

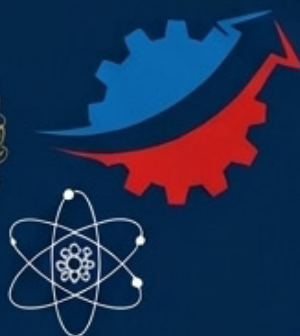
MUHANDISLIK

& IQTISODIYOT

*ijtimoiy-igʻtisodiy, innovatsion texnik,
fan va taʼlimga oid ilmiy-amaliy jurnal*

2026-YIL

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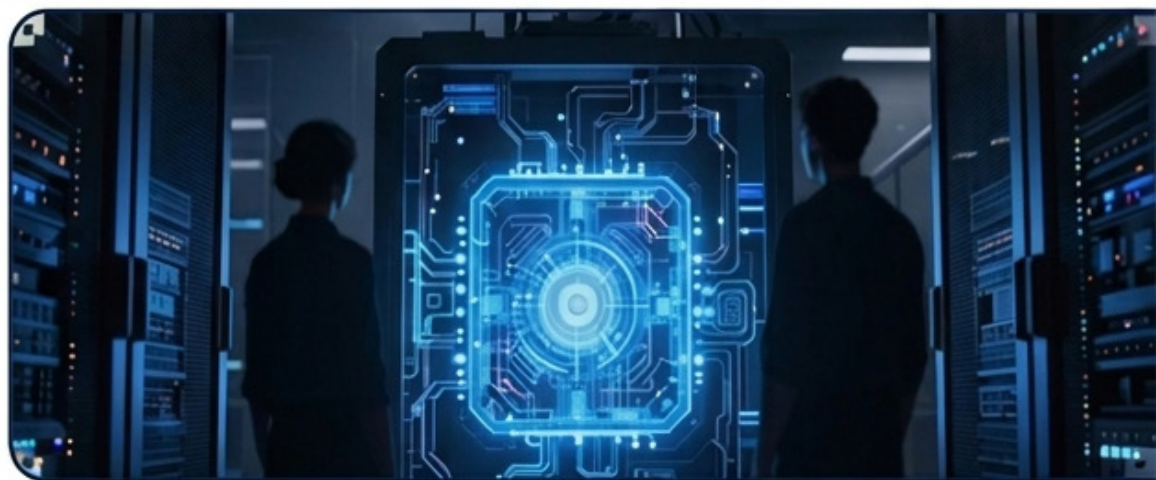
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- 05.01.00 – Axborot texnologiyalari, boshqaruv va kompyuter grafikasi
- 05.01.01 – Muhandislik geometriyasi va kompyuter grafikasi. Audio va video texnologiyalari
- 05.01.02 – Tizimli tahlil, boshqaruv va axborotni qayta ishlash
- 05.01.03 – Informatikaning nazariy asoslari
- 05.01.04 – Hisoblash mashinalari, majmualari va kompyuter tarmoqlarining matematik va dasturiy ta'minoti
- 05.01.05 – Axborotlarni himoyalash usullari va tizimlari. Axborot xavfsizligi
- 05.01.06 – Hisoblash texnikasi va boshqaruv tizimlarining elementlari va qurilmalari
- 05.01.07 – Matematik modellash
- 05.01.11 – Raqamli texnologiyalar va sun'iy intellekt
- 05.02.00 – Mashinasozlik va mashinashunoslik
- 05.02.08 – Yer usti majmualari va uchish apparatlari
- 05.03.02 – Metrologiya va metrologiya ta'minoti
- 05.04.01 – Telekommunikatsiya va kompyuter tizimlari, telekommunikatsiya tarmoqlari va qurilmalari. Axborotlarni taqsimlash
- 05.05.03 – Yorug'lik texnikasi. Maxsus yoritish texnologiyasi
- 05.05.05 – Issiqlik texnikasining nazariy asoslari
- 05.05.06 – Qayta tiklanadigan energiya turlari asosidagi energiya qurilmalari
- 05.06.01 – To'qimachilik va yengil sanoat ishlab chiqarishlari materialshunosligi
- 05.08.03 – Temir yo'l transportini ishlatish
- 05.08.06 – "G'ildirakli va gusenisali mashinalar va ularni ishlatish" (texnika fanlari)
- 05.09.01 – Qurilish konstruksiyalari, bino va inshootlar
- 05.09.04 – Suv ta'minoti. Kanalizatsiya. Suv havzalarini muhofazalovchi qurilish tizimlari
- 10.00.06 – Qiyosiy adabiyotshunoslik, chog'ishtirma tilshunoslik va tarjimashunoslik
- 10.00.04 – Yevropa, Amerika va Avstraliya xalqlari tili va adabiyoti
- 08.00.01 – Iqtisodiyot nazariyasi
- 08.00.02 – Makroiqtisodiyot
- 08.00.03 – Sanoat iqtisodiyoti
- 08.00.04 – Qishloq xo'jaligi iqtisodiyoti
- 08.00.05 – Xizmat ko'rsatish tarmoqlari iqtisodiyoti
- 08.00.06 – Ekonometrika va statistika
- 08.00.07 – Moliya, pul muomalasi va kredit
- 08.00.08 – Buxgalteriya hisobi, iqtisodiy tahlil va audit
- 08.00.09 – Jahon iqtisodiyoti
- 08.00.10 – Demografiya. Mehnat iqtisodiyoti
- 08.00.11 – Marketing
- 08.00.12 – Mintaqaviy iqtisodiyot
- 08.00.13 – Menejment
- 08.00.14 – Iqtisodiyotda axborot tizimlari va texnologiyalari
- 08.00.15 – Tadbirkorlik va kichik biznes iqtisodiyoti
- 08.00.16 – Raqamli iqtisodiyot va xalqaro raqamli integratsiya
- 08.00.17 – Turizm va mehmonxona faoliyati

