PROPERTIES OF CONCRETE WITH COATED AGGREGATES UNDER DIFFERENT LOADING CONDITIONS

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Abstract

Properties of concrete can be improved using different coating materials and chemicals. Some of the materials, however, are not effective as there is a weak bond between the coarse aggregate and the cement mortar. Hence, in this research, the mechanical and dynamic properties of concrete with epoxy resin, epoxy-sand and silicon coated aggregates at different volume fractions ranging from 5 to 15 percent were experimentally investigated. The test results indicate that there are improvements in compressive strength of concrete ranging from 10 % to 18 %, in which a maximum strength was achieved by using 15 percent epoxy-sand coating. Furthermore, a 5 % epoxy resin coating, resulting in an increase in compressive and tensile strengths of concrete by 5% and there are enhancements in static and dynamic modulus of elasticity by 2.7 %. In general, concrete specimens made with aggregates coated with epoxy-sand have higher performance in compressive strength as compared to using aggregates epoxy and silicon coated aggregates. Based on the findings of this study, it is recommended that coating of coarse aggregates with epoxy and epoxy-sand can be used as an alternative building and construction material to enhance the mechanical and dynamic properties of concrete.

Key Words: Shrinkage, Strain, Coated aggregates, Epoxy resin, Silicon, Static elastic modulus

1. Introduction

1.1. Background

On daily works, concrete structures must resist a variety of dynamic loads such as earthquakes, explosions, ocean waves, and wind loads. Concrete's strength and deformation characteristics under dynamic loads differ from those under static loads, and this difference may become a key factor in limiting structural safety under certain conditions. The loading-rate dependence of material response under dynamic conditions causes material behavior to differ significantly from that observed under quasi-static conditions. As a result, it is critical for the design of structures subjected to all types of loading that are likely to occur during the design lifetime. Understanding the behavior of concrete and mortar at very high strain rates is critical and must be studied [1].

Evidences show that the presence of certain micro-fine coatings on coarse aggregates encountered in actual field conditions and has adverse consequences for the properties of hardened concrete. The effects of these coatings on concrete performance and mechanical properties compared to washed aggregate concrete.

Improving the interface characteristic between the surface of aggregate and mortar through enhancement of hardness and texture of surface of coated aggregate will enhance the performance of concrete mechanics. An attempt has been made to use coated aggregate in concrete production. In this study, the normal aggregate was partially replaced by epoxy, epoxy-sand, and silicon coated aggregate in proportions of 5%, 10% and 15%, and the mechanical properties (compressive strength, split tensile strength, shrinkage, statics, and dynamic modulus of elasticity, etc) were investigated under different loading rates (0.6 MPa/sec, 2.22 MPa/sec, and 4.44 MPa/sec).

1.2. Research Significance

This research tries to investigate the use and performance of coated aggregates in concrete. The study also devotes to investigate experimentally the effect of epoxy resin, epoxy-sand and silicon coated aggregates on the properties of concrete, which includes compressive strength, split tensile strength, shrinkage, statics and dynamic modulus of elasticity, etc.

In this experimental investigation, natural and partially coated aggregates with different volume fraction of epoxy resin, epoxy-sand and silicon were used.

2. Literature Review

Many studies have shown that aggregates coated with polymer, waste plastics, low density polyethylene (LDPE), polyethylene terephthalate (PET), epoxy, clay, and other materials improve the mechanical properties of concrete. Furthermore, these coated aggregates used for surfacing of bituminous mix for flexible pavements and concrete mixes of flexible pavement significantly improve concrete bond strength behavior.

Coating pumice aggregate with a polymer was applied to aggregate grain groups with sizes ranging from 4-8 mm to 8-16 mm. The coating was made by spraying polymers with a paint spray gun in the conventional manner.

Coated and uncoated lightweight aggregates had specific weights ranging from 0.98 to 1.64 g/cm^3. When compared to control specimens, the average water absorption rate of uncoated lightweight aggregates in fractions of 4-8 mm and 8-16 mm was decreased. The experimental test result showed that the 24-hour water absorption rate for fine aggregates did not exceed 20% and 30% for coarse aggregates [2].

Plastic-coated aggregate in bituminous mix for flexible pavement with a percentage coat of 0.4 %, 0.6 % and 0.8 % were applied and the results show that the Los Angeles abrasion value has a significant change and a better resistance to abrasion than the uncoated aggregate. This shows that coating of aggregate resulting in better, durable and long-life asphalt concrete [3].

