Research Article

Salama Nasim Yousif Al-Labban*, Firas Abdulhadi Abdullah, Yahya Hamza Karagoly, Mustafa Salman Shubber, Suhad Abdulsattar Hasan and Qusay A. Jabal

Waste aggregate concrete properties using waste tiles as coarse aggregate and modified with PC superplasticizer

https://doi.org/10.1515/eng-2022-0356
received March 24, 2022; accepted July 04, 2022

Abstract: Concrete is the most popular construction material and has a relatively high compressive strength and it does not crack under its own weight, but its tensile strength is much lower compared to its compressive strength. The compressive strength can be changed according to the water to cement ratio during concrete formation or mixing, while the tensile strength rises when additives are used, concrete needs reinforcing steel, and added to plain concrete, resulting in reinforced concrete. In other terms, concrete consists of sand or fine aggregate, gravel (which is a coarse aggregate), water, and cement (which is considered a bonding material), and it is a brittle material that needs reinforcement and also some admixtures to improve its low tensile resist. This research aims to increase and improve some mechanical properties of concrete by using waste tiles as coarse aggregate. The study includes replacing normal aggregates with waste tile and using them as crushed aggregate with 25, 50, 75, and 100% replacement. Studies show increment in compressive and tensile strength and flexural strength by using waste tile aggregate compared with ordinary concrete; compressive strength increased from 34.1 MPa for reference mixes without waste tiles to 39.8 MPa using waste tiles. The study included improving all mixes with polycarboxylate superplasticizer and gaining high strength concrete, especially mixes with 50, 75, and 100% waste tile aggregate; the compressive strength with totally waste tile replacement gave the highest value of compressive strength, which was 57.5 MPa, tensile and flexural strength also increased by using waste tile aggregate, and 100% replacement shows optimum values of mechanical properties in this study.

Keywords: waste tiles, waste aggregate concrete, compressive strength, tensile strength, flexural strength, superplasticizer

*** Corresponding author: Salama Nasim Yousif Al-Labban,** Departmentof Civil Engineering, Faculty of Engineering, University of Kufa, Najaf, Iraq, e-mail: sallama.allaban@uokufa.edu.iq
Firas Abdulhadi Abdullah: Departmentof Civil Engineering, Faculty of Engineering, University of Kufa, Najaf, Iraq, e-mail: firas.altufaili@uokufa.edu.iq
Yahya Hamza Karagoly: Civil Engineering Department, Faculty of Engineering, University of Babylon, Babylon, Iraq, e-mail: eng.yahya.karagoly@uobabylon.edu.iq
Mustafa Salman Shubber: Departmentof Civil Engineering, Faculty of Engineering, University of Kufa, Najaf, Iraq, e-mail: mustafaa.shubber@uokufa.edu.iq
Suhad Abdulsattar Hasan: Departmentof Civil Engineering, Faculty of Engineering, University of Kufa, Najaf, Iraq, e-mail: suhad.almahboobi@uokufa.edu.iq
Qusay A. Jabal: Departmentof Civil Engineering, Faculty of Engineering, University of Kufa, Najaf, Iraq, e-mail: qusay.alatiya@uokufa.edu.iq

1 Introduction

Concrete is the most excellent material used in the construction projects all over the world, because of its low cost compared with the steel used in steel structures. Concrete is highly used in bridges, foundations, multistory buildings, tower construction, houses, tunnels, water tanks, water pipes, sewerage structures, or even in repairs like cement pastes; this highly and large use makes concrete the best composite material in the world.

