International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 2918-2925

Flexural Behaviour of Latex Modified Fly Ash Based Reinforced Concrete Beams

P.Palson[1] and B. Vidivelli[2,*]

[1] *Assistant Professor, Department of Civil and Structural Engineering, Annamalai University, Chidambaram, India.*
[2*] *Professor, Department of Civil and Structural Engineering, Annamalai University, Chidambaram, India.*

Abstract

This paper discussed flexural behaviour of reinforced concrete beams with Styrene Butadiene Rubber (SBR) latex and Fly Ash as partial replacement of Cement. The latex modified concrete using SBR latex are prepared with various polymer-binder ratios with 30% fly ash contents, and tested for compressive strength, flexure strength and elastic modulus. Latex contents were varied as 5, 10, and 15percent by mass of binder (cement and fly ash). The effect of the polymer-binder ratio and fly ash content on the properties of latex modified concrete was examined. It is concluded from the test results that the compressive strength and tangent modular decreasing with polymer binder ratio. Flexural strength is increasing with polymer binder ratio. Based on mechanical properties 10 percentage of Latex was selected for casting of beams. The moment at mid –span with deflection and moment curvature relationship were established. The Latex modified beams have improved ductility and energy absorption capacity than those of made by reference concretes and that refer to styrene butadiene rubber polymer on the properties and behaviour of reinforced concrete beams.

Keywords: Latex modified concrete, SBR, Fly ash, compressive strength, flexural strength, flexural behaviour, ductility, energy absorption,

INTRODUCTION

In the last three decades many research studies have been carried out on the use of different polymers suitable for admixing into fresh concrete to provide the mechanical properties, among them styrene butadiene rubber latex has been widely used in the past(Joao and Marcos,2002: Ru W. et al., 2006: Zhengxian Y et al., 2009).

Latex is colloidal dispersion of small spherical organic polymer particles in water. The particles are held in suspension in water by coating their surface with a surfactant. Latex modified concrete (LMC) is made by using composite binder of inorganic cement and organic polymer latexes have a network structure which consist of cement gels and microfilms of polymers.

Latex is polymer system formed by the emulsion polymerization of monomers and it contains 50% solid by weight. Since mechanical properties, hydration process in cement and durability of concrete are highly dependent on the state of microstructure. Previous research studies have shown that the polymer as modifier is promising in improving micro-structure of concrete. Consequently the properties of LMC are improved over the conventional concrete.

Introduction of latex in concrete has been provided to improve mechanical properties, physical and chemical properties. Suitable latex formation greatly improves the fundamental strength property of concrete. Latex modified concrete has already found wide range of practical application and proved to be a versatile building material exhibiting superior performance over conventional concrete.

In this present investigation the effect of adding SBR latex on mechanical properties and flexural behaviour of normal concrete and fly as based concrete have been investigated. Fly ash was added to latex modified concrete because adding latex can reduce the compressive strength of the mix. The purpose of adding fly ash is to improve the properties of the LMC. The latex modified concrete containing styrene-butadiene rubber (SBR) are prepared with various latex percentages (5%, 10%, and 15% by weight of binder) and fixed fly ash content (30% partial replacement by weight of cement). Compressive strength, flexural strength studied at 7,28,56,90 days of age. For the selected mix, elastic modulus and flexural behaviour of latex modified concrete beam with and without fly ash was investigated at the age of 28 days.

PROPERTIES OF THE MATERILAS

Cement: Ordinary Portland cement of 43 grade confirming to IS 8112:1989.Physical properties of the cement are shown in Table 1.

Fly Ash (FA): Class C fly ash, obtained from NLC INDIA Ltd, Neyveli. Specific gravity 2.58 and passed on 75mm size sieve.

Table 1. Physical Properties of cement

Property	Value
Specific gravity	3.15
Initial setting time	75 min
Final setting time	200 min
Compressive strength at 28 days	48.4 N/mm^2

Fine Aggregate: Natural River sand passing through 4.75mm IS sieve having fineness modulus 3.12, specific gravity 2.61 and confirming to Zone III of IS 383:1970.

