FEATURES OF NON-AUTOCLAVATED AERATED CONCRETE WITH POLYPROPYLENE WASTE

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ANNOTATION

This article describes the technology of non-autoclaved aerated concrete production adding the fiber from polypropylene waste. This study investigates the development of a sustainable and high-performance non-autoclave aerated concrete by incorporating recycled polypropylene fibers derived from industrial waste. Traditional aerated concrete production often relies on energy-intensive autoclaving processes, however, this research explores an ambient-pressure curing method to reduce carbon footprint and production costs. The experimental program evaluates the influence of varying fiber concentrations on the physical and mechanical properties of the concrete, specifically focusing on compressive strength, thermal conductivity, and shrinkage behavior. By utilizing waste polypropylene fibers, the study aims to mitigate the inherent brittleness of non-autoclave mixes and improve crack resistance. Preliminary results indicate that the addition of recycled fibers significantly enhances the flexibility and ductility of the material compared to control specimens. Furthermore, the integration of waste materials contributes to a more circular economy within the construction industry. The findings suggest that polypropylene fiber modified non-autoclaved aerated concrete presents a viable, eco-friendly alternative for thermal insulation and lightweight structural applications in modern building technologies.

1. Introduction

The global construction industry is currently facing a dual challenge: the rising demand for energy-efficient building materials and the urgent need to reduce the environmental impact of traditional manufacturing processes. Aerated Concrete has long been recognized as a premier solution for thermal insulation and lightweight construction. However, the standard production of Autoclaved Aerated Concrete requires high-pressure steam curing at temperatures reaching 180°C to 200°C, a process that consumes significant energy and requires expensive industrial infrastructure. In response to these challenges, Non-Autoclave Aerated Concrete has emerged as a promising alternative. By utilizing chemical foaming agents and ambient-pressure curing, non-autoclave concrete eliminates the need for autoclaving, thereby reducing the carbon footprint and production costs. Despite these advantages, non-autoclave aerated concrete often suffers from lower mechanical strength and a higher tendency for drying shrinkage compared to its autoclaved counterparts. These drawbacks frequently lead to micro-cracking, which compromises the structural integrity and durability of the material. The integration of fiber reinforcement has proven to be an effective strategy for overcoming the inherent brittleness of cementitious matrices. While synthetic fibers are widely used, the environmental cost of producing virgin polymers remains high. Consequently, the utilization of recycled polypropylene fibers-derived from industrial and consumer waste-presents a synergistic opportunity. Incorporating these waste fibers into the non-autoclave aerated concrete matrix not only enhances the tensile strength and crack resistance of the material through the "bridging effect" but also addresses the critical issue of plastic waste management.

2. Materials and methods

1. While the foundational mechanics of these mixtures are driven by the tripartite interaction of binders, fillers, and water, the inclusion of specific additives allows for the engineering of mortars with precisely tailored characteristics, enabling their performance even in high-stress environments. Historically, aerated concrete production relied primarily on portland cement, but the evolution of the field has seen a transition toward binders derived from industrial by-products like ash and slag. This shift has facilitated the creation of both thermal insulation and structural-grade aerated concrete suitable for the envelopes of low-rise constructions. Current formulation strategies for these mixtures prioritize advancements in material dispersion to achieve optimal efficiency. Specifically, non-autoclaved aerated concrete is manufactured using specialized cements, finely ground lime, various waste components, and aluminum powder as a gas-forming agent. Although the capital investment requirement is significantly lower—often by a factor of hundreds—than that of its autoclaved counterpart, it typically exhibits deficiencies in critical performance areas such as fire safety, frost durability, and long-term stability. To rectify these shortcomings, researchers incorporate diverse chemical modifiers including calcium chloride, microsilica, and semi-aqueous gypsum. Furthermore, the introduction of dispersed reinforcement through synthetic fibers like glass or polypropylene waste at 0.1-0.7% of the cement mass represent promising avenues for enhancing structural integrity and strength. The composition of other substances in the experimental samples can be seen in Table 1.