Using waste materials in concrete gives several benefits, such as reducing the total cost of concrete structures, less environmental pollution, and higher mechanical properties in concrete [1,2]. Tamanna and Sharma [3] studied the effect of replacing average aggregate in concrete with waste tiles as coarse aggregate and found that replacing leads to increasing compressive strength of concrete; Adehola and Kuye [4] studied the effect of using waste tiles as aggregate in concrete by replacing average aggregate with 10, 20, and 25% and gain improvement in compressive strength for all replacements. Ceramic tiles are used in other research studies as aggregate in concrete, and Amos [5] studied the use of ceramic as waste aggregate in mixes with grade 25 and found slight decrement in compressive strength. Magesh [6] used coarse and fine ceramic tiles as the replacement from average aggregate in concrete; the compressive strength increased from 28 MPa for control mix to 31 MPa for 50% replacement in his study, and the optimum dosage was 50%. Also, he gained increment in tensile and flexural strength by using waste ceramic tiles. Naveen [7] studied the use of waste tiles as aggregate in concrete for 10, 20, 30, and 40% replacements from average aggregate and got increment in compressive, tensile, and flexural strength by using waste tiles aggregate. Daniyal [8] studied the application of waste ceramic tiles as coarse aggregate in concrete, and found that coarse waste ceramic tiles improve the compressive strength of concrete up to 20% replacement. Shruthi [9] studied the compressive and tensile strength of concrete by using waste ceramic tiles and found out that the optimum ratio of replacement that gives maximum compressive strength was 30% from normal aggregates. Concrete is the most significant material worldwide and its properties differ from steel structures upon comparing the durability considerations and its fire resistance; all steel structures totally collapsed under fire, but concrete was not totally collapsed under fire, it is more durable, so, developing the concrete industry is our goal. This study aimed to use different percentages of replacements until 100% replacement of waste tiles as coarse aggregate in concrete. It modified all mixes with polycarboxylate (PC) superplasticizer to gain high-strength concrete.

2 Experimental program

2.1 Materials and mixes

Ordinary Portland cement is used in all mixes with a cement is used content of 600 kg for each cubic meter with mix proportion as shown in Table 1. Table 2 shows mix details improved with superplasticizer Type PC-200.

Table 1: Reference mix details (without PC superplasticizer)

Cement	Fine aggregate	Coarse aggregate	Water	Mix prop
600 kg	600 kg	1,000 kg	240 kg	1:1:1.67

Ordinary red sand used as fine aggregate in concrete with zone 3 sieve grading confirms Indian standards I.S-383 [10]. The sieve analysis of sand is shown in Table 3. Coarse aggregate was used with a maximum size of 20 mm in this study, and the sieve analysis of coarse aggregate is shown in Table 4. Waste tiles are used as replacement of coarse aggregate only with ratios of 0.0, 25, 50, 75, and 100%, and some properties of waste tiles are shown in Table 5. Figure 1 shows the waste ceramic after crushing it to use it as waste aggregate.

2.2 Testing procedure

Three types of tests for all specimens are used in this research. Compressive strength test was carried out by using 10 × 10 × 10 cm cubes and tested after 28 days from casting by uni-axial compression load and the average value of three specimens for each mix was found. Compressive strength was found by using simple equation (1). Figure 2 shows cubic concrete specimens after testing for compressive strength test. After casting the concrete in molds, the specimens must be left in laboratory air for 24 h to achieve the hardened state of concrete, and then the specimens must be taken out from metal molds and submerged in clean water for 27 days in order to be cured and achieve the complete chemical reactions in cement paste and that gives the hardened state to concrete, which can hold them from water and dry them from surface water and left for 1 h before testing them in compression machine. Each specimen is tested on smooth surface not on rough surface caused by casting under air effects; this rough texture of concrete can cause errors in data of compression results, and so the testing must be accurate by loading specimens on smooth surfaces.

$$\sigma = P / A, \quad (1)$$

where σ is the compressive strength of the cubic specimen, P is the maximum load at failure due to compression machine, and A is the area of the top of the cubic specimen of concrete subjected to compression load.

Tensile strength test was carried out using 10 × 20 cm cylinders and tested by using splitting test method, and the value of splitting tensile strength can be found from the following equation:

$$F_t = 2P / \pi DL, \quad (2)$$

where F_t is the tensile strength, P is the maximum load, D is the diameter of concrete specimen, and L is the height of the cylindrical specimen.

Table 2: Modified mix details (with PC superplasticizer)

Cement	Fine aggregate	Coarse aggregate	Water	PC-200 superplasticizer	Mix prop
600 kg	600 kg	1,000 kg	150 kg	9.6 L	1:1:1.67

Table 3: Fine aggregate sieve analysis (zone 3 grading)

Sieve dimension	Passing by weight (%)	Indian limits for zone 3 (I.S-383 specification)
10 mm	100	100
4.75 mm	94.3	90–100
2.36 mm	90.6	85–100
1.18 mm	83.7	75–100
600 μm	71.2	60–79
300 μm	25.8	12–40
150 μm	1.3	0–10