Table 2. Mix proportions of concrete

S.No	Mix Details		Cement kg/m³	Fly Ash kg/m³	FA kg/m³	CA kg/m³	W/B ratio	P/B ratio	Slump Value in mm	% of water reduced
1	C	Control	425.73	0.00	672.6	1122.42	0.45	0.00	50	0.00
2	CL5	5% Latex	425.73	0.00	671.27	1121.05	0.40	0.05	55	5
3	CL10	10%Latex	425.73	0.00	670.40	1119.66	0.36	0.10	65	10
4	CL15	15%Latex	425.73	0.00	669.56	1118.20	0.31	0.15	75	15
5	CL5FA30	5%Latex+30%FA	298.01	127.72	662.53	1106.45	0.40	0.05	70	5
6	CL10FA30	10%Latex+30%FA	298.01	127.72	661.31	1104.42	0.36	0.10	65	10
7	CL15FA30	15%Latex+30%FA	298.01	127.72	660.80	1103.56	0.31	0.15	75	15

Note: W/B-Water binder ratio, **P/B**-Polymer binder ratio

Coarse aggregate: Crushed stone with a nominal maximum size of 20mm having fineness modulus 6.86 as per IS383:1970.

Polymer Latex: Styrene Butadiene copolymer Latex manufactured by Fosroc India limited.

Colour: Milky white emulsion pH: 8.5

Specific gravity 1.01

Total polymer solids: 50%

Materials addition and replacement:

- Latex -5%,10%,15% addition
- Fly ash - 30 % replacement of cement

Mix Design

In this study concrete Mix M_{30} was considered as control concrete (C).The mix design for the above grade of concrete as done based on IS10269:2009 for the workability range of 50-75mm. The control concrete mixture was comprised of Portland cement, water, coarse and fine aggregate. The mix proportion of control concrete is presented in Table 2.

Latex modified concrete (LMC): In this research latex modified concrete composition containing 5 %(CL5), 10 %(CL10) and 15% (CL15) SBR latex by mass of cement were prepared by modifying control concrete. Since the SBR latex used in this study contained 50%of water required to be added in the concrete was accordingly adjusted. Some additional percentage of water to mass of binder also adjusted to maintain the slump between 50-75mm. Additional percentages of water content adjusted (reduced) is shown in the Table 2. Fly ash (FA) of 30% by mass of cement added with latex modified concrete to explore the possibility of strength reduction which may take place due to the latex addition. Three concrete mixtures were designed with latex modification and three mixtures of latex and Fly ash (CL5FA30, CL10FA30, and CL15FA30).

Test Details

The weighed ingredients for the batch were mixed in a tilting drum type concrete mixture machine. The test specimens for compression (150 x 150 x 150mm cube), flexural strength (100 x 100 x 500mm prism),and modulus of elasticity of the concrete (150mm dia x300mm height cylinder),and 125 x 250 x 3200mm beams were cast in steel moulds with mould releasing agent applied. The fresh concrete mix was filled in the steel mould in three equal layers and each layer was well compacted using table vibrator. Before the initial setting time of the concrete, top surfaces of the specimens were levelled using finishing trowel. The conventional concrete specimens were demoulded after 24 hours of casting and then moist cured for 28 days. The curing of latex modified concrete should be such that both hydration of cement and polymer formation take place yielding a strong co-matrix of hydrated cement inter penetrated by polymer film. While the hydration process is promoted by presence of moisture, film formation takes place only on drying. Therefore, the curing protocol for LMC specimens involves a combination of moist curing to promote cement hydration followed by drying to promote film formation. The latex modified cement concrete specimens were subjected to 2 days moist curing, 5 days water curing and 21 days air curing.

EXPERIEMENTAL INVESTIGATIONS

Mechanical Properties of Latex modified concrete:

Compressive Strength

The compressive strength tests were conducted on a compression testing machine as per IS: 516-1959.The cubes 150mm size were tested at the ages 7days,28 days,56 days and 90 days. For each concrete composition three specimens were tested. Average value of three samples has been reported as compressive strength in Table 3.The compressive strength developments with respect to control concrete specimens at the age of 28,56, and 90 days cured are presented in Figure 1.

