University of Baghdad
College of Engineering
JOURNAL OF ENGINEERING

Journal of Engineering

journal homepage: www.jcoeng.edu.iq

Volume 31 Number 1 January 2025

Effect of Crushed Concrete on Some Properties of Modified Reactive Powder Concrete Reinforced with Micro Steel Fibers

Rusul Hussain Saeed *, **Nada Mahdi Fawzi**

Department of Civil Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq

ABSTRACT

The disposal of concrete debris is in high demand due to the rising amount generated by demolition activities and the breaking up of concrete goods during transportation and production. Moreover, it is imperative to preserve natural resources. In recent times, there has been a growing inclination to utilize these waste materials as a partial replacement for aggregate. This paper presents the results of a study that examined the utilization of crushed concrete as aggregates. The crushed concrete was sourced from inspected cube samples of a road project in Baghdad and subsequently reduced in size till they reached a maximum dimension of 10 mm. The original reactive powder concrete was used to make crushed concrete (25% and 100% by volume of the concrete), micro-steel fibers (1% by volume of the concrete), and fine sand (no more than 1% by volume of the concrete). Study of the properties of reactive and regular powder concrete, including their compressive and flexural strengths, as well as their density. When 25% crushed concrete was added to modified reactive powder concrete, its compressive strength increased by 16.86% and its flexural strength increased by 10.57%. After seven days and twenty-eight days of testing, respectively, these enhancements were noted. A 12.04% decrease in compressive strength at seven days and an 18.2% decrease at 28 days occurred when sand was replaced with 100% broken concrete in the mixture. In a similar vein, flexural strength dropped by 23.5% after seven days and 20.6% after twenty-eight days.

Keywords: Modified reactive powder concrete, Crushed concrete, Compressive strength, Flexural strength, Density.

1. INTRODUCTION

Concrete engineers have shown a growing interest in sustainable development in recent years. Utilizing local materials and repurposing agricultural and industrial waste in construction can benefit the environment and the economy **(Bederina et al., 2012; Muhsin and Fawzi, 2021; Hussain and Aljalawi, 2022; Jaafar et al., 2023)**. Using waste materials

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2025.01.07

Article received: 05/03/2024
Article revised: 12/06/2024
Article accepted: 24/07/2024
Article published: 01/01/2025

to make building constituents can decrease the environmental effect of cement and concrete manufacture. The key concept in using recycled building and demolition materials is selective demolition. This involves carefully organizing the materials while demolishing the structure **(Verian et al., 2018; Muhsin and Fawzi, 2021; Hussain and Aljalawi, 2022).** The type and amount of mortar found identify recycled aggregates. The water-to-cement ratio determines the porosity of reused concrete, and the mortar is porous **(Nagataki, 2004; Kou and Poon, 2012)**. The crushing technique and aggregate size determine how much mortar is applied to recycled material **(Kou, 2006; Memon et al., 2022)**. Before using recycled aggregates in concrete, attachment mortar density and absorption capacity must be determined **(Shi et al., 2016).**

RPC is a novel form of concrete created by improving the composition of cementitious materials. RPC provides distinct advantages over conventional cement-based materials due to its consistent particle sizes, porosity, and microstructures **(Yazıcı et al., 2009).** The high cement-to-water ratio, numerous superplasticizers, finely crushed quartz, and silica fume in the binder make the substance unique **(Richard and Cheyrezy, 2006; Hussain and Aljalawi, 2022).** Unlike conventional reactive powder concrete (RPC), some studies use coarse aggregate. Researchers employed coarse aggregate to make modified reactive powder concrete (MRPC). **(Ravindrarajah et al., 1987)** studied the impacts of employing fine and coarse aggregates of crushed concrete on concrete's compressive and tensile strengths. Both bound and loose mortar give recycled aggregates distinct characteristics compared to their natural counterparts. The strength and modulus of elasticity of medium-strength concrete decrease by around 10% and 35% when recycled aggregates are used in equivalent mixes instead of natural aggregates. Additionally, drying shrinkage is about doubled. The effect on deformational characteristics of recycled fine aggregate is less pronounced than that of recycled coarse aggregate. Recycled aggregates have a negligible impact on the characteristics of newly mixed concrete.

