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EFFECT OF JOINT THICKNESS ON BRICKWORK STRENGTH AND DEFORMABILITY

The results of studies according to the strength of masonry from silicate brick compressive, depending on the thickness of the mortar joints. Determination of the deformability of masonry from silicate bricks made on samples-fours made of silicate corpulent cells connected in cement-sand mortar. Correlations obtained the mean strength of masonry in compression and deformation modulus of masonry at different values of the controlled parameter, which is the ratio of the thickness of the bricks to the thickness of the seam. It was shown that the strength of masonry in compression decreases with decreasing values of T_b/t_{joint}, that is, by increasing the thickness of the seam. Deformation modulus of masonry takes the maximum value at the largest and the smallest values of T_b/t_{joint} (samples P8 and P20) and the minimum – at the value for P15. A statistical evaluation of compressive strength of brick-fours samples at different ratios T_b/t_{joint}, determined that this size distribution laws subject to normal distribution defined statistical parameters: sample mean, sample standard deviation and coefficient of variation.

Keywords: *the brickwork, mortar joint, compression strength, deformation modulus, statistical evaluation.*

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ВПЛИВ ТОВЩИНИ РОЗЧИННИХ ШВІВ НА МІЦНІСТЬ І ДЕФОРМАТИВНІСТЬ ЦЕГЛЯНОЇ КЛАДКИ

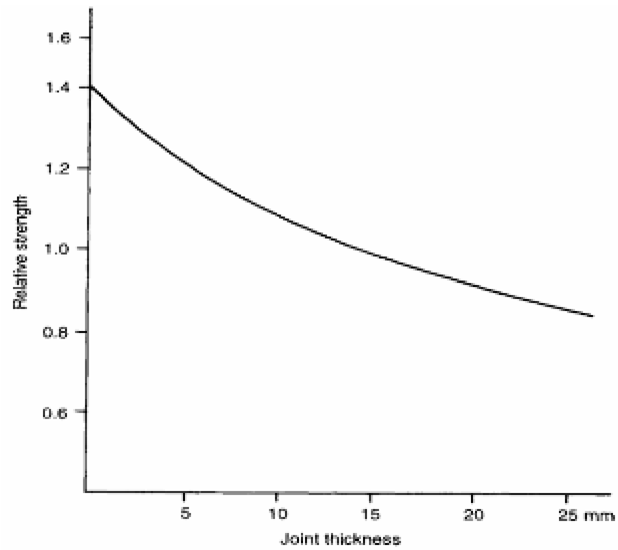
Наведено результати досліджень залежності міцності цегляної кладки із силікатної цегли на стиск залежно від товщини розчинних швів. Визначення деформованості кам'яної кладки із силікатної цегли виконувалося на зразках-четвірках, виготовлених із силікатних повнотілих елементів, з'єднаних цементно-піщаним розчином. Одержано кореляційні залежності середнього значення міцності кладки при стисненні й модуля деформації кладки при різних значеннях контрольованого параметра, який являє собою відношення товщини цегли до товщини шва. Показано, що міцність кладки на стиск знижується при зменшенні значення $T_к/t_{шва}$, тобто при збільшенні товщини шва. Модуль деформації кладки приймав максимальні величини при найбільшому і найменшому значеннях параметра $T_к/t_{шва}$ (для зразків П8 і П20) і мінімальні – при значенні для П15. Виконано статистичне оцінювання міцності на стиск цегляних зразків-четвірок при різних співвідношеннях $T_к/t_{шва}$; доведено, що закони розподілу цієї величини підпорядковуються нормальному розподілу; визначено статистичні параметри: вибіркове середнє, вибіркове середньоквадратичне і коефіцієнт варіації.

