Qazaq Highway
Science and Innovation
https://science-jolshy.qazjolgzi.kz/ru/index

ISSN
3008-1491

DEVELOPMENT OF NOISE-INSULATING CONCRETE BASED ON RECYCLED INDUSTRIAL WASTE TO IMPROVE ACOUSTIC PROPERTIES OF BUILDING STRUCTURES

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Abstract. This study investigates the development and characterization of a noise-insulating concrete (NIC) incorporating industrial waste (polypropylene, slag, and microsilica) to enhance acoustic performance and sustainability. The research aimed to identify a concrete composition balancing mechanical strength, density, and sound absorption. In the first phase, concrete samples were formulated using recycled polypropylene and other by-products, then cured and tested for compressive strength and density. The second phase focused on measuring the samples' acoustic properties via sound absorption coefficient tests, following GOST standards. Results showed that NIC with polypropylene treatment and active additives achieved a significantly higher compressive strength (2.63 MPa) than other variants, demonstrating improved structural integrity. Moreover, NIC outperformed cellular concrete in sound insulation tests, reducing noise from 98.5 dB to 41.6 dB at 70 cm. This novel approach not only facilitates an effective solution to urban noise pollution but also contributes to eco-friendly construction practices.

Keywords: concrete, slag, cement, polypropylene, noise, testing, sound, waste, material, microsilica

Introduction

The growing demand for environmentally friendly building materials makes researchers look for innovative approaches, in particular to the use of industrial waste in construction [1]. One promising area is the development of soundproofing materials, which play a crucial role in reducing noise pollution in urban environments [2]. Concrete, widely used in construction, has traditionally been valued for its strength and durability, but enhancing its sound insulation properties by incorporating industrial waste not only provides environmental advantages but also offers an effective solution for noise control in buildings [3–7].

The aim of the research is to develop sound-absorbing concrete made from industrial waste based on polypropylene, slag and microsilica. The research is aimed at improving the environmental friendliness of construction materials, while meeting the need for effective noise reduction, which is important in the operation of civil buildings and comfortable living of people.

The laboratory tests carried out studied both the physical properties of concrete, such as strength and density, and its sound absorption characteristics, providing valuable insights into the practical application of these materials as noise insulation.

Methodology

This research was carried out in two stages. In the first stage, concrete compositions were developed using industrial wastes such as polypropylene, slag, micro silica (Figure 1). The aim was to identify a composition that balanced strength, density and sound absorption, making it suitable for practical construction applications. Waste materials were chosen for their availability and potential to improve acoustic properties. Concrete samples were poured into 100x100 mm forms and the strength set of concrete samples was carried out within 28 days according to GOST 10180-2012 [8]. The density of the samples was determined according to GOST 12730.1-2020 [9]. Measurement of acoustic characteristics, such as sound absorption coefficient, was carried out in accordance with GOST 23499-2009 [10].

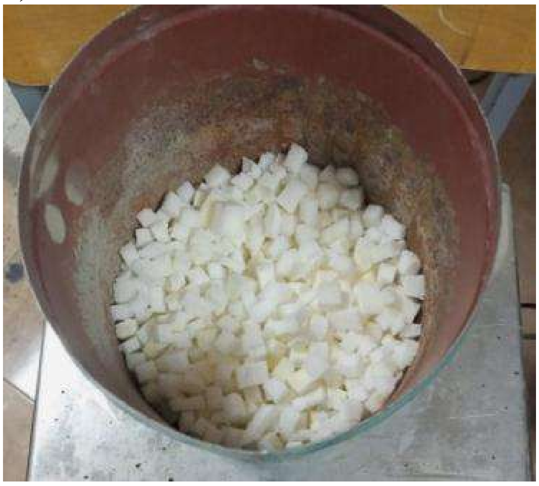
In the second stage, physical and acoustic properties were tested (Figure 1-4).

After curing, the concrete specimens were tested for physical properties. Compressive strength was measured using a PGM-500MG4A universal testing press machine, and density was calculated based on mass and volume. After these tests, the acoustic properties of the samples were evaluated by measuring the sound absorption coefficient according to GOST 23499-2009. The results of the physical and acoustic tests were compared to evaluate the performance of the concrete specimens.

