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NEW SCALES FOR EVALUATING VENTILATION EFFICIENCY AS AFFECTED BY SUPPLY AND EXHAUST OPENINGS BASED ON SPATIAL DISTRIBUTION OF CONTAMINANT

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ABSTRACT

Three new scales for measuring ventilation effectiveness in a room (SVE4, 5, 6) are defined and added to the authors' evaluation system of SVEs (Scale for Ventilation Efficiency 1, 2, 3 ; Kato and Murakami, 1988). The first of new scales (SVE4) indicates the contribution ratio of a supply opening to air at a point, and its distribution can be used to comprehend the sphere of influence (territory) of that supply opening. The second one (SVE5) gives the contribution ratio of an exhaust opening to air to be exhausted at a point. The third one (SVE6) indicates the residual life time (life expectancy) of air at a point; it corresponds to SVE1 (residence time of contaminant generated at a point) though the method of the calculation is different. The three new SVEs as well as the previously defined three scales are evaluated from the distributions of contaminant concentration in a room.

The proposed new scales could be evaluated by experiments. However, numerical simulations of airflows and contaminant distributions make it much easier to obtain them. In order to confirm the usefulness of these scales, the characteristics of ventilation effectiveness in rooms are analyzed.

KEYWORDS

SVE, Contribution ratio, Territory, Supply and Exhaust Opening, Age of Air, Numerical Simulation, Room Airflow, Contaminant Distribution

INTRODUCTION

We define here a contribution ratio of a supply opening and that of an exhaust opening to indoor air at a point, and propose a method for calculating them. With these contribution ratios, quantitative analyses of the influence of supply and exhaust openings on ventilation characteristics at a point or in a local area become possible. We also propose here a new method for calculating residual life time (life expectancy) of air in a room. With this new method and the authors' previously proposed method for calculating age of air, analyses of spatial distributions of age, residual life time, and residence time of air become quite easy.

Contribution Ratio of a Supply Opening

In a ventilated room, supplied air gradually diffuses within the room. When there is more than one supply opening, the air supplied from each opening mixes with that supplied by the others. Since air is usually

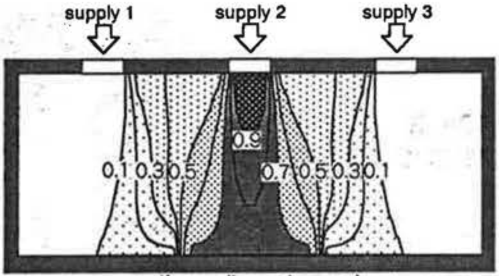


Figure 1
Spatial distribution of contribution ratio of supply outlet at center(SVE4)
SVE4 shows concentration at a point of the supplied air from the supply outlet in question (here supply 2)

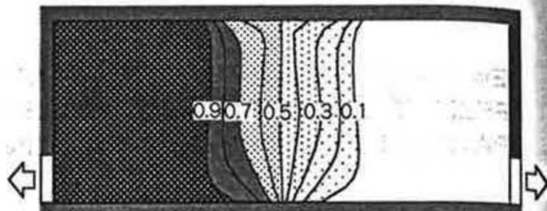


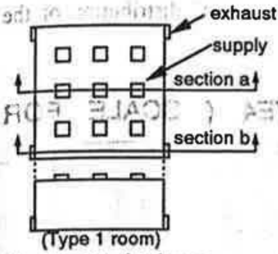
Figure 2
Spatial distribution of contribution ratio of exhaust inlet at left side(SVE5)
SVE5 shows probability of the air at a point to be exhausted from the exhaust inlet in question (here exhaust a)

imperfectly mixed, the air supplied by each opening does not diffuse uniformly throughout the room. The mixing ratio of the air from each supply opening, i.e. the contribution ratio of each opening to air at a point, thus differs from point to point. This concept of "contribution ratio" becomes clearer when it is expressed as the physical "concentration" or "dilution ratio" of the air supplied from each opening. The total contribution ratio at each point, or the total concentration of air from each supply opening is , of course 100 %. Figure 1 shows an example of the spatial distribution of the contribution ratio of a supply opening. The contribution ratio just at the supply opening is 100 %. As the air from a given supply opening mixes with the air from other supply openings, the contribution ratio of that supply opening decreases. In this study the contribution ratio of a supply opening is called SVE4. Detailed definition and explanation will be given later.

