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Guidelines for implementing the Passive House concept in the city and the surroundings of Urumqi, Xinjiang, China

Introduction

Passive Houses are buildings constructed according to a highly energy efficient building concept. With minimal energy consumption, they provide a very high living comfort for the residents throughout the year, in terms of thermal comfort and excellent air quality. The essential properties of a Passive House are an optimised building envelope - in order to reduce the transmission losses and allow suitable use and control of solar gains - and a significant reduction of ventilation heat losses. The requirements for the components of any individual building that is to be built to meet the Passive House standard are essentially governed by the local climate. This report summarises the results of a study carried out to investigate suitable approaches to implementing the Passive House concept in the climate of the city and surrounding areas of Urumqi in Xinjiang, China.

All calculations were carried out with the well established Passive House Planning Package (PHPP) and are based on the model of an end of terrace house that was built within the context of the EXPO 2000 in Hannover, Germany. The individual components and characteristics of this building were varied systematically in order to provide a first orientation which factors need to be considered most when designing a Passive House in Urumqi. Aspects that were considered are the required insulation level, window quality and size, orientation, airtightness, efficiency of heat recovery, the building's compactness, shading, summer ventilation concepts etc.

Climate

Climatic data were used from the EOSWEB source on the internet [EOSWEB 2009] and from the Meteonorm database [Meteonorm 2008]. Temperature data were also taken from several sources as reported by ifeu, Jianfeng Chen. The radiation data were processed to fit the specific PHPP format.

Climatic data sets were chosen for two locations, the greater Urumqi region and the city center. These two climatic data sets differ due to two reasons: elevation and smog. Urumqi itself is located at an elevation of about 900 m. The region to which the EOSWEB data refer covers a whole 1° by 1° grid cell, with an average elevation of 1777 m. This would usually result in temperature differences of 4 to 5 K. In summer, a corresponding temperature difference of approximately 4 K can indeed be perceived between the EOSWEB data and the ground-measured Meteonorm data, whereas in winter this temperature difference is reduced to approximately 1 K. Given the special microclimatic situation, with high mountains surrounding the city and low wind speeds during wintertime, formation of a cold air layer in the valley appears plausible. Therefore, the Meteonorm temperatures (which are close to those given by the China Meteorological Administration) were used for the city center without correction. For the surroundings, the EOSWEB data were used. The PHPP includes the possibility to make elevation corrections. This was applied for both data sets with a correction to 930,5 m for the city and 1665,5 m for the surroundings, in accordance with supplied data for planned projects. These corrections, however, are relatively small in both cases and therefore do not have a significant effect on the results.

Urumqi is said to be the most polluted city in the world, with heavy haze frequently obscuring the view of the sky [Li 2008]. The smog is supposed to be due to vehicle exhausts, coal-fired power and heating plants, and cooking. Pollution levels are heaviest in winter and comparatively moderate in summer. Typical visibilities in the city centre in winter appear to be on the order of 20 km. The solar radiation data given by Meteonorm are an interpolation from several stations, the most important of which is located at 3 km distance from the centre of Urumqi. These data are about 25 % lower than the EOSWEB data in winter and about 10 % higher in summer. To provide a conservative estimate regarding the smog situation, another 10% reduction of the winter data was applied for the city centre, whereas the summer data for the city center were used without correction. For the surroundings of the city, the EOSWEB radiation data were used without corrections.

Heating and cooling load data were also adapted to the specific temperature and radiation situations.

What is a Passive House in Urumqi?

The results confirm that it is possible to achieve the maximum 15 kWh/(m²a) energy demand of Passive Houses in the climate of Urumqi, with reasonable optimization methods. As shown in Fig. 1, the results indicate however, that the corresponding heating load in this climate will be higher than 10 W/m², the approximate limit for the feasibility of supply air heating. This implies that space heating solely via the supply air might only be possible with further improvements to the building; otherwise an additional or alternative heating system will be required. Solutions can be found that eliminate the need for active cooling in summer.

