AMERICAN Journal of Engineering, Mechanics and Architecture
Volume 4, Issue 05, 2026 ISSN (E): 2993-2637

Using Metallurgical Slags in the Construction of Cement-Concrete Roads

Khahramon Muydinovich Inoyatov
Associate Professor, Candidate of Technical Sciences Turan International University

Azamatjon Abdurashid og'li Rakhimjonov
Master's Student Namangan State Technical University

Abstract: This study investigates the feasibility of incorporating metallurgical waste, specifically slag, as a partial replacement material in cement concrete mixtures for road construction. Experimental studies were conducted using different proportions of slag to evaluate its effects on compressive strength, density, and overall performance. The results indicate that the inclusion of slag improves the mechanical properties of concrete, particularly long-term strength and durability. Microstructural observations suggest that slag contributes to additional cementitious reactions, resulting in a denser structure and reduced porosity. Furthermore, the use of metallurgical waste reduces cement consumption and provides environmental benefits by recycling industrial by-products. The findings confirm that slag-based concrete is a promising and sustainable alternative for cement-concrete pavements.

Keywords: Cement-Concrete Pavement, Portland Cement, Metallurgical Slag, Industrial Waste, Sustainable Construction, Road Engineering

Introduction

Automobile roads play a crucial role in the economic development of modern countries. In the Republic of Uzbekistan, due to the shortage of road bitumen, it is mainly imported from neighboring countries. At the same time, locally available materials such as sand, gravel, and crushed stone, along with domestically produced cement meeting European standards, create favorable conditions for the construction of cement-concrete roads.

According to the State Committee of Statistics of Uzbekistan, as of January 1, 2025, the total length of roads in operation reached 42.4 thousand kilometers, and in 2024, 1.4 billion tons of cargo were transported by road transport, representing a 4.8% increase compared to 2023 and 11.9% growth over the past five years [1,2,3,4,5]. These figures highlight the increasing demand for durable and cost-effective road infrastructure.

Road pavements are generally classified into asphalt concrete and cement concrete types. Asphalt roads typically have a service life of 10–15 years, whereas cement-concrete roads can last up to 50 years. Although the initial construction cost of cement-concrete roads is approximately 15–20% higher, their maintenance costs are significantly lower, and their long-term performance makes them economically advantageous.

Methodology

One of the key challenges in cement-concrete road construction is the high cost of Portland cement. To address this issue, the use of industrial waste materials, particularly metallurgical slag, has been widely studied [6,7,8,9]. The comprehensive utilization of industrial by-products not only reduces environmental pollution but also decreases production costs and conserves natural resources [10,11].

Metallurgical slag can be used both as a filler and as a supplementary cementitious material. When ground to a particle size smaller than 0.5 mm and added at approximately 5% of the cement mass, slag can enhance the strength of concrete while reducing cement consumption. Additionally, replacing up to 7% of fine aggregate with slag has been shown to maintain or improve mechanical properties.

Experimental studies were carried out at the Department of Automobile Roads, Namangan State Technical University. Concrete mixtures were prepared with partial replacement of sand by steel slag. The compositions were designed according to GOST 27006—2019 standards [12,13].

Results and Discussion

Laboratory tests were conducted to evaluate the compressive strength and density of concrete samples containing slag. The results indicate that the optimal slag content is approximately 7% of the fine aggregate mass.

Concrete samples with slag demonstrated an average compressive strength of approximately 15.1 MPa after 28 days. The improvement in strength can be attributed to the pozzolanic and latent hydraulic properties of slag, which promote additional binding reactions and refine the microstructure [14,15].