The waste plastics films, cups and foams were shredded into sizes of ranging from 2.5 mm - 4.36 mm and the aggregates were heated to 170 °C and the shredded waste plastics were sprayed over the hot aggregate. Upon this process, plastics have got softened and coated over the aggregate. The extent of coating was varied by using different percentage of plastics between 1 % to 5 %. Significant improvements in aggregate strength were observed, owing to the fact that when the plastic was coated over the aggregate, the aggregate surface was covered with a thin film of polymer [4].

To investigate the performance of plastic-coated aggregate in bituminous mix of flexible pavements, plastic-coated aggregates with different percentages: 5%, 7%, 9%, 11%, 13%, and 15% were made. The use of waste plastic in construction also allows for the safe disposal of plastic waste, which helps to protect the environment from pollution. Test results showed that waste plastics can potentially be used as a modifier for bituminous concrete mix because when it is coated over the aggregates of the mixture, it reduces porosity, moisture absorption, and improves the mix's binding property. The optimal bitumen content was determined to be 5.17% by weight of aggregates, and the optimal plastic content to be added as a modifier to the bituminous concrete mix was determined to be 9% by weight of bitumen content. The tensile strength ratio (TSR) was also found to be maximum at 9% waste plastic addition [5].

Polymer waste (bags, cups, foams, and so on) ranging in size from 1.6 mm to 4.75 mm is coated over hot aggregates (heated to 170 °C). Coating molten polymer over the aggregate can be made to bind with bitumen, which helps to improve the aggregate's properties. This process also contributes to a 10-15% reduction in bitumen consumption, which is being replaced by waste polymers. Furthermore, the polymer coating had a better binding property as observed in the binder extraction test, a lower penetration value (65mm), and thus a higher load carrying capacity [6].

The aggregate mix was heated and the shredded plastics waste was added to the aggregate. When it is sprayed over the hot aggregate, the plastic coating forms over the aggregate. Plastics coated aggregate (PCA) bitumen mix showed improved binding property and less moistening property. The sample showed a higher Marshall stability, increased in strength and load bearing capacity of the road is improved accordingly [7,8].

To investigate improvements in strength, stiffness, and the amount and type of micro cracks, uniaxial compression tests are performed on concretes with coated and uncoated aggregates. In the research, high polymer polystyrene pellets were added to commercial grade toluene to make a 5 % or 10 % solution by weight. The aggregate to be coated was washed, dried at 105 °C for 24hr, allowed to cool, and then submerged three (or eight) times in the polystyrene solution, being allowed to drain and dry between each application. Tension bond tests were conducted on various layers of coating: 8 coats of 10 % solution (0.0010-in. coating) and 3 coats of 5 % solution (0.0004-in. coating). Tests were made at 28 days and the result shows that coatings cause a significant reduction in bond strength. The standard polystyrene coating caused a 10 % reduction in compressive strength while the thick coating (with 8 coats of 10 % solutions) reduces the compressive strength by 23%. A large reduction in tensile paste-aggregate bond ranging from 60 % to 95 % was recorded and a significant reduction in compressive-shear paste-aggregate bond strength (75 to 80 %) was observed for a large fraction of coarse aggregate particles. This also causes 10 to 15 % reduction in the ultimate strength of concrete [9].

When clay-coated aggregates are used in the preparation of concrete, some of the clay will enter the water phase before the dry cement is added. The degrees of detachment and the hydration reaction depend on the nature of the clay. Clay coatings on coarse aggregates have an impact on the properties of fresh and hardened concrete samples, even when they are present in amounts less than 1.5%. The study on drying shrinkage reveals that clays with crystalline swelling cause higher values of drying shrinkage in concrete and adding extra water did not cause significant increases in its shrinkage property at later age. Shrinkage values for NaM and kaolin coated aggregates were equal at 0.45 w/c ratio and even with extra water content [10].

For evaluation of mechanical properties of concrete, different tests are needed to be investigated. Among these tests, split tensile strength is one of the basic and fundamental material characteristics used to predict crack formation [11]. The split tensile strength is tested by applying a diametric compressive load along the entire length of the specimen until failure occurs. This loading induces tensile stresses on the plane containing the applied load as well as compressive stresses in the area around the applied load, and the stresses are computed accordingly [12-14].

