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An Experimental Work on Performance of FRPC for Two-Ways Slabs

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Abstract - Polymer concrete is a composite material that results from the polymerization of a monomer aggregate mixture. The polymerized monomer acts as a binder for the aggregates, and the resulting composite is called "Concrete." The developments in the field of polymer concrete date back to the late 1950s when these materials were developed as a replacement of cement concrete in some specific applications. Early usage of polymer concrete has been reported for building cladding and so forth. Later on, because of rapid curing, excellent bond to cement concrete and steel reinforcement, high strength and durability, it was extensively used for the construction industry. Various types of polymers can be applied in cementitious systems as polymerizing admixtures to modify the cement matrix by introducing a polymer film into it or where the hydraulic cement paste and the polymer simultaneously form into separate but interdependent, phases in the matrix. This polymer-modified cement concrete is produced by the addition of higher molecular-weight polymers to concrete batches for the purposes of improved adhesion, greater chemical resistance, lower permeability, lower drying shrinkage, improved tensile strength, or accelerated cure. Various chemical families and physical forms of polymers have been used for the purpose of improving performance, but Styrene-Butadiene Rubber (S.B.R.) latex, acrylic, and epoxy additives are the most commonly used. Epoxy resin is a polymeric material and is a non-hardening liquid substance; it forms three-dimensional mesh structures by the reaction of the multifunctional epoxy compound. Cement hydration and epoxy polymerization occur simultaneously to form a structure that is similar to the latex-modified cementitious system. An epoxy-modified cementitious system develops higher strength and adhesion and has lower permeability, better water resistance, and chemical.

Key Words: Compressive strength, Split tensile strength, Shear strength, Flexural strength

1.INTRODUCTION

The discovery of Portland cement in the 18th century represented a turning point in the history of construction. Products readily utilized before the conception of Portland cement, such as lime and clay, though malleable and easy to work, did not achieve a high strength when cured. Portland cement provided a solution to this problem. Blended with a suitable aggregate and mixed with water, it produced a product with a far superior mechanical strength. The advantages of such a product were soon realized, and a revolution in building construction began. Rather than using bricks and stones, bonded by a mortar, large sections of the buildings' outer-structure could be pre-cast and assembled on-site. Cost savings in terms of the labour and time required to gather new buildings were realized. The use of an inner steel structure provided additional structural support enabling the construction of building to reach new heights and the development of modern skyscrapers. Although the benefits of Portland cement can be seen, there are certain limitations. One of its disadvantages is its rigidity when cured. The cured matrix has a limited capability to deform as a result of movement. If the force of this movement exceeds the natural flexibility of the cured material, cracking is induced.

Depending upon the extent, location within the building, and type of structure, it can be a costly process to rectify as well as looking aesthetically unpleasing. A classic example is cracking within concrete renders applied onto the exterior of buildings. Incorporating polymers into cementitious materials proved a way of overcoming or improving the disadvantages of cement- based materials. Analysis of polymer modified cementitious materials has clearly shown an improvement in flexural strength and impact resistance of the final product. It is, in turn, results in tolerance to movement and deformation. An insight into the potential benefits of combining Portland cement and a polymer observed during the experiments conducted throughout the 1920-1930s. By blending a natural polymer with Portland cement, an improvement in the workability and ease of use of the resultant mix was identified. Natural in origin, this polymer could be readily harvested and processed to produce the desired polymer product.

2. MATERIALS AND MIX DESIGN

In this section, material properties are presented, and also the optimum dosage of stone powder as a partial replacement to cement was found. To find optimum dosage cube, compressive strength was taken into consideration, and to support the results, EDAX analysis also presented.

2.1 Materials Used

- Cement
- Fine Aggregate
- Natural Course Aggregate
- Water
- Epoxy resin
- Bethamcherla Stone
- Steel Fiber

2.2 Mix Design

By using the above materials and as per IS 10262:2009 code, the min was designed to attain M20 grade concrete. (the calculation relating to mix design can be viewed in Appendix I). The summary of the design proportion is depicted shown below Table-6.

