REBUILDING A MASONRY/CONCRETE SINGLE-FAMILY HOUSE FOR ECONOMICAL HEATING AND COMFORTABLE LIFE

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ABSTRACT
Masonry was the most common material used in construction in ubran areas in Sweden for a long time. It was not until the 1920s that reinforced concrete became widely used. A combination of materials became common in multi-family housing and, in some cases, also in single-family housing; floor slabs were made of concrete, walls were made of brick masonry and roof structures were constructed of wood. A late example of such houses has been the topic of the author's recent technical contribution in rebuilding economical structures for modern living. The project serves as an example of modernizing with a sense of proportion. The house is a two-storey structure constructed between 1959 and 1961, by the Swedish architect Folke Hedérus, "the most talented architect of his generation". The house, situated on Lidingö, an insular community close to Stockholm, has a living area of some 300 m^2. The roof, originally being flat, its edges are now lifted from 140 to 340 mm to allow for an increase of mineral wool insulation, and have an inward inclination towards a runway with only two outlets (originally three). The vertical storm water piping was increased from 120 to 150 mm for compensation. The large thin glasses windows of the façade are replaced by modern glass panes, lowering the heat transmission factor from 2.6 to 1.1 W/m^2 K. The insulation of wooden parts of the second floor is doubled from 100 to 200 mm of mineral wool. The concrete floor of the lower storey, originally un-insulated, was covered with 100 mm cellular plastic, glued upwards. Brick walls were however not modified. In total, the heat losses from the vertical parts were halved. In addition, and most important, the ventilation and heating systems were separated by replacing circulating hot air with water circuits on each floor.

KEYWORDS: brick masonry, floor heating, heat insulation, rehabilitation, slopes

INTRODUCTION
Single family housing in Sweden is normally constructed with wood, and in some cases AAC (autoclaved aerated concrete), is used for row houses, however brick is uncommon to be used in such construction. Single family houses constructed with bricks are prestigious especially if they have concrete floor slabs. These houses also have a high thermal constant, which means that they react slowly to outdoor thermal variation, but they are, in most cases, poorly insulated and energy consuming in heating. This deficiency makes these houses nowadays very costly,

regardless of the source of energy used in heating. In order to reduce their dependence on exterior energy input is a prime interest in combination with building restoration in general.

Not all houses can be economically restored, however, in the sense that the investment is sound, adding an equal amount or even more than the original investment cost to the value of the building may be worthwhile. This is not the case with 90,000 single family houses (more than two years production of dwellings in Sweden) according to a new investigation [1]. In most cases, the location has become unattractive. It is an important political problem, calling for state subsidies or other means of support to preserve the building stock, in the interest of architectural heritage. The alternative would be continuous neglect and eventually demolition. On the other hand, to restore prestigious buildings in good locations can be very profitable, beside the fact that the indoor climate is much improved.

Fig 1. Outline of a one-family house from the late 1950s. Architect: Folke Hedérus

One high-class two-story house, Villa Nordmark (named after the first owner) located on the island Lidingö close to Stockholm, has been the topic of the author's attention between 2008 and 2009, when it has been radically restored under his supervision. A drawing of the house is shown in Fig 1. It was designed in the late 1950s by the local architect Folke Hedérus and built in 1959 to 1961, in a style influenced by the famous American architecture Frank Lloyd Wright. The drawings of the house were published in the Swedish periodical *Arkitektur* [2], before construction was completed. It had interior and exterior masonry rendered walls and two concrete floor slabs. The roof of the house was flat and constructed of wood. The house had large insulated double glass panes, which were North American novelty at the time the house was built. The heating system was based on combusting oil, then abundant and cheap, transferring heat onto hot water, which was feeding two circulating air batteries, letting hot air out underneath all the façade glasses. Each battery served one storey, Fig 2.

