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Enhancing Early-age Properties of Self-curing Recycled Aggregate Concrete

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ABSTRACT

Recycled aggregate self-curing concrete is one of the new concrete types. It does not need to be cured using traditional curing techniques. Also, it is composed of coarse recycled aggregates rather than using traditional natural coarse aggregates to build water supply reservoirs in the concrete and continue the hydration process; some recycled aggregates can hold large amounts of water that are not included in the mixing water. This research aims to enhance self-curing recycled aggregate concrete's early-age properties. The early-age properties of recycled aggregate self-curing concrete are discussed in terms of slump values, plastic shrinkage settlement tests, and plastic shrinkage panel tests. The hardened concrete properties are noted in terms of compressive strength, splitting tensile strength, flexural strength, and bond strength (after 7, 28, and 56 days). Test results indicated that, in comparison to concrete cast using dolomite as natural aggregate, using recycled aggregate minimizes plastic shrinkage and plastic shrinkage cracks. Using polyethylene glycol (PEG400) and super absorbent polymer (SAP) as chemical curing agents also reduces plastic shrinkage and plastic shrinkage cracks in concrete

Keywords: *Self-curing concrete; Recycled aggregate; super absorbent polymer (SAP); Polyethylene Glycol PEG 400; Plastic shrinkage.*

1. Introduction

Concrete that has not been adequately cured loses some of its strength, durability, and resistance to abrasion. Insufficient curing causes thermal and plastic shrinkage cracks in concrete, as well as a significant reduction in the surface layer's strength. Plastic shrinkage cracks and a weak, dusty surface are caused by evaporation from the exposed horizontal surface of the concrete when it is not kept moist during the first 24 hours after casting [1]. When evaporation outpaces bleeding, plastic shrinkage happens. Plastic shrinkage cracking propagates when the capillary pore stress rises as a result of increased surface tension brought on by menisci formation in the pores. Plastic shrinkage is influenced by cement fineness and the water-to-binder ratio. Plastic shrinkage strain is reduced when the evaporated water is changed through bleeding water, which can be supplied through saturated recycled concrete aggregates.

Curing is the process of keeping concrete at an appropriate temperature and moisture content in its early stages so that the required properties can emerge. Self-curing concrete is a type of concrete that can be cured by itself [2, 3, 4]. Several materials can be used as chemical self-curing agents that are added to cement during the mixing process, such as polyethylene glycol (PEG200, 400, and 600) and polyacrylamide, which improve the concrete properties [5, 6, 7]. Another method to make concrete cure itself is by using permeable coarse aggregate, which acts as internal reservoirs to have water during mixing, and then providing it to concrete as internal curing. Several materials can be used as internal reservoirs, such as pumice) [8, 9], crushed concrete aggregates [2, 3], lightweight expanded clay aggregates "LECA" [4], perlite [5], and crushed burnt clay brick [6]. To improve internal curing, some portions of sand were substituted with saturated lightweight aggregates) [7].

Ohio's transportation department uses the self-curing method to decrease concrete pavement's early-age cracking) [8, 9].

There is a growing trend towards using various industrial wastes in place of natural aggregates. [3, 10, 11]. Self-curing leads to uninterrupted and effective curing by retaining the required quantity of water for adequate cement hydration and maintaining the high relative humidity (RH), thereby resulting in hard and dense concrete with reduced thermal and shrinkage cracks.

2. Aim and Research Significance

This investigation aims to study the feasibility of improving self-curing recycled aggregate concrete's early-age properties. The main variables in this research are recycled aggregate used (crushed concrete and crushed red brick compared to crushed dolomite as natural coarse aggregates) and curing agents to obtain self-curing concrete .The super absorbent Polymer (SAP), at 0.3% of cement weight, and Polyethylene Glycol (PEG400), at 0.5% of cement weight, as an admixture to reduce shrinkage.

The outputs of this study are experimental results that the researchers can assimilate and disseminate to judge and use this type of concrete

The innovation in this research is the comparative study of the early-age properties of recycled aggregate self-curing concrete RA-SC mixes cast using different coarse aggregate types and different internal curing materials.

The importance of this research is to provide sufficient data for the researchers and engineers concerned with using recycled aggregate self-curing concrete as an economical and green concrete type in desert sites or other places where the concrete curing processes are difficult.

3. Experimental Program

All tests in this research are carried out in the quality control and testing of the building materials research laboratory in the Civil Engineering Department of the Faculty of Engineering, Menoufia University. The test specimen design, materials used, and testing procedures are covered in the following sections.

The experimental program is shown in Fig. (1).

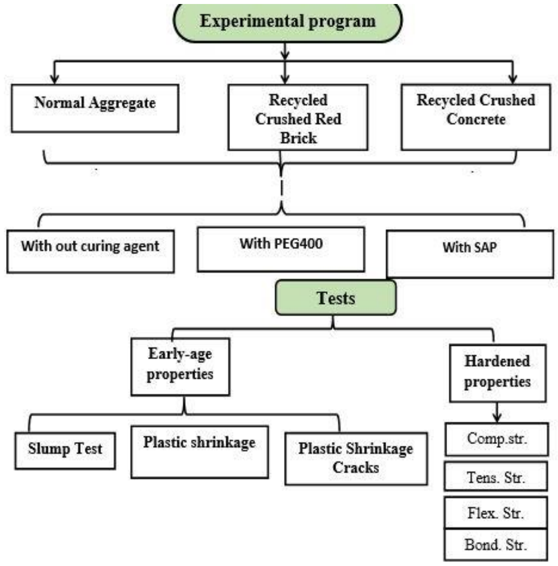

Figure 1- the Flow chart of the experimental program

3.1. Materials

Ordinary Portland cement (CEM I 42.5 N) from the Suez cement factory is used. It meets the requirements of the Egyptian Standard Specification (E.S.S. 4756-1/2022) [12].

The fine aggregate used is natural silica sand that satisfies the Egyptian standard specifications (E.S.S. 1109/2021) [13]. With a specific gravity of 2.6 t/m3 and a fineness modulus of 2.61, it is almost entirely pure and free of contaminants. Table (1) shows its physical properties. Its grading is shown in Table (2) and Fig. (2).

Table 1- Physical properties of the sand used

Property		Value
Specific Gravity	t/m3	2.63
Volumetric Weight	t/m3	1.71
Voids Ratio,	%	33.5
%Absorption	%	0.8

Table 2- Grading of the sand used.

Sieve size (mm)	9.5	4.75	2.36	1.18	0.61	0.31	0.16
Passing ASTM C33	100	95-100	80-100	50-85	25-60	5 - 30	0-10
% passing sand	100	98	94	85	55	9	6

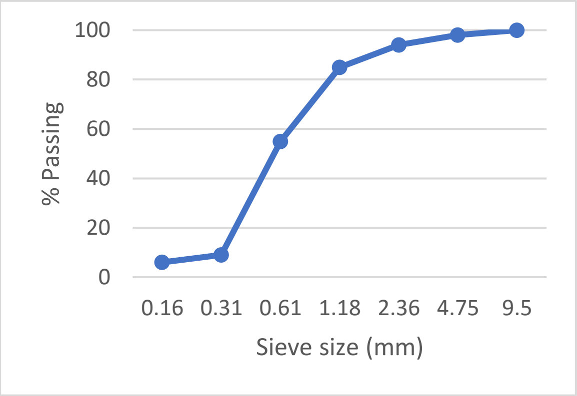

Figure 2- Grading of the sand used

The coarse aggregate used is recycled aggregate (crushed red brick (CRB) and crushed concrete (RCA)) as well as dolomite. It satisfies ASTM C-33 [14], as shown in Tables (3), (4), and Fig (3).
Most of the dolomite particles are angular and irregular in shape, with very few of them being flat.

