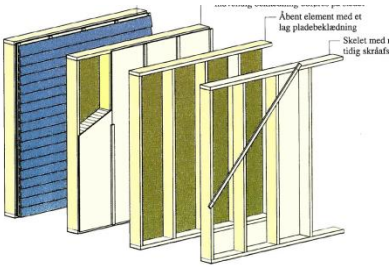


Figure 21 - Horizontal joint.

Protection against the weather

In cold periods the fresh concrete shall be protected against frost. That could be done with a isolation mat combined with electric heating leads.

WOODEN ELEMENTS



Wooden wall elements can be constructed very easily. You start on doing the frame which consists of studs and the size of the depends on how big the construction is and what the function behind it will be. You can put the inner layer on first and then the insulation between the internal layer and external layer and finish by closing it with the external layer.

Wooden wall elements can be combined with heavy internal or external layer with right finishes. It is possible to combine them with some steel brackets or layers some prevent the wood and the concrete connection.

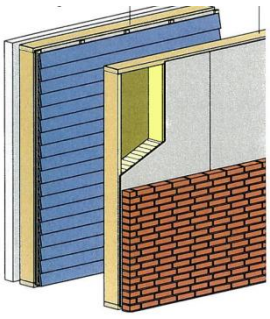


Figure 22 - Wooden Elements.

Those external walls made out of wood are most of the time having frame with insulation between the studs. Inside it consist of dpm layer which prevent moisture and a covering consisting of boards.

You can have all kind of internal cladding fixed from factories and some examples are: Plywood, Plasterboards, Fiber gypsum boards, hardboards, Chipboards, Wood wool cement boards and furring for later fixing boards after erecting the facade elements. When we are choosing those layers we have to think about what is the function of those rooms we are covering them with. It can be for example for fire resistance, moisture, stability function and maybe sound insulated.

Here you can see example of wooden element and its construction from outside to inside:

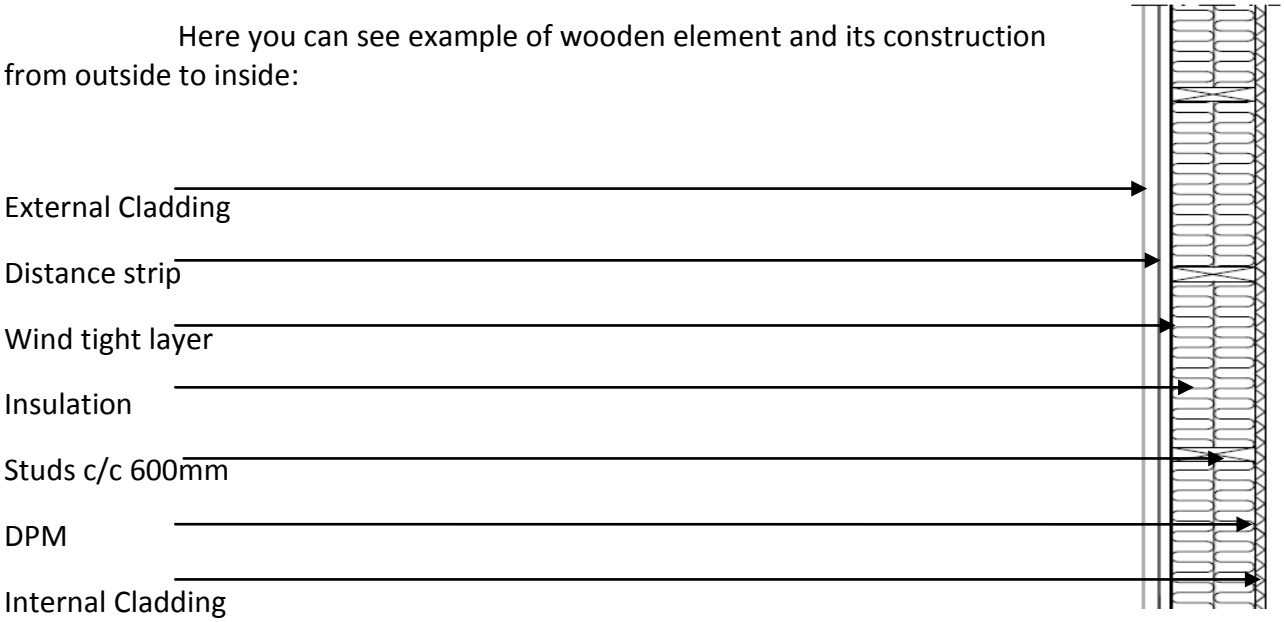


Figure 23 - Wooden wall construction.

