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## DESIGNING OF PASSIVE RESIDENTIAL BUILDINGS – CASE STUDY

### PROJEKTOWANIE PASYWNYCH BUDYNKÓW MIESZKALNYCH – STUDIUM PRZYPADKU

#### Abstract

This paper describes the process of designing the passive residential buildings. The analysis is carried out on the basis of the Mannheim project, created as an entry for the Isover competition – Multi-Comfort House. Particular steps of the design process are analyzed for meeting the requirements of passive standard building. The specific solutions adopted in the Mannheim project are presented as an example.

*Keywords: passive, residential, design, Mannheim, low-energy, passive house*

#### Streszczenie

W artykule opisano proces projektowania pasywnych budynków mieszkalnych. Analizę przeprowadzono na podstawie projektu stworzonego w Mannheim do konkursu Isover Multi-Comfort House. Poszczególne etapy procesu projektowania są analizowane pod kątem spełniania wymogów określonych w standardzie budynku pasywnego. Szczegółowe rozwiązania przyjęte w projekcie Mannheim przedstawiono jako przykład.

*Słowa kluczowe: pasywny projekt mieszkaniowy Mannheim, energooszczędny, dom pasywny*

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## Symbols

- $\lambda$  – heat conductivity coefficient
- $G$  – solar energy transmittance of glass
- $R$  – thermal resistance
- $U$  – overall heat transfer coefficient

## 1. Introduction

A passive building is an ultra low-energy building, where heat losses are minimized to the extent, when additional heat source is no longer necessary [1]. The annual heat requirement is equal to or less than 15 kWh/m<sup>2</sup>/year and the primary energy requirement is less than 120 kWh/m<sup>2</sup>/year. The standard is not confined to residential properties; several office buildings, schools, kindergartens and sports facilities have also been developed to the passive standard.

The project described in this paper was created as an entry for the Isover Multi-Comfort House competition. The main scope of the competition was to design residential buildings on the given site in Mannheim (Germany), while fulfilling the passive buildings' requirements. The features taken into account – apart from energetic requirements – included sound insulation, ease and time of construction, fire protection, architectural design and landscaping of the area. The assignment was to create a project of four buildings, accommodating 150 or less apartments and having the gross floor area of approximately 10440 m<sup>2</sup>. The orientation of the site is North-East, the site has a triangular shape, with the longest side of triangle facing North.

## 2. Analysis of site and location

The process of designing every building starts with the analysis of site's orientation and possible building's location [3]. In case of passive buildings, the orientation is crucial, in terms of heat gains through the solar energy. If there is a possibility of choosing the site's shape and location, the most efficient is a flat or South-sloping site, free of obstructions to the South. The shape of the site should allow accommodating a relatively large southern wall. The principle is that the majority of windows should be located on the southern façade – it will maximize the heat gain through the solar energy and therefore its year-round temperatures and comfort. On the other hand, the number of transparent openings on the northern façade should be minimized or not used at all in order to maintain the highest wall insulation possible. The leaning walls were oriented South and the shorter base South-West, which was much more efficient in terms of solar energy, than the rectangular shape. The form of trapeze had to be modified in order to obtain a shape with no acute angles, which are disadvantageous in terms of insulation.

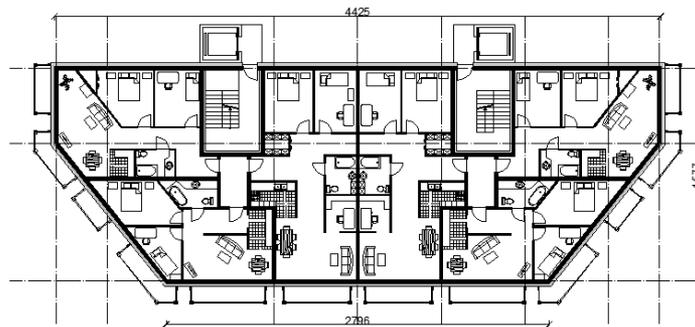


Fig. 1. First floor plan of the Mannheim building

### 3. Building layout

In the Mannheim project the residential building had to be planned with ca. 6 flats on each floor, which meant the need to provide as much daylight to every flat as possible, while maintaining the northern wall of the building with as little window openings as possible. In addition the vertical transport zone with the elevator shaft had to be planned. Such task led to several problems – first, the transport zone had to be placed. The simplest solution in terms of delivering daylight to all apartments would be to place the core in the center of the building. However, such solution is not acceptable for passive building – the elevator shaft does not fulfill the air-tightness regulations, therefore it has to be placed outside of the insulated part of the building. Due to space restrictions placing the elevator shaft along with the staircase outside of the mass of the building was not possible. The solution applied in the project consisted of the heated staircase placed within the building and non-heated elevator shaft placed outside. Such design allowed maintaining a simple line of the thermal insulation and was space-efficient, however required heating the staircase, which could generate additional costs.

### 4. Thermal insulation

Thermal insulation is one of the most important features of a passive building. Obtaining the correct U-value of exterior walls and ceilings is essential for controlling heat loss and gain. The most important principle is that the thermal insulation must be of highest quality and must form a closed and continued building envelope. The form of a passive building should be as compact as possible. Required and recommended values of  $\lambda$  are shown in Table 1. In case of Mannheim project, the prefabricated concrete system VST was used as a structure of whole building. The insulation of the exterior walls was designed as a 25 cm layer of Isover Multimax. On the flat roof, a 32 cm layer of Isover Exporit was used. Such solution allowed obtaining the U-factor equal to 0.10 W/m<sup>2</sup>K for both flat roof and exterior walls (Table 1). The occurrence of thermal bridges has significant influence on the performance of the building

envelope [1, 2, 4–9]. The problem of thermal bridges has been solved using typical solutions for passive buildings. Separate steel supporting structure for balconies allowed to get rid of cold bridges in connection between walls and balcony slab. To assure correct connection between insulation of vertical walls and slabs, the insulation blocks with heat conductivity as low as 0.2 W/mK were used.

