IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 20, Issue 4 Ser. I (July. – August. 2023), PP 14-26
www.iosrjournals.org

The Influence Of Utilizing A Seashell As A Partial Substitute For Sand On The Plain And Fiber-Reinforced Concrete

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Abstract
Waste Recycling Is Essential Economically And Environmentally. The Principal Purpose Of This Investigation Is To Analyze The Probability Of Utilizing Seashells (SS) And Their Effect As A Partial Alternative For Sand On The Characteristics Of Plain Concrete (PC) And Fiber-Reinforced Concrete (FRC). Six Percent (0%, 10%, 20%, 30%, 40%, And 50%) Of Seashells Were Used. The Proportion Of Steel Fiber (SF) And Polypropylene Fiber (PPF) Used In This Investigation Was 1% And 0.30% Of The Concrete Volume, Respectively. The Water/Cement (W/C) Proportion Was 0.65 For All Concrete Mixes. The Unit Weight And Slump Of Concrete Reduced With The Growth In The Substitute Ratio Of A Seashell For All Concrete Mixtures While The Absorption Ratio (WA) Increased. A High Difference Was Noticed In The WA For Concrete With And Without Seashells, Particularly At The Increased Levels Of Seashells. The Plain And FRC Compressive Strength And Indirect Tensile Strength Declined With The Development Of The Seashell Substitute Percentage. The Lowering In The Compressive Strength Of The PC Was 7.88%, 10.37%, 17.84%, 19.50%, And 20.06% Compared To The Control Concrete (0% SS) For Seashell Substitute Percentages Of 10%, 20%, 30%, 40%, And 50%, Respectively. This Decrease Was (5.61%, 17.58%, 19.35%, 24.67%, And 26%) And (10.07%, 15.67%, 19.78%, 20.52%, And 20.90%) For The Polypropylene And Steel FRC, Respectively.

Keywords: *Recycling, Seashells, Splitting Tensile Strength, Compressive Strength, FRC, Plain Concrete.*

Date of Submission: 28-06-2023 Date of Acceptance: 08-07-2023

I. Introduction

The technique to keep the environment is to decrease and recycle wastes from different industries like waste glass, slag, ceramic scraps, and seashells [1–4]. With more additional production for growing people, more waste is produced. These wastes will create many environmental problems. Thus recycling is necessary. A Seashell is extremely hard and made by an animal that lives in the sea. Empty seashells are mainly found on the beach and gathered as rubbish by beachcombers. Seashells are probably utilized in concrete manufacture as a substitute for fine aggregate, coarse aggregate, and cement. In an earlier study analysis, the slump was the principal property utilized to evaluate the fresh concrete workability containing seashells as aggregate. Commonly, workability drops as the ratio substitution of the seashells develops. Increased substitute ratios resulted in significantly down marks of the slump. The decrease in a concrete slump was referred to the development in the surface area **[5, 6],** rough surface and angular, elongated, flaky, or irregular form of the seashells **[7, 8],** and also, more increased water absorption (WA) of the seashells compared to natural aggregate **[9].** The irregular forms raise the frictional resistance between the seashell particles. The WA happens because of the formation of inner gaps within the seashell surface. The concrete density lowers as the aggregate substitution by seashell growths. This drop in unit weight applies to concrete in both hardened and fresh stages. Although the specific gravity of a seashell is similar or a little smaller than those of ordinary aggregates, the irregular or angular form of a SS and the existence of organic substances create extra trapped air in the concrete, which decreases the unit weight **[10, 11, 8, and 12].** The concrete density of 28 days containing until 50% of some coarse seashells is more than 2.1 gr./cm3 and hence can yet be considered normal-weight concrete **[5,6,13].** When sand is substituted with a crushed mussel shell until 100% replacement level, the hardened concrete density exceeds 2000 kg/m3 **[8].** For 50% sand (fine aggregate) substitution, the least bulk density gave a 10% drop compared to the control density. Reducing the SS particle size grows the pervious concrete unit weight **[11].** This decrease is possible because finer seashell particles generate lower voids levels in concrete and possess comparatively greater unit weight than coarse shells. In previous studies, crushed SS as a coarse aggregate substitution created concrete of lower strength and lightweight. This concrete is appropriate for lower-strength applications like pavers **[14, 15].** A recent investigation decided that the crushed seashells utilized as the aggregate substitution could reduce the mechanical characteristics and grow the porosity due to entrapped air increase in concrete **[16].** Generally, the concrete compressive strength lowers by using a mix of coarse seashell aggregates. The drop in concrete strength is mainly referred to the more seashell aggregates water absorption, the flaky or elongated form of SS, and the existence of the organic substances. Furthermore, the increased seashell surface area leads to little available cement paste for coating, thus generating a drop in bond strength. Elongated and flaky aggregates possess an insufficient bond with the paste of cement and form more voids inner the concrete structure, thus a reduction in compressive strength **[17, 11, 8, 18. 19].** Concrete mixtures incorporating smaller-sized seashell particles commonly reveal greater compressive strength **[20, 11].** This growth in compressive strength can be referred to descending voids range and adequate aggregate-paste bond. Crushed seashell utilized as a partial substitution of sand at 5%to20% replacement ratios provides greater compressive strength than PC in most matters **[9, 21, and 12].** This increase is attributed to the rarity of grains less than 0.10cm. Moreover, the angular and coarser fine aggregates enhance the interlocking adhesive of the concrete matrix **[12].** A previous study deduces that coarse seashell aggregate using decreases in the flexural and indirect tensile strengths. The causes for the drop in the flexural and indirect tensile strengths are identical to those registered for the lowering in compressive strength **[18].** Slight growth in 28 days of flexural and indirect tensile strength can be observed for concrete incorporating some seashell types as partial sand substitution until 20% **[18].** The concrete durability of seashell aggregate shows different influences. Shrinkage characteristics and chloride migration commonly grow with the increasing seashells' aggregate content. Previous studies revealed conflicting opinions on the impact of seashell aggregate on the freeze-thaw resistance, the air content, and the water transport characteristics of concrete **[10, 22].** Recycling oyster shells as a partial sand replacement at a 20% ratio has a minor impact on the acid attack resistance of concrete and concrete carbonation **[22, 23].** Pervious concrete fabricated with cockle shell aggregate possesses more acceptable sound absorption characteristics than traditional pervious concrete **[24].** Fibers contribute numerous benefits to ordinary concrete and can improve tensile strength and toughness **[25].** Until now, experimenters have familiarly examined the properties of reinforced concrete with single fibers, for example, steel **[26, 27],** glass **[28],** polypropylene **[29],** and basalt fibers **[30].** Reinforcement of fibers remarkably improves the indirect tensile strength **[31]** and flexural strength **[32].** The WA capability of concrete is too decreased owing to the steel fiber usage **[31].** The bridging influence of fibers creates concrete of high toughness **[33],** which is appropriate for impact loadings. Due to fiber use, the residual strength of PC after the peak stress is enhanced **[34].** The fibers of high tensile strength prevent the sudden fracture of fracture sections under tensile loading by the bridging action. Also, the degradation of PC under freeze-thaw activity **[35]** and the acid attack **[28]** can be governed by the fibers bridging action**.** The single steel fiber enhances the mechanical behavior such as flexural strength, tensile strength, toughness, etc.) of PC but increases the concrete weight **[36].** Steel fiber is weak to rust owing to the magnetic and electric attractions **[37].** Hybrid mixtures of steel fiber and polypropylene fibers can give excellent diffusion and impact toughness than single steel fibers **[38, 39].** Single-fiber reinforcement contributes just a minimum degree of crack-bridging influences **[40].** A good mixing proportion of single SF and synthetic fibers can improve mechanical behavior **[41].** The inactive character of artificial fibers can reduce the concrete corrosion potential. Also, cheaper and lightweight PPF can mainly lower the weight of FRC. Until now, there is a great rarity of research related to the effect study of using seashells in fiber-reinforced concrete. This study mainly aims to know the impact of using seashells as an alternative to sand in ordinary and fiber-reinforced concrete.

