Experiences of prototyping passive house design

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Abstract

Öresund Green was Skanska's first self-developed single-family house to be based on passive house techniques. It was completed in June 2011. Öresund Green is a development of the Öresund house model, and incorporates the same architectural features but has been modified to a masonry house which the meet Swedish passive house standards.

The Öresund Green house was constructed to be more airtight and better insulated than conventional houses, and is equipped with a highly efficient heat recovery ventilation system.

The external walls of the Öresund Green house are made from a new type of block that was developed by Skanska and Weber. The block, known as Leca® Isoblock Rex, is 500 mm thick and contains a 300 mm layer of inorganic polyurethane (PUR) insulation, which provides around 50 percent better insulation than normal mineral wool. The Leca blocks are also easy to make air tight with internal plaster and ensure there are no thermal bridges.

The Öresund Green house costs approximately 7 % more to construct than a conventional house in Sweden. However, the house is designed to annually use 37 kWh/m^2 for space heating and hot water compared with the Swedish standards, which demand less than 110 kWh/m^2 (currently 90 kWh/m^2). A conventional Skanska Nya Hem property annually uses 65-75 kWh/m^2. The house has an extremely air tight shell, with an air permeability of 0.20 l/s/m^2 compared with the Swedish passive house maximum of 0.3 l/s/m^2. These savings correspond directly with reduced utility costs for the residents of the Öresund Green house. The greater construction costs of an Öresund Green house can be repaid in 10 to 15 years through reduced energy costs.

The Strandgränd Öresund Green house is a prototype, and Skanska is currently monitoring and assessing how the design, production and performance of the building can be improved in the future. Öresund Green has helped to further develop both Skanska's and Weber´s competence and experience of passive houses. The project is thus also an important learning experience in building techniques development. From the perspective of a material manufacturer it is difficult and expensive to develop new products on their own which will succeed on the market. It means not only anticipating market needs. It also means finding innovating solutions, having proper production facilities as well as financial muscles to bare necessary investments. On top of this the new solutions need to be competitive in price. Contractors can often be rich in experiences and ideas but they normally lack their own building material production facilities. One way of speeding up and raising success rate of product development can be to join forces, manufacturers and contractors together.

When prototyping new products and systems in cooperation, knowledge and resources can be utilized from both parties. Thresholds for testing production and construction lowers dramatically.

The Leca® Isoblock Rex has since been used in several new low energy designs by other building companies in both residential and non-residential buildings.

Keywords: Öresund Green; Prototyping; Passive house; Leca Isoblock Rex; Masonry; Skanska; Weber

The Öresund Green House

The objective with this project was not only to develop a passive house that with a good margin reaches the Swedish requirements. It also attempted to avoid solutions which has been noticed and criticized in previous Passive House projects, such as moisture in organic materials, complex air sealing and thermal bridges.

The house was based on a previously existing house model, Öresund 149. This first pilot house was calculated to be about 20% higher cost than the original house to produce. The 3D design was completed July 2010. Production was completed in spring 2011. Öresund Green was Skanska's first self-developed single family house to be based on passive house techniques. Skanska first constructed the Öresund Green house as a prototype in the Strandgränd residential project in Bunkeflostrand. Bunkeflostrand is a suburb of Malmö, in southern Sweden. Only one Öresund Green house was constructed on the site. Although the Strandgränd project also included 48 conventional Swedish houses and 19 Uniqhouses, which are Nordic Swan environmentally certified concept houses developed by Skanska.

Figure 1 The Öresund Green House

Öresund Green (Figure 1) is a development of the Öresund house model, and incorporates the same architectural features but has been modified to meet Swedish passive house standards. Skanska added Öresund Green house to its recent experience of building other passive house residential projects in Sweden and to its Scandinavian Living concept.. The house is on two levels and offers 149 m^2 of living space. It has either three or four bedrooms, depending on the upstairs layout, which can include an upstairs living room.

General specifications and solutions

The Öresund Green house is more airtight and better insulated than conventional houses, and is equipped with a highly efficient heat recovery ventilation system. The development of single-family houses based on passive house techniques is part of Skanska's strategy to give customers the opportunity to live more sustainably and reduce their energy costs. The Öresund Green house costs approximately 7 % more to construct than a conventional house in Sweden. However, the Öresund Green house uses approximately 60 percent less energy for space heating and hot water than the Swedish energy standards, which, in this project, required less than 110kWh/m^2 per year. The Öresund Green house is designed to annually use 37 kWh/m^2 for space heating and hot water. These savings correspond directly with reduced utility costs for the residents of the Öresund Green house. The greater construction costs of an Öresund Green house can be repaid in 10 to 15 years through reduced energy costs. Skanska have estimated that a family can typically save around 1100 Euro per year compared with a conventional Skanska residential property.