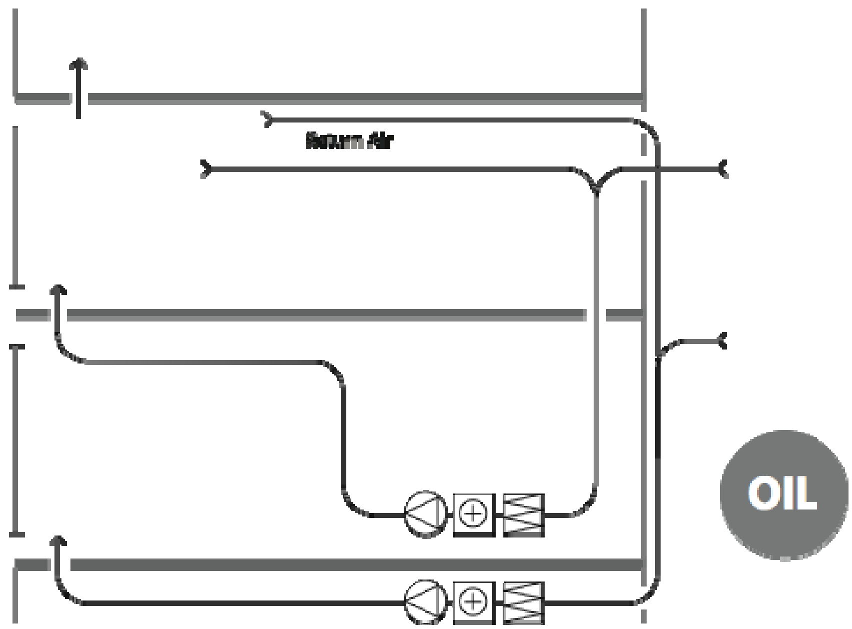

Fig 2. The original heating system, combining heat and ventilation in circulation.

PURPOSE OF REBUILDING

The purpose of rebuilding was to modernize the heating system and to refurbish the whole building for a new owner. The current rule in Sweden [3] is that the energy requirement for heating should not exceed 110 kWh/m^2/year. Circulating air should be avoided for hygienic reasons. Also, experience showed that air circulation when exposed to low exterior temperatures may become fierce and unpleasant, in case the insulation is not very efficient. After discussions, the solution was to drill deep holes into the ground rock from which heat is taken to a heat pump, where it is converted into hot water feeding the internal requirements. In addition, insulation had to be improved.

Preserving the architecture of the original house has been a concern. This was particularly relevant to the extension of a relax-room and the change from flat to a sloping roof. The novelty of the 1950s to promote flat roofs covered by some synthetic foil (Prevanol in this case) has proven to be a mistake, especially in single family houses, which are in general left unattended. Such roof systems are un-permissive when it comes to any leakage from ageing, which inevitably happens in the long term, and must now be avoided. In this case the lift of the roof level, the slope of the roof and an increased insulation depth remedied the leakage problem. To accommodate this geometry, a frame of constant height around the roof was needed and the masonry in exterior walls and chimneys were extended upwards with a number of courses. For fire protection, chimneys have to be one meter higher than the adjacent roof level.

THERMAL INSULATION

The original thermal insulation was rather moderate, reflecting the low price of the fossil fuel. The insulation was 140 mm mineral wool on the roof, 100 mm mineral wool on the exterior walls, and the bottom floor was left completely un-insulated. The intention was that this concrete floor would serve as a heat exchanger, which is surprising, considering that the return air flow does not go through the volume under the floor. Apparently, such flow was originally intended but omitted for some practical reason. The consequence should have been to insulate the floor underneath, which happened only now in combination with the rebuilding. Referring to Fig 3, the floor was insulated with a 100 mm foam (polystyrene) insulation glued upwards to the concrete. The roof got an additional 200 mm mineral fibre insulation, a total of 340 mm and had an inward inclination for a quick run-off of rain (the current level of roof insulation in new production would be 450-500 mm, reflecting the fact that heat losses towards the open sky are relatively dominant due to radiation.) Wooden walls of the second floor were given an extra 100 mm mineral fibre insulation, totalling 200 mm. (A current level of wall insulation in new production would be 300 mm.) and brick walls were not touched.

