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Effect of Partial Replacement of Coarse Aggregatesby Wind Turbine Blade Waste - Resin Aggregates in Concrete

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Abstract: Concrete is a versatile building material by its strength, durability and mouldability. Popularityof concrete is increasing in spite of its eco-detrimental effects due to the clinkering of cement, sand mining and quarrying. To reduce the carbon footprint of concrete, addition of pozzolona materials to cement and replacement of aggregates by industrial waste is the most feasible way. Wind turbine blades are composed of reinforcing bars made up of resin or polyester material. Recycling of this material is challenging and opportunities are minimal. Imbibing this recycled wind turbine blade waste as coarse aggregate will subside the demand for natural material and also decrease the manufacturing cost. In M-30 grade concrete, coarse aggregates were replaced by waste resin aggregates by 0 to 100%. Compressive strength reduces linearly with increase in replacement of resin waste. However, the strength of concrete at 10% replacement was almost same as that of conventional concrete. Utilization of industrial waste will reduce the quarrying and makes the concrete eco-friendly. This concrete can be adopted where resin aggregates are found in abundance.
Keywords: Concrete, resin wastes, coarse aggregates, compressive strength

1. INTRODUCTION

Construction sector has considered concrete as a versatile material, being adoptive for non-structural and structural parameters. Concrete is a homogeneous mixture of cement, fine and coarse aggregates along with water [1,2]. Cement is the binding material, which is the costliestingredient in concrete. Aggregates acts as the filler material in the cement composites and it constitutes about 70-80% in concrete volume. Due to the increased construction activities, demand for aggregates has increased which in turn increases the cost of material [3][4]. Meanwhile, cost of conventional construction materials upsurge frequently due to increase in demand and thus inflate the cost ofconstruction. Many research activities claim that recycled products can be adopted as building material with minimal processing, which makes the concrete sustainable [1].

To reduce the ecological imbalance, pollution and cost of material, it is essential to identify and use the alternative for aggregates[3]. With the improvement in technology and production mechanism, it is possible to reuse or recycle the material for various purposes in which concrete is found to be most feasible and economical product to imbibe industrial solid waste material [5]. Recycling is a process of convalescing useful materials from waste and utilizing them in the manufacturing process of some other useful product. For civil engineering sector, recycling refers to chemical modification, mechanical processing, thermal treatment, fillers [6]. Recycled resin aggregate exhibit negligible water absorption and hence, slump of concretemix increases with increase in replacement levels[7].

Even though the quality and long term properties are debatable, concrete with recycled materials are depicting satisfactory mechanical properties in concrete. An attempt has been made to replace coarse aggregates with crushed windmill resin waste in this study. With the advent of sustainable engineering concept; reduction of waste, reuse of stable material, and recycling of waste is being effectively adopted in civil engineering. Recycling will conservenatural resources, minimizes transportation related expenditure and subside environmental degradation [6].

2. MATERIALS AND METHODOLOGY

Materials:

Cement: 53 grade cement was considered for this study and the characteristics of cement wereexamined as per IS: 269 – 2015[8] and IS 4031- 1996[9]and represented in Table 1.

Table 1: Properties of cement

Properties	Values
Specific Gravity	3.10
Normal Consistency (%)	31
Initial setting time(minutes)	40
Final Setting time(minutes)	340
Fineness (%)	99

Fine aggregates: Manufactured – Sand [M-sand] was procured from local quarry for fine aggregate. The characteristics of M-sand were examined as per IS: 383- 2016 [10] and IS: 2386- 1963 [11]. Properties of fine aggregate are represented in Table 2.

Table 2: Properties of M-sand

Properties	M-Sand
Specific Gravity	2.61
Water Absorption (%)	2.2
Zone	II
Bulk Density (kg/m^3)	1412

Coarse aggregates: Conventional coarse aggregates were procured from local quarry. Resin waste aggregates were prepared by crushing bars of windmill waste. The properties of the boththe materials were examined according to IS: 383-2016 [10] and listed in table 3

Table 3: Properties of Conventional coarse aggregates and Crushed Mangalore tiles

Properties	Coarse Aggregate	Wind turbine Resin Aggregate
Specific Gravity	2.67	1.24
Water Absorption (%)	0.40	0
Bulk Density (kg/m^3)	1581	1038

Water: Portable water abiding by IS-456:2000 [12] was used for casting and curing of concrete.

3. METHODOLOGY

M30 grade Concrete was designed as per IS: 10262-2009 [13] and 1:1.57:2.63 proportions with 0.45 water cement [w/c] ratio. In the mix, conventional coarse aggregates were replaced by volume with crushed resin bars at 10% from 0-100%. Fresh concrete was measured for workability using slump cone test as per IS 1199-2018 [14]. Concrete was filled to moulds in 3 layers and with effective compaction using needle vibrator. After 24 hours of casting,

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specimens were demoulded and subjected to water curing by immersing in curing tank. The cubes specimens were subjected to compression test as per IS:516-1959 [15]. The optimum values were obtained from each replacement and final mix was prepared for optimum values and those specimens were checked for compression, split tensile and flexural strength as per IS:516- 1959 [15].