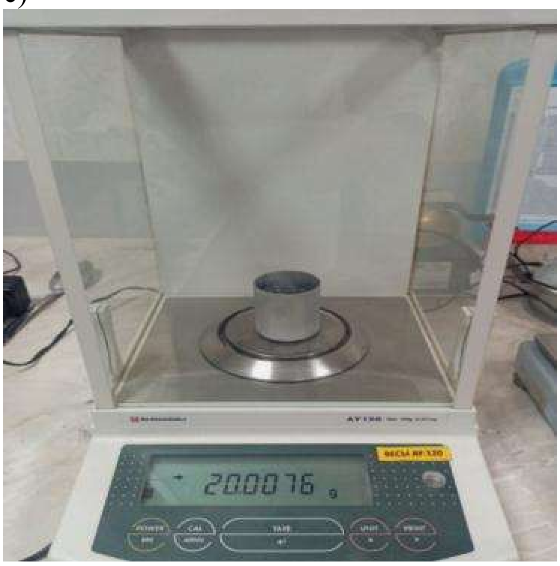
Laboratory compression tests of concrete specimens were carried out (Figure 2).

a)

b)



c)



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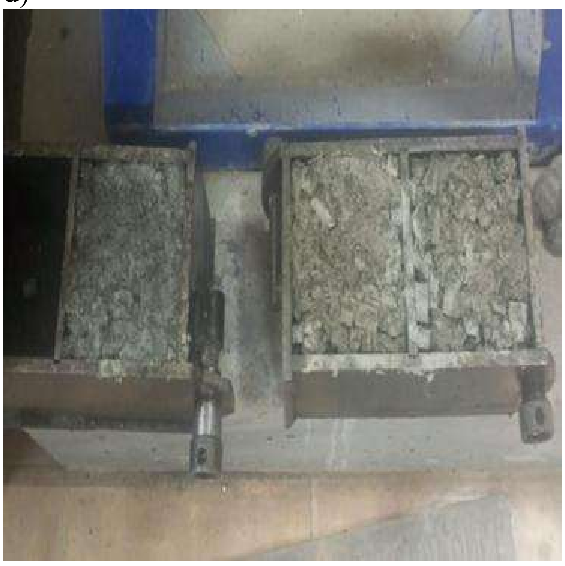


a) cement, b) polypropylene, c) scales AY-120, d) forms with samples

Figure 1 – Polypropylene Waste for Noise Insulating Concrete (NIC)