In the region of each supply jet, the value of the contribution ratio of each supply opening is very high. The sphere of influence of each supply opening is very clear in such cases. However, in a recirculating region, the contribution ratio for each supply opening is not clear. When designing room air distribution, the concept of supply jet territory helps in comprehending intuitively the structure of a flowfield composed of contributions from various supply jets. The territory of supply opening 2 can be easily imagined from Figure 1.

Contribution Ratio of an Exhaust Opening

The same situation of course holds true for exhaust openings. When there is more than one exhaust opening, a single opening does not evacuate all the air from a room. The contribution ratio of each opening to evacuating the air at a point is sure to differ from point to point, just as did the contribution ratio of each supply opening. Since the contribution ratio of each exhaust opening does not directly or physically correspond to the "concentration" or "dilution ratio", we propose here a new method which enables us to relate the contribution ratio to the "concentration" of the exhaust air. Figure 2 shows an example of the spatial distribution of the contribution ratio of an exhaust opening. The contribution ratio of the exhaust immediately in front of the exhaust opening is 100 %. In this study the contribution ratio is called SVE5. Detailed definition and explanation will be given later. The concept of exhaust opening territory is useful in practical ventilation design as it is in the case of the supply opening. The territory of an exhaust opening can be easily imagined from Figure 2.



illustrated plane

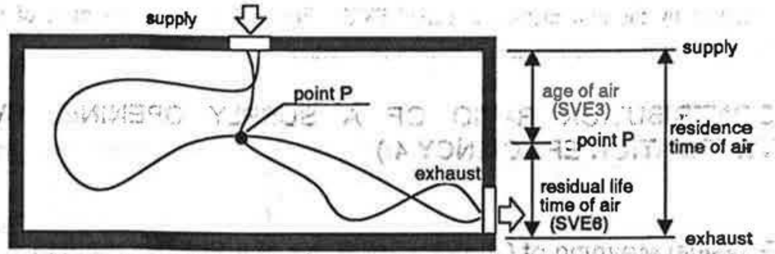
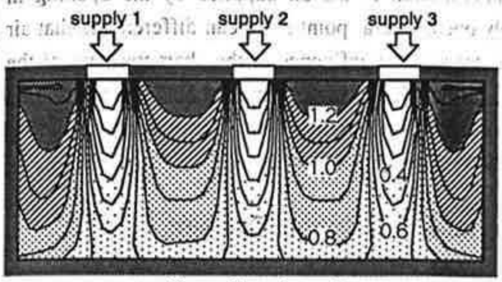


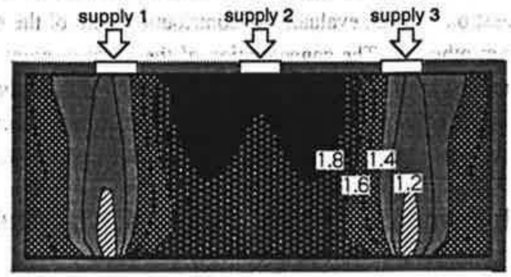
Figure 3 Age and residual life time of air



section a (Type 1 room)

Figure 4 Spatial distribution of age of air(SVE3)

contaminant distribution of uniform generation



section a (Type 1 room)

Figure 5 Spatial distribution of residual life time of air (SVE6)

contaminant distribution of uniform generation in time-reversed virtual field

Previous Studies

Concepts similar to the above mentioned contribution ratios and territories have of course been of interest to ventilation engineers for many years. In particular, the cover range of an exhaust inlet has been of wide concern in industrial ventilation, kitchen ventilation, and other ventilation fields where exhausting contaminated air is a serious problem. The concept of the sphere of influence of a supply outlet has also been widely used by air-conditioning engineers, for whom supply airflow is one of the most important tools for controlling indoor air climate. For analysis of the supplied air distribution in a room, tracer gas was injected into the supply airflow. Togari and Hayakawa (1987) analyzed the performance of the air-conditioning system of a large indoor space with this method.

In this study, the authors have clarified that both kinds of contribution ratio and their distributions can be calculated with almost similar methods using diffusion fields analyzed by numerical simulation.

Age and Residual Life Time of Air

The concepts of age and residual life time of air, shown in Figure 3, have been well known in the field of ventilation engineering (Sandberg and Sjöeberg, 1983). The present authors pointed out that the spatial distribution of the age of air can be easily calculated from the SVE3 of their previously proposed scales, as is shown in Figure 4. They also have suggested that the residual life time of air (residence time of contaminant generated at a point) can be calculated as SVE1 (spatial average of contaminant concentration) and that its spatial distribution can be obtained by scanning the source point throughout the room. In the present study we conceived a new method for calculating the spatial distribution of the residual life time of air by extension from calculating the contribution ratio of an exhaust opening. In this study the residual life time of air obtained by the new method is called SVE6. Figure 5 shows an example of the spatial distribution of the residual life time of air obtained by the new method.