Table 4: Coarse aggregate sieve analysis for normal and waste tile aggregates

Sieve dimension (mm)	Passing by weight (%)	Indian standards (I.S-383) (%)
40	100	100
20	95.4	90–100
10	27.8	25–55
5	2.7	0–10

Flexural strength is determined by using third point loading according to British Standard 1881 [11]; the flexural strength can be found in equation (3). The flexural strength was determined using 100 × 100 × 400 mm beams, three beams tested for each mix, and the average value of flexural strength was found. Also, all beams were tested 28 days after casting.

$$F_b = PL / bd^2, \quad (3)$$

where F_b is the flexural strength of the concrete beam, P is the maximum load applied, L is the distance between supports, b and d are the width and the depth of the beam, respectively.

Figure 3 shows concrete specimen under compression test, and also shows after failure load, the flexural strength test for a waste aggregate concrete beam.

3 Results and discussion

Table 6 shows the mechanical properties of ordinary concrete mixes and mixes with 25, 50, 75, and 100% replacement of waste tile aggregates. The compressive strength increased from 34.1 MPa for reference mix to 39.78 MPa for mixes with 100% replacement; tensile strength also increased from 1.8 to 2.93 MPa. Flexural strength increased from 3.1 MPa to about 4.6 MPa by using 100% replacement, which can be attributed to the excellent properties of waste tiles that have excellent flexural and compressive strength and also low absorption; and also, the second reason is the sharp edges of aggregate that achieve an excellent bond with cement paste.

Table 7 shows all mixes in Table 6 (same mix proportions) but improved with PC superplasticizer. Compressive strength is highly increased by using superplasticizer; it increased from 45.47 MPa for reference mixes to 57.5 MPa for 100% waste tile aggregates. From Table 6 it can also be seen that high strength concrete (exceeds 50 MPa) is achieved in waste tile aggregate concrete in this study, especially in 50, 75, and 100% replacement and that is a good achievement which makes concrete in less cost and higher mechanical property achievement and less environmental pollution due to using waste materials.

Figures 4–6 show the relationship between compressive tensile and flexural strength and % replacement of average aggregate with waste aggregates.

In contrast, Figures 7–9 show the relationship between compressive, tensile, and flexural strength and %

Table 5: Fine aggregate sieve analysis (zone 3 grading)

Waste tiles	Original tiles	Flexural strength	Absorption	Compressive strength
Description and values	Najaf, Iraq, waste from laboratories after test	8.51 MPa	2.60%	More than 80 MPa for 12 × 13 cm piece

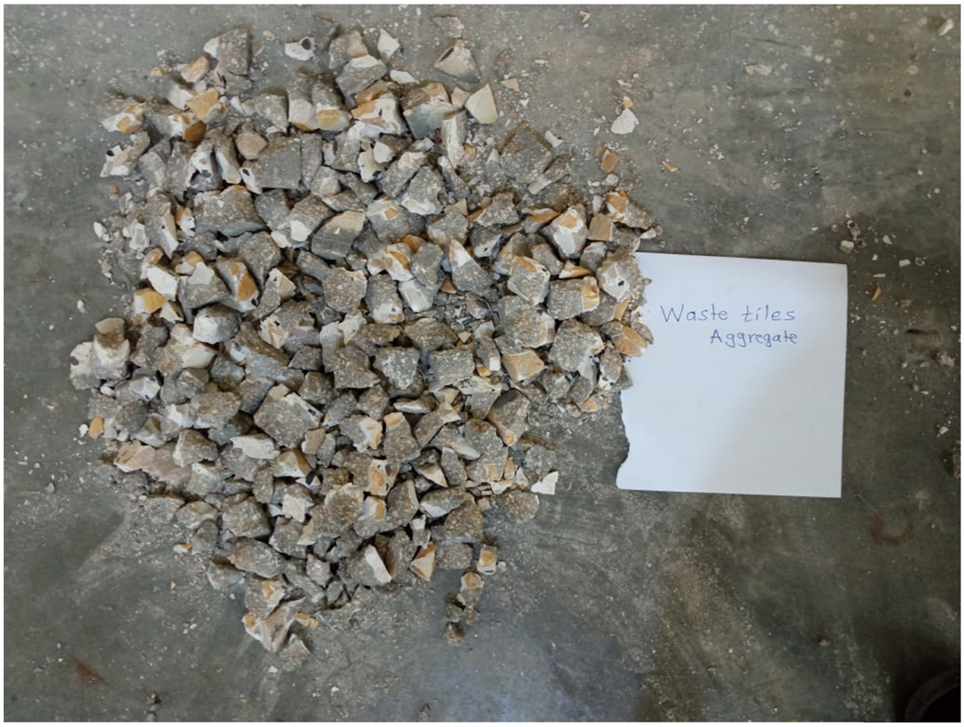

Figure 1: Waste ceramic after crushing, used as a coarse aggregate in concrete.