Ma'lumot uchun, OAK
Rayosatining 2024-yil 28-avgustdagi 360/5-son qarori bilan "Dissertatsiyalar asosiy ilmiy natijalarini chop etishga tavsiya etilgan milliy ilmiy nashrlar ro'yxati"ga texnika va iqtisodiyot fanlari bo'yicha "Muhandislik va iqtisodiyot" jurnali ro'yxatga kiritilgan.

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STABLE CEMENT COMPOSITES BASED ON WASTE TIRE RUBBER AND FLY ASH

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Abstract. The possibilities of producing an environmentally sustainable cement-based concrete composite using waste tire rubber and fly ash were investigated. In the modern construction industry, waste recycling and its conversion into useful products are of great importance. From this perspective, the influence of incorporating waste tire rubber into concrete on the microstructure and physical properties of the material was investigated.

During the experiment, concrete mixtures were prepared using cement, fly ash, natural sand, gravel, and crushed waste tire rubber. Fly ash was used as a pozzolanic supplementary material to replace 15 % of the cement. Rubber was selected as a component for partially replacing sand, and its content was investigated at levels of 0 %, 3 %, 5 %, and 8 %. The water-to-binder ratio was maintained within the range of 0.45–0.50.

After curing the prepared specimens for 7 and 28 days, their density, water absorption, and compressive strength were determined, and microstructural analyses were performed.

Keywords: fly ash, natural sand, cement, SEM analysis, waste tire rubber, FTIR analysis.

Annotatsiya. Ishlatilgan avtomobil shinalari rezinasi va uchuvchi kuldan foydalanish asosida sement bog'lovchili ekologik barqaror beton kompozitsion material olish imkoniyatlari o'rganildi. Zamonaviy qurilish sanoatida chiqindilarni qayta ishlash va ularni foydali mahsulotlarga aylantirish muhim ahamiyat kasb etadi. Shu nuqtayi nazardan, shina rezinasini beton tarkibiga kiritishning material mikrostrukturasi va fizik xususiyatlariga ta'siri tadqiq qilindi.

Tajriba davomida sement, uchuvchi kul, tabiiy qum, shag'al va maydalangan avtomobil shinalari rezinasi asosida beton qorishmalari tayyorlandi. Uchuvchi kul sementning 15 % ini almashtiruvchi puqçolan qo'shimcha sifatida qo'llanildi. Rezina qumning ma'lum qismini almashtiruvchi komponent sifatida tanlanib, uning miqdori 0 %, 3 %, 5 % va 8 % darajalarda o'rganildi. Suv-bog'lovchi modda nisbati 0,45–0,50 oralig'ida saqlandi.