CONTRIBUTION RATIO OF A SUPPLY OPENING, SVE4 (SCALE FOR VENTILATION EFFICIENCY 4)

Physical Meaning of Contribution Ratio of a Supply Opening

Since the contribution ratio is defined as the concentration of the air supplied by the opening in question, we can evaluate the contribution ratio of the supply opening at a point if we can differentiate that air from other air. The concentration of the air at a point indicates well the influence of the characteristics of the supplied air (e.g. temperature, air quality) at the opening. Differentiation of the supplied air from air coming through other openings is done easily by mixing a tracer gas in the given supply outlet. The concentration of the tracer gas indicates clearly the concentration (contribution ratio) of the supplied air.

Mathematical Definition of SVE4; Contribution Ratio of a Supply Opening

$$SVE4(X, n) = Cn(X) / Cn_0, \quad (1)$$

here,

$SVE4(X, n)$: contribution ratio of the n − th supply opening at point X

Cn : concentration at point X where tracer is generated at the n − th supply opening in generation rate q (kg/s)

Cn_0 : concentration of the tracer at the n − th supply opening, $Cn_0 = q/Qn$

q : tracer generation rate at the n − th supply opening (kg/s)

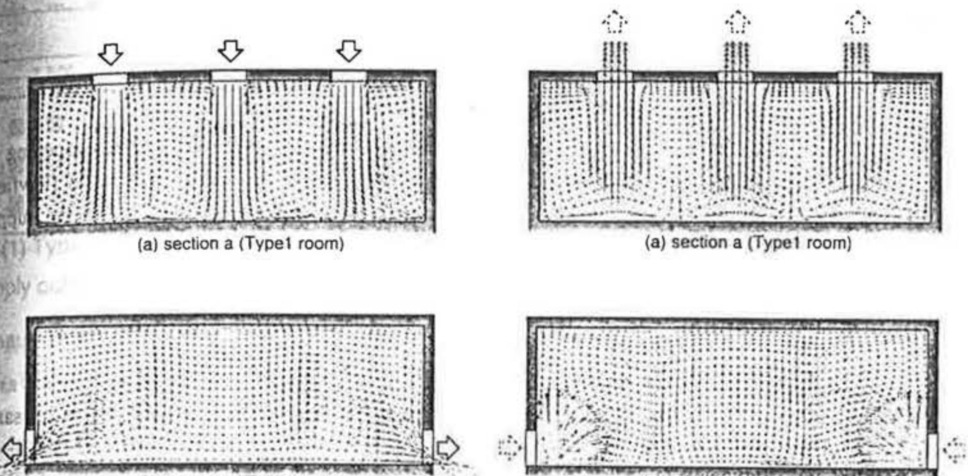
Qn : air flow rate at the n − th supply opening (m^3/s)

Equation (1) indicates that SVE4 is the dilution rate of the supplied air in question. Figure 1 shows an example of the spatial distribution of SVE4 in a room with 9 supply openings arranged in the ceiling.

CONTRIBUTION RATIO OF AN EXHAUST OPENING, SVE5 (SCALE FOR VENTILATION EFFICIENCY 5)

Conventional Method for Estimating Contribution Ratio of a Exhaust Opening

The contribution ratio of a exhaust opening shows the probability of air at a point being exhausted through that exhaust opening. This probability at a point is measured well by the tracer gas method. When a tracer gas is generated at a given the point and its concentration at each exhaust opening is measured, we can evaluate the probability of air being exhausted through each exhaust opening. The spatial distribution of this probability is obtained by scanning the tracer generation point throughout the room. This method is applicable in the field tests, model experiments, and also in such numerical simulations as are required for SVE1 (spatial average of concentration) and SVE2 (mean radius of diffusion), which are based on the diffusion fields of a contaminant source point.