External cladding can be made horizontal and vertical cladding. When you have it horizontal you fasten it to a distance strips which are located on the studs. Vertical cladding is little bit more complicated because there you have to put furring on the distance strip so you can fasten the vertical cladding on the horizontal furring. There by you get air cavity between the distance strips which are c/c 600 put on the wall.

Inside between the internal insulation we have the electricity which are put on the DPM and some distance strips which are located between the insulation and the internal cladding is fasten on it and finished.

Roof elements are building component with insulation and finished ceiling. When we have to choose between roof elements it is very important to consider the building type it is going to cover. We have then the moisture classes which is important to choose from when deciding the type of roof element.

Those classes are 3:

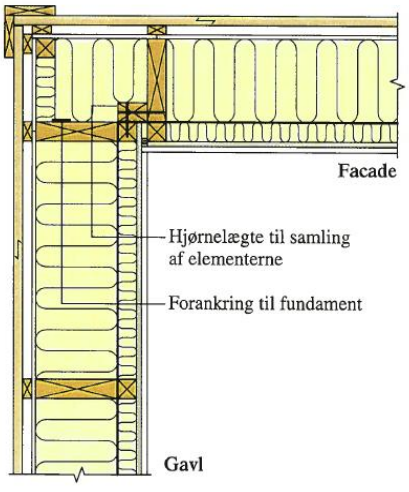
- Room climate class 1 is 0-5 g water per. m2 air used for dry store rooms, dry production units and sports buildings without spectators
- Room climate class 2 is 5-10 g water per. m2 air used for Dwellings and offices, Institutions and schools, industrial buildings without damping device and sports buildings with spectators.
- Room climate class 3 is more than 10 g water per. m2 air used for Buildings for swimming, wet rooms, printing houses with damping device and humid industry.

There are some types of different roofs, we can have non-ventilated cold roof in climate class 1 and 2, cold ventilated roof in class 1 and 2 and unventilated warm roof in climate class 1,2 and 3.

Unventilated roof elements is much more sensitive for the moisture condition when building. If a Hygrodiode membrane is used as dpm any moisture in the element will be driven to the dpm where it condensates if the sun shines. Remember that the consultants must secure that no moisture will enter into the element while mounting. You must describe to deliver the elements with the first layer of bitumen fixed. Place a bitumen felt strip following the mounting sequence it is good during night to seal the elements.

DETAILS

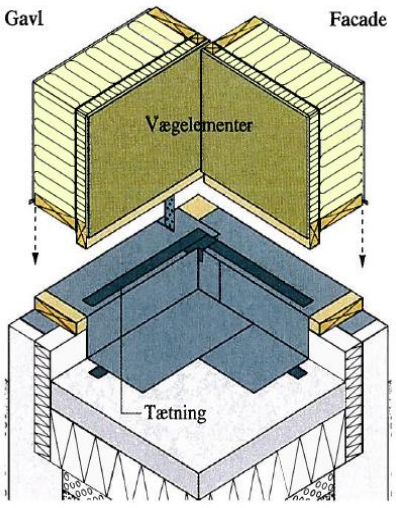
Here are some examples of details and finishes of roof and wall elements, three of them are made by author:



Figur 71 Ydervægselementer samles med en hjørnelægte, der sikrer både lufttæthed og overførelse af lodrette kræfter, så kun gavlen skal forankres.

Figure 24 -Corner finish/wood wall.

Figure 25



Figur 75 Der tætnes mellem radonmembranen og vægelementernes underside. Det er vigtigt at tætningerne mødes i hjørnet.

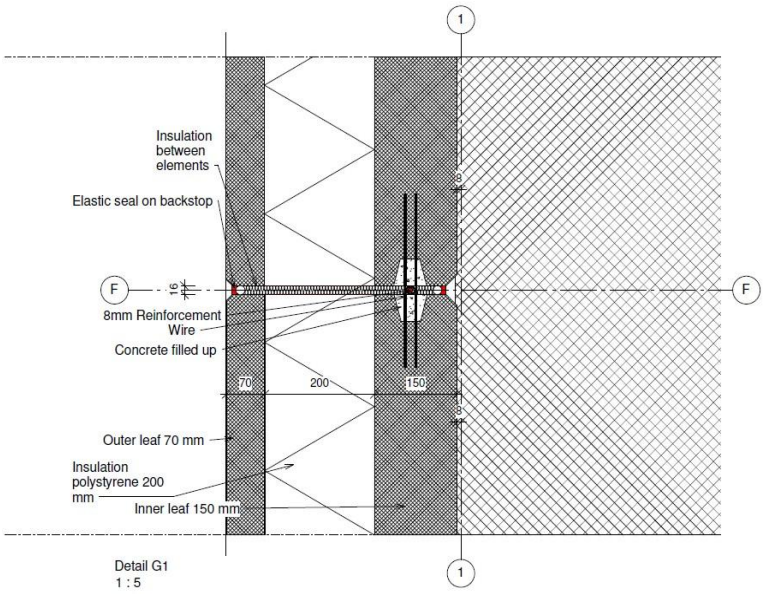


Figure 26 - Connection of concrete elements.

