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Effect of Silica Fume on Some Properties of No-Fine Concrete with Recycled Coarse Aggregate

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ABSTRACT

No-fines Concrete is a lightweight porous concrete produced by omitting sand from the traditional concrete mix. It helps replenish the groundwater aquifer by directly allowing precipitation to seep into the earth thanks to its wide pores. This work studied the influence of partially replacing cement with silica fume (SF) with percentages of 5, 8, and 10% on some properties of no-fine concrete made using recycled coarse aggregate. The natural coarse aggregate (NA) was replaced with 10%, 20%, and 30% by crushed reactive powder concrete waste volume as recycled aggregate (RA). The optimum percentage was 10% RA with 10% SF, which indicated a substantial improvement in the no-fine concrete's strength, dry density, and water absorption compared to the design mix. The results exhibit increases in percentages in compressive strength, tensile strength, flexural strength, and dry density by 18%, 14%, 16%, and 1%, respectively, while exhibiting a decrease in water absorption by 5% at 28 days.

Keywords: No-fine concrete, Recycled coarse aggregate, Silica fume, Modulus of elasticity, Dry density.

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تأثير غبار السيليكا على بعض خواص الخرسانة الخالية من الركام الناعم الحاوية على الركام الخشن المعاد تدويره

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

الخلاصة

الخرسانة الخالية من الركام الناعم هي خرسانة مسامية خفيفة الوزن يتم انتاجها بازالة الرمل من مزيج الخرسانة التقليدية. بسبب مسامتها الكبيرة ، فهي تساعد في نفاذ مياه الأمطار بشكل مباشر إلى الأرض ، وإعادة ملئ طبقة المياه الجوفية. في هذا العمل, تم دراسة تأثير الاستبدال الجزئي للسمنت بغبار السليكا بنسب 5٪ ، 8٪ ، 10٪ على الخواص الميكانيكية للخرسانة الخالية من الركام الناعم و المحتوية على الركام الخشن المعاد تدويره. تم استبدال الركام الخشن الطبيعي بنسب 10%, 20% و 30% حجميا بمخلفات خرسانة المساحيق الفعالة كركام معاد تدويره. كانت النسب المثلى هي 10٪ ركام معاد تدويره مع 10٪ غبار سيليكا، مما أظهر تحسنًا ملحوظًا في خواص الخرسانة الخالية من الركام الناعم مقارنةً بالخلطة التصميمية. تظهر النتائج زيادة في النسب المئوية في قوة الانضغاط, قوة الشد, قوة الانثناء, و الكثافة الجافة بنسبة 18٪ و 14٪ و 16٪ و 1% على التوالي, بينما تظهر نقصان في الامتصاص بنسبة 5% بعمر 28 يوم.

الكلمات المفتاحية: الخرسانة الخالية من الركام الناعم, ركام خشن معاد تدويره, غبار السيليكا, معامل المرونة, الكثافة الجافة.

1. INTRODUCTION

No-fines concrete (NF) is a kind of lightweight concrete that consists only of cement, water, and coarse aggregate, excluding fine aggregate. This concrete type is called pervious, porous, or zero-fine concrete. The aggregate is typically a single size and held together with cement paste. Thus, large particles accumulated, each coated in a 1.3 mm cement paste layer. This type of concrete has more voids than normal concrete, resulting in a much lower strength. It has been employed in a variety of applications, particularly pavement. The interior and exterior walls of buildings are frequently made with no-fine concrete. No-fine concrete is also utilized in insulation and partition construction. NF can be used as rural road pavement with a design load of three tons. Furthermore, it could be used as a sub-base material in rigid or flexible pavements **(Alam et al., 2014; Salih and Fidel, 2016; Jiahao et al., 2019; Pradhan and Behera, 2022)**.