Table -1: Physical Properties of Cement

Sl.No.	Property	Experimental Value	Limits as per IS12269-1987
1	Fineness of Cement	301 m²/kg	>225 m²/kg
2	Specific Gravity	3.1	Nill
3	Normal Consistency	33%	
4	Setting Time		
	Initial Setting time	45 minutes	>30minutes
	Final setting time	360 minutes	<600minutes
5	Compressive Strength		
	3 days	32 Mpa	>27MPa
	7 days	46 Mpa	>37MPa
	28 days	58 Mpa	>53MPa

Table -2: Physical Properties of Fine Aggregate

S.No.	Property	Values
1	Specific Gravity	2.58
2	Fineness Modulus	2.80
3	Bulk Density	
	Loose State	15.75 kN/m³
	Compacted State	17.05 kN/m³
4	Grading of Sand	Zone - II

Table -3: Sieve Analysis of Fine Aggregate

S.No	IS Sieve	Weight retained	% Weight retained	Cumulative % weight retained	% Passing	Grading limits of fine aggregates as per IS:383-1970
1	10 mm	0	0	0	100	100
2	4.75 mm	15	1.5	1.5	98.5	90-100
3	2.36 mm	30	3	4.5	95.5	75-100
4	1.18 μ	315	31.5	36	64	55-90
5	600 μ	275	27.5	64	36.5	35-59
6	300 μ	210	21	85	15.5	Aug-30
7	150 μ	60	6	91	9.5	0-10

Table -4: Properties of Bethamcherla stone dust

S. No	Property	Value
1	Silicon-di-Oxide (SiO_2)	23.93%
2	Aluminium tri oxide (Al_2O_3)	3.56%
3	Ferric Oxide (Fe_2O_3)	1.86%
4	Calcium Oxide (CaO)	38.55 %
5	Magnesium Oxide (MgO)	1.07%
6	Manganese oxide(MnO)	0.05
7	Titanium oxide(Tio_2)	0.18
8	Potassium oxide (K_2O)	0.62
9	Loss on Ignition	0.308

Table -5: Properties of Bethamcherla stone dust

Sl.No.	Property	
1	Length of Fiber (l)	50 mm
2	Diameter (d)	0.75 mm
3	Aspect ratio	66.67
4	Tensile Strength	450 Mpa
5	Physical form	Undulated along the length
6	Material Type	Low Carbon Drawn Wire

Table -6: Mix Proportion

W/C ratio	Water (kg/m³)	Cement (kg/m³)	Fine aggregate (kg/m³)	Coarse aggregate (kg/m3)	Mix proportion
0.5	197.16	394.32	627.86	1189.76	1:1.59:3.01

3. STRENGTH PROPERTIES OF POLYMER CONCRETE

To determine specified strengths, a total of75 specimens were cast, and breakup foreach category, for various as shown in Table -7, BPA mixes, 15 cubes and 15 cylinders were cast to find compressive strengths. For split, tensile strengths total 15 cylinders, and for shear strength, 15 cylinders were cast. For the evaluation of flexural strength, atotal of 15 beams were cast.

Table -7: Arrangement of cubes, cylinders and beams

Sl.No	BPA (%)	Cubes	Cylinders	Beams
1	**R**(0%BPA)	3	3	3
2	5	3	3	3
3	10	3	3	3
4	15	3	3	3
5	20	3	3	3

3.1 Casting, Curing and Testing

- The cubes and cylinders were cast with a standard size of 150x150x150mm and 150mm (diameter) x300mm (height), respectively.
- The beams were cast with a size of 150x150x750mm.
- All the materials are weighed as per mix design and kept aside individually.
- The cement, sand, coarse aggregate, and stone powder were added uniformly.
- Half the quantity of water is added to those materials.
- Later BPA polymer is pored over the materials and mixed thoroughly.
- The fresh concrete mix is placed in the cubes, cylinders, and beam specimens.
- During placing in the respective moulds the concrete was poured in three layers, and each later tampered with a tamping rod.
- Finally, for all specimens, compaction was provided by table vibrator, and after this, the specimens are kept aside in the laboratory.
- The concerned specimens were removed after twenty-four hours from the moulds, and the specimens are immersed in water for 7 days.
- Later the specimens are taken out and kept for 21 days under the shed.

Table -8: Compressive strength of Cubes

Sl.No.	% of BPA	Peak Load (kN)	Peak Stress (MPa)	Average Stress (MPa)
1	0 (Reference Concrete)	693.2	30.81	31.28
		710.8	31.59	
		707.3	31.44	
2	5	739.1	32.85	33.35
		757.9	33.68	
		754.1	33.52	
3	10	853.3	37.92	38.5
		874.9	38.89	
		870.6	38.69	
4	15	805.6	35.8	36.35
		826.1	36.71	
		822	36.53	
5	20	653.8	29.06	29.5
		670.4	29.8	
		667.1	29.65	

Table -9: Compressive strength of Cylinders

Sl.No.	% of BPA	Peak Load (kN)	Peak Stress (MPa)	Average Stress (MPa)
1	0 (Reference Concrete)	433	24.51	24.88
		444	25.13	
		441.8	25	
2	5	476.9	26.99	27.4
		489	27.67	
		486.6	27.54	
3	10	574.9	32.53	33.03
		589.5	33.36	
		586.6	33.2	
4	15	508.2	28.76	29.2
		521.1	29.49	
		518.5	29.35	
5	20	392.3	22.2	22.54
		402.3	22.77	
		400.3	22.65	