Tayyorlangan namunalar 7 va 28 kun davomida qotirilgandan so'ng, ularning zichligi, suv shimuvchanligi va siqilishdagi mustahkamligi aniqlandi hamda mikrostrukturaviy tahlillar amalga oshirildi.

Kalit so'zlar: uchuvchi kul, tabiiy qum, sement, SEM tahlili, chiqindi shinalar rezinasi, FTIR tahlili.

Аннотация. Исследованы возможности получения экологически устойчивого композиционного бетонного материала на основе цементного вяжущего с использованием резины из отработанных автомобильных шин и золы-уноса. В современной строительной промышленности переработка отходов и их преобразование в полезные продукты имеют большое значение. В связи с этим исследовано влияние введения резины из отработанных автомобильных шин в состав бетона на микроструктуру и физические свойства материала.

В ходе эксперимента были приготовлены бетонные смеси на основе цемента, золы-уноса, природного песка, щебня и измельчённой резины из отработанных автомобильных шин. Зола-унос использовалась в качестве пуццолоановой добавки, замещающей 15 % цемента. Резина была выбрана в качестве компонента для частичной замены песка, при этом её содержание исследовалось на уровнях 0 %, 3 %, 5 % и 8 %. Водовязущее отношение поддерживалось в диапазоне 0,45–0,50.

После твердения подготовленных образцов в течение 7 и 28 суток были определены их плотность, водопоглощение и прочность при сжатии, а также проведён микроструктурный анализ.



Ключевые слова: зола-унос, природный песок, цемент, SEM-анализ, резина из отработанных автомобильных шин, FTIR-анализ.

INTRODUCTION

In recent years, the processing of waste and its use as a secondary raw material have become important scientific research directions on a global scale. In particular, the substantial increase in the volume of used car tires (waste tire rubber) has increased the importance of addressing associated environmental issues. According to statistics, millions of tons of tire waste are generated annually worldwide, a considerable proportion of which accumulates in the environment without being processed. The durability of tire rubber highlights the importance of developing effective recycling approaches that support the sustainable use and protection of soil and water resources. Therefore, the transformation of this waste into useful materials is of great importance for addressing contemporary environmental challenges.

The construction industry is one of the sectors that consumes significant amounts of natural resources. The production of traditional concrete requires large quantities of sand, gravel, and cement. At the same time, the development of resource-efficient cement production technologies provides important opportunities to reduce carbon dioxide (CO₂) emissions and contribute to environmental sustainability. From this perspective, enhancing the environmental sustainability of building materials and reducing pressure on natural resources through the use of waste materials constitute important scientific objectives.

In recent years, a number of studies have explored the possibility of improving the physical and mechanical properties of concrete by incorporating waste tire rubber. According to the results of scientific studies, rubber particles can increase the elasticity of concrete, improve its resistance to impact and vibration, and limit the development of microcracks. At the same time, due to the hydrophobic properties of rubber and the characteristics of chemical bonding with the cement matrix, the use of rubber in high quantities may influence the compressive strength of concrete. Therefore, it is necessary to optimize the amount of rubber and thoroughly investigate the mechanisms of its influence on the structure of concrete.

On the other hand, fly ash is a widely available industrial by-product and is extensively used as a pozzolanic material that replaces part of the cement. Previous studies have shown that amorphous silicate and aluminate components in fly ash participate in secondary reactions during cement hydration, increasing the microstructural density of concrete, reducing porosity, and improving its long-term strength. At the same time, the use of fly ash makes it possible to reduce carbon emissions by decreasing cement consumption.

Analysis of the literature shows that, although waste tire rubber and fly ash have been studied separately, their combined use and potential synergistic effects provide opportunities for further comprehensive investigation.