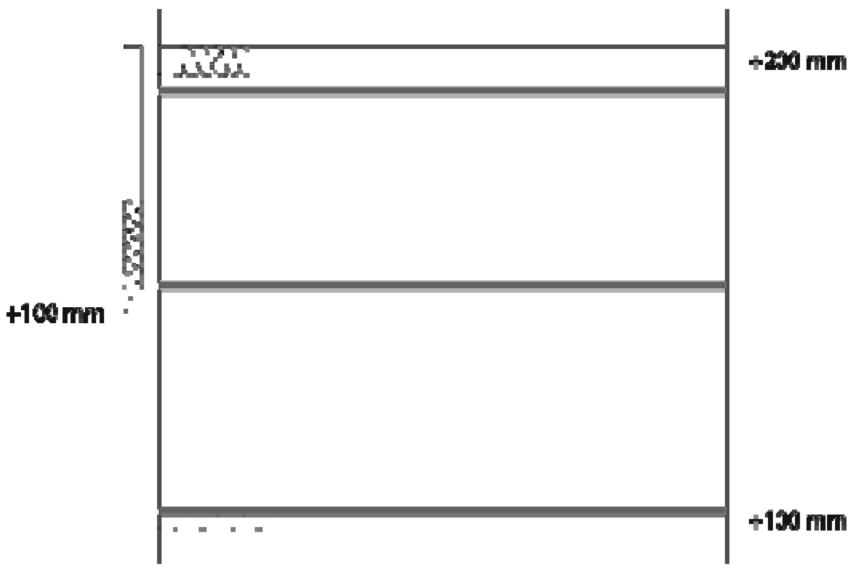

Fig 3. Improving the insulation of all possible surfaces, except masonry

The strengthening of the insulation around the building envelope not only reduced the heat losses but also improved the internal thermal convenience of the inhabitants. It was estimated that the new level of insulation, not quite up to the modern level but possible to accommodate geometrically, would give a comfortable enough indoor climate with reasonable costs.

GLASS EXCHANGE

All around the building, glass was exchanged. Insulating panes was a new technology in 1959 to1961. It is believed that the house was one of the pioneering projects for this new possibility coming from the USA (another project was a well-known bank office in the centre of Stockholm, which still has them). Seven panes are 6 m^2, a practical limit at the time and still a restrictive economical advice. The house has only two small opening windows but several glass doors, from the kitchen and from all five bedrooms.

The heat transmission factor of a two-pane insulating glass at the time of building was 2.6 $W/m^2 K$, according to available records. Now the same two-pane glass has a factor equal to 1.1 $W/m^2 K$. It is a radically new product, thanks to heavy inert gas trapped between the panes, now 18 mm apart, whereas the original distance was 12 mm. Also, the inner surfaces are now coated with metal reflection films (a neutral value, indicating no heat losses through glass over a full year in Sweden, is 1.2 W/m^2 K. So the present level means that there is in fact a heat gain over the year, a solar contribution to the budget for heating the building.)

FLOOR HEATING

The heating after rebuilding relies mainly on floor heating, which is applied wherever possible. The central floor of the bottom storey was covered with high quality brown lime-stone from Jämtland, which was not altered. Also, for a wooden part of the top storey floor, floor heating was not applied. On all other surfaces of concrete, floor heating was applied after removing the top layer of grout, as shown in Fig 4. After placing an insulating pad, the pipes were embedded in new grout or, if the geometry did not permit, covered by a fibre plate. All wet floors are finished with dense ceramic tiles. All dry floors are covered with carpets, which is in accordance with the original architecture.

Fig 4. Floor heating system. Circulating hot water on all floors, except natural stone. Pipes buried in polystyrene foam or in concrete on foam

Secondary heat is delivered through ventilation, like before the rebuilding, but with a constant and limited flow, a convector of 7.5 kW, without a fan on the bottom floor to compensate for the missing floor heating, and a 1.5 kW ceiling radiation element. All units are fed with hot water from the heat pump.