(Khalil, 2012) examined an MRPC fabricated utilizing crushed, graded natural aggregate with a maximum size of 12.5mm. The compressive strength of crushed coarse aggregate can reach up to 150 MPa. The suggested model posits that the absence of coarse aggregate leads to increased compaction in reactive powder concrete (RPC). This discovery contradicts the strength values of MRPC, which consist of crimped and hooked steel fibers. MRPC is known for its exceptional compressive strength, splitting tensile strength, modulus of rupture, impact strength, and static modulus of elasticity. **(Aliabdo et al., 2014)** examined the use of pulverized bricks from demolished constructions as powder, fine, and coarse aggregates in concrete. The results suggest that the inclusion of 25% brick powder, based on the weight of cement, led to a reduction in the pores of the mortar microstructure. Additionally, this improved the mortar's compressive strength. The compressive strength, splitting tensile strength, and modulus of elasticity of brick-crushed concrete were lower than those of limestone concrete. **(Borg et al., 2018)** developed RPC using rough material. The new RPC is modified Reactive Powder Concrete (MRPC). Significant waste, including bricks, glass, concrete, and mortar, is generated during construction or demolition. Producing reused construction ingredients from this waste is a cost-effective and eco-friendly disposal method. Reused Construction and demolition waste is processed through grinding, drying, and grading to create powders in building materials. **(Zheng et al., 2018)** examined how substituting Normal Coarse Aggregate (NCA) with Reused Concrete Aggregate (RCA) or Recycled Brick Aggregate (RBA) affects hardened concrete compressive strength. Changing the water-to-cement ratio made concrete grades C25 and C50. Grades were evaluated using

0%,25%,50%,75%, and 100% replacement proportions. The best degrading procedure was used to sift the RCA and RBA to develop their performance in concrete mixes. The 28-day compressive strength of C25 and C50 recycled concrete samples declined 7.2 % and 9.6% when all NCA was replaced with RCA. When all NCA was replaced with recycled brick aggregate, decreases were 11% and 13%. RBA concrete employs recycled brick aggregate, however RCA concrete uses recycled concrete aggregate and is more effective. Unlike preceding studies on hardened concrete using RCA or RBA, our present experiments display that adopting the ideal recycled aggregate gradation raises compressive strength. **(Al-Attar and Al-Numan, 2019)** employed multiple methods to improve RPC by incorporating naturally graded coarse aggregate. The investigation observed the progress of strength, full absorption, and ability to penetrate Reactive Powder Concrete (RPC) after a six-month exposure to kerosene and petrol oil. The findings suggest that the concept of coarse aggregate may need to be reevaluated. Replacing fine particles with larger particles in roller-compacted concrete (RPC) leads to enhanced outcomes. The ideal ratio of fine-to-coarse particles should range from 0% to 25% by weight. **(Hasan, 2022)** repurposed fine aggregates from old glass and concrete to solve trash disposal difficulties. Seven mixes were made. The reference combination was made from used glass sand. Each recycled resource (waste concrete and glass) was mixed with 25%, 50%, or 75% glass sand. Compressive and flexural strength were assessed at 14, 28, and 90 days. Heat treatment at 90°C for 90 days was performed on samples at 20°C. The study indicated that resistance decreases increased with recycled fine aggregate %. The best waste concrete and glass replacement ratio was 25%.

Only a limited number of studies have been identified about the production of MRPC using coarse aggregate. The primary aim of this study is to develop eco-friendly MRPC (Magnetorheological Polymers Concrete) by utilizing recycled materials, specifically crushed concrete. The objective is to reduce environmental pollution by substituting a portion of the fine aggregate (with a maximum particle size of 600 μm) with waste crushed concrete as coarse aggregate, with a maximum size of 10 mm. Additionally, the study aims to examine the impact of incorporating coarse aggregate on the mechanical properties of MRPC, such as compressive strength, flexural strength, and density. Furthermore, this investigation seeks to address the existing knowledge gap in this particular field.

2. EXPERIMENTAL WORK

2.1 Materials

2.1.1 Cement

The research made use of OPC (CEMI 42.5R) cement that conforms with the chemical and physical requirements outlined in **(IQS No. 5, 2019),** as shown in **Tables 1 and 2**.

2.1.2 Sand

Fine aggregate is used in mortar and concrete and is composed of small pieces of crushed stone or sand. Fine aggregate that met the normal specifications in Iraq and passed a 600μm sieve was used in the study. **(IQS No.45, 1984),** as shown in **Tables 3 and 4.**

Table1. The physical properties of the cement.

Physical properties	Test Results	Limits of (IQS. No.5, 2019)
Specific surface area (Blaine approach) (m^2/kg)	390.8	≥ 280
Setting time (Vicat's approach) Initial setting (min)	142 min	≥ 45 min
Setting time (Vicat's approach) Final setting time	6.5 hr	≤ 10 hr.
Soundness by Autoclave Approach (%)	0.7	≤ 0.80
Compressive Strength (MPa)		
Compressive Strength (2) day	25	≥20
Compressive Strength (28) day	45	≥ 42.5

Table 2. Chemical composition of the cement.

