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AN EXPERIMENTAL STUDY ON BEHAVIOR OF POLYMER CEMENT CONCRETE

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ABSTRACT

Polymer as admixture can improve the properties like higher strength and lower water permeability than the conventional concrete. Rheomix 141 is styrene-butadiene co–polymer latex, specifically designed for use with cement composites. It is used in mortar and concrete as an admixture to increase resistance to water penetration, improve abrasion resistance and durability. The objective of the present investigation is to study the behavior of polymer cement concrete in the hardened state. The variables studied include the grade of concrete and dosage of polymer. Five different grades of concrete M20 to M60 with polymer quantities starting from 5% to 10% were used in the present work. The various mechanical properties like compressive strength, splitting tensile strength, flexural strength, stress–strain characteristics, and modulus of elasticity and permeability characteristics of concrete have been studied. The results obtained thus are encouraging for partial addition of polymer with cement up to 10%.

Keywords: Polymer Concrete; admixtures; rheomix; strength characteristics; permeability

1. INTRODUCTION

A polymer-modified cementetious material has been available for over more than 70 years. Polymers are made from simple organic molecules (monomers) that combine to form more complex structures through a process called polymerization. The polymers are dispersed in water or redispersible powders. These are added to hydraulic cement, with or without aggregate or admixtures, depending on the desired results. The addition of a minor amount of a polymer to a cement mix can significantly enhance the properties of the resulting material, which is known as polymer–modified cement based material. These additives known as admixtures can be in the form of polymer particles or liquids.

The mechanical properties of polymer concrete are very important in many of its

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structural applications. Therefore, the objective of this paper is to study the mechanical properties of polymer concrete using Rheomix 141.

Kawamura Akio [14]) developed the process of development and the fundamental properties of MMA polymer concrete. Chung [3] reported that the cement based materials are the dominant structural materials for the Civil Infrastructure. The results of the study carried out by Rossignolo et al [12] on the effects of styrene–butadiene rubber latex (SBR) modification on the durability of lightweight concrete demonstrate that the performance of SBR-modified LWAC exposed to aggressive environments was better than unmodified one. Also, SBR-modified LWAC led to lower water absorption and significant resistance improvement to chemical attack and corrosion.

Afridi et al [1] reported that the polymer particles used as admixture can reduce the stresses due to carbonation related shrinkage and control the crack formation. Afridi et al [2] compared the coalescence of polymer particles (continuous polymer films formation) in powdered polymer-modified mortars (PPMMs) and aqueous polymer-modified mortars (APMMs) and found that poor coalescence of polymer particles or development of inferior quality polymers films in PPMMs as compared to that observed in APMMs. The effect of adding glass and carbon fibers on the compressive and tensile behavior of polyester polymer concrete (PC) was investigated by Kallol Sett and Vipulanandan[13]. Oshima et al[16] introduced Styrene-butadiene copolymer in rubber and found that it improves rebound resilience and processability without effecting other mechanical properties. Rozenbaum.O., et al [17] investigated on the consequences of styrene-butadiene rubber (SBR) latex addition on the hardness and structural properties of a cement matrix have been. The results show that the primary effect of latex addition is the decrease in the capillary porosity and a shift of the pore-size distribution towards the nanometer range. Wang et al [18] carried out their study on Physical and mechanical properties of styrene-butadiene rubber emulsion modified cement mortars. Polymer-modified cement mortars were prepared by varying polymer/cement mass ratio (P/C) with a constant water/cement mass ratio of 0.4.