Table 3- Crushed concrete, crushed red brick, and dolomite's physical characteristics

Property	**Dolomite**	**Crushed Concrete**	**Crushed Red Brick**
specific gravity	2.63	2.5	2.17
absorption%	1	3.4	6.8

Table 4- Crushed concrete, Grading of the dolomite, crushed concrete, and crushed red bricks used (according to ASTM C33).

Sieve size *(mm)*	**25**	**19**	**9.5**	**4.75**	**2.36**
Passing ASTM C-33	100	90-100	20-55	0-10	0-5
% Passing Dolomite	100	91	45	1	1
% Passing crushed red bricks	100	95	50	2	1
% Passing crushed concrete	100	93	45	2	1

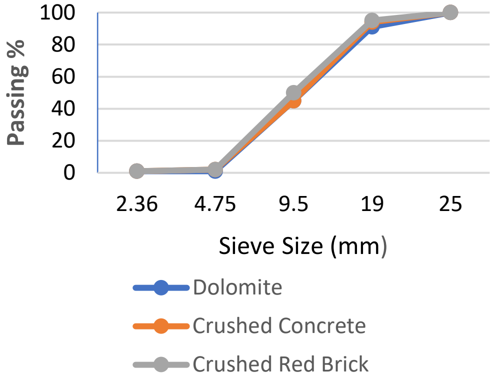

Figure 3- Grading of the dolomite, crushed concrete, and crushed red bricks used according to ASTM C33.

Water was used as regular, potable, pure drinking water. It has no alkanets or acids in it. It satisfies E.C.P. 203-2020 [15].
Polyethylene glycol "PEG 400" is a type of polyethylene glycol with a low molecular weight that is employed as a chemical curing agent. It is transparent, colorless, and viscous. PEG400 has a strong hydrophilic character and is soluble in water. It was acquired from Pioneers for Chemicals in Egypt. Table (5) displays the attributes of PEG400.

Table ٥-Technical information of Polyethylene Glycol 400 "PEG400" used (as provided by the manufacturer)

Sr. No.	**Item test**	**Unites**	**Specification**
1	Appearance	-	Clear viscous liquid
2	Solubility	In water g/l	Miscible
3	Density	g/ml	1 .13
4	pH	At 25°C	5--7
5	Melting point	ºC	5 ºC

The super absorbent polymer (SAP) is copolymerized by acrylate, which is a functional polymer material possessing excellent water absorption and water-holding ability. SAP is mostly used for absorbing, holding, or obstructing fluids. The properties of SAP used are shown in Table (6).

High-tensile steel reinforcing bars of diameter 12 mm satisfy the E.S.S. 262 [16]. It was used as embedded rebars in concrete cubes to measure the bond between concrete and steel.

Table 6- Properties of SAP used (as obtained from the manufacturer)

Property	Description
Form-dry	Crystalline white powder/granules
Form-wet	Transparent gel
Particle size	0.2 mm
Water absorption with distilled water	800 g for 1 g
the pH of absorbed water	Neutral
Density	1.08 (g/cm^3)
Bulk density	0.85 (g/cm^3)
Hydration / Dehydration	Reversible
Decomposition in sunlight	6 months
Available water	95% approx.

3.2. Concrete and Test Samples

3.2.1. Concrete Mixes

The concrete mixes used in this research are shown in Table (7). The mix proportions were obtained based on previous research [17].

There are three stages to the experimental program that is being done. The first stage was performed to study the effect of using polyethylene glycol "PEG 400" and the super absorbent polymer "SAP" on the early-age and hardened concrete properties of the concrete cast using dolomite as a natural aggregate.

The second stage involved using crushed concrete (as a 25 and 50% replacement of dolomite as natural aggregate) to cast recycled concrete and examining the effects of using "PEG 400" and the super absorbent polymer "SAP" on the properties of the hardened and early-age concrete.

The third stage involved examining the impact of utilizing "PEG 400" and the super absorbent polymer "SAP" on the properties of the hardened and early-age concrete. The recycled concrete was made using cast crushed red brick, with dolomite being replaced with 25 and 50% of the natural aggregate, respectively.

3.2.2. Concrete Tests

The early-age properties of concrete are discussed in terms of the plastic shrinkage settlement test *(according to ASTM C827* [18]*)*, as shown in Figs. (4) and (5), and the plastic shrinkage panel test *(according to ASTM C1579* [19]*)*, as shown in Fig. (6).

The properties of the hardened concrete are observed at 7, 28, and 56 days in terms of compressive strength, tensile splitting strength, flexural strength, and bond strength. The specimens used in this study are cubes (100x100x100mm) to determine the compressive strength, cylinders (100mm diameter and 200mm height) to determine the tensile strength, prisms (with dimensions of 100x100x500mm) to determine the flexural strength, and cubes (with dimensions of 150x150x150mm) with embedded steel bars to determine the bond strength. Also, cylinders (100 mm in diameter and 200 mm in height) were used to conduct a plastic shrinkage settlement test, as well as two plates with dimensions of 600 x 900 mm and 250 mm in thickness to conduct plastic shrinkage plate tests.

Figure 4- Plastic shrinkage settlement device

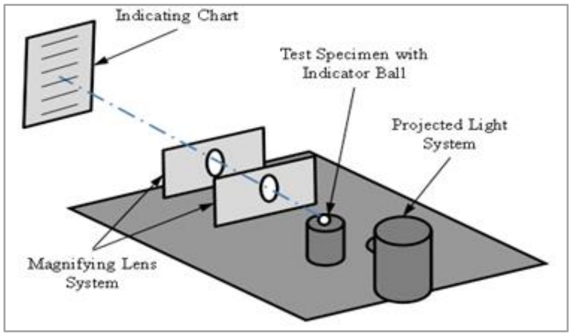

Figure 5- The apparatus for early change in height adapted from ASTM C827(plastic shrinkage tests)

Figure 6- Plastic shrinkage panel tests

Table 8- Concrete mixes used.

						C.A (kg)			Additions		Tested Samples			
							Type							
Stage	Mix Code	Description	C *(kg)*	W *(kg)*	F.A (kg)	Dolomite *(kg)*	Crushed Concrete *(kg)*	Crushed Red Brick *(kg)*	P.E.G 400 *(kg)*	SAP *(kg)*	Compressive Strength	Tensile Strength	Flexural Strength	Bond Strength
1	D1	100 %Dolomite	435	205	662.5	1037.5	--	--	--	--		9 cylinders 10*20 for each mix	9 prisms 10*10*50 for each mix	9 cubes 15*15*15 for each mix
	D2	100 %D				1037.5	--	--	2.18	--				
	D3	100 %D				1037.5	--	--	----	1.3				
2	C1	75%Dolomite+25% Crushed Concrete				778.125	246.4	--	--	----				
	C2	75%D+25% CC				778.125	246.4	--	2.18	----				
	C3	75%Dolomite+25% CC				778.125	246.4	--	--	1.3				
	C4	50%D+50% CC				518.75	492.8	--	--	--				
	C5	50%D+50% CC				518.75	492.8	--	2.18	--				
	C6	50%D+50% CC				518.75	492.8	--	--	1.3				
3	B1	75%Dolomite+25% Crushed Red Brick				778.125	--	224.14	--	--				
	B2	75%D+25% CRB				778.125	--	224.14	2.18	--				
	B3	75%D+25% CRB				778.125	--	224.14	--	1.3				
	B4	50%Dolomite+50% Crushed Red Brick				518.75	--	448.2	--	--				
	B5	50%D+50% CRB				518.75	--	448.2	2.18	--				
	B6	50%D+50% CRB				518.75	--	448.2	--	1.3				

3.2.3. Change in Height at Early Age Test (Plastic Shrinkage Tests)

The standard test method for change in height at the early age of cylindrical specimens of cementitious mixtures' C827 test method [18] covers the determination of change in height of cylindrical specimens from the time of molding until the mixture is hard. Height change measurements at early ages for cementitious mixtures of paste, grout, mortar, and concrete.

