Budownictwo i Architektura 19(4) 2020, 139-152
DOI: 10.35784/bud-arch.2127

Received: 30.01.2020; Revised: 09.06.2020;
Accepted: 09.06.2020; Avaliable online: 02.11.2020

Crossref Similarity Check Powered by iThenticate

Orginal Article

© 2020 Budownictwo i Architektura
This is an open-access article distributed under the terms of the CC-BY-SA 3.0

Factors determining the quality of masonry – differentiation of resistance and reliability

Joanna Zięba[1], Lidia Buda-Ożóg[2], Izabela Skrzypczak[3]

[1] *Department of Building Structures, Faculty of Civil Engineering and Environmental Engineering, Rzeszow University of Technology, 2 Poznańska Street, Rzeszow 35-084, Poland, j.zieba@prz.edu.pl 0000-0003-1800-5697*
[2] *Department of Building Structures, Faculty of Civil Engineering and Environmental Engineering, Rzeszow University of Technology, 2 Poznańska Street, Rzeszow 35-084, Poland, lida@prz.edu.pl 0000-0002-1205-1345*
[3] *Department of Geodesy and Geotechnics, Faculty of Civil Engineering and Environmental Engineering, Rzeszow University of Technology, 2 Poznańska Street, Rzeszow 35-084, Poland, izas@prz.edu.pl 0000-0003-0978-3040*

Abstract: A house or any other building without walls is truly hard to imagine. The first thing usually associated with walls is, of course, masonry. Today, masonry walls perform a load-bearing function in buildings up to four above-ground floors, in the higher parts of the buildings they perform a protective and stiffening function. However, there is a widespread opinion that the designer does not have to check the bearing capacity of masonry structures because masonry are were stand, are standing and will stand. Not everyone, however, currently works the wall as it should. The problem is that a lot of emphasis is now placed on reducing construction times. Therefore, there are a number of factors affecting the quality of the masonry structure, which overall reduce their safety. The article presents the influence of the quality of masonry on the differentiation of bearing capacity and reliability of an example masonry structure. The analyses included various values γ_m of the partial factor, recommended in the national annex PN-EN 1996-1 [1], depending on the category of masonry units, class execution of works and type of mortar. In addition, a decrease in load capacity and reliability caused by the increase of the initial eccentric resulting from the inaccuracy of the masonry wall was examined.

Keywords: masonry structures, reliability of construction, compressive strength, quality assurance

1. Introduction

Masonry structures are a type of structure which are still widely used in construction. Thanks to modern engineering tools, we can easily check the limited state of masonry elements.

However, in the light of today's requirements, checking only the limit state is not a sufficient step in the design process. The basis in the design of the structure is sufficiently safe and reliable design of the structure [2].

Regardless of the material chosen for the wall, its main function is to transfer loads to the lower parts of the structure and therefore it must be properly designed [3]. Errors in masonry structures can occur both at the design and execution stages. Until recently, there was a widespread opinion in the country that walls do not need to be checked computationally. In low-rise single-family buildings, the effort of the walls is indeed insignificant – which, however, does not exempt from checking the load-bearing conditions of the most loaded wall fragment. Even in buildings with a small number of floors, the load-bearing capacity of walls loaded mainly vertically may already fail, especially in elements with a small cross-section, such as window pillars and columns. Failure to check the load capacity of the wall for vertical loads may result in the adoption of too weak material or too small cross-section of the wall structural part, which may lead to overloading of the wall.

Despite the constant development of construction technologies, traditional masonry structures still remain one of the most common types of wall erection (it is estimated that in Poland they constitute about 90% of all walls made). Despite their popularity and long-standing tradition, masonry structures are still not free from manufacturing errors that may affect the fulfillment of the requirements set for buildings. It can easily be noticed just how important these issues are when recalling the seven so-called basic requirements for buildings, which are as follows:

- resistance and stability of the structure;
- fire safety;
- hygiene, health and the environment;
- safety of use and availability of facilities;
- noise protection;
- energy saving and thermal insulation;
- sustainable use of natural resources.

