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DEVELOPMENT AND VERIFICATION OF METHOD FOR BUILDING COOLING LOAD CALCULATION FOR LATVIAN CLIMATE CONDITIONS

ĒKAS AUKSTUMA SLODZES APRĒĶINA METODIKAS IZSTRĀDE UN PĀRBAUDE LATVIJAS KLIMATISKAJIEM APSTĀKĻIEM

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Introduction

A growth of energy consumption in building sector is like a force to consider and estimate energy loads of buildings in the best possible way. There are several cooling load calculation methods and approaches what are used but still there are not useful cooling load calculation methods for Latvia. Local climatic conditions are essential parameters for buildings because the overall energy consumption in buildings interdependent on climatic conditions. The main building cooling load components are: solar radiation transmission load, ventilation and infiltration load and internal load. Prediction of hour cooling load in a building is fundamental for the optimal cost and energy use reduction.

Principles of cooling load calculation method

The efficient use and conservation of energy requires accurate predictions of energy consumption. This cooling load calculation method is based on the Latvian standard LVS EN 15255:2007 "Thermal performance of buildings – Sensible room cooling load calculation – General criteria and validation procedures" (identical to European standard EN 15255:2007) [0]. This standard sets out the level of input and output data, and prescribes the boundary conditions required for a calculation method of the sensible cooling load of a single room under constant and/or floating temperature taking into account the limit of the peak cooling load of the system. It includes a classification scheme of the calculation method and the criteria to be met by a calculation.

In addition to draw out the calculation method was used also Latvian standard LVS EN 15265:2007 "Thermal performance of buildings – Calculation of energy needs for space heating and cooling using dynamic methods – General criteria and validation procedures" for some assumptions and basic information, for example, the energy flow in building (Figure 1.)

