Examplary Retrofitting of an Old School Building in Stuttgart (EROS)

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Aim of the Project

By the EROS Project the potentials of a retrofitting process for a typical school building in West-Germany were to be demonstrated from an energetic point of view.

Combining the renewal of the space heating system with the reconstruction of the building envelope yields synergetic effects. The project aims at minimizing the future energy consumption and optimizing the economy of the retrofitting at the same time. Thus, both operating costs and emissions are reduced. The goal is to improve the thermal insulation at least according to the standard of the German regulations on thermal insulation (1995) for new buildings.

The Building Complex

The block of buildings to be renovated is a primary school in the city of Stuttgart, built in several segments during the thirties, the fifties and the seventies. The floor area of 5420 m^2 includes the classrooms, halls, lobbies and staircases and a gymnasium. Each part of the construction is typical for its period. Thus the building represents the average school building in the western part of Germany.

Energy Consumption before Retrofitting

The energy consumption in the early nineties averaged at about 210 kWh/m^2a, the original value of 1977 being 382 kWh/m^2a. This was mainly the result of "good housekeeping", that is 'no-cost measures'. The Normalized Performance Index (NPI) for electricity was 11 - 12 kWh/m^2a.

The Project

Supervised by Stuttgart's municipial office of environmental protection, the Fraunhofer-Institut für Bauphysik (IBP) and the Institut für Kernenergie und Energiesysteme (IKE) worked out an action plan from an energetic point of view. In this process the municipial office for construction, the architect, engineers and our project partners from industry were involved. The conceptional phase was completed during spring 1996. An architect together with an HVAC-engineer planned and realised the retrofitting, supervised by the municipial office for construction. The work in the school buildings started in the summer break 1996 and is to be finished until summer break 1997. Åfter the realization phase a two-year period of measuring the actual energy consumption has to give proof of the concept.

The first step was to get a detailled picture of the status quo. Both the building envelope and the heating system had to be analyzed. Based on surface area, heat transmission coefficients and the occupation of the building, the theoretical heat demand was calculated. The IKE did the analysis of the heating system including boilers, piping, control and radiators.

Status Quo of the Building Fabric (IBP)

From an energetic point of view the building fabric met the requirements during the time of construction: The first segment, building 1, is a solid brick building. In the 1950's a reinforced concrete building with solid brick clothing was added (building 2). Building 3, added 20 years later, is a reinforced concrete framework with three-ply-boards as internal and external thermal insulation.

All buildings suffer from severe heat losses through heat bridges, especially at the building component connections. The windows are mostly composite windows with wooden frames (double glazing) without sealing. They show severe deficiencies. The lighting has to be considered as poor due to strong dazzlement - effects. Thus the artificial lighting is switched on during daylight hours despite sufficient daylight supply while the blindings are closed at the same time.

Concept of the Building

Due to the very heterogeneous wall types different thermal insulation systems are used. A list of possible insulation systems was developed (i.e. heat insulation plaster, composite thermal insulation, internal insulation). For all buildings, the greatest possible savings can be achieved by insulating the outside walls. Styrofoam as internal insulation will be applied where the original facades shall be kept untouched. On most of the other facades an external insulation will be applied. Different systems will be compared regarding energy efficiency and costs to gain experience for future planning. Insulating the roof of the gymnasium yields great savings, too.

Much smaller is the influence of improved windows. For the windows the potential of the passive use of solar energy and aspects of lighting have to be considered.

A low-E coated glazing with a lower thermal transmission coefficient (U - value) will reduce the heat loss of the building but at the same time suffers from a lower g-value and a lower light transmission due to the infrared reflecting layer on the glass. Thus north facing windows will intentionally have different properties compared to south facing windows. The glazing has to be optimized with respect to the total energy consumption including heat and lighting. Different types of frames (aluminum, wood-aluminum and PVC) combined with various glazings (k_v = 1,8 / 1,3, / 1,0 and 0,8 W/m^{2}K) are compared.

The roof of building 2 can be easily insulated by teachers and students themselves using styrofoam. The costs can be reduced significantly and the school community usually has a much closer relation to energy issues when own activities of the school community are involved. In other projects insulating roofs of school buildings (total area 13.000 m^2) we observed a reduction of energy consumption exceeding the calculated amount by a factor of up to 2.

The combination of measures with the optimum cost effectiveness was evaluated, at first for all building components separately. The next step was to compare the best solution for each component for the whole building. The annual heat savings are plotted versus the cost of the measurement. In this evaluation it is considered that additional insulation reduces the heat load and thus leads to a smaller heating system. (0,54 DM/W for the radiator and 0,18 DM/W for the boiler).

The replacement of the lighting system is not cost effective. Only if the painting of the room (higher reflection) and the new lamps are considered no cost measures, the additional control system is cost effective. In a segment of building 2 two different control strategies are implemented, both with the EIB system.

Status Quo of the Heating System

For the HVAC-system, too, the technical standard is typical for the time of construction. No major retrofitting was done so far. All three buildings of the school get their heat from a boiler house in the oldest building. The low-pressure steam boilers (1969) with 800 kW where originally fired with coal and later converted with an oil/gas burner. The boilers are switched on and off by the caretaker. Building 1 is still heated with steam, building 2 and 3 have a hot water system fed by a heat exchanger. Piping and radiators stem from the time of construction. The circuits have a weather compensating control with fixed time settings. In the classrooms no further control devices are installed.

operating status (window, blindings, lighting etc.) will lead to a precise understanding of the actual conditions in the school.

Financing

The financing of the project relies on three partners:
The city of Stuttgart takes care of the basic renovation. 11 partners from industry sponsor the project with a total amount of DM 700,000. The federal secretary of state for research gives an additional funding of DM 1,900,000 for the research part of the retrofitting. The project is calculated with total costs of DM 4,200,000.

Conclusion

When retrofitting old buildings, not only the building deficiencies must be repared. The complete building with both the building shell and the HVAC - system has to be analysed to find the concept with the best cost efficiency. With the low budget of the municipalities this approach is a novel one and will be hard to establish.