II. Materials

In this investigation, ordinary cement was utilized. The cement characteristics were tested according to the **ESS 2421/2005 [42]** and displayed its rightness for concrete production. Sand with the largest size of 4.75 mm was utilized. Basalt with two sizes was used, the first (4.75 mm to 12.5 mm) and the second (12.5 mm to 25 mm). The percentage of the contribution of each size in all the concrete mixtures was 50% of the weight of basalt. The sand and basalt characteristics were approved with **ESS 1109/2002 [43]. Tables 1 and 2, and 3** show the cement and aggregate properties, respectively. **Figs. 1 and 2** display the aggregate particle size distribution and aggregate form utilized in this paper.

Table 1 Characteristics of cement

Characteristics		Results
Soundness (mm)		1.0
Setting time (minute)	Final	164
	Initial	107
Compressive strength (N/mm^2)	3days	22.2
	28days	48.3

Table 2 Chemical characteristics of seashell and cement

Composition	CaO	SiO2	Fe2O3	MgO	Al2O3	K2O	Na2O	SO3	L.I.
seashell	53.6	0.12	0.05	0.19	0.11	0.01	0.51	0.31	44.5
Cement	63.8	22.40	1.82	3.2	3.21	1.25	1.16	2.75	-

L.I. = Loss of ignition.

Table 3 Basalt, sand, and seashell characteristics

Property	Basalt	Sand	Seashell
ness modulus	-	2.22	3.61
Maximum grain size (mm)	25	4.75	4.75
Compacted unit weight (gr/cm^3)	1.65	1.68	0.86
Loose unit weight (gr/cm^3)	1.45	1.58	0.70
Specific weight (g/cm3)	3.00	2.72	1.80
Water absorption%	1.39	2.58	3.85

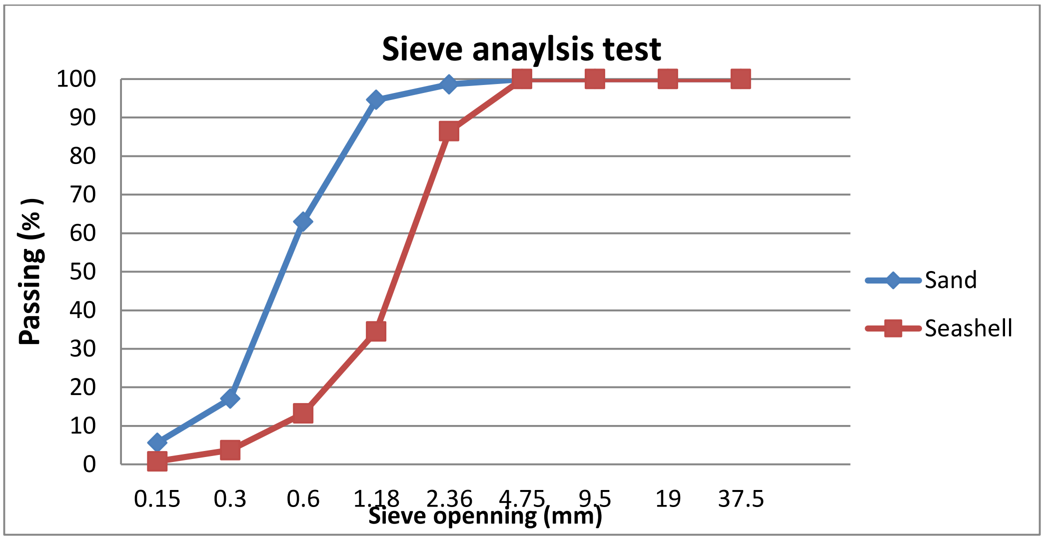

Fig.1. Sand and seashell grain size distribution

(a) Basalt (4.75-12mm)

(b) Basalt (12-25mm)

(c) Sand **(d) Seashells**

Fig.2. Aggregates

The seashells were collected, washed, and dried. After crushing, seashells were sieved on a 4.75 mm sieve. **Table 3** reveals the physical engineering properties of seashells, and **Fig. 2** shows the seashells used in this research. Steel and polypropylene fibers (SF and PPF) were used in this investigation. Steel fiber of diameter 0.5 mm and length 50 mm is used with a content of 1% by volume of concrete. Polypropylene fiber with a specific gravity of 0.92 is utilized with a ratio of 0.3% by volume of concrete.

