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COMPRSSIVE STRENGTH EXAMINATION OF USING SEA SAND AS FINE AGGREGATE REPLACEMENT IN EPOXY BLENDED CEMENT CONCRETE

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ABSTRACT

Concrete, the most widely used building material consumes large quantities of aggregates for its production. The use of aggregates has generated major environmental issues, necessitating the adoption of an alternate material to satisfy demand. Polymer concrete essentially is used for special applications and their usage is also not uncommon in today's world. The current study attempts to increase service life of seasand concrete by combining it with epoxy resin. Initially the removal of some minute impurities such as clay, organic matter and other traces were removed by subjecting them to water washing continuously for about three hours. The removal of chloride ions from sea sand indirectly extends the service life of the concrete produced using sea sand in concrete. Some important physical & mechanical properties of concrete were studied on sea sand concrete containing epoxy resin as cement replacement. The effort include evaluating the qualities of concrete made with sea sand as a replacement for natural river sand up to 50 & 12% epoxy resin as a partial substitute for cement

KEYWORDS: Sea sand, River sand, cement, epoxy resin, blended concrete physical and mechanical properties

INTRODUCTION

Today, concrete is the most often utilised building material. It can be found everywhere, from workplaces to schools, highways to trains, and dams to houses. Concrete is a necessary material in today's globe due to rising urbanisation, and it is anticipated that several billion tonnes of concrete are produced each year. The versatility of the concrete material is due to their moulding capacity and desirable engineering characteristics. Though concrete possess several desirable properties their brittleness makes them unsuitable for use in heavy load carrying applications. Concrete is essentially a mixture of cement, aggregates & water.

Thus, the utilization of concrete eventually makes sand as the second most consumed material in the world. Concrete also contains several types of admixtures and additives to attain certain desirable characteristics depending on the purpose for which they are to be used. It is difficult to think of another construction material that isas adaptable as concrete. It is the preferred material for applications that need strength, performance, durability, impermeability, fire resistance, and abrasion resistance. The flexibility and moldability of this material, as well as its high compressive strength and the development of reinforcing and prestressing processes to compensate for its low tensile strength, have all contributed greatly to its widespread use. It is now

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so entwined with every human activity that it impacts every human being on a daily basis. Strength and durability are frequently regarded as the most significant characteristics in the construction of concrete structures.

In India and other countries, concrete is the most often utilized building material. It's tough to conceive of another building material that is as versatile as concrete. It is the preferred material for applications that need strength, performance, durability, impermeability, fire resistance, and abrasion resistance. It is so intricately tied to all building activities that it impacts every human being on a daily basis. As a result, substantial study is being conducted throughout the world into the different elements of this one-of-a-kind substance, leading to remarkable advancement.

The use of extra cementing ingredients or mineral admixtures has been one of the key thrust areas of concrete research. When exposed to free lime, the materials generated from industrial waste are pozzolanic in nature and have cementing qualities comparable to conventional Portland cement. Their usage in concrete to partially replace cement conserves cement and power, enhances strength and durability, and aids in environmental protection. Thus, the researchers strongly advise producing high-performance concrete with these extra components.

Concrete is the most widely utilised building material in civil engineering. It is an artificial compound that is normally generated by mixing suitable amounts of binding material, fine aggregates, coarse aggregates, water, and admixtures. Concrete is used in construction to increase strength, provide a tougher flexural structure, improve workability, and hence increase durability. Cement absorbs water, hardens, and joins the other components together to produce a stone-like solid. After drying, concrete does not harden; instead, water reacts with the cement in a chemical process called as hydration. In a concrete mix, cement and water combine to form a paste or matrix that fills the holes in the tiny particles and binds them (fine and coarse) together.