By combining the above requirements with the standard definition of masonry, which says that: masonry is a construction material made of masonry elements arranged in a specific way and permanently connected with each other with a proper mortar, a general conclusion can be made – the relevant elements have the effect of obtaining the assumed properties of masonry, properly selected mortar, as well as the quality of masonry work carried out. The basic source of information on the correct design and construction of walls is the package of Eurocode 6 standards: EN 1996-1-1 [1], EN 1996-1-2 [4], EN 1996-2 [5], EN 1996-3 [6].

2. The issue of masonry structure analysis due to their quality

When erecting masonry walls, not only their deviations from the vertical and level should be checked, but also the quality of details: corners and lintels, wreaths and wall reworking, in general – careful masonry work. There are a number of factors worth paying attention to when working with masonry, including: the quality of the building material – the masonry element and mortar, the quality of the masonry. The stages of erecting walls require inspection. For example, the first layer of the wall is very important – it must be well laid and leveled. Also, subsequent layers of walls must be erected in accordance with the masonry art (principles of

re-walling elements, wall connections, etc.) If the construction project lacks guidelines for the implementation of any of the details, they can be found in the relevant standards, ITB instructions and wall material manufacturers (they often have their own implementation recommendations).

In the design process, the quality of the masonry structure is reflected in the safety level adopted by the designer. Determining the value of the partial factor adopted in the calculations of the masonry structure is based on the determination of: the class execution of masonry works, the category of masonry elements, the type of mortar. The values of the basic partial factor determined by the polish annex EN 1996-1-1 [1] are presented in the table 1.

Table 1. The exemplary values of the partial factor γ_m according to the polish annex EC6. *Source:* [1]

Material	Classes of execution control	
	A	B
masonry made with units of category I, designed mortar	1.7	2.0
masonry made with units of category I, prescribed mortar	2.0	2.2
masonry made with units of category II, any mortar	2.2	2.5

2.1. Classes of execution control according to the polish annex EC6 [1]

The construction of masonry elements is based on a number of basic assumptions, including the class of masonry. EN 1996-1-1 [1] distinguishes between five classes of execution of works 1 to 5, including two in the polish annex: class 2 and class 3, named accordingly class A and class B. The designer of the structure decides about the choice of the class of masonry works. The category of wall A may be adopted if:

- the works are carried out by a well-trained team under the supervision of a bricklayer;
- factory-made mortars are used, and if they are mortars made on site, the dosing of ingredients and mortar strength should be controlled;
- the quality of work is controlled by a person with appropriate qualifications, independent of the contractor.

In the event that the conditions for the construction of a category A wall are not met, the category of execution of wall B should be used.

2.2. Specificity of masonry units

At the construction stage, it is not always possible to determine the quality of the materials used. Features such as frost resistance, tendency to excessive shrinkage or swelling usually only appear after the first heating period. Commercially approved materials should meet the requirements of the standards used, e.g. masonry components of EN 771-1: 6 [7]. A distinction is made between category I and category II masonry [8]:

- category I includes masonry elements whose manufacturer declares that the plant uses quality control, the results of which state that the probability of occurrence of average compressive strength lower than the declared strength is not more than 5%;
- category II includes masonry elements whose manufacturer declares their average strength, and the other requirements of category I are not met.

Ensuring that the probability of occurrence of average compressive strength lower than the declared strength is not more than 5% requires ongoing monitoring of the strength of the

produced elements. They will be found in the standard for masonry elements EN 771 [7], which consists of the parts: EN 771-1 – clay masonry units, EN 771-2 – calcium silicate masonry units , EN 771-3 – concrete masonry units (from regular concrete or aggregate concrete light), EN 771-4 – autoclaved aerated concrete masonry units, EN 771-5 – manufactured stone masonry units, EN 771-6 – natural stone masonry units. Compressive strength is one of the most important functional properties of masonry units. However, you should be aware that the impact of this parameter does not translate proportionally into the compressive strength of the masonry wall. Therefore, equating the compressive strength of masonry units with the masonry wall compressive strength is a mistake. For example, the article [9] presents what factors influence the compressive strength of the masonry wall when calculating it in accordance with the applicable standard.