4. RESULTS AND DISCUSSION

Mechanical properties of concrete are determined from compression strength test, split tensile strength test and flexural strength test. The compressive strength of concrete decides the grade of concrete which is directly proportional to the split tensile and flexural strength.

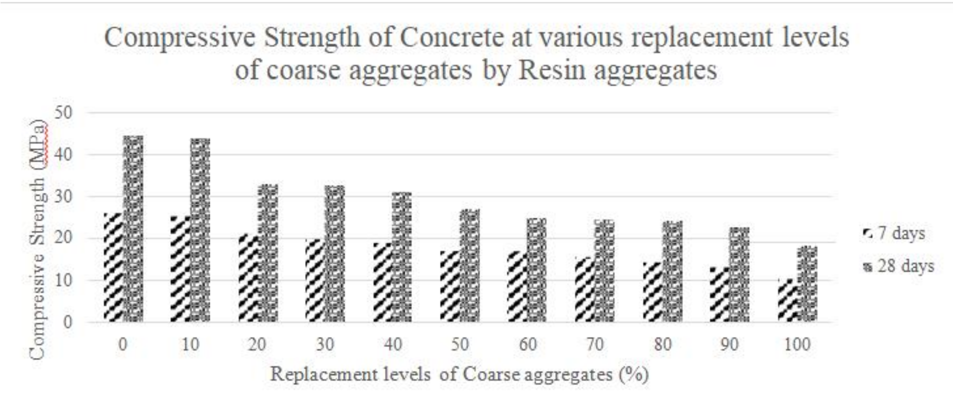

Figure 1: Variation of compressive strength of concrete with replacement of coarse aggregates by Resin aggregates

It can be noticed from figure 1 that, upto 10% replacement of natural coarse aggregates with resin aggregates, the compressive strength achieved at 28 days satisfied the target strength criteria. It is also observed that, initial strength of concrete (at 7 days) was almost same for the concrete specimens containing 10% of resin aggregates and normal concrete. With further increase in replacement levels, strength of concrete decreases gradually till 18 MPa at 100% replacement. Thus, it can be stated that, incorporation of resin aggregates in-place of natural coarse aggregates will reduce the strength of concrete with increment in replacement levels.

The variation of split tensile strength of concrete with variation in coarse aggregates replacement levels are represented in figure 2.

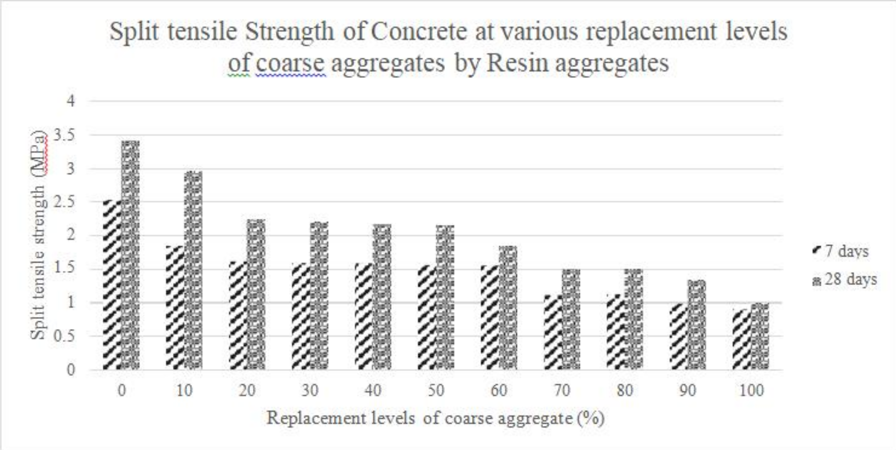

Figure 2. Split tensile strength of Concrete for various replacement levels of coarse aggregates by Resin aggregates

With the increase in resin aggregate content in concrete, split tensile strength decreases at 28 days. It is also observed that, initial tensile strength of concrete (at 7 days) followed the same trend. It might be because of less bonding of aggregates with the matrix as the resin aggregates are having smooth surface with texture evenness. The failure of the concrete was along interfacial transition zone, indicating the poor bonding with the paste and mortar matrix due its surface smoothness and water repellent behavior.