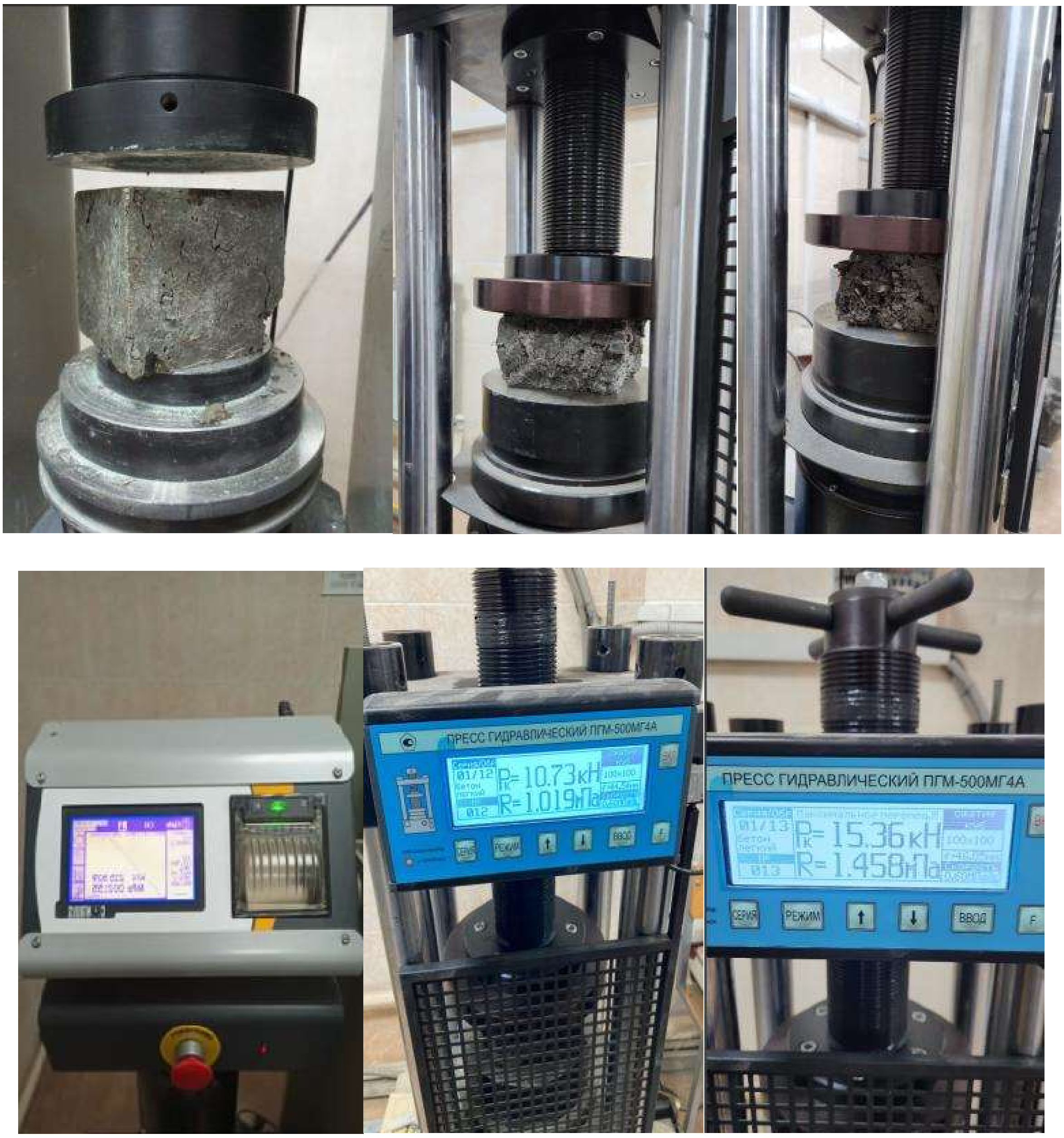


Figure 2 – Laboratory compression testing of concrete specimens

The research was conducted in 2 steps:

Step 1 - Preparation of noise insulation concrete

The materials in the ratio to weight of cement presented in Table 1 were used in the formulation of the developed noise insulating NIC concrete.

Sequence of concrete mix preparation:

1 Prepare 0.25 parts water of the total volume and the entire amount of acrylic latex. The slurry is then mixed manually or with a mixer at medium speed for 15 seconds.

2 Then the entire amount of polyethylene crumbs is put into the bowl of the cement mixer. Then, mixing at a medium speed of 120-145 rpm for 30 sec, pour in the prepared suspension of water and acrylic latex.

3 Next, the entire volume of steel slag is stirred and added simultaneously for 30 sec at medium speed.

4 The mixer is then stopped and all materials are collected from the walls of the mixer bowl into the centre of the bowl for 15 sec.

5 Continue stirring at a high speed of 250-300 rpm.

6 The resulting mass is dried in a desiccator for at least 4 hours at a temperature of 70-80 ºC.

7 The dried mass is then placed in a concrete mixer, the entire volume of cement, water and sand is added and mixed at medium speed for 3 to 5 minutes.