Materials that have been recycled are now favoured in construction as a replacement for aggregates because of their environmental benefits. From both an environmental and economic standpoint, recycled aggregate is superior to natural aggregate. An enormous amount of waste material would be produced by demolishing old reinforced concrete structures, posing a major environmental threat. The ideal solution to deal with the issue of waste concrete is to recycle a significant amount of it, specifically by employing recycled coarse aggregate concrete technology. The recycled aggregate quality exhibits significant variation based on the source concrete from which it is generated, such as water absorption, and as a result, affects the concrete properties **(Farhan, 2019; Ye et al., 2022; Abdullah et**

al.,2021; Khalid and Abbas, 2023; Sriravindrarajah et al., 2012; Parihar and Pastariya, 2020).

Silica Fume has already been acknowledged as a pozzolanic additive that effectively improves concrete's chemical durability and mechanical characteristics. SF is a byproduct substance that reduces waste. In the ferrosilicon and silicon industries, the smelting process provides non-crystalline silica. It can be used as a mixture at the concrete mixer, as packed powders or a slurry, or even as a factory-blended cement component. The utilization of SF has the potential to decrease cement consumption, thereby reducing CO_2 emissions **(Galishnikova et al., 2020; Jain and Pawade, 2015; Imam et al.,2018).**

Various researchers did several investigations to study the characteristics of no-fine concrete. **(Liu et al., 2018)** investigated how SF influences the characteristics of environmentally friendly previous concrete. The study employed the equivalent volume method to substitute cement with varying levels of SF (3%, 6%, 9%, and 12%). The results showed that the inclusion of SF had a notable positive impact on the durability and strength of previous concrete, particularly in terms of its resistance to freeze-thaw cycles. Employing the equal volume replacement technique resulted in small changes to the permeability and porosity of all previous concrete mixes, with variations in the SF content.

(Galishnikova et al., 2020) investigated the impact of incorporating RA as a substitute for NA in previous concrete at varying proportions from 0% to 100% with an increment of 25%. Additionally, the influence of introducing 5% and 10% of SF as a cement substitute on the characteristics of previous RA concrete was examined. The results demonstrated that a reduction in the characteristics of concrete occurred when the proportion of RA increased. The inclusion of SF resulted in a development in mechanical characteristics. It was described that the inclusion of 5% SF into concrete containing 50% RA increased by 5.5% and 4.2% in the density of hardened and fresh pervious concrete, respectively, and increased compressive, tensile, and flexural strengths by 100, 20, and 20.3%, respectively, at 28 days. **(Bhutta et al., 2013)** inspected the use of RA in producing porous concrete with appropriate strength and permeability. Styrene butadiene rubber-based re-dispersible polymer powder and latex were added to improve the strength characteristics of the mixtures. When RA was used instead of natural aggregate, the compressive strength of the porous concrete was reduced. However, polymer modification greatly enhanced the compressive strengths employing regular and RA by 57 and 79%, respectively.

This study examines the influence of using SF in the proportion of 5, 8, and 10% as a partial substitution of cement in NF with RA. The RA employed was demolished waste reactive powder concrete as a partial replacement of NA in the proportion of 10, 20, and 30 % to choose the optimum percentage. The characteristics examined in this study were compressive strength, tensile strength, flexural strength, dry density, and water absorption.

2. EXPERIMENTAL WORK

2.1 Materials

2.1.1 Cement

Ordinary Portland cement grade 32.5R was employed in this study under the brand name Al-Mas. The chemical and physical characteristics exhibited in **Tables 1 and 2.** have been according to the Iraqi Specification **(IQS No.5, 2019)**.

Table 1. The chemical properties of cement

Oxide compositions	Content %	Iraqi specification **(IQS No.5, 2019)** limits for ordinary Portland cement
SiO_2	21.62	-
CaO	61.55	-
Fe_2O_3	3.32	-
Al_2O_3	5.94	-
SO_3	2.25	SO_3 <2.8 If $C_3A > 3.5$
I.R	0.77	Max. 1.5
L.O.I*	1.07	Max. 4
MgO	2.85	Max. 5
Main Components		
C_3S	35.11	-
C_2S	35.07	-
C_4AF	10.09	-
C_3A	10.13	-

*Loss of Ignition

Table 2. The physical properties of cement

Physical Properties		Results	Specification ((**IQS No.5, 2019)** limits for ordinary Portland cement
Specific Surface Area (Blaine), (kg/m^2)		306	Min. 250
Setting Time	Initial (min)	106	Min. 45
	Final (hrs.)	4.83	Max. 10
Compressive Strength MPa at age	28 days	33.31	Min. 32.5
	2 days	11.25	Min. 10

