FLEXURAL BEHAVIOUR OF RICE HUSK ASH POLYMER MODIFIED REINFORCED CONCRETE BEAMS

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ABSTRACT: *This research paper focuses on the tensile and flexural strength of Rice Husk Ash Polymer Modified Reinforced Concrete (RHAPMC). RHAPMC was prepared by replacing cement with locally extracted Rice Hush Ash (RHA), a supplementary cementing material, at 10 % and incorporation of 5 % Re-dispersible Polymer-Modified Powder (RPP). To study the tensile and flexural behaviour of RHAPMC, concrete and RHAPMC cylinders of 150 mm x 300 mm and reinforced concrete and rice husk ash polymer modified reinforced concrete beams of 3'x 6''x 6''(900 mm x150 mm x150 mm) size were made. The beams were loaded up to the ultimate load to determine the flexural behavior and to investigate the load-deflection relationship. From the results it is obvious that RHAPMC has improved tensile strength as compared to ordinary concrete and RHAPMC beams has shown more load carrying capacity, more ductility and more deflection with prolonged failure than those of ordinary reinforced concrete beams.*

Keywords: Tensile strength, Flexural strength, Deflection, Cement replacement, RHAPMC.

1. INTRODUCTION

Concrete, a man-made composite material, is mostly utilized material of construction over the Earth, more or less 10,000 million tonnes per annum [1]. Although it is being used in construction industries all around the world nevertheless it has some inherited deficiency in terms of strength and durability; such deficiencies pay the way for its limitation in the field of repair and re-habitation of structures. In ordinary cement concrete and mortar, calcium silicate hydrates, calcium hydroxide and aggregates are bound together by week van der Waals forces that cause the poor performances of cement concrete and mortar in certain domains [2]. Research is being carried out all around the world to improve such deficiency of the concrete as repair material. Performance of cement mortar and concretes can be improved with polymeric compounds [3-6]. Polymeric compounds which can improve limitations of cement mortar/concrete, mainly; Polymer latex/dispersions, Re-dispersible polymer powder, Water-soluble polymers and Liquid polymers [7, 8].

Polymer modified concrete is a latest high performance material to a relative extent, which has extensive applications due to its advantages that make it to be more successful than cement concrete [9-14]. Most notably advantages put forth by the polymer concrete are: Splendid mechanical strength, rapid curing, having the property of making ingredients to stick together, able to resist the abrasion and weathering, water tightness and giving good results against thermal properties [15-21]. There are various areas to utilize polymer concrete/polymer modified concrete i.e. manufacturing of precast concrete beams etc; in water retaining structures; dams, dikes, reservoirs and piers; highway surfaces and bridge decks; additionally to the petrochemical industry, underground constructions, roads surfaces and coating or repairing materials in the chemical and food industries [10, 18, 22]. Due to the special characteristics of PC/PMC that is also being used for repair and rehabilitation overlaying/underlying for bridge surfaces, stadium floors, laboratories, hospitals, factories and other structural system.

The prime aim of this experimental study is to improve the flexural behaviour of concrete by the utilization of rice husk ash as a supplementary cementing material and by incorporating re-dispersible polymer powder as a binder.

2. MATERIALS

2.1. Cement

OPC confirming to ASTM C 150 type I was used in this experimental work. Physical & chemical properties of the cement are presented by [23] illustrated in Table 1.

2.2. Aggregate

Fine and coarse aggregate having maximum size of 4.75 mm and 19 mm has been used respectively.

2.3. Rice husk ash

Rice husk ash extracted from locally available rice husk in the vicinity of district Nawabshah, Sindh, Pakistan has been used in this research study. Physical and chemical properties of the extracted ash are shown in Table 1.

2.4. Polymer modifier

Re-dispersible polymer powder VINNAPAS 5044 N produced by Wacker is used in this research.

2.5. Plasticizer

Peramin Sulfonated Melamine Formaldehyde (SMF-10) a plasticizer has been used.

2.6. Reinforcement

The deformed steel bars of grade 60 were used for reinforcement of beams. The diameters of main and hanger bars were 12mm and 10mm respectively.