Figure 1. 28-day sample made from concrete mix with steel slag ø5 mm small aggregate

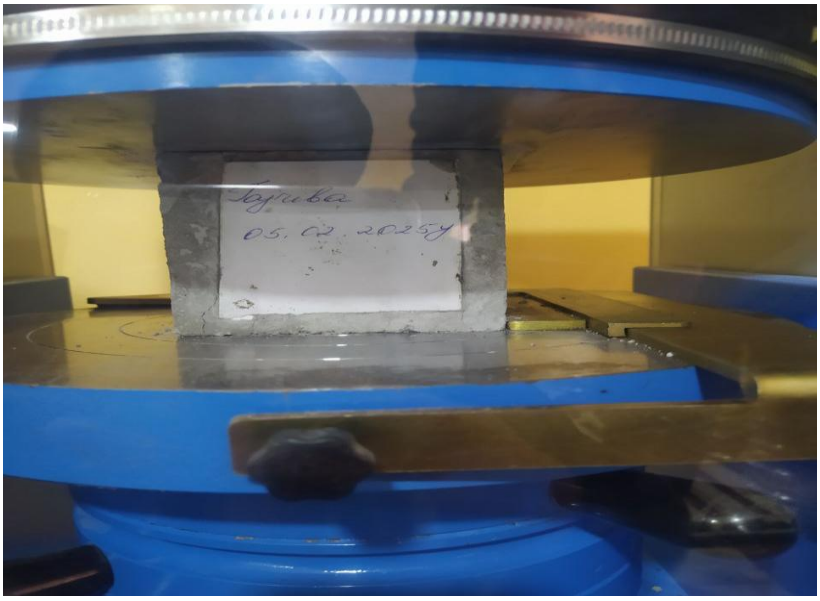

Figure 2. A scene from the process of testing the sample under a UTEST brand hydraulic press

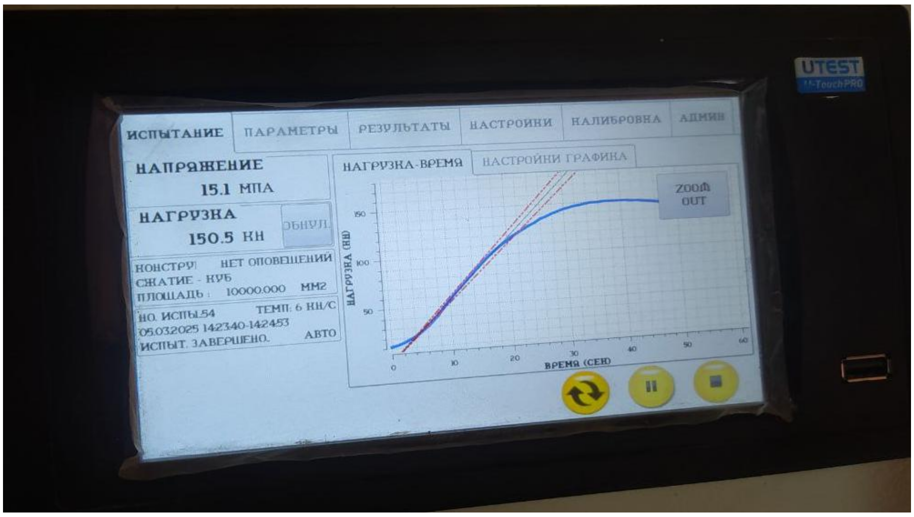

Figure 3. a snapshot of the process of testing a sample

Table 1. The concrete composition, density of the concrete mix, and strength of the concrete are indicated

Concrete composition determination	cement/ water	Cement kg	Sand kg	flint stone kg	Water kg	Super water reducing additive, kg	Average concrete strength, MPa	True density of concrete Rf, kg/m3
Initial basic composition	2,2	400	800	980	180	3,2	45,2	2363
Initial additional content №1	1,9	380	948(sand)+ 72(slag)	850	200	-	15.1	2450
№2	1,9	380	946(sand)+ 74(sla	850	200	-	15.0	2450

			g)					
№3	1,9	380	944(sand)+ 70(slag)	850	200	-	15.4	2444
№4	1,9	380	942(sand)+ 78(slag)	850	200	-	14.8	2450
№5	1,9	380	940(sand)+ 68(slag)	850	200	-	15.3	2438

The above practical experiments show that the optimal strength of samples with metal slag added as a filler to the concrete mixture is 15.1 MPa. This value confirms the active participation of metal slag in the system as a filler and a positive effect on the densification of the structure. It also shows that this additive, when used in optimal quantities, improves the mechanical properties of the material, increases its operational stability, and is effective as an economically affordable and environmentally friendly raw material. The results obtained scientifically substantiate that a 7% metal slag additive can be one of the optimal options for the material composition.

