Classification of Indoor Climate, Construction, and Finishing Materials

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Abstract

Good indoor climate is one of the main goals of building design and construction. Studies all over the word have shown that this goal is far too seldom obtained as research results are not applied to the practice.

To overcome this problem of information transfer between research and practice, a design guide for good indoor climate was prepared in Finland. It was done with co-operation between the Finnish Association of Construction Clients, the Finnish Association of Architects, the Finnish Association of Consulting Engineers, and the Finnish Society of Indoor Air Quality and Climate.

The documents consists of three parts: 1) Classification of Indoor Climate, 2) Classification of Construction Cleanliness, and 3) Classification of Finishing Materials. Because requirements for all buildings are not always the same, all the parts present the criteria and requirements on two or three quality levels. The lowest category corresponds to the present building practice set by official building codes. Higher categories present significant improvement in the design and construction for better indoor climate. The construction client selects the categories with the design team at an early stage of a construction project. The classification can be referred to in the building specifications. It can be used in new constructions and in evaluation of old buildings, as well as in renovations.

The Classification of Indoor Climate includes target values for indoor air quality and climate. It also gives the most important design values for heating, ventilation and air-conditioning equipment. The Classification of Construction Cleanliness deals mainly with the principles and procedures to be followed at various stages of construction works. The Classification of Finishing Materials contains limit values for chemical emissions of building materials. In addition, it presents the maximum surface area of materials allowed in a space to obtain the requirements of the selected category of indoor climate.

The Classification is intended to be used during the design and contracting phases of construction works and mechanical systems for buildings. It also gives guidelines to manufacturers of equipment and materials to produce better building products in respect of good indoor climate. The Classification can be used both for new constructions and renovations, and also during the evaluation of buildings.

Keywords: air quality, cleanliness, design values, healthy buildings, indoor climate, material emissions, ventilation

Introduction

Indoor climate has become more important for health and comfort during recent years. As people stay indoors approximately 90% of the time, the quality of indoor air for the health is even more important than outdoor air. Good indoor climate reduces illness and the symptoms of sick building syndrome. It also influences comfort and working efficiency. The costs caused by poor indoor climate in the Finnish building stock has been estimated to be 18 billion Finnish marks per year (app. 3 billion ECU), corresponding to the costs of energy consumption of buildings.

Good indoor climate is one of the most important factors in assessing the quality of a building. Research and practice have, unfortunately, shown that good indoor climate is not always achieved. Indoor climate is influenced simultaneously by several factors, such as heating, ventilation and air conditioning, construction methods and materials, operation, maintenance and use of buildings. The Classification of Indoor Climate, Construction, and Finishing Materials /1/ presents guidelines considering all these factors. It has three parts and is intended to be used in design and construction of buildings and their mechanical systems. It also encourages manufacturers of equipment and materials to produce low-emitting building products.

The Classification of Indoor Climate, Construction, and Finishing Materials was developed by Finnish Society of Indoor Air Quality and Climate (FiSIAQ) based on Finnish and international research results. The work was sponsored by the Finnish Ministry of the Environment.

The Finnish classification

The final quality of indoor climate is influenced simultaneously by heating, ventilating and air-conditioning systems and equipment, by the performance of the construction and materials, and by the operation and maintenance of the building. To achieve a good indoor climate, all the guidelines presented in the Classification need to be taken into account throughout all the phases of design, construction and operation. The Classification has three parts: Part 1, Indoor climate; Part 2, Cleanliness of construction; Part 3, Finishing materials and it is intended to be used during the design and contracting of construction works and mechanical systems for buildings, and in the manufacturing of equipment and materials to build healthier and more comfortable buildings. The Classification can be applied to new buildings and for evaluation of all buildings and, when applicable, also during renovation. The Classification gives target and design values for indoor climate and supports the work of clients, designers, equipment manufacturers, contractors and operation personnel. The Classification can be referred to when writing up specifications of construction and mechanical systems. It can be used even as an attachment to such specifications. The Classification does not overrule official building codes or interpretations of them.

When the ultimate goal is good indoor climate, the best category of each part of the Classification has to be selected. The low category of one part cannot be totally compensated by a high category of another part. Thus, for example, the high emissions of building materials are difficult to be compensated by increasing the ventilation.

