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Research on the Influence of the Distribution Pattern of Building Clusters in Coastal Areas on Wind Environment -Focused on Busan area in Korea

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Abstract. With the development of urbanization, the heat island phenomenon has led to further deterioration of the urban thermal environment, resulting in wind environment differences. To study the thermal environment of the city, this paper takes the Busan area in South Korea as the research object and analyzes the connection between the layout of buildings and the wind environment based on the microscopic wind environment characteristics of the coastal area using CFD air-fluid simulation software and suggests that the monsoon influence brought by the coastal currents should be paid attention to, the layout of wind-oriented building groups should be improved, urban air ducts should be established to enhance the ventilation efficiency, and the wind environment of the urban public environment and buildings should be guaranteed. The wind environment quality of urban public environment and indoor environment should be ensured.

1 Introduction

With the development of urbanization, dense high-rise buildings, increased artificial land coverage and urban heat island phenomenon affect the airflow in cities, leading to further deterioration of the urban thermal environment, resulting in differences in the wind environment from region to region. The wind environment has an important relationship with human thermal comfort and air pollutant concentration. In the environment of the accelerated industrial development process, air quality problems are becoming more serious due to the high concentration of fine dust in cities. Fine particulate matter hurts the urban environment and human health, so international environmental protection organizations pay more attention to the research related to air quality and wind environment. New environmental policies are being implemented to address the thermal environment and airborne fine dust in cities[1]. In this study, we investigated and analysed the distribution pattern of coastal buildings in Busan, Korea, and simulated the influence and connection between the layout of buildings and the wind environment based on the microscopic wind environment characteristics of the coastal area and investigated the reasonable distribution pattern of coastal buildings.

2 Theoretical background

2.1 Concept of wind environment

The main cause of wind is the difference in atmospheric pressure caused by the different warming of the surface. When the sun heats one part of the atmosphere differently than the other, it causes the warmer air to expand, so that the pressure at the higher temperature is smaller than at the lower temperature, and the air always moves from high to low pressure, and this air movement is the wind. During the daytime on the coast, the sun heats the air on land faster than the air over water. The hot air expands and rises, and the cooler air from the ocean moves to the land to replace the rising air[2]. Depending on the scale of the study, winds can also be divided into two categories: atmospheric circulation and local winds. The wind environment studies the direct interaction of the wind within the atmospheric boundary layer with human activities and created objects on the Earth's surface and is a comprehensive discipline with multidisciplinary interaction between aerodynamics and climatology, structural dynamics, etc[3]. The two main indicators used to study the wind environment are wind direction and wind speed. Wind direction refers to the direction of the horizon from which the wind blows, e.g., northwest wind refers to the wind from the northwest. Currently, 16 directions are commonly used to indicate the direction of the wind. Wind speed is a physical quantity characterizing the distance the wind advances per unit time in m/s. To

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visually describe the distribution of wind direction and wind speed, the wind rose diagrams are usually used to provide an overview of the local wind environment conditions.

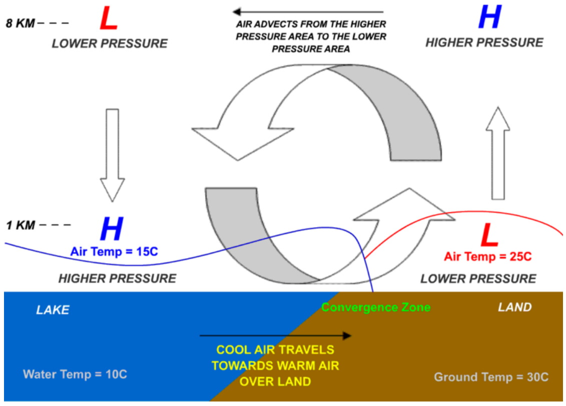

Figure 1. Weather & Climate. (Vaughan Weather, 2006)