LITERATURE REVIEW

The utilization of waste tire rubber in cement-based composites has attracted considerable attention in recent years due to the increasing volume of end-of-life tires and the growing importance of their effective utilization. Researchers have investigated the incorporation of recycled tire rubber into concrete as a partial replacement for conventional aggregates, particularly natural sand. Siddique et al. [19] demonstrated that the incorporation of recycled rubber and plastic into concrete can contribute to waste reduction while providing an alternative source of secondary raw materials for construction applications. More recent studies have further confirmed the potential of waste tire rubber as a component of sustainable cement-based materials [2, 8, 10].

A major research direction has focused on the influence of waste tire rubber on the mechanical and physical properties of concrete. Hasan et al. [2] investigated the effect of waste tire rubber particles on the properties of rubberized concrete and reported that the incorporation of rubber changes the mechanical behavior of the cement composite. Abd [3] also examined the effects of waste tire rubber on compressive strength and damping properties, indicating that rubber can provide beneficial energy-absorbing and damping characteristics, while the selection of an appropriate rubber content is important for maintaining compressive strength. Gupta et al. [14] studied the impact resistance of rubberized concrete and demonstrated the potential of rubber particles to improve the ability of concrete to withstand impact loading. Similarly, Chougan et al. [15] investigated the performance of rubberized concrete under extreme conditions, demonstrating the potential application of rubber-containing concrete in environments where improved deformation and impact resistance are required.

Changes in compressive strength associated with increasing rubber content are generally attributed to the characteristics of the interfacial transition zone between hydrophobic rubber particles and the hydrophilic cement matrix. Zhao et al. [10] reviewed the use of waste tire rubber in cement-based materials and highlighted the importance of rubber particle characteristics, particle size, surface properties, and replacement ratio in

determining the final properties of the composite. Huang et al. [17] also demonstrated the applicability of scrap tire rubber in permeable concrete, confirming that the incorporation of rubber can modify both the mechanical and functional characteristics of cement-based materials.

Several studies have investigated approaches to improving the performance of rubberized concrete through the simultaneous incorporation of supplementary cementitious materials. Xie et al. [9] investigated rubberized concrete containing additional cementitious materials and showed that supplementary materials can contribute to balancing the changes associated with the incorporation of rubber. Li et al. [11] specifically studied the microstructure and properties of rubberized concrete containing fly ash. Their results indicate that fly ash can contribute to the refinement of the cementitious matrix and improve certain performance characteristics of rubber-containing concrete.

Fly ash itself is widely recognized as an important industrial by-product for the development of sustainable cement-based materials. Its finely divided and predominantly spherical particles can improve the packing characteristics of cementitious mixtures, while its pozzolanic components can participate in secondary hydration reactions. The use of fly ash as a partial replacement for cement can also reduce the consumption of Portland cement and, consequently, the environmental impact associated with cement production. Ahmed et al. [1] investigated the partial replacement of cement with fly ash in fiber-reinforced rubberized concrete and demonstrated the importance of combining waste tire rubber with supplementary cementitious materials to achieve improved composite performance.

Recent investigations have continued to examine the combined effects of waste tire rubber and mineral supplementary materials. Yang et al. [4] studied the effects of waste tire rubber on concrete performance, while Fuqaha et al. [5] investigated rubberized concrete containing fly ash. These studies confirm the growing scientific interest in developing multifunctional concrete composites in which waste materials can simultaneously serve as aggregate substitutes and supplementary components of the cementitious matrix.

From a microstructural perspective, the combined incorporation of rubber and fly ash can provide complementary effects. Rubber particles may act as an elastic and energy-absorbing phase, helping to accommodate deformation and restrict the propagation of microcracks. In contrast, the fine particles of fly ash can function as a microfiller and participate in pozzolanic reactions, contributing to a denser cementitious matrix. Therefore, the simultaneous use of these materials may provide a potential pathway for balancing mechanical performance, deformation capacity, durability, and environmental sustainability.

The progress achieved in previous studies provides a strong scientific basis and creates additional opportunities for further investigation of the combined utilization of waste tire rubber and fly ash. In particular, additional research can contribute to establishing the relationship between the rubber replacement level, microstructural characteristics, porosity, water absorption, and mechanical strength. Determining the optimum rubber content is also important because an appropriate concentration may provide beneficial elastic and crack-resistance effects, while higher incorporation levels may influence porosity and the interfacial bond with the cement matrix. Therefore, a systematic investigation of different rubber contents in fly ash-containing cement composites is necessary.