Table 1

***U*-value [W/m<sup>2</sup>K] for non-transparent exterior partitions in Mannheim building**

Partition type	<i>U</i> -value	Thickness and type of insulation	Total partition thickness
	[W/m <sup>2</sup> K]		
Exterior wall	0.105*	25 cm	53.5 cm
		Isover MULTIMAX 30 $\lambda = 0.03$ W/mK	
Flat roof	0.10*	32 cm	51.5 cm
		Isover EXPORIT $\lambda = 0.035$ W/mK	
Slab above unheated basement	0.127*	15 cm	46 cm
		Isover TOPDECK $\lambda = 0.032$ W/mK	
* Required value: 0.15 W/m <sup>2</sup> K recommended value: 0.10 W/m <sup>2</sup> K of <i>U</i> -value.			

## 5. Windows and glazing

Windows and doors can account for more heat gain or loss than any other element in an insulated building envelope. A well designed glazing system can improve internal daylight levels, reduce glare, and help maintain thermal comfort by reducing heat gain and loss. This contributes to energy efficiency by reducing the need for artificial heating, cooling or lighting.

By considering the transmission of heat and light through the glazing system at the design stage of the project, the window performance can be significantly improved.

Maintaining the heat loss through windows and glazing as low as possible is essential for obtaining good results in thermal calculations of the building. Windows used for passive buildings are required to have low heat conductivity (low *U*-value), as well as high solar energy transmittance of glass. Special types of windows are produced with insulated frames, as well as double or triple glazing and argon filling. Such solution assures excellent performance of windows (*U*-value even as low as 0.6 W/m<sup>2</sup>K) and maintains the temperature of interior surface close to the air temperature in the room. Apart from type, the windows size plays significant role in heat gains and losses. On the southern wall, the area of glazing should be as big as possible, as the windows deliver more energy than they cause heat losses. The optimal glazing area for south facing façade is 60% of whole wall area, however the quality of glazing is far more important than quantity.

The windows used in Mannheim building are double glazed, argon filled VADB Plus 550+ windows with glazing of  $U_g$ -value of  $0.7 \text{ W/m}^2\text{K}$ , fixed in insulation layer. The approximate area of the southern wall glazing is 50% of wall surface. Initially windows with less effective features have been assumed, however after performing the calculations in PHPP package it turned out, that the results were not sufficient. Only changing the type of the windows had a significant effect on the results, while enlarging the area of glazing did not change the results in a meaningful way. The calculations proved that the type of the window is the key feature in glazing design.

## 6. Analysis of shading

Shading should be designed to take into account the sun's path in summer and winter. Diversity of sun shades, blinds and eaves should be used in order to control the transfer of solar energy into the building. In order to avoid the possibility of over-heating the rooms in summer – when the sun position is high – the system of sun protection should be used. On the other hand, during winter – the solar energy is desired and helps to heat the room. System of sun protection should be designed after carrying out shading analysis of the building, including such factors as sun position, as well as possible surrounding obstacles shading the building. Vegetation could be helpful in shading design – it causes shading in summer, when the leaves are growing and passes the sunlight in winter.

The shading in Mannheim building has been assured by balconies – placed on the southern wall – which served as eaves in summer, and in winter did not block the sun in its lower position. Additionally, the moving, fixed on rollers sun blinds have been used to allow users of flats to control the quantity of sunlight coming through to the rooms. Climbing plants – such as clematis or vine – planted on balconies serve as 'vegetative' blinds in summer.

## 7. Airtightness

Building envelopes under the passive standard are required to be extremely airtight compared to conventional constructions. Airtightness is achieved through air barriers, careful sealing of every construction joint in the building envelope and sealing of all service penetrations. In airtight building the air flow is easier to control. The building is also more resistant to humidity – its acoustic parameters are not influenced by gaps in structure and heat losses are smaller. Airtightness is controlled by blower door test, in passive buildings the requirement of airtightness  $0.6 \text{ h}^{-1}$  has to be kept.

In Mannheim building, the airtightness has been assured by variety of means. In residential buildings of more than 4 floors an elevator is required, however it cannot be used in a passive airtight building – since elevator shaft is not possible to insulate. That issue was solved by designing the building layout with elevator on the outside of the building. Every joint and connection in the structure have been analyzed and designed with precision regarding airtightness and thermal bridges. Additionally, the chosen window type also fulfilled the passive standards. Blower door test produced the result of result of  $0.6 \text{ h}^{-1}$ , which is a required value for building developed to a passive standard.

## 8. Heat recuperation and ventilation

As passive buildings are exceptionally airtight, the use of mechanical ventilation is required in every design. Ventilation serves mostly as a source of fresh air – essential for well-being and health of building's users. Recommended plan of ventilation comprises possibly short and not branched ventilation ducts. Air speed at normal usage must not exceed 3 m/s in any duct. Heating of passive house is dependent on climate zone – in temperate climate, a heat recovery system is necessary, as insulation alone would not be sufficient to warm the house in winter. There are several types of heat recovery systems, all of which however, have to meet the requirement of minimum 75% heat recovery rate.

The system assumed in calculations for Mannheim building is an internal heat recovery ventilation system, with 75% heat recovery rate and easy reach to every flat.

## 9. Conclusions

Designing a passive building involves multiple tasks and problems, which have to be solved in order to obtain a passive standard building. Designing a residential building raises even more complex issues, which have to be faced. However – with materials and solutions available today – every residential building can be a passive standard building.

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