International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 11 | Nov - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Strength and Durability Behavior of Concrete Incorporating Scrap Tire Crumb Rubber

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Abstract

Waste tyres are non-biodegradable and accumulate in large stockpiles, while concrete production consumes ever larger quantities of natural aggregate. This study investigates M25 concrete in which crumb rubber from scrap tyres partially replaces coarse aggregate by volume at 0%, 5%, 10%, 15%, 20% and 25%. The mix was designed as per IS 10262:2019 for a target mean strength of 31.6 MPa with a water–cement ratio of 0.49 and proportions of 1:2.03:3.38. Compressive strength at 7 and 28 days, split tensile strength, flexural strength, residual compressive strength after immersion in 5% and 10% HCl and H_2SO_4, and residual strength after exposure to 200 °C and 400 °C were determined. The 28-day compressive strength rose from 32.89 MPa for conventional concrete to 35.56 MPa at 15% replacement (+8.1%) but fell to 24.08 MPa and 17.60 MPa at 20% and 25%. Split tensile strength peaked at 3.04 MPa at 15% replacement (+10.5%). Up to 15% replacement, the rubberised mixes retained more strength than conventional concrete under acid attack and elevated temperature; after 10% H_2SO_4 exposure, the 15% mix retained 22.43 MPa against 19.26 MPa for the control. A crumb rubber content of 10–15% is recommended for M25 concrete.

Keywords: Crumb rubber concrete; Waste tyre recycling; Compressive strength; Split tensile strength; Acid resistance; Elevated temperature

1. Introduction

Concrete is the most widely used construction material, and its production depletes natural sand and coarse aggregate. At the same time, discarded vehicle tyres are a growing solid-waste problem: they are non-biodegradable, occupy large landfill volumes, and stockpiles pose fire and health hazards. Landfilling, burning and stockpiling are only short-term solutions, so recycling tyre rubber into construction materials is an attractive option. Crumb rubber, produced by mechanically or cryogenically grinding tyres and removing their steel and textile, ranges in size from 4.75 mm to below 0.075 mm.

Rubber particles are flexible and lightweight, absorb energy and can delay cracking in concrete, but they are much less stiff than mineral aggregate and bond weakly with cement paste, so strength usually falls at high contents. Identifying a replacement level that retains or improves strength is therefore essential. The objectives of this study are to (i) evaluate the compressive, split tensile and flexural strength of M25 concrete with 5–25% crumb rubber replacing coarse aggregate, (ii) assess its resistance to HCl and H_2SO_4 attack and to elevated temperatures of 200 °C and 400 °C, and (iii) identify a suitable replacement level.

2. Literature Review

Reviews consistently report that increasing crumb rubber content reduces compressive, tensile and flexural strength and elastic modulus, because rubber is soft and bonds weakly with the cement paste, while improving ductility, impact resistance and energy absorption [3], [7], [8]. Treating the rubber surface improves its bond with the matrix [11], [12]. Low replacement levels can be beneficial: Sofi et al. found that 3% waste tyre rubber fines improved the compressive and split tensile strength of M40 concrete [2], and Barmoh et al. reported higher split tensile and flexural strengths with 2.5% NaOH-treated crumb rubber in high-strength concrete [6].

Durability can be improved by modifying the rubber or the binder. Modified crumb rubber concrete showed 400% higher frost resistance than plain concrete and 110.07% better impermeability than unmodified rubber concrete [4]. Silica fume, GGBFS and fly ash improved the ductility and impermeability of rubber concrete [5]; metakaolin-based high-strength

concrete incorporating crumb rubber has been developed and its durability assessed [9], [10]. Combining crumb rubber with industrial wastes and supplementary cementitious materials, with machine-learning strength prediction, has also been explored [1]. Comparatively few studies, however, examine crumb rubber as a coarse aggregate replacement in ordinary M25 concrete under both acid attack and elevated temperature, which this study addresses.

3. Materials and Methodology

Materials. Ordinary Portland cement of 53 grade (specific gravity 3.1), natural sand as fine aggregate, crushed stone coarse aggregate of 20 mm (specific gravity 2.912) and 12.5 mm (specific gravity 2.9) nominal size, potable water and crumb rubber from discarded vehicle tyres were used. The crumb rubber (Fig. 1) was produced by shredding tyres and removing the steel wires and textile fibres.