A group of masonry elements is also important in the analysis of the masonry structure. The group of masonry elements is determined on the basis of:

- the volume of all holes (percentage share in gross volume);
- single hole volume (percentage of gross volume);
- declared thickness of internal and external walls declared equivalent thickness of internal and external walls (% of gross width).

Based on the group of masonry elements, the *K* factor can be determined which determines the characteristic strength of the masonry wall.

2.3. Specificity of mortar

The specific type and strength of mortar provided in the design must be strictly used. The selection of the right mortar protects against possible defects in masonry constructions. The mortar should have adequate adhesion and strength adapted to the masonry element. The mortar should not have strength far exceeding the strength of masonry elements (too high mortar strength may cause wall damage). In addition to the permanent connection of elements, its second, equally important task is to evenly distribute the loads. Therefore, it is important to evenly distribute the mortar over the entire surface of the joined elements. A distinction is made between mortars produced on the factory and mortars produced on the building site.

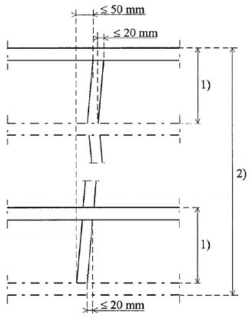
- the use of factory-made mortars and mortars manufactured on construction (for which the dosage of ingredients and strength of the mortar are controlled) authorizes the classification of works as category A;
- the use of mortars manufactured on construction, for which the mortar brand is determined only on the basis of its approximate volume composition, qualifies the performance of works as category B.

Guidelines for the correct execution of welds are clearly specified in EN 1996-1-1 [1]. Support joints (usually horizontal unless otherwise anticipated by the designer) and vertical joints made using ordinary mortars and light mortars should have an actual thickness of not less than 6 mm and not more than 15 mm (nominally 10 mm), while vertical and weld joints when using thin-joint mortar they should have an actual thickness of not less than 0.5 mm and not more than 3 mm (on average 2 mm). Masonry with unfilled vertical joints (unless the design clearly indicates the need to fill the vertical joint) can be made using masonry with profiled faces (tongue and grooves). When filling vertical joints, they can be considered filled if the mortar is on the entire joint height and width above 40% of the width of the masonry element. If at least one of the joined elements has a smooth face, the vertical joint should be filled with mortar.

2.3. The “verticality” of the masonry wall

In light of the requirements of EN 1996-1-1 [1], all construction works should be carried out in accordance with the given requirements and with permissible deviations. Most wall scratches can be avoided by improving the quality of the work. The performance of masonry structures significantly affects the load-bearing capacity, deformability and durability. The design recommendations provided in the standards for checking the limit states are only valid if the wall meets the relevant construction requirements. Only then can the simplifications adopted in the calculation models help ensure an appropriate level of security. Deviations of the made masonry structure from its assumed shape and location should not exceed the values given by the manufacturer of building materials and in the design documentation. EN 1996-2 [5] lists the permissible deviations – Table 2.

Table 2. Permissible deviations for masonry elements. *Source:* [5]



Verticality	Maximum deviation
in anyone storey	± 20 mm
in total height of building of three storeys or more	± 50 mm
vertical alignment	± 20 mm

When analysing walls subjected to vertical loading, eccentricity resulting from construction deviations and differences in the material properties of individual components, should be made. An initial eccentricity, e_{init}, shall be assumed for the full height of a wall to allow for construction imperfections. The initial eccentricity, e_{init} may be assumed to be $h_{ef}/450$, where h_{ef} is the effective height of the wall. The effective height of a load bearing wall shall be assessed taking account of the relative stiffness of the elements of structure connected to the wall and the efficiency of the connections.

3. Impact of the quality of masonry on resistance and reliability

To illustrate the difference in the resistance of masonry walls resulting from the appropriate quality of masonry, an example of calculation of resistance for masonry made of clay masonry units by one of the Polish producers was presented. The work also shows the impact of the classes execution of works, categories of masonry units and mortar type on the reliability level of the designed structure. In addition, a decrease in load capacity and reliability caused by the increase of the initial eccentric resulting from the inaccuracy of the masonry was examined.

3.1. An example of differentiation of the resistance

The analysed masonry structures are located on the ground floor of a building. The height of the masonry wall is 2.75 m. The overview diagram of the analysed structure is shown in the figure – Fig. 1.