III. Experimental procedure

Mixture proportioning

In this study, there are three groups of concrete mixtures, the first is ordinary concrete, the second is polypropylene fiber concrete, and the third is steel fiber concrete. The proportions of seashells replaced for sand were (10%, 20%, 30%, 40%, and 50%) from the weight. The W/C ratio was 0.65 for all concrete mixes. **Table 4** displays the concrete mixes' ratios.

Table 4 Concrete mixes proportions

Group no.	Mix no	PPF%	SF %	Seashell %	Seashell kg/m^3	Sand kg/m^3	W/C	Water kg/m^3	Basalt kg/m^3	Cement kg/m^3
1	1	0%	0%	0%	0	584	0.65	227.5	1168	350
	2			10%	58.4	525.6		227.5	1168	350
	3			20%	116.8	467.2		227.5	1168	350
	4			30%	175.2	408.8		227.5	1168	350
	5			40%	233.6	350.4		227.5	1168	350
	6			50%	292	292		227.5	1168	350
2	7	0.30%	0%	0%	0	584	0.65	227.5	1168	350
	8			10%	58.4	525.6		227.5	1168	350
	9			20%	116.8	467.2		227.5	1168	350
	10			30%	175.2	408.8		227.5	1168	350
	11			40%	233.6	350.4		227.5	1168	350
	12			50%	292	292		227.5	1168	350
3	13	0%	1%	0%	0	584	0.65	227.5	1168	350
	14			10%	58.4	525.6		227.5	1168	350
	15			20%	116.8	467.2		227.5	1168	350
	16			30%	175.2	408.8		227.5	1168	350
	17			40%	233.6	350.4		227.5	1168	350
	18			50%	292	292		227.5	1168	350

Test procedure

Tests for the slump, density, water absorption, compressive, and indirect tensile strengths of concrete mixtures were carried out agreeing to **ASTM C143/C143M-00 [44], ASTM C642 [45], ASTM C642 [45], ASTM C39/C39M-18 [46], and ESS 1658 /2006 [47],** respectively. Three samples were examined for each mixture, and the medium of the results is registered. Cylinders of 15*30 cm and cubes of 15*15*15 cm were utilized for indirect tensile and compressive strengths, respectively.

IV. Results and discussion

Slump tests

The slump test is significant for defining fresh concrete workability and indicates its grade. **Fig. 3** and **Table 5** display the slump test values of the plain and fiber-reinforced concrete. For seashell ratios, 0%, 10%, 20%, 30%, 40%, and 50%, the slump values were (13, 10, 8.5, 7.5, 7.1, and 6.5 cm) and (10.5, 8.5, 7.7, 7.1, 6.5, and 6.1 cm) and (10, 8, 7.4, 6.9, 6, and 5.8 cm) for plain, PPF, and SF concretes, respectively. The slump values illustrate that the slump decreases as SS increases for all concrete mixtures. The slump decrease can be related to the rough surface and irregular form of seashells, the increased surface area, which raises the water need, and increased WA compared to natural sand. The rough surface and irregular shape raise the frictional resistance between the SS particles, while the WA happens owing to the inner voids inside the seashell surface. The previous results agree with studies that concluded with an increase in the ratio of seashells, the values of slump decreased **[7, 8, 9, 51, and 52].** It can also be noted that the slump values of the FRC were smaller than the ordinary concrete for all seashell replacement ratios, especially for the steel fiber concrete. The lowest value slump was obtained when PPF and SF were mixed into concrete, which can be ascribed to the large fibres surface area, which acts inversely on the fresh concrete characteristics due to its spread over a large area and obstructs the motion of plastic concrete. These results reinforce the findings of the earlier study **[53].** The slump values of SF concrete were smaller than that of polypropylene fiber concrete for all seashell ratios, which can be attributed to the proportion of SF (1%) being higher than that of PPF (0.30%), which means an increase in the surface area of steel fiber concrete than polypropylene fiber concrete. Despite the slump reduction of all concrete mixtures with increasing the seashells ratio, the concrete workability is nevertheless good.

Table 5 Slump of all concrete mixes

SS content %	Slump (cm)		
	Group 1 (plain concrete)	Group 2 (PPF concrete)	Group 3 (SF concrete)
0%	13	10.5	10
10%	10	8.5	8
20%	8.5	7.7	7.4
30%	7.5	7.1	6.9
40%	7.1	6.5	6
50%	6.5	6.1	5.8