The Öresund Green house high energy efficiency can contribute toward reduced energy use and carbon emissions compared with conventional house types. The house is also equipped with a solar water heating system and water efficient fixtures. During the construction of the Öresund Green house at Strandgränd, Skanska promoted stakeholder communication and high standards of health and safety. The project also raised awareness of energy efficient housing and will be used to refine the Öresund Green house type for future residential projects.

Öresund Green houses have a mechanical air ventilation system that provides good indoor air quality by supplying fresh air to the living room and bedrooms. The system removes stale air from the kitchen and bathrooms to promote air circulation in the house. The Öresund Green house has stone walls, which provide a more even indoor temperature compared with conventional Swedish wooden houses. The bathroom is also equipped with an under floor electric heating unit to promote occupant comfort.

The Öresund Green house provides residents with a flexible and functional home, which allows various space uses and layouts for present and future occupants. The absence of radiators in the house also allows flexibility in placing furniture. The Öresund Green house can be constructed with three bedrooms in total and an enlarged upstairs living room, instead of four bedrooms, a more open planned kitchen and living room space on the ground floor is another option.

The Öresund Green house in Strandgränd was used for demonstrations and study visits were held during construction and further visits were arranged following the project's completion. The project consequently raised awareness of passive houses both internally within Skanska and externally through the various study visits.

In this project as well as in all Skanska projects, Low-VOC (Volatile Organic Compounds) and non-toxic materials, and Skanska's Restricted Substances List were incorporated into the project.

Use of energy

The house has an extremely air tight shell, with an air permeability of 0.20 l/s/m^2 compared with the Swedish passive house maximum of 0.3 l/s/m^2. The windows and doors are well insulated with a u-value of 0.9 W/m2 or less and exterior sun shields help to prevent the house overheating in the summer. The foundations are insulated with 400 mm of insulation beneath the slab and 300 mm around the beam edges. The external walls of the Öresund Green house are made from a new type of block that was developed by Skanska. The block, known as Leca® Isoblock Rex, is 500 mm thick and contains a 300 mm layer of inorganic polyurethane (PUR) insulation, which provides around 50 percent better insulation than normal mineral wool. The Leca blocks are also easy to make air tight with internal plaster and ensure there are no thermal bridges.

The heat recovery system is specially designed for passive houses and recycles around 85 percent of the energy from the outgoing air back into the building. A small gas heater provides additional heat to warm the incoming air during very cold weather. Skanska equipped the Öresund Green house with a gas heater. Natural gas has a primary energy factor of 1.16, which means that 1.16 kW of energy is consumed to provide every kW of heating. In comparison, the Swedish electricity mix has a factor of 2.0 if electricity were to be used to heat the incoming air, which would consume 2 kW for every kW of heat provided.

Öresund Green is fitted with a solar heating system, which meets around 65 % of a typical Swedish family's domestic hot water requirements. The system is designed to annually provide the house with approximately 1,600 kWh of hot water. The Öresund Green house was fitted with water efficient fixtures and fittings to ensure that it uses approximately 10 percent less than a typical Swedish house. The use of hot water is monitored as well as energy used for space heating etc (Figure 2).

The Öresund Green house in Strandgränd annually emits around 20 kgCO_2e per m^2, which is around a third less than a typical Skanska Nya Hem house. This calculation is based on 0.28 kgCO_2e and 0.35 kgCO_2e for natural gas and electricity respectively.