Oxide Compositions	Weight (%)	Limits of (IQS No. 5, 2019)
Lime (CaO)	62.73	-----
Iron oxide (Fe_2O_3)	3.71	-----
Alumina (Al_2O_3)	6.33	-----
Silica (SiO_2)	19.64	-----
Insoluble residue (IR)	0.45	Max (1.5)
Magnesia (MgO)	2.67	Max (5)
Loss on Ignition (LOI)	2.14	Max (4)
Sulfate (SO_3)	2.48	$SO_3 \leq 2.8$ if C3A > 3.5 $SO_3 \leq 2.5$ if C3A ≤ 3.5

Table 3. Aggregate gradation of fine aggregate.

Sieve size (mm)	Cumulative Passing %	Limits of (IQS. No.45, 1984) Zone 4
10	100	100
4.75	100	95-100
2.36	100	95-100
1.18	100	90-100
0.6	100	80-100
0.3	30	15-50
0.15	7	0-15

Table 4. Physical and chemical characteristics of fine aggregates.

Physical & Chemical properties	Test results	Limits of (IQS No.45, 1984)	Specification
Specific gravity	2.60	------	**(ASTM C128, 2015)**
Fineness modulus	1.687	------	**(Iraqi Reference Guide No. 500, 1994)**
Dry rodded Density (kg/m^3)	1.418	------	**(ASTM C29/C29M, 2009)**
Absorption (%)	1.05	------	**(ASTM C128, 2015)**
Sulfate content (%)	0.13	Max (0.5)%	**(IQS No.45, 1984)**

2.1.3 Silica Fume

The physical characteristics and strength activity index of silica fume, as shown in **Tables 5 and 6** comply with the **(ASTM C1240, 2015).**

Table 5. Chemical composition of silica fume (SF)

Oxide	Test results	(ASTM C1240, 2015) requirement
Silicon Oxide (SiO_2)	93.1	Min (85)%
Aluminum Oxide(Al_2O_3)	0.31	------
Magnesium Oxide (MgO)	0.34	------
Iron Oxide (Fe_2O_3)	1.3	------
Calcium Oxide (CaO)	2.8	------
Loss of Ignition	2.16	Max (6) %

Table 6. Physical requirements of silica fume (SF)

Physical properties	Test results	(ASTM C1240, 2015) requirement
Percentage Retained on 45µm (No.325) Sieve	7.6	≤ 10
Accelerated Pozzolanic Strength Activities Index with the OPC at 7 days, min percent of control	107.2	Min (105)

2.1.4 Water

Mixing water meets **(IQS 1703, 2018)**

2.1.5 Superplasticizer

A chemical addition that improves the fluidity and manipulability of concrete. Construction employs it to strengthen and prolong the durability of concrete constructions. The use of Fosroc Structuro W420-EB, a superplasticizer, was aimed at improving the workability and facilitating the incorporation of fibers. The F and G superplasticizers were specially employed. The typical superplasticizer dosage ranged from 0.2% to 2% liters per 100 kg cementitious material **(ASTM C494, 2015)**. The dose of sp used in this study is 2% (L/100 Kg) of cementitious materials

2.1.6 Fiber

The aspect ratio (L/D) for micro-steel fibers equals 60, where L is 12 mm and D is 0.2 mm. Volume fraction used in this study is 1% by volume of concrete

2.1.7 Crushed Concrete

The 10 mm crushed concrete was obtained from analyzed cube specimens of a road project in Baghdad. The crushed concrete underwent sorting and was thereafter split into coarse aggregate for MRPC mixes. The crushed concrete aggregate is sieved conferring to **(IQS. No. 45, 1984),** as shown in **Table 7**.

Table 7. Sieve analysis of crushed concrete.

Sieve opening size (mm)	Passing %	(IQS No. 45, 1984)
10	100	85-100
4.75	23	0-25
2.36	4.7	0-5

2.2 Modified Reactive Powder Concrete Design

The volume of micro-steel fibers in the concrete is 1%. A dosage of 2 Lit of superplasticizer per 100 kg of cementitious material was employed. The mixtures in Table 8 contained 11% silica fume relative to the weight of the cement (80 Kg/m^3), a cement content of 720 kg/m^3, and a water-to-cement ratio of 0.24. The specified design strength for MRPC was 82 (MPa). Table 8 displays the MRPC of the mix design.

Table 8. Mix design of MRPC.

Mixes	Cement (kg/m^3)	W/Cm %	Sp Lit/100 kg	Sand (kg/m^3)	Silica Fume % by Weight of Cement	Crushed Concrete aggregate (kg/m^3)
MRPC0	720	0.24	2	950	11	0
MRPC25	720	0.24	2	712.5	11	237.5
MRPC100	720	0.24	2	0	11	950

2.3 Mixing

The following procedures are used to make concrete mixtures:

- The dry ingredients were mixed for a duration of six minutes.
- The dry ingredients were mixed for three minutes after the water and superplasticizer were each added separately.
- After three minutes of rotating and mixing, the fibers were evenly distributed onto the concrete surface.