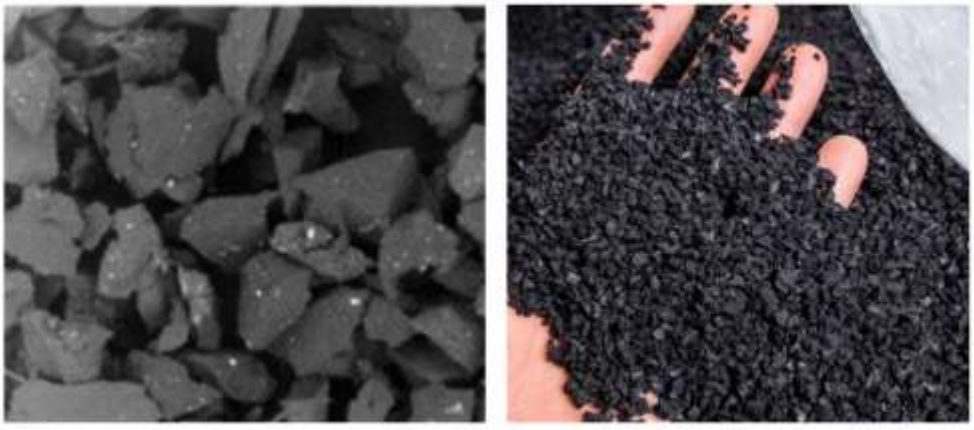


Fig. 1. Crumb rubber used in the study: (a) crumb rubber, (b) small-size crumb rubber

Mix design. M25 concrete was designed as per IS 10262:2019 for a target mean strength of 25 + 1.65 × 4 = 31.6 MPa, assuming 1% entrapped air and a slump of 25–75 mm. The resulting proportions are given in Table 1. Crumb rubber replaced the coarse aggregate by volume at 0% (conventional concrete), 5%, 10%, 15%, 20% and 25%.

Table 1. Mix proportion of M25 grade concrete (per cubic metre)

Material	Quantity
Cement	350 kg
Water	171.5 litres
Fine aggregate	712 kg
Coarse aggregate	1,184 kg
Water–cement ratio	0.49
Mix proportion by mass	1 : 2.03 : 3.38

Testing. Specimens were cast in oiled moulds in three layers, each tamped 35 times, demoulded after 24 hours and cured in clean water. Compressive strength was determined on cubes at 7 and 28 days, split tensile strength on cylinders, and flexural strength on beams as per IS 516. For durability, cubes were immersed in 5% and 10% HCl and 5% and 10% H_2SO_4 solutions and tested for residual compressive strength. Further cubes were heated to 200 °C and 400 °C and tested for residual compressive strength after cooling. Fig. 2 shows the casting and acid immersion.

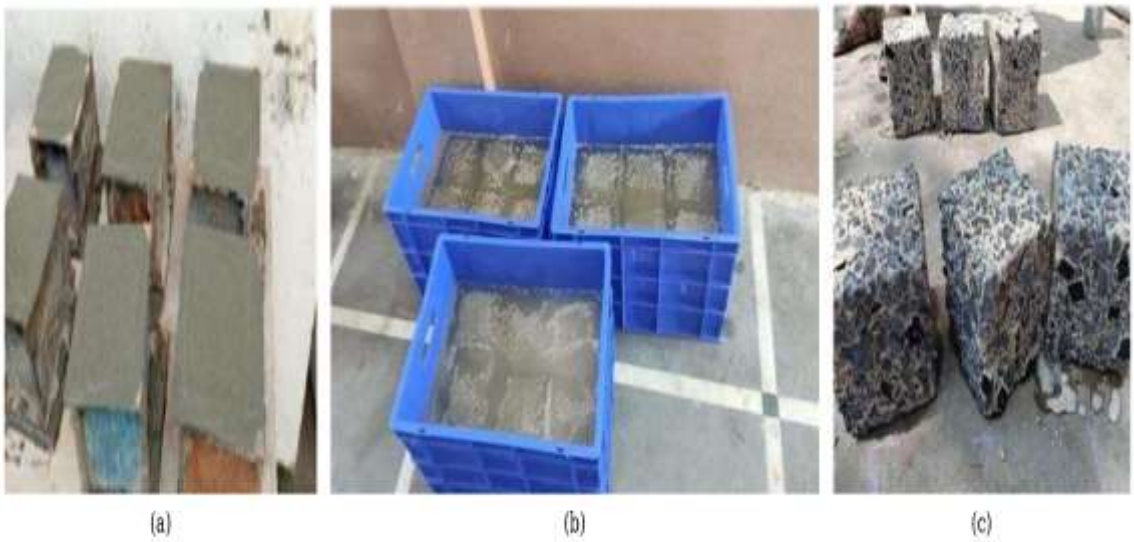


Fig. 2. (a) Casting of cubes, (b) immersion of cubes in 5% and 10% HCl, (c) specimens after acid exposure