The compressive strength of concrete is more affected by the loading rate. As the loading rate increases, so does the compressive strength of the concrete. In general, the compressive strength of concrete specimens under dynamic loading is greater than the strength under static loading, and the dynamic compressive strength tends to increase as the loading rate increases [1].

Among the available Nondestructive Testing (NDT) methods, Ultrasonic Pulse Velocity (UPV) methods are one of the most promising for evaluating concrete structures because they allow for an examination of material homogeneity. It is possible to gain complete control of a structure by utilizing the properties that change over time. Using the analysis of the propagation variations of the ultrasonic velocity wave, it is also possible to detect heterogeneous regions in the concrete [15].

Because only negligible stress is applied during ultrasonic pulse velocity (UPV) measurements and resonance frequency tests, dynamic modulus has been assumed to be the initial tangent modulus at zero stress determined in the standard test [16]. The determination of pulse velocity through the concrete specimen is tested in the UPV test. An electro acoustical transducer in contact with one face of the concrete specimen generates longitudinal stress wave pulses, which are received by another transducer in contact with the other face of the concrete specimen. The time required for a pulse to pass through a length specimen (transit time) is computed, and the corresponding pulse velocity (UPV) is calculated by dividing the length of the specimen by the transit time [17]. It helps to predict the dynamic modulus of elasticity of concrete. According to BIS 13311-1 (1992), the following formula is used for calculating the dynamic modulus of elasticity of concrete [18].

$$E_{Dyn} = \frac{\rho \times (UPV)^2 (1-2\nu)(1+\nu)}{(1-\nu)} \qquad (2.1)$$

Where:

E_{Dyn} : dynamic modulus of elasticity in MPa

UPV : ultrasonic pulse velocity in km/sec

ρ : density of the specimen in kg/m^3

ν : Poisson ‘s ratio of concrete (0.24)

Table 1

Quality of Concrete [18]

Pulse velocity (m/s)	Concrete Quality Grading
Above 4500	Excellent
3500 – 4500	Good
3000 - 3500	Medium
Less than 3000	Doubtful

3. Experimental Program

The experimental specimens are designed to investigate the effect of aggregate coatings on concrete behavior. In the following section, the materials, methodology and equipment and instruments used in the experimental program are presented.

3.1 Materials

- **Cement: -** Cement OPC (CEM I 42.5 R) is used in this experiment
- **Sand: -** Fine aggregate with sizes of less than 2 mm is used
- **Natural coarse aggregate: -** Coarse aggregates with sizes of 2 mm-32 mm are used (Fig. 1)

Fig. 1. Natural (uncoated) aggregate

- **Coating Materials**

  Three types of coating materials are used. These are: -
  - Epoxy, T 19-32/1000 (Epilox® T 19-32/1000)
  - Epoxy- sand (Epilox® T 19-32/1000 and sand of sizes 1 mm-2 mm)
  - Silicon - SILIXON10

Table 2 below shows the different types and amount of coating materials used in this experiment. Moreover, characterization and properties of epoxy resin, hardener, coupling agent, silicon base and silicon catalyst are presented in Table 3.

Table 2
Coating Materials

No.	Coating Materials	5 % (gm)	10 % (gm)	15 % (gm)
1	Epoxy (T 19-32/1000)	82.67	165.33	248
	Hardener (H 10-34)	43.33	86.67	130
	Coupling Agent (BYK C-8001)	2.63	5.27	7.9
2	Silicon 10 (base)	75	150	
	Silicon 10 (Catalyst)	75	150	

The mix ratio of coating materials is: the ratio of epoxy, hardener and coupling agent is 1:0.5:0.032. The ratio of silicon 10 (base) and catalyst is 1:1. The coating materials used are shown in Fig. 2.

(a)

(b)

Fig. 2. (a) Epilox® T 19-32/1000 (Resin, Hardener and coupling agent)
(b) "SILIXON 10" (Base and Catalyst)

In order to get the required gradation of aggregates (three grades; 2–8 mm, 8–16 mm and 16–32 mm) and sand, samples are crushed and sieved according to DIN EN 933-2012 [19]. The proportion of materials is determined using a volume-based mix design method. The DIN EN 12390-2 standard [20] is used for specimen production and concrete curing. Table 4 shows the proportions of the concrete mix. Concrete samples were cast and cured for 28 days using a mix design with a cement-sand ratio of 1:1.4 and a water-cement ratio of 0.47. Furthermore, different volume fractions of coated aggregates were used (5%, 10%, and 15%).