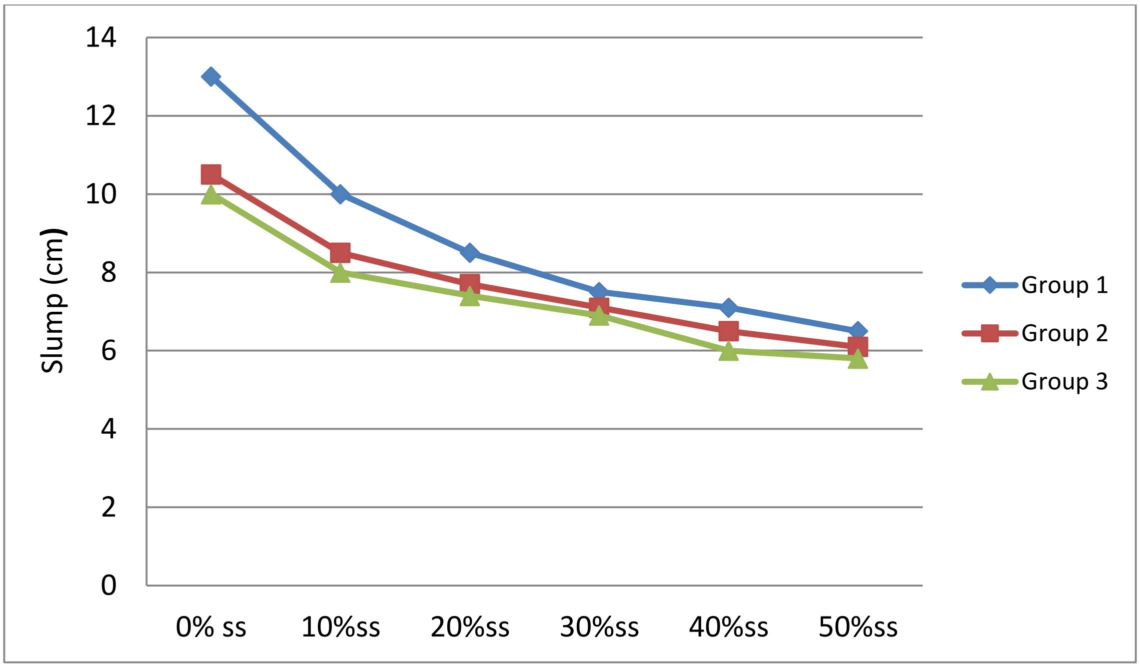

Fig.3. Slump values of all concrete mixes

Density

Fig. 4 and Table 6 show the values of the concrete density at 28 days for all concrete mixtures. There is a lack of concrete density as the seashell substitution ratio increases. The decrease in density of specimens prepared of 10%, 20%, 30%, 40%, and 50% seashells are approximately (1.39%, 2.17%, 2.95%, 4.58%, and 5.11%) and (0.73%, 1.39%, 2.98%, 4.65%, and 5.10%) and (1.52%, 2.16%, 4.48%, 4.64%, and 5.6%) compared to control concretes for plain, PPF, and SF concretes, respectively as shown in **Fig.5.** These results match the findings of **[48]**, where the W/C ratio of 0.60 was utilized and discovered a drop in density when crushed seashells substitute growths. The reduction in the unit weight of the seashell concrete mixes can be ascribed to the lower seashell-specific gravity used in this study than the sand (see Table 3). Also, the density reduction can be referred to the irregular or angular form of a seashell and the existence of organic materials that create extra entrapped air in the concrete, which decreases the unit weight **[11], [12].** The unit weight of fiber concrete exceeded that of ordinary concrete for all seashell ratios, especially for steel fiber concrete. As predicted, the density increased with a 1% SF addition. The growth in the concrete unit weight is attributed to the entry of high-unit-weight steel filaments in an ordinary matrix. The SF reinforces the binder matrix or microstructure **[54], [55].** It can be observed the intensity of the growth in the concrete unit weight was reduced when a 0.30% PPF ratio was added, which can be attributed to the development in the porosity or air content of the matrix owing to the adverse impact of PPF on concrete workability.

Table 6 Density of all concrete mixes after 28 days

SS content %	Density (kg/m^3)		
	Group 1 (plain concrete)	Group 2 (PPF concrete)	Group 3 (SF concrete)
0%	2444(control)	2450(control)	2498(control)
10%	2410(-1.39%)	2432(-0.73%)	2460(-1.52%)
20%	2391(-2.17%)	2416(-1.39%)	2444(-2.16%)
30%	2372(-2.95%)	2377(-2.98%)	2386(-4.48%)
40%	2332(-4.58%)	2336(-4.65%)	2382(-4.64%)
50%	2319(-5.11%)	2325(-5.10%)	2358(-5.60%)

