KPU International Journal of Engineering & Technology
Volume 2, Issue2, Dec. 2022
e-ISSN:2790-0819, p-ISSN:2790-0800
Date Received: 2022-10-11
Date Accepted: 2022-12-23
Date Published: 2022-12-30

Use of Worn Tires as Aggregates Replacement and its Effect on Certain Properties of Concrete

AHMAD MASOUD AHMADYAR[1], SIFATULLAH BAHIJ[2*], SEBGHATULLAH KARIMI[3]

[1]Graduate Student, Department of Civil & Industrial Construction, Kabul Polytechnic University, 5th District, Kabul, Afghanistan. Email: hmdyar@gmail.com

[2*]Assistant Professor, Department of Civil & Industrial Construction, Kabul Polytechnic University, 5th District, Kabul, Afghanistan, and Ph.D. Candidate, Civil Engineering Department, National Institute of Applied Sciences-Strasbourg, Strasbourg, France. Email: sifatullah.bahij@kpu.edu.af

[3]Associate Professor, Department of Civil & Industrial Construction, Kabul Polytechnic University, 5th District, Kabul, Afghanistan. Email: karimi.pharmacy@gmail.com

Abstract

This article aims to investigate the replacement of natural aggregates with worn tires and its effect on certain properties of concrete. Therefore, worn tire aggregates were used as fillers in the concrete mixtures at 5%, 10%, and 15%. The prepared samples were examined for physical properties such as dry density, porosity, and water absorption, ultrasonic pulse velocity (UPV) after 28 days of curing as well as mechanical parameters such as compressive, split tensile, and flexural strengths after 7 and 28 days of curing. The results show that the physical properties of concrete have improved with the incorporation of rubber, and this improvement was more significant for higher percentages of worn tires. In contrast, the mechanical properties have decreased with the increase of rubber content in concrete mixtures, yet rubber concrete exhibited ductile characteristics as opposed to the brittle behaviors of conventional ones. Finally, it was found that the concrete containing rubber has lower sound transmission properties compared to the reference ones.

Keywords: Rubber concrete, ® Worn tires, Mechanical properties, Physical properties, and Ultrasonic pulse velocity

* Corresponding Author

1. Introduction

Recently, people are using their potential to consume more. The result of such consumption is nothing unless a reduction in initial resources and increasing landfill space. Therefore, humans usually try to find broader sources with low prices and ways to get rid of waste. Rubber is one of the significant waste materials in the modern world and causes many environmental problems. Rubber has been used as the most important material in various parts of people's lives, but the most prevalent application is in automobile tires.

Globally, more than three billion tires are produced annually, and roughly 1.5 billion tires reach the end of their service lives each year [1,2]. On the other hand, landfilling, energy recovery, material recovery, retreading, and reuse/export are the most common waste tire management methods [3]. Furthermore, it was reported that around 64% of worn tires were disposed of in landfills, illegally dumped, or hoarded, while just 13% were recycled globally in 2014 [4].

Besides, the Deputy Ministry of Revenues and Customs has reported that a total of 246,713 tons of tires were imported into Afghanistan in 2019 and 2020. The same amount will be wasted once they are used. On the other hand, there is no proper treatment for their waste, and the only solution for waste is landfilling or part of them being used in brick kilns and bathrooms.

Moreover, the researchers have found that the gaseous (CO, NO_2, and SO_2) emissions of waste tires after burning were higher than the permitted limit. For example, the SO_2 emissions were higher than the USEPA's permitted limit (156.74 $\mu g/m^3$). The USEPA-allowable limit for CO due to automobile and truck tires was surpassed (10,285.71 $\mu g/m^3$), while the USEPA-allowable level for NO_2 concentration (56.33 $\mu g/m^3$) was only met by bicycle tires. It shows that open burning of scrap tires (OBST) releases dangerous pollutants that constitute a major threat to both the environment and human health. Therefore, partial replacement of aggregates with worn tire waste will provide the best solution for tire waste consumption, solve problems of lack of aggregates on construction sites, and decrease environmental problems [5].

Several studies were conducted to explore the effect of the incorporation of waste tires as fine or coarse aggregates on different properties of cementitious materials. For instance, experimental work was conducted to study the effect of the incorporation of waste tires into concrete compositions. It was found that the physical properties of rubber-based concrete were improved compared to the normal ones [5–8], while the mechanical properties of rubber concrete had decreased [9]. Furthermore, using scrap tire rubber aggregates in place of conventional aggregates enhanced concrete's permeability, ductility, energy dissipation, damping, and reduced thermal conductivity [9,10]. In addition, waste tires as coarse aggregates were incorporated into concrete mixtures to study various properties of concrete, such as compressive strength, tensile strength, ductility, etc. It was discovered that rubber concrete is lighter and absorbs less water compared to the control ones [11]. Moreover, the density, flexural strength, and compressive strength of double-layer concrete paving blocks were affected, while tire rubber was partially replaced by natural aggregates. The outcomes highlight that it may be possible to create double-layer concrete paving blocks by substituting waste tire rubber

with natural aggregates. Here, the mechanical properties (compressive and flexural strengths) could be balanced with other factors. However, if the percentage of replaced aggregates exceeds 20%, the mechanical strengths will suffer significantly [12]. Contrarily, the incorporation of a higher content of waste rubber in concrete mixtures resulted in the reduction of mechanical strength as well as Young's modulus of elasticity [9,10]. However, the incorporation of mineral admixtures (silica fume) in rubber concrete resulted in the improvement of compressive strength [11]. Additionally, several studies in this area have shown that the incorporation of worn tires resulted in the reduction of concrete's compressive, split tensile, and flexural strengths [13–19].