8 The resulting concrete mixture is compacted using a vibrating pad or submersible mixer in accordance with [6].

9 The concrete mixture is then used for its intended purpose.

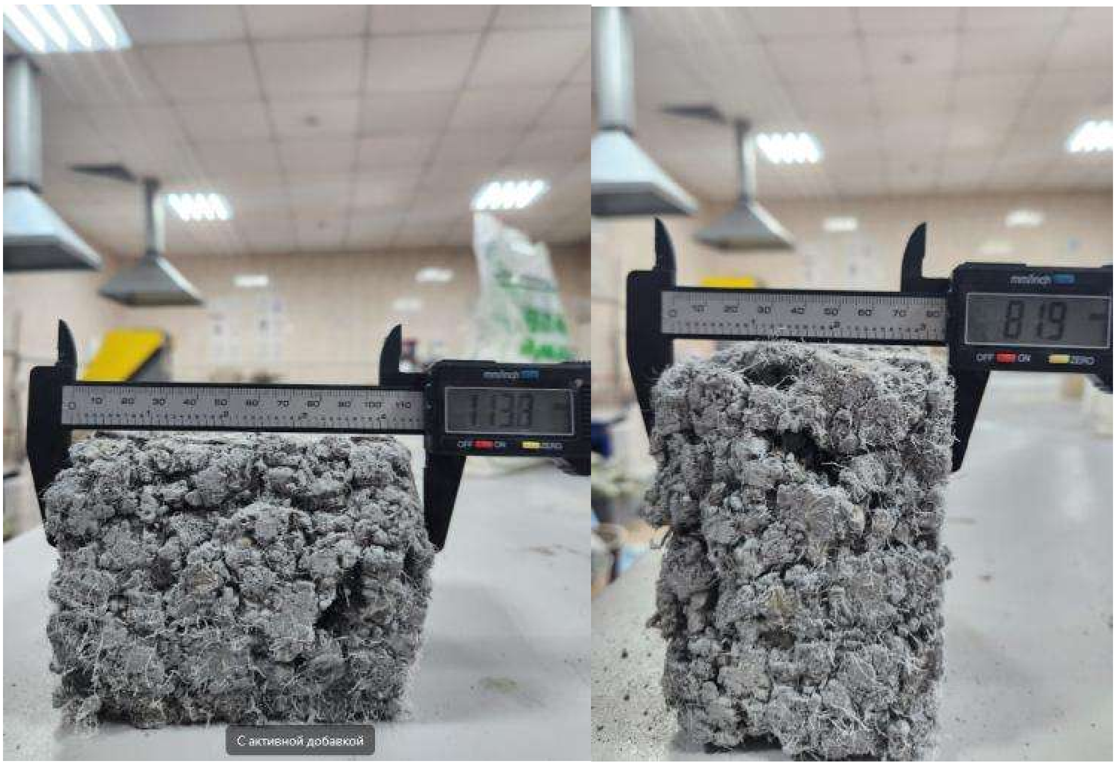
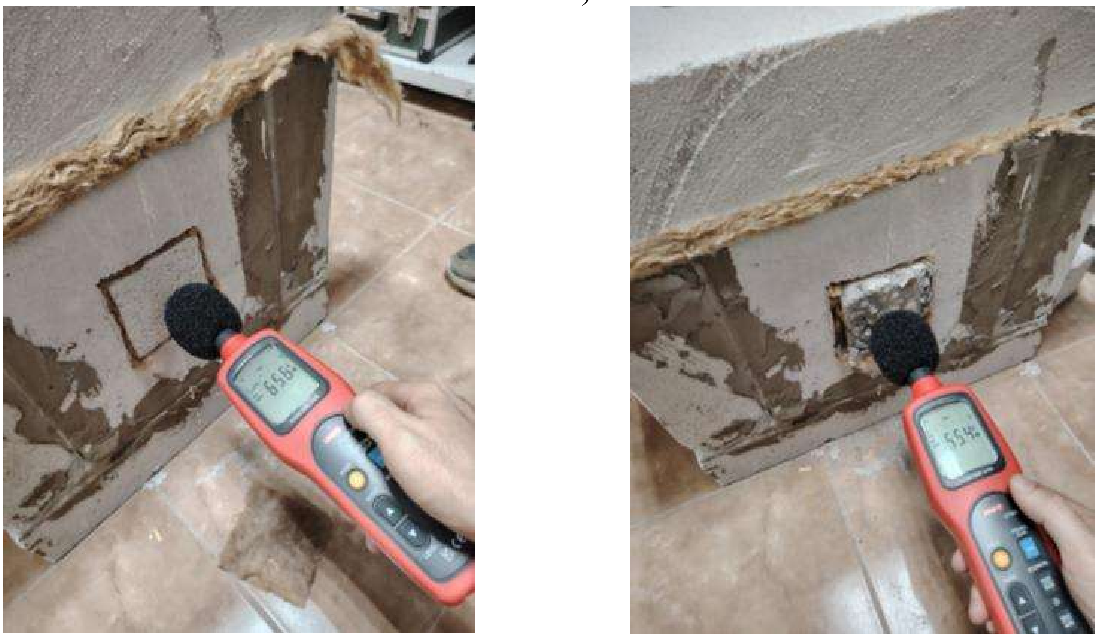


Figure 3 – Geometric indices of tested specimens of noise insulating concrete (NIC) after compression testing

Table 1 - Composition of noise insulation concrete

Material	Quantity, in ratio to cement weight
Cement	1
Polypropylene*	0.05
Acrylic latex	0.0625
Water	1
Steel slag	1.25
Sand	1.5
Microsilica	2.5
Note: *Treated polypropylene is made from waste from the production of physically cross-linked polyethylene, with sheets of physically cross-linked polyethylene cut into 10 mm rib cubes.	