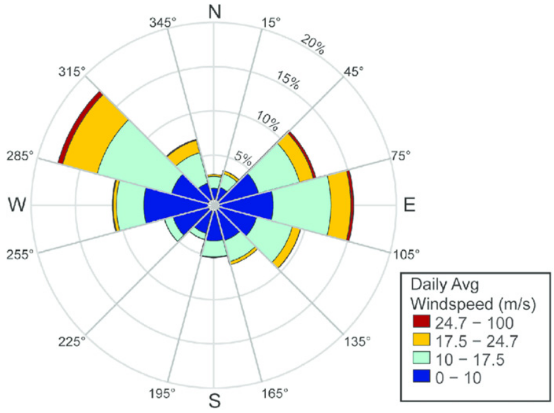

Figure 2. Wind rose diagram[4].

2.2 The influence of the distribution pattern of the building group on the wind environment

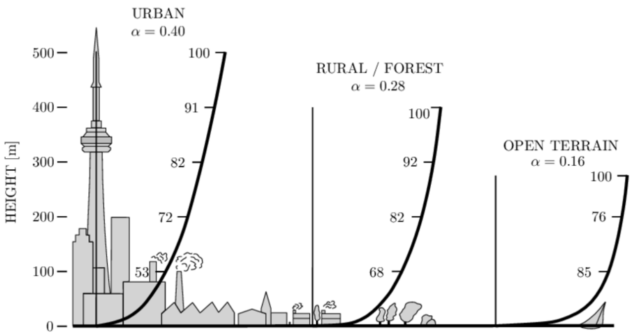

Figure 3. Gradient wind[5].

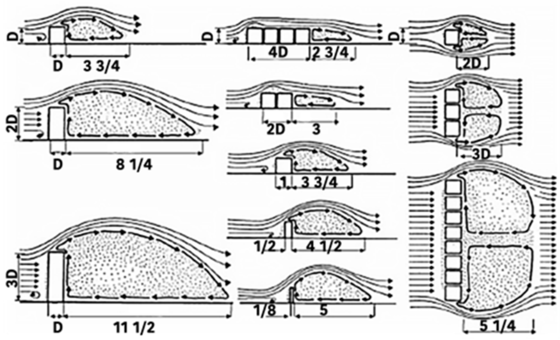

Figure 4. Environmental wind flows around buildings. (Brendan Rogers, 2016)

With the development of cities and the increase in population density, modern cities show a tendency to develop high-density, high-rise buildings. This pattern of building development increases the airflow obstruction in the city. Due to the high pollution emissions in densely populated streets, the unreasonable building distribution pattern leads to stagnant airflow and insufficient air diffusion, which leads to more harmful gas inhalation and endangers people's health. Therefore, the design of the appropriate high-density urban forms is essential to improve air mobility and air quality. As the building height rises, the gradient wind will be generated, as in Figure 5. The gradient wind effect will lead to high wind speed and high wind pressure on the surface of the building, which will not only lead to excessive airflow through some of the buildings but also negatively affects the indoor living environment inside the building. Different building layouts will produce different sizes of wind shadow areas. Its size is related to the shape of the building and the angle of wind projection. The wind shadow refers to the projection on the ground of the vortex area produced by the wind blowing towards the building at the back of the building. The wind in the wind shadow area is weak, the wind direction is not stable, which is not conducive to the downwind airflow around the building. The reasonable layout of the building group should be so that the downwind building is as little as possible blocked by the wind shadow of the upwind building[6].