2.4 Curing

Continuous water delivery is essential for concrete curing because of the process of cement hydration, a chemical reaction that occurs at every stage. Externally curing traditional concrete involves maintaining a warm and moist environment around the mixture, rather than allowing it to cure on the surface **(Gawad and Fawzi, 2021; Amouri and Fawzi, 2022).** The curing process of RPC is regarded as a crucial factor in its creation as it substantially impacts the reactivity of its components **(Mayhoub et al., 2021).**
During the early stages of development, the strength growth rate is higher at higher curing temperatures than at lower curing temperatures **(Fawzi and Agha, 2012).** Following a 24-hour mold removal, the models are immersed in water. Temperatures reach 35°C until exam day conferring to **(ASTM C684, 2003)** (water warm). **Fig. 1** shows a water Bath device for curing the samples of MRPC.

Figure 1. Water bath device for curing the samples of MRPC.

2.5 Testing

2.5.1 Density Determination

The **(Iraqi Reference Guide No. 274, 1992)** was consulted for the test. Calculation of MRPC density using Eq. (1)

$$D = \frac{Weight}{v} \tag{1}$$

where D is the density of the specimen in (gm/cm^3) or (kg/m^3). Weight is the weight of the specimen in (gm or kg), and v is the volume of the specimen in (m^3 or mm^3)**.** Three cubes were used for testing with dimensions (50 mm *50 mm*50 mm) for each age.

2.5.2 Compressive Strength

MRPC compressive strength was tested using three cubes for testing with measurements (50 mm×50 mm× 50 mm). The test followed **(ASTM C109/109M, 2020)**. Use Eq. (2) to calculate compressive strength.

$$CS = \frac{total\ maximum\ load\ in(N)}{area\ of\ loaded\ surface\ in(mm^2)} \tag{2}$$

where CS is the compressive strength in (Mpa).

Figure 2. Compressive strength test: (A) sample for test; (B) compressive strength device.

2.5.3 Flexural Strength

Tests were done on (50 mmx 50mm x 250mm) two prismatic samples following **(ASTM C293/C293M, 2016).** Use Eq. (3) to calculate flexural strength.

$$fr = \frac{3pl}{2bd^2} \quad (3)$$

where *fr* is the Flexural strength in (Mpa), p is the total maximum load in (N), l is the length of span (mm), b is the width of the specimen (mm), d is the depth of the specimen (mm)

Figure 3. Flexural strength test: (A) sample for test; (C) sample under test.

3. RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength of the concrete increased when 25% of the sand was replaced with crushed concrete. The substantial decrease in compressive strength observed when using 100% replacement compared to the mixture with 25% replacement is because the recycled aggregate has a higher porosity, leading to increased absorption and more micro-cracks in the original adhesive mortar. The mentioned reasons will ultimately render the interfacial transition zone (ITZ) rather feeble in relation to the sand employed **(Ahmed et al., 2017)**. The 25% ratio of crushed concrete yielded the highest compressive strength. This performance improvement is because, in contrast to the conventional method, the cement matrix's microstructure is much denser **(Abbas and Abd, 2021). Table 9** and **Fig. 4** show the outcomes of the compressive strength tests conducted on MRPC specimens.

Table 9. Compressive Strength Test Results (Mpa).

No.	Mixes	Cube 1	Cube 2	Cube 3	Average for Age7 (Day)	Cube 1	Cube 2	Cube 3	Average for Age 28 (Day)
1	MRPC0	83	82	84	83	102	103	106	104
2	MRPC25	95	99	97	97	115	117	113	115
3	MRPC100	72	73	74	73	103	101	99	101

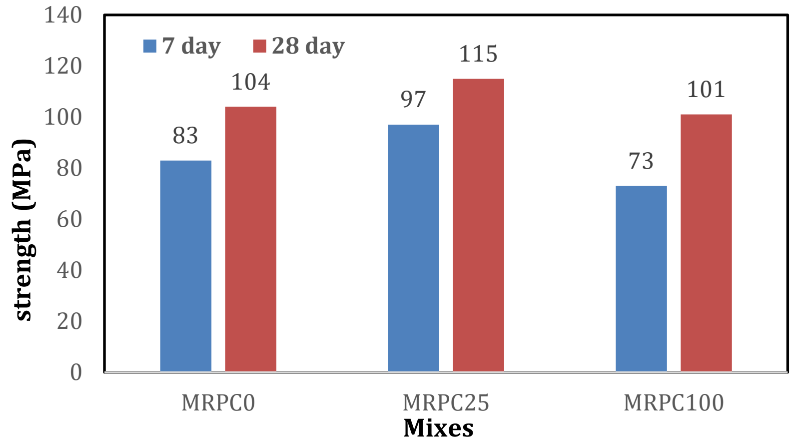

Figure 4. Compressive strength at age 7 and 28 days of curing.