Ключові слова: *цегляна кладка, розчинний шов, міцність на стиск, модуль деформації, статистичне оцінювання.*

Introduction. The theory calculation of building designs increasingly introduced probabilistic methods that have directly regulated by DBN V.1.2-14-2009 [1], and some industry documents. The advantage of these methods lies in their ability to quantify the probability of failure of the product (design) and possible loss of that refusal. Notable works of A.Y. Driving, A.R. Rzhanitsin [2], V.D. Reiser [3], A.P. Pshenichkin, B.I. Snarskis, A.S. Lychev [4], B.M. Kolotilkin, A.V. Perelmouter, S.F. Pichugin [5], V.A. Pashinsky, A.I. Weinberg [6], Augusti, Barratt, Yonson, Hoej [7] et al., have made a significant contribution to the development of probabilistic methods for the calculation of construction elements. Among the prerequisites for the application of reliability theory are the collection, classification and analysis of statistical data related to a particular aspect of the work of building structures.

Analysis of recent sources of research and publications. Masonry work is inseparable from the technological processes and the construction and operating conditions. Notable works BelNIIS authors V.N. Derkach, A.V. Galalyuk [8] to determine the ratio of transverse strain masonry of ceramic bricks, Russian researchers: O.M. Donchenko, A.E. Naumov [9] on the strength of a centrally compressed masonry, taking into account the technological factors, Y.V. Savinov on the impact of defects and damage to supporting structures [10], Parisi F., Augenti N., Brehm E., Lissel Sh. [11, 12] suggest undoubted abiding interest in the work of masonry structures. Among the several factors determining the strength undoubtedly masonry compressive strength in addition to a brick and mortar, also affects the thickness of the seam.

Notable works of foreign researchers A.W. Henry, B.P. Sinha, S.R. Davis [13, 14] declare that increasing the thickness of the mortar joint will reduce the strength of the masonry (per unit height). This effect is of great importance for the masonry as shown in pic. 1.



Picture 1 – Effect of joint thickness on brickwork strength

In the works of R.H. Atkinson, B.P. Amadei, S. Saeb, S. Sture the results multiple studies masonry shear and compression [15].

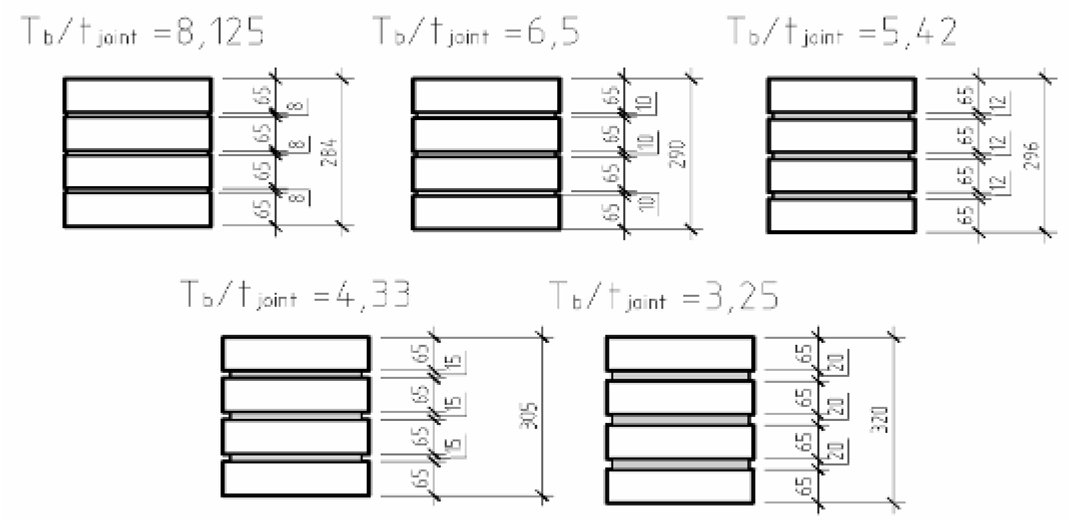
Russian scientists also noted [16] that the thinner seam, the stronger masonry.

Highlight unsolved parts of the general problem. First of all, we should define the relationship between the thickness of the seam and the strength of masonry, as there is no accurate data as a different thickness of the seam affects the strength of masonry in compression. Laws of distribution of the strength of the brickwork on the thickness of the mortar joint is not installed. The solution to this problem is relevant in both the design of new structures made of brick, and during the examination and reconstruction operated brick buildings.