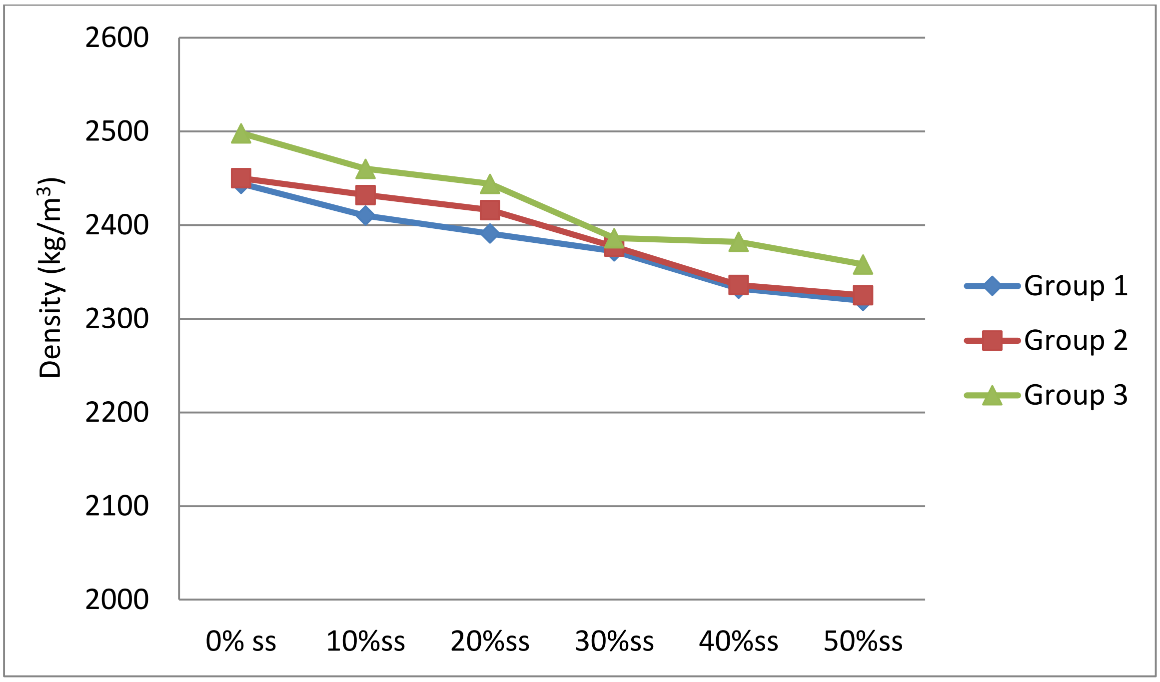

Fig.4. Density of all concrete mixes after 28 days

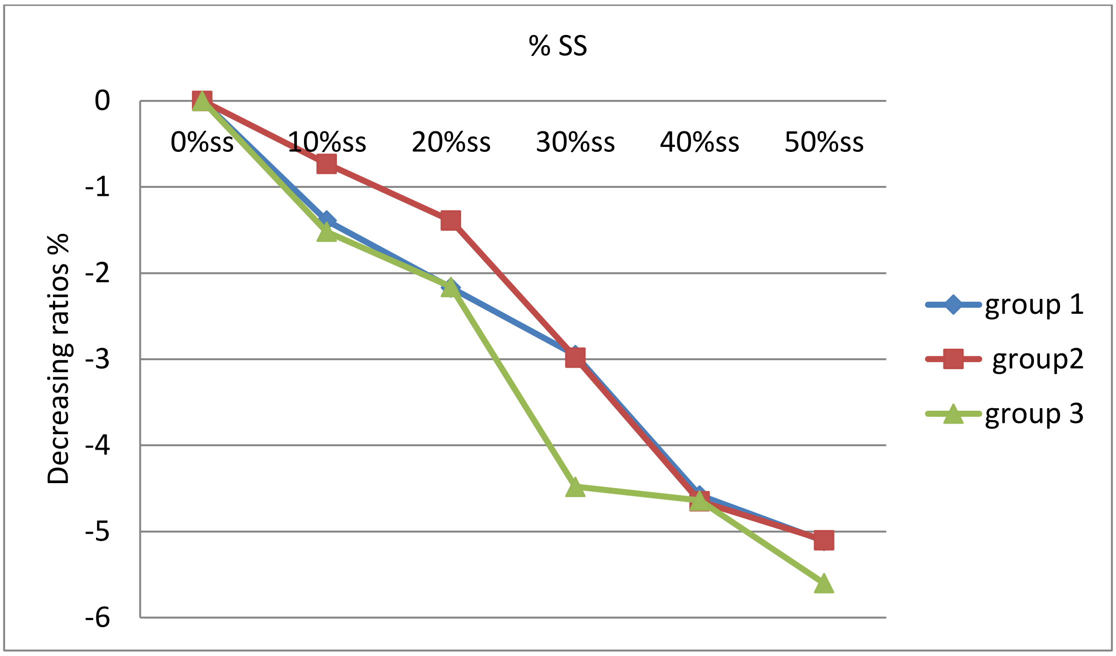

Fig.5. Density decreasing ratios after 28 days

Water absorption (WA)

Concrete durability is affected by the permeability of dangerous exterior agents into the concrete microstructure. Thus, water absorption is the indirect inspection method of concrete durability, as it calculates the porous voids volume **[56].**

Table 7 and Fig. 6 show the findings of seashell replacement on concrete absorption. The results display that the WA increases by developing the replacement proportion of the seashell in all concrete mixtures. A high difference was noticed in the WA for concrete with and without seashells as a partial sand substitute, especially at the high ratios of seashells. The increasing ratios in water absorption of 10%, 20%, 30%, 40%, and 50% seashell ratios were (1.96%, 5.23%, 11.76%, 16.34%, and 22.22 %) and (8.61%, 15.89%, 29.14%, 39.74%, and 45.03 %) and (11.63%, 20.16%, 24.03%, 32.56%, and 41.09 %), related to control concrete for plain, PPF, SF concretes, respectively as shown in **Fig. 7**. As it is clear from the **Fig. 7**, the effect of seashell replacement is very effective on all types of concrete, especially at higher percentages of seashells. This increase was expected because the seashell absorption ratio was higher than sand. Also, the water absorption increased owing to the internal void's existence within the seashell's surface. In addition, the reduced concrete compactness generated by the disturbed aggregate packing generates higher water absorption **[49, 50].** Also, from the results, it can be observed that the lowest water absorption rate was for steel FRC (1.29%, 1.44%, 1.55%, 1.6%, 1.71%, and 1.82%){for SS content 0% to 50%} which can be ascribed to the fact that SF reduce the permeability of concrete as a result of decreased micro-cracks resulting from the drying shrinkage **[56]**.

Table 7 Concrete mixes' water absorption after 28 days

SS content %	Water absorption %		
	Group 1 (plain concrete)	Group 2 (PPF concrete)	Group 3 (SF concrete)
0%	1.53(control)	1.51(control)	1.29(control)
10%	1.56(1.96%)	1.64(8.61%)	1.44(11.63%)
20%	1.61(5.23%)	1.75(15.89%)	1.55(20.16%)
30%	1.71(11.76%)	1.95(29.14%)	1.60(24.03%)
40%	1.78(16.34%)	2.11(39.74%)	1.71(32.56%)
50%	1.87(22.22%)	2.19(45.03%)	1.82(41.09%)