Selection of categories

The Classifications of Indoor Climate and Finishing Materials have three categories, and the Classification of Construction Cleanliness two categories. Indoor Climate category S 1, Construction Cleanliness category Pl, and Material category Ml correspond to the best quality. Categories S3, P2 and M3 are in line with the official quality set by building codes and regulations.

The categories for indoor climate, construction cleanliness, and finishing materials shall be selected at an early stage of a construction project. The client selects the categories with the design team. With the help of the Classification of Indoor Climate, the target values for the indoor climate are specified. After this, the category of Construction Cleanliness is selected in accordance with the Classification of Construction Cleanliness. The Classification of Finishing Materials is used when selecting building materials. If necessary, the target values and requirements can be selected from different categories. However, when the ultimate goal is good indoor climate, the best category for each part of the Classification shall be selected. The low category of one part cannot be totally compensated by use of a high category for another part. Thus, for example, the high emissions of building materials are difficult to be compensated by increasing ventilation. So far, it has not been possible to take into account material emissions when selecting airflows for ventilation because the finishing materials have been selected at a late stage of the construction process.

The classification of indoor climate (Part 1)

The Classification of Indoor Climate deals with common work and living spaces (office and public buildings, schools, day-care centers, dwellings, and other buildings of similar type). The Classification has three categories: Categories I, II and III. Category I is the best meaning higher satisfaction with indoor climate and lower level of complaints. For example in respect of room temperature, Category I corresponds to 90% of satisfaction. Category III corresponds to the requirements set by building codes.

Target values

The target values of indoor climate factors (Table 1) are used to specify the target level of indoor climate at an early stage of a building project. The target values can also be used for checking the indoor climate and compliance with the requirements. The target values apply to the zone of occupancy of a room which usually extends from the floor surface up to 1.8 meters from it. It begins 0.6 meters from the walls.

The concentrations of indoor air pollutants presented in Table 1 will not be exceeded in general if the ventilation rates are as high as specified in the tables, and if there are no specific pollutant sources in the room. Thus, the measurement of indoor air pollutants is not generally required.

The Classification does not give limit values for concentration of microbes because the building may have mold damages even if the room air does not contain high concentration of bioaerosoles. The concentration of bioaerosoles may vary strongly depending on time, location, conditions and species of microbes.

Design values

The design values presented in Table 2 should be used specifically in dimensioning of heating and air conditioning equipment. The designer also has to define the conditions where the building conforms to the design values including loads and operation of the room (number of occupants, lighting load, equipment load, etc.) and external loads of a room. Design weather conditions are given in the document, too.

Verification of limit values

The design and limit values of a building should be checked when the building is in operation, in winter when the outdoor temperature is below -5 °C, and in summer when the outdoor temperature is above 20 °C and the weather is clear. The compliance of design and target values in other than design conditions have to be checked with calculations taking into consideration also the capacity of heating and cooling equipment. Design and limit values of indoor climate have to be measured with the instruments which a have calibration certificate.

Classification of cleanliness of construction (Part 2)

The Classification of Cleanliness of Construction gives the requirements for construction and air handling equipment, their installation and use. The extend and level of requirements depend on the category which is aimed at. The Classification has two stages: Category 1 corresponds to the best quality and category 2 to the level of present construction practice. Good indoor air quality provides co-operation between all parties involved in the construction project and the fulfillment of all the requirements given. The requirements are given mainly to contractors but also to designers, equipment manufacturers, and users of the building.

The requirements in category 1 include, for example, the following:

Air handling system and equipment

Ductwork. The ductwork has to be cleaned after the manufacturing so that the interior surface of the ducts does not contain oil residues or other harmful substances. The ductwork should be protected from dirt and rain during the storage at the factory and during transportation, as well as at the construction site and in the temporary storage at the installation site. Open ends of ductwork have to be capped during the breaks of installation. The ductwork has to be built so that it can be easily cleaned without damaging the equipment. The ductwork has to be cleaned before the operational test of the air handling systems.

The use of air conditioning equipment during the construction work. The final air conditioning equipment shall not be used for heating, ventilating or air conditioning of the building during the construction process. The operation of air conditioning equipment should be limited only to perform the balancing and measurements after the operational tests.

Air handling units. The supply air of the air handling units has to be cleaned with a filter with dust removal efficiency better than EU 7 (F7). The supply air must not bypass the filter media through the holes or openings between the frames and air handling unit.