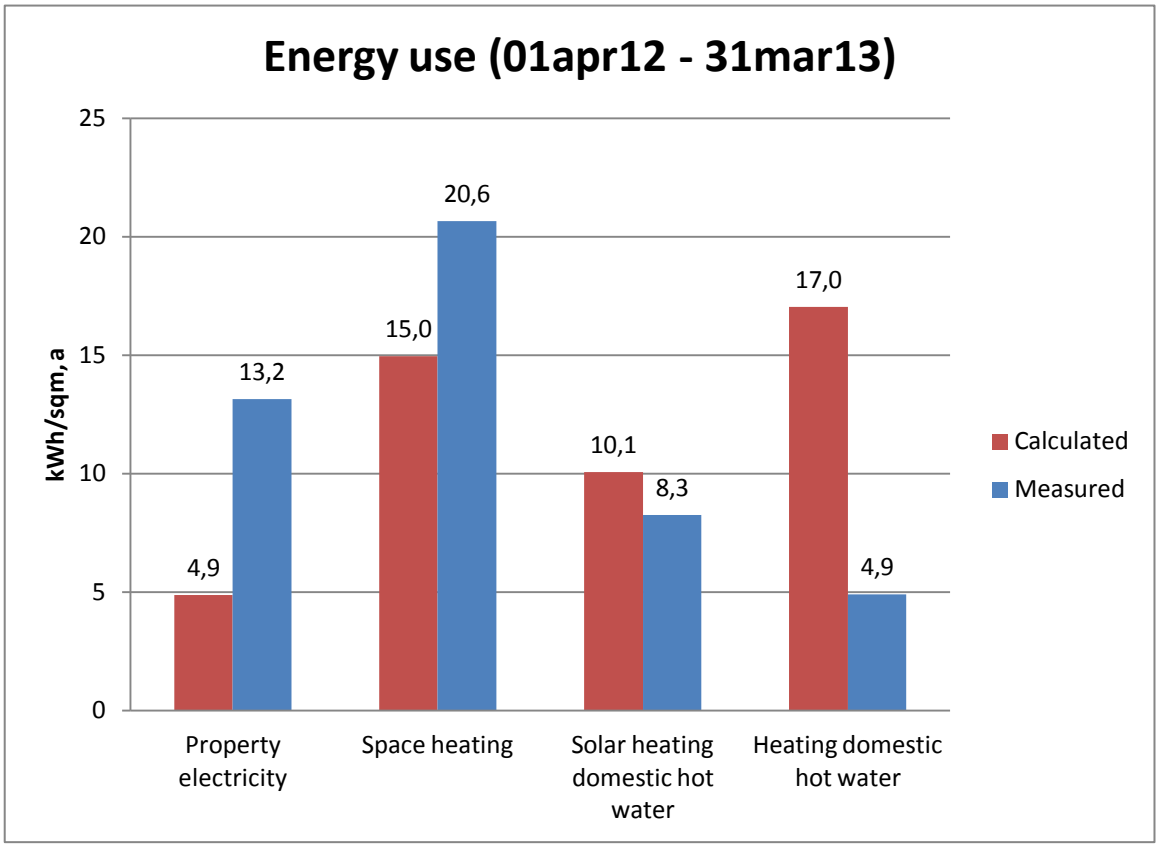

Figure 2 Use of energy in Öresund Green

Comments on measured versus calculated energy

Measured energy is not corrected for annual variations. Residents moved in for the first time2012-07-13, which means the house stood empty for about 3 ½ months. Increased energy use for heating could be due to heat from residents and appliances "free heat" was missing during this period. Increase of residential electricity not analyzed. Total energy use for water heating is the sum of solar heating and hot water.

Total measured energy consumption (excluding electricity) is 38.7 kWh / m^2 year, compared with an estimated 36.9 kWh / m^2 year. This compares with BBR requirement of 110 kWh / m^2 year that applies to this project. Due to some initial problems with the resolution of the measurements it was not possible to divide data into values on a monthly base. These problems are however now taken care of and the future analysis of consumed energy will be possible to do more in detail. Measurements of energy consumption will continue for a few years and offer the opportunity for reliable assessment of the buildings performance.

Construction phase

There were no accidents on site during the construction (Figure 3) of the Öresund Green house. Skanska's and Weber's standard health and safety practices were followed throughout the construction. A small number of Skanska personnel worked on the Öresund Green project. All workers were from the Malmö area. Most of the contractors were also from the surrounding area. The house required unique solutions, such as the solar water heating system and the special roof construction, which were sourced from outside southern Sweden. However, the ventilation system was sourced from Gothenburg. Waste was recycled on the Strandgränd site and data was collected for the project as a whole. Specific waste data for the Öresund Green house was not recorded because it was one of several houses constructed on the site. Prefabricated panels were used for the roof of the Öresund Green house, which were ready for mounting and helped to reduce waste on site.

Figure 3 The Öresund Green House during construction

Prototyping building products

Market expectations

The general higher demands on sustainable building characteristics, such as low energy consumption and lower CO_2 footprint, together with demands on living standards and comfort calls for a technical leap in building solutions. This is affecting all aspects as construction, use and maintenance of buildings. Expectations from authorities and consumers forces both material suppliers and contractors to develop new systems and technology. Considering the impact (Figure 4), it is crucial for the building industry to contribute in the process of protecting the future environment.