4. Results and Discussion

4.1 Compressive Strength

The compressive strengths are given in Table 2 and Fig. 3. Up to 15% replacement, the 7-day strength was practically unchanged (25.78–26.15 MPa) and the 28-day strength increased progressively, by 4.04%, 6.02% and 8.12% at 5%, 10% and 15% replacement, to a maximum of 35.56 MPa. Beyond 15%, strength fell sharply: at 28 days the 20% and 25% mixes reached only 24.08 MPa and 17.60 MPa, 26.8% and 46.5% below the control, so neither achieved the M25 grade. At low contents the rubber particles are well dispersed and the stronger crushed stone still carries the load. At higher contents the soft, weakly bonded rubber forms a larger volume of compressible inclusions and weak interfaces where cracks initiate.

Table 2. Compressive strength of conventional and crumb rubber concrete (N/mm²)

Mix	7 days	28 days
Conventional	25.78	32.89
5% replacement	25.83	34.22
10% replacement	25.89	34.87
15% replacement	26.15	35.56
20% replacement	16.14	24.08
25% replacement	9.81	17.60

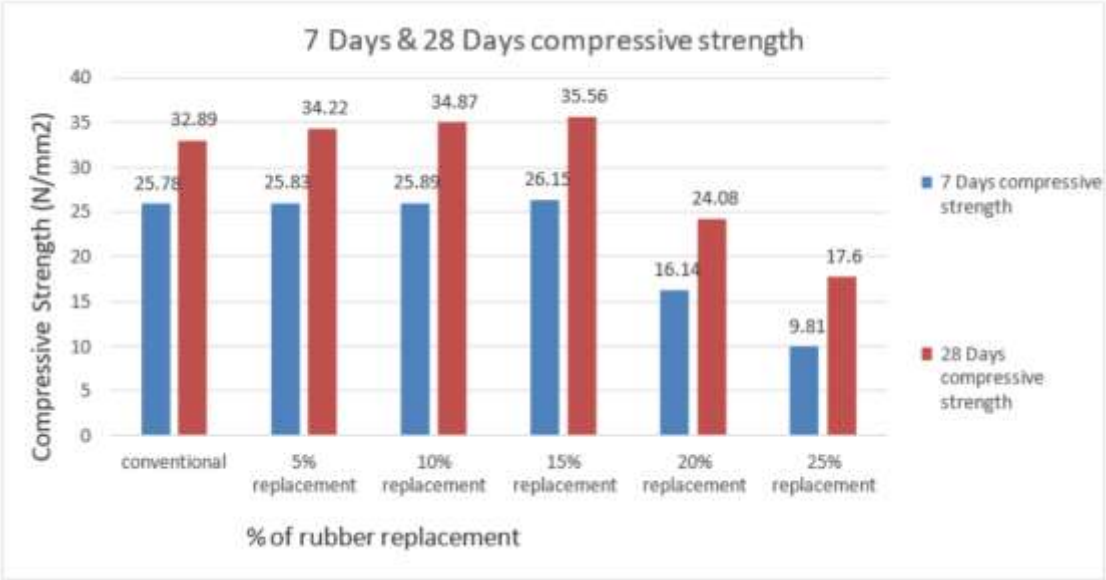


Fig. 3. 7-day and 28-day compressive strength

4.2 Split Tensile and Flexural Strength

The split tensile and flexural results are given in Table 3. Split tensile strength increased from 2.75 MPa for conventional concrete to a maximum of 3.04 MPa at 15% replacement (+10.5%), and even the 20% and 25% mixes remained at or above the control (2.87 and 2.76 MPa). The rubber particles bridge developing cracks and deform before failure, which delays splitting. Flexural strength followed a similar trend, increasing from 24.0 to 26.0 N/mm² at 10% replacement (+8.3%) and falling below the control only at 25% (22.8 N/mm²). The tensile properties are therefore less sensitive to rubber content than compressive strength.