Table 3 Results of Compressive Strength

S. No	MIX DETAILS	Average Compressive Strength N/mm²			
		7 Days	28Days	56Days	90Days
1	C	30.56	38.65	42.00	43.90
2	CL5	29.19	35.28	38.21	40.21
3	CL10	27.60	33.00	35.67	38.28
4	CL15	25.80	29.81	32.49	34.78
5	CL5FA30	29.86	37.18	40.89	43.50
6	CL10FA30	27.98	34.98	38.82	41.62
7	CL15FA30	27.15	32.37	36.22	38.84

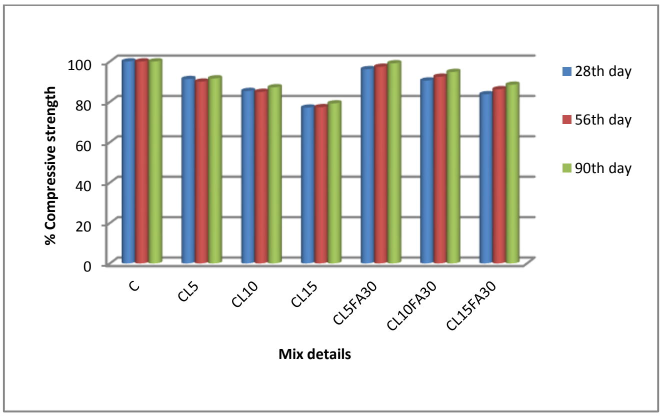

Figure 1. Compressive Strength Development

Flexural Strength

Concrete specimens of size 100mm x 100mm x 500mm were tested under standard four points bending in flexural testing machine. Specimens were tested at different ages. The flexural strength was calculated as the average of the three tested specimens and shown in Table 4. The flexural strength developments of LMC and LMC with silica fume at different ages with respect to the control concrete were shown in Figure 2.

Table 4. Results of Flexural Strength

S. No	MIX DETAILS	Flexural Strength N/mm²			
		7 Days	28Days	56Days	90Days
1	C	3.80	4.50	4.80	5.00
2	CL5	3.99	4.83	5.20	5.46
3	CL10	4.30	5.10	5.36	5.76
4	CL15	4.78	5.46	5.86	6.25
5	CL5FA30	4.21	5.20	5.56	6.10
6	CL10FA30	4.54	5.47	5.90	6.48
7	CL15FA30	4.87	5.73	6.23	6.85

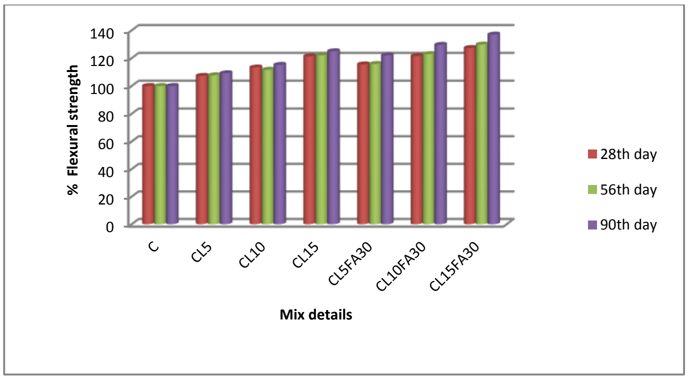

Figure 2. Flexural Strength Development

Modulus of Elasticity

Cylindrical specimens of size 150mm diameter and 300mm height were used for the determination of modulus of elasticity as per IS: 516-1959.Concrete mixes with 10% latex content provided the average strength development for both compression and flexural strength. Hence elastic modulus test and test on beams were conducted for selected mixes (CL10, CL10FA30) only. Specimens were loaded uniaxial in a compression testing machine and deformations were recorded using dial gauge of 0.01mm least count at an interval of 10kN until the peak load. Stress strain curves obtained from cylinder compressive strength test were shown in Figure 4. The elastic moduli of the selected concrete mixes are shown in Table 5.