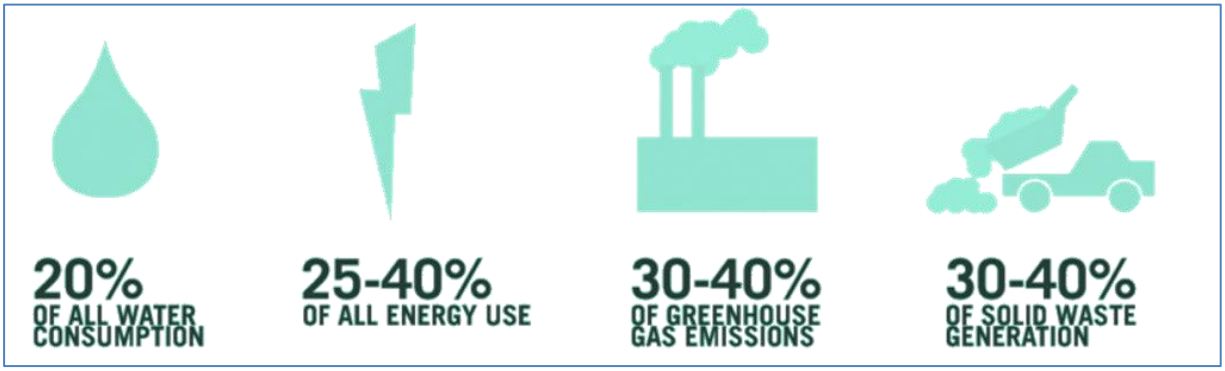

Figure 4 Example of the building industry utilization of resources

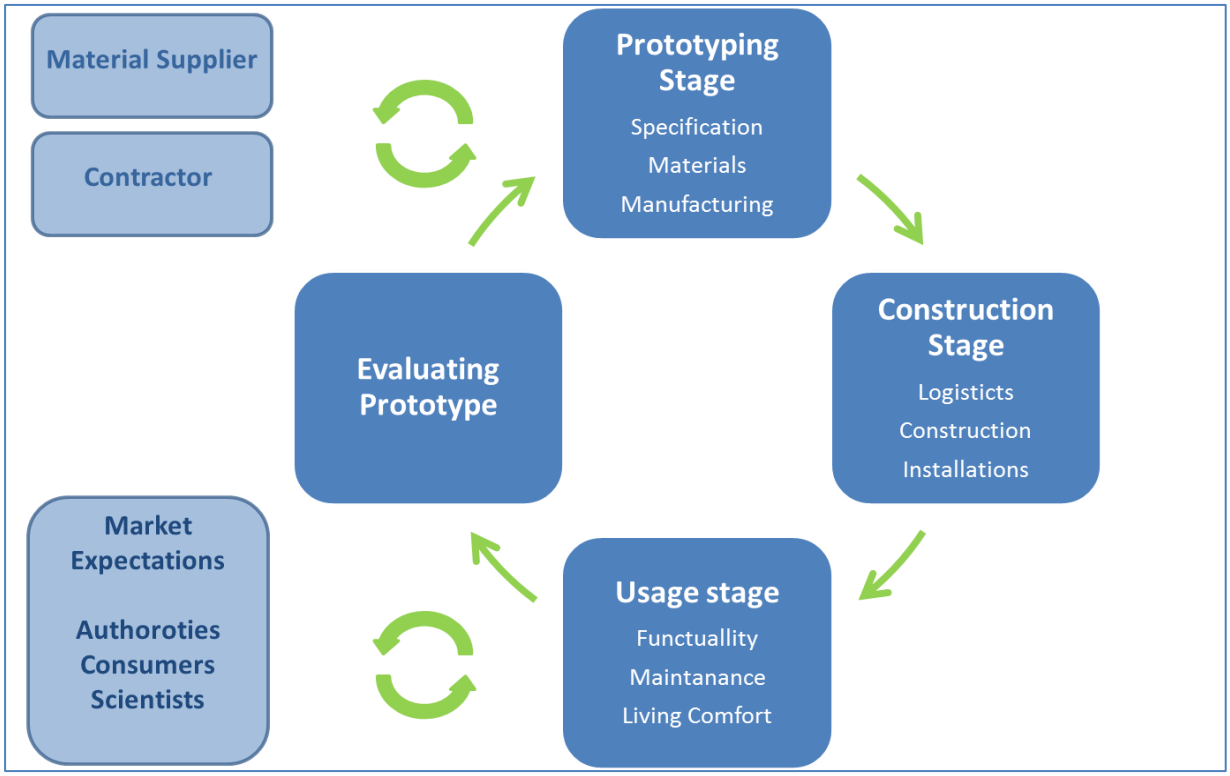

Figure 5 Example of Prototyping Cycle

It is worthwhile to dwell on how these new technologies and technical leaps can be reached. From the perspective of a material manufacturer it is difficult and expensive to develop new products on