The apparatus used in this test is a projected light source, a lamp, indicating charts, and a condensing lens that is powerful enough to correctly project a light beam onto a wall at a distance of around three meters from the light source. Also, a magnifying lens system such that the image of the indicator ball produced by the projected light source is cast on the indicating chart is about 3 m. Molds are cylinders of diameter about 100mm and 200mm in height. The reading is taken several times during the first 3 hours after casting the concrete, with the final reading at 24 hours. Results can be represented in the form of a change in the height of the specimen. The changes in the height of the test specimens can be calculated as follows:

$$°H = (I/MH) \times 100$$

where: °H = change in height, %: I = indicating chart reading, in. (mm), H = initial height of test specimen, in. (mm), and M magnification of the lens system (equal to 100).

3.2.4. Plastic Shrinkage Panel Testes

Tests were performed with slabs that were 0.9 meters long, 0.6 meters wide, and 25 mm thick. The slab molds were made from wood. The slab size was selected based on experiments conducted [20] following ASTM C1579 [19].

On a level surface (a laboratory floor), plain concrete slabs are exposed to the following conditions: a wind speed of 22 km/h, a relative humidity of 40%, and a temperature of 25 °C, respectively. To achieve a true comparison of shrinkage cracking, thirty slabs (two slabs for each trial mix) were cast and tested simultaneously in the same environmental conditions. Six panels were used as control specimens, two panels (without curing agent), and four panels for PEG400 and SAP admixture (without recycled aggregate). The other twenty-four panels were cast using crushed red brick and crushed concrete.

Crack widths, lengths, and distributions were measured after 24 hours of casting for all panels. All test panels were stored under plastic sheets to minimize evaporation until the crack width measurement time. The corresponding cracking reduction (CRR) ratio was calculated based on ASTM C1579.

$$\text{CRR}=\left(1-\frac{Average\ Crack\ \ Area\ of\ Modified\ Concrete}{Average\ Crack\ Area\ of\ Control\ Concrete}\right)*100$$

4. Test Results and Discussions

The results in this study are derived in terms of slump values, plastic shrinkage, plastic shrinkage cracks, compressive strength, tensile strength, flexural strength, and bond strength.

4.1. Early-age Properties of Concrete

The early-age properties of concrete are discussed in terms of slump values, plastic shrinkage settlement, and plastic shrinkage cracks.

4.1.1. Slump Test Results

Concrete's slump values increase when PEG400 and SAP are used, as Table (8) demonstrates.

Also, it shows that the workability of concrete made from dolomite is higher than that of concrete made from crushed concrete or crushed red bricks, which may be attributed to the lower voids of the surface of crushed dolomite compared to recycled aggregate, which is in agreement with [21].

Table 8- Slump values

Mixes		Slump Value *(mm)*
Aggregate type	Code	
Dolomite	D1	55
	D2	70
	D3	70
Crushed Concrete as a recycled aggregate replacement (25%, 50%) of dolomite	C1	45
	C2	60
	C3	60
	C4	40
	C5	55
	C6	55
Crushed red brick as a recycled aggregate replacement (25%, 50%) of dolomite	B1	40
	B2	55
	B3	55
	B4	35
	B5	50
	B6	50

4.1.2. Plastic Shrinkage Cracks

The results of cracks according to plate tests indicate that, in addition to additives like SAP and PEG, using recycled aggregate reduces plastic shrinkage and plastic shrinkage cracks in concrete (see Table 9 for the width, length, area, and crack reduction ratio, or "CRR" factor). Self-curing recycled aggregate concrete has fewer fractures than conventional concrete made of natural dolomite, as shown in Figs (7 to 12). Compared to concrete made with crushed concrete, concrete cast using crushed red brick has a smaller fracture area. Where the highest value of the dolomite-infused concrete was found. Slabs with varying mixes' crack patterns are displayed in Figs (13 to 27)

This might be a reference to SAP's capacity to absorb aqueous solutions or, in the case of concrete, pore solutions and subsequently release them, thereby reducing plastic shrinkage and cracking. When pores close and the cementitious system's internal relative humidity falls, these problems are resolved. That might concur with [22]. Also, the results refer to the fact that polyethylene glycol (PEG), a shrinkage-reducing additive, promotes greater hydration during self-curing, hence lowering shrinkage cracks. That may agree with [23].

Table 9- Crack width, length, area, and crack reduction ratio CRR factor.

Mix Code	Av. Crack Width (mm)	Av. Crack Length (mm)	Av. Crack Area (mm2)	CRR (%)
D1	0.3	120	36.00	-
D2	0.25	72.0	18.00	50.00
D3	0.23	88.33	20.32	42.75
C1	0.27	48.75	13.16	63.44
C2	0.23	34.38	7.91	78.06
C3	0.2	32.0	6.40	82.22
C4	0.17	38.33	6.52	84.4
C5	0.125	32.0	4.00	88.90
C6	0.14	31.0	4.34	87.94
B1	0.132	45.0	5.94	83.50
B2	0.11	30.0	3.3	83.50
B3	0.1	20.0	2.00	94.44
B4	0.14	35.56	4.98	90.8
B5	0.1	29.0	2.90	87.11
B6	0.13	28.33	3.69	89.53

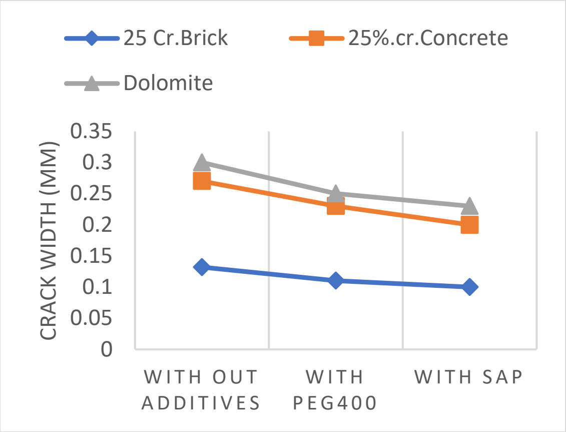

Figure 7- Relation between crack width and curing type with Natural Dolomite,25% cr. Brick and 25% cr. Concrete.