Formulation of the problem. Determining the relationship between the width of the joint mortar and masonry compressive strength, as well as establishing the nature of the distribution of the compressive strength of masonry with different ratios of T_b/t_{joint}.

The main material and results. Determination of the deformability of masonry from silicate bricks made on samples-fours made of silicate corpulent cells connected in cement-sand mortar. Samples were tested in accordance with DSTU B EN 1052-1: 2011 «Методи випробування кам'яної кладки. Частина 1. Визначення міцності кладки» [17] applied to the characteristics of the samples.

For the experimental determination of the strength of masonry samples depending on the controlled parameter - the thickness of the horizontal mortar joints, it has been tested 5-series models fours. Each series, consisted of 10 samples was made using masonry mortar f_m = 6,5MPa (age solution was 120 days), and single-grade silica brick M150. Each test sample was formed of 4 bricks, the thickness of the seam was varied as follows: 8, 10, 12, 15, 20 mm, while the height of the sample is respectively h_{s1} = 284 mm, h_{s2} = 290 mm, h_{s3} = 296 mm, h_{s4} = 305 mm, h_{s5} = 320 mm (pic. 2). It determines the relationship between the compressive strength of samples and the values of the ratio of the thickness of the brick and the seam (controlled variable T_b/t_{joint}), which makes for different values of the thickness of the seam: $T_b/t_{joint}(1)$ = 8,125, $T_b/t_{joint}(2)$ = 6,5, $T_b/t_{joint}(3)$ = 5,42, $T_b/t_{joint}(4)$ = 4,33, $T_b/t_{joint}(5)$ = 3,25.



Picture 2 – Scheme of masonry brickwork samples

To measure the transverse strain used dial gauges ICH-10 with a price of 0,01 mm, installed on both sides of the specimen, as shown in pic. 3.

Pressing prototypes produced with the help of a hydraulic press MS-1000. Samples were installed in the press so that their vertical axis coincides with the axis of load application. Load is applied in steps of 2,0 t (19,62 kN), fixed the failure load and the load cracking. Measurements of deformations produced before the destruction of the sample, and the average value was determined by two indicators, installed on both sides of the sample. Force increases evenly with the loading rate was chosen such that to achieve the destruction of the sample in the range of 10 – 15 minutes from the start of the load applications. When removing the instrument samples the load is maintained at the level of standing.

The nature of the test samples crack brickwork shown in pic. 4.

Picture 3 – Picture test samples in the press

Based on the test results were established: the strength of a sample of masonry in compression – f_i and determines the average value of compressive strength f (N/mm^2), the elastic modulus E.

The compressive strength of masonry individual test sample is calculated with an accuracy of 0,1 N/mm^2 by the formula (1):

$$f_i = \frac{F_{i,max}}{A_i} , \quad (1)$$

where $F_{i,max}$ – maximum load on the test specimen, N;

A_i – sectional area of the individual test sample masonry, mm.

Secant modulus of elasticity E_i is defined as the secant modulus at an average value of relative deformation ε_i, appliances and two fixed load of 1/3 of the breaking load $F_{i,max}$:

$$E_i = \frac{F_{i,max}}{3 \cdot \varepsilon_i \cdot A_i} . \quad (2)$$

The test results. During experimental studies obtained graphs of relative-enforcement samples masonry under load and determine their elastic moduli and compressive strength (Table 1). The test results were processed using probabilistic and statistical methods, curves were constructed normal distribution, performed statistical evaluation. The resistance of the masonry is determined by the degree of reliability of 95% for the ten samples for five values of the controlled parameter T_b/t_{joint}.