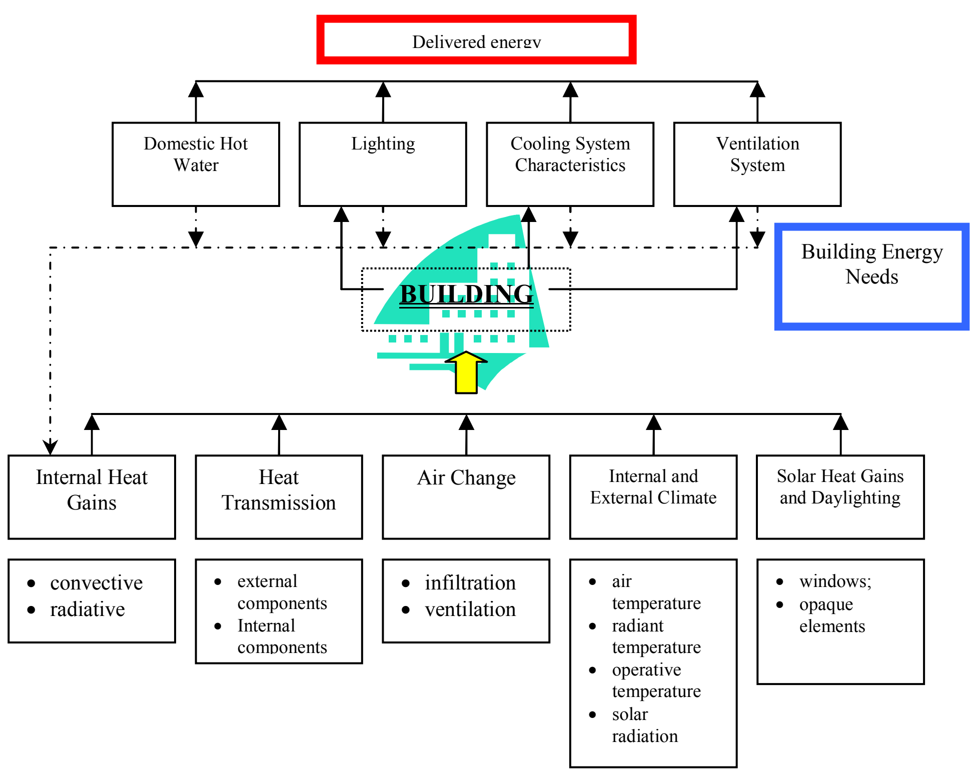

Figure 1. Energy flow in building based on Latvian standard LVS EN 15265:2007

The cooling load calculation method is based on a network of resistances and capacity (HC three-node model) of the heat transfers between the internal and external environment (Figure 2.). This calculation model is based on the simplification of the heat transfer between the internal and external environment.
The method must provide complex thermal analysis of buildings and integrated (systemic) different heat transfer mechanisms interacting in a complex manner [2].
The relevant nodes are defined related to internal air temperature (Θ_i), star temperature (Θ_s), mass temperature (Θ_m), external air temperature (Θ_e) and equivalent external sol-air temperature of external components (Θ_{es}, Θ_{em}). The equivalent conductances *H* [W/K] and heat capacity *C* [J/K] between the internal and the external environment are thermal conductance due to air ventilation (H_v), thermal conductances of external components between outside and inside (H_{es}, H_{em}), thermal conductances corresponding to the heat exchange between the internal surfuces and the internal air (H_{is}, H_{ms}), heat capacity of the enclosure elements (C_m) and the equivalent thermal mass area (A_m). The heat flows [W] are heat flow to Θ_i node (Φ_i), heat flow to Θ_s node (Φ_s) and heat flow to Θ_m node (Φ_m).
The results (output data) of the calculation are hourly values of the room cooling load (P, [W]), the internal air temperature (Θ_i, [°C]) and operative temperature (Θ_{op}, [°C]).
The calculation consider number of assumptions as a minimum requirements, for example, Θ_i is uniform throughout the room, the long-wave radiative and the convective heat transfer at the internal surface of each component are treated separately, thermal bridges are treaded by steady state calculation etc.

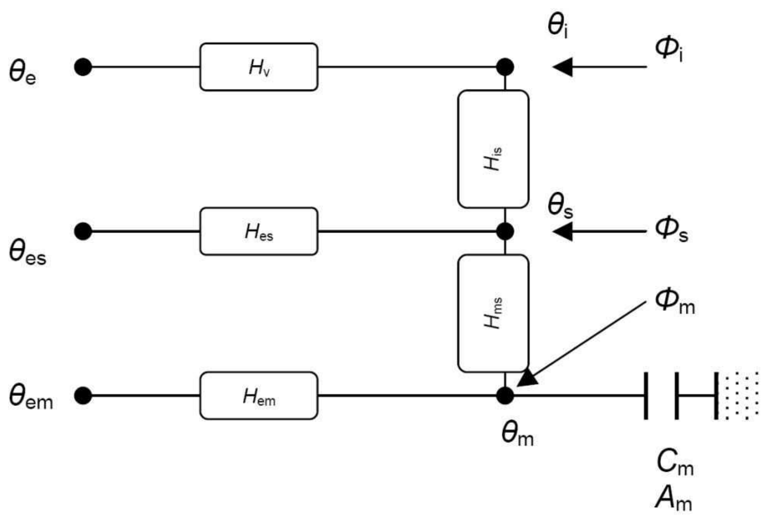

Figure 2. Cooling load calculation network []

The calculation of the internal temperatures and required cooling power is based on (1) the calculation of the room behaviour for a given time step, the internal room temperature is a function of the applied cooling power and (2) the cooling system behaviour through its control device, the applied cooling power is linked to the internal room temperature. The combination of both enables the calculation of the internal temperatures and actual cooling power for each time step.
Accurate cooling load prediction in a building include adjusting the starting time of cooling to meet start-up loads, minimizing or limiting the energy on-peak demand, energy and cost optimization [3].