(a) section a (Type1 room)

(a) section a (Type1 room)

(b) section b (Type1 room)

(b) section b (Type1 room)

(1) real velocity field for air mass in a room

(2) virtual velocity field with reverse-time case

Figure 6 Comparison of time reversed with real velocity field of air mass

Reverse Tracing of Flowfield over Time for Calculating Contribution Ratio of an Exhaust Opening

In this study, for the calculation of the contribution ratio of an exhaust opening, a new and different method which is simpler and more direct than the conventional method was conceived. The key concept of the new method is the reverse tracing of a flowfield through the passage of time. Mathematically this implies that the solution of the transport equation of the contaminant (concentration) on the flowfield is obtained with time integration in the negative direction. The procedure of negative time advancing in the transport equation is equivalent to that of positive time advancing with negative convection and diffusion. Reverse time tracing of the flowfield thus means that the diffusion field is obtained from the virtual flowfield with negative convection and diffusion, that is, from the virtual flowfield with reversed flow direction.

When tracer gas is generated at the exhaust opening and time is reversed, the air mass containing the tracer gas flows in the reverse direction as negative time advances, so the tracer in the air mass returns from the exhaust opening and is convected towards the room. In this situation, the diluted tracer in the room is certain to be exhausted entirely within a known time and its concentration at any given point therefore indicates the probability of that air mass being exhausted through that exhaust opening. This diffusion field thus directly indicates the distribution of the contribution ratio of the exhaust opening as well as that of the supply opening. Figure 6 shows both a real and physical flowfield (Figure 6(1)) used to calculate the contribution ratio of a supply opening (Figure 1) and also a virtual flowfield simulated by reversed time tracing (Figure 6(2)) used to calculate the contribution ratio of an exhaust opening (Figure 2). Reversed time tracing virtually creates a flowfield where air comes from exhaust inlets,diffuses into the room, and is evacuated from the supply outlets.

Although this method cannot be used in real physical experiments, in the world of numerical simulation it is possible and even rather easy to apply it roughly.

Mathematical Definition of SVE5; Contribution Ratio of an Exhaust Opening

$$SVE5(X, m) = Cm(X) / Cm_0, \quad (2)$$

here,

SVE5(X, m): Contribution ratio of the m - th exhaust opening at point X

Cm :virtual concentration at point X where tracer is generated at the m - th exhaust opening in generation rate q (kg/s) and time passes inverse. (Reversal of time virtually realizes a flowfield where air comes from the exhaust inlets, diffuses into a room, and is evacuated from the supply outlets.)

Cm_0:Concentration of tracer at the m - th exhaust opening, $Cm_0 = q/Qm$

q:tracer generation rate at the m - th exhaust opening (kg/s)

Qm:Air flow rate at the m - th exhaust opening (m^3/s)

SVE5 relates to SVE4 in that it is calculated by means of reversed time tracing from the same flowfield. In that reversed time traced virtual flowfield, SVE5 is calculated as the concentration of "to - be exhausted" air still in the room. In the simulation the "exhaust air" returns from the exhaust opening into the room, where it is mixed and diluted with air returning from other exhausts. Figure 2 shows an example of SVE5 distribution obtained with this method.

NEW METHOD OF EVALUATING RESIDUAL LIFE TIME OF AIR, SVE6 (SCALE FOR VENTILATION EFFICIENCY 6)

The residual life time of air corresponds exactly to the residence time of the contaminant. Both indicate the mean elapsed time needed for air or contaminant at the point in question to be exhausted from the exhaust inlets in a room. The residence time of contaminant generated at a point is obtained from SVE1 (spatial averaged contaminant concentration), previously proposed by the present authors. Here, another method for obtaining the residual life time of air at a point is proposed.

Reverse Tracing of Flowfield over Time for Calculating Residual Life Time of Air

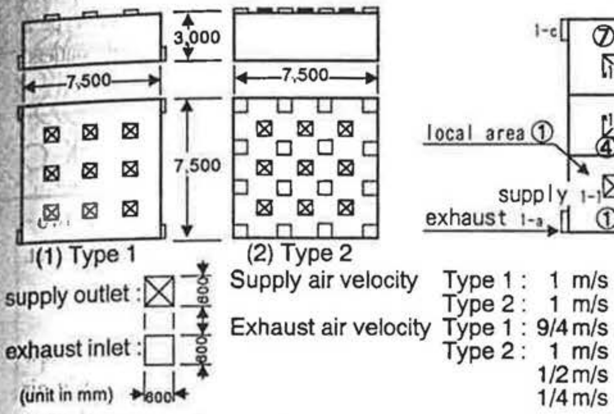
In reversed time tracing of a virtual flowfield, when the tracer is generated uniformly throughout a room, the tracer concentration at any one point corresponds to the mean elapsed time required by an air mass to travel from the exhaust opening to the point in question. Time is hence reversed, so the air mass at the exhaust opening goes back into the room and is sucked into the supply outlet (cf. Figure 6(2)). Since the tracer is assumed to be generated uniformly and constantly throughout the room, the air mass should be contaminated in proportional to the elapsed time from the exhaust opening to the point in question (cf. Figures 3 and 5). This mean elapsed time equals the mean time needed for transporting the air mass from the given point to the exhaust opening in the real, physical world. We can thus evaluate the residual life time of air at a point from the concentration at that point by means of reverse time tracing.