Table 3. Split tensile and flexural strength at 28 days

Mix	Split tensile strength (N/mm²)	Flexural strength (N/mm²)
Conventional (nominal mix)	2.75	24
5% rubber	2.83	24.8
10% rubber	2.90	26
15% rubber	3.04	25.6
20% rubber	2.87	24.6
25% rubber	2.76	22.8

4.3 Resistance to Acid Attack

The residual compressive strengths after acid immersion are given in Table 4 and compared in Figs. 4 and 5. In both acids, strength increased with rubber content up to 15% and decreased beyond it, mirroring the trend in normal compressive strength. After 5% HCl, the 15% mix retained 36.58 MPa against 33.33 MPa for the control. Sulphuric acid was far more aggressive than hydrochloric acid, because it dissolves calcium hydroxide and also forms expansive sulphate products. After 10% H_2SO_4, residual strengths ranged from only 15.61 to 22.43 MPa. Even so, the 15% mix retained 16.5% more strength than the control (22.43 against 19.26 MPa). Raising the H_2SO_4 concentration from 5% to 10% reduced the strength of the control by 25.6% but that of the 15% mix by only 18.4%. Rubber, being chemically inert, replaces part of the reactive matrix and appears to slow acid penetration at moderate contents. At 25% replacement, the weaker, more porous matrix lost the most strength (30.7%).

Table 4. Compressive strength after acid immersion (N/mm²)

Mix	5% HCl	10% HCl	5% H_2SO_4	10% H_2SO_4
Nominal mix	33.33	32.44	25.87	19.26
5% rubber	35.66	32.65	26.72	20.06
10% rubber	36.12	33.37	26.92	21.22
15% rubber	36.58	34.88	27.49	22.43
20% rubber	34.89	32.45	24.87	18.19
25% rubber	32.46	31.81	22.53	15.61