2.7. Experimental Program

For determination of tensile strength, a total of 10 number cylindrical specimen of size 150 mm x 300 mm were cast as per mix designed shown on Table 2. After de-moulding all the specimens were kept in curing tank for curing. The control mix (un-modified) samples were cured for 28-days in moist curing as per ASTM C 192 and Polymer-modified concrete mix samples were first kept in wet curing for 7-days and then kept in air for 21-days for air dry curing as per JIS A1171-2000. The splitting Tensile Test was carried out through using a Universal Load Testing Machine (UTM) with a capacity of 1800000 N by applying compression load at the rate of 0.5MPa/sec along two axial lines diametrically opposite as per ASTM C 496. The average tensile strength of five cylindrical specimens was recorded for determination of flexural strength, a total of 6 numbers RCC beams 6 inch wide, 6 inch depth and span of 3 feet were cast as ordinary reinforced concrete beams (un-modified) and rice husk ash polymer modified reinforced concrete beams. The material properties and beam specifications are shown in Table 3. For the both type of beams, all required materials were taken as per mix design as shown in Table 2. After 24 hours ordinary reinforced concrete beams (un-modified) were cured for 28-days in moist curing as per ASTM C 192 and rice husk ash polymer modified reinforced concrete beams were first kept in wet curing for 7-days and were kept in air for 21-days air dry curing as per JIS A 1171-2000. A computerized Universal Load Testing Machine (UTM) having capacity of 3000 kN was used for testing the beam specimens at a three point load arrangement over a simply supported span. A Linear Variable differential Transducer (LVDT) was logged at the center of beams to record the deflection at 0.1 seconds as shown in Figure 1.

Table 1: Chemical and Physical Properties of Rice Husk Ash (RHA)

Material	Physical Properties		Chemical Analysis (%)						
	Specific Gravity	Blaine (cm^2/g)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	LOI
Cement	3.15	3008	20.78	5.11	3.17	60.89	3	-	1.71
RHA	2251	2.05	91.74	1.12	0.98	0.81	2.18	0.00	1.50

Table 2: Mix Proportion

S No	Concrete Mix	Kg/m^3								Slump (mm)
		Cement	RHA	RPP	T.Binder	Plasticizer	Water	F.A	C.A	
1	CM	346	0	0.0	346.0	0.0	190.3	692	1038	25-50
2	RHAPMC	311.4	34.6	15.6	361.6	2.89	205.87	692	1038	

Table 3: Material Properties and Beams Specifications

Material Properties							Reinforcement detail			
Beam Type	b (in)	h (in)	d (in)	fc' (psi)	fy (psi)	L (in)	Hanger bars	Bottom bars	As (in^2)	P
CM	6	6	4.5	3335	60,000	36	2 # 3	3 # 4	0.6	0.022
RHAPMC	6	6	4.5	3596	60,000	36	2 # 3	3 # 4	0.6	0.022

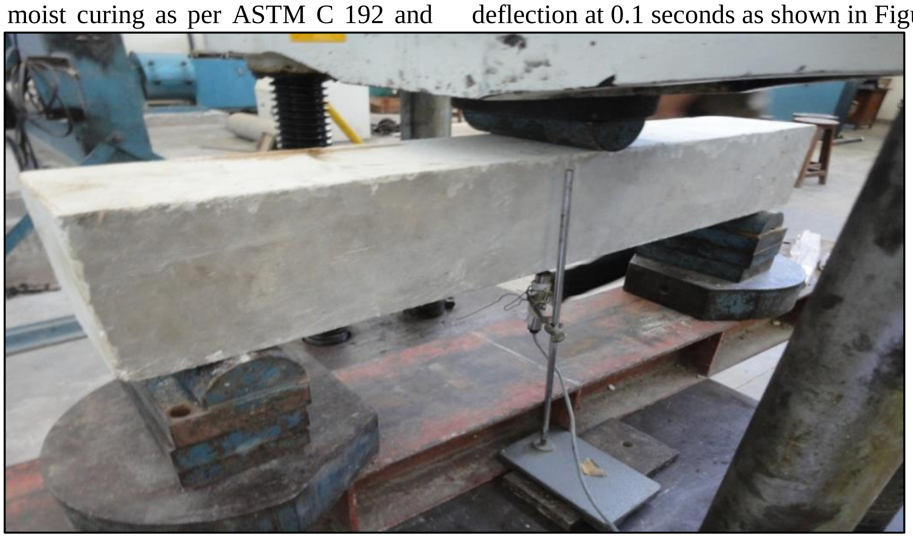

Figure.1 Computerized UTM for determination of load carrying capacity of RCC beams