The results of the experiments by Ismail [10] indicate that the polymer loading, compressive strength and bulk density increase with increases in percentage of divinyl benzene as well as with the γ-radiation doses, whereas the water absorption and apparent porosity of the specimens decrease. This behaviour is attributed to the amount of polymer deposited in the pores of the samples. Liu et al [15] reported that in polymer modified cement–based material, polymer particles are partitioned between the inside of hydrates and the surface of anhydrates cement grains. The presence of the polymer results in improved pore structure thereby decreased porosity. Tests on Polyester Polymer Concrete by Jo et al [11] have shown that using resin based on recycled Polyethylene Terephthalate (PET) has high flexural and splitting tensile strengths and it achieves about 70 to 80% of its 7-day strength in 1 day. The use of recycled PET in polymer concrete helps in reducing the cost of the material, solving some of the solid waste problems posed by plastics, and thus saving energy.

2. EXPERIMENTAL PROGRAMME

2.1. Materials

Cement: Ordinary Portland Cement (53 Grade) conforming to IS12269-1987 was used The properties of cement are given in Table 1.

Table 1: Physical properties of cement

Property	Values
Normal consistency (%)	32
Specific gravity	3.15
Initial setting time	90
Final setting time	220
Fineness of cement (%)	6
Compressive strength @ 7 days (MPa)	39.5
Compressive strength @ 28 days (MPa)	56.0

Fine and Coarse Aggregates: Fine and coarse aggregate conforming to IS 383-1970 were used and their properties are given in Tables 2a and 2b.

Table 2a: Properties of fine aggregate

Property		Values
Specific gravity		2.62
Bulk density (kg/cum)	(a) Loose	1601
	(b) Compacted	1670
Fineness modulus		2.70
Grading		Conforming to Zone II
Water absorption (%)		1.64
Bulking of sand (%)		4.00

Table 2b: Physical properties of coarse aggregate

Sl.No	Property	Values
1	Specific gravity	2.65
2	Bulk density (kg/cum) (a) Loose (b) Compacted	1592 1706
3	Fineness modulus	7.13
4	Water absorption (%)	0.20
5	Impact value (%)	18
6	Crushing value (%)	20
7	Voids (%) Loose compacted	39.20 35.60

Polymer (Styrene butadiene co-polymer latex): The Polymer (Styrene butadiene co-polymer latex) used in this investigation was RHEOMIX141 commercially marketed by BASF. Its composition, specific gravity, mean particle size, PH value and butadiene content are given in Table 3.

Table 3: Properties of polymer

Sl. No	Property	Test result
1	Composition	Milky, white styrene butadiene copolymer latex specifically made for use with Portland cement.
2	Specific gravity	1.01
3	PH value	10.50
4	Mean particle size	0.17micron
5	Butadiene content	40% by wt of RHEOMIX 141

Super Plasticizer: The super plasticizer used in the present work was CONPLAST–SP430 (Sulphonated Naphthalene polymer) commercially marketed by FOSROC Chemicals Limited (INDIA).

Water : Locally available potable water was used.

3. METHODOLOGY

The concrete mix design was carried out as per IS10262-1982. There were 5 grades of concrete viz. M20, M30, M40, M50 and M60 used in this investigation to study the effect of polymer on low, medium and high strength concrete. The polymer levels used were 5%, 7.5%, and 10%. For each of these mixes and corresponding to each percentage of polymer content, 3 cubes, 3 cylinders and 3 prisms were cast to determine the compressive, tensile and flexural strengths at the age of 28 days. Also, 3 additional cylinders were cast to test for the Young's Modulus of the material.

Plate 1. Mixing of polymer cement concrete

Plate 2. Workability Test

All the tests were carried out on Universal Testing Machine (UTM) of 1000 kN capacity. The compressive and flexural strength tests and modulus of elasticity test were conducted as per IS 516-1959 (6). Splitting Tensile Strength of Concrete test was carried out as per IS 5816-1999(7) to determine the cylinder split tensile strength. Permeability test was conducted as per AIM – 381.

4. TEST RESULTS AND DISCUSSION

The compressive strength, splitting tensile strength and modulus of elasticity values are shown for different grades of concrete and for different percentages of polymer quantities in Tables 4, 5 and 6.