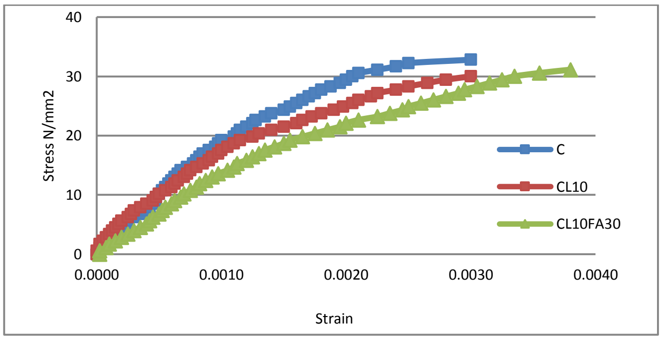

Figure 3. Stress Strain Curve

Table 5. Elastic Modulus of Concrete Mixes at 28 days

S. No	Mix	Elastic Modulus N/mm²
1	C	33333
2	CL10	26666
3	CL10FA30	25000

Flexural Test on Beams

The Experimental programme consisted of casting and testing of six reinforced concrete beam of size 125 x 250 x3200mm. Out these six beams, two beams were control concrete(C) beams, two were latex modified concrete (CL10) and two beams were latex modified concrete with fly ash (CL10FA30). Concrete mixes with 10% latex content provided the average strength development for both compression and flexural strength. Based on the compressive strength and flexural strength, best mixes were selected from latex modified concrete and latex modified concrete mix with fly ash. Details of tested beams were shown in Table 6.

Details of RC beam specimen section with reinforcement are shown in Figure 4. The reinforcement used was 2-12mm diameter Fe415 steel on the tension side and 2- 8mm diameter in the compression zone. Test setup and typical tested specimens are shown in Figure 6 and Figure 7 respectively.

The main objective of this study is to investigate the flexural behaviour and ductility of the conventional reinforced concrete beams and to improve the foresaid properties by the addition of latex and mineral admixture fly ash.

All the beam specimen were tested by applying 4 point static loading to have constant applied moment at middle of 1000 mm of an effective span of 3000mm.Load cell of 300kN with least count of 0.83 kN was used to measure the applied load. The load was applied in increments and each stage the following measurements were made.

All the beams were simply supported and were loaded monotonically up to failure in four point bending.

(i) The deflection at mid span and one third portion from each support using a dial gauge having least count of 0.01mm.

(ii) Demec gauge reading at mid span with 5 demec positions at top and 5 demec positions at bottom.

(iii) Crack width and crack growth was also noted along with the mode of failure for each test specimen. Crack width measured at the least count of 0.02mm.

Details of test results are given in Table 7 and 8. The load versus deflection plot and moment versus curvature plot are shown in Figure 7 and 8. Energy absorption capacity of the beams could be obtained from load versus deflection curve of the specimens. Area under the load deflection considered in this study as energy absorption capacity of beams. This study adopted the ductility ratio defined by curvature at ultimate load to curvature at yield load. Results of energy absorption and ductility index are listed in Table 9. Cracking patterns of the tested beams at failure are shown in figure 6. Values of the load and crack width of all beams are listed in Table 10.The load versus crack width plot are shown in Figure 9.

