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Study on use of Polyester Resin as Coarse Aggregate in Concrete

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Abstract: The high demand for coarse aggregate recently has resulted in extreme excavation of rocks due to which it will pose a threat to our environment. Due to this, recently the government has laid down strict restrictions on quarries due to its negative impact on environment. The main objective of this paper is to study the possibility of completely replacing the natural coarse aggregates with polyester resin in concrete. Concrete cubes were casted using cement, sand and polymer resin by trial method. Two mixes were prepared by taking 63% and 53% of the coarse aggregate from the total aggregates of the concrete. In this study, the extent of natural aggregates that can be replaced by polyester resin as coarse aggregates without sacrificing the strength of the concrete are discussed.

Keywords: *Polyester Resin, Workability, Coarse Aggregates, Compressive Strength, Split-Tensile Test*

1. Introduction

The developmental activities over world are increasing due to this demand for the construction material is also increasing exponentially. The heavy demand for the building material in the market making it scarce day by day. Hence in order to keep the developmental activities abreast and curtail the cost factor alternative building material should be looked for.

In this work, an attempt is made to address the possibility of completely replacing the natural coarse aggregates with Polyester Resin in concrete.

Polyester resin is an unsaturated, thermosetting resin produced by a reaction between several organic acids and polyhydric alcohols. It is most commonly used in the construction of moulded reinforced fiber and composite products.

Polyester resins are the most widely used resin systems, particularly in the marine industry. By far the majority of dinghies, yachts and workboats built in composites make use of this resin system.

Most polyester resins are viscous, pale colored liquids consisting of a solution of polyester in a monomer which is usually styrene. The addition of styrene in amounts of up to 50% helps to make the resin easier to handle by reducing its viscosity. The styrene also performs the vital function of enabling the resin to cure from a liquid to a solid by 'cross-linking' the molecular chains of the polyester, without the evolution of any by-products. These resins can therefore be moulded without the use of pressure and are called 'contact' or 'low pressure resins. Polyester resins have a limited storage life as they will set or 'gel' on their own over a long period of time. Often small quantities of inhibitor are added during the resin manufacture to slow this gelling action.

2. Methodology

The work was performed in three stages:

Stage1: Determination of physical properties of polyester resin aggregates according to IS: 2386(Part 1)-1963 and IS 2386 (Part 3)-1963.

Stage2: Designing a suitable trail mix and characterizing the properties of concrete using polyester resin as coarse aggregates.

Stage3: Comparing the properties of polyester resin aggregate concrete with that of natural local aggregate concrete.

2.1. Physical Properties of Polyester Resin Aggregates

2.1.1. Specific Gravity Test

Specific gravity of the material is the ratio of weight of known volume of the material to the weight of equal volume of water, both weights being measured at the same standard temperature. The specific gravity test of samples was conducted using pycnometer in accordance to IS: 2386 (Part 3)-1963. The average specific gravity of sample was found to be 1.11

Figure 1: *Polyester resin aggregates*

2.1.2. Sieve analysis

Grading of sample is one of important factors which affect workability of the concrete mix. Sieve analysis was done according to IS: 2386(Part 1)-1963. The results are tabulated as follows.

Table 1: *Results of sieve analysis*

IS Sieve Size	Weight Retained	Cumulative % passing
10	0	100
4.75mm	18	96.4
2.36mm	12	94
1.18mm	98	73.6
600 micron	120	49.6
300 micron	189	11.8
150 micron	56.5	0.5
Pan	0	0

Fineness modulus is a ready index of coarseness or fineness of the material. It is an empirical factor obtained by adding the cumulative percentages of aggregates retained on each sieve and dividing this sum by an arbitrary number 100.

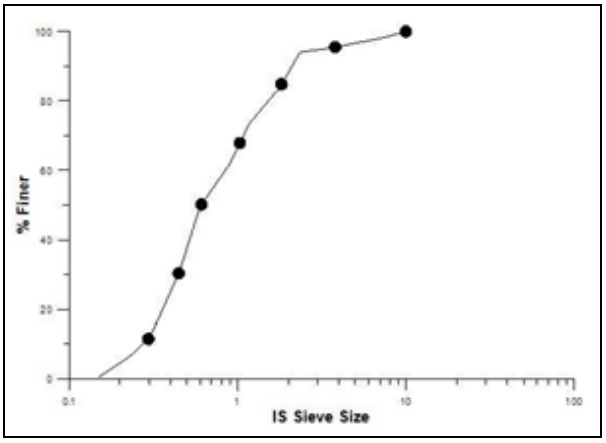

Figure 2: *Grain size distribution curve*

2.1.3. Rothfuchs Method

Rothfuchs method was proposed in 1935 as it is reasonable quick and simple and can be applied to the mixtures of any number of components. It consists essentially of the following stages

1. The cumulative curve of the required aggregate particle-size distribution is plotted, using the usual linear ordinates for the percentage passing but choosing the scale of sieve size such that the particle size distribution plots as the straight line. This is readily done by drawing an inclined straight line and marking on it the sizes corresponding to various percentages passing
2. The particle size distribution curve of the aggregates to be mixed is plotted on this scale.
3. With the aid of a transparent straight edge, the straight lines that most nearly approximate to the particle-size distribution curve of the single aggregates are drawn. This is done by selecting for each curve a straight line such that the areas enclosed between it and the curves is minimum and are balanced about the straight line.
4. The opposite ends of these straight lines are joined together, and the proportions for mixing can be read off from the points where these joining lines cross the straight lines representing the required mixture.
5. From this method the values obtained for the percentage of polyester resin aggregates from the total aggregates to be used for the concrete mixes are 53%, 58%, and 63%.

