Abstract of Thesis

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Title	Natural Ventilation Assessment using Computational Fluids Dynamics to Improve Air Quality in Urban Areas（都市大気質改善に向けたCFDによる自然換気評価）

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Urban areas represent a major environmental challenge because the air quality degradation in urban environments could impact a great part of the global population. The dispersion of air pollutants in urban areas is conditioned by the interaction of three main factors: the pollution sources, the urban form and components, and meteorological variables. Appropriate quantitively and qualitatively assessment of these interactions will allow better urban planning practices to reduce air pollution in cities.

In the second chapter of this doctoral dissertation, a review about urban modeling scales, urban geometries types, and mathematical formulation to numerically model urban areas using Computational Fluids Dynamics (CFD) is presented.

The third chapter presents a qualitative and quantitative assessment of the interaction between meteorological variables and the urban form and components. Three ideal urban environments are studied to investigate urban features such as building packing density and the relationship with meteorological variables. Also, two real urban environments located in Osaka, Japan, are presented. The locations were selected to identify the variables influencing the ventilation efficiency in urban areas. The ventilation efficiency indices employed were the local age of air, purging flow rate, and air exchange efficiency. The results indicated that the local age of air, the purging flow rate, and the air exchange efficiency could help describe the urban environment's characteristics. However, the air exchange efficiency requires further considerations. The results also indicated that similarly, when the spread of contaminants is diminished for specific building packing density, the same occurs to street widths.

In chapter four, the interaction between meteorological variables and urban components was quantitative and qualitative assessed to know the role in distributing pollutants in secondary streets and the influence of emission sources. The ventilation efficiency was evaluated using the local age of air in idealized building blocks with a four-way intersection of two perpendicular streets. The results indicated that the wind speed influences the levels of pollutants but does not alter the distribution of contaminants in the intersections and secondary streets.

Chapter five describes the interaction between the emission source, urban form and components, and meteorological variables. The emission source was evaluated considering reactive pollutants (nitrogen monoxide, nitrogen dioxide, and ozone) in a realistic urban environment located in Umeda Shin-Michi, Osaka, Japan. A 24 hours simulation by integrating a CFD model coupled with a chemical reaction model (CBM-IV), a radiation model, and boundary conditions from mesoscale models (WRF-CMAQ) was conducted. The conclusions were that the production of NOx or fading of O_3 was mainly found in regions with low wind speed and high turbulence. Also, the distribution of O_3 was directly affected by chemical reactions near the roadside, where fresh NO was being emitted (NOx titration). The results indicated that the same urban form under different meteorological variables (wind speed, wind direction) and emission rates lead to a very different distribution of reactive contaminants during the day.

In the last chapter, recommendations for future studies about the variation of the urban forms and components (urban trees, open spaces, water bodies, building packing density), different meteorological variables (wind direction, humidity, temperature), and other ventilation efficiency indices are mentioned. This doctoral dissertation intends to advance the description of the factors influencing the dispersion of air pollutants in urban areas so that the urban development process would benefit from a more comprehensive understanding of the urban area dynamics.

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論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

本論文では、将来の世界人口の半分以上が居住すると推定される都市において、居住者の健康を守るためには都市大気環境を良好に保つ必要性を示し、自動車からの大気汚染物質量、建物占有密度や道路幅に代表される都市構造、風速風向等の気象条件と都市大気環境の関係を理想街区と実街区を対象に、数値流体力学（CFD）を用いて明らかにしている。

大気汚染物質量、都市構造、気象条件と都市大気環境の関係を示す適切な指標が存在していないことから、屋内空気環境指標として一般的に使用されている代表的な3つの換気効率指標である局所空気齢、パージ流量、空気交換効率が都市街区においても適用できることを示している。

建物形状が均一な理想街区を用いて、建物占有密度と道路幅を変えてCFDを用いた数値実験を行い、局所空気齢は道路幅が狭くなるほど大きな値になること、パージ流量は道路幅が広くなるほど、建物占有密度が小さくなるほど大きな値になること、空気交換効率は道路幅と建物占有密度に依存しないことを明らかにし、建物占有密度が高い平野町街区と建物占有密度が低い舞洲街区の換気効率を局所空気齢、パージ流量、空気交換効率で説明できることを示している。

次に、建物形状が均一な理想街区を用いて、風速と大気汚染物質量発生位置を変えてCFDを用いた数値実験を行い、局所空気齢は風速が大きいほど小さな値になること、大気汚染物質量発生位置が風下にある方が大きな値になることを明らかにし、局所空気齢を用いて大気汚染濃度を無次元すると、風速に依存せず大気汚染濃度分布は均一になることを示している。

更に、梅田新道近傍の実街区を対象に、大気汚染物質量は主要道路の自動車から排出されると設定して、光化学反応モデルを組み込んだCFDを用いた数値実験を行いO_3、NO_2、NO濃度の日変動を予測し、CFDモデルが観測値をよく再現できることを明らかにするとともに、実街区の建物構造と風速風向の時間変動により生じるO_3、NO_2、NO濃度の空間分布の時間変動と街区の換気効率の関係を明らかにしている。

以上のように、本論文は環境エネルギー工学、特に都市環境工学に寄与することが大きい。

よって本論文は博士論文として価値あるものと認める。