In conclusion, the literature review presents that several investigations have been carried out in this area, although the majority of them concentered on the mechanical characteristics of rubber concrete. However, this article focuses on the use of worn tires as a partial replacement with coarse aggregates to investigate their effect on the physical, mechanical, and acoustic characteristics of rubber concrete in comparison with the normal ones. The specific tests could be slump value, compressive strength, tensile strength, flexural strength, water absorption, dry density, porosity, and ultrasonic pulse velocity. In addition, this article's focus on Afghanistan's geography and conditions set it apart from earlier ones in another important way.

2. Experimental Work

2.1. Materials

The worn tire used in this experimental study was MILSTAR-HEAVY DUTY, made by Apollo Company, with the specifications as shown in Figure 1.



Figure 1. Worn tires made by Apollo Company

The Ghori Portland Cement used in this study was produced by the Pol-e Khumri factory of Afghanistan following ASTM C150 requirements [20], and it had a specific gravity of 3.034 and a surface area of 2900 cm^2/gr. Additionally, crushed coarse aggregates with a size of 10–25 mm and natural river sand with a maximum particle size of 4.75 mm have also been employed as coarse and fine aggregates. The crumb rubber was ground into various sizes after removing the steel and textile fibers. The difference in the specific gravity of river sand and crumb rubber was taken into consideration while replacing. The size distributions for sand, gravel, and rubber are shown in Figure 2.

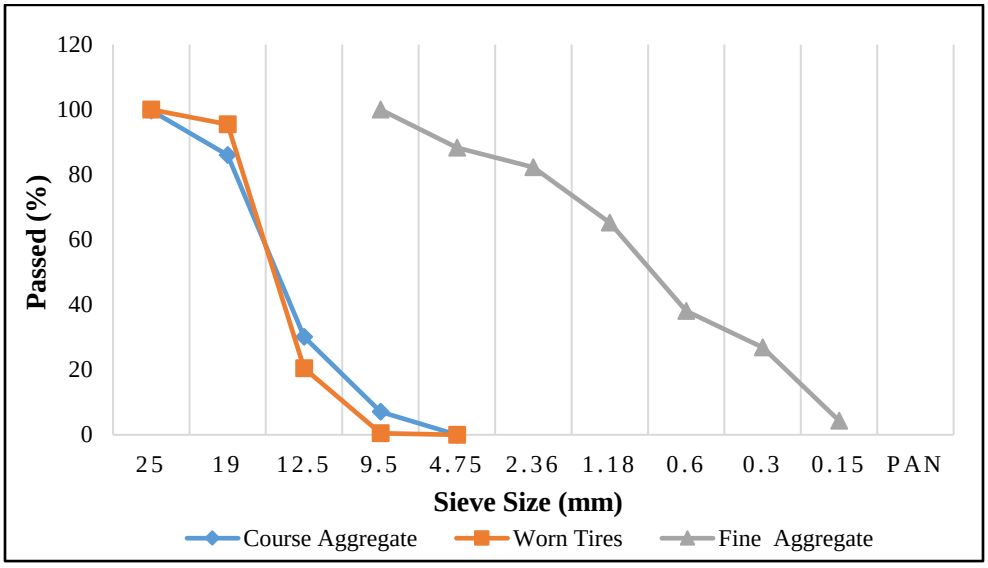


Figure 2. Grading of rubber, coarse and fine aggregates

From particle size analysis, it was observed that crumb rubber contains slightly coarser particles, and has lesser water absorption than fine and coarse aggregates. The low water absorption values add to the quality of concrete. In addition, some physical properties of fine and coarse aggregates and worn tires are presented in Table 1.

Table 1. Physical properties of filler materials

Type of aggregates	***Specific gravity***	***Bulk density (kg/m^3)***
Fine aggregates	2.704	1742.895
Coarse aggregates	2.693	1535.164
Worn tires	1.129	556.870

Moreover, the superplasticizer type G named BEVETOL-SPL, a product of Izomat Company, following EN 934-2 standard considerations [21], was added to the concrete mixture to improve the workability of rubber concrete.

2.2. Methods

Before casting the samples, the molds were oiled for easy demolding. The concrete mixtures were prepared using a tilting drum mixer. Then the concrete was placed in the molds to prepare samples of various shapes and sizes, as shown in ***Table 2***. After that, the samples were kept in the molds for 24 hours before being cured for 7 and 28 days under a temperature of (20 ± 2) C°.

Table 2. Specification of concrete samples

No	*Type of samples*	*Description*	*Conducted tests*
1	Cube 100 mm	Reference	Compressive strength, UPV, water absorption, dry density, and porosity
		5% of worn tires	
		10% of worn tires	
		15% of worn tires	
2	Cylinder (100×200) mm	Reference	Split tensile strength
		5% of worn tires	
		10% of worn tires	
		15% of worn tires	
3	Beam (100×100×500) mm	Reference	Flexural strength
		5% of worn tires	
		10% of worn tires	
		15% of worn tires	

The material proportions were calculated following ACI 291.1 [22], which has a constant w/c ratio of 0.45 and a total binder content of 433 kg/m^3. The mixed proportion of concrete mixtures containing various percentages of worn tires is shown in ***Table 3***. In addition, the dry density, porosity, and water absorption were calculated using ASTM C642-06 [23]. A compression test was performed using the ADR touch SOLO 1500 machine. The pacing rate for the cubic sample compression test was set at 3.0 KN/s to get the compressive strength following ASTM C39 [24]. The split tensile strength test was performed on the same machine according to ASTM C496 [25] with a pacing rate of 0.94 KN/s. The beams were used for flexural testing following ASTM C78 [26]. Finally, the ultrasonic pulse velocity (UPV) test has been conducted on 100 mm cubes utilizing the direct approach and the ELE Pundit Pulse Device according to the ASTM C597 standard [27].