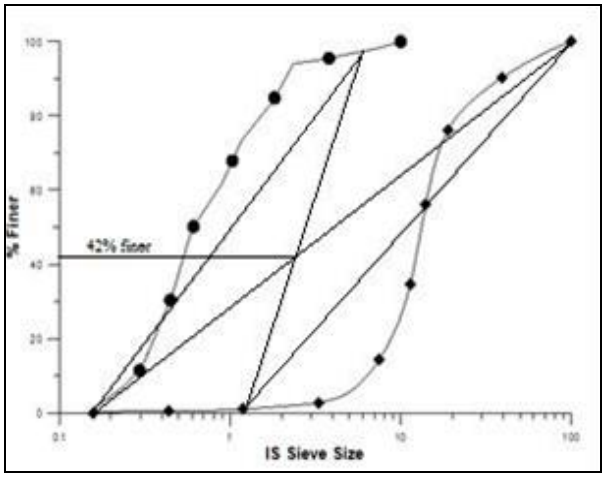

Figure 3: *Rothfuchs method graph*

2.1.4. Maximum Density Method

For the values obtained for the percentage of polyester resin aggregates from the total aggregates from the Rothfuchs method, its density were to be determined using the maximum density method the density of the total aggregates were tested. The results obtained are given in the following table

Table 2: *Results of maximum density method*

Sl. No.	Polyester resin in total aggregates (%)	Density (kg/m^3)
1	53	1240
3	63	1280

2.2. Concrete Mixes

Trial Mixes of the concrete were prepared for 63% and 53% of the coarse aggregate from the total aggregates of the concrete with the maximum size of aggregates being 20mm. Details of the trial concrete mixes are given in the table 4 made from 63% of the coarse aggregate from the total aggregates are given below:

Specific Gravity of the cement = 3.15
Specific Gravity of Coarse aggregates = 1.11
Specific Gravity of fine aggregates = 2.6
Water absorption of fine aggregates = 1.9%

Table 3: *Details of trail concrete mixes*

Percentage Coarse Aggregate Mix	53	63
W/C Ratio	0.5	0.5
Water Content(litre/m^3)	186	186
Cement Content(kg/m^3)	372	372
Fine Aggregate (kg/m^3)	825.954	650.219
Coarse aggregate(kg/m3)	397.63	472.659
Mix proportion	1:2:22:1.07	1:1:75:1.27

2.2.1. Slump Test

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199-1959 is followed. The slump measured is recorded in mm of subsidence of the specimen during the test.

The slump obtained for the given concrete mix for 63% coarse aggregate at 0.5water cement ratio is 42mm.

2.2.2. Preparation of Standard Cubes and Cylinders

The cubical mould of size 150mm for compressive strength and the cylindrical mould of diameter 150mm and height 300mm size for split tensile strength tests evaluation were prepared. For compression test 5 cubes of 150mm size, 2 numbers for 7 days and 3 numbers for 28days and two cylinders for concrete cylinders made from 53% and 63% polyester resin aggregates and one cylinders for concrete cylinders at 28 days made from 53% and 63% natural aggregates were casted.

2.2.3. Curing and Hardened Concrete

The test specimens in their mould were left undisturbed at room temperature for 24 hours inside the laboratory. The mould of the cubes and cylinders were stripped and all the specimens were transferred to the normal curing tank.

2.2.4. Testing of Hardened Concrete

After the curing period the concrete cubes were tested for its compressive strength after 7 days and 28 days and concrete cylinders were tested for split tensile strength after 28 days.

2.2.5. Compressive Strength test on Concrete Cubes

Concrete is very strong in compression. It is assumed that whole of the compression will be taken up by the concrete while designing any concrete structure. Strength of the structure indirectly indicates the quality of the structure. This test is not only important from structural point of view but also other properties such as fatigue, impact, shrinkage, creep, deformation and thermal sensitivity bears some relationship with it. Also water to cement of the concrete influences durability, dimensional stability and other properties of concrete.

2.2.6. Split-Tensile Test on Cylinders

Cracking behavior is governed by tensile strength and it also affects properties like stiffness, damping action, and durability of concrete. The behavior of concrete under shear load should also be taken into consideration while designing structure. There are two methods to determine the tensile strength; one is direct tensile test and the other is indirect tensile test like flexural and split tensile strength. Split-tensile is the easiest test that can be conducted to determine the tensile strength of concrete.

