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Assessment of Reactive-Powder-Concrete Strength Using Waste Brick Sand Subjected to Internal and External Curing Conditions

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ABSTRACT

The discarded construction waste materials can be re-used as a new source of aggregate. These wastes, such as clay bricks, can be managed by recycling them into new construction materials after being collected, dried, crushed, and ground for use in concrete production. This study aims to investigate the feasibility of using recycled brick waste as sand to produce sustainable reactive-powder-concrete (R-P-C), and to assess the influence of various curing techniques on its mechanical strength. In this study, two sustainable R-P-C mixtures (BM15 and BM30) were prepared, containing 15% and 30% brick waste as sand (BS), as a volume replacement for Sika sand in the reference mixture (RM). The mixtures were cured under three curing techniques: coating (C), high temperature + normal curing (HN) with three cycles: 1 day (HN1), 2 days (HN2), and 3 days (HN3) of immersion in (50 ± 2)°C water plus normal curing until the age of testing, and autogenous + normal curing (AN), in addition to normal curing (N) as a control curing technique. The results indicated that the high temperature + normal curing was the most effective curing method for all mixtures, with improvements of 16.03%, 17.45%, and 18.53% for HN1, HN2, and HN3, respectively, in compressive strength at 28 days for RM. Additionally, results showed that sustainable R-P-C mixtures exhibited higher compressive strength than RM, with improvements up to 15.39% at 28 days, accompanied by proportional improvements in splitting tensile and flexural strengths for all mixtures under all curing regimes. These findings indicate that recycled brick as sand, when combined with proper curing, can produce sustainable R-P-C mixtures with high mechanical strength.

Keywords: Reactive powder concrete, Sustainable reactive powder concrete, External curing, Internal curing, Recycled brick sand.

1. INTRODUCTION

Reactive-powder-concrete (R-P-C) is a high-performance-concrete with high durability and good mechanical properties, developed in France during the 1990s (**Abdulrahman et al., 2018)**. R-P-C comprises very fine-powders, including Portland cement, sand, silica fume, and quartz

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powder. Superplasticizers are also used to enhance the workability of R-P-C and reduce the W/C ratio. Additionally, steel fibers are sometimes incorporated **(Danha et al., 2013; Soutsos et al., 2015)**. The incorporation of steel fibers is beneficial because R-P-C exhibits brittle failure under both compressive and tensile stresses **(Muhsin and Fawzi, 2021)**. Fibers can improve the performance of concrete under both static and dynamic loads **(Abd and Ahmed, 2021)**. In particular, short-length fibers help improve the quasi-brittle behavior and tensile damage resistance of concrete **(Singh, 2017; Mishra et al., 2017)**. All powdered materials are required to have a particle size of < 600 μm, this fine particle size can be extensively utilized in structural engineering applications, particularly in areas subjected to high loads, high cutting forces, and tensile stresses (**Abdulrahman et al., 2018)**. **(Giri and Priyadarshini, 2022; Zamora-Castro et al., 2021; Cheng et al., 2022)** and several other researchers have explored alternative materials to replace conventional aggregates in concrete. One of these alternative materials is brick waste, which is produced in large amounts from the construction process and demolition activities. The percentage of brick waste ranges between (24-30) % of the total waste produced during demolition, representing the largest percentage of demolition remains **(Abaas and Abbas, 2022)**. (**Bayu et al., 2025; Abdullah et al., 2021)** and several other studies have investigated the potential of utilizing brick waste as a replacement for conventional aggregate in concrete production, as an economical and effective option for enhancing sustainability, protecting the raw materials and the environment, and reducing dead loads and transportation costs. Brick waste can work as an internal curing agent, and for a more efficient internal curing process, the internal curing material should have a high absorption capacity and be able to easily release the absorbed-water when subjected to pressure **(Golias et al., 2012)**. **(Naceri and Hamina, 2009)** observed that demolished brick-aggregate exhibited increased water absorption, making it highly suitable for internal curing. The mechanism relies on the fact that when brick-aggregate is mixed with water, its highly porous structure absorbs and retains a significant amount of water. During the cement hydration process, the absorbed water is gradually released, providing a continuous supply of moisture to the cement matrix and enhancing the hydration process **(Rasheed and Mahmmod, 2013)**. **(Ahmed et al., 2024; Moujoud et al., 2023; Xu et al., 2024)** have reported that utilizing brick waste as a replacement for fine-aggregate in concrete leads to a greener environment.

Additionally, many studies have demonstrated that the inclusion of brick waste enhances the concrete elastic modulus as well as its compressive, flexural, and tensile strengths **(Bayu et al., 2025)**. **(Rani and Jenifer, 2016; Irfan et al., 2017; Vaitheki et al., 2019)** evaluated the suitability of brick waste as crushed aggregate in the production of concrete at various replacement levels. **(Kumar et al., 2018)** conducted an investigation on partial replacement of (0, 22, 25, 28, and 31)%. The results indicated that the highest tensile strength was achieved at 28% replacement. **(Abbas and Abbood, 2021)** studied the effects of replacing (10, 20, and 30)% of normal sand with brick sand. Their results showed that the mechanical properties (compressive, flexural and tensile strengths) improved, with improvement values reaching up to (12.5, 12.6, and 11.1)%, respectively, at 20% replacement level. While many research studies have explored the re-use of demolition waste in conventional concrete, there are limited studies focusing on the use of recycled brick waste as a fine aggregate in R-P-C. Moreover, the influence of different curing regimes (especially combined curing) on the mechanical strength of the sustainable R-P-C mixtures containing recycled materials remains under-investigated. This research aims to assess the influence of replacing sand with recycled brick waste as sand under different curing regimes on the compressive, tensile, and flexural strengths of R-P-C mixtures. Ultimately, the research investigates whether sustainable R-P-C can achieve or enhance the mechanical strength of reference R-P-C, thus offering an eco-friendly and technically viable construction material.

2. EXPERIMENTAL INVESTIGATION

A summary of the experiment is presented in **Fig. 1**.