Table 3. A mix ratio of materials for 1m^3 of concrete

Materials	***Weight of materials for 1m^3 of concrete***			
	Percentages of worn tires			
	0%	***5%***	***10%***	***15%***
Water (kg)	195	195	195	195
BEVETOL-SPL (gr)	2.5	3.4	4.2	4.9
Cement (kg)	433	433	433	433
Fine aggregate (kg)	652	652	652	652
Coarse aggregate (kg)	1060	1037.8	1015.6	993.4
Worn tires (kg)	0	22.2	44.4	66.6

3. Result and Discussions

3.1. Workability

The workability of concrete mixtures containing various percentages of worn tires is shown in Figure 3. It was observed that the workability of concrete mixtures had decreased for the samples containing worn tires, and this reduction was more significant for higher percentages. For example, concrete with 0% of worn tires had a slump value of 80 mm, while for concrete mixtures containing 15% of worn tires, only a 5 mm slump was obtained. Therefore, BEVETOL-SPL superplasticizer was added to the concrete mixture according to its technical specifications to improve the workability of the concrete. This reduction could be related to the flaky and flat-surfaced shapes of rubber aggregates, which have a higher surface area compared to natural aggregates. Therefore, such a higher surface of rubber aggregates results in the enhancement of friction, the reduction of inter-particle movement, and finally a reduction in workability.

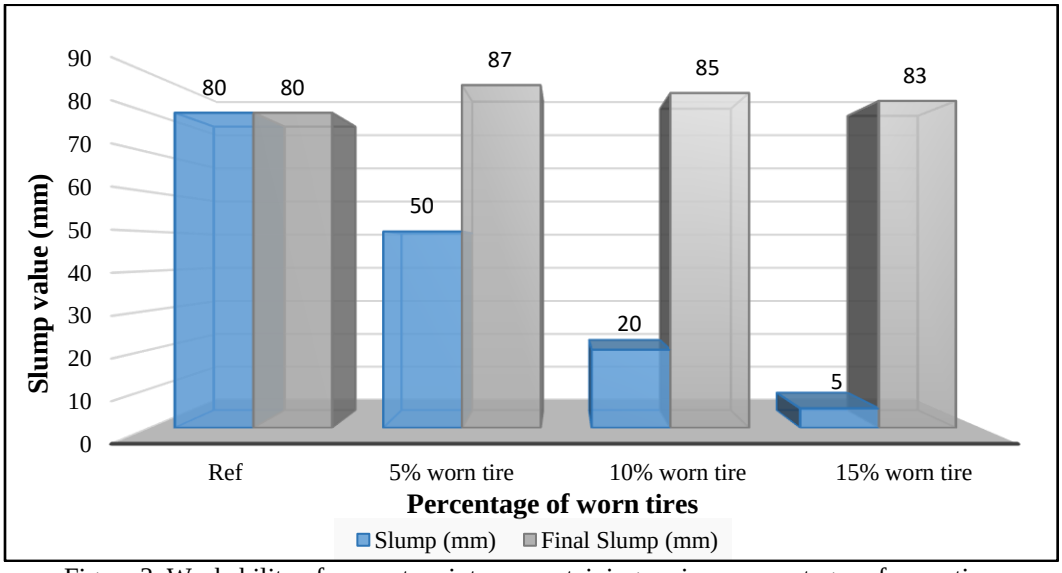


Figure 3. Workability of concrete mixtures containing various percentages of worn tires

3.2. Physical Properties

3.2.1. Dry Density

The dry density of concrete is determined by its mass-to-volume ratio. The dry density was determined after exposing the 28-day hardened cubic specimens to a 110 °C oven for 24 hours. The outcomes of dry density for reference specimens and the ones containing different contents of worn tires are shown in ***Figure 4***. It could be observed that the dry density has decreased with the increase in the percentage of worn tires in concrete mixtures. For instance, the dry density was reduced by up to 8.4% when 15% of the mixture's worn tires were replaced. This could be attributed to the lower specific gravity of rubber aggregates compared to the natural coarse and fine aggregates [28]. In addition, the increase in rubber percentages increases the air content, which results in a further reduction of the dry density.

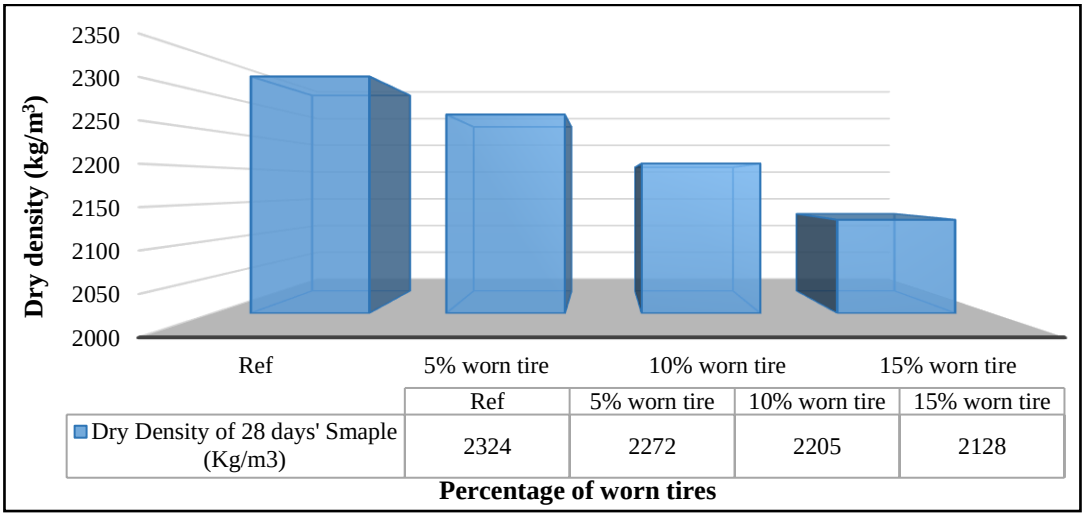


Figure 4. The dry density of concrete mixtures containing various percentages of worn tires

