DEST Software to Analyze System Zoning and Energy Consumption in Air Conditioning Systems

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Abstract: This paper reports on a study on how to appropriately divide system zoning by using DeST software to calculate the basis dynamic temperature and load of all rooms in an office building. Influent factors of weather conditions, building envelope conditions and building structure were analyzed in this simulation. We found that load was the fundamental factor involved in system zoning. Surplus heat recovery in inner zone is also recommended to maintain inner zone comfort and save energy.

Key words: DeST, inner zone, system zoning, air conditioning system

1. INTRODUCTION

Nowadays, large areas, large depth and energy consumption, and complicated function are common phenomena in public buildings. How to deal with the inner zone in a building has become an important problem that can't be ignored, especially for some big buildings such as office building, super market, large shopping mall, etc. Some air conditioning system tests in office building were reported that users in different zones (inner zone and outer zone) often complained different temperature feelings (hot and cold). The temperature difference between inner and outer zone could be up to 4 . In transitional season, especial in winter, inner zone users in office buildings often complained too hot. All of these problems are common in office building, which needed to be solved to ensure good IAQ (indoor air quality) and thermal comfort.

Different designers always have different zoning limits. Some American designers considered that zone dividing would be needed when building depth exceeded 8m, while designers in Europe, Japan and China considered 3～5m would be the zoning limit [1]. However, it is not the proper way.

In our study, DeST (designer's simulation toolkits), energy simulation software was used to simulate annual dynamic load in a large office building. Influent factors of weather condition, building envelopes condition and building structure were analyzed in this simulation.

2. SIMULATION MODEL AND TOOL

2.1 Simulation Model

An office building was selected to this simulation. Envelope and indoor conditions were as follows: external wall heat-transfer coefficient: 1.062W/(m^2.K); external window heat-transfer coefficient: 3.24W/(m^2.K); internal wall heat-transfer coefficient: 2.33W/(m^2.K); person density: 0.1person/m^2; lighting load: 40W/m^2; facility load: 20W/m^2.

Indoor design parameter: winter indoor temperature: 22～24 ; summer indoor temperature: 24～26 ; winter indoor relative humidity: 40%～50%; summer indoor relative humidity: 50%～60%. Working time of air conditioning system was 7:00～20:00. Fig.1 shows a schematic view of the building.

In order to analyze the necessity of system zoning and zoning limits, indoor conditions were fixed but weather condition (two Chinese cities were selected: Beijing and Harbin), building envelopes condition (ratio of window-wall) and building structure (building depth) were changed.

In detail, 4 cases were studied:

1) Depth 6m, glass curtain wall, Beijing;
2) Depth 6m, window-wall ratio 0.5, Beijing;

3) Depth 8m, window-wall ratio 0.5, Harbin;
4) Depth 8m, window-wall ratio 0.5, Beijing.

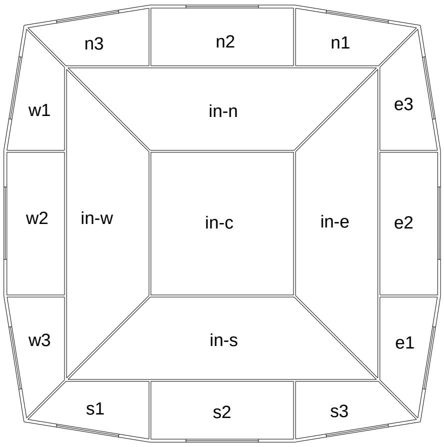


Fig.1 Schematic view of the building

2.2 Overview of DeST

Building simulation becomes more and more important along with the high requirement of indoor air quality and energy saving. A few simulation software have been developed and applied, such as ESP-r[2], BLAST[3], DOE-2[4], TRANSYS[5], HVACSIM+[6], etc.

DeST was the abbreviation of Designers' simulation toolkits, which was designed by Tsinghua University, China. Its stage simulation concept makes connection between building and system possible. Meanwhile, both analysis of building's thermal characteristic and simulation of system performance could be achieved by DeST, and coupling problems between building and system could be solved, either.[7].

