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TOTAL PERFORMANCE - USEFUL TOOL TO MEASURE QUALITY OF BUILDINGS

BY

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Abstract. The concept of total performance meets the modern vision of improving the products quality, including the buildings. Building quality can be assessed by the extent to which all performance criteria are met, which refers to functionality, safety and quality of the interior environment.

This paper presents the results of a study concerning the evaluation of the quality of an education building in terms of the quality of indoor environment. Are taken into account both the levels of performance values as determined by measurement and the processing results based on the users' responses to a questionnaire relative to the way of perception of indoor environment quality. Comparison of the results of measurements with subjective assessments confirms the importance of the organism adaptability to environmental conditions, but also the necessity of objective measurements of characteristic parameters values, in order to obtain an accurate assessment of total performance.

Key words: total building performance; inhabitants' requirements; performance criteria.

1. Introduction

The approach of the complex issue of buildings from the point of view of performance concept takes part in the global trend for conceptual improvement of design and assessment methods. Research programs, having as

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objective the elaboration of some assessment frame on the base of performance concept, have been developed in the most developed countries beginning with the ’70.

An important step in this approach is the introduction of the Total Building Performance concept (TBP), appeared in USA, during the last decades of the last century (Hartkopf *et al*., 1986). It offers an assessment instrument of building quality, from the point of view of measure in which are satisfied the ensemble of performance requirements, respectively: spatiality, energy performance, air quality, thermal comfort, acoustic comfort and visual comfort.

This field was the subject of many studies, with different approaches. At Singapore, the Centre for Total Building Performance is functioning near Building and Construction Authority (BCA) and near National University of Singapore. The Centre for TBP has as many objectives the developing of complex methodologies, based on some results of systematic studies and researches, for the application of TBP concept in terms of indicators (mandates) of performance and their integration in the building system (Kian, 2001).

In the same time, complex instruments have been created in order to assess the buildings and urban areas quality from the point of view of measure in which are satisfied the durability criteria (LEED, CASBEE BREAM, GBTool, Green Star Australia, etc.). Finally, the assessment is made through a complex indicator (score) upon which a durability certificate is issued, the building/urban ensemble being granted with a platinum, gold or bronze medal.

2. Specific Aspects Concerning the Use of TBP Concept for the Building Quality Assessment

According some authors (Baird, 2009) the assessment systems, mentioned above, are exclusively focused on technical and measurable aspects, as energy consumption, use of water and materials resources. This makes that, in certain circumstances, the actual performance of a building not to be in concordance with that estimated by means mentioned above. Studies made on buildings in use show that not always the fulfillment of some standardized performance levels, expressed by measurable physical quantities or possible to determine by calculation, is in full accordance with the satisfaction level of users’ expectations. In this respect, based on data provided by literature, may be seen the following considerations:

a) The total performance of the building is determined by three sub-components of the building system, respectively building, installations and equipments and the inhabitant’s behaviour, the contribution of each depending on the quality of design, execution and management of exploitation (Backer, 2009).

b) Wong and Jan (2003) propose the concept of separation of overall performance in two areas of application, the first referring to the performance criteria relating to integrity, protection against destructive environmental action, etc., and the second referring to those related to indoor environment quality from the point of view of comfort and optimum air composition.

c) The total performance evaluation involves the evaluation of effective level of performance for each of the considered requirements. From this point of view, it can be identified three categories of performance criteria:

α) criteria whose actual level of performance can only be judged on the objective basis, calculations, simulations, measurements, etc.; they refer to structural integrity, fire safety, energy performance, etc.;

β) criteria whose actual level of performance can be estimated both on objective bases and subjective ones, in this category being included criteria related to indoor environment quality;

γ) criteria that can be evaluated exclusively on subjective basis, such as architectural appearance, functionality, way of framing in the urban ensemble, etc.

Po Seng Kian (2001) shows that a full analysis of an operating space, in order to establish a diagnosis, requires experts' assessments, direct measurements, but also the perception of users expressed in replies to some questionnaires.

V. Backer (2009) shows that current comfort standards do not sufficiently take into account the body's adaptability to environmental conditions, which is manifested by the body's ability to make changes on the environmental conditions as well as on personal comfort in order to improve the comfort. This capacity is used especially in areas where environmental quality is maintained by passive systems, in which natural ventilation has the first place determining the presence of some adaptive opportunities such as

a) possibility to adapt the clothing to the indoor environment conditions;

b) possibility to open windows (the existence of mobile mesh window);

c) the existence of some adjacent spaces (atrium, green-house spaces, etc.);

d) the possibility to control shading systems;

e) local heating/cooling systems, etc.

