The Durability of Large-Block Hollow Ceramics

D Zheldakov¹, S Tursukov²
¹NIISF RAASN, 127238 Moscow, Russia
²SCRB CA, 450008 Ufa, Republic of Bashkortostan

E-mail: djeld@mail.ru

Abstract. Increased requirements for heat insulation of building enclosure contribute to widening of modern effective building materials. One of those items is large-block hollow ceramics. Large-block hollow ceramics is actively used for building enclosure because of high properties and increasing production. However, its usage in outer walls and material’s humidification significantly decreases the durability of ceramic blocks. This article is about durability of large-block hollow ceramics. The main scientific hypothesis is that the web’s material of the block has increased chemical destruction speed compared to shell’s material. Also, article include the results of laboratory experiments of material’s destruction based on the process of material’s chemical corrosion that were conducted by developed methods of determination the corrosive activity of moisture and material’s chemical durability. Based on the results of pilot researches at one of Russian factories, the method of large-block ceramic material’s research was developed. The first stage results of research are shown. The results of research confirms the decrease of web’s material strength compared to strength of shell’s material.

1. Introduction
Increased requirements for heat conduction of building enclosure, introduced in Set of Rules 50.13330.2012 “Buildings heat insulation. Updated version of Construction Standards and Regulations 23-02-2003”, also increased the amount of new products from the market of construction materials. One of them is large-block hollow ceramics. Products made of large-block hollow ceramics have a certain advantages: low heat conduction coefficient (0.14-0.19 W/(m*°C)), low weight (average density – 600-900 kg/m³), significant compressive strength (10.0-20.0 MPa). Blocks can sustain 50 freeze-thaw cycles. In addition, blocks preserve high aesthetic qualities of the bricks. In accordance to State Standard 530-2012, blocks are produced with many nominal sizes: from 2.1 to 14.3 Nominal Format (15.6 for polished tiles) (Figure 1). Most popular formats are: 2.1 NF; 6.9 NF; 10.7 NF; 14.3 NF [1]. These block sizes provide high workability of brickwork.

Figure 1. Types of ceramic tiles.
Due to undeniable advantages of large-block hollow ceramics it’s production consistently grow. Percentage of ceramic blocks in overall ceramic production evaluated around 10% (2014-2015 yy. – 9% [2]). As an example, Republic of Bashkortostan produced 15-16% amount of blocks in overall ceramic materials production in 2017-2018 yy., but the consumption in overall amount of small-piece materials totals about 8%. There are 200.000 m² built with the use of ceramic blocks in republic in 2018 [3].

Due to high properties and increasing production, large-block hollow ceramics, developed mainly for inner constructions, started to be actively used for building enclosure with mineral wool on the outer side. There are examples of large-block hollow ceramics used for building enclosure for buildings not higher than three-story.

Since outer insulation with 100 mm mineral wool and finish of the façade by Thermal Insulation Composite Façade Systems, hollow ceramic’s material almost ignore polythermal loads. Many organizations started to use this building enclosure construction when designing multi-story apartment buildings. Therefore, 6 million standard units were shipped for the construction of multi-story apartment buildings in Republic of Bashkortostan in 2019 [3]. The change of building enclosure construction caused the change of heat-humidity characteristics of large-block hollow ceramics and mainly – increased humidity of ceramic material.

In accordance to chemical corrosion of construction ceramics [4, 5], brick destruction can actively proceed at positive temperatures. In addition, humidification intensifies the process of ceramic material’s corrosion. These statements confirmed by field observations of standard sized ceramic destruction (Figure 2).

![Figure 2. Example of hollow ceramic destruction.](image_url)

Chemical destruction process of wall’s ceramic material can be simplified as following [5]: when the moisture gets into the wall’s ceramic material, alkalis form from oxides of alkaline and alkaline-earth metals that present in amorphous part. Formed alkalis actively interact with silicon and
aluminum oxides, destroying brick’s material to 30 um particles. Speed of ceramic destruction depends on many parameters and mainly based on: amount of moisture inside the construction; amount of formed alkalis; speed of interaction of alkalis with silicon and aluminum oxides. For the research of destruction process and to measure the critical durability of the construction ceramic material, methods of laboratory experiments were developed [6] that are being widely tested.