Compared with other energy simulation software, indoor base temperature (temperature uninfluenced by HVAC system) is used to connect building and system. Stage design and simulation is the basic feature of DeST.

DeST can be used to optimise building envelopes design, air conditioning system design heat/cooling source design and HVAC design, check air treating-units, assess building energy efficiency.

In our study, annual dynamic load provided by DeST was analysed to explain necessity of system zoning and zoning limits.

3. RESULTS AND DISCUSSIONS

3.1 Necessity of System Zoning

By simulation, inner zone and outer zone annual dynamic load were calculated, as shown in Fig.2. In January, February, November and December, cooling was need in inner zone but heating in outer zone, shown in Fig.2a and Fig.2b (Because of the similarity of load characteristics of room w2, n2 and e2, e2 hadn't been shown in Fig.2.Same in other Figs.). Therefore, for some building with large depth and inside partition, system zoning was necessary.

3.2 Building Envelopes Condition

In order to analyse building envelopes condition influence on system zoning and dividing limits, two cases were studied: 1) depth: 6m, glass curtain wall, Beijing; 2) depth: 6m, window-wall ratio 0.5, Beijing.

The results were showed in Fig.3 and Fig.4. Different building envelopes condition impacted inner zone load little and distribution of inner zone dynamic load were the same, as shown in Fig.3b and Fig.4b.However, because of the difference of wall, load of room s2 in case1 was larger than load in case 2, as shown in Fig.3a and Fig.4a. Load of room s2 in two cases were like as inner zone load, cooling load needed all year. So, it was not the criteria of system zoning judged by having external envelopes or not. Judging by real annual dynamic load was much more proper.

3.3 Weather Condition

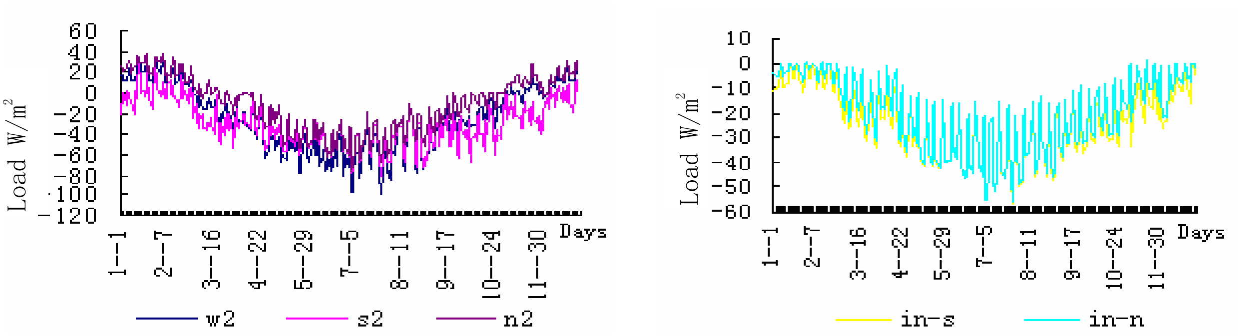
In order to analyse weather condition influence on system zoning and zoning limits, another two cases were studied: 3) depth: 8m, window-wall ratio 0.5, Harbin; 4) depth: 8m, window-wall ratio 0.5, Beijing.

By simulation, we could find that more cooling load was needed in case4 than in case3. For room s2, the load distribution in case3 was the same as other outer zone rooms, requiring heating load in winter, as shown in Fig.1. However, the load distribution in case4 was like as inner zone rooms, requiring cooling load all year, as shown in Fig.5. Because it was cold in Harbin than it in Beijing, impacted by the outdoor weather, much more cooling load was needed in case3. Load characteristics of room s2 in two cases were different, which influenced the system zoning. The same building in different cities had different load characteristic, thus different system zoning was demanded. Real annual dynamic load was the more proper criteria of system zoning.