The matrix typically accounts for 22-34% of overall volume of concrete. Green or wet concrete is freshly mixed concrete that has not yet been set, whereas set or hardened concrete has been set and hardened. Due to chemical reactions between the water and binding ingredients, the concrete mix in the mould hardens to the consistency of stone after curing. The rising demand for the use of a large quantity of concrete raises the cost of the binding ingredient (cement) and depletes natural supplies of fine aggregate, which raises the cost of concrete.

Cement concrete is one of those materials that appears simple but is actually rather sophisticated. Many of its complicated behaviors have yet to be discovered in order to successfully and efficiently utilise this material. Long-term drying shrinkage, creep, fatigue, morphology of gel structure, bond, fracture mechanism, and polymer modified concrete, fibrous concrete are some of the areas of continuing research to gain a better knowledge of the behavior of these materials. (Hashemi *et al*. 2018).

As of 2015-2016, India's yearly cement output was around 283 million tonnes. (Vigneshwar & Adma, 2018). Concrete, unlike other building materials, is a site-made substance, and as such, its quality, characteristics, and performance can vary greatly due to the usage of natural resources other than cement. To manufacture concrete of specified characteristics from materials of different properties, an extensive understanding of the interplay of numerous constituents that go into the creation of concrete is necessary, both in fresh and hardened states. Concrete technologists and site

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engineers both require this expertise. Cement-based materials are frequently employed in civil engineering structures due to their good physical qualities and inexpensive cost.

These materials, however, have a variety of disadvantages They are fragile, have a low failure strain, & have low tension strength. Concrete is a sturdy and durable substance. When strengthened with steel, it is resistant to cyclones, earthquakes, and explosions, as well as fire. Concrete uses less energy to manufacture than many other engineering materials such as steel and rubber. Currently, a significant range of mineral admixtures that are byproducts of other industries are being utilised to make high-quality concrete. Polymer modification and fibre reinforcement have both been utilised successfully in practice to solve these issues. In this article, the combined use of polymers and fibers was examined experimentally. However, it is necessary to first summarize the different impacts of polymers and fibers in concrete.

LITERATURE REVIEW

The higher usage of fine aggregates in concrete to attain required workability and to fill in the voids present in the concrete, has resulted in the unavoidable excessive use of sand exceeding their natural renewal rate. Mining sand from their natural surroundings has also had major environmental consequences that are irreversible (Khashayar *et al.* 2018).

The use of river sand as fine aggregates should be reduced. Alternate materials are now being used in concrete production to alleviate the loss of natural diversity due to sand extraction. At the moment, worldwide cement output is estimated to be over 4 billion tonnes. (Ali & Jeong, 2019).

The annual demand for aggregates has been expected to grow globally by about 5% and India is known to be one of the largest national markets for aggregates. The concept of sustainability in building construction has also placed a severe demand on reducing natural aggregates in concrete production. Different amount of wastes produced from different industrial processes have been used as fine aggregate replacement in concrete. The use of industrial wastes & byproducts has also been discovered to significantly boost strength & stability of concrete. Fine aggregate substitutes that are often employed include silica fume (Hossein etal. 2019), slag (Gaurav etal. 2015), flyash, & ferrochrome ash (Mohantyetal. 2019).

The high strength, chemical resistance and impermeable nature of the polymer concretes make them one of the most widely used construction material for civil engineering purposes. Polymer concrete is used to make certain structural parts that require exceptional durability (Wahid et al 2020). Conventional concretes were developed centuries ago and hence their usage is widespread and familiar to every construction worker. In contrast, the polymer concretes were developed only about half century ago and hence their usage is not known to many (Pedram and Vahab 2020).

Limeira *et al.*(2011) established two different limits for the chloride concentrations in concrete to reduce leaking in heavily reinforced concrete chloride content limit of 0.05% by mass of aggregate in concrete including the chlorides missing from the entire concrete component or 0.04% by the weight of cement in concrete.