3.2 Density Determination

Replacing 25% and 100% of the sand with crushed concrete by weight resulted in the hardened test specimen having a higher dry density than the reference mix after seven and 28 days, respectively. Due to cement hydration, concrete density increases with curing. Cement is the primary factor in solidifying concrete through a chemical process called hydration. Cement particles undergo a chemical reaction with water When hydrated, it results in the formation of calcium silicate hydrates (CSH) and other crystalline compounds. The process of hydrating concrete improves its long-term strength and durability. During the process of hydration, the minuscule openings in the concrete framework are filled with hydration products, resulting in a reduction in the material's total porosity. The increased density of concrete over time is a result of several causes, including the creation of hydration products, a decrease in porosity, and an increase in strength, as indicated in **Table 10** and **Fig. 5**. The density of crushed concrete is higher than that of natural sand due to the presence of many materials (such as cement, sand, and gravel) with varying densities. Therefore, the density of MRPC (recycled concrete) increases as the proportion of crushed concrete utilized increases.

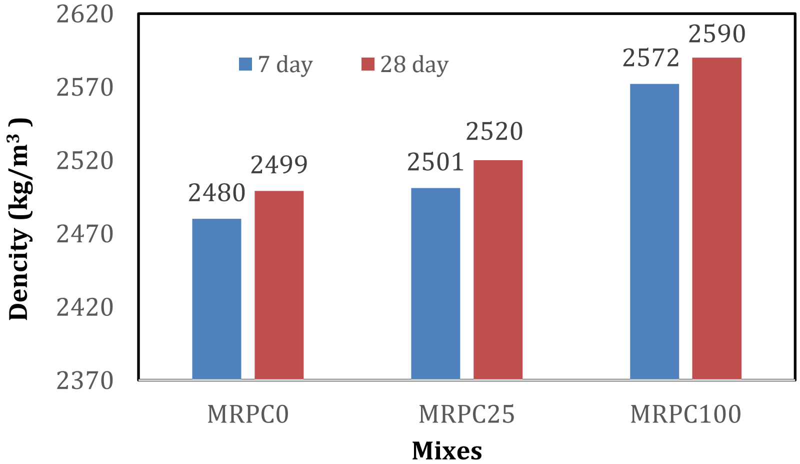

Figure 5. Density with different ratios of crushed concrete aggregate at ages 7 and 28 days of curing.

Table 10. Results of density of MRPC (kg/m^3).

No.	Mixes	Cube 1	Cube 2	Cube 3	Average for Age 7 day	Cube 1	Cube 2	Cube 3	Average for Age 28 day
1	MRPC0	2481	2480	2479	2480	2496	2500	2501	2499
2	MRPC25	2501	2502	2500	2501	2518	2522	2520	2520
3	MRPC100	2574	2570	2572	2572	2592	2591	2588	2590

3.3 Flexural strength

According to **Table 11** and **Fig. 6.**, because crushed concrete absorbs more water than regular aggregate, using it as a replacement for all the aggregate in a concrete mix reduces the material's flexural strength. Recycling concrete aggregates also alters the concrete's characteristics (CS. and fr.) due to its surface irregularities.

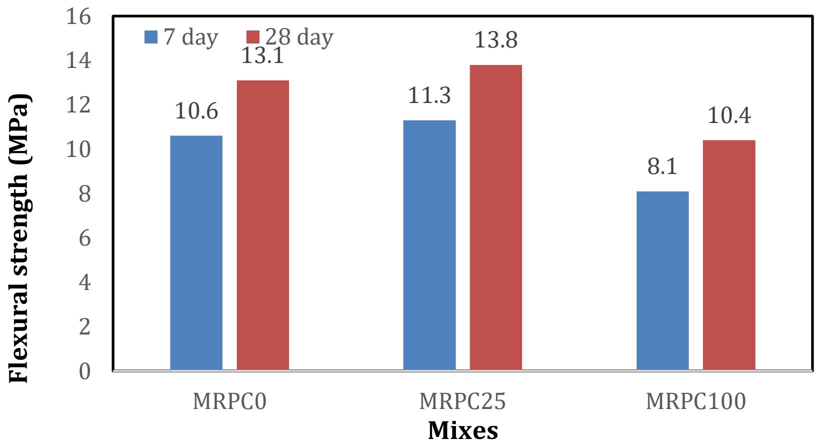

Figure 6. Flexural strength with different ratios of crushed Concrete aggregate at age 7 and 28 days of curing.

Table 11. Flexural strength test results (MPa).