3.4 Building Depth

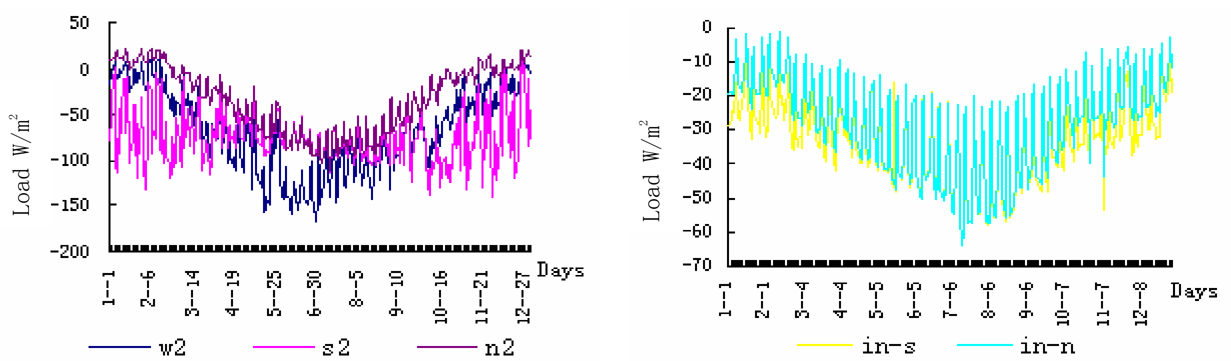
In order to analyse building structure influence on system zoning and zoning limits, two cases were compared: 2) depth: 6m, window-wall ratio 0.5, Beijing; 4) depth: 8m, window-wall ratio 0.5, Beijing.

The simulation results were shown as Fig.4 and Fig.5. Although the depths of two cases were different, the distribution trends in room w2, n2 were the same, except absolute value of load. In these outer zones, heating load was remanded in January, February, November and December. Because of the south orientation sun radiation, load distribution of room s2 was different from room w2 and n2, but the same as inner zones', no matter depth 6m or 8m. Therefore, it was inexact to determine zoning limits artificially just by depth. In fact, building depth was just a manifestation form of load, but the annual dynamic load was the real and basic criteria.



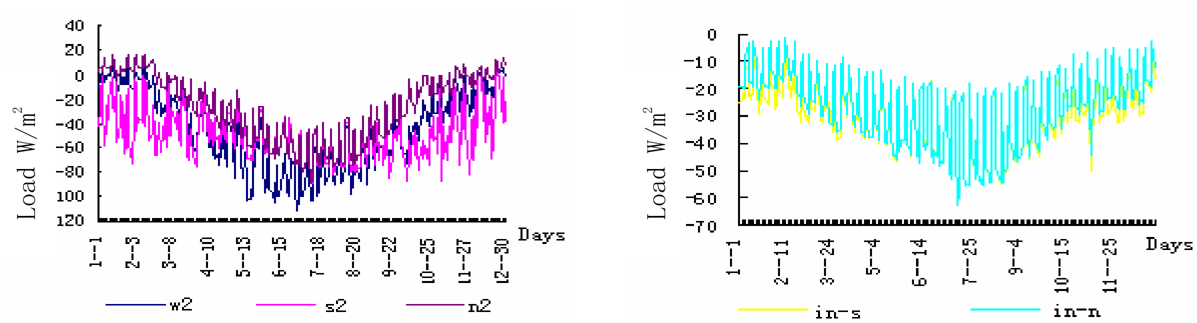
(a) (b)

Fig.2 Annual dynamic load: a) outer zone; b) inner zone (depth 8m; window-wall ratio 0.5; Harbin)