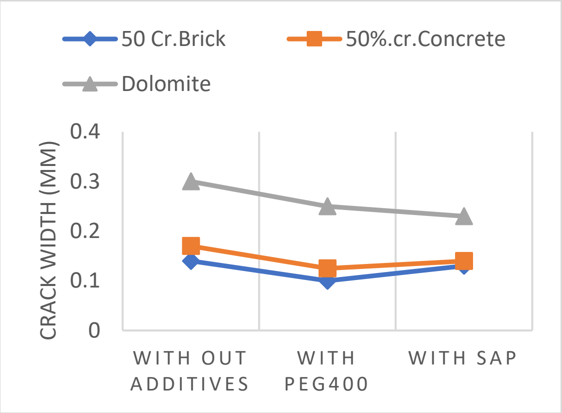

Figure 8- Relation between crack width and curing type with Natural Dolomite,٥٠% cr. Brick and ٥٠% cr. Concrete

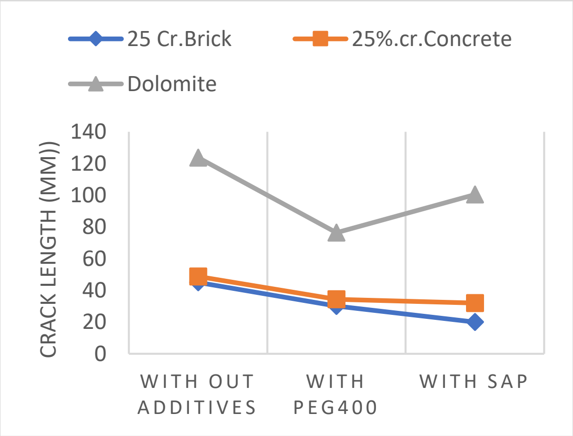

Figure 9- Relation between crack length and curing type with Natural Dolomite,٢٥% cr. Brick and ٢٥% cr. Concrete

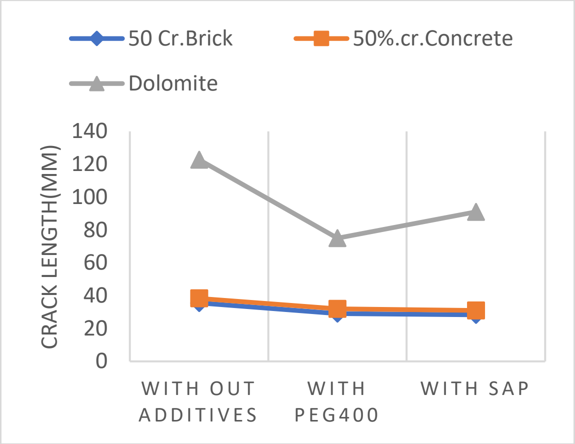

Figure 10- Relation between crack length and curing type with Natural Dolomite,50% cr. Brick and 50% cr. Concrete

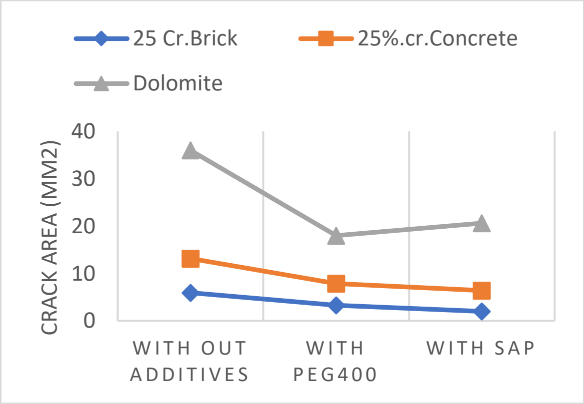

Figure 11- Relation between crack area and curing type with Natural Dolomite,25% cr. Brick and 25% cr. Concrete.

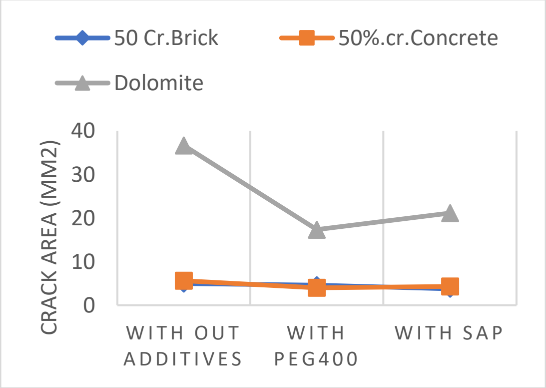

Figure 12- Relation between crack area and curing type with Natural Dolomite,50% cr. Brick and 50% cr. Concrete.