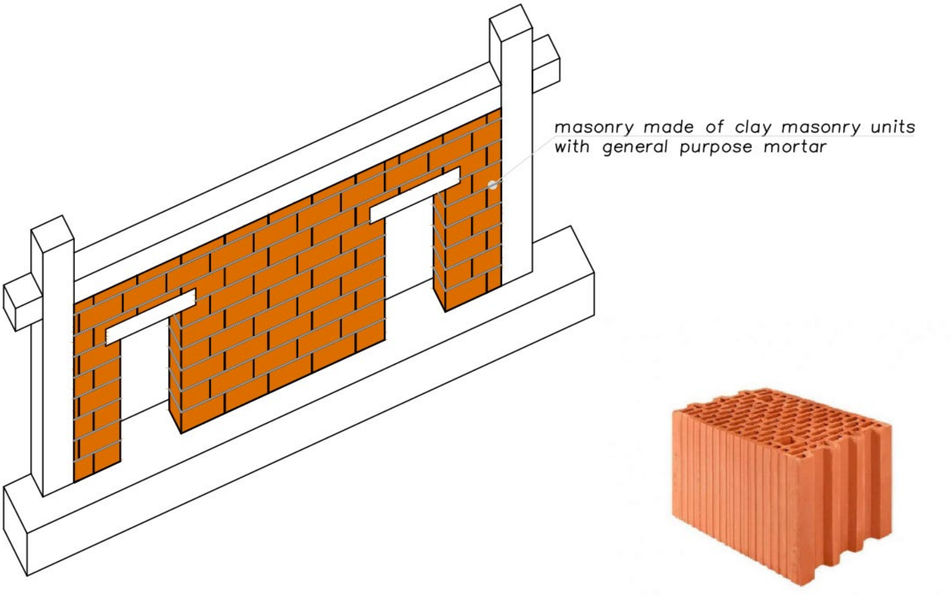


Fig. 1. The overview diagram of the analysed structure. *Source:* own study

The framework model suggested by Eurocode for determining the resistance of the masonry was used. The wall should therefore be analysedat three points : at the top – point '1', in the middle – point 'm', at the bottom – point '2'. Design value of the vertical resistance of a masonry wall was determined from the formula:

$$N_{Rd} = \phi A f_d \tag{1}$$

where:

ϕ – reduction coefficient, in the analysed example only the initial eccentricity was taken into account, therefore:

$$\phi = 1 - 2\frac{e_{init}}{t} \tag{2}$$

A – masonry area;

f_d – design compressive strength of masonry.

Design compressive strength of masonry using Eurocode 6 [1] was assumed. Characteristic compressive strength of masonry of clay units with general purpose mortar is determined by formula:

$$f_k = K f_b^{0,7} f_m^{0,3} \tag{3}$$

where:

K – coefficient, for clay masonry units with general purpose mortar $K = 0.40$;

f_b – compressive strength of clay masonry units, $f_b = 15$ MPa;

f_m – compressive strength of mortar, $f_m = 5$ MPa.

Design compressive strength of masonry is determined by formula:

$$f_d = \frac{f_k}{\gamma_M} \tag{4}$$

where:

γ_M – relevant partial factor for materials.

Table 3. Summary of load capacity calculations for the analysed masonry. *Source:* own study

<table>
<tr><th>Variant</th><th>Categories of masonry units</th><th>Classes execution of works</th><th>Type of mortar</th><th>Partial factor γ_M</th><th>Compressive strength [MPa]</th><th>Design value of resistance [kN]</th></tr>
<tr><td>1</td><td rowspan="4">I</td><td rowspan="2">A</td><td>designed mortar</td><td>1.7</td><td>2.54</td><td>611.3</td></tr>
<tr><td>2</td><td>prescribed mortar</td><td>2.0</td><td rowspan="2">2.16</td><td rowspan="2">519.6</td></tr>
<tr><td>3</td><td rowspan="2">B</td><td>designed mortar</td><td>2.0</td></tr>
<tr><td>4</td><td>prescribed mortar</td><td>2.2</td><td rowspan="2">1.96</td><td rowspan="2">472.4</td></tr>
<tr><td>5</td><td rowspan="2">II</td><td>A</td><td rowspan="2">any mortar</td><td>2.2</td></tr>
<tr><td>6</td><td>B</td><td>2.5</td><td>1.73</td><td>415.7</td></tr>
</table>

The differences in the calculated load-bearing capacity of the analysed masonry structure are presented in the form of a graph showing the percentage decrease in resistance of the masonry when switching to other variants of the structure analysis.