“Critical durability of the material” term was introduced in [7] and evaluated as amount of time, while material changes its physical, chemical and other parameters at current conditions until certain critical values.

Authors developed a working hypothesis: the web in hollow ceramic brick or block has an increased speed of chemical destruction, that means lower durability, in accordance to the shell of hollow ceramic blocks. Being destructed in the first place, the web stops working and ceramic block collapses.

2. Method

Pilot researches of large-brick hollow ceramic were conducted. On the first stage, sample’s strength of the shell and the web were measured by non-destructive control method. Measuring of material’s strength were conducted by impact method of non-destructive control with sclerometer ONIKS-2.5 [8-10]. Average compression strength of the shell’s material was 17.5 MPa and the average strength of the web was 11.3 MPa.

The research of alkalis formation with humidification were conducted according to developed method of evaluation of moisture corrosive activity [6]. Research results are shown in Figure 3.

![Figure 3](image-url)

**Figure 3.** Results of the research with evaluation of moisture corrosive activity: 1 – in the web; 2 – in the shell.

Analyzing the experiment’s results, conclusion can be made: the amount of forming alkalis in the web and the shell of the material are different. For the material of the web, the amount of formed alkalis (with the evaluation by atomic mass of metals) equals 2.206 mg/l, while for the material of the shell of ceramic block – 2.064 mg/l, i.e. there will be 6.9% more alkalis formed in the web than in the shell of the block. The result of this research allows us to make one more conclusion: the amount of potassium hydroxide, formed in the material, significantly high. Some factories make use of oxides of
alkaline metals to lower the burning temperature. Thus, those additions result in lower durability of ceramic material.

On the next stage, the research of alkalis interaction with brick material was conducted (evaluation of chemical durability of the material). The research was conducted in accordance to developed method [6]. This method allows to implement new work parameter of the construction ceramic: chemical destruction coefficient. Implemented parameter has the value in [%/hour] that gives us opportunity to use it in calculations of critical durability of the material. Practically, chemical destruction coefficient shows the speed of material destruction’s reaction under the influence of alkalis. Results of the research are shown in Figure 4.

![Chemical Destruction Coefficient](image)

**Figure 4.** Results of the research of chemical durability evaluation of ceramic construction’s material.

With the charts, based on the results of laboratory experiment, values of the chemical destruction coefficient are found and equals 18.2 %/hour for the web materials and exceeds the chemical destruction coefficient of the shell of the block by 30% that equals 14.0 %/hour.

Therefore, there are 6.9% more alkalis in the web than in the shell, as well as the speed of chemical destruction of the material is 30% faster when interacted with alkalis. Therefore, hypothesis about destruction of the web in comparison to the shell of large-brick hollow ceramics can be considered proven.

Currently, authors conduct a significant researches of critical durability of the material of large-brick hollow material at one of the factories. The scheme of setting inside the kiln of large-brick hollow ceramics are shown in Figure 5. Blocks are placed tightly which results in different amount of heat received by frontal blocks and blocks inside the setting. The web receive even less heat than the shell of the block.
Figure 5. Setting in the kiln after burning.

Figure 6. The selection scheme of the blocks from the setting.
Samples for the laboratory experiments were selected on the kiln’s exit from the setting of a single car by the following scheme (Figure 6): corner block in the first, that is right of the setting, package, in the first vertical layer of setting and in upper first horizontal layer. This sample has a marking “1.1.1”. Respectively, opposite block in the setting was chosen: fifth package, sixth horizontal layer and fourth vertical layer with marking “5.4.6”. Other samples were chosen in the central, third package in the inner, second vertical layer, from upper, first layer “3.2.1”, middle third layer “3.2.3” and lower sixth layer “3.2.6”. Also, from the third package were chosen control samples from first vertical layer in third “3.1.3” and sixth “3.1.6” horizontal layers. Executed selection in the described order allows to receive a reliable results of properties of the item’s material in setting.

Currently, the first stage of the experiment is finished – the research of the sample’s strength is conducted. Researches were made by the following method. Firstly, compressive strength were evaluated on the hydraulic press in accordance to State Standard 8462. After the test, the research of strength of separate parts of the block were conducted: header and stretcher face, as well as strength of the web. Measuring of material strength were conducted by the impact method with non-destructive control. The result was set as arithmetic average of 5 subsequent values. Impacts were made in different spots of the chosen part of the material. For the web, the arithmetic average of 10 impacts were set.

