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学位論文題目	Climatically Adapted Building Arrangement to Maximize Thermal Acceptability of Outdoors under Different Climatic Conditions （屋外空間の熱的許容度を最大化するための気候特性に適合する建物配置の研究）
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論文内容要旨

1. Introduction

With global warming and UHI (urban heat island) effects, the highest air temperature in summer season sets another new record year by year and extreme hot days last longer and longer. For that reason, more and more people are attacked by heatstroke and some of them even die from it. The main cause of hot weather is the modification of the land surface by urban development which uses materials retaining heat, such as concrete and asphalt. In order to cool down heated urban surfaces, an increasing attention is paid to urban ventilation especially in coastal cities by inducing sea breeze to the inner urban area. Therefore, the basic method to improve urban ventilation is to leave wide space between buildings. It indicates that separation and low building densities are favorable. However, to take care of outdoor thermal comfort, narrow street and compact forms are expected for sun-shading. It is clear that a significant inverse relationship with building arrangement can be found between urban ventilation and sun-shading. Moreover, since the intensity of solar radiation at ground level varies with latitude, so do the effects of sun-shading. Therefore, the climatically adapted building arrangement changes with latitude due to the different effects of urban ventilation and sun-shading. Up to now, most studies on building arrangement have been done from the single viewpoint of urban ventilation or sun-shading although it is necessary to consider both of them at the same time. The main reason is that no assessment approach is available between apparently conflicting objectives of urban ventilation and sun-shading on building arrangement. Overall, the following three aspects will be studied in the thesis.

(1) A new assessment system is developed by which building arrangements can be compared from the viewpoints of urban ventilation and sun-shading and a new system is established in order to determine climatically adapted building arrangement.

(2) To investigate climatically adapted building arrangement at different latitudes, a fundamental study is conducted in Guangzhou

(113°33'E, 23°17'N), China and Sendai (140°52'E, 38°16'N), Japan (shown in Fig. 1) under the conditions of the same analysis date and time by using the new system established in Item (1).

(3) To discuss climatically adapted building arrangement under the worst summer conditions of Guangzhou, China and Sendai, Japan, case studies are conducted by using the new system established in Item (1).

2. Thesis structure

The thesis is divided into seven chapters.

Chapter 1: Research background, review of previous research, the objectives and the thesis structure are given in Chapter 1.

Chapter 2: A numerical simulation system for outdoor wind and thermal environment is introduced in Chapter 2. The system combines commercial software, STAR-CD/RADX with additional codes which can reproduce complex outdoor wind and thermal environment with high prediction accuracy.

Chapter 3: A general introduction to human thermal comfort is given in Chapter 3. It starts with a brief overview of thermal comfort definitions, thermal comfort models and several indices, and then points out different aspects of indoor and outdoor thermal comfort which make a predominant divergence between them. Finally, a significant study done by Monteiro and Alucci is introduced to provide information about how to select an index for outdoor thermal comfort.

Chapter 4: A newly proposed assessment system to determine climatically adapted building arrangement is introduced in Chapter 4. Firstly, the definition of climatically adapted building arrangement is given, and then four kinds of assessment approaches are explained which are possible to compare building arrangements from the viewpoints of the physical environment and social benefit. Finally, the method for climatically adapted building arrangement is introduced.

Chapter 5: A fundamental study on building arrangement in Guangzhou and Sendai is conducted in Chapter 5. Firstly, outdoor wind and thermal environment in different building arrangements are simulated, and therefore the change of outdoor wind and thermal environment with building arrangements are understood. Then, based on the simulation results, outdoor thermal comfort in different building arrangements is evaluated in terms of standard effective temperature (SET*) . Finally, the climatically adapted building arrangement in Guangzhou and Sendai is determined by the newly proposed assessment system introduced in Chapter 4.

Chapter 6: Case studies for the climatically adapted building arrangement under the worst summer conditions of Guangzhou, China and Sendai, Japan are conducted in Chapter 6.

Chapter 7: Conclusions of the thesis are highlighted in Chapter 7.

3. Highlights

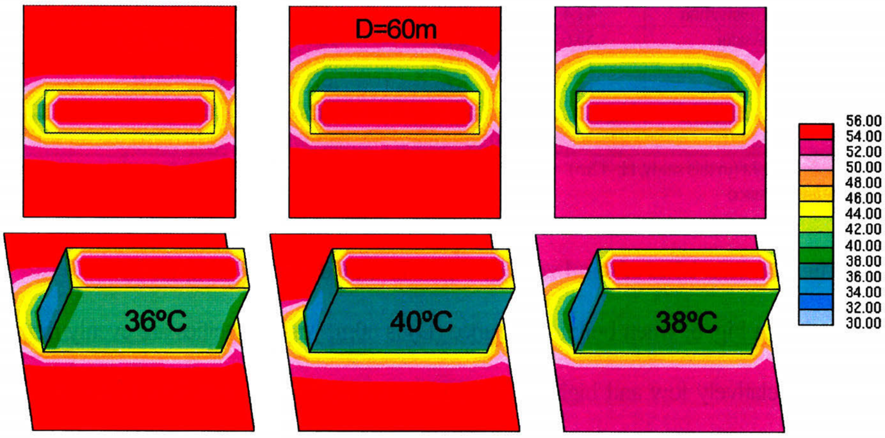
3.1 A newly proposed assessment system (Chapter 4)