Table 4: Cube compressive strength of concrete at 28 days

Percentage of polymer	Grade of concrete				
	M20	M30	M40	M50	M60
	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)
0.00	29.00	38.23	51.25	63.48	71.32
5.00	34.50	42.12	55.20	68.60	74.65
7.50	41.20	48.56	63.35	75.50	81.85
10.00	43.50	50.54	67.30	80.00	85.16

Table 5: Splitting tensile strength of concrete at 28 days

Percentage of Polymer	Grade of concrete				
	M20	M30	M40	M50	M60
	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)
0.00	3.25	3.54	3.73	3.85	4.46
5.00	3.54	3.75	3.90	3.96	4.58
7.50	3.82	4.02	4.15	4.16	4.64
10.00	4.05	4.22	4.18	4.22	4.70

Table 6: Modulus of elasticity of concrete at 28 days

Percentage of polymer	Grade of concrete				
	M20	M30	M40	M50	M60
	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)
0.00	31.09	32.57	42.67	44.97	46.2
5.00	33.65	35.41	44.80	46.69	47.81
7.50	34.50	36.25	46.87	47.16	48.84
10.00	34.90	36.42	46.89	48.26	49.26

Workability of Polymer Cement Concrete

In case of M20 grade of concrete with addition ratios 0% to 10% of Polymer, the slump values increased from 45mm to 60mm. The increase in slump is attributed to less water absorption of Polymer. The maximum percentage of increase of slump in polymer concrete was observed at 10% addition of polymer. The compaction factor for the M20 grade of concrete was observed to be increased from 0.85 to 0.96 as the polymer concrete increased from 5% to 10%. The percentage increase in compaction factor for M20 concrete was 11.5. Similar trend was observed for M30, M40, M50 and M60 grades of concrete; the maximum percentage increase being 13.30%. It is also observed that slump and compaction factor values for higher grades of concrete are less compared to corresponding lower grades of concrete. (Figures 1 & 2)

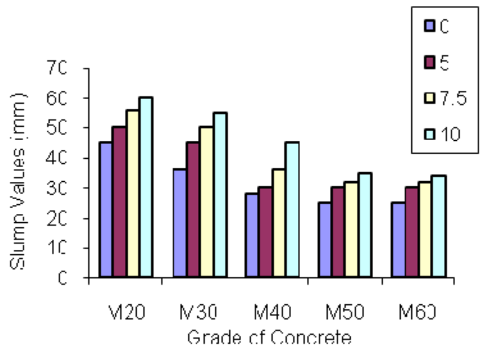

Figure 1. Variation of slump with percentage of geopolymer for various concrete mixes

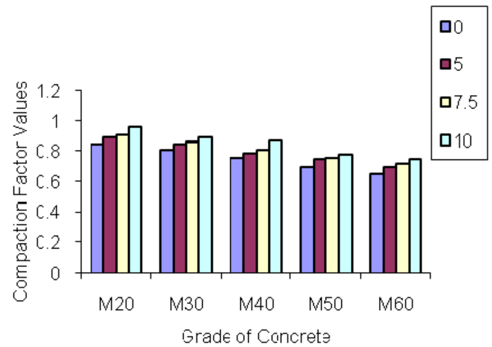

Figure 2. Variation of compaction factor with percentage of geopolymer for various concrete mixes

Compressive Strength of Concrete

The compressive strength at 28 days of M20 grade of concrete increased as the percentage of polymer increases. There is an increase in compressive strength of M20 concrete by 15.94, 29.61 and 33.33% for 5, 7.5 and 10% polymer addition respectively compared to plain concrete without polymer. Similar results were observed in M30, M40, M50 and M60 grades of concrete. The compressive strength increased up to 24.35%, 23.84%, 20.65% and 16.25% respectively in M30, M40, M50 and M60 concretes for 10% of polymer, signifying the fact that the percentage increase in compressive strength, with the addition of polymer, gradually reduces as grade of concrete increases. These are shown in Table 4 and Figure 3.