Table 6. Details of Tested Beams

S. No	Beam Designation	Mix Details
1	C	CONTROL
2	CL10	10% LATEX
3	CL10FA30	10%LATEX +30 % FA

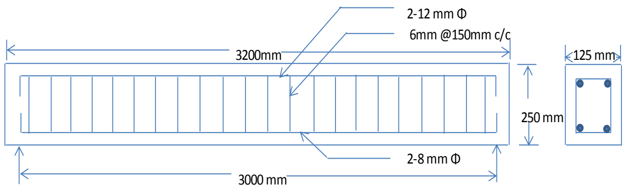

Figure 5. Details of RC Beam Specimens

Figure 5. Test setup for beam

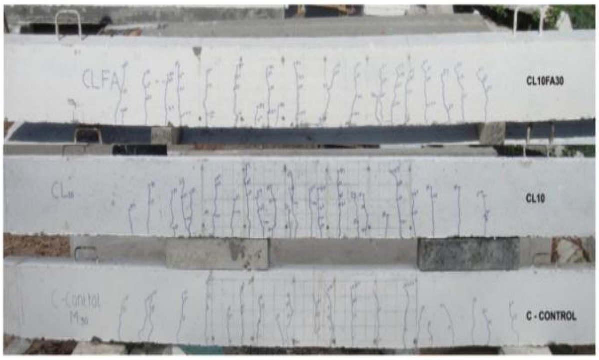

Figure 6. Typical tested specimens

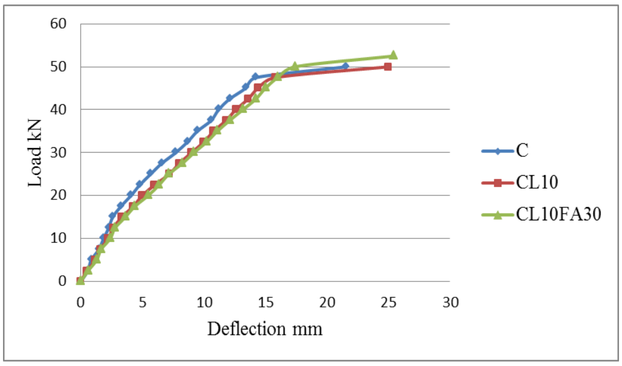

Figure 7. Load Deflection Curve

Table 7. Details of load and deflection of beams

Sl. No	Beam Designation	First crack load kN	First crack deflection mm	Yield load kN	Yield deflection mm	Ultimate load kN	Ultimate deflection mm
1	C	10	1.85	37.5	10.6	50.0	21.5
2	CL10	12.5	2.65	37.5	11.8	50.0	25.0
3	CL10FA30	15.0	3.62	39.375	13.0	52.5	25.4

Table 8. Details of moment and curvature of beams

Sl.No	Beam Designation	First crack moment kNm	Curvature at first crack load Φ_{fcr} rad/mm	Yield moment kNm	Curvature at yield load Φ_y rad/mm	Ultimate moment kNm	Curvature at ultimate load Φ_u rad/mm
1	C	5.00	1.62	18.75	9.42	25	19.39
2	CL10	6.25	1.076	18.75	10.64	25	25.81
3	CL10FA30	7.50	0.98	19.69	10.70	26.25	29.07

Table 9 Energy Absorption capacity and Ductility

S.No	Beam Index	Absolute Energy absorption capacity kNmm	Relative Energy Absorption Capacity	Ductility Index Φ_u/Φ_y
1	C-control	700	1	2.05
2	CL10	824	1.17	2.42
3	CL10FA30	846	1.20	2.71

Table 10. Load Vs Crack width

S.No	C		CL10		CL10FA30	
	Load kN	Crack width (mm)	Load kN	Crack width (mm)	Load kN	Crack width (mm)
1	0	0.00	0	0.00	0	0.00
2	10	0.08	12.5	0.06	15	0.06
3	20	0.16	20	0.11	20	0.10
4	30	0.24	30	0.22	30	0.19
5	40	0.36	40	0.32	40	0.30
6	50	0.52	50	0.45	50	0.42
7	-	-	-	-	52.5	0.56

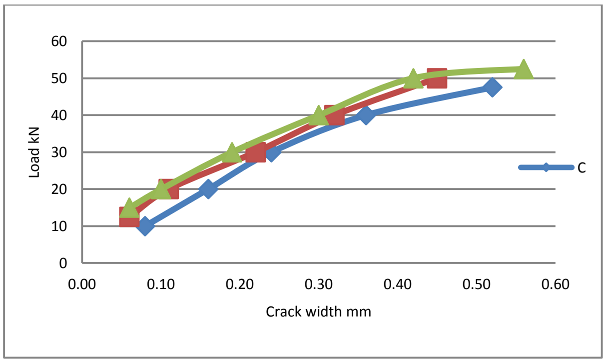

Figure 9. Load Vs Crack width

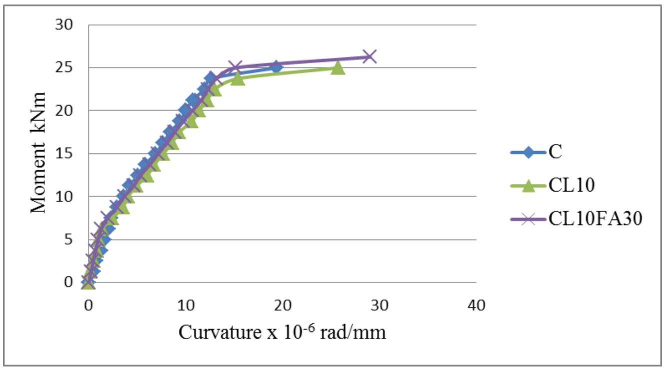

Figure 8. Moment Curvature Curve

RESULT AND DISCUSSION:

Slump test: Slump test were performed on both control and latex modified concretes. However percentage of water content is adjusted (decreased), from the results it was observed that, the addition of SBR increases slump. This shows that SBR latex has plasticizing effect due to which workability of concrete increased and maintained between 50mm to 75 mm.