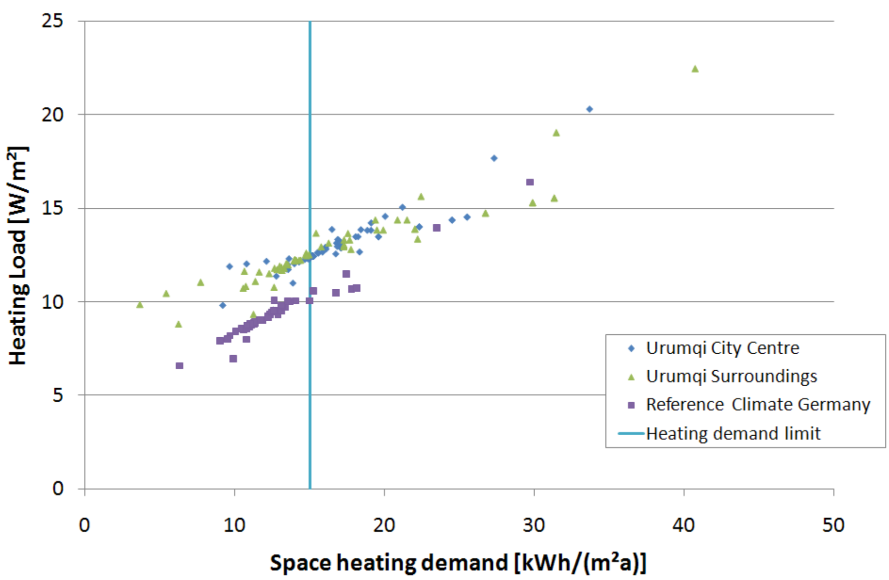

Fig. 1: Heating demand versus heating load of various calculated building characteristics.

The certification criteria for a Passive House in the region of Urumqi will, for the moment, remain the same as valid for the cool temperate climate of Central Europe[1]:

Specific Space Heating Demand	max. 15 kWh/m²a
or Heating Load	max. 10 W/m²
Useful cooling demand	max. 15 kWh/m²a
Pressurization test result n_{50}	max. 0,6 h^{-1}
Entire Specific Primary Energy Demand	max. 120 kWh/m²a

Recommendations / Guidelines

The basic method for achieving the Passive House standard in the climate of Urumqi remains the same; the essentials being:

- Reduced transmission losses via the building envelope with adequate insulation levels, minimised thermal bridges, high quality triple-glazing and insulated window frames.
- Reduced ventilation heat losses thanks to an airtight building envelope and mechanical ventilation with efficient heat recovery
- Passive heating by making use of available solar gains
- Passive cooling with shading devices and suitable ventilation concepts

When planning an energy efficient house it is also important to keep in mind the importance of a compact design and of the orientation. Reducing the surface area of a building with a certain volume significantly reduces the heating demand. From experience the relationship between the A/V-ratio and heating demand reduction is almost linear. The significance of the building's orientation is more complex, it is a determining factor for the solar influence on the energy balance and summer comfort. Southern orientation is generally favourable because the solar gains are maximised during winter but can easily be blocked with a horizontal overhang for shading in summer.

The winter temperatures in and around Urumqi are considerably colder than in Central Europe, which calls for higher insulations levels and makes it more difficult to reduce the ventilation losses. The calculations carried out with the PHPP indicate insulation thicknesses between 300 and 450 mm, depending on the compactness, orientation and quality of other building components. This corresponds to U-Values lower than 0,1 W/(m²K); the requirements being slightly stricter for the city of Urumqi with recommended U-Values lower than approx. 0,08 W/(m²K). Due to the cold outside air temperatures the airtightness of the building becomes more significant and one should aim for as low a value as possible. For Passive House certification the pressurization test must yield a result of max. 0.6 ach at a pressure difference of 50 Pa. Experience shows that even lower values can be reached in practice, appropriate planning provided. The heat recovery of the ventilation system should be highly efficient, in the range of 90%.

In order to compensate for the comparatively high transmission and ventilation losses it is very important to make use of available solar gains for passive heating. The average monthly global horizontal radiation during winter of around 99 kWh/(m²Month) is nearly twice as high in the surroundings of Urumqi, in

[1] The up-to-date certification criteria are available on www.passiv.de

comparison to the German reference climate from [DIN 4108-6], where it is only 50 kWh/(m²Month). Even in the city of Urumqi, where the incoming radiation was assumed to be noticeably reduced due to the effects of smog, the average value of 74 kWh/(m²Month) is still higher than in Germany and plays an essential role in compensating transmission losses. Optimising the window size, quality and orientation during the building design stage is therefore a very important aspect for reducing the heating demand. An open location where the sun is not constantly blocked by neighbouring high-rise buildings, trees etc., is very beneficial.