Mathematical Definition of SVE6; Residual Life Time of Air

$$SVE6(X) = C''(X) / C_0, \quad (3)$$

here,

C" :virtual concentration at point X where tracer is uniformly generated throughout room in total



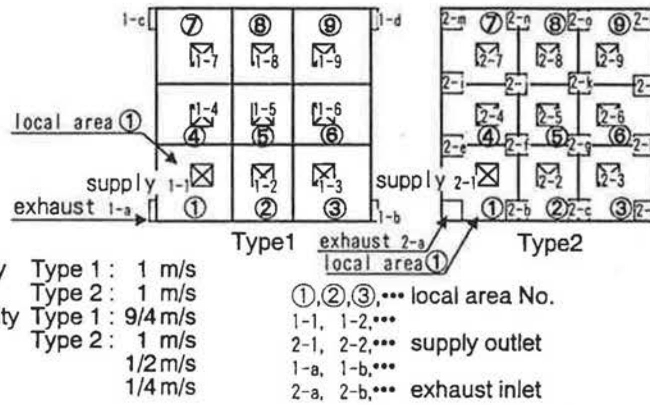


Figure 7
Configuration of model rooms

Figure 8
Layouts of supply - exhaust openings

generation rate q (kg/s) and time passes in reverse
(Time reversal realizes a virtual flowfield where air comes from exhaust inlets, diffuses into a room, and is evacuated from supply outlets.)
C_0 :Concentration under perfect mixing condition, $C_0 = q/Q$
q :total tracer generation rate in whole space (kg/s)
Q :Total air flow rate of exhaust from space (m^3/s)

SVE6 relates to SVE3 in that it is calculated by means of the reversed time tracing of the same flowfield. Although SVE6 is a concentration normalized by the reference concentration under perfect mixing conditions, it could also be related to non - dimensional time normalized by the nominal time constant, i.e. a reciprocal of the air change rate, as is SVE3 (details are given in Kato and Murakami, 1988). Since SVE3 and SVE6 correspond to the age and residual life time of air respectively, the addition of SVE3 and SVE6 yields the residence time of the air (cf. Figure 3).

With SVE3 and SVE6, we can easily obtain the spatial distribution of the age, the residual life time, and the residence time of the air.

APPLICATION EXAMPLES

In order to examine the usefulness of these three new scales, some properties of ventilation effectiveness in model clean rooms are here analyzed.

Model Room Used

Two different flowfields (Type 1 and Type 2) in rooms with nine supply outlets, shown in Figure 7, are analyzed. The layouts of the supply - exhaust openings are shown in Figure 8. These rooms are models of conventional flow - type (turbulent flow - type) clean rooms. The authors have previously demonstrated that, in this type room, the flow field is composed of series of "flow units" which consist of one supply jet and the rising streams around it (Murakami et al. 1987, 1988, 1989, 1990). By expanding this concept of flow units, they also showed that a ventilation system in which the air supply and exhaust are balanced for each flow unit confines the diffusion of contaminants to the flow unit in which they are generated (Kato et. al. 1992).

Type 1 (conventional wall exhaust) has four exhaust inlets located in the wall near the floor. Type 2 has locally balanced supply - exhaust airflow rates and exhaust inlets in the ceiling as well as supply outlets. The airflow rates of exhaust are locally balanced with the supply airflow rates.

Flow and Diffusion field Analysis

Three - dimensional numerical simulations were carried out on the basis of the standard $k - \varepsilon$ two - equation model. The details of flow simulations are described in the papers of Murakami et al. 1987 and Kato et. al. 1992.

