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EFFECT OF POLYMER ON THE MICROTRUCTUR OF CONCRETE

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Abstract:

This study is investigation carried on the use of polymers in concrete. The main objectives of the study is to study the mechanical properties of polymer concrete using Styrene –Butadiene latex modified concrete (LMC) to those of conventional concrete. Also, the main microstructural characteristics of LMC were studied using a Scanning Electron Microscope (SEM).The SEM investigation of the LMC showed major differences in its microstructure compared to that of the conventional concrete.

Key Words: Latex Modified Concrete, SBR Latex Silica Fume, Compressive Strength, Flexural Strength, Elastic Modulus, Micro Structure & SEM

Introduction:

The microstructure of the concrete is very important to concrete, because it is governs the mechanical properties of the concrete and durability of concrete. The use of polymer as a modifier in concrete in improving microstructure and enhance the durability concrete. As one of the popular polymer suitable for admixing into fresh mortar and concrete, styrene-butadiene rubber (SBR) latex has been widely used for a long time.

The addition of latex allows improving the some unwanted behaviour of hardened concrete brittleness and low flexural strength. Additionally, cohesion and adhesion of the fresh and hardened concrete are significantly enhanced. These effects are owed to the formation of polymer film which results from the coalescence of latex particles when water is consumed by cement hydration and evaporation.

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.

This study reports part of the experimental investigations on using mineral admixtures silica fume along with the polymer (SBR) latex in concrete as a partial replacement of cement.

Experimental Investigation:

In the experimental study, generally a good quality cement of grade 43 is preferred but it may vary according to the grade of performance needed. Natural River sand of specific gravity 2.61 and conforming to zone III of IS 383:1970 was used for the present study. The shape and particle size distribution of the aggregate is very important as it affects the packing and voids content. The moisture content, water absorption, grading and variations in fines content of all aggregate should be closely and continuously monitored and must be taken into account in order to produce concrete of constant quality. Coarse aggregate used in this study had a maximum size of 20mm confirming to IS 383:1970 specifications. Specific gravity of coarse aggregate used was 2.70. Ordinary potable water was used. The pH value is not less than 8.0.

The experimental programme was planned to study the following properties:

Cement:

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

Silica Fume (SF):

Mineral admixture obtained from ELKEM INDIA (P) Ltd, confirming to ASTM-1240.Specific gravity 2.2

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

Coarse Aggregate:

Crushed stone with a nominal maximum size of 20mm as per IS: 383:1970 with fineness modulus 6.86 and specific gravity 2.70.

Polymer Latex:

Styrene Butadiene Rubber 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
- ✓ Silica fume - 8 % 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 mix 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. Silica fume (SF) of 8% 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. Concrete mixtures of three were designed with latex modification and three mixtures of latex and silica fume (CL5SF8, CL10F8, and CL15SF8).

Table 2: Mix Proportions

S.No	Mix Details		Cement kg/m^3	SF kg/m^3	FA kg/m^3	CA kg/m^3	W/B ratio	P/B ratio	% of water adjusted	Slump in mm
1	C	Control	425.73	0.00	672.09	1122.42	0.45	0.00	0.00	50
2	CL5	5% Latex	425.73	0.00	671.27	1121.05	0.40	0.05	5	55
3	CL10	10%Latex	425.73	0.00	670.43	1119.66	0.35	0.10	10	65
4	CL15	15%Latex	425.73	0.00	672.37	1124.31	0.30	0.15	15	75
5	CL5SF8	5%Latex+8%SF	391.63	34.10	657.55	1106.10	0.42	0.05	0.00	53
6	CL10SF8	10%Latex+8%SF	391.63	34.10	647.07	1088.49	0.40	0.10	0.00	55
7	CL15SF8	15%Latex+8%SF	391.63	34.10	646.04	1087.07	0.35	0.15	5	55

W/B-Water Binder ratio, P/B-Polymer Binder ratio

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 elasticity of the concrete (150mm dia x300mm height cylinder)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.

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 is presented in Figure 1.