Table -10: Split Tensile Strength

SNo.	%BPA	Peak Load (kN)	Peak Stress (MPa)	Average Stress (MPa)
1	0 (Reference concrete)	160.8	2.28	2.31
		164.9	2.33	
		164.1	2.32	
2	5	174.8	2.47	2.51
		179.2	2.54	
		178.3	2.52	
3	10	201.2	2.85	2.89
		206.3	2.92	
		205.3	2.9	
4	15	181	2.56	2.6
		185.6	2.63	
		184.7	2.61	
5	20	150.4	2.13	2.16
		154.2	2.18	
		153.4	2.17	

Table -11: Shear Strength

Sl.No.	%BPA	Peak Load (kN)	Peak Stress (MPa)	Average Stress (MPa)
1	0 (Reference mix)	38.8	4.31	4.38
		39.8	4.42	
		39.6	4.4	
2	5	41.2	4.58	4.65
		42.3	4.7	
		42.1	4.67	
3	10	47	5.22	5.3
		48.2	5.35	
		47.9	5.33	
4	15	41.4	4.6	4.67
		42.5	4.72	
		42.2	4.69	
5	20	36.5	4.06	4.12
		37.5	4.16	
		37.3	4.14	

Table -12: Flexural Strength

Sl.No.	% of BPA	Peak Load (kN)	Peak Stress (MPa)	Average Stress (MPa)
1	0 (Reference concrete)	25.9	4.61	4.68
		26.6	4.73	
		26.5	4.7	
2	5	28.5	5.07	5.15
		29.3	5.2	
		29.1	5.18	
3	10	32.4	5.75	5.84
		33.2	5.9	
		33	5.87	
4	15	28.3	5.03	5.11
		29	5.16	
		28.9	5.14	
5	20	24.4	4.34	4.41
		25.1	4.45	
		24.9	4.43	

4. CONCLUSIONS

1. The use of Bethamcharla stone powder for concrete is viable and found that 10% of replacement to cement is optimum.
2. The maximum compressive strength for 10% stone powder is obtained (31.28MPa), and this is 9.27% higher than the reference concrete (M20 grade concrete).
3. The mix with 10%Bisphenol A (BPA) showed maximum strengths than other mixes.
4. The concrete with 10% stone powder (replacement to cement) and 10%BPA (as an additive to concrete by weight of cement) showed higher strengths than other mixes, and those were considered as optimum levels.
5. The mix with 10% SP and 10%BPA showed 23.10% higher compressive strength than the reference mix.
6. The concrete mix (10%SP+10%BPA) with 1 and 2% of steel fibers showed 18.98 and 24.00% higher cube compressive strength than the reference mix. The split, shear, and flexural strengths are increased by 12.36 & 19.14%, 8.81 &14.51 and 5.65 & 11.64% for 1 and 2% of steel fibers respectively.

7. The simply supported polymer concrete slab under four points loading with 0,1 and 2% of steel fibers showed higher strength of 27.27, 63.33,109.09% at first crack, and 25.00,36.80 and 41.30% at ultimate load than the reference concrete.

8. The simply supported polymer concrete slab under four points loading with0,1 and 2% steel fibers showed maximum deflections and higher energy absorption than the reference concrete, and the energy absorption is varying from 108.36 to 193.58KJ/m^3.

9. For simply supported polymer concrete slabs, the average bending moment equation based on yield line theory is $M=0.034wl^2+0.169$ P. This equation estimated the failure load satisfactorily for the present study.

10. The fixed polymer concrete slab under four points loading with 0,1 and 2% of steel fibers showed higher strength of 13.15,56.96 and 115.18% at first crack and 9.10,40.00 and 50.80% at ultimate load than the reference concrete.

11. The fixed polymer concrete slab under four points loading with 0,1 and 2% steel fibers showed maximum deflections, and higher energy absorption than the reference concrete and the maximum deflections are varying from 17.4 to 24.20 mm. The energy absorption is varying from 237.90 to 476.40 KJ/m^3.

12. For fixed polymer concrete slabs, the average bending moment equation based on yield line theory is $M=0.016wl^2+0.103P$, and this equation estimated the failure load satisfactorily for the present study.

13. The simply supported slabs with 0,1 and 2% of steel fibers, under single point loading (Punching shear), showed a percentage increment of 42.28,90.47 and 161.19% at first crack and 23.91,65.21 and 86.69% at an ultimate stage when compared with reference concrete.

14. The simply supported slabs with 0, 1, and 2% of steel fibers, under single point loading (Punching shear), showed maximum deflections of 18.5, 20.2, and 22.00 mm, respectively.

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