№	Components	Unit of measurement	Amount
1	Cement	g	240
2	polypropylene fiber	%	0.1-0.7
3	Fine aggregate	g	360
4	Lime	g	10
5	Aluminum powder	g	0,47
6	Water	ml	264
7	Caustic soda	g	3
8	Sodium sulfate	g	4,6

The prepared samples were stored in a special environment with an air temperature of 20°C and a relative humidity of 95%, in accordance with the standard hardening requirements. During the experiment, the physical and mechanical properties of the samples were comprehensively studied for 7 and 28 days under normal hardening conditions. The required quantity of water was established through a cone slump test, targeting a spread diameter of 200±5 mm. All solid constituents were utilized in a dehydrated state and measured precisely by weight to ensure accuracy. The initial phase involved the dry blending of cement, lime, and aggregate using a heavy-duty construction mixer. The quicklime was prepared by sifting until it reached a particle size of 0.63 mm or finer. Water, along with the soda, was combined with the dry ingredients and mixed thoroughly for three minutes. Following this, aluminum powder was introduced, and the slurry was agitated for an additional two minutes. The resulting mixture was transferred into molds, filling them to approximately two-thirds of their total height to allow for expansion. The rising process and the initial development of structural integrity occurred under ambient conditions. Once stable, the specimens were removed from the molds and transferred to a specialized curing chamber to undergo a standard 28-day hardening period. The experimental framework focused on evaluating the performance of samples containing varying levels of polypropylene fiber and soda against a control specimen. The first phase of testing investigated the impact of fiber at concentrations of 0.015%, 0.02%, 0.025%, and 0.03%. The subsequent phase evaluated the influence producing samples with replacement levels of 3%, 5%, 7%, and 10%.

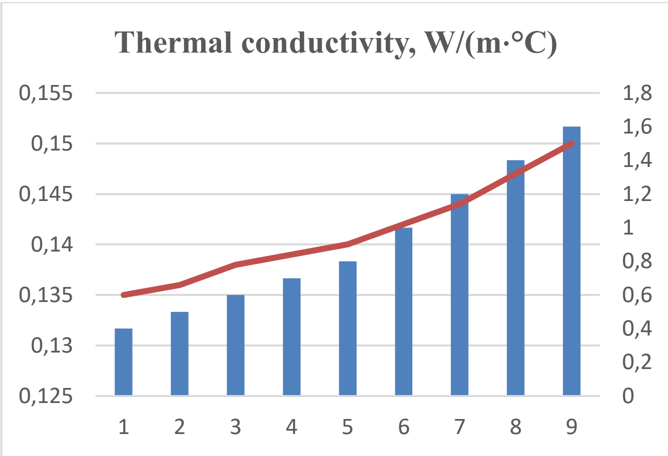
3.Physical properties

Composition and physical and mechanical properties of aerated concrete using construc

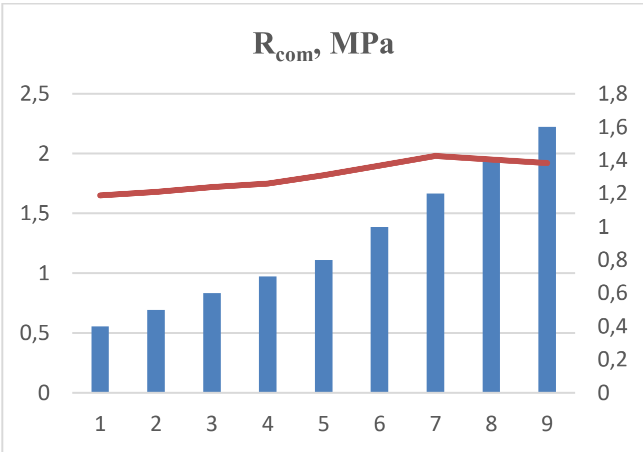
Polypropylene fiber, g	Thermal conductivity, W/(m·°C)	ρ,kg/m^3	P_{com}, MPa
0,4	0,135	620	1,65

0,5	0,136	622	1,68
0,6	0,138	625	1,72
0,7	0,139	628	1,75
0,8	0,14	632	1,82
1	0,142	635	1,9
1,2	0,144	640	1,98
1,4	0,147	645	1,95
1,6	0,15	652	1,92

In the next stage, the effect of building fiber on the strength and calculated thermal conductivity of aerated concrete was studied. The results of this study are presented in Figure 1.