2.1.2 Coarse aggregate

The coarse aggregates utilized in this study were NA from the Al-Nibaai quarry and RA from demolished waste reactive powder concrete, as shown in **Fig. 1**. Both were single-sized and per Iraqi specifications **(IQS No.45, 1984)**. The characteristics of the coarse aggregate employed in this study are demonstrated in **Table 3.**

Table 3. The properties of coarse aggregate

Property	RA	NA	Limit of Iraqi specification **(IQS No.45, 1984)**
Density kg/m^3	1510	1695	-
Absorption %	3	0.75	-
Sulfate content %	0.08	0.07	≤ 0.1
Specific gravity	2.5	2.68	-

Figure 1. Demolished reactive powder concrete aggregate

2.1.3 Silica fume

The SF utilized in this study is illustrated in **Fig. 2**. Its properties are presented in **Table 4.** It complies with ASTM C1240-20 **(ASTM C1240, 2020)**.

Table 4. Typical SF properties At 25°C

Property	Value
State	Sub-micron powder
Color	grey powder
Bulk density	620 kg/m^3
Specific gravity	2.3
Chemical Requirements	
(H_2O)	2%
(SiO_2)	92.83%
(L.O.I)	1.6%
Physical Requirements	
Oversize particles retained on a 45-micron sieve	8%
Specific Surface Area	20 m^2/g
Pozzolanic Strength Activity Index, 7 days	127.6%

Figure 2. SF used in the mixes

2.1.4 Mixing water

The water employed in this study conforms to Iraqi Specification No. 1703/2018 **(IQS No. 1703, 2018),** and its properties are shown in **Table 5**.

Table 5. Mixing water properties

Properties	Details
PH	7.4
Cl^-	132.03 mg/liter
SO_4^{-2}	254.45 mg/liter
Color	Nil
Adore	Nil

2.1.5 Admixture

This study employed a high-range water reducer admixture with brand name (BETONAC-1030) and conforming to **(ASTM C494, 2019)**. **Table 6.** Show the characteristics of a superplasticizer (SP).

Table 6. Technical Properties of BETONIC-1030 SP*

Properties	Details
Color	Light yellow
Density	1.14 gm/ml ±0.02
pH	7.5
Chloride content	Nil

*according to the manufacturer

2.2 Mix Design, Specimens, and Tests

Seven different mixes were prepared for this study after several trail mixes: the reference mix, three mixes where recycled demolished concrete aggregate was added in percentages of 10, 20, and 30% to replace the NA by volume, and three mixes in which SF replaced cement in three percentages of 5, 8, and 10% by weight and contained RA after choosing the best percentage of coarse aggregate replacement. The cement-to-aggregate ratio was 1:4 by weight; the cement weight was 275 kg/m^{3}The w/c was 0.30, and the SP dose was 0.1% by the cement's weight, which improved the workability of the mixes with RA and SF and kept a constant w/c of 0.3. **Table 7.** Presents the mixes details. Following are the steps that were taken to mix the materials with a 0.1 m^3 capacity mixer: First, the interior of the mixer had been moistened and cleaned before use. The required amount of natural coarse aggregates was placed within the mixer and the half-required water and blended for a minute. The cement was placed inside the mixer with the remaining amount of water, and it continued to run till the cement paste had well covered the coarse aggregate and a homogeneous mixture had been produced. The same procedure was used to prepare mixes with RA and SF, except that the RA was blended with the natural aggregate, the SF was blended with the cement, and the SP was added to the water. The mixture was cast in oil-metal cylinders (100×200) mm, prisms (80×80×380) mm, and cubes (100×100×100) mm in layers and compacted with simple rodding, and it was conforming to **(ASTM C192/C 192M, 2019)**. Subsequently,