No.	Mixes	prism 1	prism 2	Average for Age7 day	prism 1	prism 2	Average for Age 28 day
1	MRPC0	10.5	10.7	10.6	12.9	13.3	13.1
2	MRPC25	11.6	11	11.3	13.4	14.2	13.8
3	MRPC100	7.9	8.3	8.1	10.6	10.2	10.4

4. CONCLUSIONS

As a result of the characteristics of modified reactive powder concrete, the most prominent of which is its height strength, this research focused on producing modified reactive powder concrete mixtures sustainably to reduce environmental pollution through recycling crushed concrete and using silica fume. Based on the experimental results,

- By utilizing reused crushed concrete as coarse aggregate in RPC, a compressive strength of 115 MPa can be attained. This contradicts the model, suggesting that RPC's high compressive strength is due to the lack of coarse aggregate, as mentioned in the reference.

- 25% of the sand's weight was replaced with crushed concrete, which improved the mechanical strength of MRPC.
- The flexural strength of modified reactive powder concrete (MRPC) reduces according to the increase in replacement ratio of crushed concrete, in comparison to the reference mixture. The increased surface area and non-uniform shape of the recycled crushed concrete resulted in a 16.86% and 10.57% increase in the compressive strength of MRPC (with 25% crushed concrete) compared to the normal reactive powder concrete after 7 and 28 days of testing, respectively .
- The compressive strength decreased by 12.04% at seven days and 18.2% at 28 days when 100% crushed concrete was substituted for sand.
- Compared to the reference mixture, incorporating 25% crushed concrete increases flexural strength by 6.6% and 5.3% at 7 and 28 days.
- Compared to the reference mixture, flexural strength decreases by 23.5% and 20.6% when 100% crushed concrete is used.
- The Increase in flexural strength when using 25% due to the mixture became more dense and the void is less than using 100% and the additional mortar in crushed concert may be contribute to the interaction with cement which leads to an increase in strength and decrease when using 100% due to increased absorption and voids of the mixture .
- Utilizing locally available materials can create economically viable Modified Reactive Powder Concrete (MRPC).

NOMENCLATURE

Symbol	Description	Symbol	Description
b	The average width of the specimen (mm).	L	The average length of the specimen (mm).
CS	The compressive strength in (MPa)	MRPC	Modified Reactive powder concrete
CS	The compressive strength	OPC	Ordinary Portland cement
CSH	calcium silicate hydrates	P	The maximum applied load indicated by the tested machine (N).
d	The average depth of the specimen (mm).	RPC	Reactive powder concrete
D	The density of the specimen in (gm/cm^3) or (kg/m^3)	SP	Superplasticizer
f_r	The flexural strength (MPa).	v	The volume of the specimen in (m^3 or mm^3)

Acknowledgements

This work was supported by the Department of Civil Engineering, College of Engineering, University of Baghdad.

Credit Authorship Contribution Statement

Rusul Hussain Saeed: Writing – original draft, Validation, Methodology.
Nada Mahdi Fawzi: Review & editing, Validation, Proof reading.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Abbas, Z.K., and Abd, S.K., 2021. Study of using of recycled brick waste (RBW) to produce environmental friendly concrete: A review. *Journal of Engineering*, 27(11), pp. 1–14. https://doi.org/10.31026/j.eng.2021.11.01.

Ahmed, L.A., Hassan, S.S., and Al-Ameer, O.A., 2017. Ultra-high performance reinforced by polypropylene fiber concrete made with recycled coarse aggregate. *Kufa Journal of Engineering*, 8 (3), pp. 128-141.

Al-Attar, T.S., Ali, A.S., and Al-Numan, B.S., 2019. The effect of coarse aggregate inclusion on the performance of reactive powder concrete exposed to oil products. In IOP Conference Series: Materials Science and Engineering, IOP Publishing, P. 12044. https://doi.org/10.1088/1757-899X/579/1/012044.

Aliabdo, A.A., Abd-Elmoaty, A.E.M., and Hassan, H.H., 2014. Utilization of crushed clay brick in concrete industry. *Alexandria Engineering Journal*. 53(1), pp. 151–168. https://doi.org/10.1016/j.aej.2013.12.003.

Amouri, M. S., and Fawzi, N.M., 2022. The effect of different curing temperatures on the properties of geopolymer reinforced with micro steel fibers. *Engineering, Technology & Applied Science Research*, 12 (1), pp. 8029–8032. https://doi.org/10.48084/etasr.4629.

ASTM C109/C109M, 2020. Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens), ASTM International.

ASTM C1240, 2015. Standard Specification for Silica Fume Used in Cementitious Mixtures. ASTM International.

ASTM C128, 2015. Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate. https://doi.org/10.1520/C0128-1.