Systematic studies made in this field show that in spaces with adaptive opportunity, the inhabitants have the ability to adapt to temperatures with 5°C over the upper limit and with 3°C under the lower limit, leading to significant differences between the performance level assessed on objective bases and those resulted from the users' assessing.

3. Case Study. Assessment of Total Performance Concerning the Indoor Environment Quality in an University Education Room

3.1. Occupants' Assessing

In order to get some data on the extent to which users' expectations are met to indoor environment quality inside a lecture room, questionnaires were distributed to a number of 100 persons, which use this space in different period of the academic semester. These questionnaires asked for assessment on a scale from 1 to 5 of the indoor environment features concerning to

a) Functionality.

b) Aesthetic architectural appearance.

c) Thermal comfort during the winter season.

d) Thermal comfort during the summer season.

e) Acoustic comfort.

f) Visual comfort.

g) Air quality.

Depending on the frequency, the results are presented in Fig. 1.

The significance of the scoring being: 1 – unsatisfactory; 2 – satisfactory; 3 – well; 4 – very well; 5 – exceptionally.

Analysing the get results, it may be emphasized the following findings:

a) the majority of occupants consider that the space functionality at level well, very well and exceptional (92.5%);

b) concerning aesthetic architectural appearance, 27.5% consider that it is satisfactory and only 62.5% consider it as being well and very well;

c) the thermal comfort during winter season is estimated as being very well and exceptional by 75% of occupants;

d) the thermal comfort during summer season is estimated as being well and very well by 55% users, but 25% consider it as satisfactory, and 2.5% as unsatisfactory;

e) the same unsatisfactory percentage is registered for the acoustic and visual comfort;

f) concerning the air quality, the unsatisfactory percentage is 12.5% and only 37.5% consider the air quality as being very well.

Taking into account the scores for each requirement in absolute terms and refering to the maximum possible level of satisfaction of 500 points (if all requirements would be satisfied at exceptional level) it results the mean level of satisfaction that is represented in Fig. 2. The significance of the scoring being: a) functionality, b) aesthetic architectural appearance; c) thermal comfort during