The dependence of the strength of the samples of masonry compressive modulus of controlled parameterT_b/t_{joint} approximated by polynomials of the second degree (pic. 6, 7):

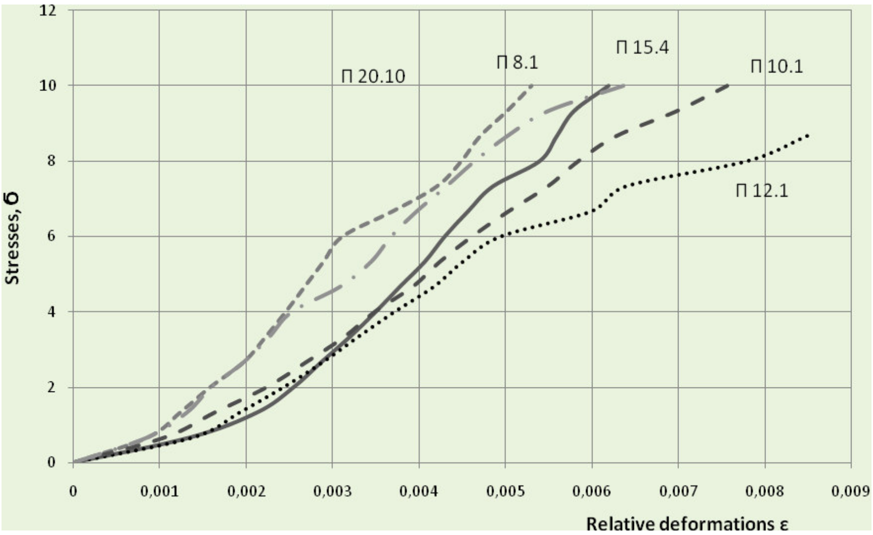
$$f = 0,1x^2 – 0,78x + 11,17; \quad (3)$$

$$E = 11,92x^2 – 128,42x + 811,36, \quad (4)$$

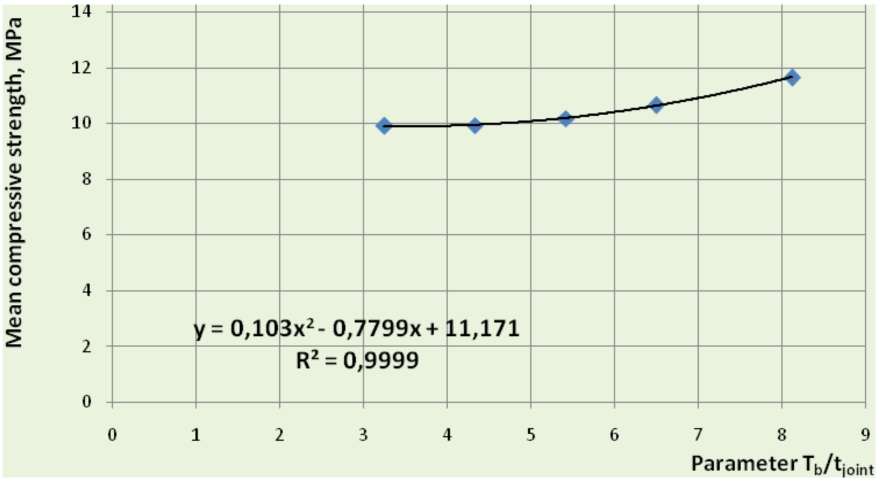
where $x = T_b/t_{joint}$.

a) b) c) d) e) f) g) h) i) j)