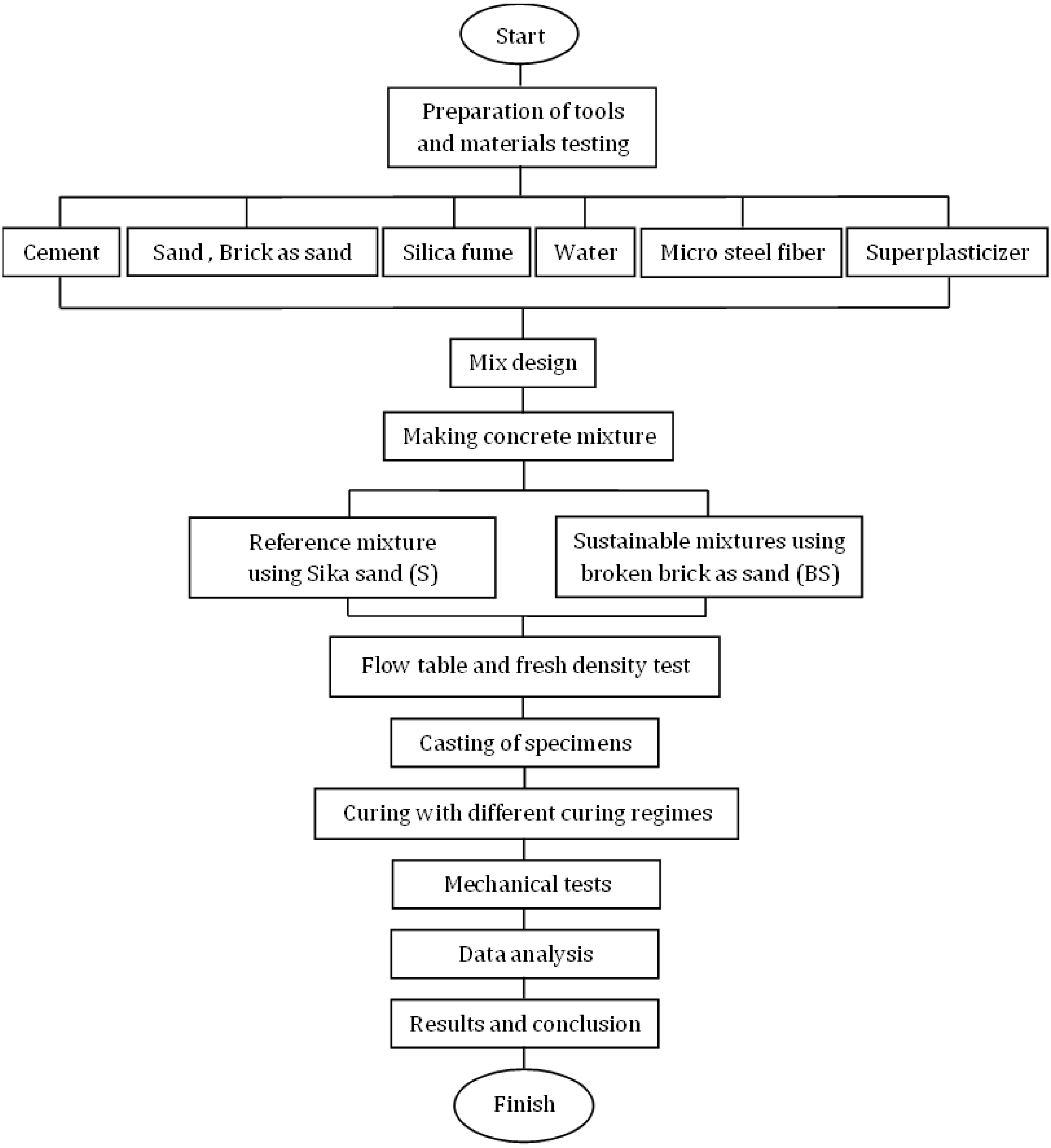


Figure 1. Research flow chart

2.1 Ingredients

- Cement (C): Portland ordinary-cement (CEM 1-42.5 R), conforming to **(IQS No.5, 2019)**.
- Sand: Two types of sand were used in this research. The first is Sika quartz sand (S) (< 0.6 mm), conforming to **(IQS No.45, 1984)**, with bulk density and absorption values equal to 1500 kg/m^3 and 1.2%, respectively. The second is recycled brick as sand (BS), produced by

grinding broken bricks to a particle size of < 0.6 mm, with bulk density, specific gravity, and absorption values equal to 1160 kg/m^3, 2.22, and 16%, respectively. The SO_3 content was 0.2% for Sika sand, and 0.01% for brick sand (both within IQS limits (≤ 0.5%)).

• Silica fume (SF): Amorphous submicron powder silica fume, comply with **(ASTM C1240, 2020)**.

The chemical composition of cement, and silica fume are presented in **Table 1**, while their physical characteristics are presented in **Table 2**. All tests was conducted at Building Research Centre (BRC).

• Micro steel fibers (MSF): Straight steel fibers with a length of 13mm and nominal diameter of 0.2mm, resulting in an aspect ratio (L/d) of 65.

• Superplasticizer (SP): SikaViscocrete-180GS-type F&G (high range admixtures, water reducing, and retarding) with a density of 1.070 ± 0.02 g/cm^3 and a PH value of (4-6), conforming to **(ASTM C494/C494M, 2017)**.

• Water (W): Tap water conforming to **(IQS No. 1703, 2018)**, used for both mixing and curing.

Table 1. Chemical composition of ingredients.

Chemical composition	Cement	(IQS No. 5, 2019) limits	Silica fume	(ASTM C1240, 2020) limits
CaO	62.0	-	0.12	-
SiO_2	21.0	-	92.7	≥ 85.0
Al_2O_3	5.3	-	0.22	-
MgO	3.1	≤ 5.0%	0.13	-
Fe_2O_3	3.4	-	0.1	-
SO_3	2.1	2.8% if C_3A > 3.5%	-	-
Moisture Content	-	-	0.7	≤ 3.0
LOI	2.7	≤ 4.0%	2.8	≤ 6.0

Table 2. Physical characteristics of ingredients.

Physical characteristics	Cement	(IQS No. 5, 2019) limits	Silica fume	(ASTM C1240, 2020) limits
Specific surface area (m^2/kg)	286 m^2/kg	≥ 280 m^2/kg	16 m^2/kg	≥15 m^2/kg
Specific gravity	3.15	-	2.2	-
Compressive strength (MPa)	2 days: 21.5 & 28 days: 45.7	2 days ≥ 20 & 28 days ≥ 42.5	-	-
Strength activity index (%)	-	-	120	≥ 105

2.2 Design and Preparation

2.2.1 Strength Design and Concrete Mixes

The reactive-powder-concrete (R-P-C) was produced by the recommendations of **(Richard and Cheyrezy, 1995; Khreef and Abbas, 2021; Luti and Abbas, 2024)** in addition to several trial mixes.