▶ Polypropylene fiber ▶ Thermal conductivity



▶ Polypropylene fiber ▶ R_{com}, MPa

Laboratory studies have revealed that the concentration of polypropylene fiber exerts a significant influence on the structural stability and mechanical integrity of aerated concrete. According to the experimental data, as the fiber content was increased from 0.4 g to 1.2 g, the compressive strength of the material demonstrated a linear enhancement, rising from 1.65 MPa to 1.98 MPa. This phenomenon is attributed to the polypropylene fibers forming a micro-reinforcing framework within the concrete matrix, which effectively inhibits the propagation of micro-cracks. During the structural formation phase, the increased fiber content leads to a slight rise in mixture viscosity, which is essential for stabilizing the gas evolution process. However, when the fiber dosage reached the 1.4–1.6 g range, a decline in strength to 1.95–1.92 MPa was observed. This reduction was evaluated as a consequence of the "balling effect" (fiber clumping) and the subsequent weakening of the cement paste's adhesion around the fibers. Conversely, density values increased proportionally with the fiber content, rising from 620 kg/m³ to 652 kg/m³, confirming the correlation between the material's porosity and the density of its skeletal framework.

Analysis of the research results indicates that a polypropylene fiber content of 1.2 g represents the optimal dosage. At this point, the compressive strength reaches its peak value of 1.98 MPa, while the thermal conductivity coefficient of 0.144 W/(m·°C) fully complies with energy efficiency requirements. These findings serve as a primary benchmark (reference standard) for the subsequent stages of complex modification using industrial by-products, such as slag and waste sand. Furthermore, it was determined that the composition reinforced with polypropylene fibers showed a 3–5.5% improvement compared to standard industrial formulations. On this basis, the following chapter investigates the pioneering research into aerated concrete compositions utilizing slag and construction waste, specifically examining the physical and mechanical properties of blocks when these components are introduced simultaneously.

In the next stage of the experiments, we will consider the properties of aerated concrete obtained with polypropylene fiber, cast iron slag and constuction waste sand. Composition of aerated concrete mixture using cast iron smelting slag waste sand and polypropylene fiber for the preparation of cubes in laboratory conditions:

Components	**Unit of measurement**	**Amount**
Cement	g	210
Cast iron slag	g	21
polypropylene fiber	g	0.9
Fine aggregate	g	312
Construction waste sand	g	49
Lime	g	10
Aluminium powder	g	0,47
Water	ml	264
Caustic soda	g	3

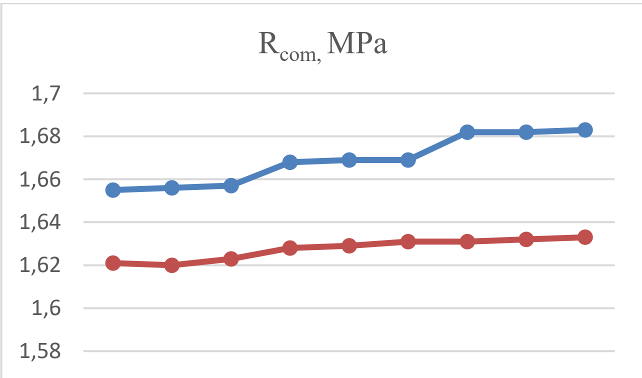
Sodium sulfate	g	4,6

The amounts of slag, construction waste sand, and polypropylene fiber used in the composition of aerated concrete, as well as their physical and mechanical properties

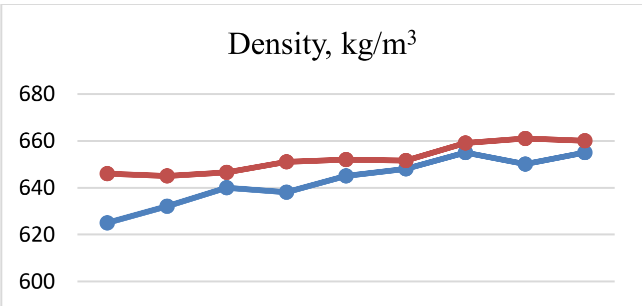
Sample	Cast iron slag, (%)	construction waste sand, (%)	polypropylene fiber, (%)	Thermal conductivity, W/(m·°C)	ρ, kg/m3	R_{com}, MPa
1	5	5	0,6	0,136	625	1,78
2	7,5	7,5	0,7	0,138	632	1,88
3	10	10	0,9	0,14	640	2,05
4	12,5	7,5	0,8	0,141	638	2,12
5	**15**	**5**	**1**	**0,139**	**645**	**2,28**
6	7,5	12,5	0,85	0,143	648	1,92
7	5	15	1,1	0,146	655	1,85
8	10	15	0,95	0,145	650	2,02
9	15	15	1,2	0,149	655	2,35