RESEARCH METHODOLOGY

In this research work, cement-based concrete composite materials were prepared using waste tire rubber and fly ash, and their physical and microstructural properties were studied.

Portland cement, fly ash, natural sand, gravel (coarse aggregate), water, and crushed waste tire rubber were used as the main raw materials for the experiment. Portland cement was selected as the main binding material. Fly ash was used as a pozzolanic supplementary material replacing part of the cement, and its amount was determined as 15 % of the total binder mass.

Natural sand was used as a fine aggregate and gravel as a coarse aggregate. Waste tire rubber was pre-crushed, and its particle size was selected within the range of 0.25–1 mm. Rubber was incorporated into the concrete composition as a component replacing part of the sand.



Figure 1. Tires from which samples were taken for the laboratory process of obtaining a composite material from car tires.

The basic composition of the concrete mixture was determined as follows: cement — 425 g, fly ash — 75 g, sand — 700 g, gravel — 1,100 g, and water — 225–240 ml. The water-to-binder (W/B) ratio was maintained within the range of 0.45–0.50.

For the purpose of studying the effect of rubber content, four types of samples were prepared. No rubber was added to the control sample (0 %). In the remaining samples, rubber was used as a component replacing part of the sand at levels of 3 %, 5 %, and 8 %, respectively.

Accordingly, in the sample containing 3 % rubber, the amount of sand was 679 g and the amount of rubber was 21 g. In the sample containing 5 % rubber, 665 g of sand and 35 g of rubber were used, while in the sample containing 8 % rubber, 644 g of sand and 56 g of rubber were used.

The concrete mixture was prepared in several stages. Initially, cement, fly ash, and sand were dry-mixed until a homogeneous mixture was obtained. Rubber powder was then added to the mixture, and mixing was continued for several minutes. Subsequently, gravel was added and mixed until all components were evenly distributed.

At the next stage, water was gradually added, and the mixture was stirred for 3–5 minutes using a mechanical mixer. The prepared concrete mixture was placed in special molds and vibrated for compaction.

The samples were stored in the molds for 24 hours, after which they were removed from the molds and stored under standard conditions in an aqueous medium for 7 and 28 days for curing.

ANALYSIS AND RESULTS

SEM and FTIR analyses were conducted to assess the microstructural and chemical properties of waste tire rubber and fly ash. The obtained results made it possible to determine the roles of these materials in the composition of concrete.

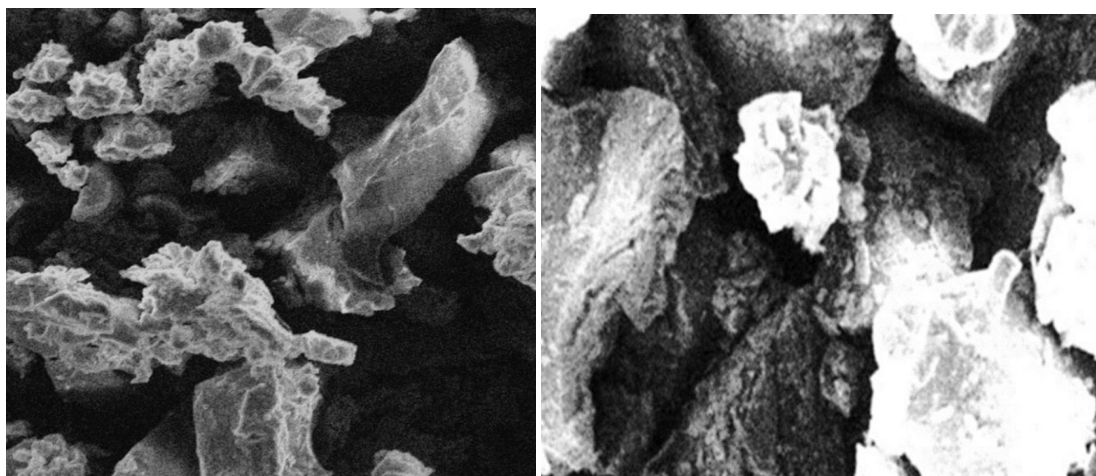


Figure 2. SEM image of waste tire rubber.