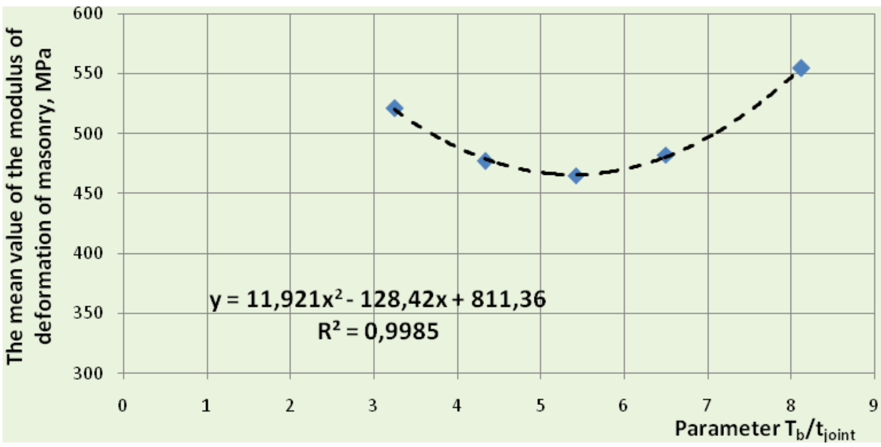
Picture 4 – The character of crack-fours samples from silicate bricks:
a) P8; b) P10; c – e) P12;
f – g) P15; h – j) P20



Picture 5 – The graphs «б - ε» characteristic prototypes series P8-P20



Picture 6 – Schedule correlation average value of the compressive strength of masonry at a controlled parameter T_b/t_{joint}

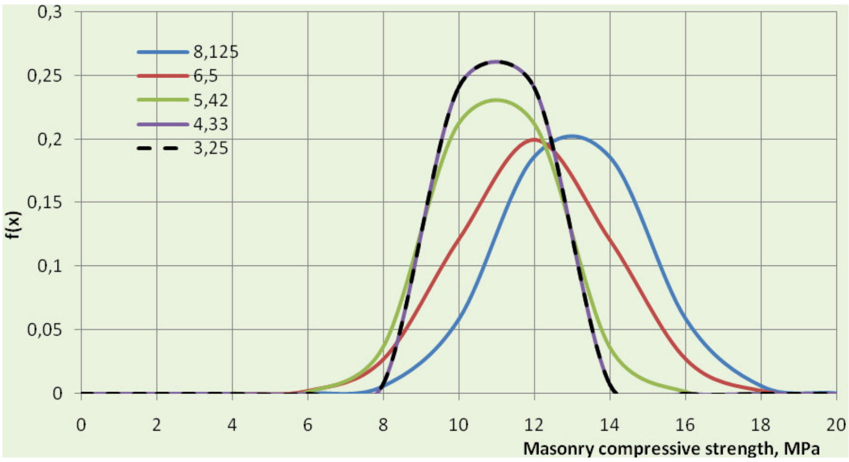


Picture 7 – Schedule correlation average of the deformation modulus of masonry at a controlled parameter T_b/t_{joint}

Table 1 – Values of strength and deformation characteristics of masonry samples from experimental studies

Series number	Parameter T_b/t_{joint}	The average value of compressive strength, MPa (N/mm^2)	The average value of the modulus of elasticity, MPa (N/mm^2)
P8	8,125	11,64	554,29
P10	6,5	10,65	482,15
P12	5,42	10,175	465,08
P15	4,33	9,92	477,08
P20	3,25	9,908	520,90

A statistical evaluation of the compressive strength of the brick samples-fours, received distributions of this magnitude and determine the statistical parameters: the sample mean, the sample standard and coefficient of variation.



Picture 8 – The density of the distribution of the compressive strength of masonry with different ratios T_b/t_{joint}

Conclusions. The research of dependence of the strength of masonry from silicate brick compressive, depending on the thickness of the mortar joints. The correlation function mean value masonry compressive strength and modulus of deformation of masonry for different values of the controlled parameter, which represents the ratio of the thickness to the thickness of the brick seam. Experimental studies show that the strength of masonry in compression decreases with decreasing values of T_b/t_{joint}, by increasing the thickness of the seam. Module deformation laying takes the maximum value at the largest and the smallest values of T_b/t_{joint} (for P8 and P20) and the minimum – at the value for P15. Established laws of distribution of the compressive strength of masonry with different ratios of T_b/t_{joint} and perform statistical evaluation of the test item.

