Obsidian expansion kinetics

A Safaryan¹, T Sarkisyan¹, T Paytyan¹² and A Baghdagyulyan¹
¹National University of Architecture and Construction of Armenia, 105 Teryan Street, Yerevan, Republic of Armenia
E-mail:²paytyantatevik@gmail.com

Abstract. According to the modern terminology, the term «perlite» means natural glassy mountainous rock that has the expansion feature when heated causing high porous pumice-like material. Scientifically, in the first place, perlite (containing different quantities of water) itself that is hydrated volcanic glass, in the second place, pechstein that is even and fairly strong hydrated glass, in the third place, obsidian that is glass containing little water, in the fourth place, the so-called porous perlite that is scientifically regarded as little porous pumice, can be pertained to technical perlite. Thus, in Armenia according to technical significance «perlite», glassy mountainous rock, divided into perlite and obsidian. The igneous rock consists of volcanic glass the water content of which does not exceed 1%. In Armenia, in ancient times obsidian was expanded and used in the upper layers of the dome of the three-floored temple Zvartnotc. Expanded obsidian can be used as artificial porous aggregate for lightweight concrete of different designation. Obsidian is expanded at temperature of 1050-1150°C. The lowest average density of 200-350 kg/m³ (in a piece) is obtained at thermal processing of obsidian with the coarseness from 5 to 20mm and the duration of 3-10 minutes. On the basis of expanded obsidian heat-insulating and acoustic materials can be developed: lightweight and cell concrete and plastering with cement and gypsum.

1. Introduction

According to the modern terminology, the term «perlite» means natural glassy mountainous rock that has the expansion feature when heated causing high porous pumice-like material. Scientifically, in the first place, perlite (containing different quantities of water) itself that is hydrated volcanic glass, in the second place, pechstein that is even and fairly strong hydrated glass, in the third place, obsidian that is glass containing little water, in the fourth place, the so-called porous perlite that is scientifically regarded as little porous pumice, can be pertained to technical perlite. Thus, in Armenia according to technical significance «perlite» glassy mountainous rock is divided into perlite and obsidian. The content of water till 1% is considered limitary for obsidian [1-6].

The characteristic feature of this stone is the ability of expansion when heated. This ability of obsidian was described in the scientific literature at the end of XIX century, when G. Abikh and A. Gumbolt approved the possibility of obtaining the pumice-like materialou of obsidian. Later, in the 1930s of the XX century this theory was developed by the other authors, the founders of expansion technology of Acid structure volcanic glass [9]. However, as it was recently proved, the «secret» of obsidian expansion was
known in Armenia at least in the 7th century. In particular, expended obsidian was used in construction works of Zvatnotc temple aiming at dead masses load reduction on the lower bearing structures [7,8].

Testing the suitability of raw material for production of expanded sand and gravel results to the following definitions: macroscopic raw evaluation, sample selection, determination of mass loss during calcination (DMLC), determination of average density of natural and expended material and coefficient of rock expansion.

Fractions 2, 5, 10, 20 mm in the amount of not less than 1 kg of each fraction are taken to determine the average density and expansion of the rock.

Expansion coefficient of the rock is the main quality indicator of the raw material. The higher the value of this coefficient, the lower the average density of the expanded material, the better its thermophysical and acoustic properties.

The expansion degree is determined by the expansion coefficient, expressing the ratio of the expanded mass volume to the absolutely dry material volume:

$$K_v = \frac{V_2}{V_1} = (\frac{\rho_1}{\rho_2}) (1 - \frac{DMLC}{100})$$

where $K_v$ - expansion coefficient,$V_1$ and $\rho_1$ – volume and density of the absolutely dry material accordingly, $V_2$ and $\rho_2$ – volume and density of the expanded material (in a piece) accordingly, DMLC - determination of mass loss during calcination, % [9].

2. Methodology

The main feature of the raw material suitability is its expansion ability during thermal processing in the range of 1050-1150°C and at this formation of the material having cellular construction with density ranging 200 -1350 kg/m³ in a piece.