3.2.2. Porosity

The porosity of concrete mixtures containing 0%, 5%, 10%, and 15% of worn tires was measured and their results are shown in ***Figure 5***. The outcomes indicate that the rubber concrete has higher porosity compared to the normal one, and this enhancement was more significant for the mixtures containing a higher content of worn tires. For example, concrete samples with 15% of worn tires had 11.1% higher porosity than the reference. This could be because of weak adhesion between rubber and cement paste, which results in micro-cracks and cavities. In addition, the crumb rubber functioned as an air-entraining agent, which might improve the concrete's porosity [28].

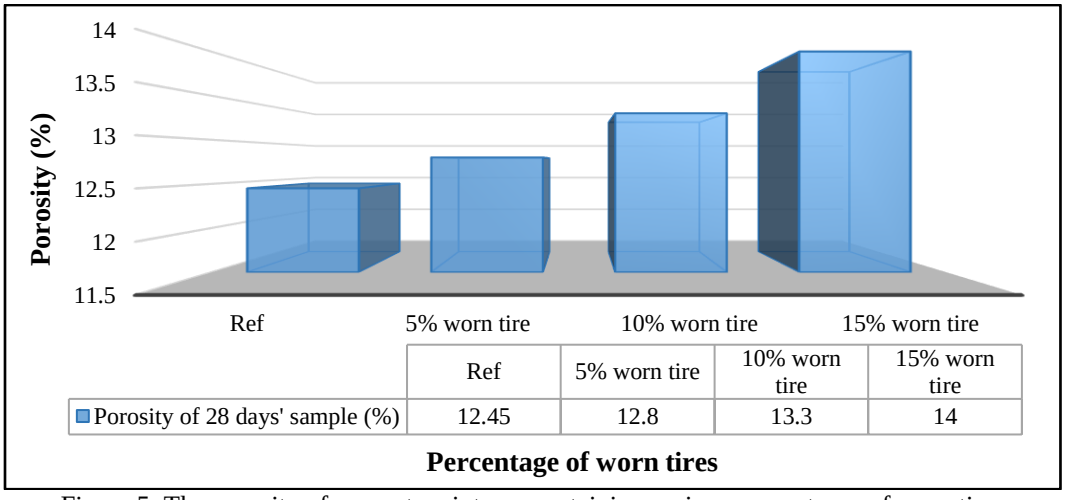


Figure 5. The porosity of concrete mixtures containing various percentages of worn tires

3.2.3. Water absorption

The outputs of water absorption are shown in ***Figure 6***, and it highlights that with the increase of rubber content in concrete mixtures, the water absorption has enhanced as well. The water absorption has increased by 9.7%, 15.3%, and 21.5% for the samples

containing 5%, 10%, and 15% of worn tires compared to the reference concrete, respectively. This is because of the rubber's hydrophobic properties and the porous microstructure of rubber concrete [15].

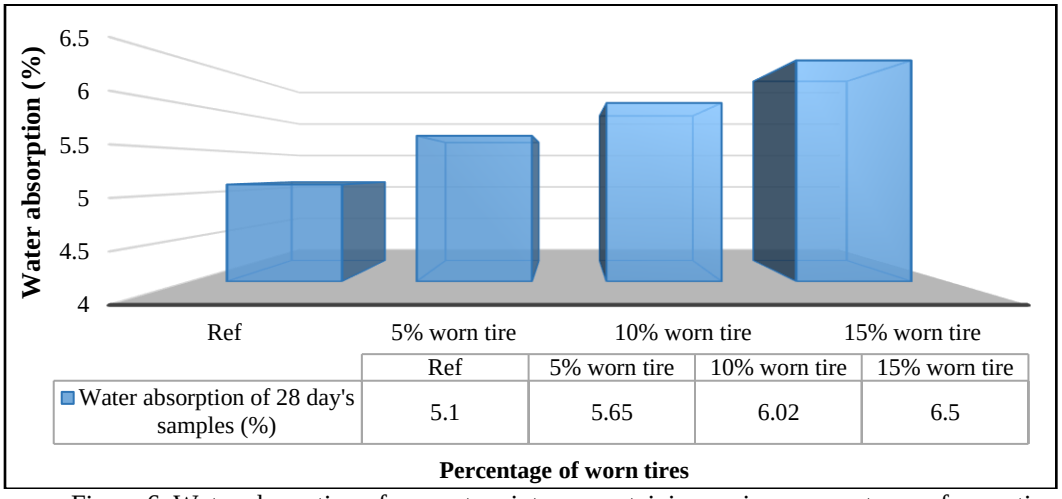


Figure 6. Water absorption of concrete mixtures containing various percentages of worn tires

3.3. Mechanical Properties

3.3.1. Compressive strength

A material or structure's compressive strength refers to its capacity to sustain compressive stresses without breaking or deforming. The compressive strength of concrete specimens observed after 7 and 28 days of curing is shown in Figure 7**,** and the outcomes show that the incorporation of worn tires resulted in the reduction of compressive strength. Specifically, 28 days' compressive strength decreased by 15.0%, 30.9%, and 42.6% with the incorporation of 5%, 10%, and 15% of worn tires compared to the control specimens, respectively. This is because of the rubber's hydrophobic properties and a weak interfacial connection between cement paste and rubber, which reduces the mechanical strength. In addition, rubber particles cause weak spots inside the concrete, where there is a higher concentration of stresses and, as a result, a reduction in the mechanical strengths due to the rubber's lower modulus of elasticity [15].