Two types of mixtures were prepared for this research: a reference mixture (RM), containing 100% Sika sand, and sustainable mixtures (BM15 and BM30), containing recycled brick sand as a partial replacement for sand, at replacement ratios of 15% and 30% (by volume). The W/Cm ratio was kept constant at 0.204 for all mixtures. The contents of the selected materials are presented in **Fig. 2** and **Table 3**. All mixtures' flow table results complied with

(ASTM C1437, 2020) with a target value of 110 ± 5 mm. The measured flow values of the reference and sustainable R-P-C mixtures ranged from 110 mm to 113.5 mm.

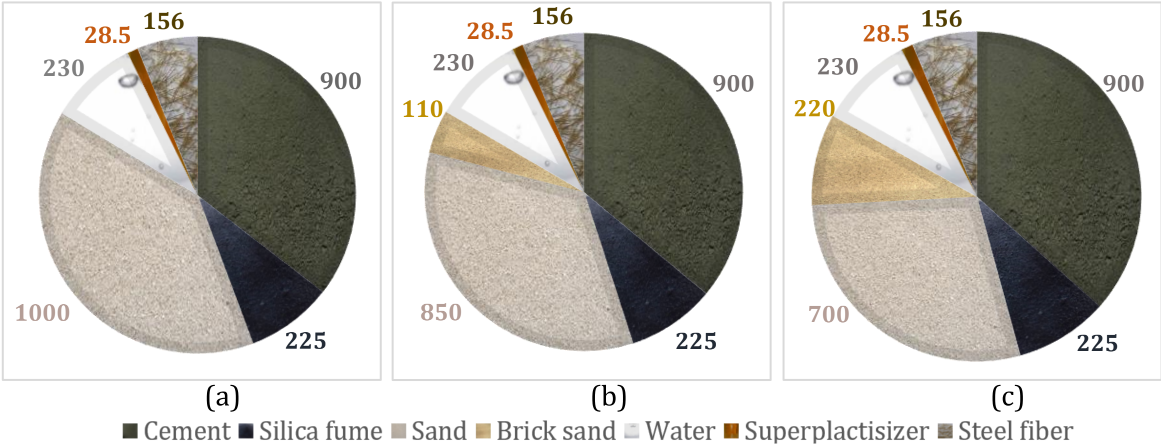


Figure 2. The ingredients and their proportions by (kg/m³) for (a) RM, (b) BM15, (c) BM30

Table 3. R-P-C mixtures proportions by (kg/m³)

Mix ID		S	BS	SF	C	W	W/Cm	SP	MSF
RM		1000	-	225	900	230	0.204	20.2	156
BM	**15%** (by volume)	850	110						
	30% (by volume)	700	220						

2.2.2 Mixing and Casting

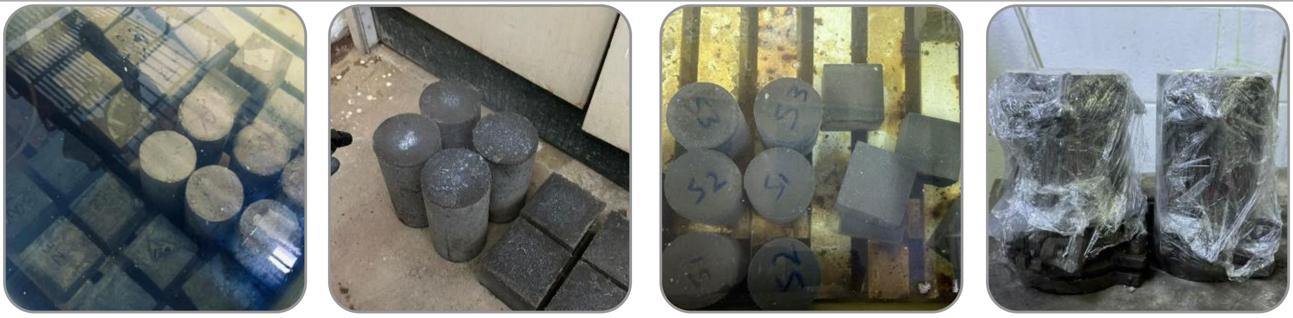
The mixing program was adopted from **(Richard and Cheyrezy, 1995; Khreef and Abbas, 2021; Luti and Abbas, 2024)**. To achieve the aims of this study, three types of molds were prepared: cubes (100x100x100)mm, cylinders (100x200)mm, and prisms (75x75x300)mm. All molds were compacted using a vibration table. The cubic molds were filled in two layers in accordance to **(BS EN 12390-2, 2019)**, while cylindrical and prismatic molds were also filled in two layers according to **(ASTM C192/C192M, 2019)**.

2.2.3 Curing

This study examined the influence of two types of curing (external and internal curing) on the mechanical strength of R-P-C. The external curing procedures are shown in **Fig. 3**.
The internal curing was achieved by partially replacing Sika sand with brick sand, as previously described.

2.2.3 Testing

Three mechanical tests (compressive, flexural, and splitting tensile strengths) were conducted. **Table 4** presents the details of these tests.
Based on the failure patterns illustrated in **Table 4**, it can be concluded that the failue mode of both cube and cylinder specimens are satisfactory, in accordance to **(BS EN 12390-2, 2019; ASTM C496/C496M, 2017)**, respectively. The observed cracks appeared approximately equally on all exposed faces, with little damage to the surfaces in contact with the testing platens.



Normal curing (N): Specimens were submerged in normal water at room temperature, in accordance to (**ASTM C192/C192M–19, 2019).**	**Coating (C):** Specimens were sprayed with Sika Antisol WB IQ) after casting as follows: • Upper surfaces: after 2 hours • Other surfaces: after one day (after removing the molds) in accordance with (**Hassoon and Abbas, 2024**).	**High temperature +Normal curing (HN)**: specimens were submerged in water at (50 ± 2)°C, then in normal water in accordance with (**Khreef and Abbas, 2021),** for various days as follows: •HN1:1 day in mold+ 1 day in 50°C water + 27 days normal curing. •HN2:1 day in mold+ 2 days in 50°C water + 26 days normal curing. •HN3:1 day in mold+ 3 days in 50°C water + 25 days normal curing.	**Autogenous + Normal curing (AN)**: Specimens were covered with plastic wrap at room temperature for 2 days, according to (**ASTM C684-99, 2003)** followed by submergion in normal water for 26 days in accordance with (**ASTM C192/C192M–19, 2019)**

Figure 3. External curing procedures.

Table 4. Test setup and tested specimen.