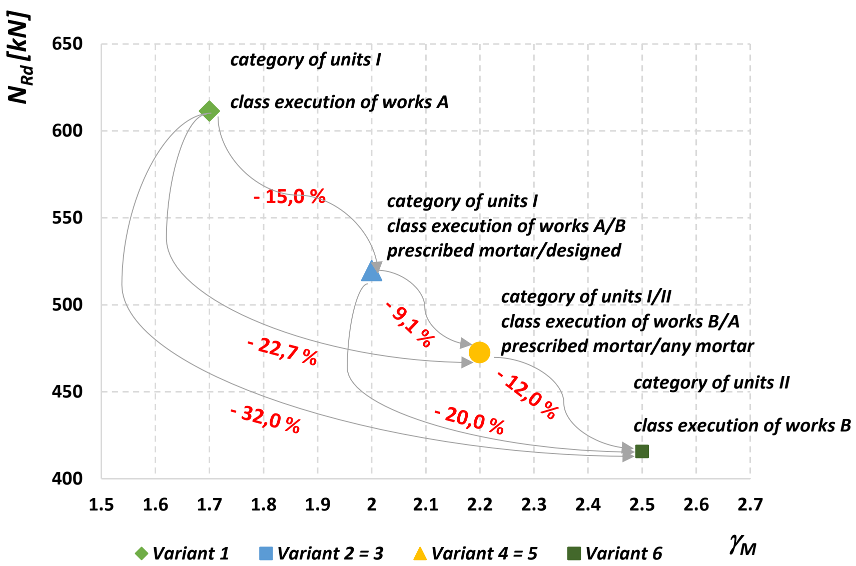


Fig. 2. Differences in the calculated resistances of the analysed masonry. *Source:* own study

In the next stage of calculations, the value of the initial eccentric e_{init} was increased to the level of the maximum allowable deviation assumed in the Eurocode, i.e. e = 0.02 m. A decrease in masonry resistance of almost 13% was observed.

3.2. An example of differentiating masonry reliability

The properties and quality of materials affect the assessment of the reliability of building structures. A properly designed construction is one for which dependence is fulfilled:

$$N_{Rd} \geq N_{Ed} \tag{5}$$

where:

N_{Rd} – design value of the resistance;

N_{Ed} – design value of effect of action.

The designed resistance of a structural element is determined by the adopted calculation model and material properties [14]. Usually, they correspond to the specified quantile of the adopted statistical distribution of a specific material or product property [15], [16]. The procedure for the reliability analysis, in relation to the class execution of work and partial factors recommended in EC0 [10] and EN-ISO 2394 [9] was carried out. It has been assumed that the designed value of the resistance is equal to the designed value of effect of actions: $N_{Rd} = N_{Ed}$. Permanent and variable actions according to EC0 [10] can be combined with the relationships: 6.10a, 6.10b, 6.10. In the work with regard to the analysed structural element, only permanent actions and one variable action are considered. In order to determine the average of actions, the coefficient of variation for a constant action of $v = 0.10$ and for a variable action of $v = 0.20$ [12] was assumed. The relation between permanent and variable actions according to the formula was defined:

$$\chi = \frac{Q_k}{\left(G_k + Q_k\right)} \tag{6}$$

where:

G_k – characteristic value of a permanent action;

Q_k – characteristic value of a variable action.

Referring to literature, the coefficient of variation for the compressive strength of masonry $v = 0.19$ for variant 1 [13]. In the further part of the calculations, the coefficient of variation was increased by analogy to the percentage decrease in resistance for subsequent variants. The increase in the coefficient of variation is the result of a decrease in the quality of the masonry structure. For the presented element, the state of limit function has been built as follows:

$$Z = \left(1 - 2\frac{e_{init}}{t}\right) \cdot t \cdot l \cdot f_d - N_{Ed} \tag{7}$$

where:

e_{init} – initial eccentricity of a wall;

t – thickness of a wall;

l – length of a wall.