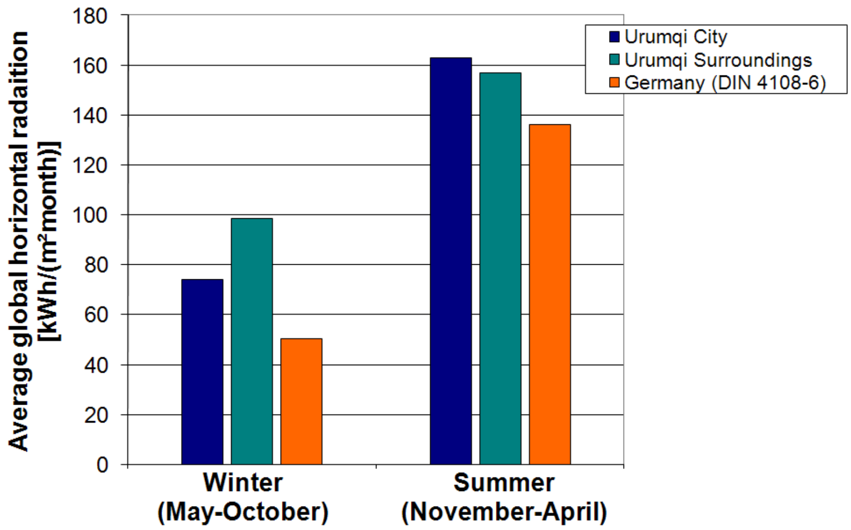

Fig. 2: Average global horizontal radiation in the city and the surroundings of Urumqi during winter in summer, compared to reference values in Germany.

The climate in <u>summer</u> is also more extreme than in Central Europe, with higher temperatures and more incoming solar radiation. The PHPP results indicate that summer comfort in a Passive House can nevertheless be achieved without active cooling, if appropriate passive cooling methods are used. One important aspect is the reduction of solar loads with exterior shading elements. Interior shading is a lot less effective and will definitely not provide enough protection in this sunny climate. Fixed elements, for example an overhang can be used to provide some shade, always keeping in mind that they might also affect the beneficial solar gains in winter. The best solution are moveable blinds, shutters, or the like, that can be manually or even automatically adjusted to the current needs. Especially in the city of Urumqi moveable exterior shading will be an essential component of a Passive House. Internal heat gains should also be minimised by using efficient equipment. Any Passive House built in and around the city of Urumqi will require additional summer ventilation, regardless of the shading situation. This can be implemented manually by tilting or opening windows when it is cooler outside than inside the building (e.g. at night) or by automatically increasing the mechanical air change rate when appropriate. The highest air change can be achieved with cross ventilation through the windows; this should be kept in mind when positioning the windows during the design stage. With no active cooling present, the PHPP calculates an overheating percentage which corresponds to the number of hours per year during which the average indoor temperature exceeds 25 °C. For comfort reasons this should not exceed 10%, the PHI generally recommends aiming below 5%.

Windows are a central component of any Passive House, both for the summer and for the winter comfort. The requirement is always to find a suitable and affordable solution for the local climate. The cold, yet sunny winter of Urumqi calls for low U-values in order to minimise transmission losses and ensure thermal comfort, but it also calls for a high g-value in order not to block the needed solar gains. Even triple glazing with a well-insulated frame, as they are certified and used for Passive Houses in Central Europe, might not suffice to fulfil the Passive House Comfort Criterion during very cold periods in Urumqi. The surface temperatures must not fall below approx. 16 °C in order to avoid uncomfortable radiation asymmetries and, in a worst case scenario, the growth of mould. This aspect needs further consideration. One possible option might be e.g. the use of countersash windows, with an exterior well-insulating and separately framed element that can be removed when not needed. This additional element could be glazed and permanently fixed during the winter months or alternatively contain an insulating panel, which could then be used to cover the windows at night when the outside temperatures are very low.

The climate in the city of Urumqi is less favourable for building a Passive House than that in the greater region around the city. It is colder and less sunny in winter but also warmer and sunnier during summer. The recommended approaches and methods for energy efficient construction are the same for both locations but it will certainly be easier to reach the Passive House standard outside of the city. The PHPP should be used in the very early stages of planning a new building in order to assess the relevance and high quality requirements for individual building components.

Literature

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