Heat recovery from the exhaust air. The pressure of supply and exhaust air has to be controlled so that exhaust air cannot flow through possible leakages in the heat recovery unit to the supply air. Regenerative heat recovery equipment (heat wheel etc.) can be used only when the exhaust air does not contain tobacco smoke or other harmful contaminants.

Use of return air. Return air should not be used in air handling units with the exception of air handling units which only serve one dwelling.

The construction of air handling units. The interior surfaces of air handling units have to be easy to clean. The air handling units have to be air tight so that unclean air cannot enter to the supply air flow.

Cleaning of the ducts. Supply air ductwork has to be inspected with a maximum interval of five years. If the duct contains dust (dust accumulates when sweeping the surface), the ductwork has to be cleaned.

Replacement of filters. The filters of air handling units have to be replaced according to final pressure drop defined by the designer or, at latest, when 50 % of the area of the back side of the filter media has changed its color due to dust.

Structural and architectural work

The section dealing with construction work presents the requirements in the following areas: 1) Separation of the rooms with different categories; 2) Transportation of materials and accessories; 3) Storage of building materials on the construction site; 4) Protection of building materials during the installation and actual construction work; 5) Labeling and protection of cleaner areas during the construction; 6) Cleaning of the spaces during the construction; 7) The final cleaning of the spaces.

Classification of finishing materials (Part 3)

The purpose of the Classification of Finishing Materials is to present requirements for the materials used in common living and work spaces to achieve good indoor air quality. The goal is also to enhance the use and development of low-emitting materials. However, the use of low-emitting materials does not guarantee good room air quality. Ventilation has at the same time to be adequate and the materials should be used according to the manufacturers' specifications. For example, very few materials can stand for excessive moisture. Materials should also be easy to clean.

The Classification of Finishing Materials has three categories, category A being the best and category C containing materials with highest emission rates. Because total emission and concentration in room air depend on the amount of used materials, the Classification gives guidelines for the use of various materials. When the best indoor air category I is selected, the use of higher-emitting **materials** (categories B and C) has to be limited.

Requirements for finishing materials

Category A: Category A is designated for natural materials, such as stone and glass, which are known to be safe in respect of emissions, and for materials which fulfil1 the following requirements: 1) The emission of total volatile organic compounds (TVOC) is below 0.2 mg/m²h; 2) The emission of formaldehyde is below 0.05 mg/m²h; 3) The emission of ammonia is below 0.03 mg/m²h; 4) The emission of the carcinogenic compounds (due to IARC) is below 0.005 mg/m²h; 5) Material is not odorous (dissatisfaction with the odor is below 15%).

Category B: 1) The emission of total volatile organic compounds (TVOC) is below 0.4 mg/m²h; 2) The emission of formaldehyde is below 0.125 mg/m²h; 3) The emission of ammonia is below 0.06 mg/m²h; 4) The emission of the carcinogenic compounds (due to

IARC) is below 0.005 mg/m²h; 5) Material is not strongly odorous (dissatisfaction with the odor is below 30%).

Category C: Category C is for the materials which do not have emission data or the emission data exceed the values specified for materials of category B.

Classified materials must have a product specification which should present emission data and the possible limitations for the use of material and the requirements for environmental conditions when the material is applied. The producer should also have an acceptable quality control system.

The emissions of the materials shall not be greater when the material is in actual use than in the measurement test conditions. For example, the materials which are intended to be used in wet conditions have to stand for high moisture concentration without damage or increase in emissions.

The use of finishing materials

The finishing materials should be selected mainly from category A for the indoor climate category I. The finishing materials belonging to category B must not cover more than 20% of the interior surfaces of a room or not more than 1 m² per floor area. The use of the materials belonging to category C should be limited to minimum.

The finishing materials used in indoor climate category II should belong mainly to categories A and B. Materials belonging to category C should not cover more than 20% of the interior surfaces of a room or not more than 1 m² per floor area.

Measurement methods

The measurement of emissions should be performed when the material is in the actual final form intended for its use. Material emissions shall be measured according to the methods specified in Nordtest or ECA guidelines /4, 5/. The sampling and analyses of chemicals have to be made according to commonly accepted methods. Emissions of materials shall be measured after four weeks from the date of the production or the date when the material is unwrapped from the air tight packing. The samples shall be stored for four weeks before the test in a climate chamber. The time of four weeks will be calculated for paints, levelling agents, adhesives, sealants, etc., from the date of application on the surface. The procedures used in the sample selection and preparation follow the principles outlined in the project "European Data Base on Indoor Air Pollution Sources" /3/.