In the experimental program, dimensions and shape of concrete specimens for strength tests are prepared based on DIN EN 12390-1 standard [21] and a total of 150 concrete specimens were prepared (30-cylindrical specimens with a diameter of 150 mm and a height of 300 mm, 90-cube specimens with size of 150 mm, and 30-beam with dimensions of 400 mm × 100 mm × 100 mm). Tests were performed in the “Bauhaus-Universität Weimar F. A. Finger Institute for Building Materials Science Concrete Laboratory” following DIN Fachbericht 100 standard [22].

Table 3
Characterization of Coating Materials

	Epilox® T 19-32/1000	Coupling Agent BYK-C 8001	"SILIXON 10" Silicone
Density	approx. 1.14 g/cm³ (20 °C)	1.035 g/cm^3 (20 °C)	approx. 1.07 g/cm³
Other properties	▪ liquid, solvent-free, crystallization-inhibited, ▪ low-molecular and low viscosity epoxy resin ▪ viscosity at 25 °C (1.0-1.3 (Pa·s))	▪ melting point/range < -76 °F (< -60 °C) ▪ initial boiling point 194 °C (1,013 hPa) ▪ vapor pressure ca. 0.55 hPa (20 °C)	▪ very soft but tear-resistant RTV2 silicone ▪ resistant to aging and high chemical resistance to aggressive media ▪ curing at 25 °C, 2-3 hrs

Table 4
Concrete Mix design

Mix design	kg/m³	Bulk Density	Coated aggregates [kg/m^3]		
			5 %	10 %	15 %
Cement OPC (CEM I 42.5 R)	390.0	3.10			
Water (w/c = 0.47)	183.3	1.00			
Sand 0/2 mm	533.0	2.65			
Gravel 2/8 mm	262.0	2.60			
Gravel 8/16 mm	436.0	2.60	21.8	43.6	65.4
Gravel 16/32 mm	523.0	2.60	26.15	52.3	78.45

Designation of different concrete mixtures and mix proportions of concrete is shown in Table 5.

Table 5
Mix Type and Specimen Notation

Sample No.	Mix Type (% by weight)	Specimen Notation
1	Control mix (0% coated aggregate)	CM
2	5 % epoxy coated aggregate	5ECA
3	10 % epoxy coated aggregate	10ECA
4	15 % epoxy coated aggregate	15ECA
5	5 % epoxy-sand coated aggregate	5ESCA
6	10 % epoxy-sand coated aggregate	10ESCA
7	15 % epoxy-sand coated aggregate	15ESCA
8	5 % silicon coated aggregate	5SiCA
9	10 % silicon coated aggregate	10SiCA
10	15 % silicon coated aggregate	15SiCA

3.2 Method of Coating

The manual method of coating (hand coating) is used to cover the aggregate. Coating was applied to aggregates with different grain groups ranging from 8-16 mm and 16-32 mm. The coated aggregates were dried for three days at a temperature of 23 ± 2 °C. Coating was applied to the aggregate with epoxy and silicon (Figs. 3 and 4).

The following procedures were followed for coating aggregates with epoxy-sand:-

1. Coating was applied to the aggregate with epoxy resin
2. Blend the epoxy resin coated aggregate with sand while it is in wet state (after 25-30 min.). During this process, the sand is sticking to the aggregate surface (Figs. 5 a and b).

Fig. 3. Epoxy resin coated aggregates

Fig. 4. Silicon coated aggregates

(a) 8-16 mm aggregates

(b) 16-32 mm aggregates
Fig. 5. Epoxy-sand coated aggregates

3.3 Method of Testing

To examine on mechanical properties and characteristics of coated aggregates, different loading rates are applied and the following tests are performed at the 28th days aged concrete specimens.

- Compressive strength test was conducted following DIN EN 12390-4 [23] testing procedure on the cubical specimens (size: 150 mm)
- Split tensile strength test was conducted as per DIN EN 12390-6 [24] (cylindrical specimens with a diameter of 150 mm and a height of 300 mm are used).
- Young's modulus or modulus of elasticity test utilizes using a universal testing machine (TIRA test 28600). A uniaxial force is applied to the test specimen and the force and strain data are measured as per DIN EN 12390-13 [25].
- Ultrasonic pulse velocity (UPV) test was performed for measuring the speed of sound through concrete to determine the dynamic modulus of elasticity of concrete.