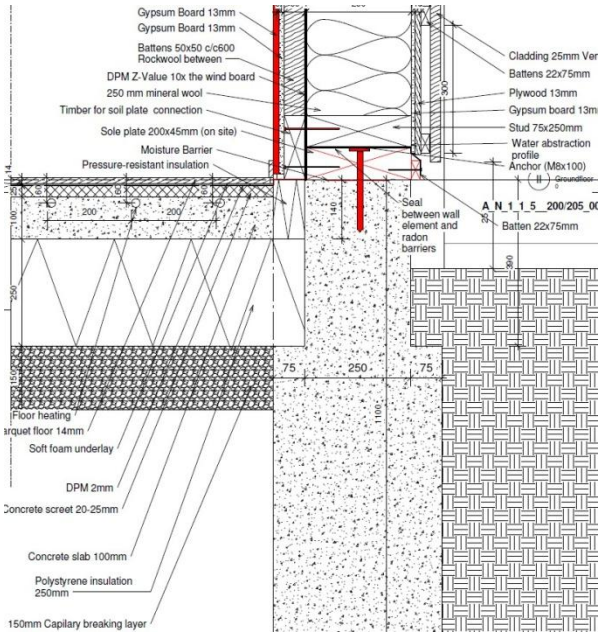


Figure 27 - Wooden wall connected to foundation.

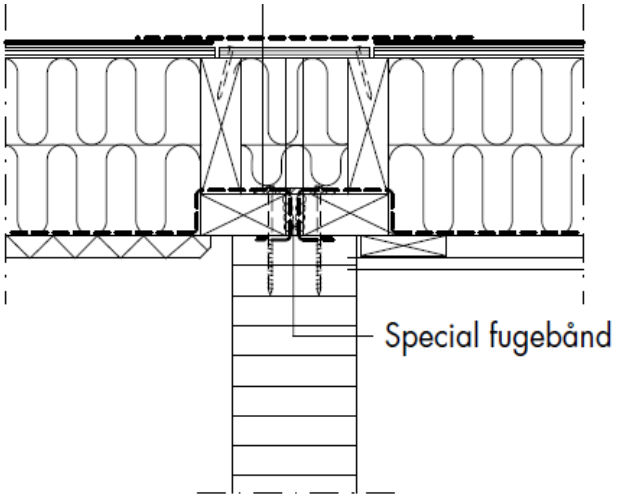


Figure 28 - Roof connection.

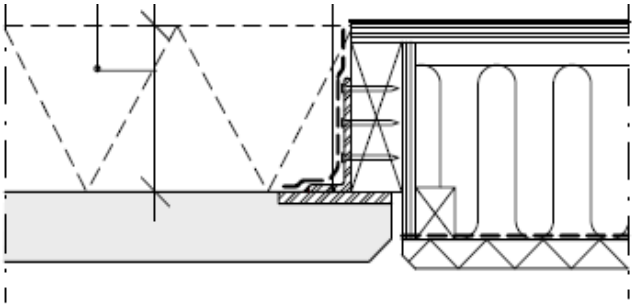


Figure 30 - Roof element connection to TTS structure.