a) б)



a) aerated concrete b) noise insolating concrete

Figure 4 – UT353 noise meter test

Step 2 - Physical and acoustic properties of noise insulating concrete (NIC)

The initial study showed that the use of waste polypropylene and polypropylene reinforcing fiber UARP with or without active additive in the composition of noise insulating concrete has a significant effect on its physical and mechanical properties. The compressive strength of the concrete with additives is lower than that of the control specimen, which may indicate improved noise insulation properties due to the reduction in material density. The modulus of elasticity of the specimens with additives is also lower, indicating greater deformability of the material under load, which may be preferred in interior partitions where vibration absorption is required. Further research should focus on optimizing the formulations to achieve a better balance between strength and noise insulation.

Results and Discussion

Results were obtained for the samples of slag concrete under study (Table 2), which represent the study of the characteristics of noise insulating concrete (NIC) with active admixture, without active admixture and treated with polypropylene. The control concrete sample weighs 2360 grams with dimensions 10x10x10 cm, age 28 days, density 2.36 g/cm^3 and predicted compressive strength 21.55 MPa. NIC without active additive is lighter, weighing 1140 grams (Table 2), and its density and compressive strength are lower at 1.14 g/cm^3 and 1.02 MPa, respectively. NIC with active additive also weighs 1140 grams but has different dimensions and density (Table 2), also the compressive strength of this sample is higher - 1.46 MPa. The polypropylene-treated NIC sample with active additive has the highest density among all samples and significantly higher compressive strength - 2.63 MPa.

Table 2 - Obtained results of concrete samples

Sample	Weight (g)	Dimensions (cm)	Age (day)	Density (g/cm³)	Compressive strength (MPa)
Control sample	2345	10x10x10	14	2.34	16.50
NIC without active additive	1260	10.9x10.9x8.97	14	1.26	1
NIC with active additive	1145	11.38x11.38x8.19	14	1.14	1.33
Control sample	2360	10x10x10	28	2.36	21.55
NIC without active additive	1140	10.9x10.9x8.97	28	1.14	1.02
NIC with active additive	1140	11.38x11.38x8.19	28	1.14	1.46
NIC treated with polypropylene	1445	10.35x10.07x9.77	28	1.44	2.63

The current study shows that polypropylene-treated soundproof concrete containing active additives shows a significant increase in compressive strength of 2.63 MPa (Table 2). Compared to the previous tests, the increase was 1.17 MPa. This result confirms that polypropylene treatment contributes to a significant increase in the strength properties of noise insulation concrete.

The sound insulation properties of two concrete samples - noise insulating and cellular concrete (Figure 5) - were tested using a UT353 UNI-T sound level meter at two distances: near (2 mm) and far from the surface (70 cm) (Table 3). The baseline sound level emitted by the source was measured at 98.5 dB (Figure 6).

Table 3 - Results of acoustic tests of porous and noise-insulating concrete

Sample	Distance	Sound level (dB)	Interpretation
Sound source (reference level)	N/A	98.5	Initial sound level
Noise-insulating concrete NIC	2 mm	55.4	Moderate sound absorption at the surface
Noise-insulating concrete NIC	70 cm	41.6	Significant sound reduction, high sound insulation at a distance
Cellular concrete	2 mm	65.6	Greater sound transmission near the surface, less efficient absorption
Cellular concrete	70 cm	51.7	Moderate noise insulation at a distance, less effective than noise insulating concrete NIC

Conclusions

1- Noise Insulating Concrete NIC has demonstrated excellent sound insulation properties, which fulfils the conditions required for civil buildings.

2. The significant decibel reduction compared to other types of lightweight concrete indicates that the developed slag and polypropylene based noise insulating concrete formulation is highly soundproof, making it indispensable in environments where noise reduction is crucial, which are required for modern civil buildings.

3. Cellular concrete, on the contrary, proved to be less effective, transmitting more sound, especially near the wall surface. This proves that the structure of cellular concrete allows more sound to pass through, which results in a lower acoustic performance compared to noise insulating concrete NIC.

4. The developed composition of noise insulation concrete NIC is better suited for applications requiring high-performance noise insulation.

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Assemgul Nigmetova: data curation, experimental testing, analysis, interpretation, manuscript review and editing.

Conflict of Interest: The authors declare no conflict of interest.