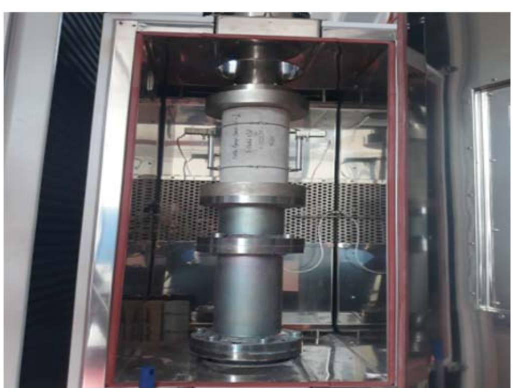
3.4 Equipment and Test Setups

Universal testing machine, data logger, universal electric compressometer for elastic modulus test, mixer, vibrator and cone for slump test, ultrasonic testing equipment which includes a pulse generation circuit and transducers are used. The test setups for different tests are shown in Figs. 6 and 7.

(a)

(b)

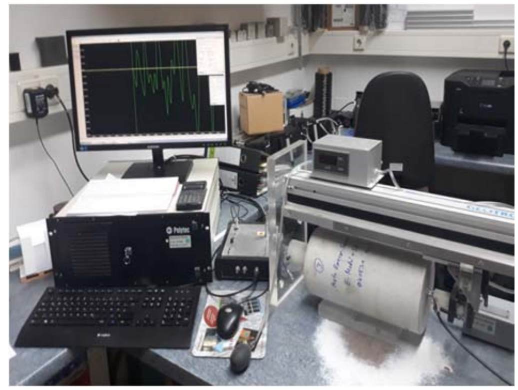
(c)



(d)

Fig. 7. Test set-up for measuring ultrasonic pulse velocity

Fig. 6. Test setups for (a) shrinkage test (b) compression test (c) split tensile test and (d) elastic modulus test



4. Results and Discussions

The test results are presented and discussed briefly in this section. The test results include the properties of conventional concrete (concrete specimen with uncoated aggregate) and concrete with coated aggregates (epoxy resin, epoxy-sand and silicon). The different test results are shown in Tables 6 and 7.

The test results related to the compressive strength of concrete specimens (under different loading rates), split tensile strength, peak stress with different fractions of coatings is given in Table 6. Each sample was tested three times and average values are presented.

Furthermore, the static modulus of elasticity of concrete is determined by measuring the strain and deformation characteristics of concrete with a universal electric compressometer. These values are also shown in Table 6.

Table 6
Experimental Results

Sample No.	Notation	Compressive strength [MPa] with different loading rates [MPa/sec]			Split tensile strength [MPa]	Static Modulus [GPa]	Peak stress [MPa]
		0.6	2.22	4.44			
1	CM	52.4	55.8	54.9	3.42	34.02	14.32
2	5ECA	54.8	56.7	56.8	3.63	33.78	14.99
3	10ECA	53.2	54.7	51.1	3.35	33.11	14.53
4	15ECA	49.37	51.1	50.9	3.11	32.72	14.11
5	5ESCA	58.8	59.5	57.8	3.04	33.72	16.06
6	10ESCA	58.0	57.4	57.0	3.18	34.31	15.86
7	15ESCA	61.8	62.6	60.0	3.48	33.00	15.23
8	5SiCA	52.9	56.7	56.7	3.25	22.17	14.33
9	10SiCA	50.4	53.6	55.4	2.76	19.23	13.78
10	15SiCA	45.23	49.09	49.75	2.75	23.5	12.75

As shown in the above table, the developments in compressive, split tensile strength and static modulus of elasticity are discussed as follows.