SVE5 and SVE6 are calculated as virtual diffusion fields from virtual flowfields with reversed flow direction. On the basis of reversed time tracing, virtual flowfields are calculated approximately so that air returns from exhaust inlets and is sucked into the supply outlets. Here, approximately reversed flowfields are obtained simply by reversing each component of the mean velocity. In this situation, the turbulent diffusion effects of flowfields are neglected. It is rather difficult to include reversed diffusion effects because, in the world of reversed time tracing, the diffusive coefficients become negative and a turbulence transport occurs from a low concentration to a high concentration region. This negative diffusion causes instability in the numerical integration and leads to divergence in the numerical simulation. In this study, the diffusion term is always treated as having a positive coefficient even in the case of reversed time tracing. In this sense, the reversed time tracing virtual flowfield arrived at in this study is not exact and only approximate.

Flowfields

Physical and time reversed virtual flowfields of Type 1 are shown in Figure 6. Flowfields of Type 2 have similar features and are here omitted. In both types of physical flow, the supply jet collides with the floor and diverges, and there are rising streams around the supply jets.

SVE4 : Contribution Ratio of Supply Outlet

Figure 9 shows the spatial distributions of SVE4 (contribution ratio of a supply outlet) for supply 1 - 5 outlet in the Type 1 room and for the supply outlet 2 - 5 in the Type 2 room. In the Type 1 room the territory of the center supply outlet is extended to include the whole space, whereas in the Type 2 room the territory is confined to the center portion because of the locally balanced supply - exhaust ventilation system. Table 1 shows the mean contribution ratio of the air coming from the each supply outlet. The mean contribution ratio is

Table 1 SVE4 for each supply outlet averaged in each local area

room type	type1									type2								
outlet No.	1-1	1-2	1-3	1-4	1-5	1-6	1-7	1-8	1-9	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9
area 1	31%	26%	1%	25%	14%	2%	1%	2%	0%	73%	11%	1%	11%	3%	0%	1%	0%	0%
area 2	3	63	3	5	19	5	0	1	0	13	61	13	2	8	2	0	0	0
area 3	1	26	31	2	14	25	0	2	1	1	11	73	0	3	11	0	0	1
area 4	3	6	0	61	20	2	3	8	0	13	2	0	61	8	0	13	2	0
area 5	1	10	1	10	58	10	1	10	1	3	9	3	9	54	9	3	9	3
area 6	0	6	3	2	20	61	0	8	3	0	2	13	0	8	61	0	2	13
area 7	1	2	0	25	14	2	31	2	1	1	0	0	11	3	0	73	11	1
area 8	0	1	0	5	19	5	3	63	3	0	0	0	2	8	2	13	61	13
area 9	0	2	1	2	14	25	1	26	31	0	0	1	0	3	11	1	11	73

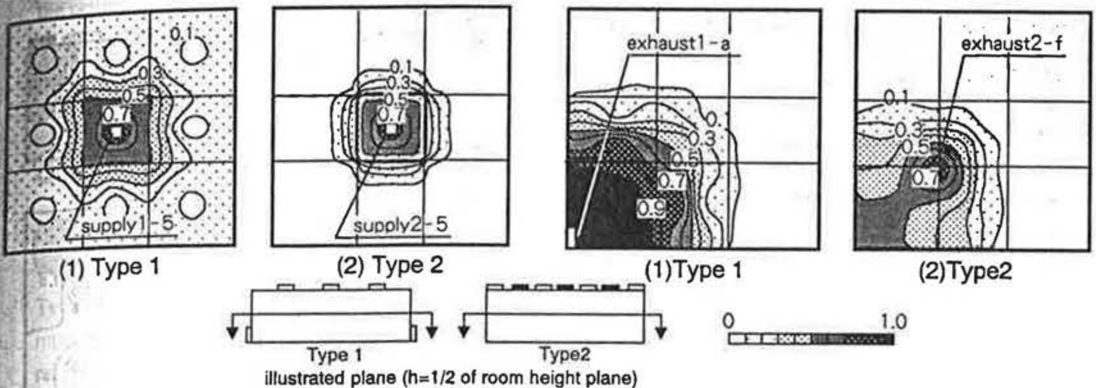


Figure 9 Distribution of SVE4 of supply 1-5, 2-5

Figure 10 Distribution of SVE5 of exhaust 1-a, 2-f

calculated within each flow unit (local area), as is shown in Figure 8. In local areas 5 in both the Type 1 and the Type 2 rooms, only about 50 % air comes from the center supply outlet and the air is mixed with air coming from the other supply outlets. Although in the Type 1 the air coming from the center supply outlet invades the other areas to a level of 15 - 20 %, in the Type 2 the air supplied from the center infiltrates the other areas to a level of below 10 %.