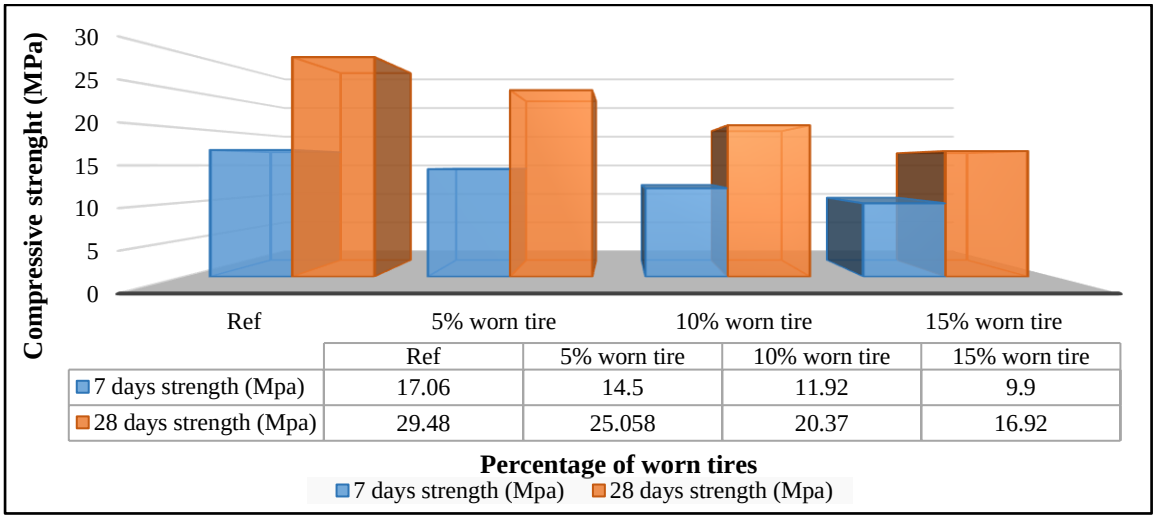


Figure 7. Compressive strength of concrete mixtures containing various percentages of worn tires

In addition, the reference samples had broken into several pieces when a compressive force was applied. While the specimens containing rubber pieces were not separated into many portions because of the flexible properties of rubber aggregates as shown in Figure 8.



a *b*

c *d*

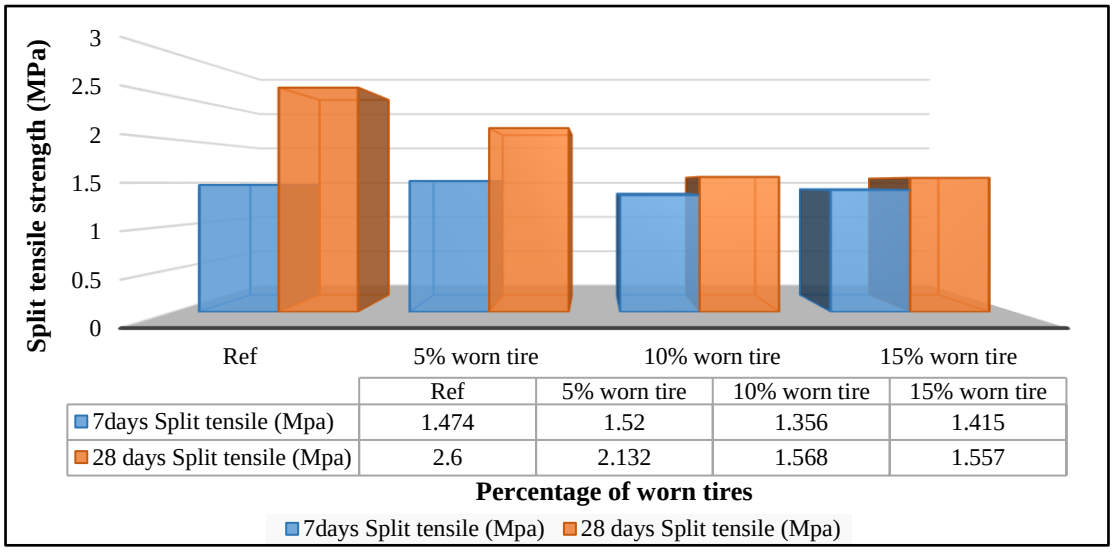
Figure 8. Cracking pattern after compression test: a) Reference, b) 5%, c) 10%, and d) 15%

3.2.2. Split tensile strength

The split tensile strength is an indirect way of determining the tensile strength of concrete using cylindrical specimens that split across the vertical diameter. Figure 9 shows the findings of split tensile strength obtained for the specimens containing various percentages of worn tires after 7 and 28 days of curing. It demonstrates that replacing natural aggregates with rubber ones did not have a considerable effect on the 7-day split tensile strength. However, the split tensile strength after 28 days of curing noticeably decreased with the incorporation of rubber waste, and this reduction was more remarkable

for higher amounts of worn tires. For example, the 28-day split tensile strength of specimens containing 15% worn tires has been reduced by 40.1% compared to the reference concrete. This is attributed to the weak bond and adhesive properties between cement paste and rubber aggregates. In addition, the weak interface zone between rubber and cement may act as a micro-crack due to weak bonding between the two materials, which accelerates concrete breakdown [13].

