IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: Linda Vesela and Jaroslav Synek 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **471** 022013

Quality Control in Building and Construction

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Abstract. When assessing construction output and buildings as such, the quality of buildings as a whole and individual construction work is a frequent and legitimate topic. In order to achieve the required quality, the quality must be predefined by the agreed characteristics, the quality marks and the values of their parameters. At the same time, we need to know the procedures, the work operations leading to their fulfilment, and the steps that the quality parameters will verify, and the criteria by which we would evaluate the quality. Construction is a product associated with the expectation of long life and durability, usually for 50 to 100 years. Thus, the relationship between quality and time is to a large extent decisive, just like the time intervals in which quality and durability will be assessed. Defining the quality requirements is the basis for the preparatory, production and evaluation procedures leading to the desired quality (quality is the degree of fulfilment of requirements by a set of internal characteristics). Qualitative requirements are determined on the basis of the user's expectations and ideas about the use of the product, the construction. The most reliable source of this information are the operational characteristics (family house, apartment house, hotel, hospital) and the operating costs considered. The information is used by the designer, contractor and building operator. They can be considered as requirements (the requirement is a need or an expectation that is set, generally assumed or mandatory) - the basis for effective design, implementation, operation and maintenance of the building. Therefore, it is necessary to pay attention to the determination of the basic requirements (their determination, including the determination of boundary conditions, limits and tolerances), and to define procedures for the fulfilment of these basic requirements in all related operations.

1. Introduction

When assessing construction output and building structures, the quality of buildings, and individual construction work is a frequent and legitimate topic. In order to achieve the required quality, the quality must be predefined by the agreed characteristics, the quality marks indexes, and the values of their parameters. At the same time, the procedures, the work operations leading to fulfilment, and the steps that the quality parameters will verify, and the criteria by which we would evaluate the quality need to be known.

Constructed structure is a product associated with the expectation of long life, and durability, usually in the range of 50 to 100 years. Thus, the relationship between the quality and the time is to a large extent decisive, just like the time intervals in which the quality, and the durability will be assessed.

In order to effectively fulfil quality requirements, it is necessary to establish procedures that would translate the quality control needs into the guidelines for the phases from design to operation, maintenance, and repair of the structures.

2. Quality and its requirements

The quality requirements definition is the basis for the preparatory, production and evaluation procedures leading to the desired quality (quality is the degree of fulfilment of requirements by a set of internal characteristics [1]). Qualitative requirements are determined on the basis of the user's expectations, and the ideas about the use of the product, the structure. The most reliable sources of this information are the operational characteristics (family house, apartment house, hotel, hospital), and the considered operating costs. The information is used by the designer, the contractor and the building operator. They can be considered as requirements (the requirement is a specified need or an expectation, generally assumed or mandatory [1], and as guides for effective design, construction, operation and maintenance of the building.

Fulfilment of requirements during the project is monitored and verified by agreed procedures. Monitoring and evaluation of the agreed quality parameters must include correct setting of tolerances to control the product quality.. Incompliance to the correct setting of tolerances is usually the basis for quality claims.

Therefore, it is necessary to pay attention to the determination of the basic requirements (their determination, including the determination of boundary conditions, limits and tolerances), and to define procedures for the fulfilment of the basic requirements in all related operations.

3. The role of requirements during the design process of building

Many aspects, and requirements need to be taken into account when designing building structures to meet the basic technical requirements. The design should be considered from the point of view of the basic requirements (ie 268/2006 Coll.), mechanical resistance and stability, fire safety and health protection, living conditions and environment, protection against noise, operation safety, energy saving and thermal insulation. Designed, and operated construction products shall comply also with requirements of the sustainable use of natural resources utilization.

When designing, and operating building products in compliance with the requirements, the designer has to work with normative values so that the final design would meet the specified general requirements (acoustic, thermal, geometric, etc.) for the construction, and the whole building. At the same time, the marginal conditions - tolerances in which the considered technical parameters are still to be observed - must be subject to their verification.