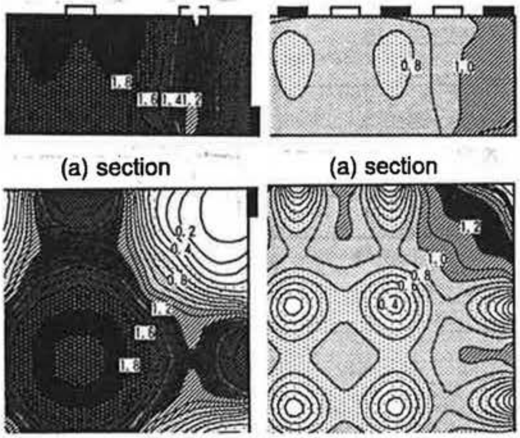
If temperature and air quality of supplied air can be controlled individually at each supply outlet, this table of the contribution ratio of each supply outlet will be useful in estimating the approximate temperature and air quality in each local area.

SVE5 : Contribution Ratio of Exhaust Inlet

Figure 10 shows the spatial distributions of SVE5 (contribution ratio of a exhaust inlet) for exhaust 1 - a in the Type 1 room and for exhaust 2 - f in the Type 2 room. Although the territories of exhaust 1 - a in Type 1 and exhaust 2 - f in Type 2 are almost identical, the values of the contribution ratio, i.e. the relative degree of exhaust (suction) of air by the exhaust inlets, are greatly different. Exhaust 1 - a exhausts air from almost one quarter of the whole space, while exhaust 2 - f exhausts less than 30 % of the air near the exhaust. Table 2 shows the contribution ratio of air exhausted through each exhaust. The value is averaged within each flow unit (each local area) shown in Figure 8. In local area 1 of Type 1, 96 % of the air in the local area will be exhausted through exhaust 1 - a. In local area 1 of Type 2, only 25 % of the air will be exhausted by exhaust 2 - f and other exhausts located within the local area (exhaust 2 - a, 2 - b, 2 - e) also have a share in exhausting

Table 2 SVE5 for each exhaust inlet averaged in each local area

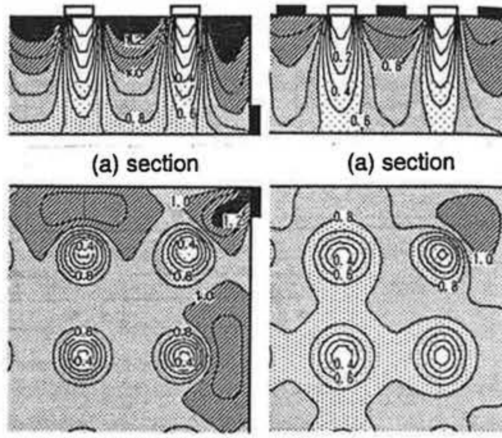
room type	type1				type2															
inlet No.	1-a	1-b	1-c	1-d	2-a	2-b	2-c	2-d	2-e	2-f	2-g	2-h	2-i	2-j	2-k	2-l	2-m	2-n	2-o	2-p
area 1	96%	2%	2%	0%	21%	23%	1%	0%	23%	25%	2%	0%	1%	2%	0%	0%	0%	0%	0%	0%
area 2	46	46	3	3	2	22	22	2	2	22	22	2	0	1	1	0	0	0	0	0
area 3	2	96	0	2	0	1	23	21	0	2	25	23	0	0	2	1	0	0	0	0
area 4	47	3	46	3	2	2	0	0	22	22	1	0	22	22	1	0	2	2	0	0
area 5	25	25	25	25	0	1	1	0	1	23	23	1	1	23	23	1	0	1	1	0
area 6	3	46	3	47	0	0	2	2	0	1	22	22	0	1	22	22	0	0	2	2
area 7	2	0	96	2	0	0	0	0	1	2	0	0	23	25	2	0	21	23	1	0
area 8	3	3	46	46	0	0	0	0	0	1	1	0	2	22	22	2	2	22	22	2
area 9	0	2	2	96	0	0	0	0	0	0	2	1	0	2	25	23	0	1	23	21