CEILING RADIATION

The total height of the glass, covering both storeys, is 5.2 m. To counteract the tendency that air will fall along the glass from cooling, the airflow comes from the vent split at the bottom and in addition, the ceiling element radiates down the glass, as shown in Fig 5. It is believed to be the first application of this new technology in a one-family house and early observations were very favourable.

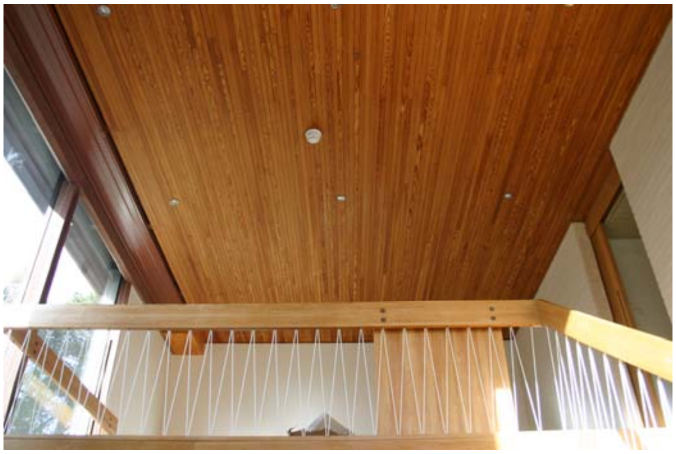

Fig 5. Ceiling radiation hot-water element (1.5 kW)

CONCLUSIONS

The full heating system is demonstrated in Fig 6. The total depth of the three holes, drilled into the rock foundation, is close to 375 m, adhering to the rule of thumb that the figure in meters should surpass the living area in square meters within the house, in this case 305 m^2. The ground rock is an indirect source of solar energy of comparatively high reputation in Sweden. It is becoming so popular that its use has to be regulated by the community, in this case Lidingö, by requiring minimum distances between installations, 24 or 30 m, depending on unit size. This is to assure that every installation should operate on the heat surplus stored in the rock, avoiding to cool-off the source.

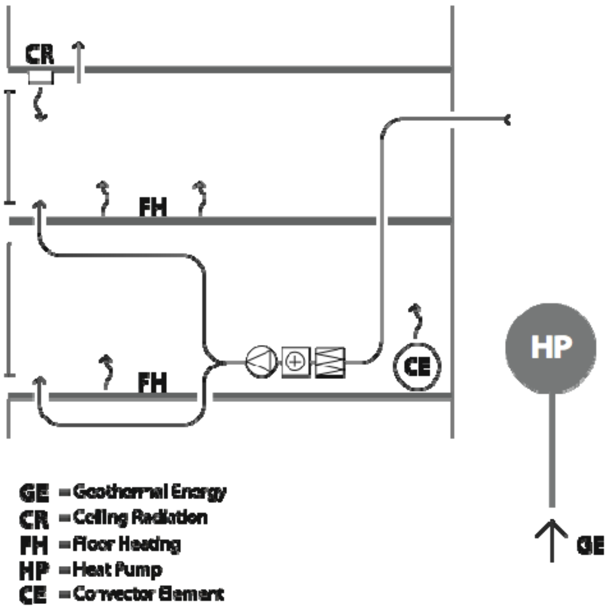

Fig 6. Total heating system after rebuilding. Geothermal energy feeds floor heating system (primary), convector and ceiling radiation elements (secondary)

According to consultants, the new heating system, demonstrated in Fig 6 is designed to deliver a pleasant climate, thermal comfort improved, at a total of 28,000 kWh electricity per annum (no solar panels yet), down from 110,000 kWh from combined electricity and oil before rebuilding. It means close to 75% reduction of energy but an increase of electricity use. After rebuilding the energy requirement accounts for 90 kWh/m^2/year, less than the required 110 kWh /m^2/year. The coming winter season will test the accuracy of this prediction. So far, let us enjoy the results, Fig 7.

Fig 7. The masonry house after rebuilding, view from the garden

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