4. Limits determination for the construction technical parameters

The marginal conditions (limit values) should be set for each controlled construction and parameter (value) to respect the properties of the designed and used materials, the construction technology’s, and taking into account the intended use of the completed building. They should therefore be defined as a tolerance interval, with a standard requirement for the mid value (usually), and the intervals defined on the basis of the product specifications, together with the construction tolerances. The tolerance intervals must be designed and judged in the interaction of related, and influencing processes.

At the same time, it is necessary to define the exact procedure for checking the technical requirements of completed structures.

5. Example - geometric accuracy

One of the important and distinctive features of the quality is the geometric accuracy (ground plan and height dimensions of the proposed space) of the element, and construction for which the marginal conditions should be determined. Determination of tolerances for room dimensions, and tolerances of measured values are the basic parameters that must be set for achieving the required result, area and volume of the room. The tolerances are often underestimated when designing the project documentation, despite the fact that the minimum required dimensions are one of the basic contractual and technical parameters of the construction, as defined in the national regulations and the contractual documents. Their non-compliance is usually severely penalized.

The design requirements for the minimum headroom defined for certain types of rooms and structures must comply with the requirements laid down by the law, or even by the technical standards. At the same time, the design must respect the possibilities of construction technology, the properties of construction regarding the material characteristics, and the knowledge of the time behaviour (creep). Only their overview forms the basis for determining the deviation of the geometrical accuracy of the (supporting) structure, which must be incorporated in the design.

In order to meet the tolerances, the client's requirements for the room size of the completed construction, the geometric deviations of the individual parts of the structure must be determined in accordance with the requirements of the technical standards for their execution and / or design.

5.1. Room height deviations

As-built ceiling height may be affected by the following deviations of geometric parameters, in particular:

- Constructional heights of ceiling support elements,
- Thickness of floor layers,
- Deflection and creeping of ceiling slab
- Thickness of surface finish - surface finish of ceilings, floors

Therefore, the geometrical precision of not only the relevant supporting structures, their surface finishes (plasters), but also the deviations of the floor layers, the possible false ceilings, and the change of the shape (deflection or creep) of the horizontal supporting structures (ceiling slab), must be considered in the design, and in the construction of supporting structures. The minimum ceiling height must therefore be increased by the tolerances allowed for the as-built supporting structures, floors, the intended deflection of the ceilings, and the thickness of the surface finish of the ceiling structure. For the finishes products (in floors, ceilings), it is necessary to include their manufacturing and installation tolerances.

The projected headroom must be determined as:

Min. headroom according to *technical, legal or functional* requirements

+ max. deviation of construction height
+ max. deviation of thickness of ceiling slab
+ max. deviation of floor thickness
+ max. projected ceiling slab deflection
+ possible surface finish of the lower face of the ceiling

5.2. Marginal conditions for Room Height design

The construction height shall be designed with the necessary tolerance for the abovementioned deviations of the known construction technology so that the minimum technical requirements of the ceiling height of the completed structures, when using the possible construction technologies, are respected.

The basis for the calculation of geometrical tolerances (marginal conditions) of the headroom are the allowed deviations from the dimensions recommended in the technical standards for the design or execution of constructions. If there are no tolerances in the standard, it must be determined individually.

5.3. Calculation

The recommended headroom $h_{sv,dop}$ should be calculated according to the following relationship

$$\boldsymbol{h_{sv,dop}} = \boldsymbol{h_{norm}} + \left(\Delta \boldsymbol{h_{kv}} + \Delta \boldsymbol{t_{sd}} + \Delta \boldsymbol{t_p} + \boldsymbol{t_{ps}} + \boldsymbol{p}\right) \times \boldsymbol{k_{0,95}} \quad (1)$$

Where h_{norm} is the required minimum headroom

Δh_{kv} is the deviation of the construction height

Δt_{sd} is the deviation of the thickness of the ceiling slab

Δt_p is the deviation of the floor thickness

t_{ps} is the thickness of the surface treatment of the lower face of the ceiling slab

p is the assumed deflection of the ceiling slab

$k_{0,95}$ is the probability coefficient for the occurrence of maximum deviations

Deviations are considered in positive values.