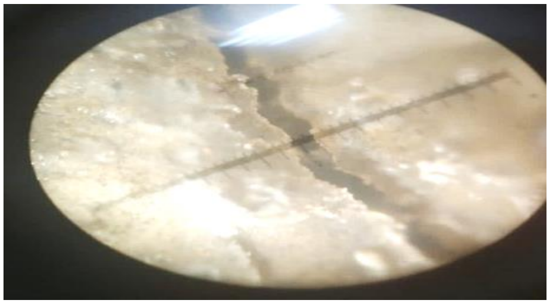

Figure 13-Crack pattern of slab D1

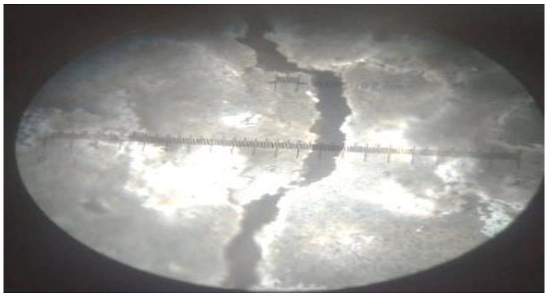

Figure 14- Crack pattern of slab D2

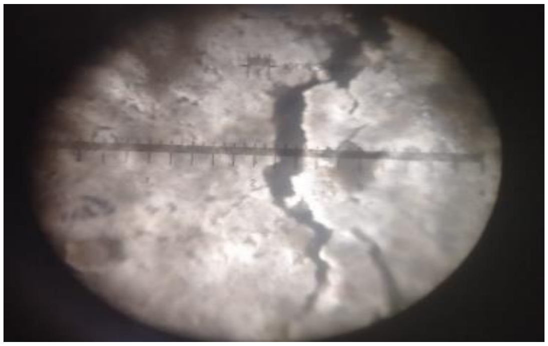

Figure 15- Crack pattern of slab D3

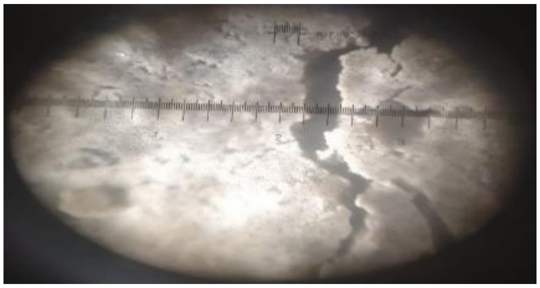

Figure 16- Crack pattern of slab C1

Figure 17- Crack pattern of slab C2

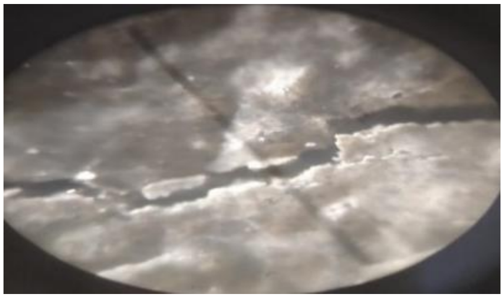

Figure 18- Crack pattern of slab C3

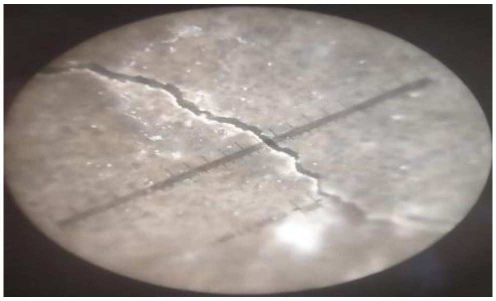

Figure 19- Crack pattern of slab C4

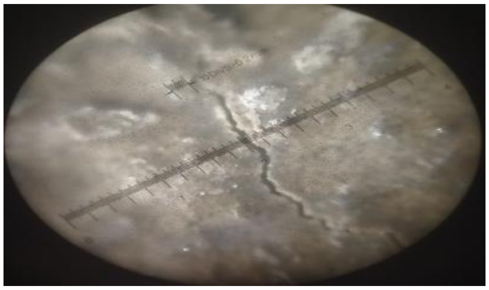

Figure 20- Crack pattern of slab C5

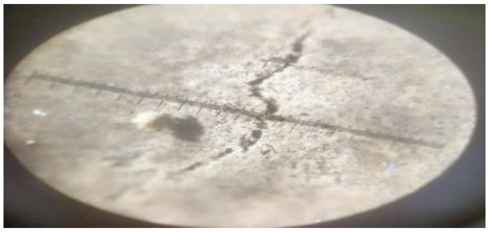

Figure 21- Crack pattern of slab C6

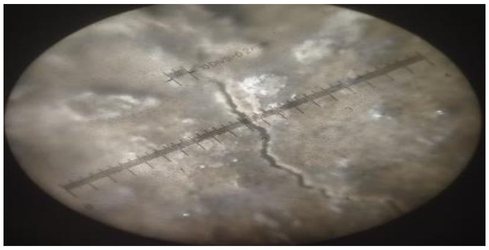

Figure 22-Crack pattern of slab B1

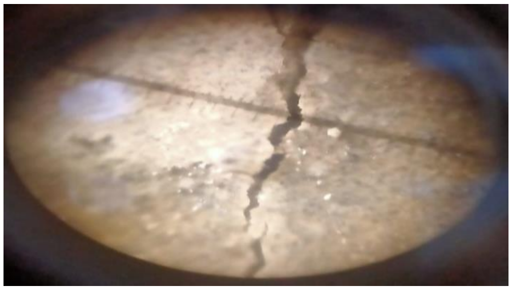

Figure 23- Crack pattern of slab B2

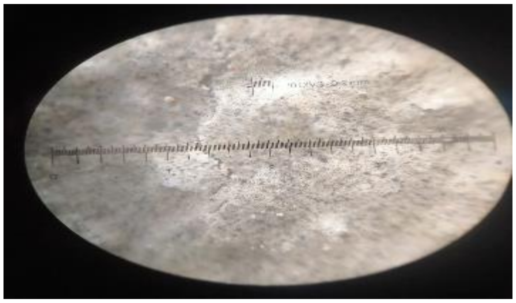

Figure 24- Crack pattern of slab B3

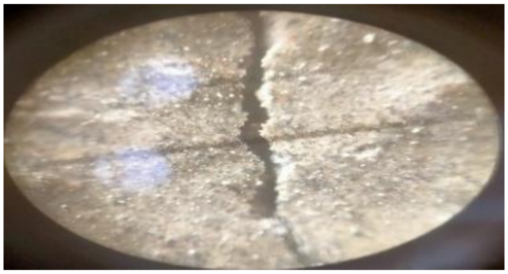

Figure 25- Crack pattern of slab B4

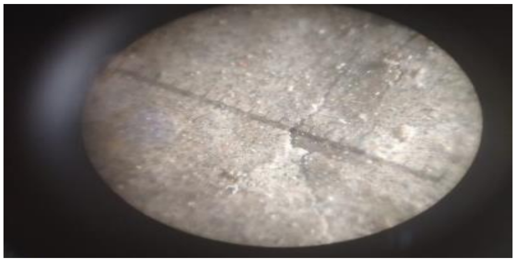

Figure 26- Crack pattern of slab B5

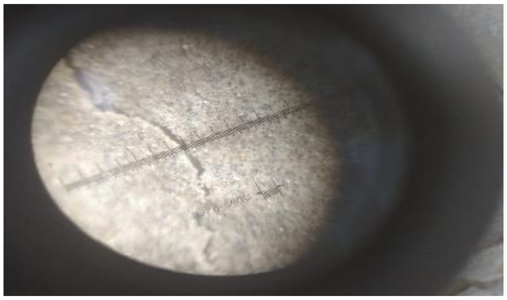

Figure 27- Crack pattern of slab B6

4.1.3. Plastic Shrinkage Settlement

The results of plastic shrinkage settlement tests are discussed in terms of change in the height of the specimen as shown in Table (10). There is a linear relationship between the change in the height of the specimen and plastic shrinkage (as change in height increases, the plastic shrinkage increases).

4.2. Mechanical Properties Results

Figures (28 to 35) show the relationship between the curing agent used (PEG400, SAP, and without an agent) and compressive, tensile, flexural, and bond strength values at 7 days. It shows that:

Using a replacement ratio of 25% of natural dolomite with crushed concrete, the compressive strength, tensile strength, flexural strength, and bond strength decreased by 10.1%, 5%, 3.4%, and 4.2%, respectively, compared to using dolomite.

The compressive strength, tensile strength, flexural strength, and bond strength dropped by 12.1%, 5%, 3.4%, and 8.3%, respectively, when 50% of the dolomite was replaced with crushed concrete as opposed to natural dolomite.

Concrete made by using 25% replacement of dolomite with crushed red brick, the compressive strength, tensile strength, flexural strength, and bond strength decreased by 14%, 10%, 3.4%, and 8.3%, respectively, compared to using natural dolomite.

Concrete made by using 25% replacement of dolomite with crushed red brick, the compressive strength, tensile strength, flexural strength, and bond strength decreased by 14%, 10%, 3.4%, and 8.3%, respectively, compared to using natural dolomite.

In comparison to using natural dolomite, the compressive strength, tensile strength, flexural strength, and bond strength decreased by 15%, 10%, 3.4%, and 8.3%, respectively, when 50% replacement of the natural dolomite was replaced with crushed red brick.

Figures (36 to 43) show the relationship between curing-agent (using PEG400, SAP, and without an agent) and compressive, tensile, flexural, and strength values at 28 days. It shows that:

In comparison to using natural dolomite, the compressive strength, tensile strength, flexural strength, and bond strength decreased by 12.2%, 7.1%, 3.8%, and 3.3%, respectively, when a 25% replacement ratio of crushed concrete was used.

When using 50% replacement of natural dolomite with crushed concrete, the compressive strength, tensile strength, flexural strength, and bond strength decreased by 1٣.٤%, 7.1%, 5.1%, and 11.7%, respectively, compared to using natural dolomite.