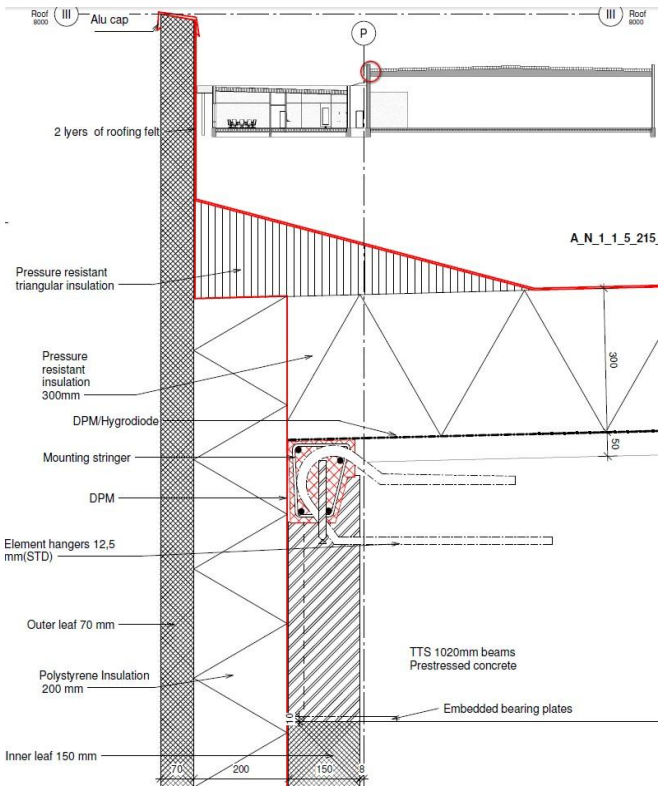


Figure 29 - TTS connection to concrete facade.

SUMMARY OF WORKING PROGRESS

It started all when my teachers Karsten Bank Olesen and Gordon Lindsay Alcock introduced the class to the elective subject. I read than about it in the semester syllabus and knew than what it was about.

I decided than to write about Prefabricated elements. I chose that subject because I wanted to know more about it and also to gain more information about what is possible to do with prefabricated elements and differences of using it. I wanted to learn a little bit about the history, what is the advantages and disadvantages and which kind of Architecture is possible to make out of it with constructions and finishes.

I collected information mainly through the internet from sites like Palsgaard, BETONELEMENT, Træelement and WIKIPEDIA and from books which I took from the Library in VIA University College. I also interviewed some people to find out alternative solutions for prefabricated elements. I talked with my father which is constructing manager in Iceland and my consultant.

PERSONAL EXPERIENCE

For me personally it was very good to write this report and research for the subject on the internet and in those books I took. I learned a lot more than I can explain in this report and investigated very deep into architecture and construction part.

Prefabrication is very interesting in my point of view and after I wrote this report and gained this knowledge I could see me working with those building parts in the future.

CONCLUSION/RECOMMENDATIONS

During this writing process I learned more about prefabricated elements and investigated the history and background behind it, how it started and what impact it had. I have observed what materials is possible to use in prefabrication and what materials fits with each component. I found out what good advantages are when using prefabrication elements and also what can go wrong, disadvantages. It spare much time but can be for example very expensive to use prefabricated elements. I talked about different architectural design in different countries and possible finishes, constructions and methods.

These documents are documented in the report and I was really impressed how many different parts of prefabricated elements I could find and modern architecture. I have also talked to my father which is constructing manager and my consultant and have included the results of my interviews. I will use this knowledge in the future when I will become constructing manager/architect.

List of References

Electronic Resources

Architeria.com, n.d. Prefab Wooden House in Germany by K_M_Architektur. [Online] Available at: http://www.architeria.com/house-design/prefab-wooden-house-in-germany-by-k_m_architektur [Accessed 7 October 2011].

Articles, E., 2007. Prefabricated Building Materials. [Online] Available at: http://ezinearticles.com/?Prefabricated-Building-Materials&id=408697 [Accessed 5 October 2011].

BETONELEMENT, 2011. 2.3.1 FACADEELEMENTER, OVERFLADER – FARVET. [Online] Available at: http://www.betonelement.dk/betonelementer/2-facader/2-3-facadeelementer-overflader/2-3-1-facadeelementer-overfalder-farvet/ [Accessed 6 October 2011].

BETONELEMENT, 2011. 2.3.2 FACADEELEMENTER, OVERFLADER – FRILAGT. [Online] Available at: http://www.betonelement.dk/betonelementer/2-facader/2-3-facadeelementer-overflader/2-3-2-facadeelementer-overflader-frilagt/ [Accessed 6 October 2011].

BETONELEMENT, 2011. 2.3.3 FACADEELEMENTER, OVERFLADER – STRUKTURERET. [Online] Available at: http://www.betonelement.dk/betonelementer/2-facader/2-3-facadeelementer-overflader/2-3-3-facadeelementer-overflader-struktureret/ [Accessed 6 October 2011].

BETONELEMENT, 2011. 2.FACADER. [Online] Available at: http://www.betonelement.dk/betonelementer/2-facader/ [Accessed 6 October 2011].

BLOGGERTRICKS.COM, 2009. BLOGGERTRICKS.COM. [Online] Available at: http://engineering-photos.blogspot.com/2009/12/different-types-of-pre-fabricated.html [Accessed 4 October 2011].

