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Standardization and Quality Assurance of Non-Autoclaved Aerated Concrete

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Abstract:
Standardization and the Improvement of Non autoclaved Aerated Concrete Quality in Modern Construction: A Review In the introduction, the authors explain that conditions of large-scale production of construction units, coupled with regulatory reforms in the field of building materials, have made great demands on the production of lightweight, cost effective, and energy efficient materials. In long-lasting experience with aerated concrete, this gap of knowledge had been settled but not on the basis of an applied methodology standardised in regard to the use of chemical additives, mainly carboxymethyl cellulose, as well as for their effects on physical-mechanical properties in non autoclaved production systems.

It uses a blended study design, one of experimental and regulatory based. Concrete compositions were made from Portland cement, sand, aluminum powder, and a three-percent aqueous solution of carboxymethyl cellulose. Sample preparation, curing, and testing procedures were performed following related GOST standards to determine their density, compressive strength, contents of moisture as well as structural properties. A comparative study of conventional composition and modified composition mixtures.

The results confirm that carboxymethyl cellulose can be used as an additive to enhance pore uniformity, pore structure strength development characteristics and overall stability of the material. The results verify that, among different additive concentrations, three percent provides the optimal performance, which results in a higher concrete grade, better density control, and higher thermal efficiency without need for autoclaving.

The final results clarify that the controlled application of carboxymethyl cellulose in the production of non-autoclaved aerated concrete delivers both practical and economic advantages. Such results are significant in relation to sustainable construction practices, regulatory compliance, and development of lightweight readily applicable building materials for industrial scale.

Keywords: *Standardization, Advantages of standardization of building materials, CMC (Carboxymethylcellulose) GOST 25845-89*

1. Introduction

Standardization of building materials in construction is the process of establishing and enforcing mandatory standards for the quality, safety, and other technical parameters of building materials used in the construction of buildings and structures [1]. Standardization plays an important role in the construction industry, as it ensures the unification and homogeneity of materials, increases the reliability and durability of buildings, and ensures the safety of people. It is well known that high-quality, affordable, and modern building materials are essential for affordable housing, social facilities, and commercial and other buildings. Considering that building materials account for 55-60% of the cost of construction, modern architecture requires new, high-quality, affordable, lightweight, earthquake-resistant, and innovative building materials, the importance of the building materials industry is undeniable [2]. In particular, the large-scale construction work currently underway in the country requires the rapid development of the building materials industry. In order to develop the production of building materials in the republic and implement the above-mentioned tasks, the Decree of the President of February 20, 2019 "On the radical improvement and comprehensive development of the building materials industry" and Decrees PQ-4198 and PQ-4335 "On additional measures to accelerate the development of the building materials industry" of May 23, 2019, which provide for the development of the building materials industry, modernization, technological and technical re-equipment of the industry [3].

The standardization process includes the approval and application of quality certificates for building materials, certification, and testing for compliance with established requirements. Standards are defined at the level of government, international, or industry bodies and are mandatory for all manufacturers and suppliers of building materials.

The benefits of standardizing building materials include improved construction quality, reduced risks of accidents and defects, increased labor productivity, and reduced building repair and maintenance costs [4]. Furthermore, adherence to standards fosters innovation and attracts investment in the industry.

The importance of standardizing building materials in construction is difficult to overstate, as it has a significant impact on the quality, safety, and durability of construction projects. Here are several key aspects that underscore the importance of standardizing building materials:

1. Quality Assurance: Standardization of building materials establishes general quality requirements, preventing the use of low-quality materials in construction projects. Standards define material parameters, their physical and chemical properties, technical specifications, and quality control methods. This ensures that clients and developers receive high-quality construction results, which contributes to the durability of buildings and increases end-user satisfaction.

2. Safety: Safety standards for building materials establish requirements for operational safety and the resistance of materials to various factors, such as fire, moisture, ultraviolet radiation, etc. This helps ensure the safety of workers on construction sites and users of finished structures. For example, standards require the use of non-combustible materials.

for wall cladding, which reduces the risk of fire and ensures the safety of building residents.

3. Cost savings: Standardization of building materials helps reduce risks when selecting materials and structures for construction [5]. Pre-established quality and safety standards help identify the optimal materials for a specific project and avoid costly mistakes. Furthermore, the use of high-quality materials that meet standards increases the durability of buildings and reduces their future operation and maintenance costs. This results in cost savings both during the construction phase and throughout the entire lifespan of the facility.

4. Process harmonization: Standardization unifies the processes of production, operation, and quality control of building materials, which helps reduce technical risks and ensures consistency across all stages of construction.