Testing specification and calculation formula		**Test setup**	**Tested specimen**
Compressive strength	**(BS EN 12390-2, 2019)** $$fc = \frac{P}{A}$$ f_c: Compressive strength (MPa) P: Maximum failure load (N) A: Cross-sectional area (mm^2)		

Splitting tensile strength	**(ASTM C496/C496M, 2017)** $ft = \frac{2P}{\pi\, lD}$ ft = Splitting tensile strength (MPa) P: Maximum failure load (N) l: Length (mm) D: Diameter (mm)		
Flexural strength	**(ASTM C293/C293M, 2016)** $fr = \frac{3\, PL}{2bd^2}$ f_r : Flexural strength (MPa) P: Maximum failure load (N) L = Span length (mm) b = Average specimen width (mm) d = Average specimen depth (mm)		

3. RESULTS AND DISCUSSIONS

The results of compressive, tensile, and flexural strengths for the reference and sustainable R-P-C mixtures are listed in **Table 5**.

3.1 Compressive Strength

The results of compressive strength for the reference R-P-C mixture under normal curing were equal to (76.5, 95.2, and 109.4) MPa at 7, 28, and 90 days, respectively, the 28 days strength exceeded the required compressive strength of 90 MPa. The effects of the external curing technique can be observed through the improvements in compressive strength, as presented in **Fig. 4**, with increases of (12.75, 16.03, 17.45, 18.53, and 11.05)% for R-C, R-HNI, R-HN2, R-HN3, and R-AN respectively, compared to normal curing for the reference mixture at 28 days.

The optimum improvement was achieved by adopting R-HN3, where specimens were immersed in water-bath at a temperature of (50 ± 2) °C for 3 days, followed by normal water-bath for 25 days. This can be attributed to the superiority of cement-hydration compounds when exposed to hot-water, which leads to a dense concrete-microstructure with a higher dry density. These findings are similar to previous studies, which also reported that high temperature curing results in the higher strength compared to other curing regimes, including **(Hiremath and Yaragal, 2017; Khreef and Abbas, 2021; Luti and Abbas, 2024; Hendi and Aljalawi, 2024)**.

Although the autogenous + normal curing achieved the lowest improvements, it effectively maintains water content without evaporation loss, thus enabling proper bonding and chemical reactions, as compatible with **(Khreef and Abbas, 2021)**. Also, this method is the easiest and most cost-effective compared to other curing methods, and does not require electricity.

The improvements of sustainable mixtures (BM15 and BM30) with different curing regimes are similar to those observed in the reference mixture, as presented in **Fig. 5** .

Table 5. Tests-lab results.

Mixture ID	Compressive strength (MPa)			Tensile strength (MPa)			Flexural strength (MPa)		
	7 days	28 days	90 days	7 days	28 days	90 days	7 days	28 days	90 days
R-N	76.5	95.2	109.4	7.562	8.219	9.452	8.299	10.328	11.902
R-C	86.1	107.4	124.4	8.337	9.037	10.487	9.231	11.540	13.352
R-HN1	87.2	110.5	127.3	8.458	9.226	10.667	9.364	11.706	13.578
R-HN2	88.4	111.8	129.5	8.564	9.366	10.828	9.481	11.851	13.784
R-HN3	89.9	112.9	131.2	8.715	9.522	11.054	9.646	12.058	14.069
R-AN	84.8	105.5	122.7	8.133	8.947	10.327	9.008	11.261	13.150
B15N	85.1	103.4	116.3	8.327	8.867	10.033	9.150	11.211	12.721
B15C	96.4	117.7	132.8	9.205	9.864	11.225	10.170	12.542	14.279
B15HN1	97.2	120.2	135.9	9.347	9.988	11.363	10.353	12.763	14.584
B15HN2	98.5	121.2	138.2	9.455	10.130	11.525	10.420	12.917	14.775
B15HN3	100.6	123.3	140.3	9.566	10.299	11.764	10.545	13.130	15.055
B15AN	94.7	115.6	130.9	9.005	9.678	11.012	9.932	12.247	14.005
B30N	86.1	104.1	116.5	8.488	9.072	10.166	9.368	11.334	12.765
B30C	97.6	118.8	133.7	9.520	10.211	11.498	10.450	12.723	14.438
B30HN1	98.4	121.2	136.5	9.528	10.310	11.614	10.516	12.934	14.737
B30HN2	100.0	122.5	138.6	9.686	10.419	11.707	10.713	13.131	14.903
B30HN3	102.3	125.1	141.3	9.783	10.646	12.021	10.887	13.346	15.222
B30AN	95.8	116.7	131.6	9.261	9.993	11.238	10.235	12.595	14.264

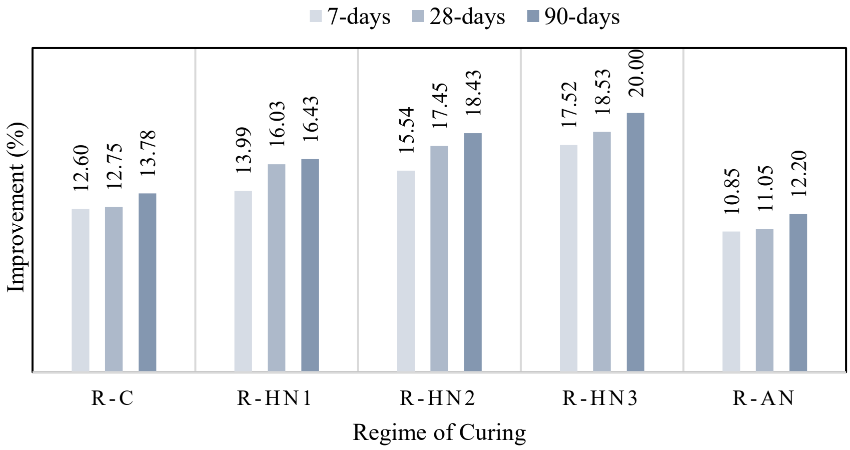
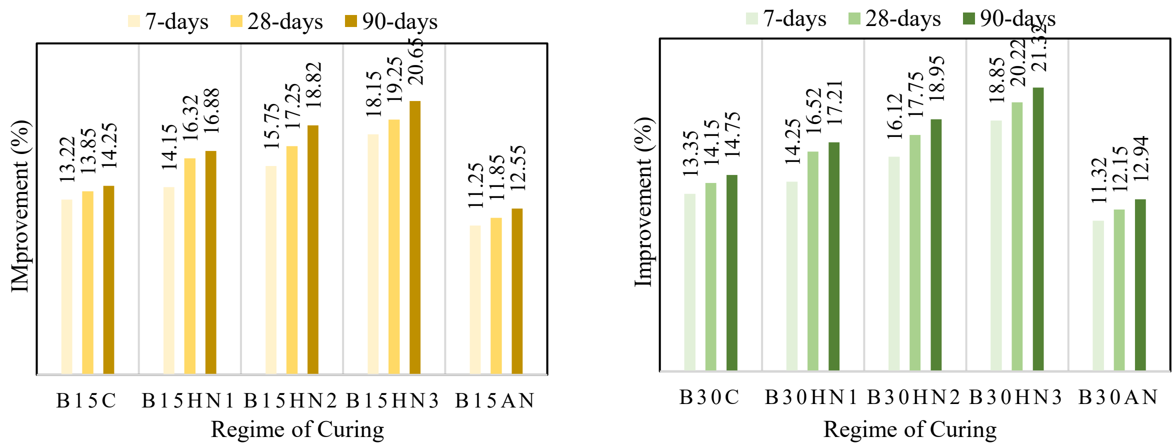