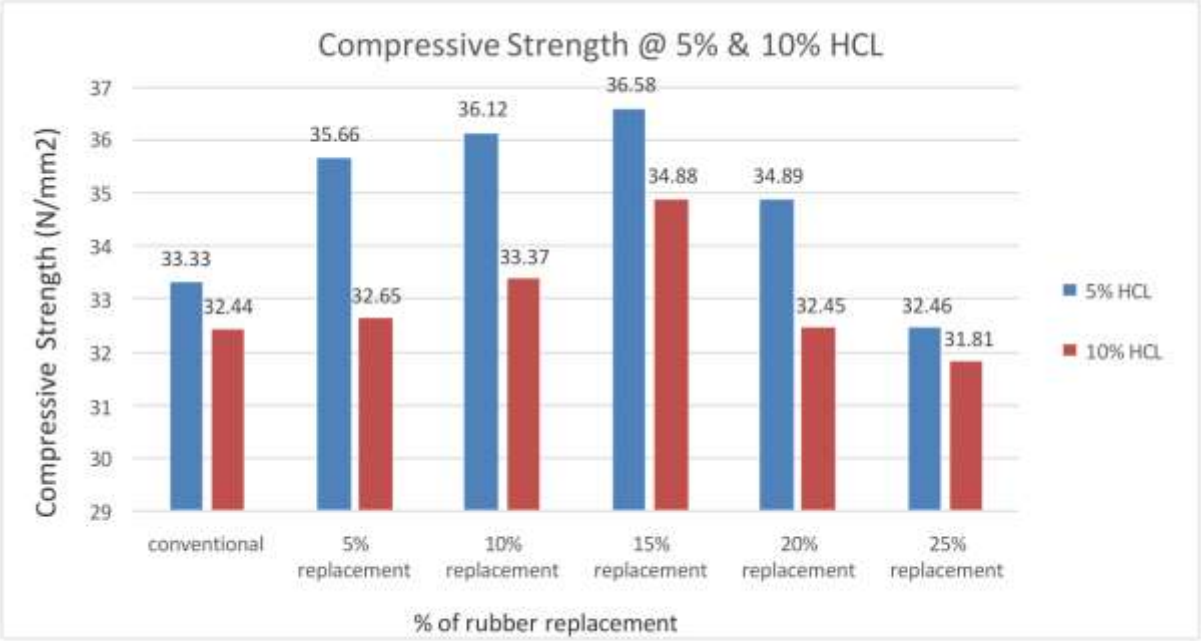


Fig. 4. Comparison of 5% and 10% HCl compressive strength

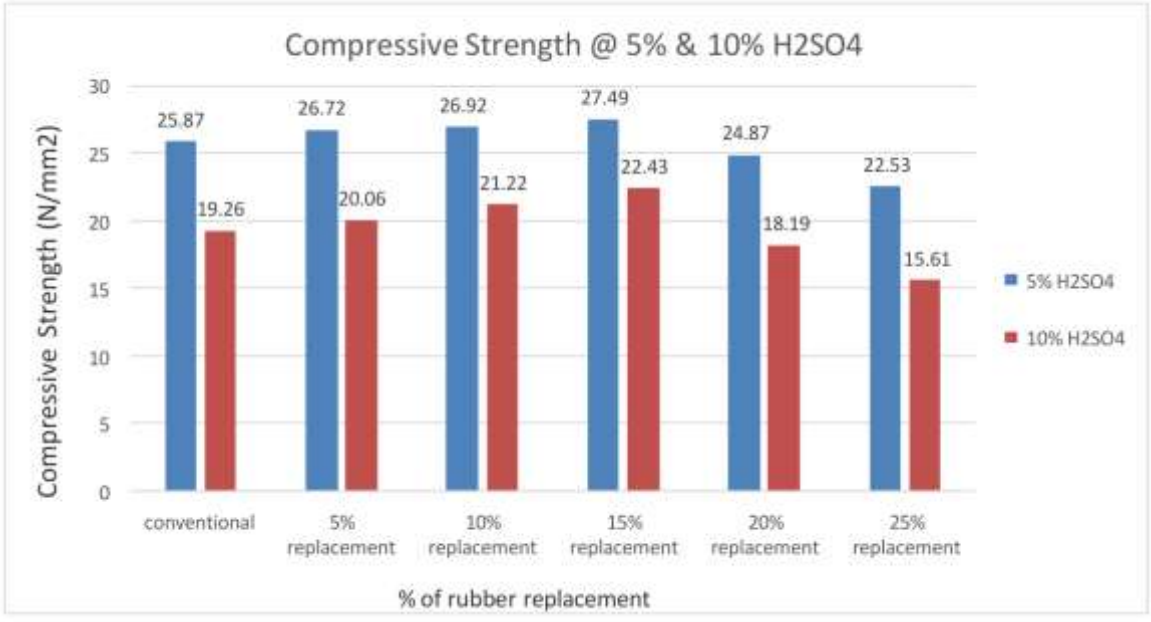


Fig. 5. Comparison of 5% and 10% H_2SO_4 compressive strength

4.4 Effect of Elevated Temperature

The compressive strengths after exposure to 200 °C and 400 °C are given in Table 5. At both temperatures, the strength again peaked at 15% replacement, with 36.45 MPa at 200 °C and 36.12 MPa at 400 °C against 33.09 and 32.94 MPa for conventional concrete. Raising the temperature from 200 °C to 400 °C caused little further loss up to 15% replacement (0.5–0.9%), but 7.7% and 5.5% at 20% and 25%. The specimens became slightly pale, with no visible cracking or spalling. Up to 15%, the voids left by softening rubber may relieve internal vapour pressure, but larger rubber contents leave a weaker skeleton.

Table 5. Compressive strength after exposure to elevated temperature (N/mm²)

Temperature exposure	Conventional	5%	10%	15%	20%	25%
200 °C	33.09	34.46	35.25	36.45	34.89	32.46
400 °C	32.94	34.24	35.08	36.12	32.20	30.67

5. Conclusions

1. Crumb rubber can replace up to 15% of the coarse aggregate in M25 concrete while increasing the 28-day compressive strength from 32.89 MPa to 35.56 MPa (+8.1%); at 20% and 25% replacement the strength falls to 24.08 MPa and 17.60 MPa, below the target grade.
2. Split tensile strength increased to 3.04 MPa at 15% replacement (+10.5%) and flexural strength to its maximum at 10% replacement (+8.3%); tensile behaviour is less sensitive to rubber content than compressive strength.
3. Mixes with up to 15% crumb rubber retained more compressive strength than conventional concrete after HCl and H_2SO_4 immersion. H_2SO_4 was the more aggressive acid, and the 15% mix retained 22.43 MPa after 10% H_2SO_4 against 19.26 MPa for the control.
4. After exposure to 200 °C and 400 °C, the 15% mix again showed the highest residual strength (36.45 and 36.12 MPa), with negligible additional loss between the two temperatures.
5. A crumb rubber content of 10–15% by volume of coarse aggregate is recommended for M25 concrete, providing better strength and durability while recycling waste tyres and conserving natural aggregate.