Identification of the transition temperatures of different polymers and categorizing them shall help in the utilization of appropriate type of polymer intended for the particular use. Some

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ways of improving the transition temperature of epoxy polymers have been done by adding certain polymers such as cross linking monomers and conomers. The addition of nano materials in the polymers also improves the transition temperature of polymers (Hassani *et al.* 2018).

A recent study conducted by Fowler 2018 has proved that modified sulphur used in concrete can sufficiently improve freeze thaw resistance of concrete. The developed concrete thus containing sulphur modified using oligomers can efficiently be used for underwater concreting and retrofit applications. Bio-based resins and recycled resins have also been to produce polymer concrete. The studies showed that alternative resins can thus be used to produce concretes that are economical thereby meeting the demands of ever increasing oil prices.

The durability characteristics & mechanical properties of crumb rubber modified epoxy polymer concrete were studied by Wang *et al.* (2019). The findings clearly shown that using rubber tyres in epoxy concrete enhances the mechanical and thermal qualities of the concrete. Rubber-modified epoxy concrete not only reduces land filling but also enhances concrete performance for use in concrete overlays and pavements. Zahra etal. (2019) investigated effects of nanocopolymer latex on characteristics of polymer modified concrete. The results revealed that adding 3% SBA latex to cement enhanced compressive & flexural strength of concrete. Furthermore, the use of an anti foaming agent and a super plasticizer improved the polymer concrete's splitting tensile strength. The use of recycled tire fibres modified using gamma radiation in polymer concrete improved their mechanical properties due to the morphological changes in the tire rubber due to gamma radiations. Vedat etal. (2019) investigated influence of fillers on characteristics of polymer concrete. The study mainly focussed on achieving two major objectives. Firstly, to enable the use of filler doped composites minimizing the use of natural aggregates. Secondly, the feasibility of using disposed plastics on concrete production is analyzed. Polymer doping improves the thermal, electrical, and mechanical characteristics of concrete, according to the findings. Production of a new type of smart polymer concrete and the measurement of pressure sensitivity was done by Yong Ding *et al.*(2019). The study showed that the resistance of concrete was increased due to the strain caused by uni-axial compression of concrete containing graphite & steel slag. The impact of three types of polymers which are of polycarboxylate origin on the early age compressive strength of concrete was done by Lajan *et al.*(2019).

OBJECTIVES OF THE RESEARCH

- Investigate the physical properties of materials used in manufacturing of concrete; and
- Determine the mechanical properties of hardened concrete.

METHODOLOGY

The properties of concrete depend on properties of materials used in concrete. Hence characterization of the materials is essential before they can be used in concrete. The materials used for production of epoxy-sea sand concrete include cement, epoxy resin, river sand & sea sand as fine aggregate, water & water reducing agent. The chemical composition of the Ordinary Portland cement as obtained through EDAX technique.

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Table 1 Physical properties of cement (as per IS 12269-1987)

Physical Properties		Value
Specific gravity		3.13
Fineness (m^2/Kg)		350
Consistency (%)		28
Setting time(min)	Initial	28
	Final	272
Soundness	Le ChatelierExpansion (mm)	10
	Autoclave Expansion (%)	0.8

Table 2 Physical properties of river sand (as per IS 383-1970)

S.No.	Properties	River Sand
1.	Maximum size (mm)	4.75
2.	Water absorption	1.3
3.	Fineness modulus	2.28
4.	Specific gravity	2.61
5.	Shell thickness (mm)	-
6.	Void ratio	0.472
7.	Bulk density (g/cc)	-
8.	Moisture content (%)	-
9.	Abrasion value (%)	-
10.	Crushing value (%)	-
11.	Impact value (%)	-

Table 3 Physical properties of sea sand

S.No.	Properties	Sea sand
1.	Particle shape, size	Rounded, 4.75 mm
2.	Fineness modulus	1.98
3.	Specific gravity	2.69
4.	Silt / Dust content	2.2%
5.	Surface moisture	Nil
6.	Water absorption	1.8%

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Table 4 Physical properties of coarse aggregate