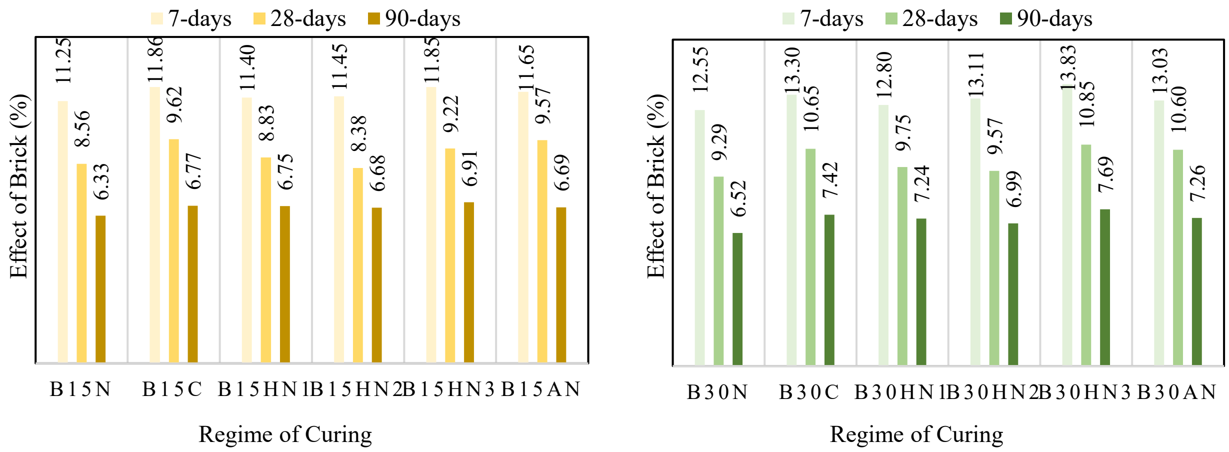
Figure 4. The compressive strength-improvements of RM under different curing regimes compared to normal curing

From the results presented in **Table 5**, it is apparent that the use of brick sand affects the compressive strength results, as shown in **Fig. 6**. These results are consistent with those reported by **(Wang et al., 2023; AlKarawi and Azzawy, 2024; Yu et al., 2024)**. The effect of brick sand can be explained by its clay-nature, which makes it highly absorbent, retaining up to 16%, and providing an additional water for internal curing, enhancing the hydration process of cement, promoting the formation of essential gel products, and leading to an improvement in compressive strength **(Belebchouche et al., 2024; Rasheed and Mahmmod, 2013)**. It should be noted that the most significant strength enhancement due to internal curing occurs at early ages, with an increase of approximately 15 ± 1% at 7 days for different curing methods, as presented in **Fig. 6**



(a) (b)

Figure 5. The improvements in compressive strength under different curing regimes compared to the normal curing method in (a) BM15, (b) BM30

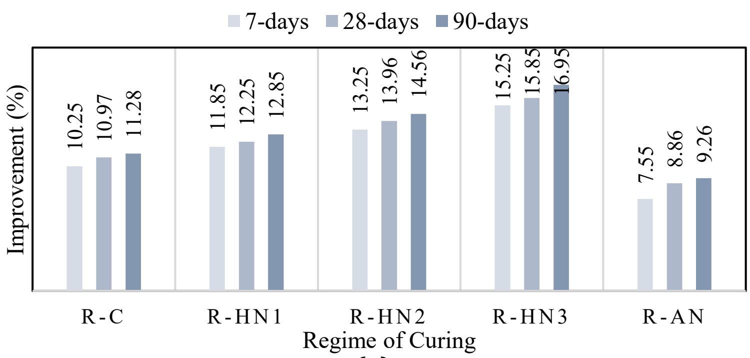


(a) (b)

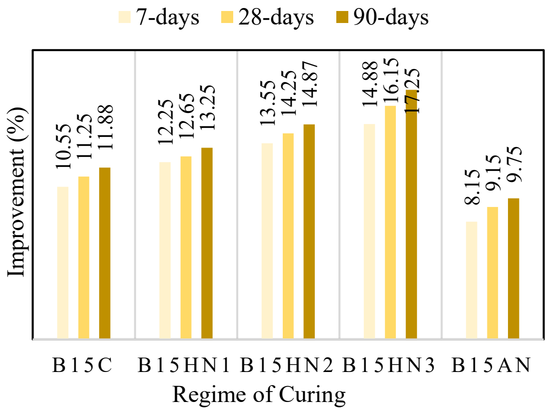
Figure 6. The effects of bricks on compressive strength in (a) BM15 , (b) BM30

3.2 Tensile and Flexural Strengths

The improvements in tensile and flexural strengths for the reference mixtures (RM) and sustainable mixtures (BM15 and BM30) followed the same trend as the compressive strength, as shown in **Figs. 7 and 8**, respectively. The effects of brick sand on tensile and flexural strengths also exhibited a similar behavior to that of compressive strength, as presented in **Figs. 9 and 10**, respectively.