When 50% replacement with crushed red brick was used instead of natural dolomite, compressive strength, tensile strength, flexural strength, and bond strength decreased by 17.9%, 7.1%, 7.7%, and 8.3%, respectively. The mechanical properties results are listed in Table (11)

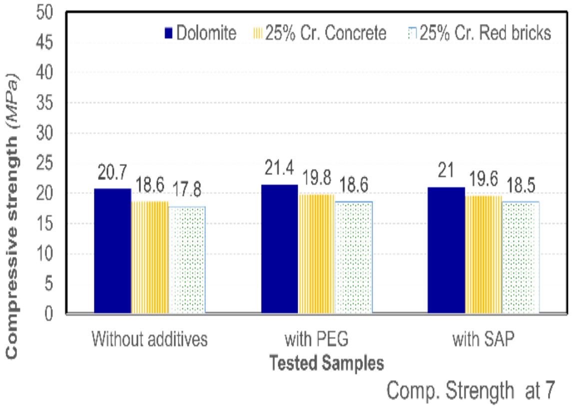

Figure 28- Relation between compressive strength and curing agent at 7 days

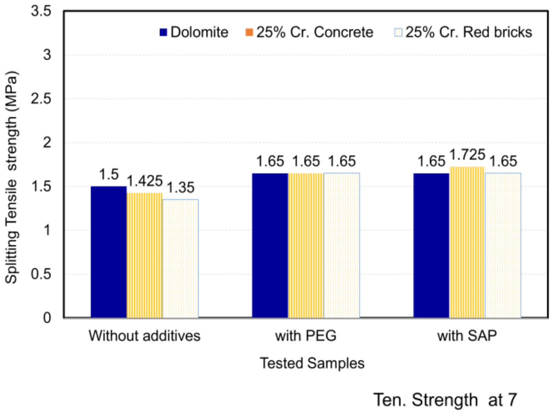

Figure 29- Relation between tensile strength and curing agent at 7 days

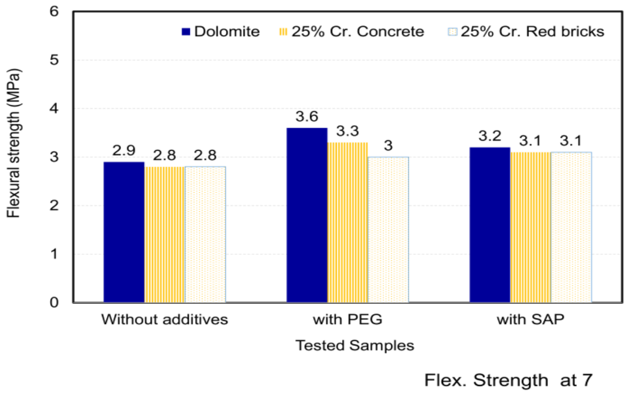

Figure 30- Relation between flexural strength and curing agent at 7 days

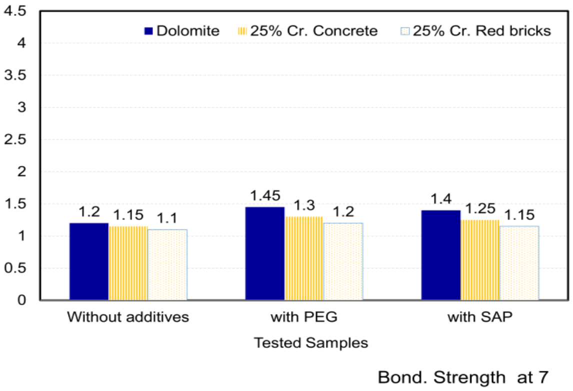

Figure 31- Relation between bond strength and curing agent at 7 days

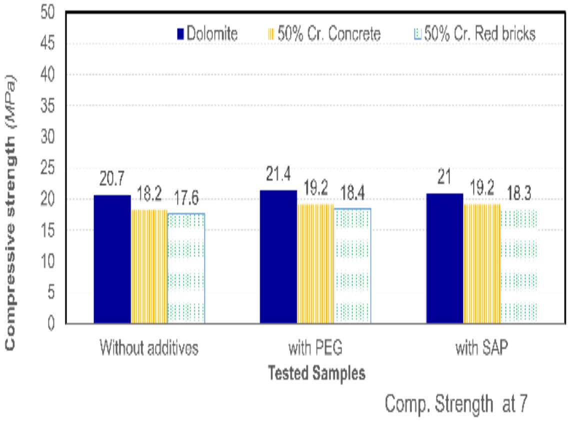

Figure 32- Relation between compressive strength and curing agent at 7 days

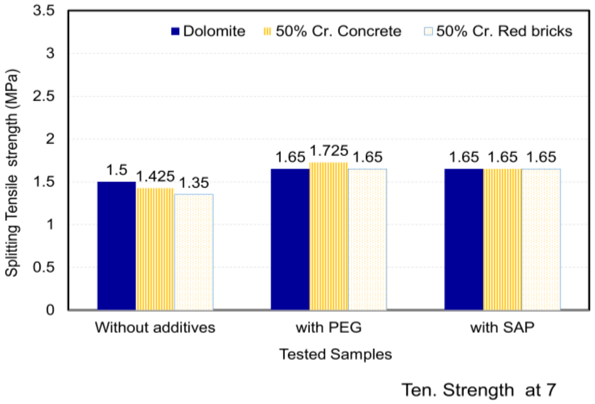

Figure 33- Relation between tensile strength and curing agent at 7 days.

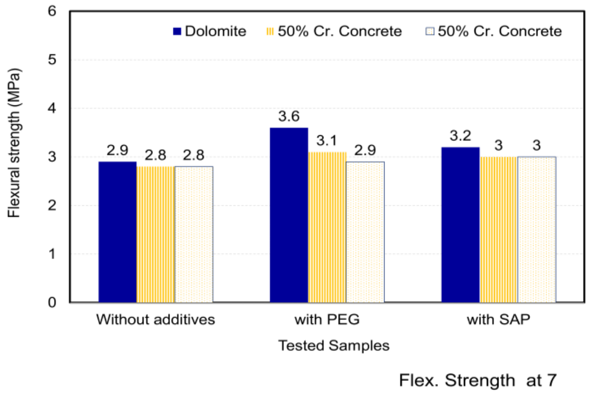

Figure 34- Relation between flexural strength and curing agent at 7 days.

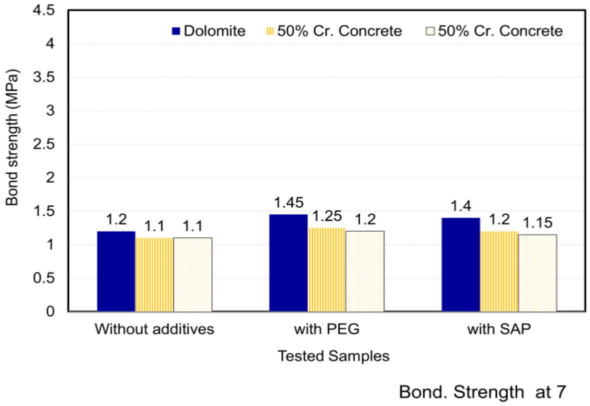

Figure 35- Relation between bond strength and curing agent at 7 days.