3. RESULTS AND DISCUSSION

3.1. Tensile Strength

The average cylindrical tensile splitting strength results of control mix (ordinary concrete), rice husk ash polymer-modified concrete are shown in Table 4. As shown in results in Table 4, the tensile strength of rice husk ash polymer modified concrete is 2.78Mpa with an increase of 49.46% than that of ordinary concrete. The increase in tensile strength might be due to the fact that the RPP has the ability to form a continuous three-dimensional network of polymer molecules in concrete which enhance cement-hydrate-aggregate bond. Such findings regarding the improvement in tensile strength validated by [24, 25].

Table 4: 28-days Tensile Splitting Strength

Mix type	Polymer to Cement Ratio%	Tensile Strength (MPA)	%age incr/decr
CM	0	1.86	-
RHAPMC	5	2.78	49.46

3.2. Load carrying Capacity of Control and Polymer-modified Reinforced Concrete Beams

Graph in Figure 2 shows the load-deflection curve of ordinary reinforced concrete beams. The graph in Figure 2 shows that the propagation of tensile cracks starts at 15kN load and at 24kN load the cracks become wider and the beams finally yield at 54kN. Graph in Figure 3 shows the load carrying capacity of rice husk ash polymer-modified reinforced concrete beams. The graph in Figure 3 shows that the load-deflection curve of RHAPMC beams is of the linear elastic in nature. Furthermore, there is no evidence of start of the tensile cracks up to the yield point of the RHAPMC beams, this is due to the fact that the addition of re-dispersible polymer powder in concrete mix develops the crack-bridging capacity in beams, such polymer-bridges detection between the layered Ca(OH)2 crystals are validated by Knapen, E. and D. Van Gemert[26]. Such effect gives rise in the linear elastic characteristics of RHAPMC beams that take up higher load as compared to un-modified concrete beams and finally it yields at 58kN load, such findings are backed by Ahmad, S., et al. [27].

3.3. Ductility of Control and Polymer-modified Reinforced Concrete Beams

Graph in Figure 2 shows load-deflection behaviour of ordinary reinforced beams. The graph in Figure 2 shows that the mid deflection at yield point reaches to 4.31mm and maximum measured deflection is 5.72 mm. The ordinary reinforced concrete beams exhibit smaller deflections that suggest the failure pattern being the non ductile in nature. No any prolong mode of failure pattern is noticed in the load-deflection curve of the ordinary reinforced concrete beams, this is due to the fact that in ordinary cement concrete the calcium-silicate-hydrate in cement paste and aggregates are bound together with the Van der Waals force which are much weaker than a chemical bond in nature. The tensile cracks, in ordinary concrete, develop easily under the force that cracks lead the earlier failure of the ordinary concrete beams. By the contrast, graph in Figure 3 shows the load-deflection behavior of the rice husk ash polymer-modified reinforced concrete beams. The RHAPMC beams show exceptionally better behavior in terms of ductility. The mid deflection under the central load at yield point reaches to 7.14 mm and maximum measured deflection is 10.16 mm. The more ductile and prolong mode of failure is observed in the load-deflection curve of RHAPMC beams, this is due to the formation of a new covalent chemical bond at the time of hydration and polymerization process. The newly developed chemical bond which is stronger in nature [28] has the capability of arresting the tensile cracks that are being developed under the load. According to Li, Z [29] the load-deflection curve for bending serves to indicate the energy-absorbing capacity or toughness of the material. Increase in toughness improves performance of material in resisting fatigue, impact and impulse loading. Moreover, the improved toughness also results in better ductility, such high ductility behavior and high flexural strength of polymer modified concrete and mortars are reported by [30-32].