Table 7. Mixes detail

Mix No.	Cement (kg/m^3)	Coarse Aggregate (kg/m^3)	Recycled Aggregate RA (kg/m^3)	Silica Fume SF (kg/m^3)
NC	275	1100	-	-
RC10	275	1002.7	97.29	-
RC20	275	905.4	194.57	-
RC30	275	808.1	291.86	-
RC10SF5	261.25	1002.7	97.29	13.75
RC10SF8	253	1002.7	97.29	22
RC10SF10	247.5	1002.7	97.29	27.5

the molds were covered with nylon and left for a day. The samples were de-molded and kept in curing tanks up to the testing date. **Fig. 3** exhibits the samples of the no-fine concrete. The specimens underwent tests for compressive strength, tensile strength, flexural strength, dry density, and water absorption in compliance with (**BS EN12390-3, 2019**; **ASTM C496/C496M, 2017**; **ASTM C293/C293M, 2016**; **EN 12390-7, 2019; ASTM C642, 2021)**, respectively. The average of three samples was obtained for tests at 7 days, 28 days, and 90 days.

(a) **(b)** **(c)**

Figure 3. No-fine concrete samples: (a) cube samples, (b) prism samples, (c) cylinder samples

3. RESULTS AND DISCUSSIONS

3.1 Compressive strength (CS)

Table 8. and **Fig. 4** show RA and SF's impact on the NF's CS. The results exhibit that the utilization of RA decreased the CS, resulting from the weak aggregate characteristics of demolished concrete, which reduced the CS of NF. The best percent of replacement was 10% by volume, which exhibited the lowest loss of CS by 11% at 28 days compared to the design mix. On the contrary, using SF as a substitute for cement in mixes containing 10% RA enhanced the CS of NF. The best proportion of SF was 10%, which caused the increase of CS by 18% at 28 days compared to the design mix. This is due to the high SF particle fineness. Despite their greater surface area, SF particles will fill the holes in the no-fine concrete during mixing and compaction. As a result, a more densely packed structure with fewer porosity forms, increasing the concrete strength, which is compatible with **(Jagan and Neelakantan, 2021)**.

Table 8. The results of compressive strength

Mix No.	Compressive Strength (MPa)		
	7 days	28 days	90 days
NC	7.52	9.9	12.1
RC10	6.89	8.85	10.61
RC20	6.07	7.90	9.69
RC30	5.51	7.13	8.78
R10SF5	7.47	9.82	11.95
R10SF8	8.13	10.57	13.01
R10SF10	8.80	11.66	14.09

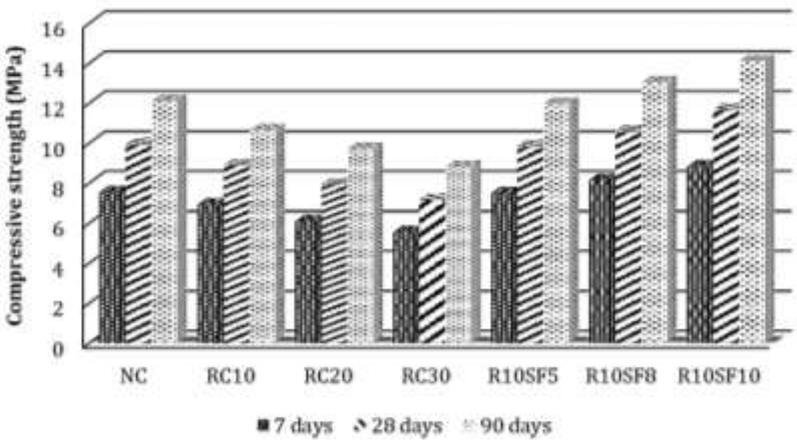

Figure 4. The influence of RA and SF on the compressive strength

3.2 Splitting Tensile Strength (TS)

Table 9. and **Fig. 5** show how RA and SF affect the TS of NF. The results showed that TS decreased with the employment of RA. The best percentage of the replacement was 10% by volume, which led to a 13% decrease after 28 days compared to the design mix. The utilization of SF as a weight substitute for cement with 10% recycled aggregate, on the contrary, increased the TS. The best percentage was 10%, which caused the increase of TS by 14% at 28 days compared to the design mix. This improvement is due to the development of concrete's microstructure, which is compatible with **(Mirza and Saif, 2010)**.

