ESPOO 2011

VTT

Robust

WP 1.8 Design Guidance on Energy Efficiency Strategies for Commercial and Residential Buildings

Jyri Nieminen

VTT

1. Introduction

Renovation of post-war buildings, especially concrete buildings of 1960 – 1980, offer an important possibility for the use of prefabricated systems for facade and roofing systems with additional insulation to bring the buildings up to modern standards. Wall over-cladding and over-roofing with steel systems has been successful in a number of projects, as illustrated in Figure 1.

Over-cladding in Helsinki

Over-roofing with steel trusses

Roof-top extension and over-cladding, Copenhagen

Over-cladding of Industrial Building, Duisburg

Over-roofing of German Sports Hall

Figure 1: Examples of steel systems in renovation

In general, improvement of energy-efficiency has not been the driver in the renovation until recent years. Over-cladding both as a simple renovation measure and energy-efficiency improvement offers substantial benefits for the building performance, as follows:

- Wall over-cladding
    - Improved weather tightness
    - Reduced energy costs

    - Improved air tightness for comfort
    - Prolonged service life of the wall
    - Improved appearance
    - Improved usability in terms of system integrated balconies and lift towers
- Over-roofing
    - Improved weather tightness
    - Reduced energy costs
    - Roof-top extension for services and lifts
    - Roof-top extension for extra space
    - Architecture: Building's appearance in connection with wall over-cladding

2. Over-cladding systems

Building dimensions

Over-cladding solutions for upgrading the thermal and weathering performance of existing buildings using prefabricated steel components requires highly accurate survey data of the external walls of the buildings. Accurate dimensions ensure that the components fit without having to make onsite-alterations. Laser scanning provides a high-accuracy measurement system for facade dimensions. Using laser survey techniques, the survey data of building facades can be gathered from the ground or adjacent buildings from a distance of up to 50 m.

Sufficient accuracy requirement for designing and fabricating prefabricated steel over-cladding solutions is 5 mm in all directions. Laser survey techniques can provide this level of accuracy as long as the correct instrument is used, the right techniques and software are adopted and environmental conditions and reflective surfaces are suitable.

Requirements for over-cladding

'Over cladding' (often combined with 'over-roofing') means the addition of a new façade to an existing building. Before the over-cladding, a condition survey need to be carried out to investigate the rate of deterioration especially in corners and window to wall connections, and in concrete walls the concrete reinforcement steel corrosion. The following requirements are identified for a wall to be over-clad:

- Clean wall: no health risks from mould etc
- Bearing capacity: extra weight due to the frame, thermal insulation and cladding can be accommodated
- Dryness: The wall has be dry or the over-cladding system has to enable drying of moisture

The renovation system should:

- Be weather-tight
- Support its own weight and the wind loads acting on it.
- Reduce heat losses (to conform to modern Regulations).
- Have a long service life (more than 30 years is recommended).

- Respect country specific fire regulations
- Smooth out the uneven and/or non-vertical walls.

The installation must be rapid to avoid moisture in the structure. Prefabricated systems are preferred for their quality and delivery cycle. In low-rise buildings up to 4 floors, prefabricated and building high elements allow for routing of new electrical and HVAC systems thus reducing the down time in the building.

Over-cladding systems

There are various generic types of over cladding systems with varying performance principles and frame applications:

Type 1: Drained and ventilated systems (normally considered as 'rain screens') achieve pressure equalisation in the cavity space behind the new cladding, and the cavity space ensures that any moisture that enters behind the rain screen is drained.

Type 2: Drained and ventilated systems may also be combined with an additional sheathing board external to the existing building, which provides an additional protective layer on which the vapour barrier may be installed.

Type 3: Face sealed cladding systems prevent any moisture ingress, provided details around windows etc are properly sealed. Composite panels (sandwich panels) can be installed to act as face sealed cladding by suitable details around windows.

Type 4: Drained but unventilated systems prevent air movement in the cavity space, but allow for drainage of any small amount of water that may enter behind the new cladding. These hybrid systems rely on minimal air movement behind the new cladding.

Strategies to improve air-tightness in renovation

As thermal insulation levels increase, the influence of air leakages on the energy use becomes more important. Air leakages can represent even more than 20% of the energy used for heating. The strategy to improve the air-tightness in renovation depends on, e.g.,:

- Building type and form
- Condition and type of load bearing materials
- Building system of wall or roof.
- Window assembly
- Facade penetrations
- Location of the air-tight and vapour-tight layer in the existing structure
- The possibility of intervention with the building during renovation work.

It is necessary to make and air-tightness test and infrared or smoke tests to locate the air leakages in the envelope structures. In existing construction, the poor air-tightness of the façade is largely due to the air leakage through the joints between the panels, blocks, building components and services penetrating the wall. In renovation of buildings, due to moisture performance, new insulation should always be placed externally to improve the thermal performance. The air leakage has to be reduced by additional measures. Furthermore, the air barrier that reduces air leakage should be positioned so as not to cause the risk of condensation. An additional vapour barrier may be required to eliminate risk of interstitial condensation, and this may also act as an air barrier.