Compressive Strength

The compressive strength of control concrete, latex modified concrete and latex modified concrete with fly ash containing different percentage of SBR were presented. It was observed that the latex modified concrete specimen showed 28 day average compressive strength of the order 35.28 N/mm^2, 33 N/mm2, 29.81 N/mm^2 at the latex content of 5%, 10%, and 15% respectively. Latex modified concrete with fly ash showed average compressive strength of order 37.18 N/mm^2, 34.98 N/mm2, 32.37 N/mm^2 at latex content of 5%, 10%, and 15% respectively, while the control concrete specimens had average compressive strength of 38.65 N/mm^2. It could be observed from results that the compressive strength of concrete generally followed a decreasing trend with the increase of the latex dosage. The compressive strength at 28 days decreased 8.72%, 14.61%, 22.87% at the latex content of 5%, 10%, and 15% respectively. The compressive strength of latex modified concrete with fly ash decreased 3.83%, 9.46%, 16.25% at the latex content of 5%, 10%, and 15% respectively at 28 days. A Similar reduction trend was observed in compressive strength at 56 days and 90 days cured specimens. At 56 days 9%, 15%, 22.64%, 2.64%, 7.57% and 13.76% compressive strength reduction were observed at the latex content of 5%, 10%, and 15% of latex for LMC and LMC with fly ash respectively with respect to 56 days control specimens. The compressive strength reductions at 90 days were 8.4%, 12.80, 20.77%, 1%, 5.42% and 11.53% for LMC and LMC with fly ash respectively with respect to the 90days control specimens. The reduction in compressive strength of latex modified concrete is due to the presence of rubber content as soft inclusion in the cement gel particles and increase in air content of latex modified concrete. Latex modified concrete with fly ash improved the compressive strength of concrete compared to latex modified concrete. Physical interaction occurred due to the fly ash, particles fill the existing spaces between the various granules of cement and those between the cement paste and the sand, which act as a filler reducing porosity cement matrix a densified structure and hence improvement in compressive strength. The decrease in compressive strength due to latex addition can at least be compensated by 4.89%, 5.16%, and 6.62 % by the addition of fly ash in latex modified concrete with latex content of 5%, 10%, and 15% respectively at 28 days.

Flexural Strength

Addition of 5%, 10% and15% latex in latex modified concrete increases the flexural strength to 7.33%, 13.33% and 21.3% respectively at the age of 28 days. The Latex modified concrete with fly ash showed an improvement of 15.55% ,21.55%, and 27.33% at the latex content of 5%,10% and 15% respectively at the age of 28 days. At 56 days 7.7%, 11.67%, 22.08%, 15.83%, 22.92% and 29.80 % flexural strength improvement were observed at the latex content of 5%, 10%, and 15% of latex for LMC and LMC with fly ash respectively. The flexural strength developments at 90 days were 9.2%, 15.25, 25%, 22%, 29.60% and 37% for LMC and LMC with fly ash respectively. A Significant flexural strength change was observed that mainly due to improvement in cement hydrate and aggregate bond because of decrease in w/B ratio and the high tensile strength of latex films present in latex modified concretes. Flexural strength depends mainly on the adhesion of aggregate grains and cement matrix. For latex modified concrete, creation of polymer membrane has a double role, that is increase the adhesion between the aggregate grains and cement matrix; and prevent progressive development of initial micro cracks due to its elasticity.

Elasticity modulus

Stress strain characteristics of latex modified cylindrical specimens in compression obtained from load controlled tests compared to the control mix. It was observed that the stress strain plot of latex modified concretes were more deformability and similar trend to that of control specimens. The latex modified concrete and LMC with fly ash showed lower moduli compared to control concrete. Consequently latex modified concretes provided a lower elasticity than unmodified (control) concrete. Compared with control concrete the LMC and LMC with fly ash showed 20%, 25% reduction in elastic modulus with 10% latex content at the age of 28 days. The deformability and elastic modulus of the latex modified concrete tend to increase and decrease, with the addition of latex.

