Development of a Wind Environment Database in Tokyo for a Comprehensive Assessment System for Heat Island Relaxation Measures

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ABSTRACT: In Japan, a new assessment system called CASBEE-HI (Comprehensive Assessment System for Building Environmental Efficiency on Heat Island Relaxation) has been developed for evaluation of the effects of various building design-related measures for heat island reduction. To assist the evaluator to examine the wind environment, a wind environment database was developed. In the present paper, a wind environment database for the special 23 wards of Tokyo is described as an example. The present Tokyo database includes results of three-dimensional (3D) CFD analysis in which all the existing buildings in the special 23 wards of Tokyo are reproduced in 3D geometries in a grid network of approximately 500,000,000 meshes with a spatial resolution of 8 m in the horizontal directions.

KEYWORDS: Heat island, Local characteristics, Geographical conditions, Wind environment database

1 INTRODUCTION

Recently, heat island issues are of much concern in urban areas in Japan and countermeasures are sought urgently. A government-organized inter-ministry council for heat island measures published an outline of heat island countermeasures\textsuperscript{1} in March 2004. Also in July 2004, the Ministry of Land, Infrastructure and Transport notified a guideline for building design to lessen heat island phenomena\textsuperscript{2} to the governors of local governments under the name of Senior Director of Housing. From the standpoint of a quantitative evaluation of effects of countermeasures for reducing building-related heat island phenomena, a new assessment system called CASBEE-HI\textsuperscript{3} (Comprehensive Assessment System for Building Environment Efficiency on Heat Island Relaxation) has been developed. The foundation of CASBEE-HI is laid upon environmental efficiency. Refer to Note 1 for an overview of the system.

Prior to applying CASBEE-HI to evaluation of effects of heat island countermeasures, the evaluator is required to conduct a survey of local wind environment since local characteristics of wind and air temperatures may be unique. They may vary strongly not only from a city to city but even inside the same city. Hence, CASBEE-HI provides two wind databases on a local area-wide scale and a street-wide scale. The present paper describes an outline of the databases.
2 LARGE AREA WIND ENVIRONMENT DATABASE EMPLOYING LAWEPS

CASBEE-HI is equipped with a database for spatial distributions of wind speed at 50m height above sea level and air temperature on a 500m grid network which are constructed from results of a local area wind prediction system LAWEPS (Local Area Wind Energy Prediction System) (Murakami et al., 2003), Japan Weather Association for Tokyo and Osaka. A 500m-mesh wind database for entire Japan is available in LAWEPS. It is therefore possible to form large area wind environment databases for any Japanese cities for heat island reduction measures if data for typical sunny summer days are extracted. Refer to Note 2 for an overview of LAWEPS.

As an example of the large area wind environment database, distribution of wind speed of daytime on a typical sunny summer day (14:00 July 17, 2004) in Tokyo is depicted in Fig. 1. Here, a typical sunny summer day is selected based on the following criteria: (1) pressure patterns are of "south high north low type" characteristic in summer, (2) air temperature is high, (3) enough sunshine is available without precipitation, (4) changes in the wind system due to sea and land breeze are clear, and (5) LAWEPS prediction is consistent with weather observation data.

3 STREET-WIDE SCALE WIND ENVIRONMENT DATABASE

The product of the above-mentioned large area wind database (i.e., LAWEPS) is atmospheric weather data on a 500m grid network. If one desires more detailed wind patterns near the ground surfaces, a wind environment database incorporating building groups is necessary. Hence, building group models for CFD are constructed from map data for the 23 special wards of Tokyo and the Osaka wards. 3-D CFD simulation is then performed using a wind environment analysis system capable of simulating wind environment of a building group with FAVOR methodology. A pedestrian-level wind environment database which accounts for local conditions near a building site has been thus established.

3.1 Formation of the database

Analysis results for the 23 special wards of Tokyo are presented as a demonstration case for the street-wide scale wind environment database.

Area division: As shown in Fig. 1, the area of analysis consists of 27km by 27km which almost covers the entire 23 special wards and the area is divided into nine sub-domains with size of 9km by 9km. The direction of incoming wind (S, SSE or SE as shown in Fig. 2) is assigned on a sub-domain by sub-domain basis from the results of LAWEPS depicted in Fig. 1.