To determine climatically adapted building arrangement, a new assessment system is developed for the first time. There are four kinds of assessment approaches in the system: (1) Acceptable area ratio in lot area (=Index 1); (2) Acceptable area ratio in open space (=Index 2); (3) The total thermal acceptability of people who live in the lot area (=Index 3=Index 1 × Floor area ratio); (4) The thermal acceptability per person who live in the lot area (=Index 4=Index 1 / Floor area ratio). The former two indices mainly focus on the physical environment, while the latter two indices concentrate on the social benefit. In the thesis, the climatically adapted building arrangement is determined by greater value of Index 3 except when the value of Index 4 is extremely small.

3.2 The decisive effects of vertical walls on outdoor radiation environment (Chapter 5)

Although more ground surface is exposed to the sunshine at the latitude of Guangzhou compared to Sendai (to refer to Figs. 2 and 3), MRT (mean radiant temperature) at the pedestrian level (at 1.5m) is even lower in Guangzhou as shown in Fig.4. It indicates that the surface temperature of vertical walls plays a more decisive role on outdoor radiation environment, and therefore the great improvement of outdoor thermal comfort can be expected by reducing the surface temperature of vertical walls.

Fig.1 The locations of Guangzhou, China and Sendai, Japan



(1) Guangzhou (2) Guangzhou situation in Sendai latitude (3) Sendai

Fig.3 The distributions of surface temperature in Guangzhou (1), Guangzhou situation in Sendai latitude (2) and Sendai (3) (D=60m)

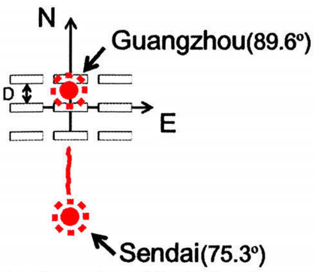


Fig.2 The solar altitude in Guangzhou and Sendai at 12:00 on 21st June

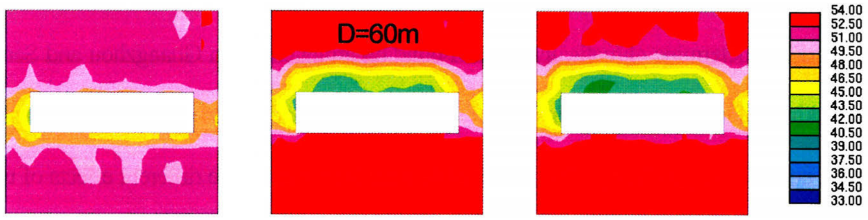


Fig.4 The distributions of MRT (mean radiate temperature) in Guangzhou (1), Guangzhou situation in Sendai latitude (2) and Sendai (3) (D=60m)

3.3 The change of outdoor radiation environment with latitude (Chapter 5)

As seen from Fig. 5, with a decrease in building distance, average MRT in Sendai decreases significantly, while in Guangzhou, it decreases only a little bit because most surfaces are always exposed to the strong sunshine due to the high altitude of the sun. Therefore, the cooling effects of building shade by reducing building distance can only be expected in Sendai and additional shading countermeasures are necessary in Guangzhou.

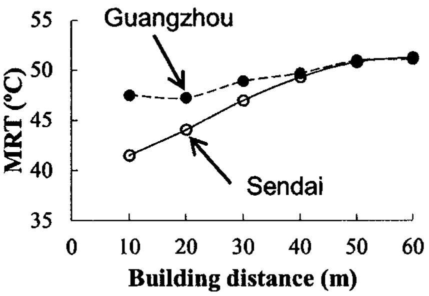
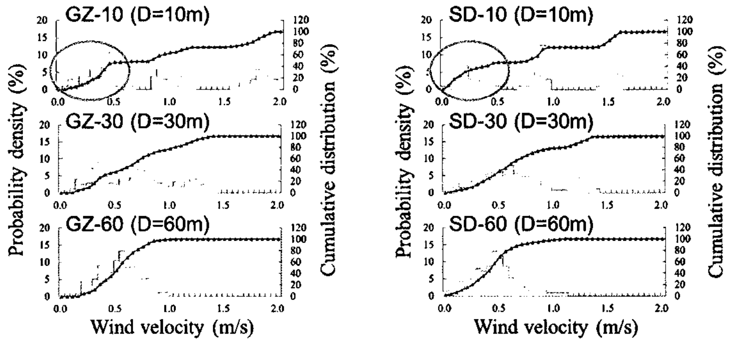


Fig.5 The change of average MRT with building distance in Guangzhou and Sendai



(1) Guangzhou (2) Sendai

Fig.6 The probability density and cumulative distribution of wind velocity in Guangzhou and Sendai at 1.5 height