4. Results

Aerated concrete blocks were prepared according to the above composition and their physical and mechanical properties were studied. The results of the comparison of the strength and average density of aerated concrete blocks with the addition of industrial waste and the composition used in production were presented.



▶ content proposed for production
▶ Industrial content



▶ content proposed for production

▶ Industrial content

In compositions where the content of cast iron melting slag was increased up to 15.0% (Experiments 5 and 9), the potential reduction in strength caused by the use of construction waste sand was fully compensated. This is attributed to the active minerals within the slag structure, which facilitate the formation of additional hydrosilicates during the cement hydration process, thereby densifying the interfacial transition zones between the cement stone and the aggregate. The incorporation of polypropylene fiber reduces the brittleness of the material and forms a micro-reinforcing framework. According to the graphical analysis, the thermal conductivity coefficient remained stable across all experimental points, ranging between 0.136 and 0.149 W/(m·°C). This data confirms that the introduction of mineral and fiber additives significantly enhances structural strength without compromising the primary thermal insulation function of the aerated concrete.

Consequently, the optimal composition was identified: for complexly modified aerated concrete, Composition No. 5—containing 15% cast iron slag, 5% construction waste sand, and 1 g/dm³ of polypropylene fiber—was determined to be the most effective point. At this stage, the compressive strength reached 2.28 MPa, representing a significant increase compared to traditional industrial samples.

A synergistic relationship was proven; specifically, the combined application of the slag's chemical activity and the mechanical reinforcing properties of the polypropylene fiber provides a scientific basis for the efficient use of low-quality construction waste sand as a viable aggregate.

Analysis of the research findings established that the newly developed aerated concrete formulation fully complies with the requirements of the GOST-25485 state standard. In particular, the material achieved a frost resistance rating of F25. Experimental evidence (Table 3.12) demonstrated that compared to traditional analogues, the average density decreased by 2.5–6%, thermal conductivity was reduced by 3–5.5%, and strength indicators increased by 8–13.5%.

Physical and mechanical properties of non-autoclaved aerated concrete blocks

Production conditions and features	Aerated concrete brand	
	D600	
	Durability R_{com}, MPa	Thermal conductivity, W/(m·°C)
The production organization offers aerated concrete properties	1,51	0,147

Properties of aerated concrete for the proposed project	2.28	0,139

Conclusion

Comprehensive scientific research was conducted to determine the optimized composition of non-autoclaved aerated concrete using industrial and construction waste materials (pig iron slag and waste sand) and polypropylene fiber. The experiments identified the patterns of influence of these components on the rheological properties of the aerated concrete mixture and the physical-mechanical indicators of the finished product. Analysis of the compositional dependencies and plotted graphs revealed that the inclusion of 13-15% pig iron slag, 5-10% construction waste sand, and 1.0-1.2 g/dm³ of polypropylene fiber is scientifically justified to ensure optimal strength and thermal performance. It was established that exceeding the specified limits for fiber and slag content excessively increases the viscosity, leading to a reduction in gas expansion height and an undesirable increase in density.

The newly developed composition was tested in accordance with GOST-25485 state standards and found to fully comply with all regulatory requirements. The results indicated that the aerated concrete reached a frost resistance rating of F25, while average density decreased by 3-6% and thermal conductivity by 3-5.5%. Furthermore, due to the micro-reinforcing effect, compressive strength improved by 8-13.5%. A software algorithm was developed to automatically calculate the aerated concrete composition for specified density grades (D600). The calculations performed via this software were compared with modern design systems. Based on the regulatory requirements of KMK 2.01.04-18 "Building Heat Engineering," the energy-efficient thickness dimensions for external wall structures were determined. The obtained results are recommended for the construction of residential buildings in various climatic regions of the Republic of Uzbekistan.

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