Table 9. The splitting tensile strength results

Mix No.	Splitting Tensile Strength (MPa)		
	7 days	28 days	90 days
NC	1.19	1.42	1.63
RC10	1.04	1.24	1.52
RC20	0.91	1.11	1. 37
RC30	0.83	1.07	1.18
R10SF5	1.15	1.36	1.55
R10SF8	1.27	1.49	1.68
R10SF10	1.37	1.62	1.78

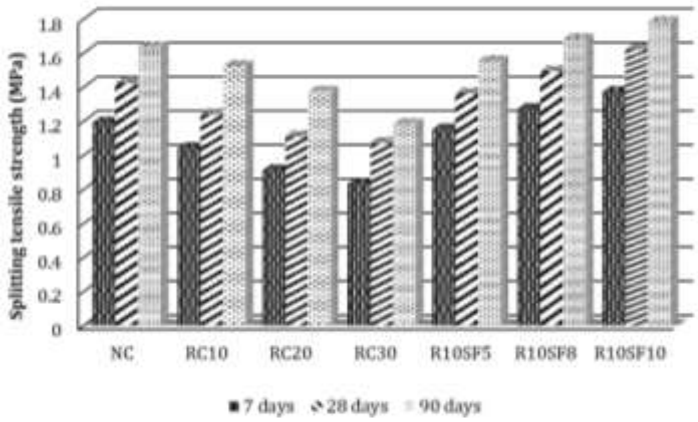

Figure 5. The influence of RA and SF on splitting tensile strength

3.3 Flexural Strength (FS)

Table 10. and **Fig 6.** demonstrates the impact of RA and SF on the FS. The results showed that FS declines when RA is used. The best percentage of RA was 10%, which showed a reduction of 9% at 28 days in comparison to the design mix. On the contrary, the employment of SF as a substitution of cement by weight with 10% RA increased the FS. The ideal percentage was 10%, which showed an increase in FS by 16% at 28 days compared to the design mix. Since FS and CS are directly related, concrete with the highest CS should also have the highest TS. Using SF to improve CS will produce a similar relative rise in FS also duo to SF's strong pozzolanic activity. This behavior is consistent with **(Abubaker and Ghanim, 2022; Shafieyzadeh, 2015)**.

Table 10. The flexural strength results

Mix No.	Flexural Strength (MPa)		
	7 days	28 days	90 days
NC	2.26	2.97	3.23
RNC10	2.07	2.69	2.95
RNC20	1.82	2.41	2.82
RNC30	1.66	2.14	2.55
R10SF5	2.23	2.93	3.19
R10SF8	2.44	3.16	3.64
R10SF10	2.57	3.46	3.73

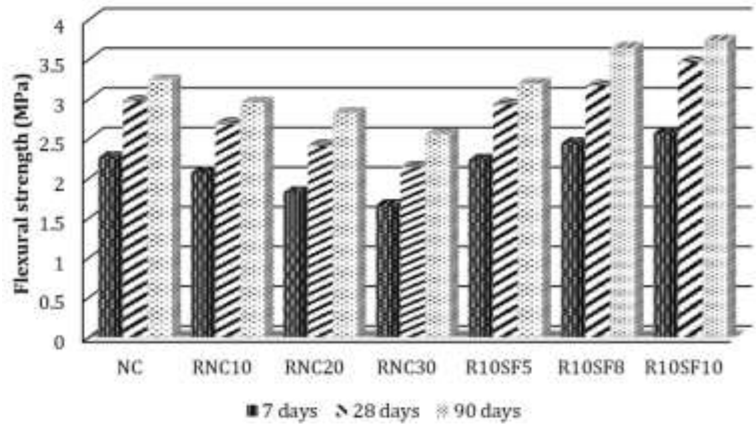

Figure 6. The Influence of RA and SF on Flexural Strength

3.4 Dry density

Table 11 and **Fig. 7** show the influence of RA and SF on the dry density at 28 days. The results showed that the dry density declined when RA is used. The best proportion of RA is 10%, showed a reduction of 2%. This can be attributed to a low density of RA. The results also exhibited that the employment of 10% SF increased the density of no-fine concrete with 10% RA by 1% compared to the reference mix. The increase in density with SF is due to the high concentration of amorphous silica in SF and its reaction with the cement lime, creating a denser concrete microstructure **(Cheng et al., 2011; Gražulytė et al., 2020)**.