Validation of cooling load calculation method

This process was started with a literature revision and analytical verification of method algorithm. Validation procedure includes the complying with maximum simplification allowed in this standard under cyclic conditions for several cases and comparison of the calculated values with those. This procedure check the room sensible heat balance model, taking account the internal, external surface and air heat balances, the conduction through the building envelope, the effect of the thermal mass of the structure and the heat balance solution method.
The investigated method complies with this standard if each of the following three conditions is fulfilled using equations (1), (2) and (3).

$$abs(\theta_{op,\max} - \theta_{op,\max,ref}) \leq 0.5K \quad (1)$$

$$abs(P_{\max} - P_{\max,ref}) / P_{\max,ref} \leq 0.05 \quad (2)$$

$$abs(P_{av} - P_{av,ref}) / P_{av,ref} \leq 0.05 \quad (3)$$

Where *abs* is the absolute value, $\theta_{op,\max,ref}$ is maximum reference operative temperature [°C], $P_{\max,ref}$ is maximum reference cooling power [W] and $P_{av,ref}$ is average reference cooling power [W].
Verification of developed cooling load calculation method using validation procedure show almost sensitive results, it is method is valid and plenty accurate. Only in equation (1) the result was not equal or less 0.5 K, but 0.9 K.

Reference room

The internal dimensions of the reference room are: length 3.6 m, depth 5.5m, height 2.8 m. The external wall including glazing is exposed to the West. The window frame fraction is assumed to be zero. Thermal transmittance of the glazing system U_g = 2.69 W/(m^2·K) and total solar energy transmittance (solar factor) S_f = 0.77. For opaque components solar absorption of all external wall surface α_{sr} = 0.6. All thermophysical properties of the opaque components of reference room, included all layers, external radiant temperature is assumed to be equal to external air temperature Θ_e.

Table 1.

Basic information about reference room

Components/ Elements	Characteristic/Parameters/Notes
Internal gains	Convective 20 W/m2 Radiative 30 W/m2 From 08:00 to 18:00
Ventilation	0 air changes per hour of air at external temperature
Glazing system	With/without external shade
External/internal walls Ceiling Floor	Layer thickness d, [m] Thermal conductance λ, [W/(m^2·K)] Density ρ, [kg/m^3] Specific heat capacity of air at constant pressure c_p, [J/(kg·K)]
Climatic data	The evolution during an hour is assumed to be linear between the previous and subsequent hour.

Approbation of cooling calculation method

Investigated cooling load calculation method with climatic data of Latvia and all parameters of reference room from standard was approbated in several ways. Climatic data for location include hourly external air temperature, the intensity of solar radiation (direct normal, diffuse horizontal and reflected component of the solar radiation reaching the surface) and the external radiant temperature (sky and surrounding). Implementations of method allow making cooling load curve, cooling daily load curve (Figure 3.) and cooling load-duration curve.
For method work out platform was used MS Excel applications. The calculation method consists of several main blocks: parameters of building, specific thermal conductances and coefficients, heat gains, heat flows and temperatures.

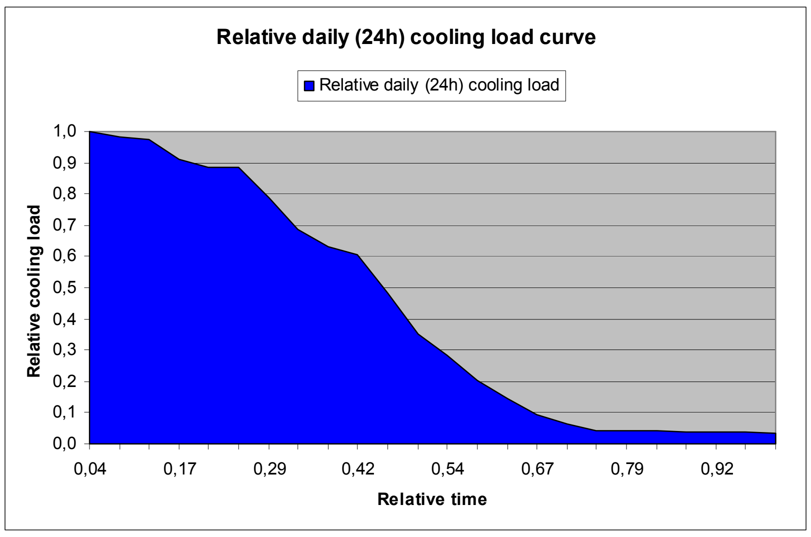

Figure 3. Relative daily cooling load curve

Assumptions of cooling season based on fact that cooling appliances are needed to keep the indoor temperatures at specified levels (internal air temperature) but length of the cooling season differs substantially from country to country and from region to region, basically for Latvia was taken period from middle of March till middle of September.