Field of analysis: The field of analysis for each sub-domain encompasses over 10km by 10km by 400m in the upper sky (A buffer zone which extends 500m outward is set up around each sub-domain of 9km by 9km.)

Building data: Based on map information, up to 390,000 buildings per sub-domain are reproduced. Building data are taken from housing map information in 2000 and no geographical features are accounted for.

Computing mesh: An orthogonal mesh system with a horizontal resolution of 8m is used. Each sub-domain is divided into 1250 × 1250 × 35 = 54,687,500 grid points which amounts to a total of 492,187,500 meshes for the entire 9 sub-domains.

Turbulence model: The standard k-ε model of turbulence is employed for computation.

Inflow condition: The standard k-ε model of turbulence is employed for computation. Inflow condition is assumed to follow the 1/4th power law and wind speed at 74.6m height is set to be 10m/s.
3.2 Result of analysis for Tokyo

Figure 3 displays a result of street-wide wind environment analysis for the 23 special wards of Tokyo. The result for an enlarged area is also presented. Wind speed at 1.5m high is reproduced. Inspection of the global picture reveals the presence of relatively strong wind along large rivers which flow roughly in the north-south direction. The enlarged image depicts detailed flow patterns among buildings. For specific applications for CASBEE-HI, required data in the vicinity of a building site for assessment are enlarged and, then, extracted from a global result.

4 CONCLUSIONS

Large area and street-wide scale wind environment DBs for in advance assessment of local wind environment are constructed for the 23 special wards of Tokyo and the Osaka wards. Wider applications to assessment using CASBEE-HI are expected.

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Notes

1) Overview of CASBEE-HI3): In CASBEE-HI, building environment efficiency (BEEHI) for reduction of heat island phenomena is defined as follows: In climate change associated with urbanization, factors that aid (1) temperature rise and the resulting (2) degradation in thermal comfort in outdoor space are considered as heat island load. Effects for improving outdoor thermal comfort in a virtual closed space (QHI) and heat island load toward outside of the virtual closed space (LHI) are evaluated by breaking down into categories, divisions and sections. Evaluation of building environment efficiency (BEEHI) is made using the following equation.

\[ \text{BEEHI} = \frac{Q_{HI}}{L_{HI}} \]  

Equation (1) suggests that fundamental countermeasures may be devised by increasing QHI and reducing LHI. In an actual evaluation process using an evaluation sheet, five viewpoints consisting of ventilation, shade, soil surface cover of exterior, exterior material of the building, and waste heat from building facilities are used for five-grade evaluation of QHI and LHI separately. BEEHI is computed through total evaluation of them.

2) Overview of LAWEPS4): A system for local area wind prediction called LAWEPS was developed by a research team consisting of the Japan Weather Association (JWA), Obayashi Corporation, E&E Solutions Inc., the Institute of Industry Science of the University of Tokyo, the Nagoya Institute of Technology, and the Tohoku University in a research project, the Development of Local Area Wind Energy Prediction Model (Chairman Shuzo Murakami of the Keio University), commissioned by NEDO (the New Energy and Industrial Technology Development Organization). LAWEPS consists of three-step mesoscale area models and two steps of microscale area models. The foundation of the mesoscale model is laid upon a weather simulation model ANEMOS (Area-oriented Numerical simulation and Environmental assessment Modeling System) developed by JWA. The microscale model is based on an engineering model incorporating a modified k-ε turbulence model which takes advantage of the latest computational fluid dynamics theory. Up to the third step computed using the mesoscale model and a 500m grid network, wind distributions over the entire Japanese land have been obtained and stored in database form. Yearly average wind speed, wind rose and wind condition curves at given altitudes may be examined by simple operation of software (source: JWA HP 5).

References:

1) Inter-ministry council for heat island measures, Outline of heat island countermeasures, March 2004.
5) Japan Weather Association homepage (http://www.jwa.or.jp/)
Fig.-1 Large area wind environment database (results of LAWEPS) (Tokyo, at 14:00 July 17, 2000, 50m above sea level)

Fig.-2 Area division and main wind directions of individual areas

Fig.-3 Overview of the street-wide scale wind environment database for the 23 special wards of Tokyo (at 14:00 July 17, 2000, 1.5m above sea level)