Table 11. The dry density results

Mix No.	Dry Density (kg/m^3)	Mix No.	Dry Density (kg/m^3)
NC	1903	R10SF5	1895
RNC10	1865	R10SF8	1913
RNC20	1822	R10SF10	1929
RNC30	1785		

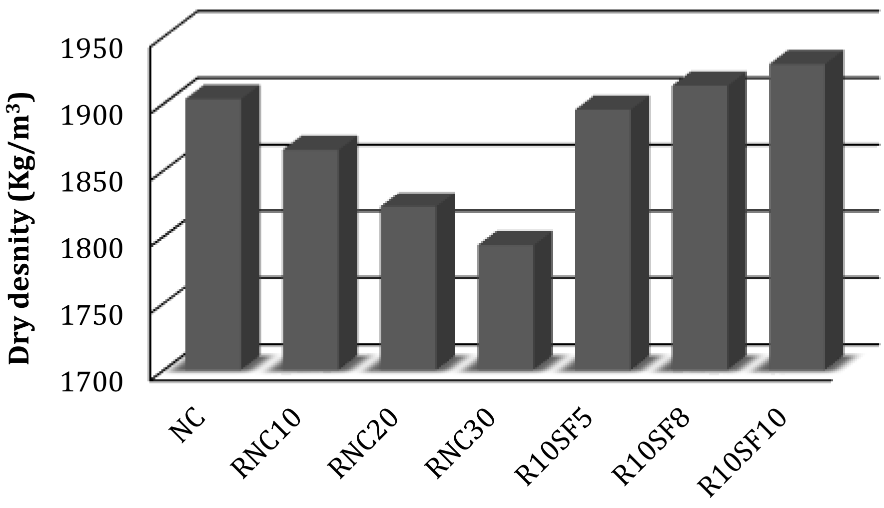

Figure 7. The influence of RA and SF on dry density

3.5 Water Absorption

Table 12. and **Fig 8.** show the effect of RA and SF on water absorption at 28 days. The results show that the absorption increased when RA was used. The best proportion of RA was 10%, which showed the least increase in absorption by 12% compared to the reference mix. This increase in absorption might be explained by a rise in voids in the mix with RA compared to that with natural aggregate. The results also exhibit that utilizing SF in the NF mixes with 10% RA decreases the water absorption; when using 10% silica fume, the water absorption decreased by 5% compared to the reference mix. This is because SF has smaller particles, making the concrete denser. Generally, SF reduced pore size, which decreased water absorption. This behavior is consistent with **(Sharaky et al., 2019).**

Table 12. The absorption results

Mix No.	Absorption (%)	Mix No.	Absorption (%)
NC	2.63	R10SF5	2.69
RNC10	2.94	R10SF8	2.57
RNC20	3.13	R10SF10	2.49
RNC30	3.18		

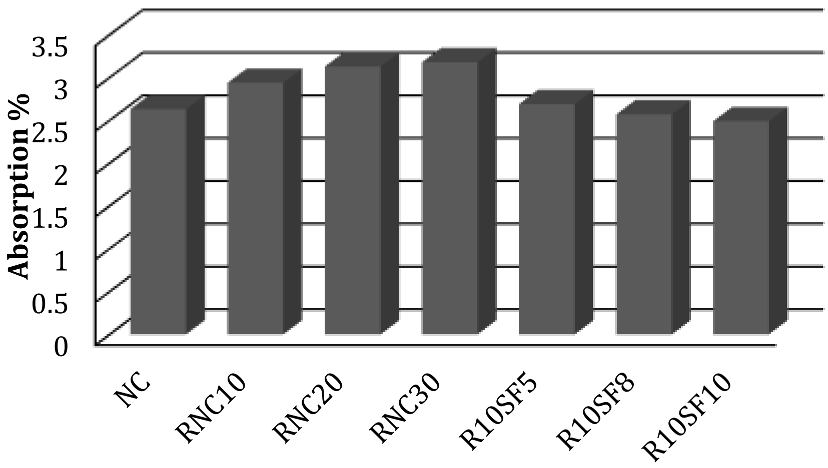

Figure 8. The influence of RA and SF on water absorption

4. CONCLUSIONS

The study investigated the influence of SF substituting 5, 8, and 10% of the cement weight in no-fine concrete with RA. Based on the results of the sample tested, the following conclusions can be drawn:

