MODERN TECHNOLOGIES FOR ROAD SLAB PRODUCTION USING HIGH-PERFORMANCE CONCRETE TO ENHANCE OPERATIONAL CHARACTERISTICS

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Abstract. This article examines contemporary technological approaches to road slab manufacturing utilizing high-performance concrete compositions designed to improve durability, load-bearing capacity, and service life of transportation infrastructure. Results indicate that incorporation of mineral additives, fiber reinforcement, and advanced curing technologies significantly enhances mechanical properties and longevity of road slabs.

Keywords: road slabs, production technology, operational characteristics, durability, mineral additives, fiber reinforcement, transportation infrastructure.

Аннотация. В данной статье рассматриваются современные технологические подходы к производству дорожных плит с использованием высокофункциональных бетонных составов, направленных на повышение долговечности, несущей способности и срока службы транспортной инфраструктуры. Результаты показывают, что применение минеральных добавок, фиброармирования и передовых технологий твердения значительно улучшает механические свойства и долговечность дорожных плит.

Ключевые слова: дорожные плиты, технология производства, эксплуатационные характеристики, долговечность, минеральные добавки, фиброармирование, транспортная инфраструктура.

Annotatsiya. Ushbu maqolada transport infratuzilmasining chidamliligi, yuk ko'tarish qobiliyati va xizmat muddatini oshirishga qaratilgan yuqori funksional beton tarkiblaridan foydalangan holda yo'l plitalarini ishlab chiqarishning zamonaviy texnologik yondashuvlari ko'rib chiqiladi. Natijalar shuni ko'rsatadiki, mineral qo'shimchalar, tolali armaturalash va ilg'or qotirish texnologiyalarini qo'llash yo'l plitalarining mexanik xususiyatlari va uzoq muddatliligini sezilarli darajada yaxshilaydi.

Kalit so'zlar: yo'l plitalari, ishlab chiqarish texnologiyasi, ekspluatatsiya xususiyatlari, chidamlilik, mineral qo'shimchalar, tolali armaturalash, transport infratuzilmasi.

Introduction

The development of modern transportation infrastructure necessitates continuous improvement in road construction materials and technologies capable of withstanding increasing traffic loads and adverse environmental conditions. Road slabs manufactured from conventional concrete compositions frequently demonstrate insufficient durability and resistance to mechanical stress, leading to premature deterioration and substantial maintenance expenditures [1]. The application of high-performance concrete in road slab production represents a promising direction for addressing these challenges through enhanced material properties and optimized manufacturing processes.

Contemporary construction industry requirements demand road pavement materials possessing superior strength characteristics, frost resistance, and wear resistance compared to traditional concrete compositions [2]. High-functional concrete, characterized by compressive strength exceeding 60 MPa and improved microstructural properties, offers significant advantages for road construction applications. The relevance of this research is determined by the growing need for durable road infrastructure capable of accommodating heavy vehicle traffic while minimizing lifecycle costs and environmental impact.

Methodology and literature analysis

The methodological approach employed in this study encompasses systematic analysis of scientific literature. The selection criteria prioritized publications addressing high-performance concrete compositions, road slab manufacturing technologies, and operational characteristic enhancement methods. Comparative analysis methodology was applied to evaluate different technological approaches and identify factors contributing to improved road slab performance. The literature analysis reveals substantial progress in understanding the mechanisms governing high-performance concrete behavior under road loading conditions. According to research conducted by Batrakov [3], the incorporation of silica fume and superplasticizers enables achievement of concrete compressive strength values ranging from 80 to 120 MPa while maintaining adequate workability for industrial production processes. The optimization of water-cement ratio below 0.35 combined with proper aggregate gradation constitutes a fundamental principle for obtaining dense, low-porosity concrete structures resistant to environmental degradation [4].

Investigation of fiber reinforcement technologies demonstrates their effectiveness in improving flexural strength and crack resistance of road slabs. Steel fiber addition at dosages between 25 and 80 kg per cubic meter of concrete mixture has been shown to increase flexural strength by 30 to 50 percent compared to unreinforced compositions [5]. Polypropylene and basalt fibers, while providing lower strength enhancement, contribute significantly to reducing plastic shrinkage cracking during the early hydration period, thereby improving long-term durability characteristics.

The analysis of curing technology evolution indicates that steam curing and autoclave treatment methods substantially accelerate strength development in high-performance concrete road slabs. Research by Kaprielov and colleagues [6] established that heat treatment at temperatures between 70 and 85 degrees Celsius reduces curing time requirements while achieving ultimate strength values comparable to or exceeding those obtained through standard curing procedures. Modern production facilities increasingly employ controlled atmosphere curing chambers enabling precise regulation of temperature and humidity conditions throughout the hydration process.