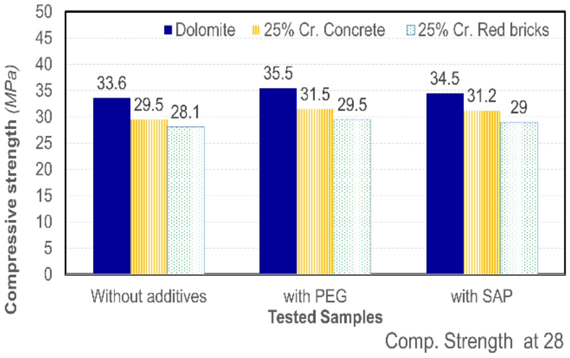

Figure 36- Relation between compressive strength and curing agent at 28 days

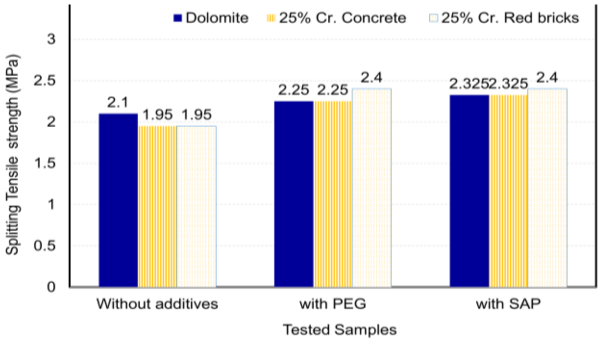

Figure 37- Relation between tensile strength and curing agent at 28 days

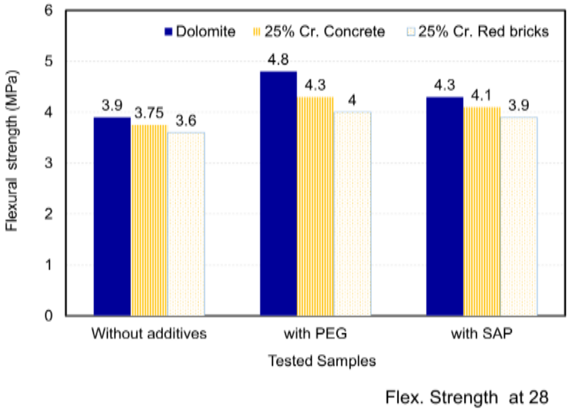

Figure 38- Relation between flexural strength and curing agent at 28 days

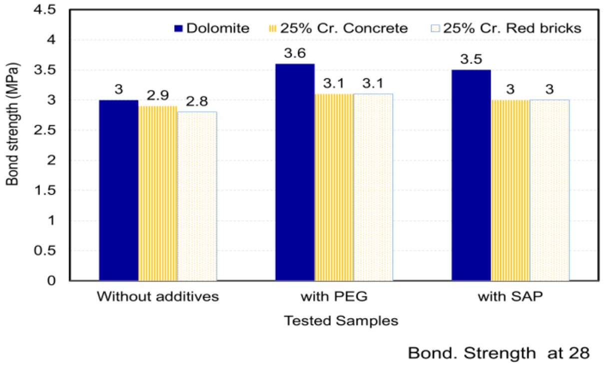

Figure 39- Relation between bond strength and curing agent at 28 days.

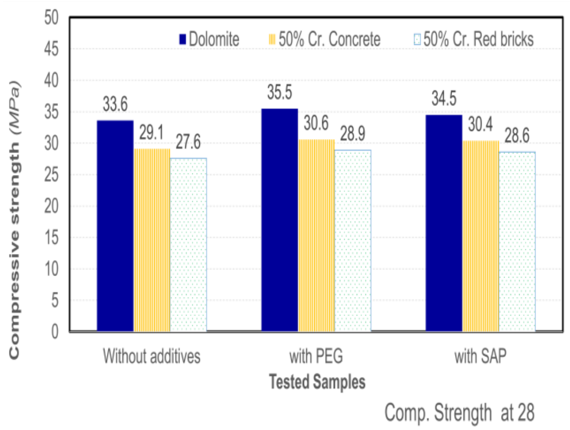

Figure 40- Relation between compressive strength and curing agent at 28 days.

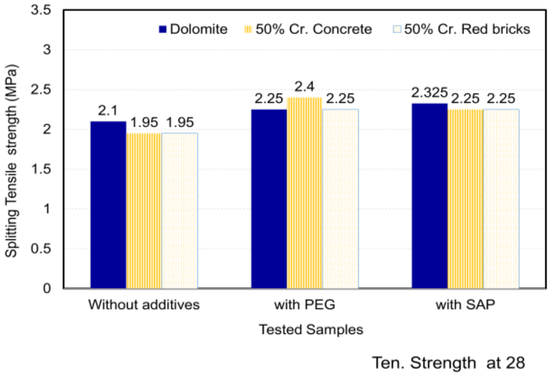

Figure 41- Relation between tensile strength and curing agent at 28 days.

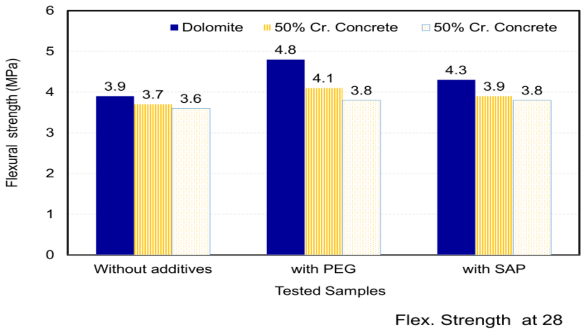

Figure 42- Relation between flexural strength and curing agent at 28 days.

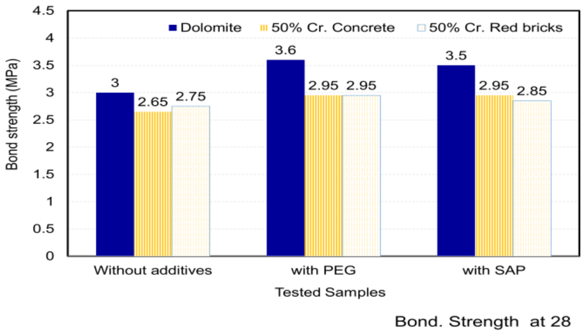

Figure 43- Relation between bond strength and curing agent at 28 days.

4.3.1 Effect of PEG 400 on the mechanical properties of concrete at 28 days.

Using PEG400 in natural dolomite-based concrete. When compared to concrete made without PEG400, the compressive strength, tensile strength, flexural strength, and bond strength increased by 5.7%, 7.1%, 23.1%, and 20%, respectively.

When 25% replacement of natural dolomite with crushed concrete material (means that 75% of the sample is natural dolomite, 25% is crushed concrete, and PEG 400 is used as a curing agent)

The results showed increases in compressive strength, tensile strength, flexural strength, and bond strength by 6.8%, 15.4%, 14.7%, and 6.9%, respectively, as compared to the same concrete made without PEG400.

When 50% replacement of natural dolomite with crushed concrete material. The percentage increases in compressive strength, tensile strength, flexural strength, and bond strength were 5.2%,23.1%, 10.8%, and 11.3%, respectively in comparison to the same concrete made without PEG400. Concrete made by replacing 25 % of natural dolomite with crushed red brick, the compressive strength, tensile strength, flexural strength, and bond strength increased by 5.0 %, 23.1%, 11.1%, and 10.7%, respectively compared to concrete made without PEG 400.