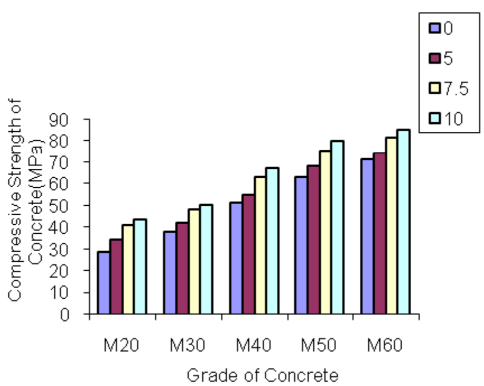

Figure 3. Variation of compressive strength with percentageof geopolymer for various

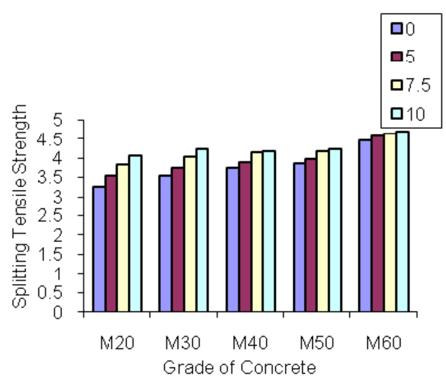

Figure 4. Variation of tensile strength with percentage of geopolymer for concrete mixes various concrete mixes

Flexural Strength

There is an increasing trend of flexural strength as the polymer content increased for all the

Plate 3. Flexural strength test

Plate 4. Compressive strength test

grades of concrete tested. But the increase in strength is significant in lower grade concretes while it is not that significant for high strength concretes. The flexural strength increased up to 18.37, 15.04, 14.48, 13.56 and 13.22% respectively for M20, M30, M40, M50 and M60 grades of concrete with the addition of 10% of polymer and the results are shown in the Figure 5.

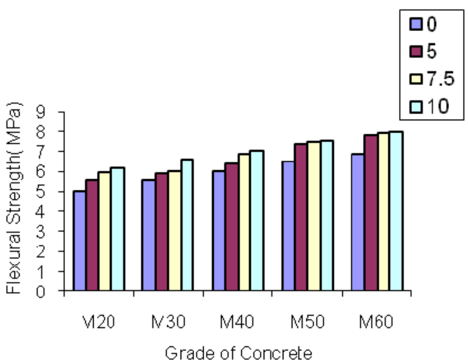

Figure 5. Variation of flexural strength with percentage geopolymer for various

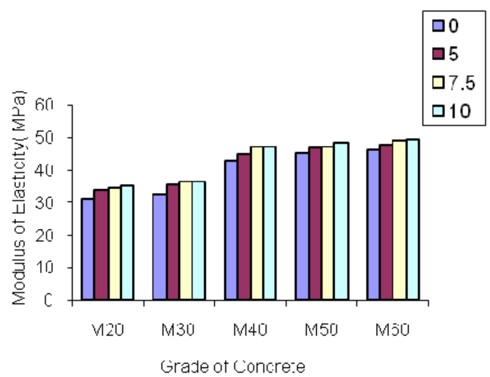

Figure 6. Variation of Young's modulus with percentage of geopolymer for concrete mixes various concrete mixes

Modulus of Elasticity

Typically the stress-strain curves for concrete of M20 grade with different percentages of polymer content are shown in Figure 7 and similarly the initial stress-strain behavior of polymer concrete for M60 for all percentages of polymer is presented in Figure 8. The similar trend was observed for all the grades of the concrete tested in this work. However, the strains of polymer concrete are slightly reduced compared to normal concrete, thereby increasing the stiffness.