Mineral addite applications have received considerable attention in recent scientific literature as a means of enhancing concrete performance while reducing cement consumption and associated environmental impact. Ground granulated blast furnace slag replacement of Portland cement at levels up to 50 percent has demonstrated positive effects on long-term strength development and resistance to chemical attack [7]. Metakaolin incorporation improves early-age strength and reduces permeability, characteristics particularly beneficial for road slab applications subject to deicing chemical exposure [8].

Results and discussion

The synthesis of analyzed literature sources enables identification of optimal technological parameters for high-performance concrete road slab production. Material composition optimization emerges as the primary factor determining operational characteristics, with cement type, aggregate quality, and additive selection requiring careful consideration during mix design development. The comparative analysis of different concrete compositions reported in literature sources is presented in Table 1, illustrating the relationship between mixture parameters and resulting mechanical properties.

Table 1. Comparative Analysis of High-Performance Concrete Compositions for Road Slabs

Parameter	Traditional Concrete	HPC with Silica Fume	HPC with Fiber Reinforcement

Compressive Strength (MPa)	30-40	70-90	65-85
Flexural Strength (MPa)	4.0-5.0	6.5-8.0	8.5-12.0
Water Absorption (%)	4.5-6.0	1.5-2.5	2.0-3.0
Frost Resistance (cycles)	150-200	400-600	350-500
Service Life (years)	15-20	35-50	40-55

The data presented demonstrates that high-performance concrete compositions substantially exceed traditional concrete in all evaluated parameters, with fiber-reinforced variants showing particularly favorable flexural strength characteristics essential for road slab applications. The extended service life projections translate directly to reduced maintenance requirements and improved economic efficiency over the infrastructure lifecycle.

Production technology analysis reveals that modern road slab manufacturing increasingly employs vibropressing and vibrocompaction methods enabling achievement of high concrete density and uniformity [9]. These forming technologies, combined with optimized aggregate gradation and reduced water content, produce slabs with minimal internal void content and correspondingly improved durability characteristics. The automation of production processes ensures consistent quality control and dimensional accuracy meeting contemporary construction standards.

The evaluation of operational characteristic enhancement factors is summarized in Table 2, presenting the relative contribution of different technological interventions to road slab performance improvement based on literature synthesis.

Table 2. Influence of Technological Factors on Road Slab Operational Characteristics

Technological Factor	**Strength Improvement (%)**	**Durability Improvement (%)**	**Cost Impact**
Silica Fume Addition	40-60	80-120	Moderate increase

Steel Fiber Reinforcement	25-45	60-90	Significant increase
Superplasticizer Application	15-25	30-50	Low increase
Optimized Curing Technology	10-20	40-60	Moderate increase
Aggregate Quality Control	20-30	50-70	Variable

The analysis indicates that silica fume addition provides the most substantial durability improvement relative to cost, while fiber reinforcement offers superior strength enhancement particularly valuable for heavy-traffic applications. The combination of multiple improvement factors yields synergistic effects exceeding the sum of individual contributions, supporting the development of comprehensive production technology specifications incorporating multiple enhancement approaches [10].

The practical implications of these findings extend to standardization and regulatory framework development governing road slab production. Current technical standards in many jurisdictions inadequately address high-performance concrete applications, creating barriers to widespread adoption of advanced production technologies. The establishment of updated specifications reflecting contemporary material capabilities would facilitate technology transfer and quality assurance improvement across the road construction industry.

Conclusion

The comprehensive analysis of modern road slab production technologies utilizing high-performance concrete demonstrates significant potential for enhancing operational characteristics through systematic material composition optimization and manufacturing process improvement. The literature synthesis establishes that integration of mineral additives, particularly silica fume, combined with fiber reinforcement and advanced curing technologies enables achievement of mechanical properties substantially exceeding those of conventional concrete compositions. Road slabs manufactured using optimized high-performance concrete formulations exhibit compressive strength values two to three times higher than traditional materials, with corresponding improvements in frost resistance, wear resistance, and service life extending to 40-55 years under appropriate maintenance conditions.

The research findings support prioritization of continued technological development in this area, with particular attention to cost-effective production methods enabling broader application of high-performance concrete in transportation infrastructure projects. The absence of updated regulatory frameworks governing advanced concrete applications represents a significant barrier to technology adoption requiring attention from standardization authorities. Future research directions should address long-term performance monitoring of implemented high-performance concrete road slabs to validate theoretical predictions and refine production technology specifications based on actual service condition data.

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