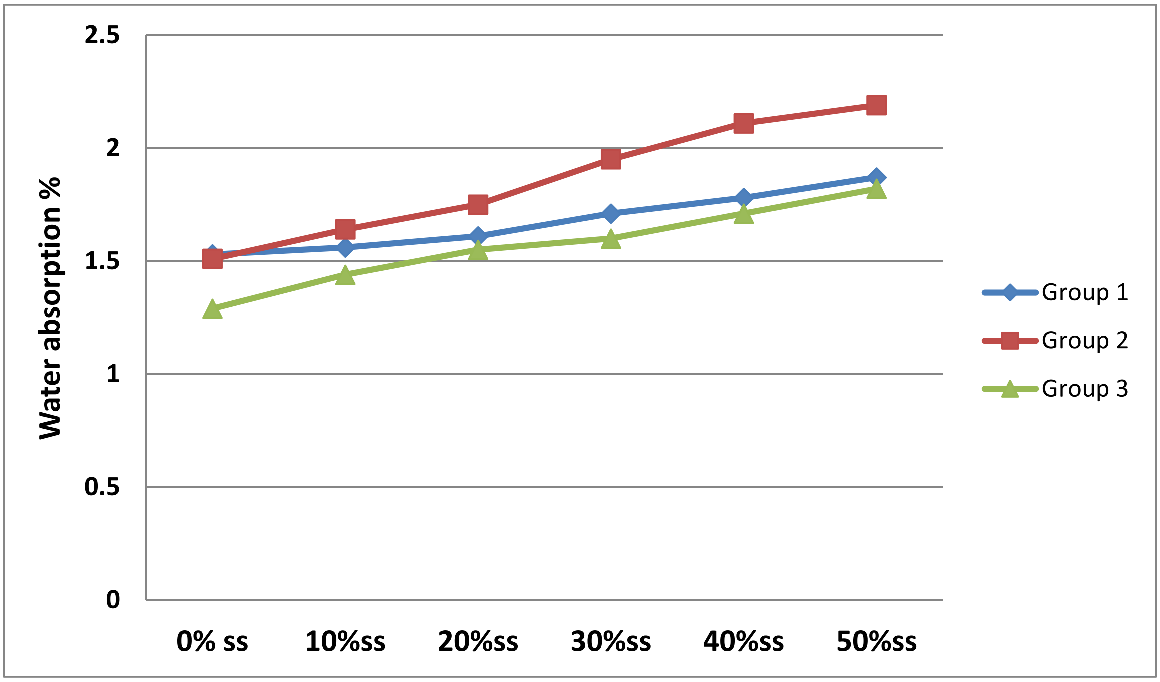

Fig.6. Concrete mixes water absorption after 28 days

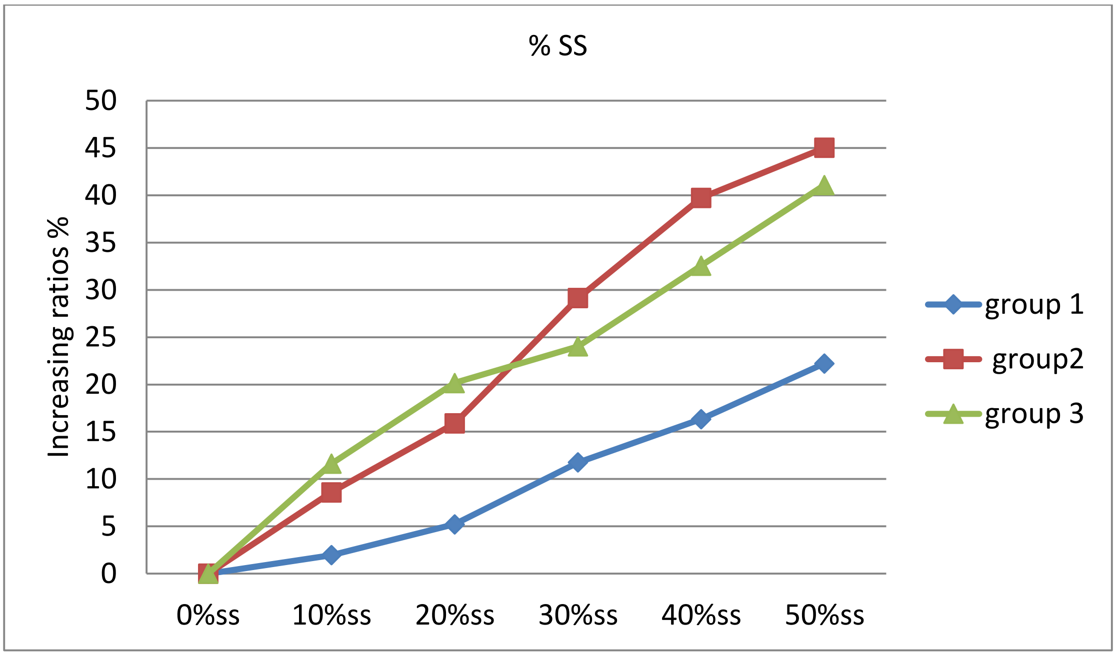

Fig.7 Increasing ratios in the water absorption ratio after 28 days

Compressive strength test

The control and seashell concrete compressive strength are revealed in **Fig. 8 and Table 8.** It is noticed the behavior of reused seashells as an aggregate (sand) substitute lowers the concrete compressive strength. With the development in the percentage of seashells, the compressive strength of all concrete mixes decreases. This decrease was (7.88%, 10.37%, 17.84%, 19.50%, and 20.06 %) and (5.61%, 17.58%, 19.35%, 24.67%, and 26 %) and (10.07%, 15.67%, 19.78%, 20.52%, and 20.90 %), related to control concrete for plain, PPF, SF concretes, respectively as revealed in **Fig. 9**. The drop is mainly referred to the more seashell aggregates water absorption, the existence of the organic materials, and the flaky or elongated form of seashells**.** Furthermore, the higher seashell surface area causes little available cement paste for coating, thus generating a drop in bond strength. Flaky and elongated aggregates have an insufficient adhesive with cement paste and form larger voids inner the concrete structure, thus a reduction in compressive strength **[17-19].** As it is apparent from the **Fig. 9**, the effect of seashell replacement is more effective on the compressive strength reduction of polypropylene and

SF concrete than plain concrete. This effect is due to the balling phenomenon in fiber-reinforced concrete, which increases the voids inside the concrete. It can also be noticed that the decrease for PPF and SF concretes is close to the reduction for plain concrete to some extent. Despite this, steel fiber concrete is the highest in compressive strength, which is normal, because SF has a large modulus of elasticity and can restrain the happening and progress of cracks **[57]**.

Table 8 Concrete compressive strength after 28 days

SS content %	Compressive strength (N/mm^2)		
	Group 1 (plain concrete)	Group 2 (PPF concrete)	Group 3 (SF concrete)
0%	28.92(control)	27.08(control)	32.16(control)
10%	26.64(-7.88%)	25.56(-5.61%)	28.92(-10.07%)
20%	25.92(-10.37%)	22.32(-17.58%)	27.12(-15.67%)
30%	23.76(-17.84%)	21.84(-19.35%)	25.8(-19.78%)
40%	23.28(-19.50%)	20.4(-24.67%)	25.56(-20.52%)
50%	23.12(-20.06%)	20.04(-26%)	25.44(-20.90%)