Figure 9. Split tensile strength of concrete mixtures containing various percentages of worn tires



	Ref	5% worn tire	10% worn tire	15% worn tire
7days Split tensile (Mpa)	1.474	1.52	1.356	1.415
28 days Split tensile (Mpa)	2.6	2.132	1.568	1.557

In addition, the samples with 5%, 10%, and 15% worn tires are cracked but not split, but the reference sample under tensile tension is completely divided into two different fragments as shown in Figure 10.



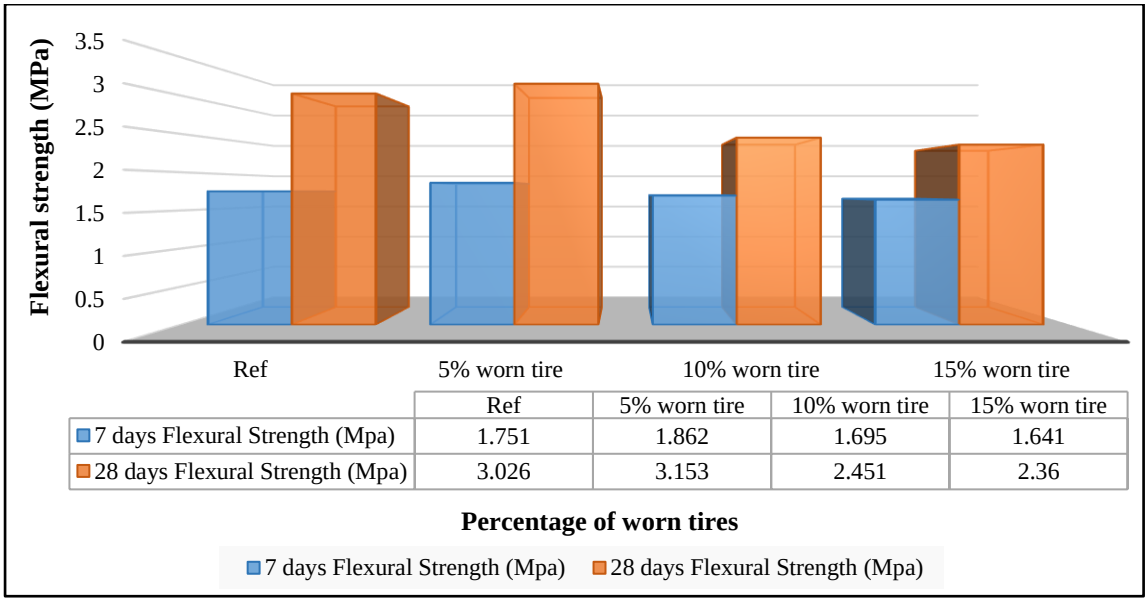
a *b*

c *d*

Figure 10. Cracking pattern after the split tensile test: a) Reference, b) 5%, c) 10%, and d) 15%

3.2.3. Flexural Strength

The outcomes of the flexural strength are displayed in Figure 11. The results demonstrate that the replacement of worn tires with coarse aggregates had a tiny impact on the flexural strength of samples after 7 days of curing. This could be because of the lower adhesion between cement paste and other concrete ingredients and the lower achieved resistance of cement. However, the 28-day samples show a considerable reduction in the flexural strength of the specimens having rubber wastes, and this reduction was more noticeable for a higher volume fraction of worn tires. As a result, a lack of strong bonding between rubber particles and cement paste is a major factor in reducing flexural strengths. It was found that chipped rubber could be easily removed from concrete after the concrete samples were broken for the flexural strength test [13].



	Ref	5% worn tire	10% worn tire	15% worn tire
7 days Flexural Strength (Mpa)	1.751	1.862	1.695	1.641
28 days Flexural Strength (Mpa)	3.026	3.153	2.451	2.36

Figure 11. Flexural strength of concrete mixtures containing various percentages of worn tires

Additionally, it was noted that the rubberized samples were more flexible while the control specimens showed brittle failure and broke into two pieces when loaded, as shown in Figure 12.



a *b*

c *d*

Figure 12. Beam cracking pattern: a) Reference, b) 5%, c) 10%, and d) 15%

3.3. Acoustic properties

An ultrasonic pulse velocity (UPV) test was conducted on 28-day cubic samples to explore the transit time of ultrasonic pulses from concrete specimens. The UPV value was measured for concrete mixtures without a rubber and with 5%, 10%, and 15% of worn tires. ***Figure 13*** shows the UPV results and indicates that with the incorporation of worn tires, the UPV value has decreased. As a comparison, the samples containing 15% of worn tires transmit sound at a pace that is 1.3 km/s slower than the reference samples. This reduction in the UPV is due to air content and crumb rubber, which entraps air on its surface [29].