1) When RA was used in place of the equal volume of natural coarse aggregate, the CS, FS, TS, and dry density of no-fine concrete decreased while the water absorption increased.
2) The best percent of RA replacement was 10%, which exhibited the least reduction in CS, FS, TS, and dry density by 11, 9, 13, and 2%, respectively, and the least increase in water absorption by 12% concerning the reference mix.
3) Using 10% SF with 10% RA increased the CS, FS, TS, and dry density by 18, 16, 14, and 1%, respectively, while decreasing the water absorption by 5% compared to the reference mix.

REFERENCES

Abubaker F., and Ghanim H., 2022. Effect of Silica fume addition on the mechanical properties of concrete. *Albahit Journal of Applied Sciences,* 3(1), pp. 1-5.

Abdullah D.J., Abbas Z.K., Abed 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. Doi:10.31026/j.eng.2021.11.01.

Alam, I., Kuddus, M., Islam, S., 2014. Laboratory investigation of no fines concrete. *Proceedings of the 2nd International Conference on Civil Engineering for Sustainable Development ICCESD-2014, KUET, Khulna, Bangladesh,* pp. 1-9.

ASTM C1240, 2020. Standard specification for silica fume used in cementitious mixture. Annual Book of ASTM Standards.

ASTM C642, 2021. standard test method for density, absorption, and voids in hardened concrete. American Society for Testing and Material International.

ASTM C496/C496M, 2017. Standard test method for splitting tensile strength of cylindrical concrete specimens. American Society for Testing and Material International.

ASTM C494, 2019. Standard specification for chemical admixture for concrete. Annual Book of ASTM Standards American Society for Testing and Materials.

ASTM C293/C293M, 2016. Standard test method for flexural strength of concrete.Using Simple Beam with Center-Point Lading. American Society for Testing and Material International.

ASTM C192/C192M, 2019. Standard practice for making and curing concrete test specimens in the laboratory. American Society for Testing and Material International.

BS EN 12390-3, 2019. Testing hardened concrete-compressive strength of test specimens. British Standard.

Bhutta, M. A., Hasanah, N., Farhayu, N., Hussin, M. W., Tahir, M. B., Mirza, J., 2013. Properties of porous concrete from waste crushed concrete (recycled aggregate). *Construction and Building Materials Journal*, 47, pp. 1243–1248. Doi:10.1016/j.conbuildmat.2013.06.022.

Cheng , A., Hsu, H.M., Chao, S.J., Lin, K.L., 2011. Experimental study on properties of pervious concrete made with recycled aggregate. *International Journal of Pavement Research and Technology Mar*, 4(2), pp. 104-10.

EN 12390-7, 2019. Testing hardened concrete. Part 7: Density of hardened concrete, British Standard.

Farhan, O.S., 2019. Effect of use recycled coarse aggregate on the behavior of axially loaded reinforced concrete columns. *Journal of Engineering*, 25(10), pp. 88–107. Doi:10.31026/j.eng.2019.10.07.

Galishnikova, V.V., Abdo, S., Fawzy, A.M., 2020. Influence of Silica fume on the pervious concrete with different levels of recycled aggregates. *Magazine of Civil Engineering*, 93(1), pp. 71-82, Doi:10.18720/MCE.93.7.

Gražulytė, J., Vaitkus, A., Šernas, O., Čygas, D., 2020. Effect of Silica fume on high-strength concrete performance. *5th World Congress on Civil, Structural, and Environmental Engineering (CSEE'20) Virtual Conference* – October 2020, pp. 1-6. Doi: 10.11159/icsect20.162.