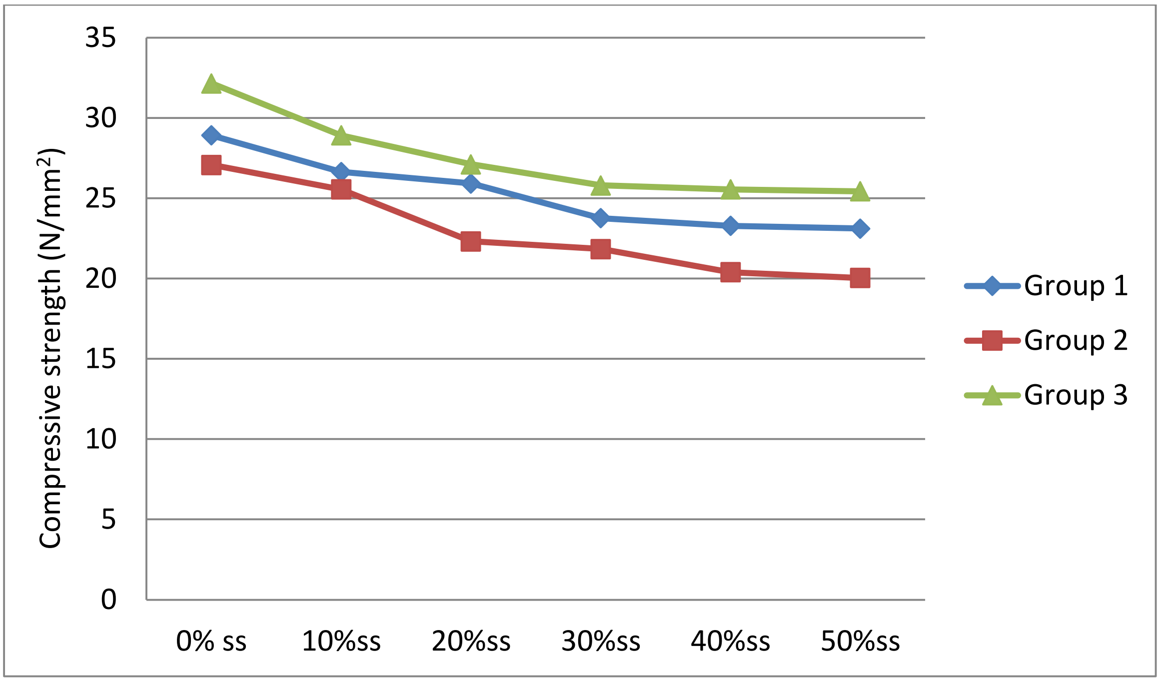

Fig. 8 Compressive strength of all concrete mixes after 28 days

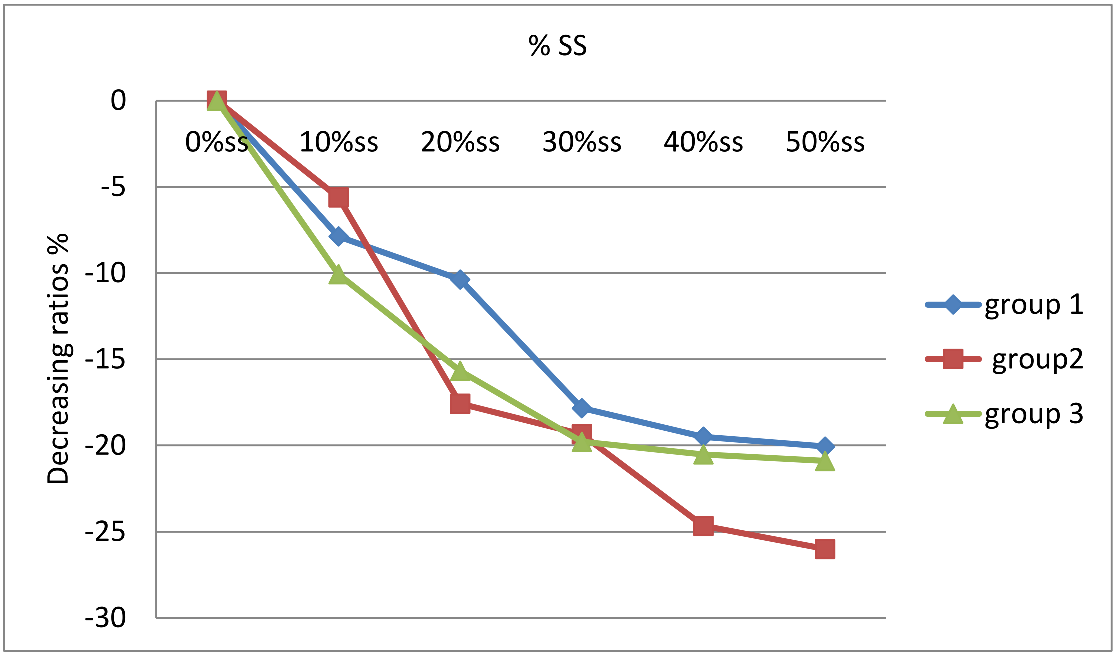

Fig.9 Decreasing ratios in the compressive strength after 28 days

Splitting tensile strength tests

Table 9 and **Fig. 10** show indirect tensile strength test results. The values illustrate that indirect tensile strength decreases gradually as seashell (SS) content increases for all concrete mixtures. The reduction in indirect tensile strength of samples prepared of 10%, 20%, 30%, 40%, and 50% seashells are approximately (4.76%, 6.75%, 9.52%, 15.87%, and 19.84%) and (6.12%, 8.16%, 16.33%, 18.37%, and 22.45%) and (5.88%, 5.88%, 7.84%, 9.80%, and 13.73%) compared to control concretes for plain, PPF, and SF concretes, respectively, as shown in **Fig. 11**. The causes for the drop in the indirect tensile strength are identical to those registered for lowering compressive strength. The indirect tensile strength values of polypropylene fiber or SF concrete are higher than those of ordinary concrete for all seashell ratios because the fibers improved the tensile properties of concrete at both macro and micro levels. PPF increases the tensile toughness of concrete by impeding the propagation of micro cracks. SF enhanced the peak strain, peak stress, and tensile toughness of concrete by extending the propagation path of macro-cracks and controlling the increase of the micro crack's width **[58]**.