The value of the expansion coefficient depends on many factors, the most important of which are the following: quantitative ratio of dissolved and crystallized water in the rock approximately characterized by DMLC, the size of the fired pieces of material, firing conditions (its order, maximum duration and temperature).

The crushed obsidian was sorted by the following grains: from 10 to 20 mm; from 5 to 10 mm, from 2.5 to 5 mm, and it was expanded at the temperatures of 1050, 1100, 1150 and 1200°C and the expansion duration at each temperature was 3, 5, 10 and 20 minutes.

In Figure 1-4 (1 - 10...20 mm, 2 - 5...10 mm, 3 - 2.5...5 mm) the dependence of obsidian expansion coefficient on temperature and duration and the whole porosity of the expanded obsidian are shown. It can be seen that 5-20 mm grains have high value of expansion coefficient which are processed at the temperatures of 1100…1150°C and fired during 3…10 minutes. The electronic micro-photos of obsidian expansion procedure are shown in Figure 5-8, and the surface of the expanded obsidian grain is shown in Figure 9-12.
Figure 1. The dependence of obsidian expansion coefficient on duration, temperature 1050°C.

Figure 2. The dependence of obsidian expansion coefficient on duration, temperature 1100°C.

Figure 3. The dependence of obsidian expansion coefficient on duration, temperature 1150°C.

Figure 4. The dependence of obsidian expansion coefficient on duration, temperature whole porosity.

Figure 5. The electronic micro-photos of obsidian expansion procedure (TEM) output.

Figure 6. The electronic micro-photos of obsidian expansion procedure (TEM) 750°C.
Figure 7. The electronic micro-photos of obsidian expansion procedure (TEM) 1050°C.

Figure 8. The electronic micro-photos of obsidian expansion procedure (TEM) 1450°C.

Figure 9. The surface of the expanded obsidian grain enlarged 200 times.

Figure 10. The surface of the expanded obsidian grain enlarged 250 times.

Figure 11. The surface of the expanded obsidian grain electronic microscopic figure of the surface.

Figure 12. The surface of the expanded obsidian grain welding of grains.
3. Conclusion
Taking into consideration of the results of the study it can be concluded that it is necessary to expand the grains of 5 to 20mm firing them at the temperature of 1050…1150°C with the duration of 3…10 minutes to obtain the expanded obsidian having high expansion coefficient and low average density (200…350 kg/m³).

Compliance with ethical standards
Conflict of interest: The authors declare that there is no conflict of interest.

References
[1] Perlite and Vermiculite 1962 Geology, methodology of trial and technology Collection of articles (Gosgeoltechizdat) 244p
[2] Komenskiy S P 1963 Perlites (features, technology and usage). State production committee on installation and special construction work of the USSR. all-USSR Scientific and Design Institute “Teploproekt” p 260
[3] Nasedkin V V , Petrov V P 1981 Collection of articles AS of the USSR, department of geology, geophysics and geochemistry (Nauka Publishing House) p 292
[4] Nasedkin V V 1975 Petrogenesis of Acid Vulcanites pp. 46-51
[5] Sagatelyan K M 1962 Perlites of Armenia. Collection “Perlite and Vermiculite” (Gosgeoltechizdat) p 29-37
[6] Avgustnik A I 1966 Physical Chemistry of Silicates (Stroyizdat) p 460
[7] Israelyan V, Chuguryan B O 1978 On Usage of Expanded Obsidian in the Construction of Zvartnotc Temple. (The Second International Symposium on Armenian Art.Yerevan.: AS of Arm SSR) p 9
[8] Israelyan V, Mkhitaryan R, Mkhitaryan G 2004 Phase-structural Transformation of Obsidian When Heated Theses Reports. Russian conference on electronic microscopy Chernogolovka p 175
[9] Fokina N G 1985 On Possibility of Intrusive Rocks Expansion (Krasnoyarskn Promstroyizdat) p 100-110