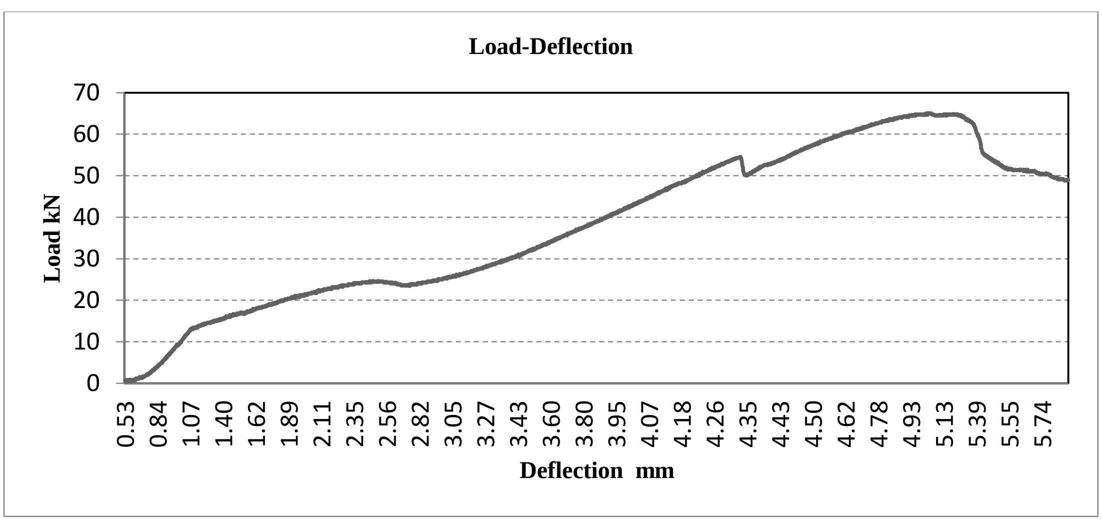

Figure. 2 Load -deflection curve of control beams

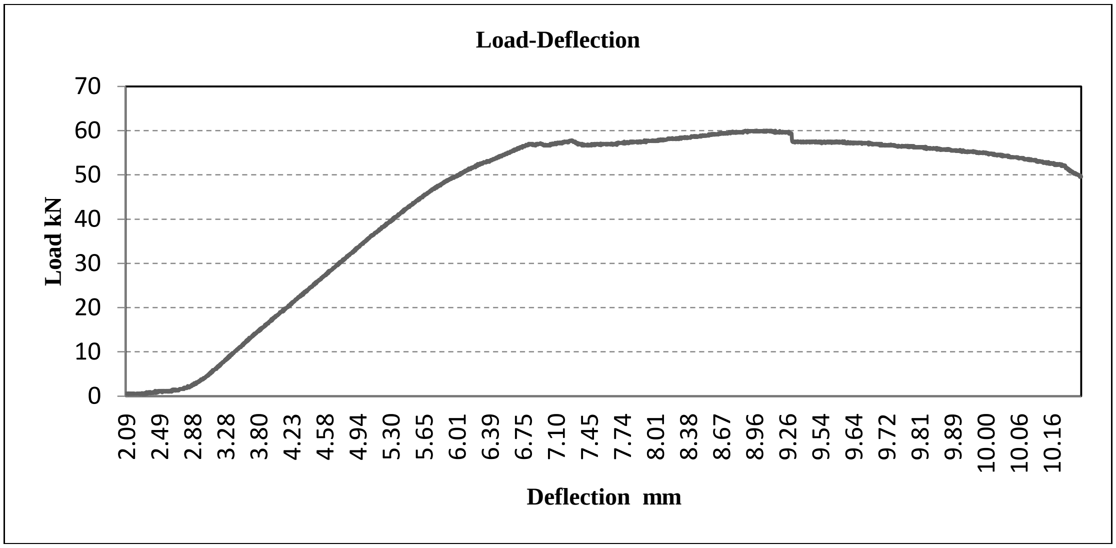

Figure.3 Load-deflection curve of RHAPMC beams

4. CONCLUSIONS

- The tensile strength of rice husk ash polymer modified concrete found as 2.78 MPa that is 49.46% more as compared to tensile strength of ordinary concrete.
- The beams cast Rice Husk Ash Polymer Modified reinforced Concrete (RHAPMC) exhibited 5.45% more load carrying capacity and revealed prolonged ductile failure with more deflection (i.e. 77.62% increase) than that of control reinforced concrete beams.

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