their own which will succeed on the market. It means not only anticipating market needs. It also means finding innovating solutions, having proper production facilities as well as financial muscles to bare necessary investments. On top of this the new solutions need to be competitive in price. Contractors can often be rich in experiences and ideas but they normally lack their own building material production facilities. One way of speeding up and raising success rate of product development can be to join forces, manufacturers and contractors together (Figure 5). When prototyping new products and systems in cooperation, knowledge and resources can be utilized from both parties. Thresholds for testing production and construction lowers dramatically.

Öresund Green project expectations

Weber was contacted by Skanska regarding the possibility to build a stone house with passive house standard. They had customers asking for stone houses for various reasons, naturally with unchanged demands on low energy consumption for the buildings. Heavy building materials have positive effect on heat storage and thermal oscillation. This however Skanska made clear to Weber was not possible to communicate effectively to their end customers. If Skanska were to build a low energy stone house it should have the same low U-values as in non-heavy material wall designs. Except from insulating properties Skanska also had expectations regarding wall thickness, air tightness and cold bridges.

Wall thickness	0,5m or less
Air tightness	< 0,2 l/s/m^2
U- Value	< 0,09
Cold bridges	Max 10% of total transmission loss

Figure 6 Masonry wall with Leca® Isoblock Rex

Leca® Isoblocks have been used in Sweden since the early nineties. It is basically a way of combining robustness and good building properties of a regular Leca Block with a better insulating material. The block consist of two blocks with an insulation in between. In this way the wall will be built up with

one robust outer shell and one inner shell in lightweight concrete, exposed to inside and outside climate and use.

The regular Leca® Isoblocks are 30 and 35 cm wide. The long time experience form building with Leca® Isoblocks shows that the thickness of the block parts needs to be of a certain minimum width. This is partly for loadbearing reasons, both vertical and horizontal, and partly for mountings and installations. Both inner and outer block part is 10cm wide. The 30cm Leca® Isoblock is built up by 10cm block – 10cm insulation - 10cm block, 10b+10i+10b. The 35 cm Leca® Isoblock is built up 10b+15i+10b. After going through the design of the Öresund Green House the regular Leca Isoblocks seemed to be a valid solution except regarding the insulating properties. To be able to meet the technical specification from Skanska a thicker insulation than 15cm was needed. A new block was produced by extending the width of the insulation part of the former blocks to meet the maximum block width of 0,5m (Figure 6). Leca® Isoblock Rex thus is buildt up 10b+30i+10b. The U-value for this block is about 0,07 resulting in a wall U-value well under 0,09 closer to 0,007 than 0,08.

The extreme width of the new block requires a large amount of manual adjustments and work in the block plant. This is possible for small prototype series, but in the long run possible production lines has to be considered. It is important to evaluate the feasibility to produce the prototypes as regular products to the right cost. It is not worthwhile to create new systems or prototypes which cannot be rationally produced.

Experiences & Spin offs

The feedback from building a first house with Leca® Isoblock Rex was of course interesting. Handling was not optimal. Compared to regular 35cm Isoblocks the Rex blocks were a little big and awkward to lift and handle on site. The masons expressed that unit size could be either smaller for easier manual handling or maybe much bigger enabling rational handling with mechanical or machinery aids. The finished result on the other hand was very good. In the beginning of the project there were some doubts about if the walls would appear too thick and clumsy. The impression inside the building is pleasant and spacious, there is no feeling of being in a bunker. Also aesthetic aspects are satisfactory. There has been a lot of interest around the project and a lot of visits on site.

Figure 7 Folkets Park, Leca® Isoblock Rex, Malmö

Since the Öresund Green project the Leca® Isoblock Rex has been used in several other buildings. Regional in south of Sweden there has been built:

- Kv Gurkan, Segergatan 50 Landskrona, HA-Bygg
- Glumslövs School, Glumslöv, Einardahls-Bygg AB
- Folkets Park Office, Malmö, ER-HO-Bygg (Figure 7)

Also there has been two residential building in more northern parts of Sweden. First after the Öresund Green house one Villa was built in Uppsala. The other villa was built on Gotland.

Villa Höör is a coming project in Höör. Phil. Doc. Henrik Davidsson teaching at LTH is building a Villa with Leca Isoblock Rex and also testing a new solution for heat exchange with natural ventilation.

Evaluations from these projects will be the base for new prototypes and further development.

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