Imam, K., Kumar, V., Srivastava, V., 2018. Review study towards effect of Silica fume on the fresh and hardened properties of concrete. *Advances in Concrete Construction.* 2018; 6(2), pp. 145-57. Doi:10.12989/acc.2018.6.2.145.

IQS No.5, 2019. Portland cement, the Central Agency for Standardization and Quality Control. Iraq, Iraqi Standard Specification

IQS No.45, 1984. Aggregate from natural sources for concrete and construction. The Central Agency for Standardization and Quality Control, Iraqi Standard Specification

IQS 1703, 2018. Water used in concrete. Iraqi Standard Specification

Jagan, S., and Neelakantan, T.R., 2021. Effect of Silica fume on the hardened and durability *properties of concrete. International Review of Applied Sciences and Engineering, 12(1), pp. 44–49.* Doi:10.1556/1848.2020.00129.

Jain, A., and Pawade, P.Y., 2015. Characteristics of silica fume concrete. *International Journal of Computer Applications*, February, 975(8887), pp. 23-26.

Jiahao, L., Lian, F.C., Hejazi, F., Azline, N., 2019. Study of properties and strength of no-fines concrete. *Sustainable Civil and Construction Engineering Conference, IOP conference Series: Earth and Environmental Science 357(012009)*, pp. 1-13. Doi:10.1088/1755-1315/357/1/012009.

Khalid, M. Q., Abbas, Z.K., 2023. Comparative study between recycled fine and coarse aggregate used in roller compacted concrete pavement. *Journal of Engineering,* 29(10), pp. 33-51. Doi:10.31026/j.eng.2023.10.03.

Liu, H., Luo, G., Wang, L., Wang, W., Li, W., Gong, Y., 2018. Laboratory evaluation of eco-friendly pervious concrete pavement material containing Silica fume, *Applied Sciences (Switzerland), Appl. Sci.* 2019, 9(73), pp. 1-14. Doi:10.3390/app9010073.

Mirza, F.A., Saif, M.A., 2010. Mmechanical properties of recycled aggregate concrete incorporating Silica fume. *Second International Conference on Sustainable Construction Materials and Technologies 28-30 June 2010 Universita Politecnica delle Marche, Ancona, Italy, pp. 1-12.*

Pastariya, S., Parihar, R.S., 2020. Experimental investigation of green concrete in construction industry by using recycled aggregate (demolished waste). *Journal of Xi'an University of Architecture & Technology,* XII(V), pp. 2245-2251.

Pradhan, S.K., Behera, N., 2022. Performance assessment of pervious concrete road on strength and permeability by using Silica fume. *Journal of Civil Engineering and Environmental Technology,* 3(4), pp. 269-73.

Salih, S.A., and Fidel, T.A., 2016. Some durability test of no-fine concrete. *Journal of Engineering*, 22(1), pp. 15–30. Doi:10.31026/j.eng.2016.01.02.

Shafieyzadeh, M., 2015. Prediction of flexural strength of concretes containing Silica fume and Styrene-Butadiene Rubber (SBR) with an empirical model. *Journal of The Institution of Engineers (India): Series A*, 96(4), pp. 349–35. Doi:10.1007/s40030-015-0140-0.

Sharaky, I.A., Megahed, F.A., Seleem, M.H., Badawy, A.M., 2019. The influence of Silica fume, nano silica and mixing method on the strength and durability of concrete. *SN Applied Sciences Journal,* pp. 1-10. Doi:10.1007/s42452-019-0621-2.

Sriravindrarajah, R., Huai Wang, N.D., Wen Ervin, L.J., 2012. Mix design for pervious recycled aggregate concrete. *International Journal of Concrete Structures and Materials, 2012 Dec;* 6(4), pp. 239-46. Doi: 10.1007/s40069-012-0024-x

Ye, P., Chen, Z., Su, W., 2022. Mechanical properties of fully recycled coarse aggregate concrete with polypropylene fiber, *Case Studies in Construction Materials,* 17, pp. 1-14. Doi:10.1016/j.cscm.2022.e01352.