Table 9 Indirect tensile strength of all concrete mixes after 28 days

SS content %	Indirect tensile strength (N/mm^2)		
	Group 1 (plain concrete)	Group 2 (PPF concrete)	Group 3 (SF concrete)
0%	2.52(control)	2.94(control)	3.06(control)
10%	2.40(-4.76%)	2.76(-6.12%)	2.88(-5.88%)
20%	2.35(-6.75%)	2.70(-8.16%)	2.88(-5.88%)
30%	2.28(-9.52%)	2.46(-16.33%)	2.82(-7.84%)
40%	2.12(-15.87%)	2.40(-18.37%)	2.76(-9.80%)
50%	2.02(-19.84%)	2.28(-22.45%)	2.64(-13.73%)

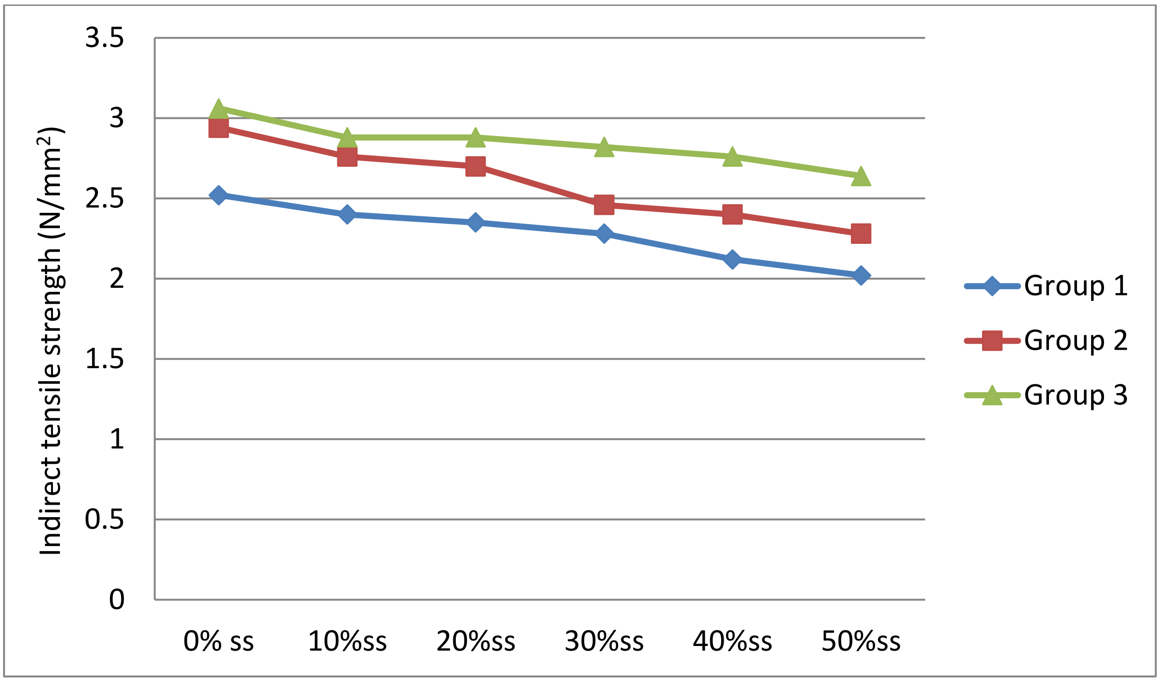

Fig.10. Splitting tensile strength (MPa) of concrete mixes at 28 days

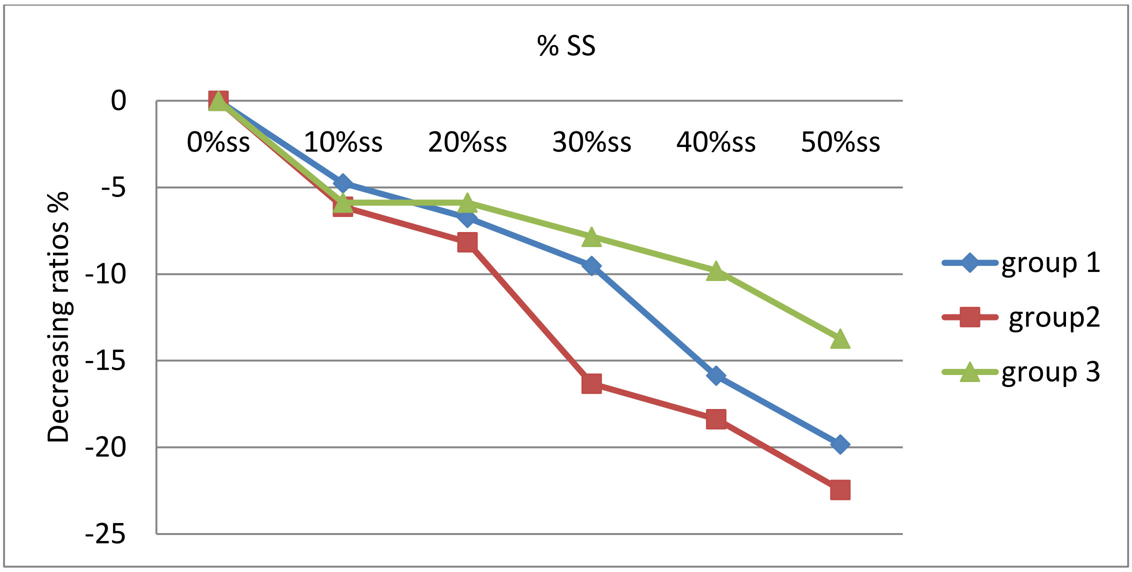

Fig.11. Decreasing ratios in the Splitting tensile strength after 28 days

V. Conclusion

1. With the increase in the seashell percentage, the slump of plain and FRC decreases.
2. The slump values of the FRC were less than the ordinary concrete for all seashell replacement ratios.
3. With the growth in the seashell percentage, the density of plain and FRC decreases.
4. The highest decrease in density was 5.6% for steel fiber concrete at a 50% seashell ratio.
5. With the growth in the seashell percentage, the WA of plain and FRC increased.
6. The WA ratio of polypropylene and steel fiber concrete is higher than plain concrete, especially at higher percentages of seashells.
7. With the growth in the percentage of seashells, the compressive strength of plain and FRC decreases.
8. The highest decrease in compressive strength was 26% for polypropylene fiber concrete at a 50% seashell ratio.
9. The splitting tensile strength decreases gradually as seashell content increases for all concrete mixtures.

Conflict of interest
There is no conflict of interest.

Data availability
Data will be made available on request.

Funding declaration
There is no funding from any party or institution for this research.

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