Table 2 – Statistical evaluation of the compressive strength of masonry at different ratios T_b/t_{joint}

Series	The law of distribution of the compressive strength	Sample mean $\overline{y_в^*}$, MPa	Selective an average quadratic $\sigma_в^*$, MPa	The coefficient of variation v, %
P8	normal	13	1,8517	14,244
P10	normal	12	1,99911	16,66
P12	normal	11	1,51186	13,744
P15	normal	11	1,06904	9,7185
P20	normal	11	1,06904	9,7185

Literature

1. DBN V.1.2-14-2009. Zagalni principi zabezpechennya nadiynosti ta constructivnoy bezpeki budivel, sporud, budivelnih konstruktsiy ta osnov. – K., 2012. – 46 p.
2. Rzhanitsyn A.R. Teoriya rasheta stroitelnyh konstrukciy na nadezhnost / A. R. Rzhanitsyn. – M.: Stroyizdat, 1978. – 239 p.
3. Raiser V. D. Teoriya nadezhnosti v stroitelnom proektirovanii / V. D. Rayzer. – M.: ACB, 1998. – 304 p.
4. Lychev A. S. Nadezhnost stroitelnyh konstruciy / A. S. Lychev. – M.: ACB, 2008. – 184 p.
5. Pichugin S. F. Nadezhnost stroitelnyh konstrukciy proizvodstvennyh zdaniy / S. F. Pichugin. – Poltava: ASMI, 2009. – 452 p.
6. Weinberg A. I. Nadezhnost i bezopasnost gidrotehnicheskih sooruzheniy. Izbrannie problemy: monographiya / A. I. Weinberg. – Kharkiv, 2008. – 304 p.
7. Hoej N. P. Risk and Safety Considerations at Different Project Phases / N. P. Hoej // International Conference «Safety, risk, and reliability – trends in engineering». – Malta, 2001. – P. 1 – 8.
8. Galaluk A. V. Issledovanie koefficienta poperechnoy deformacii kamennoy kladki iz keramicheskih kladochnih elementov / A. V. Galaluk, V. N. Derkach // 3-iy mezhd. simpozium «Problemy sovremennogo betona i zhelezobetona». – Minsk, 2011.
9. Naumov A. E. Prochnos tcentralno-szhatoy kladki s uchetom tehnologicheskih faktorov: avtoreferat diss…cand. techn. nauk 05.23.01 – stroitelnie konstrukcii, zdaniya i sooruzhenia. – Belgorod, 2010. – 23 p.
10. Savinov Y. V. Osnovnie prichiny povrezhdeniya nesuchzhih stenovyh konstrukciy i recomendacii po ih preduprezhdeniyu: avtoreferat diss…cand. techn. nauk 05.23.01 – stroitelnie konstrukcii, zdaniya i sooruzhenia. – Voronezh, 2003. – 15 p.
11. Parisi F. A shear response surface for the characterization of unit mortar interfases / F. Parisi, N. Augenti // Report of the 15th International Brick and Block Masonry Conf. – Brazil, 2012.
12. Brehm E. Reability of unreinforced masonry bracing walls / E. Brehm, S. L. Lissel // Report of the 15th International Brick and Block Masonry Conf. – Brazil, 2012.
13. Henry A. W. Design of Masonry Structures / A. W. Henry, B. P. Sinha, S. R. Davies. – Taylor&Francis, 2004. – 279 p.
14. Henry A. W. Masonry walls: Materials and Construction / A. W. Henry // Construction and Building Materials. – 2001. – P. 323 – 330.
15. Response of masonry bed joints in Direct Shear / R. H. Atkinson, B. P. Amadei, S. Saeb, S. Sture // J. Engng. Mech., ASCE. – 1989. – P. 2276 – 2296.
16. Bednov A. I. Proektirovanie, vosstanovlenie i usilenie kamennyh i armokamennyh konstrukciy / A. I. Bednov, A. I. Gabitov. – Izd. AST, 2006. – 566 p.
17. DSTU B EN 1052-1:2011. Methody viprobuvannya kam'yanoy kladki. Chastina 1. Viznachennya mitsnosti pristisku. – K.: Minregion Ukrainy, 2012 – 15 p.

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