(a)



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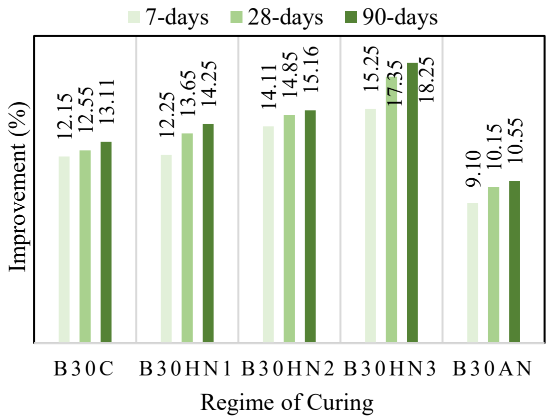
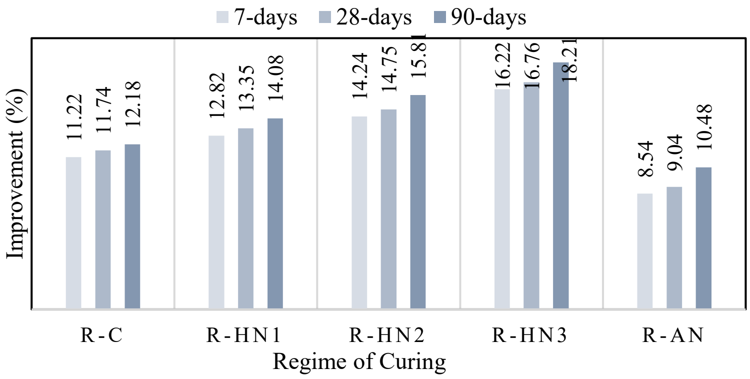
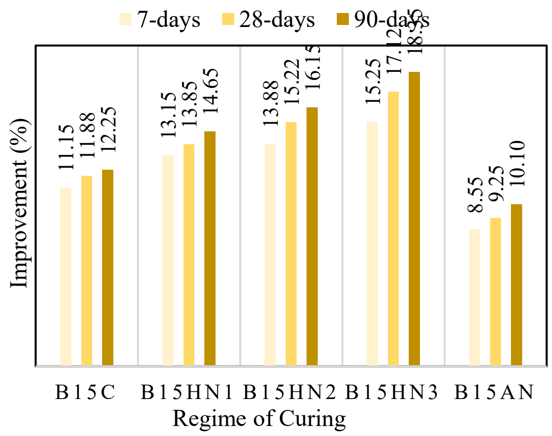


(c)

Figure 7. The improvements of tensile strength under different curing regimes compared to normal curing method in (a)RM, (b) BM15, (c) BM30



(a)



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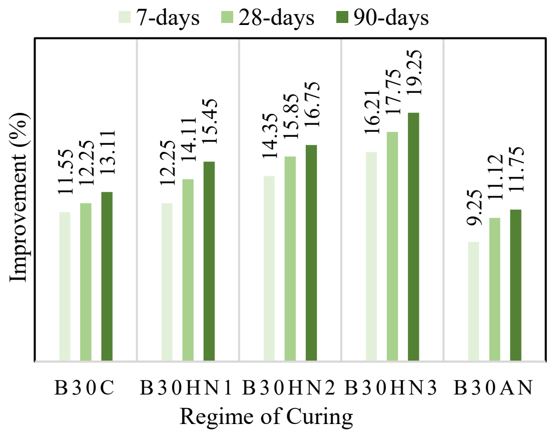

(c)

Figure 8. The improvements of flexural strength under different curing regimes compared to normal curing method in (a)RM, (b) BM15 , (c) BM30

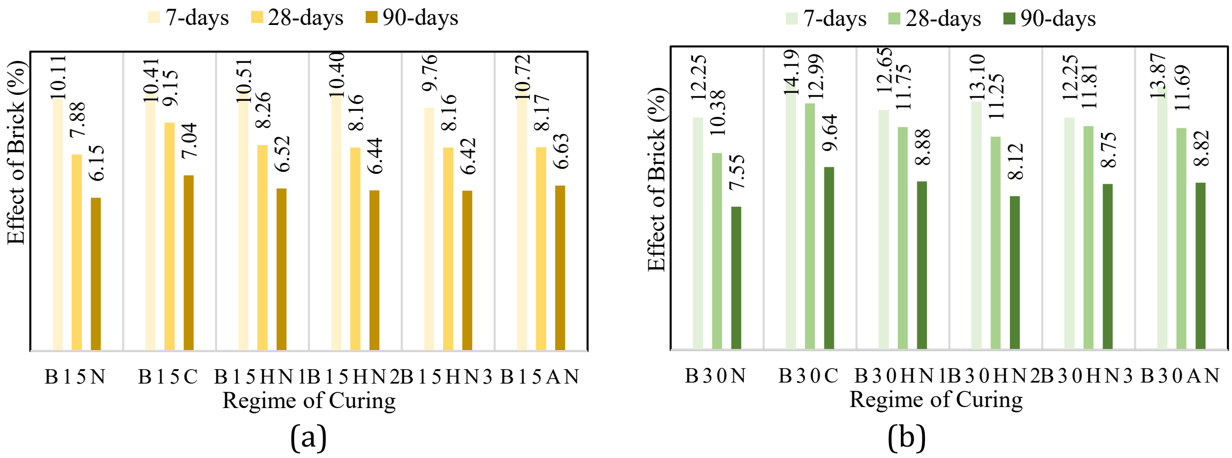

Figure 9. The effects of bricks on tensile 6strength in (a) BM15 , (b) BM30

4. CONCLUSIONS

Based on the collected data in this research, the following conclusions can be drawn:

1. The ability to produce a reference R-P-C with compressive strength of (95.2, 107.4, 110.5, 111.8, 112.9, and 105.5) MPa for normal (N), coating (C), high temperature + normal (HN1, HN2, and HN3), and autogenous + normal (AN) curing regimes respectively, at 28 days.
2. Using the recycled-waste-brick as a fine aggregate, as partial volume replacement of Sika sand by 15% and 30% in R-P-C improves its mechanical properties such as compressive, tensile, and flexural strengths.
3. The high temperature (50 ± 2)°C followed by normal curing method until 28 days resulted in the highest enhancements in compressive strength for the reference concrete mixture, up to (16.03, 17.45, and 18.53)% for R-HN1, R-HN2, and R-HN3, respectively, compared to normal curing, with similar effects in sustainable mixtures.
4. The sustainable R-P-C mixtures exhibited higher compressive strength compared to the reference mixture with improvements of (11.25, 11.86, 11.40, 11.45, 11.85, and 11.65)% at 7 days for B15N, B15C, B15HN1, B15HN2, B15HN3, and B15AN, respectively, compared to the reference mixture.
5. The combined effects of internal and external curing were more significant in sustainable R-P-C containing 30% brick sand for different curing regimes, with improvements up to (12.55, 13.30, 12.80, 13.11, 13.83, and 13.03)% at 28 days for B30N, B30C, B30HN1, B30HN2, B30HN3, and B30AN, respectively compared to the reference mixture.

In summary, this research aimed to assess the impact of recycled brick sand as a partial replacement for sand together with different curing regimes, on the compressive, tensile, and flexural strengths of R-P-C. Based on results the research aim was successfully achieved, as the sustainable mixtures which cured under various curing techniques, showed a significant improvements in the mechanical strengths, supporting the use of recycled materials in sustainable construction.