In accordance with GOST 25845-89, cellular concretes are classified by purpose, curing conditions, pore formation method, and types of binders and silica components. By purpose, cellular concretes are divided into: structural (compressive strength class not lower than B3.5; average density grade - D700 and higher, pore volume 40...55%), structural and heat-insulating (compressive strength class not lower than 51.5; average density grade not higher than D700), heat-insulating (compressive strength class not lower than 50.35; average density grade not higher than 7)400, total porosity 75...85%). By curing conditions, cellular concretes are divided into: autoclaved (synthetic curing) - hardening in a saturated steam environment at a pressure above atmospheric; Non-autoclaved (hydration-cured) concretes harden naturally, with electric heating, or in a saturated steam environment at atmospheric pressure. Based on the method of pore formation, concretes are divided into: aerated concrete, foam concrete, and gas-foam concrete [6].

2. Materials and Methods

Research methodology devised on experimental and analytical approach to evaluate standardization and quality performance of modified non autoclaved aerated concrete with carboxymethyl cellulose additives. Our approach included both normative and experimental studies aligned with existing national standards regulating cellular concretes. Initially, raw materials such as Portland cement, quartz sand, aluminum powder, chemical activators, industrial water, and CMC were selected according to the corresponding GOST requirements which assured reproducibility and compliance. These properties facilitate the formation of uniformly dispersed pores and moisture distribution over the concrete matrix during mixing. Experimental samples were prepared via controlled mixing procedures where dry components were pre-mixed prior to inclusion of aqueous CMC solution. Specimens were cast and cured in natural hydration conditions mimicking the non-autoclaved production technology [7]. Physical and mechanical properties (average density, compressive strength, moisture content, water absorption) and thermal characteristics were determined by standard methods of laboratory testing prescribed in the relevant GOST documents. Performance comparison between standard aerated concrete formulations and formulations with three percent CMC were made. Laboratory measurement data were processed in both descriptive and comparative analysis to track the development of strengths, density variations, and material efficiencies. A regulatory analysis of existing standards was also included in the methodological framework to determine whether the proposed composition complies with existing standardisation requirements of lightweight cellular concretes [8]. The use of this combined approach provided a rigorous evaluation of the performance of CMC modified non autoclaved aerated concrete but also its potential level of use in a systemised construction market.

3. Results

The following types and elements made of autoclaved aerated concrete and foam concrete are recommended for use in construction for residential and public buildings: small blocks for external and internal walls (GOST 21520-89); large blocks for external and internal walls (GOST 19010-82); unreinforced wall products (GOST 31360-2007); panels for internal load-bearing walls, partitions and ceilings of residential and public buildings (GOST 19570-74, GOST 12504-80*); panels for external walls of buildings (GOST 11118-2009); heat-insulating blocks and slabs (GOST 5742-76); roof panels for residential and public buildings [9].

Non-autoclaved aerated concrete is used to produce small blocks for external and internal walls (GOST 21520-89), thermal insulation products (GOST 5742-76), and is also used for monolithic thermal insulation of basement and attic floors, roofs, attics; monolithic internal and external walls of residential and public buildings; insulation and reinforcement of walls of reconstructed buildings; as a decorative heat-resistant material.

Bulk density (density) is determined for concrete by testing a sample, which sets requirements for equipment (scales, drying cabinets), sample preparation (in natural or standardized wet state) and testing, including waxing and weighing in water for complex-shaped samples according to GOST 12730.1-78 "Concretes. Methods for Determining Density". Specifications GOST 12730.1-78 Concretes. Methods for Determining Density GOST 12730.2-78 Concretes. Method for Determining Humidity GOST 12852.0-77 Cellular concrete. General requirements for testing methods GOST 13015-2012 Concrete and reinforced concrete products for construction. General technical requirements [10]. Rules for acceptance, marking, transportation and storage, GOST 17177-94 Building thermal insulation materials and products. Test methods GOST 18105—2010 Concrete. Rules for monitoring and evaluating strength GOST 21616—91 Strain gauges . General specifications GOST 21718—84 Building materials. Dielectric method for measuring moisture content GOST 22685—89 Molds for making control samples of concrete. Specifications GOST 23732—2011 Water for concrete and mortars. Specifications GOST 24104—2001* Laboratory scales. General specifications GOST 24211—2008 Additives for concrete and mortars. General specifications GOST 24452—80 Concrete. Methods for determining prism strength, modulus of elasticity and Poisson's ratio GOST 24816—2014 Building materials. Method for Determining Equilibrium Sorption Moisture Content GOST 25192—2012 Concretes. Classification and General Specifications GOST 25336—82 Laboratory Glassware and Equipment [11]. Types, Main Parameters, and Dimensions GOST 25898—2012 Building Materials and Products. Methods for Determining Vapor Permeability and Vapor Permeation Resistance GOST 27005—2014 Lightweight and Cellular Concretes. Rules for Control of Average Density GOST 28836—90 Strain Gauge Load Cells . General Specifications and Test Methods GOST 30108—94 Building Materials and Products. Determination of Specific Effective Activity of Natural Radionuclides GOST 30244—94 Building Materials. Flammability Test Methods GOST 30459—2008 Additives for Concrete and Building Mortars. Definition and evaluation of the effectiveness of GOST 31108—2016 General construction cements [12].