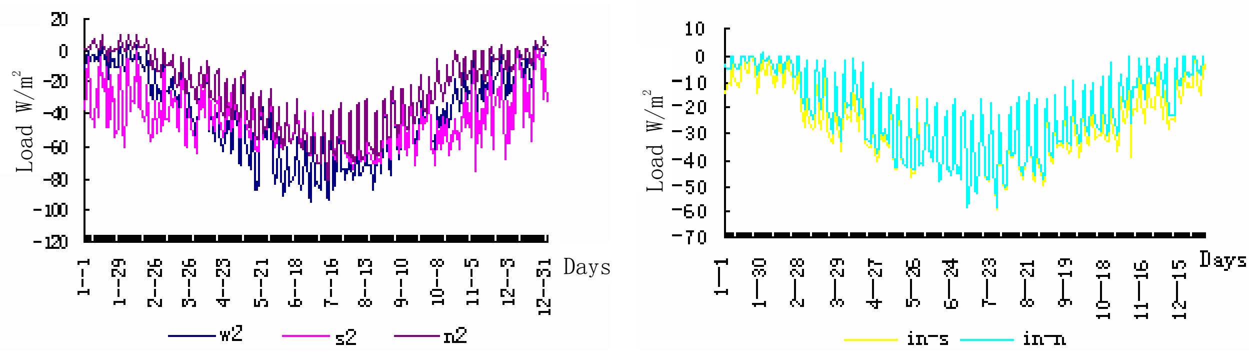
(a) (b)

Fig.3 Annual dynamic load: a) outer zone; b) inner zone (depth 6m; glass curtain wall; Beijing)



(a) (b)

Fig.4 Annual dynamic load: a) outer zone; b) inner zone (depth 6m; window-wall ratio 0.5; Beijing)



(a) **(b)**

Fig.5 Annual dynamic load: a) outer zone; b) inner zone (depth 8m; window-wall ratio 0.5; Beijing)

3.5 Recovery of Surplus Heat in Inner Zone

Surplus heat in inner zone commonly comes from heat extraction of people, lights and facilities, without impaction of outdoor weather conditions. Take case1 as example, the annual dynamic basic room temperature was almost up to 20 all year, and cooling was required all year round in room in-s, as shown in Fig.6. It showed that the absolute value of load (January, February, November and December) in room in-n and n2 were equal to each other approximately, showing in Fig.7. If surplus heat could be transferred to outer zone, not only over-heat problem could be solved, but energy could also be saved by heat recovery.

A few systems were implied to settle inner zone problem, such as VAV system, VRV system, etc. Thermal comfort could be kept by these systems, but surplus heat was unused. In order to recover surplus heat, water loop heat pump was a good choice. Water loop heat pump system is a cooling/heating air-conditioning system in which some small water/air heat pumps are paralleled together by water loop, and can reuse buildings surplus heat [8].

4. CONCLUSION

For some office building with large depth, large energy consumption, inside partition, system zoning was necessary.

The system zoning and zoning limits were impacted by weather condition, building envelopes and building structure. These factors were just manifestation form of load, only the annual and dynamic load was the basic criteria of system zoning limits.

Surplus heat was the major problem in inner zone, which could be solved by systems like VAV and VRV. However, water loop heat pump would be better to recover surplus heat. Not only thermal comfort could be achieved but more energy could also be saved.

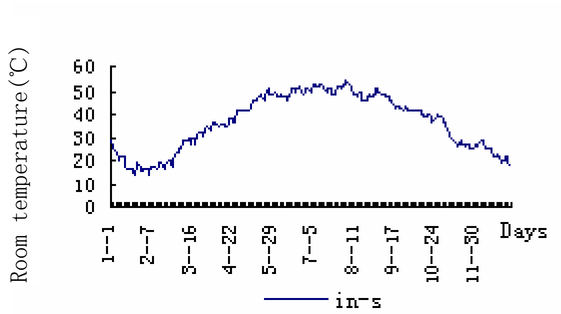


Fig.6 Annual basic room temperature

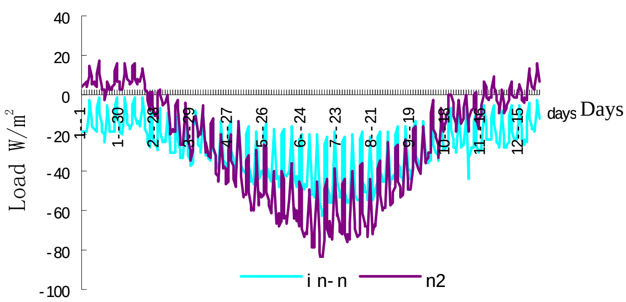


Fig.7 Annual dynamic load in room in-n and n2

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