Figure 2: Compressive strength for 100% waste tile concrete – modified mix.

Figure 3: Flexural strength test for 100% waste tile concrete – modified mix.

Table 6: Mechanical properties of reference and waste tile aggregate concrete

Mix description	Compressive strength (MPa)	Tensile strength (MPa)	Flexural strength (MPa)
Reference 1:1:1.8	34.15	1.81	3.12
25% waste aggregate replacement	35.55	2.23	3.85
50% waste aggregate replacement	37.06	2.54	4.27
75% waste aggregate replacement	38.33	2.68	4.59
100% waste aggregate replacement	39.78	2.93	4.90

Table 7: Mechanical properties of reference and waste tiles aggregate concrete modified with PC superplasticizer

Mix description	Compressive strength (MPa)	Tensile strength (MPa)	Flexural strength (MPa)
Reference 1:1:1.8	45.47	2.87	4.27
25% waste aggregate replacement	47.35	3.35	5.07
50% waste aggregate replacement	50.91	3.87	6.38
75% waste aggregate replacement	53.73	4.11	7.51
100% waste aggregate replacement	57.52	4.65	8.20

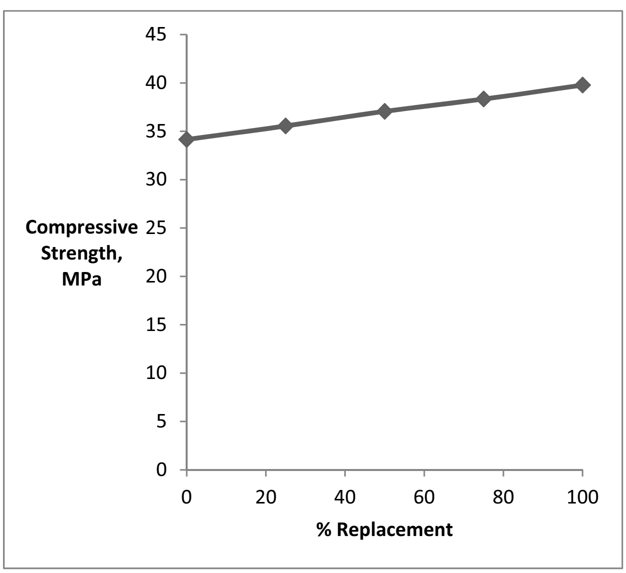

Figure 4: Relation between % replacement and compressive strength of concrete without using superplasticizer.

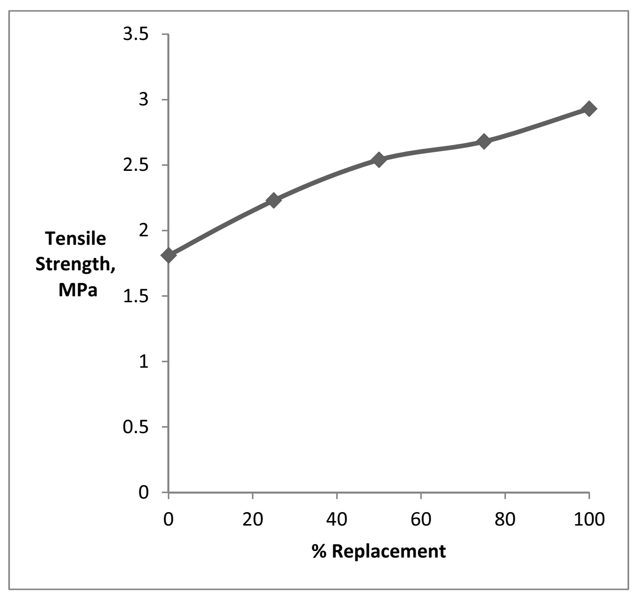

Figure 5: Relation between % replacement and tensile strength of concrete without using superplasticizer.

replacement of aggregate for concrete mixes modified with PC superplasticizer. Figures 10–12 compare the mechanical properties of mixes with and without using a superplasticizer. Figures 13 and 14 show comparison between previous study data in ref. [5] and this study The data in this study. show higher values for compressive and tensile strength compared with of data ref. [5].