Thus, the standardization of building materials plays an important role in ensuring high quality, safety and sustainability of construction projects, and also contributes to the development of the industry and increased competitiveness in the construction services market (Figure 1).

Информация о производстве отдельных видов промышленной продукции по Республике Узбекистан

Код СКП	Код ТНВЭД	Наименование	2020 год		2021 год		2022 год		Январь-декабрь 2023 года *(по крупным предприятиям)*	
			кол-во, *тонна*	стоимость, *тыс.сум* 1)	кол-во, *тонна*	стоимость, *тыс.сум* 1)	кол-во, *тонна*	стоимость, *тыс.сум* 1)	кол-во, *тонна*	стоимость, *тыс.сум* 1)
2361111	**6810.11**	**Кирпичи и блоки, строительные из цемента, бетона или искусственного камня**	**2 182 731,7**	**552 826 363,0**	**2 978 970,0**	**871 941 991,0**	**2 008 559,8**	**751 193 034,0**	**117 963,9**	**87 250 102,7**
		Андижанская область	746 746,1	121 563 843,0	161 137,2	62 885 544,0	183 542,2	52 009 413,0	-	-
		Бухарская область	64 803,6	39 704 446,0	66 583,3	25 395 697,0	19 999,6	11 030 630,0	-	-
		Джизакская область	30 869,6	6 630 573,0	51 339,1	20 997 889,0	45 644,5	15 117 323,0	-	-
		Кашкадарьинская область	72 896,8	12 673 005,0	64 023,8	12 649 659,0	39 877,9	10 564 123,0	-	-
		Навоийская область	361 237,3	57 240 148,0	432 163,1	68 235 691,0	326 067,5	70 624 047,0	9 537,8	3 237 349,0
		Наманганская область	70 246,1	22 860 213,0	40 460,8	23 561 070,0	58 355,2	34 149 594,0	-	-
		Самаркандская область	152 956,9	42 607 233,0	175 964,8	71 470 758,0	105 706,2	47 672 827,0	-	-
		Сурхандарьинская область	153 640,0	21 498 155,0	243 115,8	46 899 320,0	122 914,1	34 116 189,0	-	-
		Сырдарьинская область	28 339,8	5 738 575,0	47 234,6	12 932 345,0	28 133,3	5 750 568,0	15 620,0	18 744 000,0
		город Ташкент	313 667,8	72 909 633,0	1 376 014,4	257 523 343,0	537 538,3	128 412 657,0	92 677,0	13 392 044,0
		Ташкентская область	95 437,9	91 491 743,0	216 287,2	190 463 410,0	382 231,8	258 603 665,0	129,0	51 876 709,7
		Ферганская область	73 049,8	48 240 778,0	73 361,6	63 909 882,0	95 145,1	51 882 806,0	-	-
		Хорезмская область	16 167,9	7 733 231,0	26 302,2	11 099 832,0	28 732,2	16 320 194,0	-	-
		Республика Каракалпакстан	2 672,1	1 934 787,0	4 982,3	3 917 551,0	34 672,0	14 938 998,0	-	-

Figure 1. Information on the production of selected types of industrial products in the Republic of Uzbekistan

We have proposed a new composition for the production of lightweight cellular aerated concrete GOST 25485-2019 with the addition of CMC.

The following classes of compressive strength are established for non-autoclaved cellular concrete: BO.5; BO.75; Bl ; Bl.5; B2; B2.5; B3.5; B5; B7.5; B10; B12.5. The following grades of concrete in a dry state are assigned according to average density: D300; £>350; £>400; £>500; £>600; £>700; £>800; £>900; £>1000; £>1100; £>1200.

The following raw materials were used: Portland cement CEM I 42.5 N GOST 31108-2020 produced by Kyzylkum cement JSC, Navoi, CMC produced by the Fergana Chemical Plant of Furan Compounds, industrial water according to GOST 23732-79, sand for construction work according to

GOST 8736-93, sodium sulfate according to GOST 6318-77, caustic soda according to GOST 2263-79, aluminum powder according to GOST 5494-95.