ASTM C293. 2016. Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading). https://doi.org/10.1520/C0293_C0293M-16.

ASTM C29M, 2009. Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate.ASTM International.

ASTM C494/C494M, 2015. Standard Specification for Chemical Admixtures for Concrete. ASTM International.

ASTM C684, 2003. Standard Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens. ASTM International.

Bederina , M., Gotteich, M., Belhadj, B., Dheily, R.M., Khenfer, M.M., and Queneudec, M., 2012. Drying shrinkage studies of wood sand concrete-effect of different wood treatment. *Construction and Building Materials*, 36, pp. 1066–1075. https://doi.org/10.1016/j.conbuildmat.2012.06.010.

Borg, R.P., Hajek, P., and Fernandez Ordonez, D., 2018. Sustainable concrete: Materials and structures. *IOP Conference Series: Materials Science and Engineering*, 442, 011001. https://doi.org/10.1088/1757-899X/442/1/011001.

Fawzi, N.M., and Agha, A. S.T., 2012. The effect of curing types on compressive strength of high performance concrete. *Journal of Engineering*, 18 (07), pp. 768–783. https://doi.org/10.31026/j.eng.2012.07.01.

Gawad, M.A., and Fawzi, N.M., 2021. Use of thermostone waste aggregates for internal curing of reactive powder concrete. *In IOP Conference Series: Earth and Environmental Science,* IOP Publishing, 877 (2021) 012043. https://doi.org/10.1088/1755-1315/877/1/012043.

Hasan, S.S., 2022. Influence of waste concrete and glass recycled on the strength properties of green reactive powder concrete. *Journal of Engineering*, 28(12), pp. 56–66. https://doi.org/10.31026/j.eng.2022.12.04.

Hussain, Z.A., and Aljalawi, N., 2022. Effect of sustainable glass powder on the properties of reactive powder concrete with polypropylene fibers. *Engineering, Technology & Applied Science Research*, 12(2), pp. 8388-8392. https://doi.org/10.48084/etasr.4750.

Hussain, Z.A., and Aljalawi, N.M.F., 2022. Behavior of reactive powder concrete containing recycled glass powder reinforced by steel fiber. *Journal of the Mechanical Behavior of Materials*, 31(1), pp. 233-239. https://doi.org/10.1515/jmbm-2022-0025.

Hussain, Z.A., and Aljalawi, N.M.F., 2022. Some properties of reactive powder concrete contain recycled glass powder. *Journal of Engineering*, 28(10), pp. 42-56. https://doi.org/10.31026/j.eng.2022.10.04.

IQS. No.1703, 2018. Used Water in Concrete. Iraqi Standard Specification.

IQS. No.45, 1984. Aggregate from Natural Sources for Concrete and Construction. Iraqi Standard Specification.

IQS. No.5, 2019. Portland cement. Iraqi Standard Specification.

Iraqi Reference Guide No. 274, 1992. Methods for Concrete tests for determining the density of hardened concrete. Ministry of Planning, Central Agency for Standardization and Quality Control. pp. 1-7.

Iraqi Reference Guide No. 500, 1994. Sulfate Content Test of Aggregate. Central Organization for Standardization and Quality Control, Baghdad.

Jaafar, A.S., Abbas, Z.K., and Allawi, A.A., 2023. Studying sustainable concrete block efficiency production. A review. *Journal of Engineering*, 29 (09), pp. 134–149. https://doi.org/10.31026/j.eng.2023.09.10.

Khalil, W. I., 2012. Some properties of modified reactive powder concrete. *Journal of Engineering and Sustainable Development*, 16 (4), pp. 66–87.

Kou, S., 2006. *Reusing recycled aggregates in structural concrete*. Ph.D. thesis, Department of Civil and Structural Engineering, Hong Kong Polytechnic University.

Kou, S.C. and Poon, C.S., 2012. Enhancing the durability properties of concrete prepared with coarse recycled aggregate. *Construction and Building Materials*, 35, pp. 69-76. https://doi.org/10.1016/j.conbuildmat.2012.02.032.

Mayhoub, O.A., Nasr, E.S.A.R., Ali, Y.A., and Kohail, M., 2021. The influence of ingredients on the properties of reactive powder concrete: A review. *Ain Shams Engineering Journal*, 12, (1), pp. 145–158. https://doi.org/10.1016/j.asej.2020.07.016.

Memon, S.A., Bekzhanova, Z., and Murzakarimova, A., 2022. A review of improvement of interfacial transition zone and adherent mortar in recycled concrete aggregate. *Buildings*, 12(10), p. 1600. https://doi.org/10.3390/buildings12101600.

Muhsin, Z.F., and Fawzi, N.M., 2021. Effect of fly ash on some properties of reactive powder concrete. *Journal of Engineering*, 27(11), pp. 32–46. https://doi.org/10.31026/j.eng.2021.11.03.