Conclusion

In this paper, the application of the cooling load calculation based on standard is proposed and approved using Latvia climate conditions and data. The preliminary results show that method is useful and need to be investigated further. This method can be used to preventive cooling load of rooms or buildings and result draw on preventive load curve for further estimation related with cooling systems design to employ climatic data of Latvia. Validation procedure shows that investigated cooling load calculation method is valid and plenty accurate.

Acknowledgement

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Jaunzems D., Veidenbergs I. Ēkas aukstuma slodzes aprēķina metodikas izstrāde un pārbaude Latvijas klimatiskajiem apstākļiem
Precīza un reāla ēkas aukstuma slodzes noteikšana konkrētos klimata apstākļos ir nozīmīga, nosakot nepieciešamos ar aukstuma iekārtām un sistēmām saistītos parametrus. Izstrādātā aukstuma slodzes aprēķinu metode ir balstīta uz standartu LVS EN 15255:2007 "Ēku energoefektivitāte. Sajūtamās telpu dzesēšanas slodzes rēķināšana. Vispārīgie kritēriji un validēšana", kas nosaka šīs aprēķinu metodes galvenos obligātos pieņēmumus, kritērijus un validācijas procedūras. Ar izstrādātās metodes palīdzību var iegūt izejas datus, kas raksturo ēkas vai telpas ikstundas maksimālo aukstuma slodzi un darba temperatūras. Aprēķinos tiek izmantoti Latvijas klimata dati (Saules starojums, ārgaisa temperatūras u.c.). Aprēķinu metodikas izejas dati dod iespēju konstruēt konkrētas ēkas vai telpas aukstuma slodžu diagrammas gan diennakts, gan arī visas dzesēšanas sezonas griezumā. Izstrādātā aprēķinu metode ir aprobēta un ļauj turpmāk veikt nepieciešamos ēku vai telpu aukstuma slodzes aprēķinus, kā arī noteikt nepieciešamos dzesēšanas iekārtu un sistēmu parametrus.

Jaunzems D. Veidenbergs I. Development and verification of method for building cooling load calculation for Latvian climate conditions
Accurate and real cooling load prediction in specified climatic conditions is essential for further determination of required cooling equipment and systems parameters. Developed cooling load calculation method is based on the standard LVS EN 155255:2007"Thermal performance of buildings – Sensible room cooling load calculation – General criteria and validation procedures", which define general assumptions, criterions and validation procedures. Using this investigated method it is possible to get data that characterize and result the hourly values of the building or room cooling load and operative temperatures. The climate conditions of Latvia (solar radiation, external air temperature etc.) are used for calculations. The results of the calculation method make it possible to construct daily or cooling season cooling load curves for specific buildings or rooms. This investigated calculation method is approved and allows necessary cooling load calculations and define required parameters of cooling equipment and systems.

Яунземс Д., Веиденбергс И. Разработка и апробация методики для расчёта нагрузки охлаждения зданий в климатических условиях Латвии
Определение точной и реальной холодильной нагрузки в конкретных климатических условиях важно для определения параметров, связанных с холодильным оборудованием и системами. Разработанная методика расчёта холодильной нагрузки основана на стандарте LVS EN 15255:2007 "Энергоэффективность зданий. Расчёт ощутимой холодильной нагрузки в помещении. Общие критерии и проверка достоверности", в котором указаны главные обязательные предположения, критерии и процедуры проверки достоверности для данной методики. С помощью разработанной методики можно определить и получить выходные данные, характеризующие почасовую максимальную холодильную нагрузку в данном помещении или здании и рабочие температуры. В расчётах были использованы Латвийские климатические данные (солнечное излучение, внешняя температура и пр.).Выходные данные дают возможность создавать диаграммы холодильных нагрузок для конкретных помещений или зданий по суточным данным или для всего сезона охлаждения. Разработанная методика апробирована и даёт возможность проведения дальнейших расчётов холодильной нагрузки для зданий или помещений, а также определять необходимые параметры для холодильного оборудования и систем.