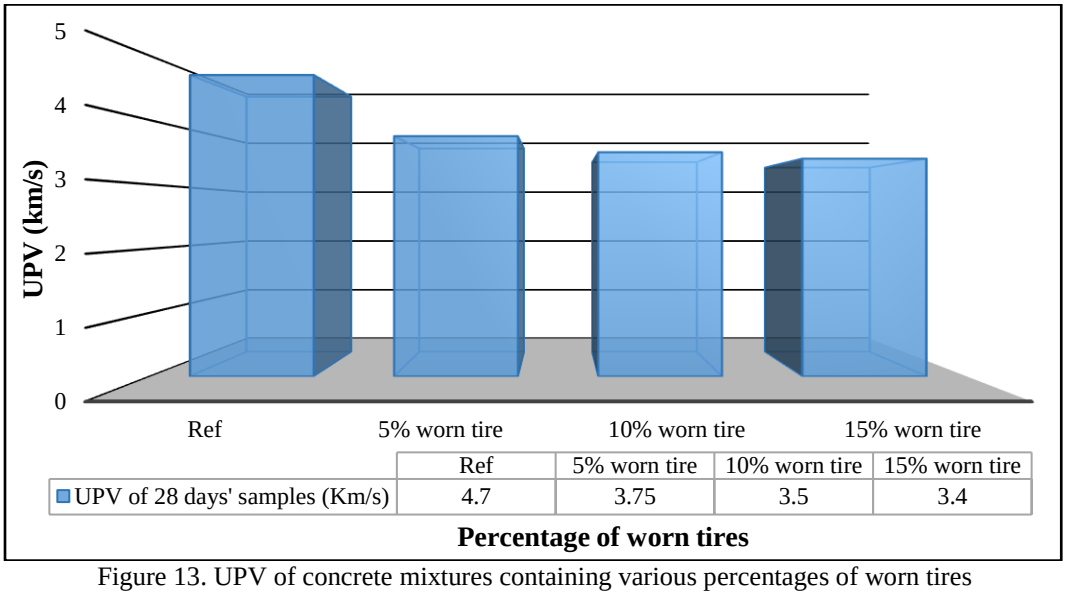


Figure 13. UPV of concrete mixtures containing various percentages of worn tires

4. Conclusions

Overall, the presence of worn tires in the composition of concrete could improve the physical, sound, and flexibility properties of concrete. On the other hand, it can negatively affect its mechanical strength. The key and specific outcomes are highlighted as follows:

- The incorporation of worn tires into concrete mixtures resulted in a decrease in workability, and this reduction was more remarkable for higher percentages of rubber.
- The addition of rubber into concrete mixtures could greatly improve the physical properties, such as water absorption and dry density, of concrete, and this enhancement was more significant for a higher volume fraction of rubber.
- The incorporation of worn tires into concrete has reduced the compressive, tensile, and flexural strengths. It means that higher percentages of worn tires have the lowest mechanical strengths. Meanwhile, it was found that the rubber concrete has more flexibility compared to the control ones.
- The highest UPV value was achieved for the reference samples, while the UPV value significantly decreased with the incorporation of worn tires, and such a reduction was more significant for higher percentages.
- Finally, the partial incorporation of worn tires in cementitious materials results in greener, cheaper, and lighter building materials. In addition, this could be a possible solution for the reduction of rubber waste materials and environmental protection. Moreover, the substitution of fine and coarse aggregates by worn tires reduces or prevents the decrease of natural resources for aggregates.

5. Acknowledgement

The University of Kabul Polytechnic, as well as everyone who assisted the authors, are appreciated.

Reference

[1] H.H. Al-Kayiem, B.A. Bhayo, E. Magaril, P. Ravi, Rudimentary Assessment of Waste-to-Wealth of Used Tires Crumbs in Thermal Energy Storage, Recycling. 7 (2022). https://doi.org/10.3390/recycling7030040.

[2] D. Mentes, C.E. Tóth, G. Nagy, G. Muránszky, C. Póliska, Investigation of gaseous and solid pollutants emitted from waste tire combustion at different temperatures, Waste Management. 149 (2022) 302–312. https://doi.org/10.1016/j.wasman.2022.06.027.

[3] K. Frikha, L. Limousy, J.P. Claret, C. Vaulot, K.F. Pérez, B.C. Garcia, S. Bennici, Potential Valorization of Waste Tires as Activated Carbon-Based Adsorbent for Organic Contaminants Removal, Materials. 15 (2022) 1–26. https://doi.org/10.3390/ma15031099.

[4] S. Kordoghli, M. Paraschiv, R. Kuncser, M. Tazerout, M. Prisecaru, F. Zagrouba, I. Georgescu, Managing the Environmental Hazards of Waste Tires, Journal of Engineering Studies and Research. 20 (2016). https://doi.org/10.29081/jesr.v20i4.52.

[5] L.A. Jimoda, I.D. Sulaymon, A.O. Alade, G.A. Adebayo, Assessment of the environmental impact of open burning of scrap tires on ambient air quality, International Journal of Environmental Science and Technology. 15 (2018) 1323–1330. https://doi.org/10.1007/s13762-017-1498-5.

[6] M. Mrad, R. El Samra, Waste Tire Management : Lebanon Case Study, Journal of Waste Management and Disposal. 3 (2020) 1–13.

[7] U.S.P.R. Arachchige, G.M. Sithari, T.G.A.H.R. Thalagahawaththa, G.M. Tharakie, K.V.H. Tharuka, Environmental pollution by the tire manufacturing industry, International Journal of Scientific and Technology Research. 8 (2019) 80–81.

[8] Z. Jankovská, M. Večeř, I. Koutník, L. Matějová, A case study of waste scrap tire-derived carbon black tested for nitrogen, carbon dioxide, and cyclohexane adsorption, Molecules. 25 (2020) 1–14. https://doi.org/10.3390/molecules25194445.

[9] K. Strukar, T. Kalman Šipoš, I. Miličević, R. Bušić, Potential use of rubber as aggregate in structural reinforced concrete element – A review, Engineering Structures. 188 (2019) 452–468. https://doi.org/10.1016/j.engstruct.2019.03.031.

[10] Y.C. Khern, S.C. Paul, S.Y. Kong, A.J. Babafemi, V. Anggraini, M.J. Miah, B. Šavija, Impact of Chemically Treated Waste Rubber Tire Aggregates on Mechanical, Durability and Thermal Properties of Concrete, Frontiers in Materials. 7 (2020) 1–11. https://doi.org/10.3389/fmats.2020.00090.