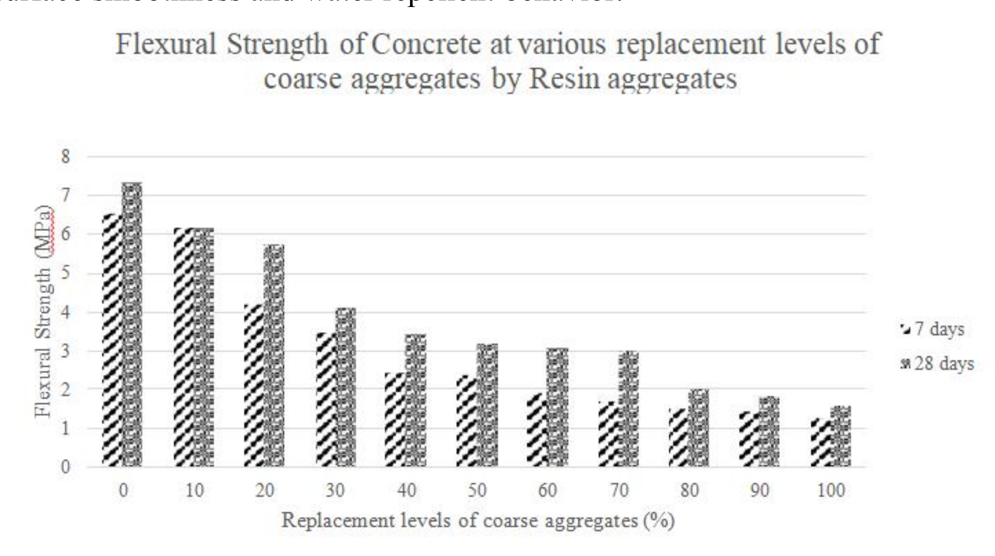

Figure 3. Flexural strength of Concrete for various replacement levels of coarse aggregates byResin aggregates

The variation of flexural strength of concrete with variation in coarse aggregates replacement levels are represented in figure 3. It can be noticed that, with the increase in replacement of natural coarse aggregates with resin aggregates, the flexural strength decreases. 7 days strength and 28 days strength follows the same behavior.

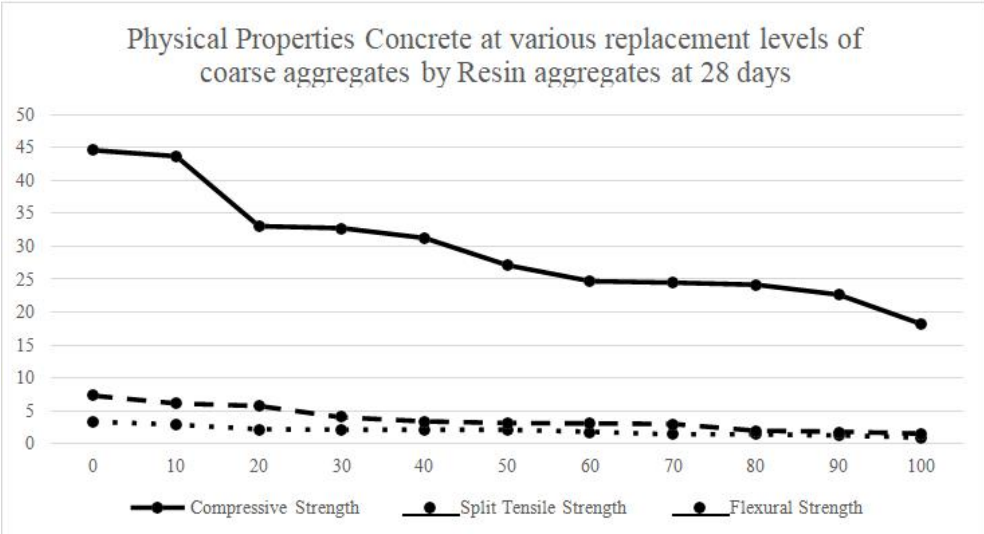

Figure 4. Physical Properties Concrete at various replacement levels of coarse aggregatesby Resin aggregates at 28 days

From figure 4, it can be observed that, at 28 days of age the of all the physical properties remains same for the replacement of coarse aggregates by resin aggregates from 0-100%. However, till 30% replacement the concrete shall be used as M30 grade concrete, eventhough the compressive strength decreases evidently after 10% replacement levels. As the compressive strength is more 20 MPa till 90% replacement, it can also be used for reinforced concrete works. At 100% replacement, compressive strength of about 18MPa was exhibited and hence, itcan also used for plain cement concrete for constructions of lesser importance.

From this studies, it can be noticed that, the decrease in the physical strength not too high by the incorporation of resin aggregates and hence, it can be considered as the effective replacement material for conventional coarse aggregates.

5. CONCLUSION

1. Compressive strength of concrete decreases gradually with increase in replacement levels ofcoarse aggregates by resin aggregates. At 10% replacement, the strength of concrete with conventional aggregates and resin aggregates is almost same.
2. Beyond 10% replacement, significant decrease in compressive strength of concrete was noticed.However, till 30% replacement levels, the concrete achieved target strength of M30grade concrete and hence, 30% can be considered as optimum replacement level of resin aggregates.
3. The split tensile strength followed the same trend as that of compressive strength. Analysis of failure pattern of cylindrical specimen depicts that, the failure of specimen was along the interfacial transition zone, which indicates lesser bonding between coarse aggregates and mortar phase.
4. Flexural strength also depicts the same trend as that compressive strength and split tensilestrength.

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