As a result of the SEM analysis, it was established that the surface of waste tire rubber particles is uneven and

porous and has a developed structure. The rubber particles had an irregular shape, and the presence of microcracks and cavities was observed on their surfaces. These characteristics increase the possibility of mechanical bonding between rubber particles and other components. Such a structure allows the rubber particles to serve as an elastic phase within the concrete, partially absorbing stresses arising under external loads and limiting the development of microcracks.

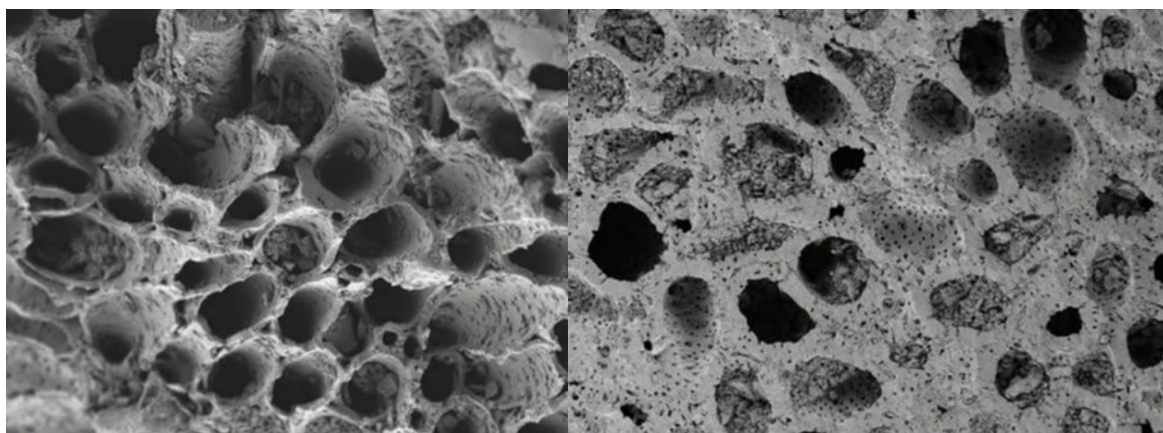


Figure 3. SEM image of fly ash.

SEM images of fly ash showed that the particles are mainly finely dispersed, partially spherical, and, in some cases, irregular in shape. Spherical particles improve the workability of the mixture, contributing to its uniform distribution within the concrete composition. The fine size of the fly ash particles enables them to function as fillers of voids in the cement matrix. As a result, the microstructure of the concrete becomes denser, and capillary porosity decreases.

FTIR analysis of the rubber material showed the presence of various functional groups in its composition. In particular, broad peaks corresponding to hydroxyl ($-OH$) groups were detected in the range of $3400-3600\text{ cm}^{-1}$, aliphatic $C-H$ bonds in the range of $2800-3000\text{ cm}^{-1}$, and aromatic $C=C$ bonds in the range of $1500-1600\text{ cm}^{-1}$. In addition, signals related to $C-O$ bonds were observed in the range of $1000-1100\text{ cm}^{-1}$. These results indicate that the rubber surface exhibits functional characteristics that may enable interaction with cement hydration products to a certain extent.

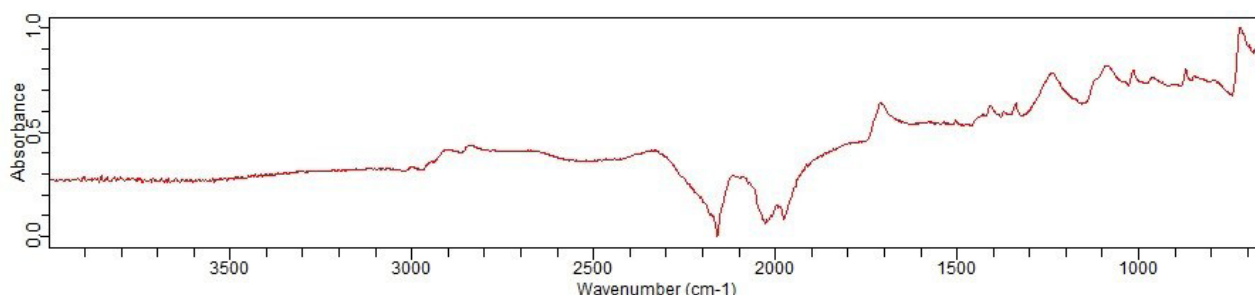


Figure 4. FTIR spectrum of waste tire rubber

Table 1
FTIR Spectral Characteristics and Functional Group Assignments of Waste Tire Rubber