S.No.	Properties	Test Result
1.	Maximum size (mm)	20
2.	Fineness modulus	7.13
3.	Specific gravity	2.62
4.	Bulk density (gm/cc)	1.44 - 1.63
5.	Water absorption (%)	0.16
6.	Aggregate crushing value (%)	17.52
7.	Aggregate impact value (%)	14.42
8.	Maximum dry density (kN/m^3)	14.72
9.	Aggregate abrasion value (%)	28.12

Table 5 Physical properties of superplasticizer

S.No	Properties	Superplasticizer
1.	Chemical base	Modified polycarboxylate based polymer
2.	Appearance / Color	Light brownish liquid
3.	pH value	3-7
4.	Density	1.1 g/cm^3 ± 0.02
5.	Dosage	1.0 – 2.0% by weight of cement

COMPRESSIVE STRENGTH TEST PROCEDURE

Compressive Strength is a mechanical property of hardened concrete at the age of 28 days. This is done by the recommendations conforming to IS 516-1959. Cube dimension (IS 10086-1982) of 150mm is used for investigating. The specimens cured in water is taken out and ensured for free from loose grits and surface water. This is conducted under load-controlled Compression Testing machine. The specimen is positioned on the machine such that its axis and the thrust axis are aligned. Loading is done at a rate of 140kg/sqcm/min. The specimen is loaded and observed until it cracks down and not able to sustain greater load. The maximum load applied is observed and compressive strength of concrete is determined by,

$$\text{Cube Compressive Strength} = P/A$$

Where,

P - Max. applied load

A - Cross-sectional area of the specimen

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Figure 1 Compressive strength testing of concrete

EXPERIMENTAL ANALYSIS FOR COMPRESSIVE STRENGTH

The compressive strength of epoxy polymer concrete mixes produced by using sea sand as partial replacement to fine aggregate at various ages subjected to ambient and water curing are shown in figure 2 and 3. It can be clearly inferred that the compressive strength of the polymer concrete reduced significantly when compared to conventional concrete mix (CM) at later ages. This is in agreement with the previously established studies which states that the later age strength compressive strength of concrete decreases due to epoxy substitution (Vipulanandan & Paul 1990).

Under ambient & water curing conditions, the compressive strength of concrete containing 25% sea sand as aggregate was approximately 24.32% and 25.89% greater than the polymer concrete mix (PC). As a result, when subjected to water curing, the ideal replacement percentage of FA by sea sand to achieve maximum compressive strength is 20%. When compared to concrete mix treated to water curing at early ages, the compressive strength of ambient cured sea sand polymer concrete was considerably greater. Other investigations have found that sea sand replacement affects concrete strength. (Jianzhuang et al., 2017).

Interestingly in present study the compressive strength of concrete was found to increase with increasing sea sand substitution. This may be due to the combined action of sea sand and epoxy resin. The finer sands also functioned as fillers reinforcing the epoxy matrix (Haider et. al 2011).

The results of the water cured sea sand polymer concrete series showed that the compressive strength of concrete can be improved by about 15% when 40% sea sand was used as fine aggregate replacement in concrete. The higher compressive strength may be due to the higher fineness and angular nature of the sea sand aggregates that contributed to the incompressibility of the aggregate phase in the concrete by filling the micro voids and increasing the packing density (Xu et al. 2020).