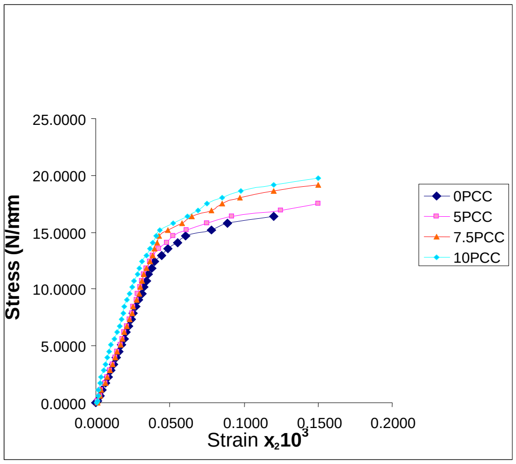

Figure 7. Stress-strain curves of M20 grade concrete for different polymer ratios

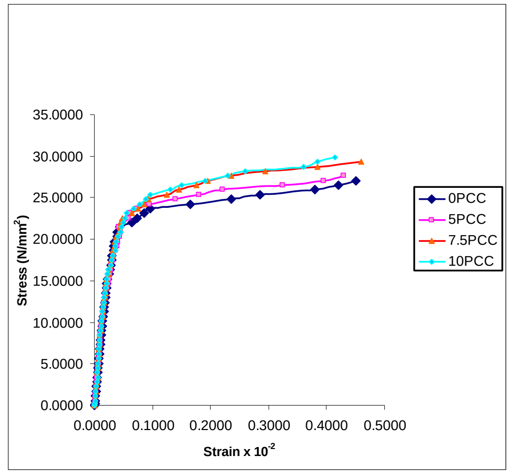

Figure 8. Stress-strain curves of M60 grade concrete for different polymer ratios

Modulus of elasticity values also followed similar trend as that of the strength. These values increased as the percentage of polymer increased for the same grade of concrete and reduced as the grade of concrete increased for the same polymer content. The increase in modulus of elasticity of M20 concrete is in the range of 7.6 to 10.91% as polymer content increased from 5 to 10%. In concretes of M30, M40, M50 and M60 grades the modulus of elasticity increased up to 10.76, 8.99, 6.81 and 6.21% respectively for 10% of polymer content (Figure 6).

Plate 5. Young’s modulus test

Plate 6. Tested specimens (splitting tensile strength)

Permeability of Concrete

It is observed that for the M20 grade of concrete the coefficient of permeability decreases as the addition of polymer increases from 5% to 10%. The decrease in permeability as polymer content increased from 5 to 10% was observed to be 32.39% for M20 concrete, and these results are shown in Table 7.

Table 7: Co-efficient of permeability of concrete at 28 days

Percentage of Admixture		Co-efficient of Permeability (cm/sec)
Grade of concrete	**Polymer**	
M20	5.0%	2.309×10^{-8}
	10.0%	1.744×10^{-8}

5. CONCLUSIONS

1. There is an increase in the workability of concrete as the polymer content increased, in all the grades of concretes from M20 to M60.
2. There is an improvement in the strength of concrete as the polymer content increased in the mix for all grades of concretes tested in this investigation.
3. The increase in strengths of concrete due to the addition of polymer is significant for low strength concretes and marginal for high strength concretes. The values of Young's Modulus also followed similar trend while the Coefficient of permeability reduced with the increased polymer content.
4. The maximum increase in compressive strength at 10 % polymer content for low medium and high strength concretes varied from 16.25% to 33.4% while the increase in split tensile strength varied between 5.1 to 19.8%. However, the increase in flexural strength ranged between 13.2 to 18.4%.
5. The maximum decrease in coefficient of permeability and increase in modulus of elasticity were 32.40% and 11% respectively for M20 grade concrete with 10% polymer content.
6. The increase in the modulus of elasticity for all the grades of concrete with 10% polymer content was observed to be in the range of 6.21% to 10.91% compared to that of conventional concrete (0% polymer).
7. In general, it is observed that the overall performance of the concrete is improved with the addition of polymer, by weight of cement, for all the grades of concretes tested. However, the effect of polymer on performance of normal concrete is superior to its effect on high strength concrete.

