Recommendation

Regarding design standard concentrations of carbon dioxide for calculating the required ventilation rate

To date, the calculation of the required ventilation rate in a building is carried out with the intent to maintain a carbon dioxide concentration of less than 1000 ppm as a comprehensive index for indoor environmental assessment. However, recent increases in the carbon dioxide concentration in the atmospheric environment have resulted in an increased global average carbon dioxide concentration of approximately 410 ppm (2019), with even higher values being shown in urban areas. Based on this, it is expected that the required ventilation rate of a ventilation design in buildings will also increase. Since the increasing ventilation rate brings about the rise in energy consumption in buildings and it will adversely affect the realization of a carbon-neutral society, the necessity and rationality of the current standard should be thoroughly investigated.

However, when considering carbon dioxide as the comprehensive index used to calculate ventilation rate, it follows that the required ventilation rate should not depend on outdoor air carbon dioxide concentrations. Hence, such an increase in the required ventilation rate is considered to be unreasonable and there has been a growing demand for the review of the current ventilation standard with the fixed indoor carbon dioxide concentration. On this basis, on December 6, 2013, the MLIT Government Office, Department of Government and Government Affairs sent a document to Prof. Shinsuke Kato, the president of SHASE at the time, entitled "Regarding the amount of outdoor air introduced (request)." The request was made for an investigation into the required ventilation rate of buildings based on the increasing carbon dioxide concentration of the outdoor air. In response to this, on April 1, 2014, SHASE established the "Indoor Air Quality Subcommittee." Discussions were then held based on survey results of domestic and international literature about the relationship between carbon dioxide concentrations and the required ventilation rate. These discussions covered (1) the actual circumstances of indoor carbon dioxide concentrations, (2) the effect carbon dioxide has on health, (3) standard values of carbon dioxide concentration, and (4) the relationship between carbon dioxide concentrations and ventilation rate design. Additionally, the symposium "Thinking about the required ventilation rate" was held on July 11, 2016. After that, this subcommittee reported "Required ventilation rate for indoor air quality". Here, following discussions between the speakers and participants, a common understanding was reached where "the design ventilation rate for indoor air quality should involve implementation under the conditions of an indoor-outdoor carbon dioxide concentration difference of 700 ppm." Furthermore, the workshop "Required ventilation rate design for indoor air quality, Part 2: Required ventilation rate for maintaining indoor air quality," was hosted at a conference held by SHASE conference in September 2020. Here, more recent research and survey results relating to societal trends were introduced. Furthermore, discussions were held on the content of the revised draft of ventilation standard SHASE-S 102-2011.

This committee re-examines the above-mentioned 2016 Ventilation Equipment Committee/Indoor Air Quality Subcommittee report: "Required ventilation rate for indoor air quality" as well as the results of the symposium held in the same year. Additionally, the committee reviewed the discussions held in the previously mentioned 2020 SHASE workshop and conducted a study based on the survey results of the latest research trends, while also considering the historical background of the carbon dioxide concentration standard values. Based on these results, the committee proposed a revision of the carbon dioxide design standard concentrations for ventilation design.

Recommendation: the design standard concentration (comprehensive index) of carbon dioxide for the required ventilation rate should be :

Outdoor air concentration + 700 ppm

The main rationale for this recommendation is as follows. Please read the report for further details.

① According to surveys conducted on the recognition of carbon dioxide and the required ventilation rate in Japan since the Meiji era, the carbon dioxide concentration of 1000 ppm, which was proposed by Pettenkofer, was recognized from an early stage, and the objective was to remove body odors and biologically released substances from people.

② Conceptualizations of sources of air pollution shifted from "people" to "people + buildings." with a boundary present in the 1980s. It was then that sick building syndrome (SBS) and building-related illness (BRI) became known societal problems. Here, carbon dioxide should no longer have been considered a ventilation index. However, the ventilation standard SHASE-S 102-2011 positioned it as a comprehensive index.

③ It was when sources of air pollution shifted to "people + buildings" that the idea of perceived air quality was proposed. Fanger and other researchers conducted a vast amount of research that showed that carbon dioxide concentration corresponded to approximately 1000 ppm because all perceived air pollution was anthropogenic. However, these results can be considered only under limited conditions. They are limited to cases of outdoor air concentrations at the time and limited further because the amount of carbon dioxide generated by people is affected by age and metabolism.