Table 10- Plastic shrinkage settlement results

Mix Code			D1	D2	D3	C1	C2	C3	C4	C5	C6	B1	B2	B3	B4	B5	B6
Time (min)	0	Values of change of height of specimen (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10		0.44	0.13	0.09	0.44	0.18	0.27	0.53	0.33	0.2	0.25	0.15	0.25	0.25	0.19	0.2
	20		0.69	0.15	0.09	0.52	0.21	0.27	0.59	0.44	0.37	0.35	0.25	0.35	0.5	0.33	0.33
	30		0.73	0.17	0.1	0.52	0.23	0.31	0.65	0.44	0.45	0.45	0.25	0.4	0.55	0.35	0.35
	40		0.75	0.18	0.12	0.52	0.25	0.31	0.65	0.44	0.47	0.5	0.25	0.4	0.58	0.35	0.38
	50		0.75	0.18	0.12	0.52	0.25	0.31	0.65	0.44	0.47	0.5	0.25	0.4	0.6	0.35	0.4
	60		0.75	0.18	0.13	0.52	0.25	0.31	0.65	0.44	0.47	0.5	0.25	0.4	0.6	0.35	0.43
	70		0.75	0.18	0.13	0.52	0.25	0.31	0.65	0.44	0.47	0.5	0.25	0.4	0.6	0.35	0.43
	190		0.75	0.2	0.13	0.52	0.25	0.31	0.65	0.44	0.47	0.5	0.25	0.4	0.6	0.35	0.43
	1440		0.75	0.2	0.13	0.52	0.25	0.31	0.65	0.44	0.47	0.5	0.25	0.4	0.6	0.35	0.43

Table 11 - Hardened concrete properties

Mix Code	Compressive Strength (MPa)			Tensile Strength (MPa)			Flexural Strength (MPa)			Bond Strength (MPa)		
	7 Days	28 Days	56 Days	7 Days	28 Days	56 Days	7 Days	28 Days	56 Days	7 Days	28 Days	56 Days
D1	20.7	33.6	35.1	1.5	2.1	2.55	2.9	3.9	4	1.2	3	3.3
D2	21.4	35.5	37	1.65	2.25	2.78	3.6	4.8	4.8	1.45	3.6	4.0
D3	21	34.5	36	1.65	2.33	2.85	3.2	4.3	4.5	1.4	3.5	3.9
C1	18.6	29.5	30.7	1.43	1.95	2.4	2.8	3.75	3.9	1.15	2.9	3.2
C2	19.8	31.5	32.9	1.65	2.25	2.7	3.3	4.3	4.6	1.3	3.1	3.5
C3	19.6	31.2	32.3	1.73	2.33	2.85	3.1	4.1	4.3	1.25	3	3.4
C4	18.2	29.1	30.3	1.43	1.95	2.33	2.8	3.7	3.9	1.1	2.65	3
C5	19.2	30.6	31.8	1.73	2.4	2.85	3.1	4.1	4.3	1.25	2.95	3.4
C6	19.2	30.4	31.7	1.65	2.25	2.7	3	3.9	4.2	1.2	2.95	3.35
B1	17.8	28.1	29.4	1.35	1.95	2.25	2.8	3.6	3.8	1.1	2.8	3.15
B2	18.6	29.5	30.8	1.65	2.4	2.7	3	4	4.1	1.2	3.1	3.4
B3	18.5	29.0	30.5	1.65	2.4	2.7	3.1	3.9	4.2	1.15	3.0	3.3
B4	17.6	27.6	29.3	1.35	1.95	2.25	2.8	3.6	3.8	1.1	2.75	3.1
B5	18.4	28.9	30.6	1.65	2.25	2.7	2.9	3.8	4.1	1.2	2.95	3.25
B6	18.3	28.6	30.2	1.65	2.25	2.7	3	3.8	4.1	1.15	2.85	3.2

A replacement ratio of 50% of natural dolomite with crushed red brick, the compressive strength, tensile strength, flexural strength, and bond strength increased by 4.7%, 15.4%,5.6%, and 7.3%, respectively, compared to the same concrete made without PEG 400.

The increase in mechanical properties due to using PEG400 may refer to the fact that concrete that contains PEG400 has a higher water retention capacity than concrete that doesn't contain it since it can decrease water evaporation. That may agree with [24].

4.3.2 Effect of SAP on mechanical properties of concrete at 28 days

Using SAP in dolomite-based concrete. When compared to concrete made without SAP, the compressive strength, tensile strength, flexural strength, and bond strength increased by 5.8%, 19.2%, 9.3%, and 4.3%, respectively.

SAP material is used in concrete that has a 25% replacement of natural aggregate with crushed concrete (which means that 75% of the sample is natural dolomite, 25% is crushed concrete, and SAP is used as a curing agent) Compared with the same concrete without SAP, the compressive strength, tensile strength, flexural strength, and bond strength increased by 5.8%, 19.2%, 9.3%, and 4.3%, respectively.

Concrete made with SAP contains 50% natural dolomite with crushed concrete. In comparison with the same concrete without SAP, the compressive strength, tensile strength, flexural strength, and bond strength increased by 4.5%, 15.4%, 5.4%, and 11.3%, respectively.

In comparison to concrete without SAP, the compressive strength, tensile strength, flexural strength, and bond strength increased by 3.2%, 23.1%, 8.3%, and 7.1%, respectively, when concrete was made by replacing 25% of the natural dolomite with crushed red brick.

SAP material is used in concrete, substituting 50% of the crushed red brick. In comparison to the same concrete without SAP, the compressive strength, tensile strength, flexural strength, and bond strength increased by 3.6%, 15.4%, 5.4%, and 3.6%, respectively.

The fact that SAP particles might encourage macropore development when absorbed water is discharged may be the reason for the increase in mechanical characteristics resulting from their use.

This phenomenon affects mechanical properties such as flexural and compressive strength, which may agree with [25, 26].

5.CONCLUSIONS

In this research, a series of experiments have been performed to investigate the behavior and early-age properties of recycled aggregates self-curing "RA-SC" concrete. Based on the experimental results presented in this research, the following conclusions could be drawn:

1. Self-curing concrete cast using natural dolomite and recycled aggregate, as coarse aggregates, has sufficient mechanical properties using PEG 400 and SAP as chemical curing agents.

2. Self-curing concrete cast using dolomite as coarse natural aggregate has a better strength than self-curing concrete cast using crushed concrete and crushed bricks as coarse recycled aggregates.

3. As the drying time increases, the plastic shrinkage settlement increases.

4. In terms of shrinkage behavior, concrete cast using recycled aggregate had less plastic shrinkage and plastic shrinkage cracks than concrete made with natural dolomite.

5. Regarding the shrinkage behavior, due to the internal curing of the concrete, it was observed that PEG400 and SAPs reduced plastic shrinkage and plastic shrinkage cracks in concrete in comparison to concrete without additives.

6. Compared to conventional concrete casts using dolomite, self-curing concrete casts using recycled aggregate had less plastic shrinkage and fewer plastic shrinkage cracks. Even for mix (B3), which contains 25% replacement of dolomite with crushed red brick and superabsorbent polymer (SAP), the values for the crack width, length, and area in Design (B3) were (0.1 mm), (20 mm), and (2.0 mm^2), respectively, while the value for the crack reduction ratio (CRR) was the highest (94.44%).

Generally, it can be concluded that recycled aggregates such as (crushed red brick and crushed concrete) can be used in self-curing concrete to produce recycled aggregate self-curing "RA-SC" efficiently because it can store a high amount of water to be used for early-age curing to reduce the shrinkage of concrete at early ages.

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