- Better results in compressive strength of concrete were achieved when 5 %, 10 % and 15 % volume fraction of epoxy-sand coatings were used.
- Coated aggregate with epoxy-sand has a rough surface and develop a strong bonding at the interface zone between the coated aggregate and mortar. The bond improvement is indirectly indicated by the betterment of compressive strength of concrete. Accordingly, higher compressive strength with an increment of 17.95 % was achieved at 15 % replacement of epoxy-sand coated aggregates.
- Concrete with silicon coated aggregates with 5% replacement achieved good concrete performances (1.0%-3.28% increment). At 15% silicon coatings, however, compressive strength was reduced in all loading scenarios.
- For 5 % volume fraction of epoxy resin coated aggregates, a significant increment in compressive strength was obtained as compared to other coating cases.
- As shown in Table 6 above, as the percentage of coatings of aggregates with epoxy resin increases, the corresponding compressive strength of concrete reduces. On the other hand, under a loading rate of 0.6 MPa, as the percentage of coatings aggregates with epoxy-sand increases, the corresponding compressive strength increases accordingly.
- When 5% epoxy resin coated aggregate is used, a maximum split tensile strength is obtained, resulting in a 6.15% increment. The tensile strength test result for 15% epoxy-sand coated aggregate shows a 1.75% increase in tensile strength. For other coating material cases, the tensile strength reduces.
- For 10 % epoxy-sand coated aggregates, a slight increment in static modulus of elasticity was achieved (0.85%). For the other cases, relatively small reductions ranging from 0.7 % - 3.85 % were observed. However, for silicon coated aggregates, a higher reduction in static modulus of elasticity (30 % - 43.5 %) was exhibited.

Table 7 shows the ultrasonic pulse velocity values of concrete with partial replacement of coated aggregates and the corresponding dynamic modulus of elasticity is computed using equation (2.1).

Table 7
Ultrasonic pulse velocity (UPV) and dynamic modulus of elasticity

Notation	Sample No.	Density	Transit time	UPV	dyn. E-Modulus	dyn. E-Modulus	Standard deviation	CoV (%)
		ρ [kg/m³]	t_L [µs]	[km/s]	$E_{Dyn.}$ [GPa]	Average [GPa]		
CM	E1	2359	64.95	4.604	42417	42.45	0.535	1.26
	E2	2360	65.40	4.576	41927			
	E3	2363	64.80	4.631	42995			

Notation	Sample No.	Density	Transit time	UPV	dyn. E-Modulus	dyn. E-Modulus	Standard deviation	CoV (%)
		ρ [kg/m³]	t_L [µs]	[km/s]	$E_{Dyn.}$ [GPa]	Average [GPa]		
5ECA	E1	2372	63.75	4.689	44235	43.62	0.550	1.26
	E2	2368	64.25	4.649	43427			
	E3	2375	64.50	4.629	43185			
10ECA	E1	2371	65.70	4.553	41695	41.55	0.475	1.14
	E2	2360	66.15	4.526	41017			
	E3	2357	65.25	4.579	41931			
5ESCA	E1	2363	65.10	4.598	42381	42.19	0.188	0.44
	E2	2364	65.35	4.577	42007			
	E3	2360	65.00	4.589	42170			
10ESCA	E1	2368	64.55	4.634	43133	42.86	0.281	0.66
	E2	2372	65.10	4.599	42571			
	E3	2379	64.90	4.609	42864			
15ESCA	E1	2379	65.80	4.558	41934	43.16	1.259	2.92
	E2	2380	64.00	4.692	44450			
	E3	2382	65.10	4.618	43098			
5SiCA	E1	2347	64.45	4.638	42822	42.51	0.559	1.32
	E2	2371	65.45	4.562	41863			
	E3	2370	64.75	4.616	42841			
10SiCA	E1	2380	67.90	4.423	39501	40.37	0.768	1.90
	E2	2372	66.80	4.496	40664			
	E3	2370	66.55	4.512	40951			

As shown in Table 7, the dynamic modulus of elasticity of concrete with 5 % silicon coated aggregate is almost the same with that of the control mix. The development of dynamic modulus of elasticity increases as the percentage replacement of aggregate with epoxy-sand coated aggregate increases. With 5% replacement of epoxy-resin coated aggregates, which is the optimal replacement, resulted in an increment of 2.76 % in dynamic modulus of elasticity was observed. For concrete specimens with varying percentages of coated aggregate replacement, the CoV of the dynamic modulus of elasticity ranges from 0.44% to 2.92%.

- Except for concrete with 10% silicon coated aggregates, all concrete made with different coated aggregates is classified as excellent grade according to BIS 13311-1 (1992) [18].

Concrete shrinkage is defined as the time-dependent strain measured in an unloaded and unrestrained specimen. The potential drying shrinkage test for a concrete block consists of measuring the change in length caused by drying from a saturated state to an equilibrium state at constant temperature. Beam specimens with dimensions of 400 mm × 100 mm × 100 mm are used for shrinkage testing.