NOMENCLATURE

Symbol	Description	Symbol	Description
A	Area, mm².	f_t	Splitting tensile strength, MPa.
b	Width, mm.	l	Length, mm.
D	Depth, mm.	P	Maximum failure load, N.
f_c	Compressive strength, MPa.	D	Diameter, mm
f_r	Flexural strength, MPa.	π	Pi (mathematical constant ≈ 3.1416).

Credit Authorship Contribution Statement

All the authors contributed equally to the preparation of this article.

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

Abaas, T., and Abbas, Z.K., 2022. Production load–bearing concrete masonry units by using recycled waste crushed clay bricks: A review. *Journal of Engineering*, 28(10), pp. 13–27. https://doi.org/10.31026/j.eng.2022.10.02.

Abbas, Z.K., and Abbood, A.A., 2021. The influence of incorporating recycled brick on concrete properties. *IOP Conference Series Materials Science and Engineering*, 1067(1), P. 012010. https://doi.org/10.1088/1757-899x/1067/1/012010.

Abdullah, D.J., 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.

Abdulrahman, M., Al-Attar, A., and Ahmad, M., 2018. Effect of different curing conditions on the mechanical properties of reactive powder concrete. *MATEC Web of Conferences*, 162, P. 02014. https://doi.org/10.1051/matecconf/201816202014.

Abd, J., and Ahmed, I.K., 2021. The effect of low velocity impact loading on self-compacting concrete reinforced with carbon fiber reinforced polymers. *Engineering Technology & Applied Science Research*, 11(5), pp. 7689–7694. https://doi.org/10.48084/etasr.4419.

ACI 517.2R-87, 1992. Accelerated Curing of Concrete at Atmospheric Pressure.

Ahmed, J.K., Atmaca, N., and Khoshnaw, G. J., 2024. Building a sustainable future: An experimental study on recycled brick waste powder in engineered geopolymer composites. *Case Studies in Construction Materials*, 20. https://doi.org/10.1016/j.cscm.2024.e02863

AlKarawi, S.N., and Azzawy, H.J.A., 2024. Employment of brick residue in the production of a lightweight concrete. *Journal of Engineering*, 30(9), pp. 27–40. https://doi.org/10.31026/j.eng.2024.09.02.

ASTM C1240-20, 2020. Standard Specification for Silica Fume Used in Cementitious Mixtures.

ASTM C1437, 2020. Standard test method for flow of hydraulic cement mortar.

ASTM C192/C192M, 2019. Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory.

ASTM C293/C293M–16, 2016. Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading).

ASTM C494/C494M, 2017. Standard Specification for Chemical Admixtures for Concrete.

ASTM C496/C496M–17, 2017. Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

ASTM C684-90, 2003. Standard Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens.

Bayu, P.S., Mirdiana, F., Muhammad, R.I., and Roesdiana, T., 2025. Analysis of the effect of brick waste on concrete compressive strength. *Journal of World Science*, 4(1), pp. 42–55. https://doi.org/10.58344/jws.v4i1.1272.

Belebchouche, C., Temami, O., Khouadjia, M.L.K., Hamlaoui, S., Berkouche, A., and Chouadra, T., 2024. Recycling of brick and road demolition waste in the production of concrete. *Science, Engineering and Technology*, 4(2). https://doi.org/10.54327/set2024/v4.i2.154.

BS EN 12390-2, 2019, Testing Hardened Concrete – Part 2: Making and Curing Specimens for Strength Tests.

Cheng, Y., Shen, N., Yu, H., Feng, L., Yang, T., and Shen, J., 2022. Effect of recycled aggregate content on water permeability and pore structure of pervious concrete pavement. *Advances in Materials Science and Engineering*, pp. 1–11. https://doi.org/10.1155/2022/4220122.

Danha, L.S., Khalil, W.I., and Al-Hassani, H.M., 2013. Mechanical properties of reactive powder concrete (RPC) with various steel fiber and silica fume contents. *Engineering and Technology Journal*, 31(16), pp. 3090–3108. https://doi.org/10.30684/etj.31.16a.8.

Giri, J.P., and Priyadarshini, M., 2022. Quantification of non-conventional brick's characteristic compressive strength. *IOP Conference Series: Materials Science and Engineering*, 1236(1), P. 012003. https://doi.org/10.1088/1757-899X/1236/1/012003

Golias, M., Castro, J., and Weiss, J., 2012. The influence of the initial moisture content of lightweight aggregate on internal curing. *Construction and Building Materials*, 35, pp. 52-62. https://doi.org/10.1016/j.conbuildmat.2012.02.074.

Hassoon, H.R., and Abbas, Z.K., 2024. Analyzing lab and field compaction methods for designing roller compacted concrete pavements (RCCP) with different curing processes, *Engineering Technology & Applied Science Research*, 14(5), pp. 17488–17493. https://doi.org/10.48084/etasr.8614.

Hendi, S.I., and Aljalawi, N.M., 2024. Effect of various curing regimes on some properties of reactive powder concrete RPC. *Journal of Engineering*, 30(11), pp.21–38. https://doi.org/10.31026/j.eng.2024.11.02.

Hiremath, P.N., and Yaragal, S.C., 2017. Effect of different curing regimes and durations on early strength development of reactive powder concrete. *Construction and Building Materials*, 154, pp. 72–87. https://doi.org/10.1016/j.conbuildmat.2017.07.181.

IQS No. 1703, 2018. Iraqi Specification Limits for Water Used in Concrete and Mortar.

IQS No.45, 1984. Iraqi Specification Limits for Aggregates Test from Natural Sources for Concrete and Building Constructions.

IQS No.5, 2019. Iraqi Specification of Portland Cement

Irfan Z., Shafi S.Z., and Bhat A.A., 2017. Utilization of surkhi as a partial replacement of sand in concrete. *International Journal for Research in Applied Science & Engineering Technology*, 5, pp. 2090-2095.

Khreef, S.M., and Abbas, Z.K., 2021. The effects of using magnetized water in reactive powder concrete with different curing methods. *IOP Conference Series Materials Science and Engineering*, 1067(1), P. 012017. https://doi.org/10.1088/1757-899x/1067/1/012017.

Kumar M., Chandramauli A., and Ashutosh, 2018. Partial replacement of fine aggregates of fire bricks with fine aggregates in concrete. *International Journal of Civil Engineering and Technology (IJCIET)*, 9 pp. 961–968.

Luti, A.A., and Abbas, Z.K., 2024. The effect of different curing methods on the properties of reactive powder concrete reinforced with various fibers. *Engineering Technology & Applied Science Research*, 14(3), pp. 14225–14232. https://doi.org/10.48084/etasr.7072.