In the calculation, maximum deviations are considered. In fact, it must not be assumed that the maximum deviations would occur all at once. The coefficient k 0.95, the recommended value of which is 0.71, is therefore included in the calculation. This value corresponds to about 95% (figure 1) of the quantile and was determined experimentally based on the as-built measured values.

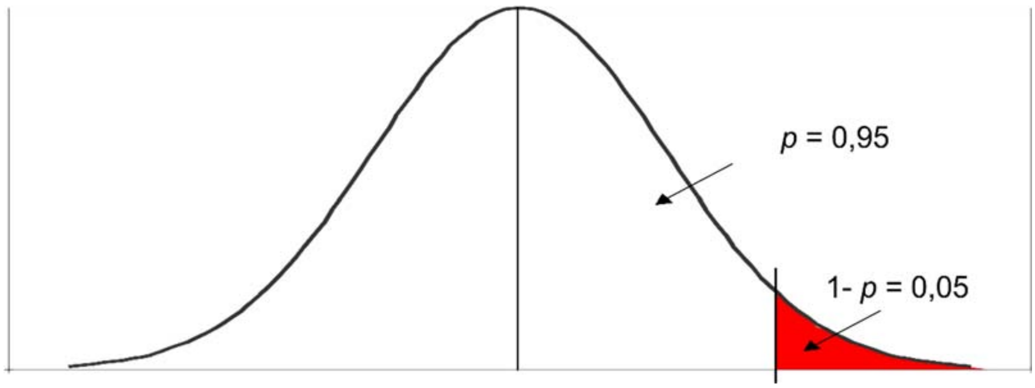

Figure 1. 95% quantile of random variables with normal distribution

To comply with standard or legal requirements for a minimum headroom, the projected headroom must be set as follows:

$$\boldsymbol{h_{sv,pd}} \geq \boldsymbol{h_{sv,dop}} > \boldsymbol{h_{sv,norm}} \quad (2)$$

where $h_{sv,pd}$ is the projected headroom

$h_{sv,dop}$ is the calculated minimum headroom

$h_{sv,norm}$ is the minimum standard requirement for headroom

5.4. Measurement of the Room Height

Room heights are controlled at a distance of 100 mm from the walls and/ or columns, in the middle of the length or the width of the rooms, figure 2. The height of the supporting beams and similar structures, figure 3, shall be checked 100 mm from the side of the supporting structure and still in the middle of the ground plan [3].

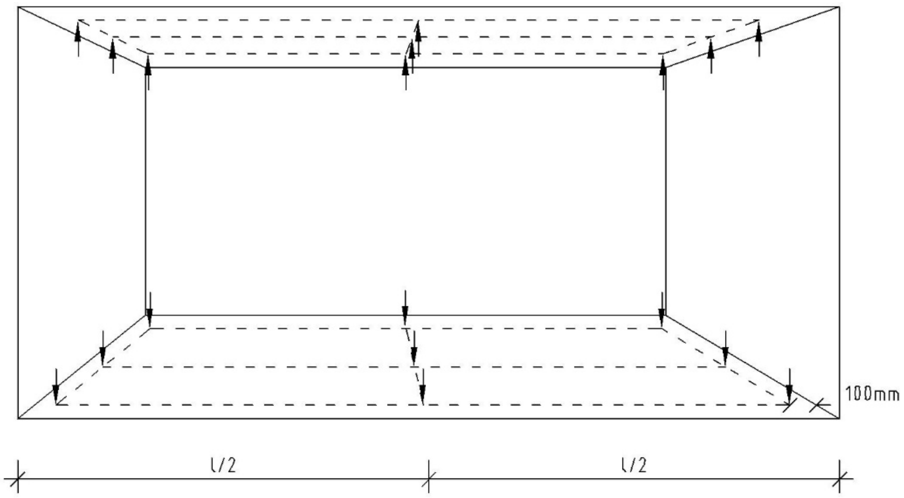

Figure 2. Measurement of Room Height

The height of the room with the supporting beam is checked in the beam axis, at a distance of 100 mm from the vertical supports (walls, columns), and in the middle of the beam.