It is important to identify the main points of air leakage before making a decision on measures to make the envelope more air-tight. Also, a proper fresh air flow for good indoor air quality has to be ensured as in old buildings the main ventilation comes through windows and air leakages in the envelope. Measures to improve the air-tightness include, i.e.:

- A material layer that has a recommended air permeability of 1 x 10^{-6} m^3/m^2 s Pa maximum, including all joints, e.g. a plastic film vapour barrier with over-lapping and sealed joints. This enables to fulfil the air-tightness requirement of a passive house. Air barrier is possible by

    - Adding a membrane on the inside of the building with an additional layer as the finished surface. A 30 mm cavity may be introduced between the interior boarding and existing wall in order to allow for services to be passed through it. Special attention should be paid on the wall to roof and wall to floor connections, as it may be impossible to seal these connections thoroughly only from inside.
    - Adding a membrane externally to the load bearing structure or existing façade with at least 3/4 of the total thermal insulation capacity outside the air barrier layer to avoid any condensation on air barrier.

- Air barrier needs to be continuous over the whole building envelope area, especially at the connections between building parts, service installations, etc..

- Window or door frame to wall connection should be filled with insulation, and sealed from both sides. It is recommended to use positioning systems for windows because of their heavy weight and necessity to provide good connection to the structure without gaps, or alternatively to integrate the windows in a prefabricated walling system.

- Ventilation ductwork installation should locate inside the air barrier. Only fresh air and exhaust air ducts need to penetrate the air barrier.

- The HVAC and sanitary installations and service penetrations of electricity, water, gas, and etc. systems should be sealed using flanges or other means of tightening either on the existing wall or inside of the new over-cladding system..

- Boarding or concrete element structures with sealed joints, fair-faced inner brick walls with plaster perform as air barriers

- Closed-cell insulation board externally to the existing wall with sealed joints.

<u>Moisture performance of renovated facades</u>

Generally, the exterior thermal insulation systems for over-cladding have a good hygrothermal performance in all climates, independent on

- Insulation thickness
- Slight ventilation or none of the cavity between the old and new structure
- A moderate water intake e.g. from driving rain

An exception is a structure where vapour tight layer is on the interior side of the over-cladding system. The hygrothermal performance of the structure is not acceptable unless:

- The existing wall structure is completely dry (relative humidity < 50%) at the time of over-cladding
- 75% of the total thermal insulation locates outside the vapour-tight layer
- The gap between over-cladding and existing wall is slightly ventilated externally .
- In warm and humid climates, the risk of summer-time condensation should be analysed

3. Energy performance

Improved thermal insulation of an office or residential building results in decreased space heating demand but may result in increased cooling demand. The heating demand can reduce by 50 - 60 % with well-designed over-cladding and over-roofing with proper, climate depended additional thermal insulation and ventilation with heat recovery.

The additional thermal insulation level for renovation depends on the climate but also on the building type, form, building rights, etc. The following guidelines should be taken into account when designing energy renovation:

- The target energy-efficiency level should be decided at the briefing of the project. The process should include all designers in the process. There are many voluntary techniques for very low energy buildings such as ‘passive house’ approach, Minergie standard or even net or nearly zero energy buildings. The decision is dependent on total costs and financing of the project.
- An efficient energy renovation requires always a whole building approach. The best energy demand/cost ration can only be achieved by looking all aspects of energy efficiency improvement as a whole.
- Reduced heating demand may lead to increased cooling demand. Passive cooling strategies should be applied to reduce or avoid the need for mechanical cooling.
- A condition survey needs to be carried out to investigate the condition of the existing facades and to study the possibilities of over-cladding and over-roofing. In many cases demolition of the existing building is economically more beneficial that renovation
- Increasing the thickness of a wall or a roof leads to other actions such as re-building the eaves, insulation of the foundations and due to architectural reasons also new windows or changing the position of the windows.

- Additional insulation in walls and roofs become economically more beneficial in connection to necessary facade renovation.
- New windows are seldom economically feasible. If the existing windows are technically in poor conditions and need to be changed, the energy benefit of new high performance windows can cover the extra costs compared to typical windows

4. Solar energy applications for over-cladding

A building integrated solar system is a system that collects solar energy and converts it into thermal or electrical energy to cover a part or all of the buildings energy demand. Typically these systems serve for space heating, hot water heating, or electricity generation. Systems that serve for multiple purposes may become more cost-effective than systems that have only single use. Therefore integration of solar systems into building components is advantageous.

Solar thermal system typically refers to water based energy system for hot water and space heating.

A solar air system is a system that collects solar energy for heating of air. The system consists of a collector and air circulation system. The collector's absorber surface converts the solar energy into heat. Air is circulated behind, through, or above the absorber. Air circulation transports the heat to either direct use or to storage for use.

The collector may be a façade or roof integrated panel that is either glazed or not. The panel can also be a part of the buildings weather skin. Solar air systems can serve multiple purposes, such as

- space heating
- heating or preheating of ventilation air
- water preheating
- solar cooling
- electricity generation by PV/hybrid systems

Solar air systems are suitable especially in renovation of buildings with poor energy performance. These systems can improve air change in buildings, however, in many countries the purity requirements on supply air do not allow for using the building envelope as a fresh air route.

The energy benefit of a solar air system reduces as the heating energy demand of a building reduces. Typically, solar air system applications are especially beneficial in large buildings with high air volumes.