Mishra A., Chandraul K., and Singh M., 2017. Experimental study on steel fiber reinforced concrete. *International Research Journal of Engineering and Technology (IRJET)*, 4(11), pp. 895–898.

Moujoud, Z., Harrati, A., Manni, A., Naim, A., El Bouari, A., and Tanane, O., 2023. Study of fired clay bricks with coconut shell waste as a renewable pore-forming agent: Technological, mechanical, and thermal properties. *Journal of Building Engineering*, 68. https://doi.org/10.1016/j.jobe.2023.106107.

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.

Naceri, A., and Hamina, M.C., 2009. Use of waste brick as a partial replacement of cement in mortar. *Waste Management*, 29(8), pp. 2378–2384. https://doi.org/10.1016/j.wasman.2009.03.026.

Rani, M.U., and Jenifer, J.M., 2016. An experimental study on partial replacement of sand with crushed brick in concrete. *IJSTE - International Journal of Science Technology & Engineering*, pp. 316–317.

Rasheed, L.S. and Mahmmod, L.M.R., 2013. Clay brick waste as internal curing agent in normal weight concrete. *International Journal of Civil Engineering*, *2*(5), pp. 45-52.

Richard, P., and Cheyrezy, M., 1995. Composition of reactive powder concretes. *Cement and Concrete Research*, 25(7), pp. 1501–1511. https://doi.org/10.1016/0008-8846(95)00144-2.

Singh, H., 2017. Construction Practice. In: Steel Fiber Reinforced Concrete. *Springer Transactions in Civil and Environmental Engineering*. Springer, Singapore. https://doi.org/10.1007/978-981-10-2507-5_6

Soutsos, M.N., Millard, S.G., and Karaiskos, K., 2015. Mix design, mechanical properties, and impact resistance of reactive powder concrete (RPC). *In International RILEM Workshop on High Performance Fiber Reinforced Cementitious Composites in Structural Applications*, Champs-sur-Marne, France: RILEM Publications SARL, pp. 549–560.

Vaitheki, R., Sangeetha, K., Mallika, V., Chitra, P., and Rathna, M.S.T., 2019. Partial replacement of fine aggregate by using spent fire brick waste. *International Journal of Advance Research and Innovative Ideas in Education (IJARIIE)*, *5*, pp. 1505-1510.

Wang, Y., Wang, M., Wang, H., Dun, Z., and Ren, L., 2023. Experimental research on application of waste concrete powder–waste brick powder–cement grout for foundation reinforcement in mining goaf. *Materials*, 16(18), P. 6075. https://doi.org/10.3390/ma16186075.

Xu, Y., Liu, S., and Heisel, F., 2024. Towards sustainable construction waste management: Study on a disassemblable brick partition wall for the architecture, construction, and engineering industry. *Circular Economy*, 3(1). https://doi.org/10.1016/j.cec.2024.100078

Yu, P., Li, T., and Gao, S., 2024. Study on the effect of recycled fine powder on the properties of cement mortar and concrete. *Desalination and Water Treatment*, 319, P. 100481. https://doi.org/10.1016/j.dwt.2024.100481.

Zamora-Castro, S. A., Salgado-Estrada, R., Sandoval-Herazo, L. C., Melendez-Armenta, R. A., Manzano-Huerta, E., Yelmi-Carrillo, E., and Herrera-May, A. L., 2021. Sustainable development of concrete through aggregates and innovative materials: A review. *Applied Sciences*, 11(2), P. 629. https://doi.org/10.3390/app11020629

تقييم مقاومة خرسانة المساحيق الفعالة باستخدام مخلفات الطابوق كرمل تحت تاثير ظروف المعالجة الداخلية والخارجية

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الخلاصة

يمكن اعادة استخدام مخلفات البناء المهملة كمصدر جديد للركام. يمكن ادارة هذه المخلفات، مثل الطابوق الطيني، عن طريق اعادة تدويرها وتحويلها إلى مواد بناء جديدة بعد جمعها، تجفيفها، سحقها، وطحنها لاستخدامها في إنتاج الخرسانة. تهدف هذه الدراسة الى التحقق من امكانية استخدام مخلفات الطابوق المعاد تدويرها كرمل لانتاج خرسانة المساحيق الفعالة (R-P-C) المستدامة، وتقييم تاثير تقنيات المعالجة المختلفة على مقاومة الخرسانة الميكانيكية. في هذه الدراسة، تم إعداد خلطتين مستدامتين (BM15 وBM30) من خرسانة المساحيق الفعالة (R-P-C) يحتويان على 15٪ و30٪ من مخلفات الطابوق كرمل (BS)، كبديل حجمي لرمل سيكا المستخدم في الخلطة المرجعية (RM). تمت معالجة الخلطات باستخدام ثلاث تقنيات معالجة: الطلاء (C)، المعالجة بدرجة حرارة عالية ثم المعالجة العادية (HN) بثلاث دورات: يوم واحد (HN1) ، يومان (HN2)، وثلاثة أيام (HN3) من الغمر في ماء بدرجة حرارة (50 ± 2)°م تليها المعالجة العادية حتى عمر الفحص، والمعالجة الذاتية ثم المعالجة العادية (AN)، بالإضافة إلى المعالجة العادية (N) كتقنية معالجة مرجعية. ببينت النتائج أن تقنية المعالجة بدرجة حرارة عالية ثم المعالجة العادية كانت الطريقة الاكثر فعالية لجميع الخلطات، مع تحسينات بلغت 16.03%، 17.45%، و 18.53% لـHN1، HN2، وHN3، على التوالي، لمقاومة الانضغاط عند 28 يومًا بالنسبة للخلطة المرجعية. بالإضافة إلى ذلك، اظهرت النتائج أن خلطات R-P-C المستدامة حققت مقاومة انضغاط أعلى مقارنة بالخلطة المرجعية (RM)، مع تحسينات وصلت حتى 15.39% عند عمر 28 يومًا، مصحوبة بتحسينات متناسبة في مقاومة الشد الانشطاري والانحناء لجميع الخلطات الخرسانية تحت جميع أنظمة المعالجة. تشير هذه النتائج الى ان مخلفات الطابوق المعاد تدويرها كرمل، عند دمجها مع طريقة معالجة مناسبة، يمكن ان تنتج خلطات R-P-C مستدامة ذات مقاومة ميكانيكية عالية.

الكلمات المفتاحية: خرسانة المساحيق الفعالة، خرسانة المساحيق الفعالة المستدامة، المعالجة الخارجية، المعالجة الداخلية، مخلفات الطابوق المعاد تدويرها كرمل.