Flexure Behaviour of Beam

The load deflection behaviour and moment curvature of test beams were investigated during the experiment.

In the pre-cracking stage, the rate of deflection increase is small and increase linearly. This is expected since the strains in the steel and concrete are relatively small.

In the case of concrete specimens without latex, crack appeared as the loading reached the first crack load of the specimen. Further increase of load resulted in the formation of additional cracks and widening of earlier cracks. Loading the beam until the ultimate stage, most of the cracks propagated towards top of the beam.

In the case of specimens with latex and (latex and fly ash), a large number of cracks developed. Latex modified concrete beams and latex modified with fly ash specimen showed similar behaviour. Addition of latex improved the first crack load. At ultimate load the deflection was found to be higher.

Referring to the experimental results following observations may be noted.

Addition of 10% latex increases the first crack load by about 25% and 50% for latex modified concrete and latex modified concrete with fly ash respectively.

Specimens with latex alone showed no significant improvement in ultimate load where as specimens with fly ash showed 5% improvement in ultimate load.

In latex modified concrete specimens, addition latex fills the voids present in concrete and improves the bond strength of the concrete. Hence an improvement in the first crack load and ultimate load was noticed.

Referring to load deflection and moment curvature curve, all curves are linear up to the first crack and then they become non-linear due to the formation of multiple cracks and propagate further upto ultimate load.

The energy absorption capacity as indicated by the area under the load deflection plot is 17% higher for the latex modified concrete beams and 21% higher for latex modified concrete beams with fly ash.

Addition of latex controls the widening of cracks due to the presence of latex film. Crack widths reduction was 25% at first crack load of 10kN and 13.46% at 50 kN load.

CONCLUSIONS

Latex modified concrete and latex modified concrete with fly ash was developed focusing on the workability and strength development. This study showed the effect of latex modification in mechanical property of latex modified concrete. The main variables were latex content 5% to 15% and Fly ash content of 30%. The conclusions are as follows.

(i) Latex addition allows w/c ratio to fall by 0.05 to 0.15 without affecting the workability in all cases studied. It is expected that such fall in w/c ratio should increase strength more appreciably in the lower w/c ratio than higher w/c ratio. But it is observed that concrete in the lower w/c ratio has reducing effect of latex addition on compressive strength that the corresponding reduction in w/c ratio cannot compensate this effect.

(ii) The reducing effect of latex addition on compressive strength of latex modified concrete could be attributed to incorporation of soft rubbery material in the matrix. Maximum reduction of compressive strength (22.87%, 16.24%) at 28 days was observed at 15% latex addition in LMC and LMC with fly ash respectively. The strength reduction is found to decrease with fly ash content and hence fly ash can be used for partially compensating the strength reduction due to latex addition.

(iii) Flexural strength increased with the increase of polymer binder ratio. Maximum increase of flexural strength was 21% and 27% at 15% latex addition for LMC and LMC with fly ash respectively at the age of 28 days. Flexural strength increased with the increase of polymer binder ratio.

(iv) Elastic modulus decreased over unmodified concrete tendency is in agreement with increased deformability of latex modified concrete over unmodified concrete. The elastic modulus reduces by 20% to 25% for LMC beams and LMC beams with fly ash.

(v) Addition Latex improved the first crack load by 25% for LMC beams and 50% for latex modified concrete beams with fly ash.

(vi) However load carrying capacity is only marginally improved. The addition of latex in concrete flexural members improves the cracking behaviour significantly

(vii) The addition of latex improved the Energy absorption capacity by 17% for LMC beam and 21% for LMC beam with fly ash.

(viii) The addition of latex improved the ductility factor significantly by 18% for latex modified concrete beams, 32% for LMC beams with fly ash.

REFERENCES

[1] ACI committee 548 Guide for the use of polymer in concrete. ACI material journal, Vol83, no. 5, 1986 pp. 813 – 819.

[2] Alessandra .E.F, de s. Almeida (2007), "*Experimental study on polymer –modified mortars with silica fume applied to porcelain tile*", Building and Environment 42, 2007 pp.2645- 2650.

[3] Alessandra. E.F, de s. Almeida (2007), "*Mineralogical study of polymer modified mortar withsilica fume",*Construction and Building Materials 20,2006 pp.882-887.