Further work should examine treated rubber, longer exposure periods, microstructure and the structural behaviour of crumb rubber concrete members.

References

[1] S. Mishra, S. Panda, D. Bhowmik, and S. Guha, "Experimental and analytical evaluation of crumb rubber concrete with multi-blended industrial waste aggregate and SCMs: Strength, durability, microstructure, and ML prediction," *Construction and Building Materials*, vol. 516, Art. no. 145677, 2026, doi: 10.1016/j.conbuildmat.2026.145677.

[2] A. Sofi, P. Nagarajan, and T. S. Kumanan, "Machine learning approach for predicting the influence of pulverized waste tire rubber fines as a sustainable cement alternative in concrete," *Waste Management*, vol. 214, Art. no. 115396, 2026, doi: 10.1016/j.wasman.2026.115396.

[3] A. J. Kilani, B. D. Ikotun, and R. Abdulwahab, "Effect of crumb rubber on concrete's and mortar's structural properties: A review," *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, vol. 49, pp. 1037–1067, 2025, doi: 10.1007/s40996-024-01647-8.

[4] S. Zhai, J. Hu, R. Hai, L. Cui, Y. Zhang, L. Yang, J. Zhang, Y. Zhang, L. Liu, and Y. Sun, "Investigation on the durability performance and mechanism analysis of modified crumb rubber concrete," *Construction and Building Materials*, vol. 471, Art. no. 140746, 2025, doi: 10.1016/j.conbuildmat.2025.140746.

[5] F. Ren, J. Mo, Q. Wang, S. Tian, M. Lai, and J. C. M. Ho, "Fillers to improve the ductility and impermeability of crumb rubber concrete," *Construction and Building Materials*, vol. 425, Art. no. 136073, 2024, doi: 10.1016/j.conbuildmat.2024.136073.

[6] A. B. Barmoh, D. O. Koteng, and C. Miruka, "Influence of partial replacement of fine aggregate with varying amounts of different particle sizes of treated crumb rubber on the mechanical and durability properties of

high-strength concrete," *International Journal of Engineering Trends and Technology*, vol. 71, no. 6, pp. 169–180, 2023, doi: 10.14445/22315381/IJETT-V71I6P219.

[7] S. He, Z. Jiang, H. Chen, Z. Chen, J. Ding, H. Deng, and A. S. Mosallam, "Mechanical properties, durability, and structural applications of rubber concrete: A state-of-the-art review," *Sustainability*, vol. 15, no. 11, Art. no. 8541, 2023, doi: 10.3390/su15118541.

[8] S. Muhammad, Q. Yuan, M. Alam, M. F. Javed, M. F. Rehman, and A. Mohamed, "Fresh and hardened properties of waste rubber tires based concrete: A state of the art review," *SN Applied Sciences*, vol. 5, Art. no. 119, 2023, doi: 10.1007/s42452-023-05336-5.

[9] A. S. Sidhu and R. Siddique, "Durability assessment of sustainable metakaolin based high strength concrete incorporating crumb tire rubber," *Journal of Building Engineering*, vol. 72, Art. no. 106660, 2023, doi: 10.1016/j.jobe.2023.106660.

[10] A. S. Sidhu and R. Siddique, "Utilisation of crumb tire rubber in development of sustainable metakaolin based high strength concrete," *Construction and Building Materials*, vol. 345, Art. no. 128412, 2022, doi: 10.1016/j.conbuildmat.2022.128412.

[11] R. A. Assaggaf, M. R. Ali, S. U. Al-Dulaijan, and M. Maslehuddin, "Properties of concrete with untreated and treated crumb rubber—A review," *Journal of Materials Research and Technology*, vol. 11, pp. 1753–1798, 2021, doi: 10.1016/j.jmrt.2021.02.019.

[12] H. H. Awan, M. F. Javed, A. Yousaf, F. Aslam, H. Alabduljabbar, and A. Mosavi, "Experimental evaluation of untreated and pretreated crumb rubber used in concrete," *Crystals*, vol. 11, no. 5, Art. no. 558, 2021, doi: 10.3390/cryst11050558.