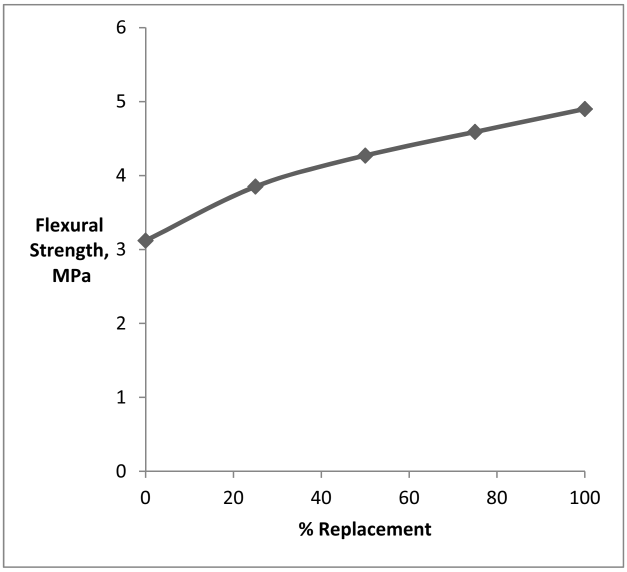

Figure 6: Relation between % replacement and flexural strength without using superplasticizer.

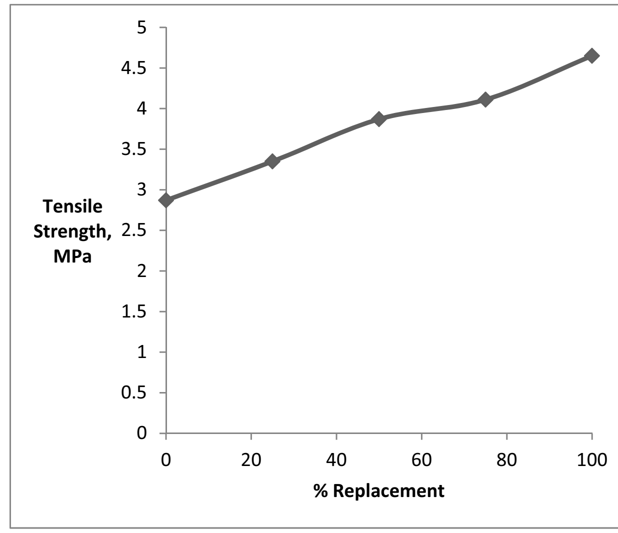

Figure 8: Relation between % replacement and tensile strength of concrete modified with PC superplasticizer.

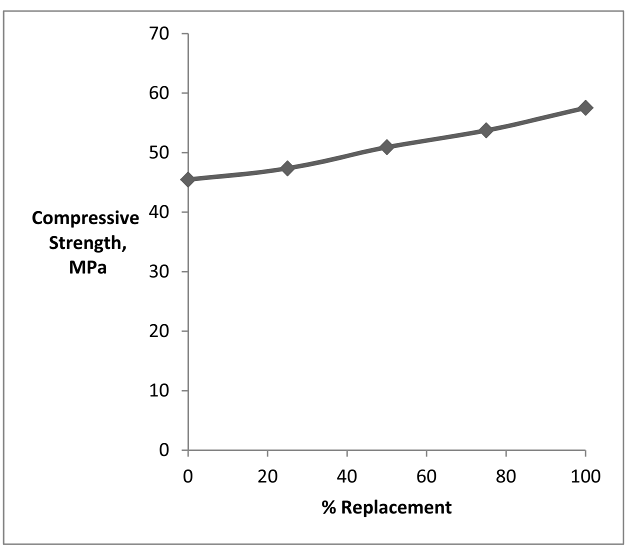

Figure 7: Relation between % replacement and compressive strength of concrete modified with PC superplasticizer.