In addition, the filling of the voids and pores by sea sand has also caused this improvement of compressive strength. Polymeric phase generally appear as bulk phases without proper mixing due to their physical property. But in the present study the epoxy resins were taken utmost care while mixing the amount matrix. The compressive strength of concrete is typically determined by the aggregate phases rather than the binder phase, and so sea sand replacement has a greater influence on compressive strength than epoxy substitution. The relative values of compressive strength of polymer concrete mixes in comparison to the conventional concrete mix

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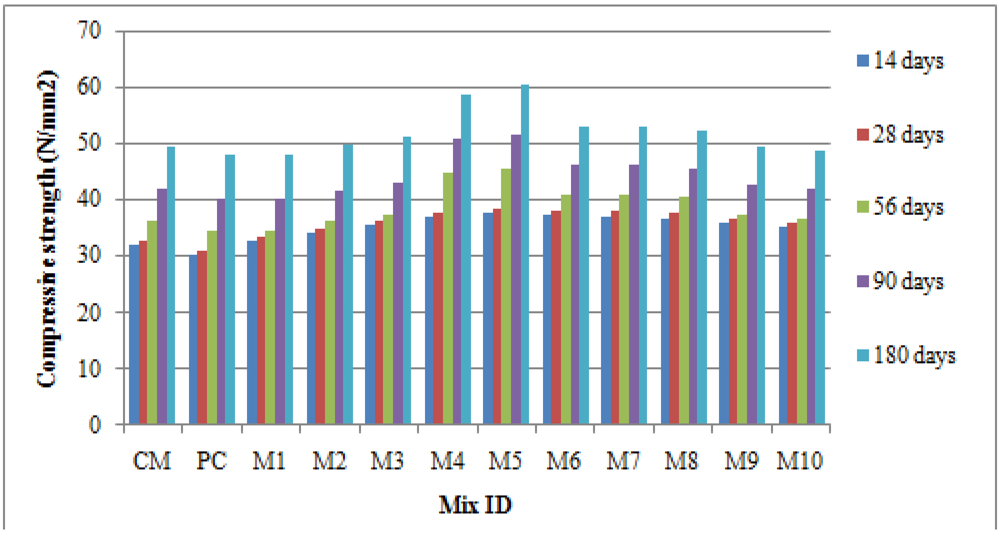
(CM) clearly reveal that compressive strength of all concrete mixes at replacement levels more than 15% were practically as high as the control concrete up to a certain threshold. The relative compressive strength of the polymer concrete mixer in comparison to the 28 days strength of the concreteis also shown in Table 6 and 7.

It can be seen that the sea sand concrete mixes attained 97% of the 28 days strength of the concrete at an early age of 14 days under ambient curing. About 85% of the 28 days of strength of concrete was attained at 14 days under water curing. The sea sand concrete series showed only little strength achievement at later ages beyond 28 days. Thus the obtained results support the previously established fact that the epoxy resin improves the strength of concrete only at early ages whereas no beneficial role to play in later age strength which is verified and confirmed by the previous studies (Rebeiz 1996, Ohama & Demura 1982).

The later age strength attainment may be due to the sea sand that also enhanced the binding of the cement matrix with the aggregates due to their higher fine nature. The strength results also show a negative influence on the compressive strength beyond 40% replacement level in the sea sand substituted concrete water cured series. The improved denseness of the concrete mixes with pore filling property of sea sand has contributed towards the strength improvement. The ambient cured epoxy concrete mixes showed improved compressive strength values at early ages due to the effect of epoxy resin which is verified and confirmed from the previous study conducted by Raman et. al 2013.