Results of the research are shown in Table 1.

Table 1. Durability of the large-block ceramic material.

| №№ of the sample | Compressive strength of the material, MPa | Decrease of the strength of the web, % | Increase of the strength of the block, % |
|------------------|------------------------------------------|--------------------------------------|----------------------------------------|
| 1.1.1            | 18,0 16,6 16,2 16,6 16,1 13,1 17,8 | 22,4                                  | 17,7                                   |
| 3.1.3            | 19,6 16,6 19,2 17,6 15,2 6,9 17,7 |                                      |                                        |
| 3.1.6            | 14,7 14,5 18,7 16,2 13,7 7,6 12,9 |                                      |                                        |
| 3.2.1            | 19,3 16,3 15,3 15,7 15,6 11,3 6,9 | 32,0                                  |                                        |
| 3.2.3            | 19,3 162,3 18,3 17,4 10,7 8,0 39,6 |                                      |                                        |
| 3.2.6            | 16,1 15,3 22,4 18,5 7,3 9,5 8,4 41,5 |                                      |                                        |
| 5.4.6            | 15,7 18,1 15,3 16,1 15,8 9,5 8,4 41,5 |                                      |                                        |
3. Conclusion

By the results of the first stage of the research, the following conclusions can be made:

1. Compressive strength of all samples that was conducted in laboratory conditions is different and lower by 16-31% of the nominal strength of 10 MPa. Average compressive strength is 7.5 MPa. Also, compressive strength, measured at the factory with automatic result by the instrument was 17.8 MPa.

2. All the researched samples had lower strength of the web than the shell. The decrease of material’s strength of the web of large-block hollow ceramics is 13 to 41.5% than the shell.

3. Average strength of the shell’s material of the sample characterized by the variation less than 15.6% (for the 3,2.3 block). The lowest strength values of the sample’s shell material were for the lower sixth’s horizontal row.

4. Sample 3.2.3, positioned in the setting center and sample 5.4.6, positioned on the lower horizontal row shown the highest decrease of the strength of the web than the shell: 39.6% for the 3.2.3 sample and 41.5% for the 5.4.6 sample.

Those results prove the decrease of strength of the web compared to the shell material’s strength. Research of the material’s durability of construction ceramics is currently in progress and would be submitted after their completion.

4. References

[1] Rubtsov O I, Bobrova E Yu, Zhukov A D 2019 Ceramic brick, stones and the full brick walls *Stroitel'nye materialy* 9 pp 8-13

[2] Semyonov A A 2016 About a Condition of the Domestic Market to Ceramic Wall Materials *Stroitel'nye materialy* 8 pp 9-14

[3] Operational data of the State Committee of the Republic of Bashkortostan on Construction and Architecture

[4] Zheldakov D Yu 2018 Chemical corrosion of bricklaying Problem definition *Stroitel'nye materialy* 6 pp 29-32

[5] Zheldakov D Yu 2019 Chemical corrosion of brick masonry Processing running *Stroitel'nye materialy* 4 pp 36-43

[6] Zheldakov D Yu 2019 Methods of investigation of kinetics of chemical corrosion process of materials of masonry *Izvestiya vysshikh uchebnykh zavedenii. Stroitel'stvo* 11 pp 78-86

[7] Zheldakov D Yu, Gagarin V G 2017 Terminology and general theory of prediction of the critical durability of the structures *Izvestiya vysshikh uchebnykh zavedenii. Tekhnologiya tekstil'noi promyshlennosti* 3 pp 114-118

[8] Izmeritel’ prochnosti udarno-impul'snyi ONIKS-2 (modifikatsiya ONIKS-2.5) Instruktsiya po primeneniyu OOO «SpetsTekhResurs» Impact-pulse ONIKS-2 strength meter (ONIKS-2.5 modification)

[9] Rekomendatsii po obsledovaniyu i otsenke tekhnicheskogo sostoyaniya kroupopanel'nykh i kamennykh zdani (Recommendations for survey and assessment of technical condition of large-panel and stone buildings) 1988

[10] Posobie po obsledovaniyu stroitel'nykh konstruktsii zdanii (Manual for inspection of building structures) 2004