(a) section (a) section

(b) plan (1) Type 1 room — (b) plan (2) Type 2 room

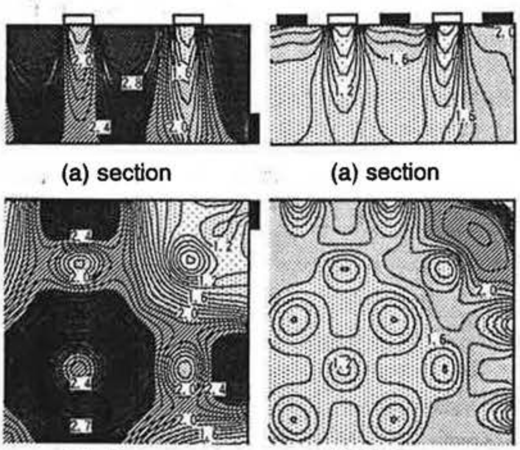
Figure 11 Distribution of SVE6



(a) section (a) section

(b) plan (1) Type 1 room — (b) plan (2) Type 2 room

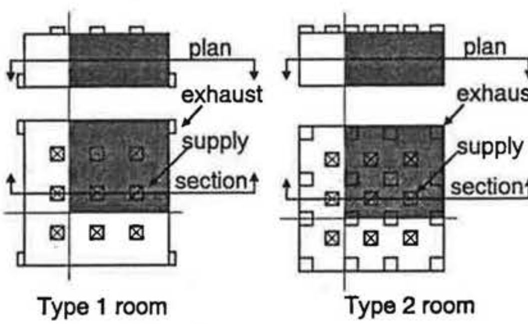
Figure 12 Distribution of SVE3



(a) section (a) section

(b) plan (1) Type 1 room — (b) plan (2) Type 2 room

Figure 13 Distribution of SVE3+SVE6



illustrated area

the air from local area 1. In local area 5 of Type 2, more than 90 % of the air is exhausted through exhausts 2 - f, 2 - g, 2 - j, and 2 - k, and the other exhausts do not share in exhausting the air of that local area. This means that contaminants generated in local area 5 hardly invade other local areas.

SVE6 : Distribution of residual life time of air

Figure 11 shows the spatial distributions of SVE6 (residual life time of air) in the Type 1 and Type 2 rooms. Although the value of SVE6 is a normalized concentration, it can also be interpreted as time normalized by an reciprocal of the air change rate, i.e. the nominal time constant. In the Type 1 room, the residual life time is clearly small near the corners of the room (below 0.4) where the exhausts are located. It is large around the center jet (over 1.8) where rising streams appear. In the Type 2 room, on the whole, the residual life time of air in the room becomes small in comparison with the Type 1 room especially around the jets where rising streams appear. Since these rising streams are exhausted directly through the exhaust inlets in the ceiling the residual life time is rather small. In the Type 2 room, which has many exhausts distributed evenly in the ceiling, the residual life time of air is below 1.0 in the most of the room; however, in the Type 1 room, which has only four exhausts, one in each corner, the residual life time of air in most of the room is over 1.0, except for near the exhausts.

Composite of SVE3 and SVE6 : Residence Time of Air in Room

Figure 13 shows the spatial distributions of the sum of SVE3 and SVE6 (residence time of air) in the Type 1 and Type 2 rooms. Figure 12 shows the spatial distributions of SVE3 (age of air) in the Type 1 and Type 2 rooms, which are used to calculate the sum of SVE3 and SVE6. The values in the figures are also interpreted as time normalized by the reciprocal of the air change rate. Under perfect mixing conditions, the residence time of air is uniformly 2 throughout the room. Under plug flow, it is uniformly 1 throughout the room (Sandberg and Sjöeberg, 1983).

In the Type 1 room, the distribution of residence time is around 2, that is, the ventilation characteristics of the Type 1 rooms are similar to those of perfect mixing conditions. In the Type 2 room, the distribution of residence time is below 2 and the ventilation characteristics are a combination of the characteristics of plug flow and perfect mixing. In the Type 2 room, many exhausts are distributed evenly located in the ceiling and this results in a short passage of air from the supply outlet to the exhaust inlet; the residual life time and the residence time of air in the room thus become correspondingly short.

With numerical simulation of flow and diffusion fields, we can obtain the spatial distributions of many useful scales of ventilation effectiveness easily and in considerable detail.

CONCLUSIONS

Three new scales for measuring ventilation effectiveness (SVE4, 5, 6) in a room are defined. SVE4 and 5 are the contribution ratio of a supply opening and that of an exhaust opening respectively. SVE6 is the residual life time of air in a room. These scales are all evaluated from the distribution of contaminant concentration in a room as were the three scales previously defined by the authors (SVE1, 2, 3). SVE5 and 6 are evaluated easily from the reversed time traced virtual flowfield, which is obtainable only by means of numerical simulation of airflow and contaminant distribution. In order to confirm the usefulness of these scales, the ventilation characteristics of airflow in a room were analyzed.

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