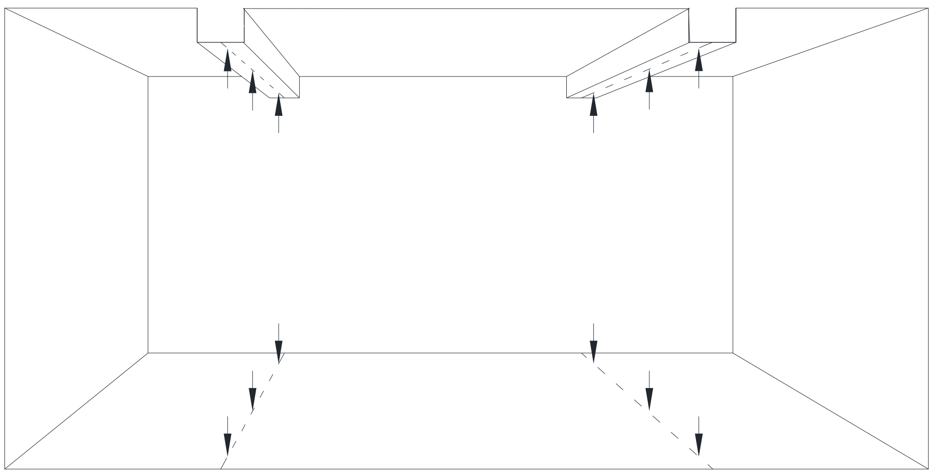

Figure 3. Measurement of Room Height with beams supporting ceiling slab

Measurements 100 mm from the edges of the vertical supports (walls, columns) are recommended because of the possibility of larger surface roughness unevenness on the edges of the structure, and this way it is possible to exclude the influence of insignificant unevenness of the ceiling or floor in the supports. Requirements for other measurement locations must be specified in the project.

5.5. Evaluation of measured data

Geometric accuracy should be checked against previously agreed control procedures.

The measured values shall be compared with the established requirements, and the number of deviations exceeding the permissible limits shall be determined.

When estimating geometric accuracy, it is assumed that the probability of occurrence of deviations of geometric accuracy corresponds to the Gaussian normal distribution and permits 5% of the quantil for measuring gauge inaccuracy, measurement procedure, etc. That is, 5% of the measured values may be higher than the established requirement. In other words, if the percentage of unacceptable deviations is within 5% of all measured values and these do not represent defects that significantly affect the quality of the construction, these deviations can be considered admissible [2].

6. Results and discussions

In order to meet the functional requirements for the building, it is necessary to design its parameters in order to always take into account a certain amount of uncertainty about the building technologies, and the products, and materials.

Therefore, standard requirements, including a provision for building construction, should always be laid down in the design documentation. Such requirements can be expressed within marginal conditions or deviations from the projected state, for example, in the following format:

$$value_{pd} = value_{norm} + deviation \quad (3)$$

Where $value_{pd}$ is the projected value, including the tolerance
$value_{norm}$ is the norm value
deviation is the considered allowable tolerance for determining the maximum deviation condition

7. Conclusions

From the above example, it is clear that, in order to achieve the required quality in accordance with the set requirements, it is necessary at all stages of the construction project to carefully address the possible deviations of the required values which do not have to be strictly related to the structure itself, but also to the interactions with other related structures or building elements, and to their long-term behaviour. Without a thorough knowledge of the context of design, implementation and use of the building, it is not possible to define the scope and the values of possible tolerances of the requirements. For each building, it is therefore necessary to determine the requirements, and above all, their tolerances field individually based on all available information from the life cycle of the building.

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