Muhsin, Z.F., and Fawzi, N.M., 2021. Effect of nano calcium Carbonate on some properties of reactive powder concrete. *In IOP Conference Series: Earth and Environmental Science*, 856(1), P. 012026). IOP Publishing. https://doi.org/10.1088/1755-1315/856/1/012026.

Nagataki, S., Gokce, A., Saeki, T., and Hisada, M., 2004. Assessment of recycling process induced damage sensitivity of recycled concrete aggregates. *Cement and Concrete Research*, 34 (6), pp. 965–971. https://doi.org/10.1016/j.cemconres.2003.11.008.

Richard, P., and Cheyrezy, M.H., 1994. Reactive powder concretes with high ductility and 200-800 MPa compressive strength. *Special Publication*, 144, pp. 507–518. https://doi.org/10.14359/4536.

Shi, C., Li, Y., Zhang, J., Li, W., Chong, L., and Xie, Z., 2016. Performance enhancement of recycled concrete aggregate–a review. *Journal of cleaner production*, *112*, pp. 466-472. https://doi.org/10.1016/j.jclepro.2015.08.057.

Sri Ravindrarajah, R., Loo, Y.H., and Tam, C.T., 1987. Recycled concrete as fine and coarse aggregates in concrete. *Magazine of Concrete Research*, 39 (141), pp. 214–220. https://doi.org/10.1680/macr.1987.39.141.214.

Verian, K.P., Ashraf, W., and Cao, Y., 2018. Properties of recycled concrete aggregate and their influence in new concrete production. *Resources, Conservation and Recycling*, 133, pp. 30-49. https://doi.org/10.1016/j.resconrec.2018.02.005.

Yazıcı, H., Yardımcı, M.Y., Aydın, S., and Karabulut, A.Ş., 2009. Mechanical properties of reactive powder concrete containing mineral admixtures under different curing regimes. *Construction and Building Materials*, *23*(3), pp.1223-1231. https://doi.org/10.1016/j.conbuildmat.2008.08.003.

Zheng, C., Lou, C. Du, G. Li, X. Liu, Z., and Li, L., 2018. Mechanical properties of recycled concrete with demolished waste concrete aggregate and clay brick aggregate. *Results in Physics*, 9, pp. 1317–1322. https://doi.org/10.1016/j.rinp.2018.04.061.

تأثير الخرسانة المكسرة على بعض خصائص خرسانة المساحيق الفعالة المعدلة

رسل حسين سعيد*، ندى مهدي فوزي

قسم الهندسة المدنية، كلية الهندسة، جامعة بغداد، بغداد، العراق

الخلاصة

نتيجة زيادة كمية مخلفات الخرسانة الناتجة من عمليات الهدم وتكسير منتجات الخرسانة اثناء عملية النقل والانتاج زادت الحاجة الى التخلص من هذه المخلفات بالاضافة الى اهمية الحفاظ على الموارد الطبيعية، فقد بدأ العمل باستغلال هذه المخلفات كبديل جزئي للركام. حيث يعرض هذا البحث نتائج دراسة استخدام الخرسانة المكسرة كركام خشن والذي تم الحصول عليه وجمعه من مخلفات نماذج الفحص لاحدى مشاريع الطرق في مدينة بغداد حيث تم تكسيره بمقاس اصغر من 10 ملم وتم استخدام الالياف المايكروية الفولاذية بنسبة 1% من حجم الخرسانة والخرسانة المكسرة بنسبة 25% ونسبة 100% تم استبدالها من وزن الرمل بالخلطة المرجعية لدراسة بعض خصائص خرسانة المساحيق الفعالة المرجعية والمعدلة والتي تتضمن الكثافة ومقاومة الانضغاط ومقاومة الانثناء عند استخدام 25% من الخرسانة المكسرة بدل من الرمل بالخلطة المرجعية وجد ان مقاومة الانضغاط لخرسانة المساحيق الفعالة المعدلة زادت بنسبة 16.86% وبنسبة 10.57% وايضا زادت مقاومة الانثناء بنسبة 6.6% وبنسبة5.3% بعمر 7 ايام و28 يوم على التوالي .عند استخدام 100 % من الخرسانة المكسرة بدل من الرمل بالخلطة المرجعية وجد نقصان بمقاومة الانضغاط بنسبة 12.04% وبنسبة 18.2% ونقصان بمقاومة الانثناء بنسبة 23.5% وبنسبة و20.6%لعمر 7 ايام و28 على التوالي.

الكلمات المفتاحية: خرسانة المساحيق الفعالة، كونكريت مكسر، مقاومة الانضغاط، مقاومة الانثناء، الكثافة.