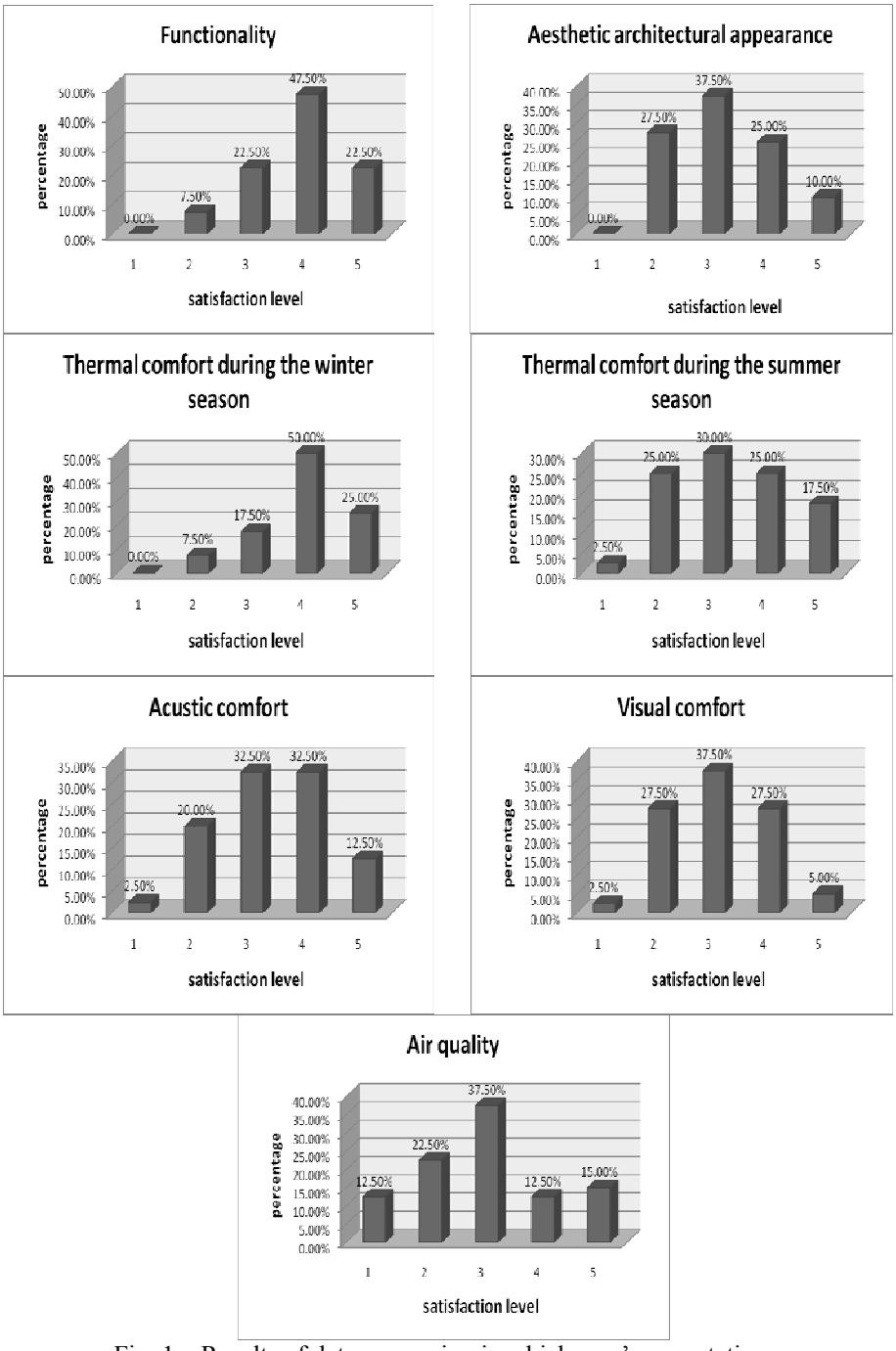

Fig. 1 – Results of data processing in which user's expectations are met on indoor environment quality in the lecture room.

the winter season; d) thermal comfort during the summer season; e) acoustic comfort; f) visual comfort; g) air quality.

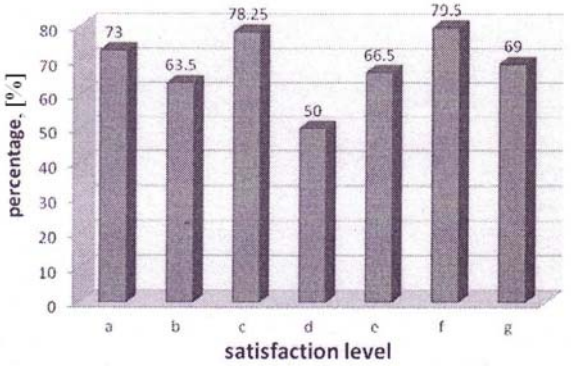

Fig. 2 – The mean level of satisfaction of quality conditions of the indoor environment estimated on the base of users' perception.

It can be noticed that the requirements with the highest level of satisfaction are the visual comfort and the thermal comfort during winter, and the lowest level is for the thermal comfort during summer.

3.2. Objective Evaluations

The indoor environment quality, in the lecture room that was the subject of the case study, was analysed also by objective measurements concerning temperature and relative humidity of the indoor air and the CO_2 concentration level during 16 hours, in January month period of the 2010 year. The measurements were made by means of an air-meter device. During this time, the room was occupied for 2 h, and the heating system worked continuously.

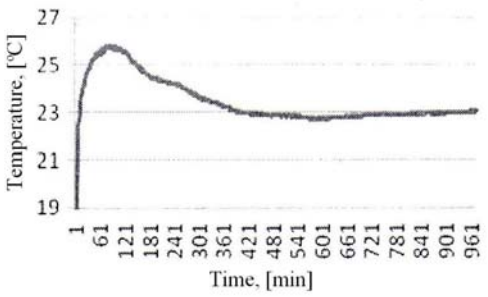

Fig. 3 – Variation of indoor air temperature inside the lecture room during the assessment time.

The assessments results emphasize the following aspects:

a) The indoor air temperature presents high values, during the employment duration these being situated between 23.5°C and 25.5°C (Fig. 3).

b) The relative humidity of indoor air (Fig. 4) is situated between 38% and 43% during the employment duration, getting down under 36% after the disappearance of vapours sources caused by the occupants presence. This kind of values, in certain combinations with air temperature values, creates for the users the satisfaction sensation from the thermal comfort point of view.