Figure 2 Compressive strength values of epoxy concrete mixes inambient curing



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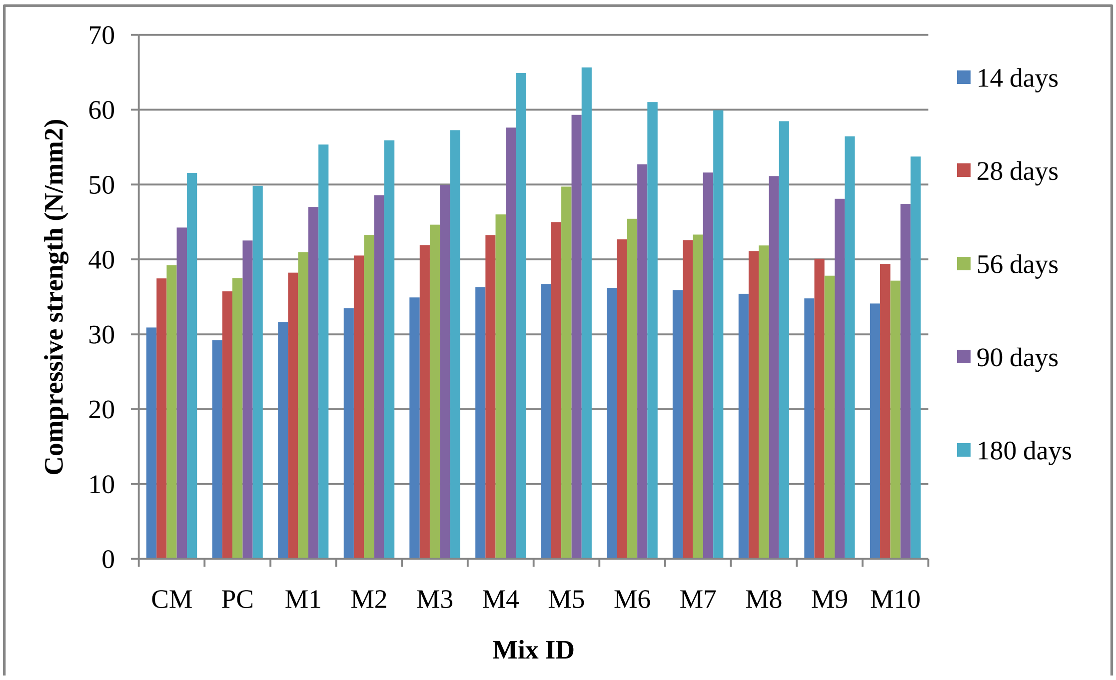

Figure 3 Compressive strength values of epoxy concrete mixes inwater curing

Table 6 Compressive strength of concrete under ambient curing

S.No	Mix ID	Compressive strength (N/mm²)				
		14 days	28 days	56 days	90 days	180 days
1	CM	31.86	32.61	36.17	41.81	49.53
2	PC	30.13	30.88	34.44	40.08	47.8
3	M1	32.56	33.38	34.52	40.16	47.88
4	M2	34.12	34.94	36.08	41.72	49.78
5	M3	35.57	36.31	37.45	43.09	51.15
6	M4	36.93	37.67	44.6	50.74	58.8
7	M5	37.65	38.39	45.32	51.46	60.52
8	M6	37.35	38.09	41.02	46.16	52.95

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9	M7	37.02	37.99	40.92	46.06	52.85
10	M8	36.56	37.53	40.46	45.6	52.39
11	M9	35.74	36.5	37.43	42.57	49.36
12	M10	35.06	35.82	36.75	41.89	48.68

Table 7 Compressive strength of concrete under water curing

S.No	Mix ID	Compressive strength (N/mm²)				
		14 days	28 days	56 days	90 days	180 days
1	CM	30.92	37.46	39.21	44.25	51.57
2	PC	29.19	35.73	37.48	42.52	49.84
3	M1	31.62	38.23	40.98	47.02	55.34
4	M2	33.48	40.53	43.28	48.58	55.9
5	M3	34.93	41.9	44.65	49.95	57.27
6	M4	36.29	43.26	46.01	57.6	64.92
7	M5	36.71	44.98	49.73	59.32	65.64
8	M6	36.21	42.68	45.43	52.7	61.02
9	M7	35.88	42.58	43.33	51.6	59.92
10	M8	35.42	41.12	41.87	51.14	58.46
11	M9	34.8	40.09	37.84	48.11	56.43
12	M10	34.12	39.41	37.16	47.43	53.75

Table 8 Compressive strength development compared to respective28 days of ambient curing (%)