REFERENCES

1. Afridi MUK, Ohama Y, Demura K, Iqbal MZ. A note on the comparison of crack resistance of $Ca(OH)_2$ crystals of unmodified and polymer-modified mortars in carbonated atmosphere, *Cement and Concrete Research*, No. 11, **31**(2001) 1643-5.

2. Afridi MUK, Ohama Y, Demura K, Iqbal MZ. Development of polymer films by the coalescence of polymer particles in powdered and aqueous polymer modified mortars, *Cement and Concrete Research*, No. 11, **33**(2003) 1715-21.
3. Chung DDL. Polymer for cement-based structural material, *Journal of Material Science*, **39**(2004) 2973-8.
4. I.S: 10262-1982, Indian standard recommended guidelines for concrete mix design, Bureau of Indian Standards, reaffirmed, New Delhi 1999.
5. I.S: 4031-1968 (part I, IV, VI)-1988, Indian standard Method of physical test for hydraulic cement, Bureau of Indian Standards, reaffirmed, New Delhi, 2000.
6. I.S: 516-1959, Method of test for strength of concrete, Bureau of Indian Standards, New Delhi, 1959.
7. I.S: 5816-1999, Method of test for splitting tensile strength of concrete, Bureau of Indian Standards, New Delhi, 1999.
8. I.S:2386 (Part I, IV, VI)-1988, Indian standard Method of test for aggregate for concrte, Bureau of Indian Standards, Reaffirmed, New Delhi, 2000.
9. I.S:383–1970, Indian standard specification for coarse and fine aggregate from natural sources for concrete, Bureau of Indian Standards, Reaffirmed, New Delhi, 1997.
10. Ismail MR. Physico-mechanical properties of GAMMA induced polymer modified mortar, *International Journal of Radiation Applications and Instrumentation*. Part C. Radiation Physics and Chemistry, No. 6, **33**(1989) 533-7.
11. Jo BW, Park SK, Kim CH. Mechanical Properties of polyester polymer concrete using recycled polyethylene terephthalate, *ACI Materials Journal*, Mar/Apr 2006.
12. João A, Rossignolo and Marcos VC. Agnesini, Durability of polymer-modified lightweight aggregate concrete, *Cement and Concrete Composites*, No. 4, **26**(2004) 375-80.
13. Kallol S, Vipulanandan C. Properties of polyester polymer concrete with glass and carbon fibers, *ACI Materials Journal*, No. 1, **101**(2004) 30-41.
14. Kuwamura A. MMA polymer concrete for prolonging the life of concrete structures, *Concrete Journal*, No. 6, **41(**2003) 18-25.
15. Liu J, Zhu LL, Wang J. Wuhan Univiversity of Technology, *Material Science*, No.1, **18**(2003) 61-120.
16. Oshima, Noboru (Suzuka, JP) Shimizu, Isamu (Kameyama, JP), Yamaguchi, Shinsuke (Higashikurume, JP), Takeuchi, Mikio (Yokkaichi, JP), Fujimaki, Tatsuo (Higashimurayama, JP) Styrene-butadiene copolymer rubber composition, United state patent No. 4575534, Application No 06/597635, Publication Date 03-11-1986.
17. Rozenbanum OM, Pellenq RJ, Van Damme H. An expérimental and mesoseopic Lettice simulation study of styrene-butadiene latex-cement composites properties, *Journal of Materials and Structures*, No. 4, **38**(2005) 467-78.
18. Wang RU, Wang PM, Li XG. Physical and mechanical properties of styrene-butadiene rubber emulsion modified cement mortars, *Cement and Concrete Research*, No. 5, **35**(2005) 900-5.