The technology for producing aerated concrete with the addition of CMC is given below: 795 g of cement were added to a container, mixed with 23.85 g of crushed dry microsilica , 780 g of sand, 1.36 g of aluminum powder, then 23.85 g of CMC were dissolved in 795 g of water and 7.5 caustic soda, 11.5 sodium sulfate and mixed thoroughly and hammered into molds (Table 1).

Table 1. Composition of cellular non-autoclaved aerated concrete without CMC

Source materials	**D 600**	**gram**	**Weight**	**795**		
Cement , g	1,113	1113	Dimensions	10	9.7	9.9
Sand , g	1,092	1092	Water absorption	21.31		
Water , g	0.896	896	Refractive power	22.79		
Aluminum Powder , g .	1,904g.	1904	Main surface	97		
Sodium sulfate , g .	0.0161g.	16.1	Volume	960.3		
Caustic soda, g .	0.0105	10.5	brand	819,8276		
			Compressive strength	23,95769		

The following tables show the composition of cellular aerated concrete with the addition of CMC in a ratio of 3% (Table 2)

Table 2. Composition of aerated concrete with the addition of 3% CMC

Source materials	D 600
Cement , g	795
Sand , g	780
Water , g	640
Aluminum Powder , g .	1.36
Sodium sulfate , g .	11.5
Caustic soda, g.	7.5
CMC , g	23.85
Microsilicon dioxide	23.4

CMC 3%			
Weight	785		
Dimensions	10	8.5	1 0
Water absorption	21,31 97		
Refractive power	9.17		
Main surface	85		
Volume	850		
Brand	923.5 294		
Compressive strength	11 , 00076		

The first table shows standard aerated concrete with its characteristic properties, produced according to GOST 25485-2019 and with a 3% CMC additive. The aqueous phase is intensively mixed with CMC to form an aqueous solution, which is then added to the cement mixture. In this case, the aqueous phase is evenly distributed throughout the entire volume [13]. CMC swells significantly in the aqueous phase and retains water within the pores, increasing the strength of the aerated concrete over time.

A 3% aqueous solution of CMC is the most effective in this case, as the water mass is evenly distributed throughout the entire volume. Thus, it was found that a 3% aqueous solution of CMC not only provides strength but also increases the grade of aerated concrete, increasing the density of the aerated concrete in each row and providing cost effectiveness. The third table shows the cost calculation and cost effectiveness, which demonstrates high profitability [14]. The obtained results indicate that the new aerated concrete block tested with the addition of CMC demonstrates improved results and characteristics, improving the quality of aerated concrete without autoclaving , and is recommended for construction.

A method of drying samples to a constant mass in a drying oven at a certain temperature (for example, 105±5°C), and then weighing them, which allows calculating the percentage of moisture from the dry mass according to GOST 12852.0-77 general requirements for testing methods for cellular concrete.

To determine the thermal conductivity of aerated concrete and thermal insulation materials and products intended for industrial equipment and pipelines, and establishes a method for determining their thermal conductivity at an average sample temperature from minus -40 °C to +300 °C according to GOST 7076-87. The compressive, axial tensile, and flexural strength of lightweight aerated concrete is determined by the method according to GOST 18105-86. One of the main ways to improve the physical and mechanical properties of aerated concrete is by adding carboxymethyl cellulose (CMC) to the concrete mix. Mixtures containing CMC exhibit greater cohesion and reduced water bleeding and segregation. Aerated concrete also exhibits greater strength , density , water resistance , and resistance to sulfate corrosion . This standard applies to structural heavyweight, lightweight, and cellular concrete (including structural and thermal insulation concrete), as well as dense silicate concrete for precast and monolithic concrete and reinforced concrete products, structures, and buildings [15]. It establishes rules for monitoring the compressive, axial, and flexural strength of concrete.

4. Conclusion

It was experimentally established that the grade of lightweight concrete increases with the addition of CMC up to 3% to the composition of lightweight concrete.

It was revealed that under optimal conditions of formation, pores in the matrix of cellular concrete develop close to spherical.

Electron microscopy images of the lightweight concrete we obtained showed a volumetric macroporosity of over 50%, with a high pore density, resulting in lighter material, improved thermal insulation properties, and reduced material consumption. This leads to interactions between pores during their formation, and in the absence of total coalescence, a porous macrostructure develops within the material.

A 3% aqueous solution of CMC is the most effective in this case, as the water content is evenly distributed throughout the entire volume. Thus, it was found that a 3% aqueous solution of CMC not only increases strength, but also increases the grade of aerated concrete, increasing the density of aerated concrete by a factor of 1, and providing cost-effectiveness.

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