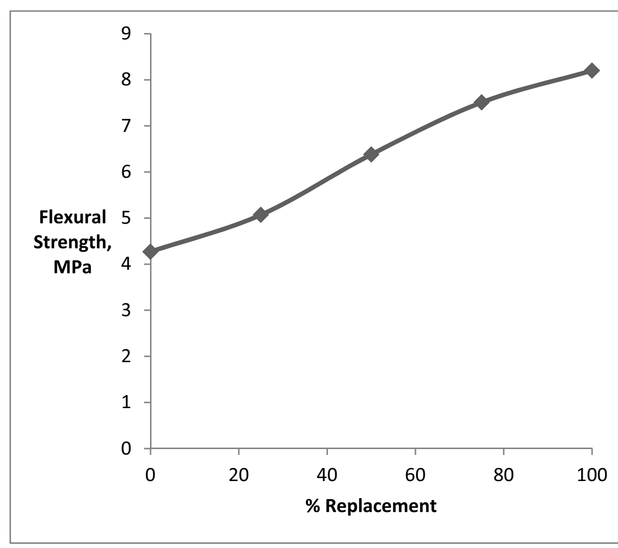

Figure 9: Relation between % replacement and flexural strength of concrete modified with PC superplasticizer.

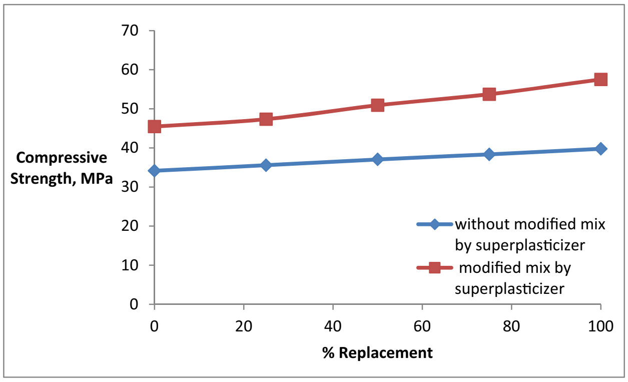

Figure 10: Compares on the relationship between compressive strength and replacement with and without modification by superplasticizer.

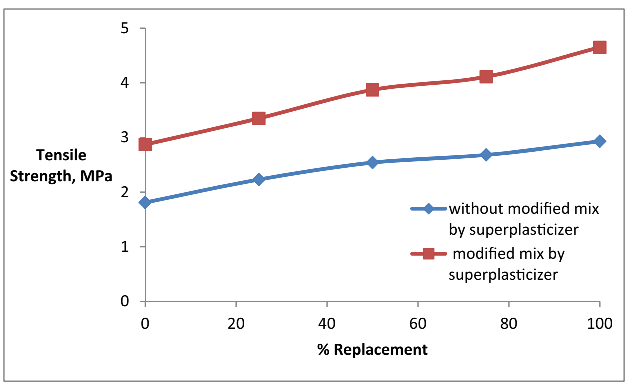

Figure 11: Compares on the relationship between tensile strength and replacement with and without modification by superplasticizer.

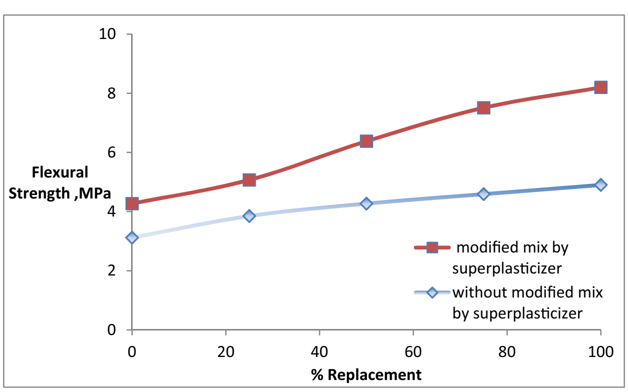

Figure 12: Compares on the relationship between flexural strength and replacement with and without modification by superplasticizer.