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3 Investigation and analysis

3.1 The distribution pattern of building complexes in the coastal area of Busan

Figure 5. Aerial view of Busan coastal area complex. (Google map)

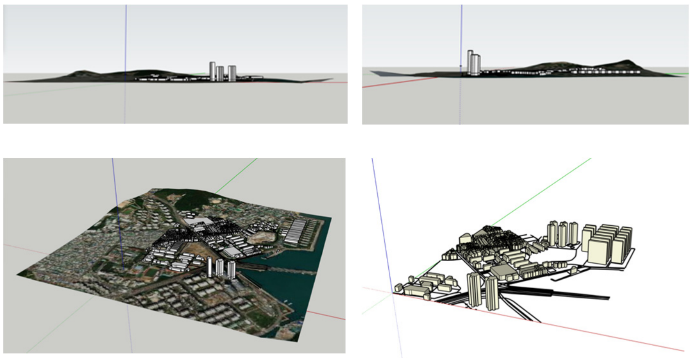

Figure 6. Modeling for the topography of the coastal area of Busan and a part of buildings complexes.

The main object of this study is the coastal area of Busan. Firstly, the geographical location of Busan was determined by a satellite map. Busan is in the southern part of the Korean Peninsula in the north-eastern part of the Asian continent and is surrounded by the sea on three sides. The city has a high degree of urban development, with a total area of 769.82 square kilometers, with dense buildings as the main distribution form. Busan is located at the southernmost tip of the Korean Peninsula, surrounded by the East Sea and the South Sea. Busan is a hilly area in the east centered on the Geumjeong Mountain Range (801.5m) and the Geumnyeon Mountain Range (415m), and a plain area in the west formed by the Nakdong River Delta, as shown in the information on the local meteorological characteristics of Busan released by the Busan Local Meteorological Bureau in 2000. The Geumnyeon Mountain Range develops from north to south along the southeast coastline, and the Geumjeong Mountain Range develops from north to south along the Nakdong River. The analysis of the building cluster modeling from the satellite map data shows that the single building form in the coastal area of Busan, Korea is almost all rectangular buildings, and the building clusters are mainly low- and medium-density high-rise clusters and high-intensity distributed low- and medium-rise clusters. The direction of building distribution is usually at a vertical angle to the coastline. From the coastal area to the inland area, the structure of the building stock is characterized by low to medium density high-rise buildings distributed in a linear pattern around the coastline, while the inland area is dominated by low- to medium-rise buildings distributed in a free and enclosed pattern, with high density and narrow space between buildings.

3.2 Analysis of the wind environment in the coastal area of Busan

The climate and wind environment of Busan can be compiled from the climate of Korea released by the Institute of Meteorology in 2004 and the characteristics of Busan local weather released by the Busan Local Meteorological Bureau in 2000. The general climate of Busan is influenced by the low latitude ocean along the southern coast, with an annual average temperature of 14.7°C and annual average precipitation of 1519.1 mm, which is a temperate climate with a warm and humid climate. The wind direction in the Busan area reflects the characteristic of north wind prevailing throughout the Korean Peninsula in winter under the influence of the Siberian continental anticyclone, and the southward wind prevailing under the influence of the marine high pressure located in the north. The overall wind direction in Busan is dominated by northeast winds, followed by northwest winds and southwest winds. the highest wind speed of 4.8 m/s is recorded in January and February, and the lowest wind speed of 3.7 m/s is recorded in June. In winter, when the cold continental high pressure expands, the wind can be unusually strong and often accompanied by rain. The wind speed in Busan is more than twice as high as the rest of Georgeanna-do, up to 3.7 m/s even in June when the wind is light. In addition, due to the influence of the coastal mountains, the wind strength of the coastal area differs from that of the inland basin surrounded by mountains in the Busan area, especially due to the influence of the coastal area, resulting in regional differences and strong winds such as typhoons.