On the basis of the prepared database, the probabilities of exceeding the ultimate limit states and the corresponding reliability indices for individual action factors have been estimated. An important element of the example solution was determination of random variables occurring in the function of the limit state of the element being analysed. In determining the appropriate probability distributions, it was suggested to use literature that is rich in items concerning, for example, the determination of the probability density function for the compressive strength of masonry. Normal distribution was used for the permanent actions. Gumbel distribution was

used for the variable action. Log – normal distribution was used for the compressive strength of masonry. The analyses consisted in determining the reliability index β using the First Order Reliability Method (FORM). The results are presented in diagrams with reference to different construction classes execution of works, for reliability class RC2. The initial eccentricity of a wall and thickness of a wall were random variables with 5% coefficient of variation.

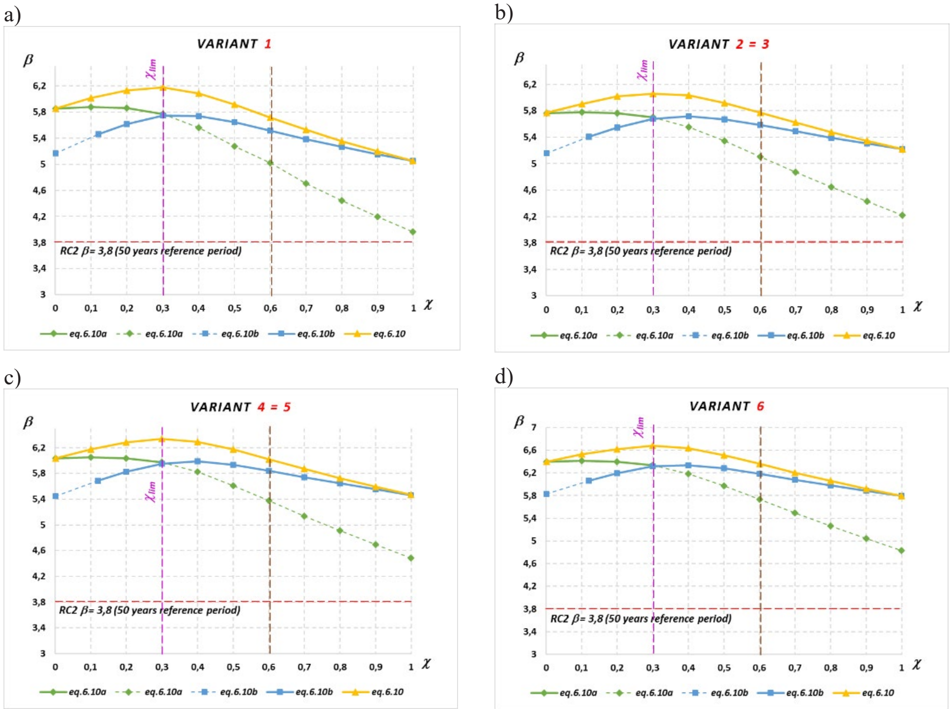


Fig. 3. Reliability coefficient curves β and load factor χ for three different combinations of standard coefficients (formulas: 6.10a, 6.10b, 6.10) – reliability class RC2: a) variant 1, b) variant 2=3, c) variant 4=5, d) variant 6. *Source:* own study

Analysing the graphs presented – Fig. 3, a slight increase in the level of safety should be noted along with the increasing partial factor from 1.7 to 2.5. The presented curves show the main intentions of the partial factor method – i.e. a higher value of the partial factor ensures a higher level of reliability in the structure. The approximate range of significance of each of the used combination formulas is marked on the charts with a solid line. The dashed line marks the remaining ranges of each curve, which for real values χ are not justified.

The minimum achieved value of β is 5.05 for variant 1, while the maximum achieved value is β = 5.79 for variant 6. The difference between the extreme values χ of the reliability indicator achieved in individual variants is about 13%. Therefore, it should be concluded that increasing the partial factor from 1.7 to 2.5 provides approximately 13% higher level of structural reliability.