The change in length of the specimens is measured up to drying age of 56 days. Samples remain in foil for up to 7 days (drying age) and changes in length were measured. After 7 days, the foil was removed and the change in length of the specimens at different curing periods were also measured. The shrinkage strain of the concrete specimens and its development was computed and shown in Fig. 8.

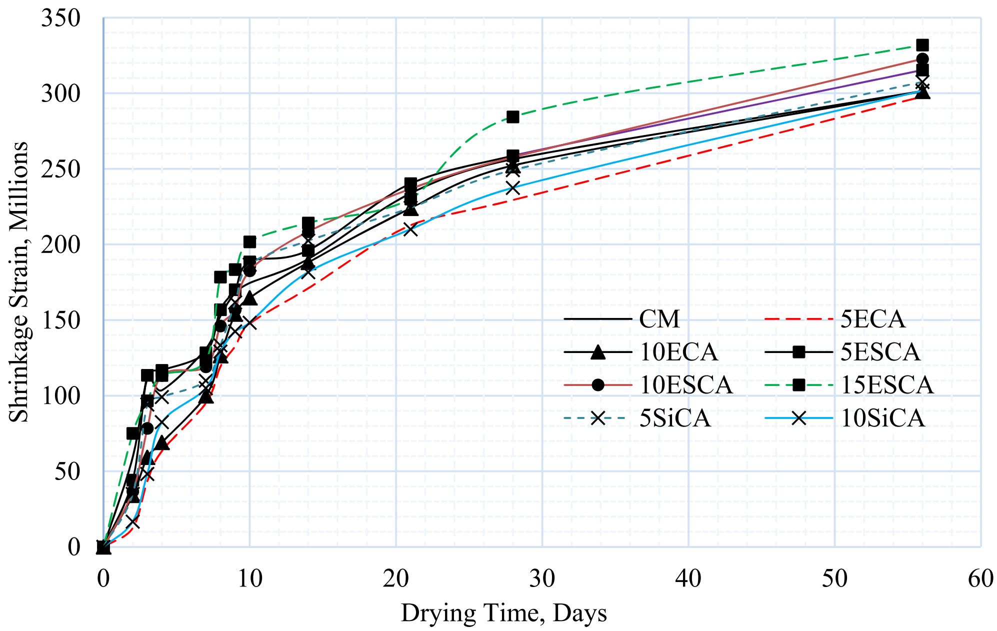


Fig. 8. Effect of coating aggregates on the drying shrinkage of concrete

Concrete specimens containing 5% epoxy resin and 10% silicon coated aggregates have a lower shrinkage value than the control mix, indicating that shrinkage in concrete is not a major issue.

For 10ECA, 10ESCA and 5SiCA mix cases, the shrinkage strains are slight increases and for other cases, especially for specimens with 5ESCA and 15ESCA mix cases, large shrinkage strain values are recorded. In general, the drying shrinkage strain of coating aggregates is less than the control mix except for 15ESCA. Thus, concretes with coated aggregates perform well with regard to drying shrinkage.

5. Conclusions

From the experimental work conducted on concrete with coated aggregates with different coating materials, the following conclusions are drawn:

1) The experimental process of coating aggregate with epoxy, epoxy-sand and silicon was successful, resulting in improved mechanical and dynamic properties of concrete.
2) At lower loading rates, epoxy alone can be used as a coating material with a volume fraction of 5% which improves the compressive strength of concrete.
3) Coating aggregate with epoxy-sand yields promising results in the mechanical and dynamic properties of concrete, with 15% epoxy-sand coated aggregates considered the optimum replacement level.
4) From the results, it is found that the shrinkage strain develops at large scale at an early age for concrete with different coated aggregates.
5) At 10% and 15% silicon coated aggregate replacement, a significant reduction in compressive strength, split tensile strength, and static modulus of elasticity of concrete was observed. This is not practically recommended to use.
6) Concrete with a 5% epoxy resin content and a 15% epoxy-sand coating has a higher dynamic modulus of elasticity. Furthermore, when compared to the control mix, concrete with 5%, 10%, and 15% epoxy-sand coated aggregates has higher compressive strengths and dynamic modulus of elasticity. These materials can be used for the constructions bridges, railway slippers, shear walls, and other structures.

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