S.No	Mix ID	ive strength development compared torespective 28 days (%)				
		14days	28days	56days	90days	180days
1	CM	97.70	100	110.92	128.21	151.89
2	PC	97.57	100	111.53	129.79	154.79
3	M1	97.54	100	103.42	120.31	143.44
4	M2	97.65	100	103.26	119.40	142.47
5	M3	97.96	100	103.14	118.67	140.87
6	M4	98.04	100	118.40	134.70	156.09
7	M5	98.07	100	118.05	134.05	157.65
8	M6	98.06	100	107.69	121.19	139.01
9	M7	97.45	100	107.71	121.24	139.12
10	M8	97.42	100	107.81	121.50	139.59
11	M9	97.92	100	102.55	116.63	135.23
12	M10	97.88	100	102.60	116.95	135.90

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Table 9 Compressive strength development compared to respective28 days of water curing (%)

S.No	Mix ID	ive strength development compared torespective 28 days (%)				
		14days	28days	56days	90days	180days
1	CM	82.54	100	104.67	118.13	137.67
2	PC	81.70	100	104.90	119.00	139.49
3	M1	82.71	100	107.19	122.99	144.76
4	M2	82.61	100	106.79	119.86	137.92
5	M3	83.37	100	106.56	119.21	136.68
6	M4	83.89	100	106.36	133.15	150.07
7	M5	81.61	100	110.56	131.88	145.93
8	M6	84.84	100	106.44	123.48	142.97
9	M7	84.26	100	101.76	121.18	140.72
10	M8	86.14	100	101.82	124.37	142.17
11	M9	86.80	100	94.39	120.00	140.76
12	M10	86.58	100	94.29	120.35	136.39

FINDINGS OF THE STUDY

Exhaustion of river sand is an unavoidable problem that creates scarcity of resources in the environment. The rapid growth of construction industry has also created an intensified demand on natural river aggregates leading to their unconditional exploitation. Ever-increasing concrete constructions throughout the world have also resulted in an everincreasing hunt for alternative aggregates to address environmental issues. Furthermore, regulatory limits on sand mining have led to the quest for alternative sand aggregates that have the potential to replace river sand aggregates. Sea sand is one such potential replacement material to natural river sand aggregates that is also economically feasible due to its vast availability and ease of mining and transportation. The inexpensive cost and minimal environmental effect of sea sand assists in its use as fine aggregates in concrete manufacturing. The following are the study's principal findings:

- Usage of epoxy resins in concrete reduced the compressive strength of concrete to a greater extent.
- The addition of sea sand to epoxy concrete enhanced compressive strength somewhat.
- The use of sea sand in epoxy concrete increased compressive strength by around 18% & 20% at 25% replacement ratio for ambient curing & water curing, respectively.

CONCLUSIONS

It can be finally concluded that usage of sea sand as fine aggregates in epoxy modified polymer concrete can be utilized for unreinforced concrete applications. The produced concrete can also be used in reinforced concrete applications where non corrosive type of reinforcements is

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used. The usage of non corrosive reinforcements is also beneficial from the economic perspective due to their less construction cost at initial stages. When long-term usage is considered, the use of sea sand in conjunction with epoxy polymer for formation of concrete is advocated. The present study showed that sea sand can effectively be used as fine aggregate in epoxy sea sand concrete by functioning both as an aggregate material and also as filler. The mechanical characteristics of the sea sand epoxy concretes were better than epoxy concrete and were comparable to that of the conventional concrete. Raw sea sands contain chlorine and sea shell impurities and hence water washing them can minimize the chlorine contents making them suitable for use in concrete construction. The use of sea sand in epoxy polymer concrete can minimize the usage of natural river sand as aggregate thereby protecting the environment. Epoxy concrete is used in situations where the exposure to chemicals is more and this property is further enhanced by the use of sea sand in epoxy concrete. From the experimental results obtained it can thus be inferred that if one part of natural river sand is replaced by using sea sand in combination with epoxy resin can mitigate both the environmental crisis and resource demand.

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