Chapter 14
The Impact of Forms of Buildings on the Air Exchange in Their Environment:
Based on the Example of Urban Development in Warsaw

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ABSTRACT

Possibilities for energy-efficient, natural ventilation of buildings in an urban environment depend on the airflow around them. This chapter deals with the issue of dependence of air exchange in urban spaces on the building forms used in them and on relative position of these buildings. The authors focus on the problem of air stagnation in dense urban development. This phenomenon increases the energy demand of buildings. The purpose of the following study is to present this problem and identify it in the selected example of existing settlements in Warsaw. The existing situation was compared with the revised spatial layout. The conclusions relate to spatial features of those building arrangements that are exposed to the problem of insufficient ventilation.

INTRODUCTION

Currently more than half of human population inhabits cities and this share is constantly rising. It is likely that by the year 2050 the figures describing the population dwelling in cities will have reached up to 70%. Cities tend to be the largest centers of housing, services, culture and communication, as well as being the largest sources of energy consumption and emissions of harmful substances. Urban housing development is therefore among the most important targets for the development of energy-saving strategies, including the modernization of existing buildings that were built in various historical periods.

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Making the proper use of natural components of the climate is an essential element of building energy concepts for nearly zero energy buildings (nZEB). The city's natural environment is strongly transformed by anthropogenic factors and as such creates a specific meso and micro climatic environment. Studies on the nature of meteorological phenomena taking place in cities reveal the interpretation of the city structure as being a surface strongly deformed in comparison to flat surfaces or surfaces slightly deformed by such factors as terrain shaping. In the latter cases, climatic factors such as sun, wind or rain are not obstructed by complex obstacles, which is the case in cities. In addition, most of the surfaces on which climate components exert influence in urban layouts consist of paved surfaces, walls and roofs of buildings, all of which happen to be heat accumulating surfaces (Harman, 2003). Thus, physical processes related to solar radiation, temperature, airflow or water circulation differ from the ones present in non-urban areas and are frequently far more complex and varied. Moreover, those processes are closely linked to the geometric shaping of the buildings, as well as their mutual arrangement (Ratti, Di Sabatino, Britter, 2006). The subject matter to be discussed in the following chapter is the aerodynamic phenomena that take place around such urban developments in case of which the link is particularly clear, as these phenomena affect the thermal characteristics and the air exchange in the building environment, which in turn in a factor directly influencing their energy economy (Ratti, Baker, Steemers, 2005).

In the case of temperate climate, which is being discussed in the chapter, the indication for wind conditions is that there is a need to protect against cool winds and rapid wind acceleration, both of which are characteristic of particular geometrical configurations of building developments (for instance high rise building environments, narrowings in building developments, long, densely built up streets, corners and creases of the building line). At the same time, proper air exchange in urban areas must be ensured. Air stagnation not only severely impairs the urban areas microclimate, but also negatively affects the energy efficiency of buildings (Che-Ani, Shahmohanadi, Sairi, Mohd-Nor, Zain, Surat, 2009). As a result of air stagnation, natural ventilation of buildings (especially at summer nights) becomes inefficient; hence such buildings display an increased demand for cooling. What is more, the multiplication of the phenomenon of too little local air exchange over a large area leads to exacerbation of the effect of urban heat island. This results in overheating of the city space and the accumulation of air pollutants.

The following chapter focuses on the problems of air stagnation in urban layouts. The phenomenon may generally be considered as having a negative impact on buildings that display low energy demands. It decreases the possibility of employing natural and hybrid ventilation and intensifies the problem of interior overheating in the summer season.

The purpose of the following chapter is to identify the phenomenon in densely built up urban areas. In the first part of the chapter, the issue of airflow around buildings has been presented, together with research methods and the theoretical background that determines the connection between wind parameters and the heat phenomena that appear in buildings. In the second part of the chapter, an analysis of the airflow around the building complex of a selected part of Warsaw has been performed. The example represents the spatial determinants of central inner-city zones of today's large Polish cities in which quarterly buildings with high density are predominant.

For the purpose of the following chapter, the results of experimental research conducted on 1:400 scale building models in the average speed aerodynamic tunnel were used. The aim of the experiment was to investigate the correlation between the phenomenon of air stagnation and the geometry of building development.

In each case, the existing situation was compared with the adjusted variant, the purpose of building development shape adjustment being the minimization of the observed phenomenon. Also, hypotheses

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