[4] Barluenga. G, Hernandez-Olivars. F,(2004) "*SBR latex modified mortar rheology and mechanical behaviour",* Cement and Concrete Composites, Vol. 34, 2004, pp. 527 – 535

[5] Bureau of Indian Standards IS 10262:2009, "Recommended Guideline for Concrete Mix Design".

[6] Bureau of Indian Standards IS 456:2000, "Code of Practice for Plain and Reinforced Concrete".

[7] Bureau of Indian Standards, IS 2386:1963, "Part – 3 Method of Test for Aggregates for Concrete – Specific Gravity, Density, Voids Absorption and Bulking".

[8] Bureau of Indian Standards, IS: 516 – 1959, "Methods of test for strength of concrete".

[9] Byan. S, Abdulkadar (2009), "*Flexural behaviour of polymer modified Reinforced concrete beams"*, Journal of engineering and Development, vol. 13, No 1 pp.89 -110.

[10] Charaborty A.K., Dutla SC., Ray I., (2000), "*Variation in effect of Acrylic latex* with *change in water cement ratio of Silica Fume modified*

Superplasticised Concrete Mortar", Journal of Institute of Engineers,Vol 80,February 2000,pp. 186-190.

[11] Charaborty A.K., SC. Dutla, Dr.I.Ray, Member (1995), "*Effect of latex and superplasticiser on Portland cement mortar in the Hardened state"*, cement & concrete composites, 17,1995 pp. 9 –21.

[12] Fowler, D.W., (1999), "*Polymers in Concrete: A vision for the 21st Century*", Cement and Concrete Composites, Vol. 21, 1999, pp. 449 – 452.

[13] Ganesan.N and Sreekala (1999), "Fracture characteristics of latex modified SFRC", Journal of structural engineering vol.26 No.1 pp.49.-54.

[14] Ganesan.N, Shivananda K.P. (2000) "*Strength and ductility of latex modified steel fibre reinforced concrete flexural members*", Journal of structural engineering vol.27 No.2pp.111-116

[15] Gao J.M., Qian C.X. (2002), "*Experimental study on properties of polymer-modified cement mortars with silica fume"*,Cement and Concrete Composites, Vol. 32, 2002, pp. 41-45

[16] James R., Lundy (1998), "*Study on the development of strength and fracture properties of styrene – butadiene copolymer latex modified concrete"*, ACI Material Journal Vol.95, No.2, pp.131 - 143.

[17] Joao A., Rossignolo, (2002), "*Mechanical Properties of Polymer – modifiedlightweightaggregate concrete",* Cement and Concrete Research 32, 2002, pp.329 – 334

[18] Joao Adriano Rossignolo, (2009), "*Interfacial interactions in concrete with silica fume and SBR latex",* Construction and building Materials 23, 2009, pp.817-821.

[19] Neelamegam. M, Kdattatreya. J (2000), "*Development of durable cement concrete using natural latex",* The Indian Concrete journal 2000, pp.472-479.

[20] Okba SH, Dieb and Reda M.M., (1997), "Evaluation of the corrosion resistance of latex modified concrete (LMC), cement and concrete research," vol. 27 No. 6, pp. 861 – 868.

[21] Radomir, J, Folic, (1998), "Experimental Research on Polymer Modified Concrete", ACI Material Journal, Vol. 95 (4), 463 - 467.

[22] Ray, I., Gupta. (1995), "Effect of Latex and Superplasticizer on Portland Cement Mortar in the Hardened State", Cement and Concrete Composties, Vol. 17, 9 – 21.

[23] RuWang, Xing-GuiLi, Pei-Ming Wang(2006)," *Influence of polymer on cement hydration in SBR-modified cement pastes"*, Cement and Concrete Research 36,2006 pp.1744-1751.

[24] ShaikhFaizuddin and Yoshihiko Ohama (2000), "*Properties of polymer modified mortar with silica fume", The Indian Concrete journal* 2000, pp.467-470.

[25] Sreekala.R, Muthumani.K (2009), "*Natural rubber latex modified fibre concrete-Initial studies for structural performance"*, The Indian concrete journal October 2009 pp.29 -35

[26] Yoshihiko Ohoma, (1998), *"Polymer Based Admixtures*", Cement and Concrete Composites, Vol. – 20 (1998) 189 – 212.