Conclusion

The experimental results demonstrate that metallurgical slag can be effectively utilized as a supplementary material in concrete production, contributing to both enhanced material properties and environmental sustainability. Optimal replacement levels were found to significantly improve compressive strength and durability while maintaining workability within acceptable limits. The improved performance is attributed to the pozzolanic and latent hydraulic properties of slag, which promote the formation of additional binding phases and refine the concrete microstructure.

In addition to technical advantages, the integration of slag reduces the environmental footprint of concrete by decreasing cement consumption and recycling industrial waste. However, the performance of slag-modified concrete depends on factors such as slag composition, particle size, and curing conditions, which should be carefully controlled in practical applications. Future research is recommended to explore long-term durability, field performance, and the behavior of such mixtures under different environmental conditions.

References

[1] Kh. Kuldashev, *Production of Building Materials Based on Industrial Waste*. Samarkand, Uzbekistan: Samarkand Publishing, 2017.

[2] I. Mutalibov *et al.*, “Improving the technology for increasing the strength of cement concrete pavements,” *[Journal/Conference Name]*, [vol.], [no.], [pp.], [year].

[3] A. Kh. Khabibullayev and A. A. Rakhimjonov, “Development of high-strength concrete using metallurgical waste,” *[Journal Name]*, [vol.], [no.], [pp.], [year].

[4] A. Alkhatib, M. Maslehuddin, and S. U. Al-Dulaijan, “Development of high performance concrete using industrial waste materials and nano-silica,” *Journal of Materials Research and Technology*, vol. 9, no. 4, pp. 8363–8374, 2020, doi: 10.1016/j.jmrt.2020.04.077.

[5] Q. Dong *et al.*, “Recycling of steel slag aggregate in Portland cement concrete,” *Journal of Cleaner Production*, vol. 282, 2021, Art. no. 124447, doi: 10.1016/j.jclepro.2020.124447.

[6] State Committee of Statistics of Uzbekistan, accessed May 12, 2026.
[7] *GOST 27006—2019, Concrete Mix Proportioning Standard*, 2019.
[8] A. M. Neville, *Properties of Concrete*, 5th ed. Harlow, U.K.: Pearson Education, 1999.
[9] P. K. Mehta and P. J. M. Monteiro, *Concrete: Microstructure, Properties, and Materials*, 4th ed. New York, NY, USA: McGraw-Hill, 2014.
[10] E. Güneyisi and M. Gesoğlu, “Durability properties of high-performance concretes incorporating slag,” *Materials and Structures*, vol. 40, no. 10, pp. 965–976, 2007.
[11] R. K. Dhir and M. R. Jones, “Durability of Portland blast-furnace slag cement concrete,” *Cement and Concrete Composites*, vol. 20, no. 2–3, pp. 163–170, 1998.
[12] H. W. Song and V. Saraswathy, “Resistance of slag cement concrete to seawater,” *Cement and Concrete Research*, vol. 28, no. 10, pp. 1367–1377, 1998.
[13] M. Otieno and R. Opeka, “Curing of slag concretes at low temperatures,” *MRS Advances*, vol. 5, no. 52, pp. 2711–2718, 2020.
[14] D. W. Law *et al*., “Durability assessment of alkali-activated slag concrete,” *Materials and Structures*, vol. 45, no. 9, pp. 1425–1437, 2012.
[15] W. Arie *et al*., “Long-term performance of alkali-activated slag concrete,” *Journal of Advanced Concrete Technology*, vol. 13, no. 5, pp. 234–245, 2015.