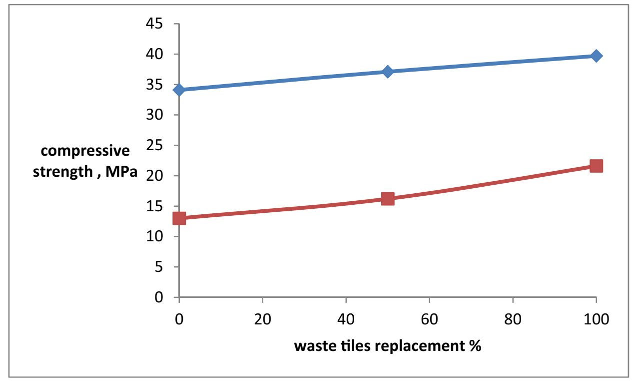

Figure 13: Compressive strength development due to waste tiles replacement (comparison with previous study given in ref. [5]).

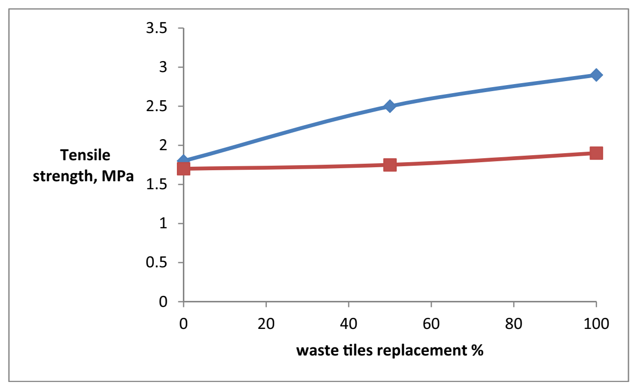

Figure 14: Tensile strength development due to waste tiles replacement (comparison with previous study given in ref. [5]).

4 Conclusion

(1) Using waste tiles as coarse aggregate improves the mechanical properties of normal concrete, giving several benefits such as less environmental pollution and less cost of concrete.

(2) Compressive strength increased by using waste tiles as coarse aggregate; the compressive strength increased from 34.1 to 39.7 MPa for mixes with 100% waste tile aggregate.

(3) Flexural and tensile strength also increased by using waste tile aggregate.

(4) Modified mixes with superplasticizers improve the mechanical properties for reference mixes and waste aggregate mixes and lead to high-strength concrete.

(5) Using waste materials in concrete can give more clean environment and less cost to concrete in addition to the improvements in the strength of concrete and that can make concrete more durable to environmental conditions such as change in weather heat or climate changes and durability against the freeze and thaw conditions and even durability to salty ground water or sulfate attack to concrete.

Conflict of interest: The authors declare that they have no conflict of interest.

Data availability statement: Most datasets generated and analyzed in this study are comprised in the submitted manuscript. The other datasets are available on reasonable request from the corresponding author with the attached information.

References

[1] Maryam A, Wadhah M. Using crushed tiles as coarse agg in conc. mix. In: Third International Conference on Civil, Environment and Waste Management, September: 12–14, 2016, Dubai, UAE, p. 106–11.
[2] Vaariseenivasan K. Properties of conc. with crushed waste ceramic tiles as coarse aggregate. Int J Civil Eng Technol. 2018;9(4):614–9.
[3] Punnet S, Tamanna. An experimental work on crushed ceramic waste tiles by coarse aggregate in the concrete mix. Int Res J Eng. Tech. 2018;5(2):1133–5.
[4] Adehola A, Kuye R. Utilization of construction waste tiles as a replacement for fine aggregate in concrete. Eng Tech Appl Sci Res. 2017;7(5):1930–3.
[5] Amos K. Full replacement of fine aggregate in concrete with crushed ceramic waste. Global J Environ Sci Tech. 2017;5(6):488–520.
[6] Magesh B. Replacement of coarse and fine aggregate by waste ceramic tiles and ceramic powder in concrete. Int J Eng Technol Eng Res. 2018;6(2):25–32.
[7] Naveen N. Partial replacement of coarse aggregate by crushed tiles and fine aggregate by granite powder to improve the concrete properties. J Mechanical. Civil Eng. 2018;13(6):168–76.
[8] Daniyal M. Application of waste ceramic tile aggregates in concrete. Int J Innovative Res Sci Eng Technol. 2015;4(12): 12808–15.
[9] Shruthi H. Reuse of ceramic waste as aggregate in concrete. Int Res J Eng Technol. 2016;3(7):115–9.
[10] Indian Standards I.S-383. Specification for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi, 2002.
[11] British Standard 1881,118. Testing concrete part 118-method for determination of flexural strength. B.S.I, 1983.