④ International ventilation standards such as ASHRAE and EN distinguish "humans" and "buildings" as sources of air pollution. They calculate the required ventilation rate for each separately, and then again as a total. Additionally, categories are set according to the occupants and room applications. Because detailed design is possible these can be said to be advanced standards. However, when selecting categories for typical offices, the ventilation rate per person for both ASHRAE and EN is 30 m^3/h. Here, the ventilation rate is almost equivalent to the volume that would be calculated when the difference between the outdoor air concentration and indoor concentration of carbon dioxide is assumed to be 700 ppm.

⑤ The Act on Maintenance of Sanitation in Buildings (1970) stated that the carbon dioxide concentration was set at less than 1000 ppm to prevent fatigue, headache, tinnitus, suffocation, and increases in flicker value. At the time, studies confirmed such physiological effects on the human body as a result of similar concentration levels. In this respect, though Pettenkofer urged the adoption of a value of 1000 ppm, there remain differences in conceptualizations of the standard value.

⑥ The carbon dioxide concentration non-conformity rate for specified buildings in the Act on Maintenance of Sanitation in Buildings has been increasing every year since 1999. Specifically, close to 30% increases have been seen in schools and offices as of 2019. This may not be due to increased outdoor air concentrations, but may instead be caused by revisions of the Act on Rationalizing Energy Use, revisions of the Act on Maintenance of Sanitation in Buildings, and energy conservation activities affected by earthquakes, etc.

⑦ International guidelines on carbon dioxide concentrations vary by country, but many of these define carbon dioxide concentrations in the form of an index. These guidelines may take the

form of those including outdoor air concentration standards, or those including only indoor concentrations themselves. For ventilation standards specified as a "comprehensive index," like those of this society, it is considered desirable to include outdoor air concentrations.

⑧ Many epidemiological studies regarding the effect of carbon dioxide on human health, including building-related illnesses (BRI), do not clarify whether these occur due to the toxicity of carbon dioxide alone. Carbon dioxide is not an index representing all other possible indoor air pollutants in a given space but it is used as an empirical indicator of the adequacy of ventilation.

Based on this rationale, carbon dioxide concentrations in ventilation design should be positioned as a comprehensive index. Further, this should be expressed with a value that uses outdoor air concentrations as a standard instead of with indoor concentrations that depend on the outdoor air concentrations. After considering standard values such as ASHRAE, as well as the increase in carbon dioxide concentrations over the past 50 years, it is recommended that a value of outdoor air concentration + 700 ppm be adopted.

The required ventilation rate calculated based on the design standard concentration of carbon dioxide in this recommendation is 30 m^3/h per person in offices. This value corresponds with the current ventilation design code in Japan; however, it should be noted that compliance with the current Japanese regulation could become challenging. The current standard value of the indoor carbon dioxide concentration according to the Act on Maintenance of Sanitation in Buildings (which applies to specified buildings with a certain total floor area) and the Building Standard Law (central air conditioning system) of Japan is 1000 ppm. However, when mechanical ventilation equipment is operating at the value of outdoor air concentration + 700 ppm, there may be cases in which the standard value is not observed. When the current standard value is maintained, the required ventilation rate per person changes depending on the outdoor air concentration. If the carbon dioxide emission rate is assumed to be 20 L/h per person, the required ventilation rate is 29 m^3/h per person at 300 ppm outdoor air carbon dioxide concentration, 33 m^3/h per person at 400 ppm, 40 m^3/h per person at 500 ppm, 50 m^3/h per person at 600 ppm, and so on. The increase in the required ventilation rate will be unavoidable to adhere to the current regulation. While this recommendation puts forth an idea that does not lead to such an increase in the required ventilation rate, the increase in the indoor carbon dioxide concentration due to the change in the outdoor air concentration should not be allowed ad infinitum. The upper limit of the indoor carbon dioxide concentration should be determined by considering the influence of carbon dioxide on the human body and it should be further investigated.

Note : This recommendation was made by Special Committee on Ventilation Requirement of SHASE. The members of this committee are listed below.
Toshio Yamanaka, U Yanagi, Naoki Kagi, Tomohiro Kobayashi, Kenichi Azuma, Go Iwashita, Tomoyuki Endo, Takeshi Ogasawara, Takashi Kurabuchi, Yasushi Kondo, Jinya Takeuchi, Akihisa Takemura, Masaki Tajima, Yoshihiro Toriumi, Kazuto Nakamura, Motoya Hayashi, Hutoshi Mihashi, Yoshihisa Momoi, Hajime Yoshino

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