In the next stage of calculations, variant 1 was modified by increasing the value of the initial eccentric e_{init} to the level of the maximum allowable deviation assumed in Eurocode 6, i.e. e = 0.02 m (variant 1A).

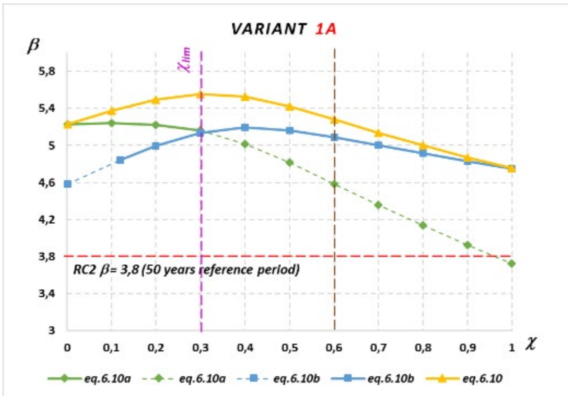


Fig. 4. Reliability coefficient curves β and load factor χ for three different combinations of standard coefficients (formulas: 6.10a, 6.10b, 6.10) – reliability class RC2: a) variant 1A. *Source:* own study

Comparing Fig. 3a and Fig. 4, one should notice smaller values of reliability index for the presented example. Increasing the initial eccentricity resulting from wall inaccuracy to 0.02 m results in a 6% lower reliability index value.

4. Quality control methods of masonry

4.1. Control of the production of masonry units

Standard EN 771 [7] was adopted by the European Committee for Standardization (CEN) and is a harmonized standard with the Construction Products Directive. All parts of this standard, with the exception of Part 6, provide for two conformity assessment systems:

- 2 + meaning mandatory certification of the factory production control and supervision over the certificate conducted by the certification body;
- 4 meaning the conduct of factory production control without external verification activities.

Certification of factory production control is carried out by a notified certification body, i.e. a body qualified by the competent minister or head of the central office and notified to the European Commission and EU Member States. According to PN-EN 771 [7], factory production control must be used in every masonry plant. In order to classify masonry elements in the 1st production category, it is necessary to use a 2 + conformity assessment system. It follows that e.g. stone masonry units described in the specification of the PN-EN 771-6 [6] natural standard can only be included in production category II.

Factory production control should include: measuring equipment; production equipment with control devices; raw materials and production process as well as finished products. The PN-EN 771 [7] standard specifies that the product compliance with the standard and the declared features is confirmed by the manufacturer on the basis of initial type tests and control tests of the manufactured products. These tests must be carried out by the manufacturer in both the 2 + conformity assessment system and in system 4. Preliminary type tests are carried out to confirm that the anticipated product properties meet the requirements of the standard and the values declared by the manufacturer. In the event of a change in raw materials or production

technology, these tests should be repeated. Type tests should cover all relevant properties of masonry elements related to their use, and thus:

- shape, dimensions and dimensional deviations;
- compressive strength;
- density and its deviations;
- frost resistance;
- water absorption;
- salt content;
- other relevant product features and applications.

Testing of masonry units should be carried out according to the methods given in the product standards. This is primarily EN 772 [17], consisting of many parts, each of which usually includes a method of testing one product feature. Factory production control should be carried out continuously, at every stage of production, by persons with appropriate qualifications and equipped with appropriate equipment. Control procedures should be recorded and their results documented.

4.2. Geodetic methods of inventorying verticality of walls

Control geodetic measurements, which include the measurement of deviations from the vertical plane of the facade walls of the building, are made to obtain information about the geometry of the object and determine deviations from their location. In the scope of measurement regarding deviations of facade walls from the vertical plane, the following methods of geodetic measurements have been the most common so far [18]: straight constant, angular spatial indentation forward, angular spatial indentation forward from 3 positions, polar 3D – total stations with reflector less measurement, polar 3D – scanning total stations (described in detail in [18]). The general principle of measuring the geometry of a building object regardless of the selected geodetic method remains the same, as the result is to obtain spatial coordinates of points selected on the building, which represent its geometry in the local coordinate system). Inventory measurements are a set of geodetic activities aimed at collecting appropriate geodetic data to determine: the location, shape and dimensions of completed buildings.