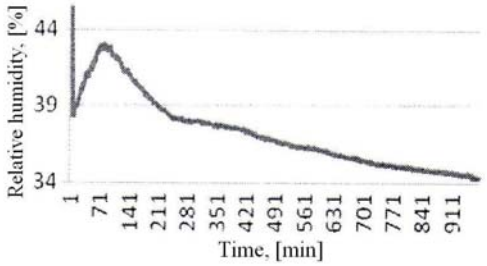

Fig. 4 – Variation of relative humidity inside the lecture room during the assessment time.

c) During the assessment time, the CO_2 concentration presents higher values than the maximum allowable ones (166 ppm), the maximum value getting to 3,669 ppm (Fig. 5).

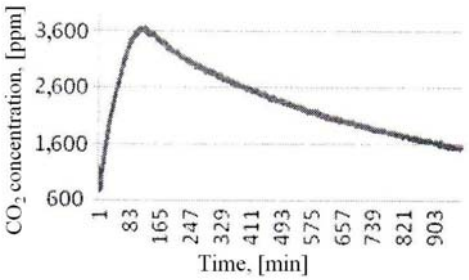

Fig. 5 – Variation of CO_2 concentration during the assessment time.

Synthetically, the parameters values that characterized the indoor environment quality are presented in Table 1.

Table 1

Values of Characteristic Parameters of the Inside Environment Resulted by Measurements

Parameter	Recorded values		
	Mean	Maximum	Minimum
Temperature, [°C]	23.45	25.8	18.9
Dew point, [°C]	14.40	17.2	11.4
Relative humidity, [%]	37.25	45.44	34.35
CO_2 concentration, [ppm]	2,373	3,669	774

Comparing the measurements results with data obtained by processing the responses to questionnaires distributed to users, it results the following observations:

a) The indoor air temperature is above the standardized value recommended by prEN 15251:2006:E - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics of 23°C for education buildings. However, the thermal comfort during the winter season is estimated as being very good and exceptional by 75% of subjects, representing a mean percentage of satisfaction of 80%. This can be explained, on one hand, by the adaptation opportunities offered by the space that means mainly the possibility to adapt the occupants' clothing to the indoor environment conditions. On the other hand, the high temperature values are combined with low values of relative humidity, which removes the sensation of discomfort by overheating.

b) Relating to air composition, the insatisfaction percentage is 12.5%, and 37.5% of users consider that the air quality is very good. The measurements show, however, that after less than one hour of occupation, the CO_2 concentration exceeds the allowable value. It results that for a correct estimation of the space performance from the indoor environment quality, the subjective assessments should be linked with results of some calculus or experimental measurements.

4. Conclusions

The concept of total buildings performance (TBP) represents an assessment instruments of buildings quality, by a simultaneous consideration of measure in which are satisfied the main requirements, in order to establish a diagnosis. This may serve to improve the building behaviour during operation period through rehabilitation or to the design of new buildings, with high performance levels.

The effective level of satisfaction of main requirements may be determined by objective methods (calculus, measurements, simulations), regulated in technical standards, but also by knowledge measure in which are satisfied the users' expectations. The indoor environment quality is an important characteristic of the building system that mainly involves this thing.

The case study made inside the education space from a building in operation emphasizes the following observations:

a) the users' estimation concerning the measure in which are satisfied some requirements, such as thermal comfort in winter conditions, are certified by results of some effective assessments;

b) the existance of important characteristics of indoor environment, with implications on the intelectual efficiency and even on occupants' health, such as

CO_2 concentration in air, where the users' perception is not enough, effective measurements being absolutely necessary.

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PERFORMANŢA TOTALĂ – INSTRUMENT UTIL PENTRU EVALUAREA CALITĂŢII CLĂDIRILOR

(Rezumat)

Conceptul de *performanţă totală* corespunde viziunii moderne privind aprecierea calităţii produselor, inclusiv a clădirilor. Calitatea clădirilor poate fi apreciată prin măsura în care sunt satisfăcute totalitatea criteriilor de performanţă, care se referă la funcţionalitate, siguranţă şi calitatea mediului interior.

Se prezintă rezultatele unui studiu privind aprecierea calităţii unei clădiri de învăţământ din punct de vedere al calităţii mediului interior. Sunt luate în considerare atât valorile nivelurilor de performanţă determinate prin măsurători cît şi cele rezultate pe baza prelucrării răspunsurilor utilizatorilor la un chestionar relativ la modul de percepţie a calităţii mediului interior.

Compararea rezultatelor măsurătorilor cu cele ale aprecierilor subiective confirmă importanţa capacităţii de adaptare a organismului la condiţiile de mediu, dar şi necesitatea unor determinări obiective ale valorilor parametrilor caracteristici, pentru a obţine o evaluare corectă a performanţei totale.