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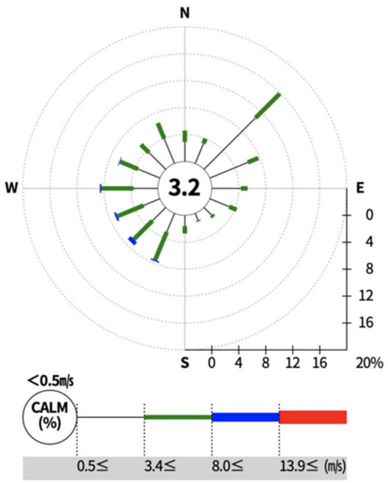

Figure 7. 2016-2021 Annual average wind value of Busan. (Korea Meteorological Administration, 2021)

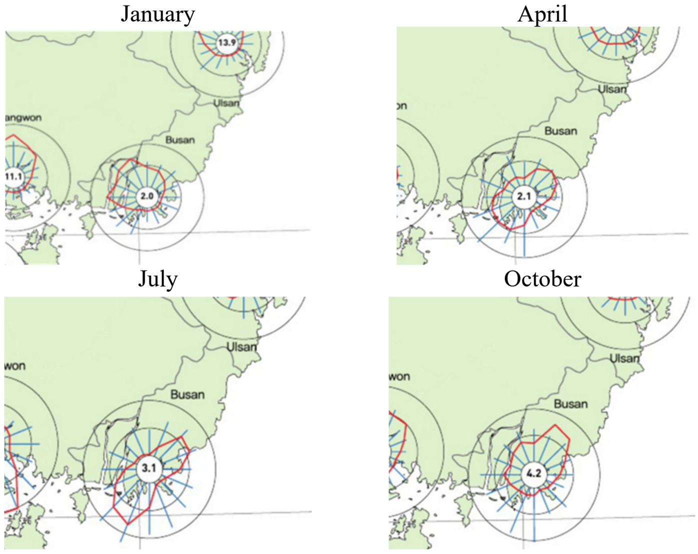

Figure 8. Average wind value of Busan in January, April, July and October. (Korea Meteorological Administration, 2012)

Since the distribution pattern of coastal building groups in Busan tends to be uniform, some of the building groups were selected for CFD simulation software analysis in this study. According to the effects of the distribution pattern of the building groups on the wind environment throughout the year and in different seasons (summer and winter), it can be seen that the influence of the coastal high-rise building groups in the upwind direction, due to the vertical angle between the orientation of the building groups and the wind direction in summer and winter, has a large windward area, forming a wind wall effect, blocking the entry of the wind, resulting in a very low ventilation efficiency, and creating a large wind shadow area in the inland area in the downwind direction, resulting in This results in a large wind shadow area in the downwind inland area, resulting in the inability to ventilate high-density low- and medium-rise buildings in the inland area. Due to the irregular distribution of high-density buildings in the downwind direction and the narrow space between buildings, more harmful gases are generated in the city that cannot be discharged and is hazardous to human health. Under the influence of the dominant wind direction throughout the year, the inland wind environment presents an overall environmental problem of low ventilation efficiency, resulting in low human comfort.

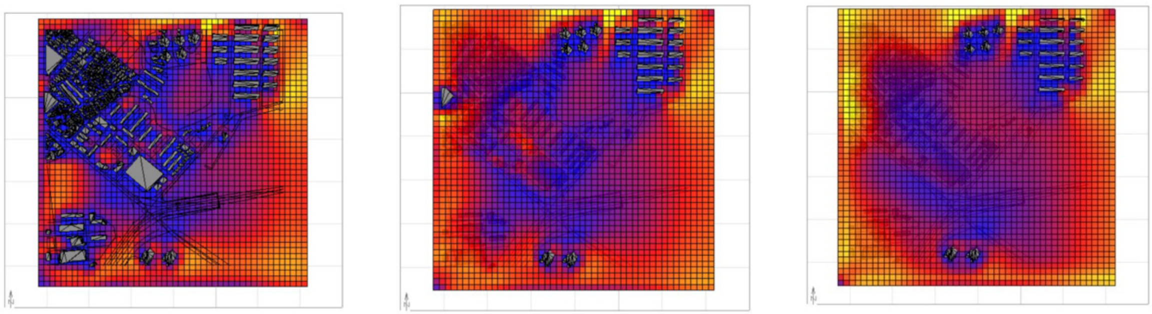

Figure 9. Year-round wind environment simulation analysis of the Busan coastal part of the building complex. (CFD air fluid simulation software)