3. Results and Discussion

3.1. General

In this section, the results of test conducted on 53% and 63% polyester resin aggregates and 53% and 63% natural aggregates are discussed.

3.2. Test on Hardened Concrete

3.2.1. Compression Tests

Compressive test was conducted in accordance with IS: 516-1959. Compressive strength test is carried out on cubical specimen of size 150mm. The test is done immediately upon removal of the specimen from curing tank in the damp condition. The surface water is wiped off and the specimen should be placed in the machine, so to apply the load to the surface other than the top and the bottom surface at cast.

The loading is applied gradually and uniformly. The ultimate load at which the specimen failed was noted for each specimen. After testing the specimen was visually inspected for the rupture surface.

Results of compression tests conducted on concrete cubes are tabulated in below tables.

Table 4: *Compressive strength results of concrete cubes made from 63% polyester resin aggregates*

Days	Sl. No	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
7	1	360	16.00	15.78
	2	350	15.55	
28	1	510	22.67	22.52
	2	500	22.22	
	3	510	22.67	

Table 5: *Compressive strength results of concrete cubes made from 53% polyester resin aggregates*

Days	Sl. No	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
7	1	330	14.67	14.67
	2	330	14.67	
28	1	460	20.44	20.59
	2	460	20.44	
	3	470	20.88	

Table 6: *Compressive strength results of concrete cubes made from 63% natural aggregates*

Days	Sl. No	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
7	1	360	16.00	15.55
	2	340	15.11	
28	1	500	20.44	22.07
	2	500	20.44	
	3	490	20.88	

Table 7: *Compressive strength results of concrete cubes made from 53% natural aggregates*

Days	Sl. No	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
7	1	380	16.89	16.89
	2	380	16.89	
28	1	540	24.00	24.22
	2	540	24.44	
	3	540	24.00	

From the above results it is observed that compressive strength of all concrete mixes increase with increase of ages. The compressive strength for 63% of polyester resin and 63% of natural aggregates are approximately equal and the difference in compressive strength is 1.5% in 7 days strength and2% in 28 days strength and the compressive strength of 53% of polyester resin is slightly less than that of 53% of natural aggregates and the difference in compressive strength is 13% in 7 days strength and 15% in 28 days strength.

3.2.2. Split Tensile Strength

The split tensile test was conducted on concrete cylinders with 63% and 53% polyester resin aggregates and also on concrete cubes with 63% and 53% natural aggregates, as per IS 5816: 1999. This is an indirect method of determining the tensile strength of concrete. Cylinder of 150mm diameter and 300mm height is tested as per I.S. specification. The specimen is placed with its axis horizontal between the platens of testing machine. Uniform load is applied until cylinder fails along the vertical diameter. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete.

Figure 4: *Test set up for split tensile test of concrete*

Results of split tensile tests conducted on concrete cubes are tabulated in below tables.

Table 8: *Split tensile strength results of concrete cylinders at 28 days made from 53% and 63% polyester resin aggregates*

Sl. No.	Resin Aggregate from total aggregates (%)	Failure Load (kN)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)
1	63	100	1.42	1.485
2		110	1.55	
3	53	90	1.27	1.27
4		90	1.27	

Table 9: *Split tensile strength results of concrete cylinders at 28 days made from 53% and 63% natural aggregates*

Sl. No.	Natural Aggregate from total aggregates (%)	Failure Load (kN)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)
1	63	160	2.26	2.26
2	53	180	2.54	2.54

From the above test results, it is clear that the cylinders prepared using polyester resin as coarse aggregates is having lesser split tensile strength compared to that prepared by natural aggregates.

3.2.3. Weight characteristics

Weight of the polyester resin aggregate concrete cubes was measured before the testing and was compared with natural coarse aggregates.

Table 10: *Weight of the cubes for 53% coarse aggregate*

Type of Aggregate	Weight(kgs)	Average(kgs)
Polyester resin aggregates	6.11	6.18
	6.20	
	6.25	
Natural aggregates	7.98	8.04
	8.12	
	8.03	

Table 11: *Weight of the cubes for 63% coarse aggregate*

Type of Aggregate	Weight(kgs)	Average(kgs)
Polyester resin aggregates	6.090	6.18
	6.105	
	5.980	
Natural aggregates	8.215	8.2663
	8.340	
	8.234	

The weights of the cubes prepared from 53% and 63% of polyester resin aggregates are approximately same.

4. Conclusions

Based on our study of using polyester resin as a coarse aggregate in concrete following conclusions may be derived

1. The concrete is lighter compared to normal concrete.
2. Polyester Resin aggregate is non-biodegradable.
3. The material has very high impact value.
4. Water absorption of the resin aggregate is almost zero.
5. This concrete can be used for general purpose.
6. It can be a good alternate material for normal coarse aggregate in case of scarcity.
7. The usage of polyester resin aggregates will reduce the environmental hazards created by excessive mining of natural aggregates.

5. Acknowledgment

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