Experience in practice

The Classification of Indoor Climate, Construction, and Finishing Materials has been adopted for several construction projects. Construction clients and designers have used it as a tool in setting target values for indoor climate and in achieving the goals during the construction. In a year, 2,000 copies of the Classification have been distributed to various parties involved in construction. The Classification has also been translated into English.

The classification has been used in several building projects.

The Classification has been received positively also by the construction industry and by the manufacturers of building materials.

The first part of the Classification, which deals with the target values of indoor climate, have been used widely by designers in various building projects. The target values have also been used as a reference values in the building investigations.

The second part dealing with construction cleanliness has maybe faced the strongest opposition from contractors, the main reason being the unawareness of the nature of the indoor climate problems. However, after the major designers having adopted the principles presented in the Classification in their design it looks like the document is gradually changing the construction practice. It is, for example, more and more common that designers specify that the ducts have to be washed after the manufacturing process and handled on the construction site with capped ends. The largest project in Finland where the classification of the construction cleanliness has been used is the NOKIA headquarters building where 25 km of cleaned ducts have been installed, and the classification followed in other aspects, too. The classification has also been used succesfully in the design and construction of an appartment building for people suffering respiratory diseases /6/.

The third part of the classification, which deals with the material emissions have been used in practice since June 1996. The driving force in the classification for material emissions has been the Finnish Building Information Institute, an organization owned by Finnish architects, which has founded a committee to classify the materials. It makes decisions on the categories of the finishing materials. In the committee, there are representatives of researchers, various construction parties, and material manufacturers. The Finnish Building Information Institute publishes data on classified products. Thus the material manufacturers get free advertisement through the Institute. The committee's decision on emission classes are based on the test data from the certified laboratories. By the end 1997 about one hundred and fifty materials have been granted with the class Ml label. The material manufacturers have started to use the classification certificate and label also in their advertisements, not only for professionals but also for public.

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Table 1. Target values of indoor climate.

Factor	unit	S1	Category s2	s3	
Room temperature, winter	°C	21-22	21-23	20-24	
Room temperature, summer	°C	22-25	22-27	22-27 (35) *	
Floor temperature		°C	19-29	19-29	17-3 1
Vertical temperature difference		°C	<2	<3	<4
Air velocity, winter	21°C	m/s	<0. 10	<0. 15	<0. 15
Air velocity, summer	24°C	m/s	<0. 15	<0.20	<0.25
	27°C	m/s	<0.20	<0.25	<0. 30
Relative humidity of air, winter		%	25-45		
Relative humidity of air, summer		%	30-60		
Noise level of heating and air-conditioning equipment		dB(A)			
offices			<30	<35	<35
living and bedrooms			<25	<25	<28
Air change rate (residence)		l/h	>0.8	>0.6	>0.4
Odor intensity		desipol	<2	<4	<5,5
Total volatile organic compounds		mg/m^3	<0.2	<0.3	<0.6
Formaldehyde (H_2CO)		mg/m^3	<0.03	<0.05	<0. 15
Ammonia (NH_3)		mg/m^3	<0.02	<0.03	<0.05
Carbon dioxide (CO_2)		ppm	<1000	<1250	<1500
		mg/m^3	<1800	<2250	<2700
Carbon monoxide (CO)		mg/m^3	<2	<5	<8
Ozone (O_3)		mg/m^3	<0.05	<0.07	<0. 10
Total suspended particles		mg/m^3	<0.06	<0.06	<0.06
Radon (Rn)		Bq/m^3	<200	<200	<200

Design values of outdoor airflows for air quality	L/s,p	L/sm^2	L/s,p	L/sm^2	L/s,p	L/sm^2
offices	16	2	12	1.5	8	1
conference rooms	12	8	9	6	6	4
classrooms	12	6	9	4.5	6	3
lecture halls	12	12	9	9	6	6
day-care centers	10	4	7,5	3	5	2
living and bedrooms	8	1	6	0.7	5	05

* room temperature shall not exceed +35 °C; room temperature shah not be above +27°C when outdoor temperature is below +15 °C

'-' stands for no specific requirements are set