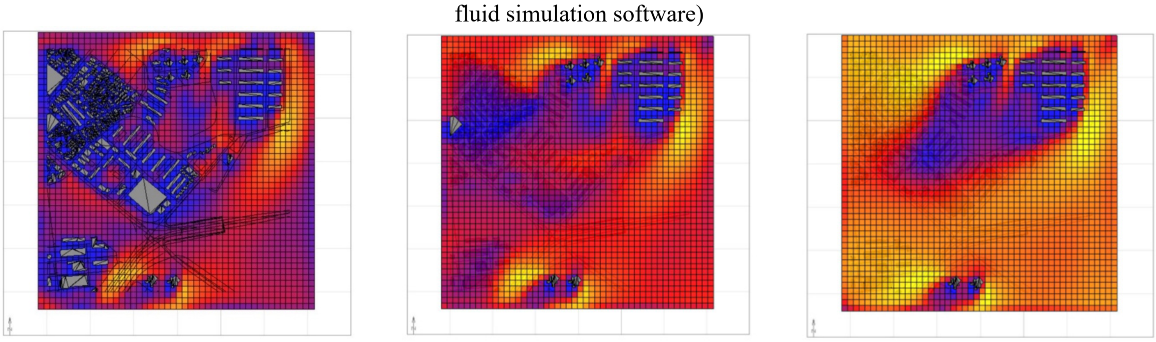

Figure 10. Wind Environment Simulation Analysis of parts of Coastal Building Complexes in Busan in Summer. (CFD Air Fluid Simulation Software)

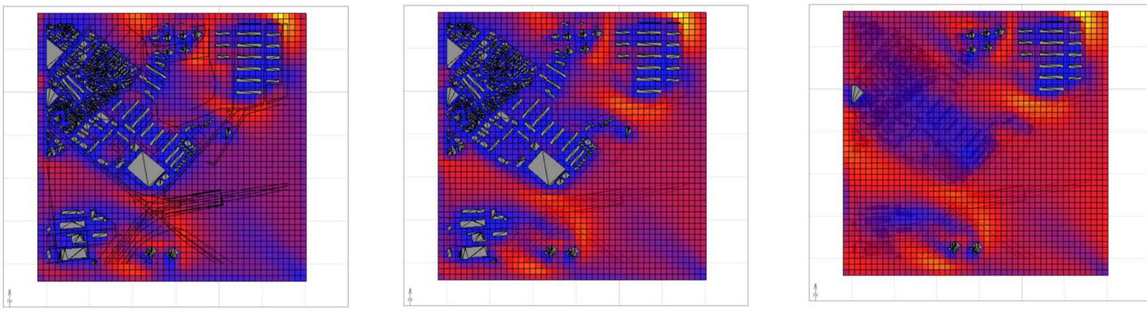

Figure 11. Wind Environment Simulation Analysis of parts of Coastal Building Complexes in Busan in Winter. (CFD Air Fluid Simulation Software)

4 Conclusion

Coastal areas have different climatic characteristics from inland areas, with large changes in wind direction, high wind speed, and natural disasters such as typhoons during the year. The layout of urban buildings has a great influence on the urban wind environment, which largely causes the unreasonable and disorderly wind field in the city. In this study, we suggest that we should not only plan according to the dominant wind direction throughout the year but also pay more attention to the influence of the monsoon brought by the coastal currents and analyze the seasonal wind direction more clearly and intuitively to analyze the environment of the area and improve the layout of the upwind building groups. It is also important to establish urban wind paths, to find the planning direction needed for future urban buildings, to use this wind resource more rationally, to design good building layout and form to solve existing wind environment problems, to improve ventilation efficiency, to improve human comfort, and to guarantee the wind environment quality of the urban public environment and indoor environment of buildings.

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These authors contribute equally to this paper and should be considered as co-first author.

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