Wavenumber (cm^{-1})	Absorption	Functional group	Description
3910	0.120	OH (hydroxyl)	Free hydroxyl groups, moisture or oxidized surface
3693	0.139	-OH	Bonded hydroxyl groups
3002	0.256	C-H (aliphatic)	Hydrocarbon chains
2916	0.390	C-H (CH_2)	Methylene groups
2842	0.397	CH (CH_3)	Methyl groups
2318	0.349	CO_2	Atmospheric carbon dioxide trail
2107	0.260	C=C or C=N	Three-bonded structures (rare)



1990	0.137	Combination oscillation	Complex vibrations
1651	0.576	C=C / H-O-H	Aromatic or water-related signal
1283	0.697	C-O	Oxygen functional group
1027	0.821	C-O / Si-O	Oxidized structure
764	0.869	C-H (aromatic)	Vibration of the aromatic ring
665	0.972	C-H (out-of-plane)	Aromatic structure

A comprehensive analysis of the SEM and FTIR results shows that rubber and fly ash perform different but complementary functions in concrete. Fly ash particles act as a compacting component within the concrete structure and reduce voids. Rubber acts as an elastic phase, improving the deformation behavior of the material and limiting the development of microcracks.

As the amount of rubber increases, the microstructure of concrete changes accordingly. The addition of a low amount of rubber increases elasticity while maintaining structural integrity. As the rubber content increases, the bonding characteristics between the rubber particles and the cement matrix change, highlighting the importance of selecting an optimal rubber content to maintain a compact interfacial zone and balanced porosity.

In general, the combined use of waste tire rubber and fly ash makes it possible to optimize the microstructural properties of concrete. As a result of the synergistic effect of these components, the elasticity and crack resistance of concrete increase while structural integrity is maintained. This makes it possible to consider these materials promising components for the development of environmentally sustainable and functional building materials.

CONCLUSION AND SUGGESTIONS

In this research work, the microstructural and physical properties of cement-based concrete composite materials prepared using waste tire rubber and fly ash were studied. The obtained results demonstrated the potential for the effective utilization of these waste materials in the construction industry.

As a result of the SEM analysis, it was established that waste tire rubber particles have an uneven, porous, and developed surface. This structure allows the rubber particles to form mechanical bonds within the cement matrix and act as an energy-absorbing phase. SEM images of fly ash showed that its particles are finely dispersed and partially spherical, confirming their effective function as a microfiller that contributes to the compaction of the concrete structure. FTIR analysis revealed the presence of hydroxyl (–OH), hydrocarbon (C–H), aromatic (C=C), and oxygen-containing (C–O) functional groups in the rubber composition. These groups indicate that the rubber surface exhibits functional characteristics that may enable interaction with cement hydration products to a certain extent.

The combined use of rubber and fly ash in concrete demonstrated their synergistic effect. Fly ash increases the microstructural density of concrete and reduces porosity, while rubber particles serve as an elastic phase, limiting the development of microcracks. It was established that the addition of a small amount of rubber (3–5 %) improves the elasticity and crack resistance of concrete. At a higher rubber content (8 % or more), optimization of the bonding characteristics and porosity becomes particularly important for maintaining the desirable mechanical properties of the composite. Therefore, selecting an appropriate rubber content is important for maintaining a balance between elasticity, crack resistance, and mechanical performance.

In general, it was established that environmentally sustainable and functional building materials can be developed using waste tire rubber and fly ash. This approach contributes not only to the utilization of industrial waste but also to the improvement of certain important properties of concrete. The research results can serve as an important scientific basis for the further development of sustainable construction technologies.

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