[11] I. Alam, U.A. Mahmood, N. Khattak, Use of Rubber as Aggregate in Concrete: A Review, International Research Journal of Engineering and Technology (IRJET). 4 (2015) 92–96. https://www.academia.edu/download/57999767/IRJET-V5I11287.pdf.

[12] J. Euniza, H. Md Nor, P.J. Ramadhansyah, H. Zaiton, Use of Waste Tyre Rubber as Aggregate in Double Layer Concrete Paving Blocks, Advanced Research in Applied Mechanics. 1 (2014) 25–30.

[13] A. Sofi, Effect of waste tire rubber on mechanical and durability properties of concrete – A review, Ain Shams Engineering Journal. 9 (2018) 2691–2700. https://doi.org/10.1016/j.asej.2017.08.007.
[14] R. Irmawaty, H. Parung, N. Md Noor, Experimental study of rubber particles from recycled tires as concrete aggregates, IOP Conference Series: Earth and Environmental Science. 473 (2020). https://doi.org/10.1088/1755-1315/473/1/012130.
[15] F.M. Silva, E.J.P. Miranda, J.M.C. Dos Santos, L.A. Gachet-Barbosa, A.E. Gomes, R.C.C. Lintz, The use of tire rubber in the production of high-performance concrete, Ceramica. 65 (2019) 110–114. https://doi.org/10.1590/0366-6913201965S12598.
[16] G. Etefa, A. Mosisa, Waste Rubber Tires: A Partial Replacement for Coarse Aggregate in Concrete Floor Tile Production, American Journal of Civil Engineering. 8 (2020) 57. https://doi.org/10.11648/j.ajce.20200803.12.
[17] N.R. Pardeshi, D.P. Singh, S.R. Patil, P.J. Gorde, P.P. Janrao, Performance and Evaluation Of Rubber As Concrete Material, International Research Journal of Engineering and Technology(IRJET). 4 (2017) 554–560. https://irjet.net/archives/V4/i1/IRJET-V4I195.pdf.
[18] Y. Tang, W. Feng, W. Feng, J. Chen, D. Bao, L. Li, Compressive properties of rubber-modified recycled aggregate concrete subjected to elevated temperatures, Construction, and Building Materials. 268 (2021) 121181. https://doi.org/10.1016/j.conbuildmat.2020.121181.
[19] A. Mohd Mustafa Al Bakri, S. Fadli, S. Nuzul, M.D.A. Bakar, K.W. Leong, Comparison of Rubber As Aggregate and, 1st International Conference On Sustainable Materials 2007_ICoMS 2007 9-11 June 2007, Penang. (2007).
[20] ASTM C150, Standard Specification for Portland Cement, American Society for Testing and Materials. (2009).
[21] EN 934-2, Admixtures for concrete, mortar, and grout, European Standard. (2012).
[22] ACI 211.1-91, Standard Practice of Selecting Proportions for Normal, Heavyweight, and Mass Concrete, ACI Manual of Concrete Practice, Part 1: Materials and General Properties of Concrete, Detroit, Michigan. (1994).
[23] ASTM C642-13, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete, American Society for Testing and Materials. (2013).
[24] ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, American Society for Testing and Materials. (2009).
[25] ASTM C496, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, American Society for Testing and Materials. (2009).
[26] ASTM C78, Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading), American Society for Testing and Materials. (2009).
[27] ASTM C597, Standard Test Method for Pulse Velocity Through Concrete, American Society for Testing and Materials. (2009).
[28] R.B.N. Khan, A. Khitab, Enhancing Physical, Mechanical and Thermal Properties of Rubberized Concrete, Engineering, and Technology Quarterly Reviews. 3

(2020) 33–45. https://doi.org/10.5281/zenodo.3852541.
[29] B.S. Mohammed, N.J. Azmi, M. Abdullahi, Evaluation of rubbercrete based on ultrasonic pulse velocity and rebound hammer tests, Construction and Building Materials. 25 (2011) 1388–1397. https://doi.org/10.1016/j.conbuildmat.2010.09.004.

Authors Profile:



AHMAD MASOUD AHMADYAR received his bachelor's degree in civil engineering from Kabul Polytechnic University in 2012, and he obtained his master's degree in structural engineering from the same university in 2022. From 2013 to 2021, he worked on NATO and governmental projects. He is currently engaged in research and plans to pursue his studies at the Ph.D. level. His area of research interest includes concrete and construction materials.



SIFATULLAH BAHIJ received his B.Sc. degree in Civil Engineering from Kabul Polytechnic University in 2012, M.Sc. degree in Civil Engineering from King Fahd University of Petroleum & Minerals, Saudi Arabia, and he is currently a Ph.D. candidate in the Civil Engineering department of National Institute of Applied Sciences, Strasbourg, France. He is a faculty member of the Civil and Industrial Construction Department of Kabul Polytechnic University, Kabul, Afghanistan. His research interests include concrete and construction materials, ultra-high performance fiber reinforced concrete (UHFRPC), green concrete and newly generated concretes, cementitious materials with plastic and rubber wastes, finite element modeling (FEM), destructive, non-destructive, SEM, interferometry, and microscopic analysis, and retrofitting of concrete elements with various cementitious and FRP materials.



SEBGHATULLAH KARIMI received his B.Sc. degree in Civil Engineering from Kabul Polytechnic University in 2007, and his M.Sc. degree in Construction Management from the University of Brighton, UK in 2012. He was a faculty member of the Civil and Industrial Construction Department of Kabul Polytechnic University, Kabul, Afghanistan from 2008 to 2021. His research interests include concrete and construction materials and construction project management.