5. Conclusion

The article presents an example of differentiating the resistance of a masonry structure and its reliability due to the changing quality of workmanship. The analyses were carried out for several variants taking into account different categories of masonry elements, classes execution of works and changing mortar type. The reference value to the quality of the masonry structure was the changing partial factor determined by the national annex EC6 [1]. Analyses showed a decrease in the resistance of the structure by approximately 32% when using extreme γ_M values χ – from 1.7 to 2.5. In addition, it is also concluded that the value of the initial eccentric resulting from the inaccuracy of wall construction and adopted in the load capacity calculation is significant for the resistance of the structure. Analysing the value of the reliability coefficient obtained for individual variants, it is concluded that its value slightly changes in the γ_M variability range – from 1.7 to 2.5.

Technological progress in masonry constructions has resulted in the creation of competitive solutions, which forces the need for more and more accurate recognition of this type of

structure. Today's available control and monitoring technologies create a field to eliminate most construction problems resulting from poor quality of workmanship. Although it is probably still not possible to design, execute and operate masonry facilities with a full guarantee of no scratches or other defects, a significant part of these damages can be eliminated at the stage of execution and design.

References

[1] EN 1996-1-1:2004 Eurocode 6: Design of masonry structures – Part 1-1: General rules for reinforced and unreinforced masonry structures. 2004 CEN.

[2] Stewart M.G., Lawrence S.J., "Model Error, Structural Reliability and Partial Safety Factors for Structural Masonry in Compression", *Masonry International*, vol. 20, no. 3, 2007, pp. 107-116.

[3] Drobiec Ł., Jasiński R., Piekarczyk A., *Masonry structures according to Eurocode 6 and related standards*. PWN, vol. 2, Warsaw, 2013.

[4] EN 1996-1-2:2005 Eurocode 6: Design of masonry structures – Part 1-2: General rules – Structural fire design. 2005 CEN

[5] EN 1996-2:2006 Eurocode 6: Design of masonry structures – Part 2: Design considerations, selection of materials and execution of masonry. 2006 CEN.

[6] EN 1996-3:2006 Eurocode 6: Part 3: Simplified calculation methods for unreinforced masonry structures. 2006 CEN.

[7] EN 771-1:6, Specification for masonry units. 2005 CEN.

[8] Buda Ożóg L., Skrzypczak I., Szylak K., Raczak A., *Masonry constructions – examples of calculations according to Eurocode 6 and probabilistic methods*. Rzeszow University of Technology Publishing House, Rzeszow, 2017.

[9] Rybarczyk T., „Czynniki wpływające na wytrzymałość muru na ściskanie", *Materiały Budowlane*, vol. 4, 2016, pp. 74-77. https://doi.org/10.15199/33.2016.04.20

[10] EN 1990:2002 Eurocode – Basis of structural design. 2002 CEN.

[11] PN-ISO 2394: General principles of reliability of building structures. 2010 CEN.

[12] Woliński Sz., *Fundamentals of Designing Structures in General Construction*. PWN, vol. 3, Warszawa, 2011, pp. 112-146.

[13] Woliński Sz., "Calibration of partial coefficients for existing structures", *Scientific Notebooks PRz*, 2011.

[14] Nowak A., Collins K., *Reliability of Structures*. CRC Press, 2012.

[15] Holicky M., Markova J., "Verification of load factors for concrete components by reliability and optimization analysis: Background documents for implementing Eurocodes", *Progress in Structural Engineering and Materials*, vol. 2, no. 4, 2000, pp. 502-507.

[16] Holicky M., Retief J.V., "Reliability assessment of alternative Eurocode and South African load combination schemes fot structural design", *Journal of South African Institution of Civil Engineering*, vol. 47, no. 1, (January 2005), pp. 15-20.

[17] EN 772-1, Methods of test for masonry units -Part 1: Determination of compressive strength. 2005 CEN.

[18] Ćwierz J., Cinal W., Kampczyk A., *Measurement of deviations of the building facade walls from the vertical plane*. https://doi.org/10.17512/znb.2016.1.04