BOLIGBETON, 2011. Facader. [Online] Available at: http://www.boligbeton.dk/index.php?id=8 [Accessed 6 October 2011].

BUILDINGS, P., 2011. Precast/Prestressed Concrete. [Online] Available at: http://www.cement.org/buildings/precast_splash.asp [Accessed 7 October 2011].

BUISNESS, H., 2011. Prefabricated Wood Buildings and Components. [Online] Available at: http://business.highbeam.com/industry-reports/wood/prefabricated-wood-buildings-components [Accessed 5 October 2011].

Components, T., 2011. Timber Doors. [Online] Available at: http://www.tcuk.co.uk/doors.php [Accessed 9 October 2011].

Concrete, G., 2011. Front Page. [Online] Available at: http://www.graphicconcrete.com/index.html [Accessed 6 October 2011].

Dalton, 2011. Dalton. [Online] Available at: www.dalton.dk [Accessed 5 October 2011].

DigsDigs, 2008-2011. Bunker House Made of Prefab Concrete Blocks – Haus Bold. [Online] Available at: http://www.digsdigs.com/bunker-house-made-of-prefab-concrete-blocks-haus-bold/ [Accessed 7 October 2011].

HARPA, 2011. ABOUT HARPA. [Online] Available at: http://en.harpa.is/about-harpa/ [Accessed 7 October 2011].

Hubpages, 2011. Advantages of prefabricated houses or modular homes. [Online] Available at: http://cerveira.hubpages.com/hub/Advantages-of-prefabricated-houses-or-modular-homes [Accessed 6 October 2011].

inhabitat, 2011. Habitat 67: Montreal's Prefab Pixel City. [Online] Available at: http://inhabitat.com/habitat-67-montreals-prefab-pixel-city/ [Accessed 7 October 2011].

inox, e., 2002. Stainless Steel Facedes. [Online] The European Stainless steel Developement Association (2nd) Available at: http://www.euro-inox.org/pdf/case/facades/Facades_EN.pdf [Accessed 7 October 2011].

magazin, d., 2011. Herringbone houses. [Online] Available at: http://www.dezeen.com/2007/11/19/herringbone-houses-by-alison-brooks-architects/ [Accessed 8 October 2011].

PREFABFAN, 2011. Why Prefab: The Advantages of Prefab Homes & Cabins. [Online] Available at: http://www.prefabfan.com/why-prefab/ [Accessed 10 October 2011].

price?, W., 2003-2011. Prefabricated buildings. [Online] Available at: http://www.whatprice.co.uk/building/pre-fabricated-buildings.html [Accessed 4 October 2011].

SCHOTT, 2011. An overview of our products, applications, brands and divisions. [Online] Available at: http://www.schott.com/english/products/index.html?WTS=1&WTC=schott_int_google_adwords&WT.seg_1=reprise/Google/INT-Glass_SpecialGlass/++glass+components-Broad [Accessed 9 October 2011].

TAASINGE, 2011. TAASINGETRÆ BYDER VILKOMMEN. [Online] Available at: http://www.taasinge.dk/cms/page280.asp [Accessed 10 October 2011].

Træ, P., 2011. Palsgaard Træ. [Online] Available at: http://www.palsgaardgruppen.dk/kviste/ [Accessed 5 October 2011].

WIKIPEDIA, 2011. Column. [Online] Available at: http://en.wikipedia.org/wiki/Columns [Accessed 9 October 2011].

WIKIPEDIA, 2011. I-beam. [Online] Available at: http://en.wikipedia.org/wiki/I-beam [Accessed 9 October 2011].

Wikipedia, 2011. Prefabricated building. [Online] Available at: http://en.wikipedia.org/wiki/Prefabricated_housing [Accessed 4 October 2011].

Wikipedia, 2011. Prefabrication. [Online] Available at: http://en.wikipedia.org/wiki/Prefabrication [Accessed 2 October 2011].

WIKIPEDIA, 2011. STEEL FRAME. [Online] Available at: http://en.wikipedia.org/wiki/Steel_frame [Accessed 9 October 2011].

Books

Davies, C., 2005. The Prefabricated Home. London: Reaktion Books Ltd.

Stacey, M., 2001. Component Design. Oxford: Architectural Press.

Gibb, A.G., 1999. off-site fabrication: Prefabrication, Pre-assembly and Modularisation. Scotland: Whittles Publishing.

Presentations

Lectures, 2011. Presentation Wood. Horsens.

Lectures, 2011. Presentation Concrete. Horsens.

TABLE OF FIGURES