Table 1 Results of Indices 1, 2, 3 and 4

		D/H=0.24 (D=10m)	D/H=0.71 (D=30m)	D/H=1.43 (D=60m)
Index 1	Guangzhou	22.3	24.4	3.5
	Sendai	28.8	25.6	10.8
Index 2	Guangzhou	41.4	32.9	4.1
	Sendai	53.6	34.0	12.7
Index 3	Guangzhou	1.50	0.96	0.08
	Sendai	1.94	0.99	0.24
Index 4	Guangzhou	0.033(1.3m²)	0.062(2.6m²)	0.015(0.6m²)
	Sendai	0.043(1.7m²)	0.064(2.6m²)	0.048(1.9m²)

H: building height (in this study, H=42m)
D: building distance

Table 2 The comparisons of the effects of urban ventilation and sun-shading when building distances decrease

	Urban ventilation		Sun-shading
Building distance ↓↓↓	Wind velocity ↓↓↓		The cooling effects ↑↑↑
Guangzhou (D=10m)	Thermal discomfort	>	The cooling effects a little bit
Sendai (D=10m)	Thermal discomfort	<	The cooling effects significant

3.4 The characteristics of wind velocity with building distance (Chapter 5)

As shown in Fig. 6, when building distance (D) is 60m, wind velocities are evenly distributed, however with a decrease in building distance, relatively low and high wind velocities are observed. Therefore, it can be said the distributions of wind velocity around buildings become polarized as building distance decreases and the proportion of relatively low wind velocity grows larger which will cause thermal discomfort. These findings suggest that building distance cannot be reduced too much.

3.5 Climatically adapted building arrangement in Guangzhou and Sendai at 12:00 on 21st June (Chapter 5)

In order to determine climatically adapted building arrangement in Guangzhou and Sendai, building arraignments are compared by four kinds of indices as shown in Table 1. From the results of Index 1, the optimal values of D/H in Guangzhou and Sendai are around 0.71 and 0.24, respectively. The distinct difference is caused by the different effects of urban ventilation and sun-shading at different latitudes. As seen from Table 2, when building distance is 10m, the cooling effects of building shade in Sendai is greater than thermal discomfort caused by low wind velocity, while the above relationship is reversed in Guangzhou, and therefore the maximum value of D/H appears when building distance is 30m.

As mentioned previously (Section 3.1), the climatically adapted building arrangement is determined according to greater value of Index 3. Based on Table 1, finally, it can be concluded that the optimal value of D/H in Guangzhou and Sendai is around 0.24.

論文審査結果の要旨

本論文は集合住宅周辺の微気候を流体数値解析と放射解析に基づく都市表面非定常熱収支解析を用いて評価し、屋外のオープンスペースの夏季の温熱環境を可能な限り許容範囲内に収めるための建物配置計画に関して基礎的検討を加えたものである。近年、都市化の進行に伴う緑地、水面等の自然被覆の減少、都市の高密度化による風速低減、都市部の集中的なエネルギー消費による人工排熱の増加等により、いわゆるヒートアイランド現象が進み、都市部の温暖化は地球温暖化の数倍のスピードで進行している。これにより都市内部の屋外生活空間の暑熱化が深刻化し、熱中症等の被害も急増している。本研究は、建物配置計画の観点から、この問題を緩和することを意図したものである。

屋外温熱環境の改善を目的とした建物配置に関しては、従来より日射遮蔽と風通しという２つの観点から、異なる分野の研究者により多くの研究がおこなわれてきた。しかし、日射遮蔽を促進するためには建物間隔を短くして日陰を増やすのが望ましく、風通しを良くするためには、建物間隔を広くし、市街地全体の空力抵抗を減少させる必要があり、両者の要請は正反対となる。従って、これらの知見をそのまま都市計画や建物配置計画に活かすのは困難であり、日射遮蔽と風通しの効果を総合的に考慮した計画論の構築が求められていた。これに対して、本研究は最新のミクロスケールの気候解析技術を用いて、中層集合住宅地の屋外生活空間の風環境、温熱環境を予測し、これらの結果から人間の温冷感を表す温熱快適性指標 SET* (Standard Effective Temperature) の空間分布を算出し、建物間隔の変化がSET*の分布に及ぼす影響を詳細に分析している。さらに、SET*が許容上限を超えない領域の面積から建物配置の優劣を評価する新たな指標を提案するとともに、これを用いて仙台と中国の広州という気候条件の異なる２つの都市における最適な建物間隔を見出している。

以上のように、本論文は系統的かつ緻密な分析により、暑熱環境緩和のための屋外居住環境計画の新たな方法論を提案したものであり、都市温暖化に伴う問題が顕在化している東アジアの高密度都市の今後の環境計画に大きく寄与し得るものである。また、本研究で示された建物配置の変更に伴う日射遮蔽効果と風通し改善効果の変化に関する分析結果は、都市気候学の分野の研究者にも多くの示唆を与えるものである。

よって、本論文は博士(工学)の学位論文として合格と認める。