Table 3: Results of Compressive Strength

S.No	Mix Details	Average Compressive Strength N/mm^2			
		7 Days	28 Days	56 Days	90 Days
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	CL5SF8	29.32	36.74	39.38	42.38
6	CL10SF8	27.92	34.65	37.69	40.64
7	CL15SF8	26.39	32.00	35.64	37.86

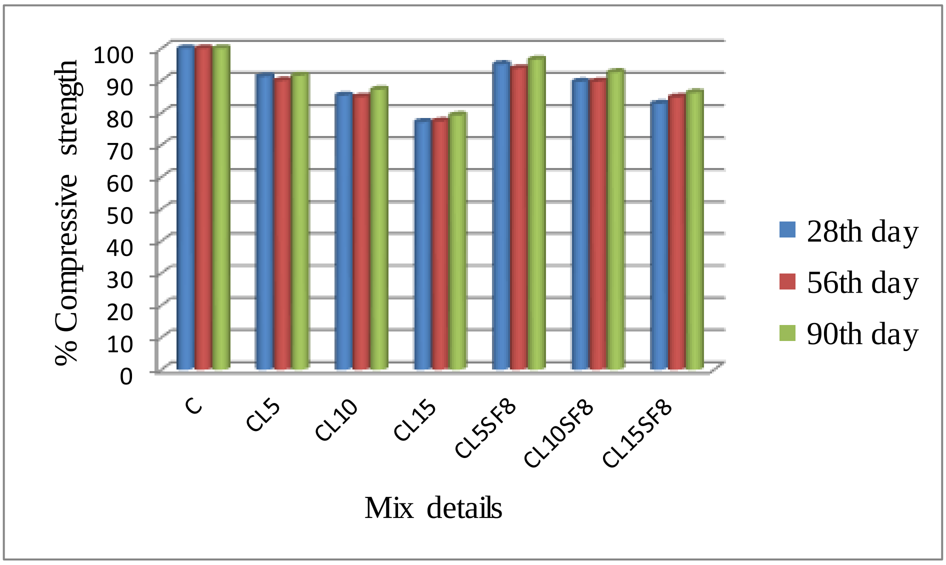

Figure 1: Compressive Strength Development

Flexural Strength:

Concrete specimens of size 100mmx100mmx500mm were tested under standard four points bending in flexural testing machine. The test set up of specimen for flexural strength of concrete is shown in Figure 2. 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 showed in Figure 2.

Table 4: Results of Flexural Strength

S.No	Mix Details	Flexural Strength N/mm^2			
		7 Days	28 Days	56 Days	90 Days
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	4.58	5.46	5.86	6.25
5	CL5SF8	4.04	4.95	5.36	5.65
6	CL10SF8	4.38	5.45	5.94	6.37
7	CL15SF8	4.93	5.67	6.30	6.70

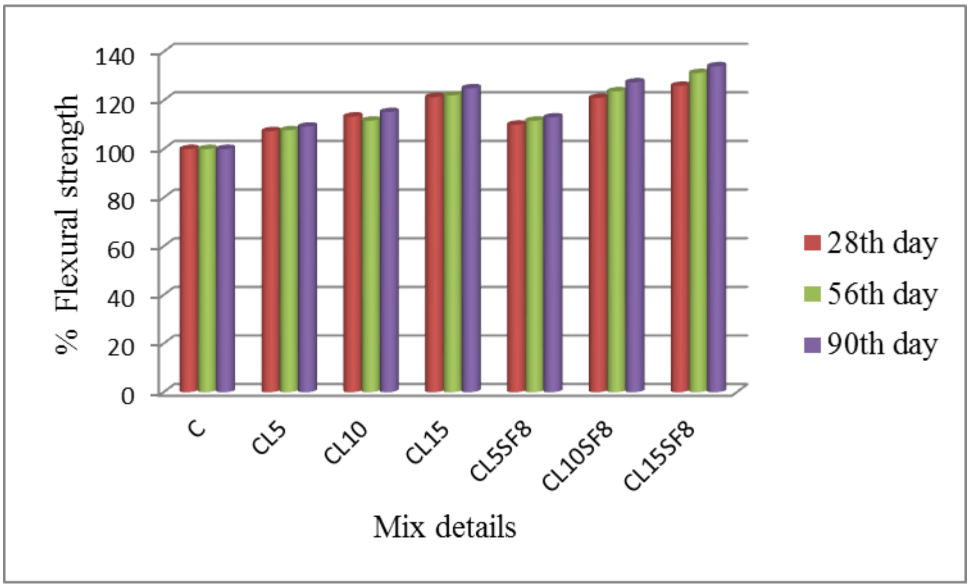

Figure 2: Flexural Strength Development

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.The test set up of modulus of elasticity for concrete is shown in Figure 4.Concrete mixes with 10% latex content provided the average strength development for both compression and flexural strength. Hence Elastic modulus test was conducted for selected mix (CL10, CL10SF8) with 10% latex content. Specimens were loaded uniaxial in a compression testing machine. 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 are shown in fig.3. The elastic moduli of the selected concrete mixes are shown in Table 5.

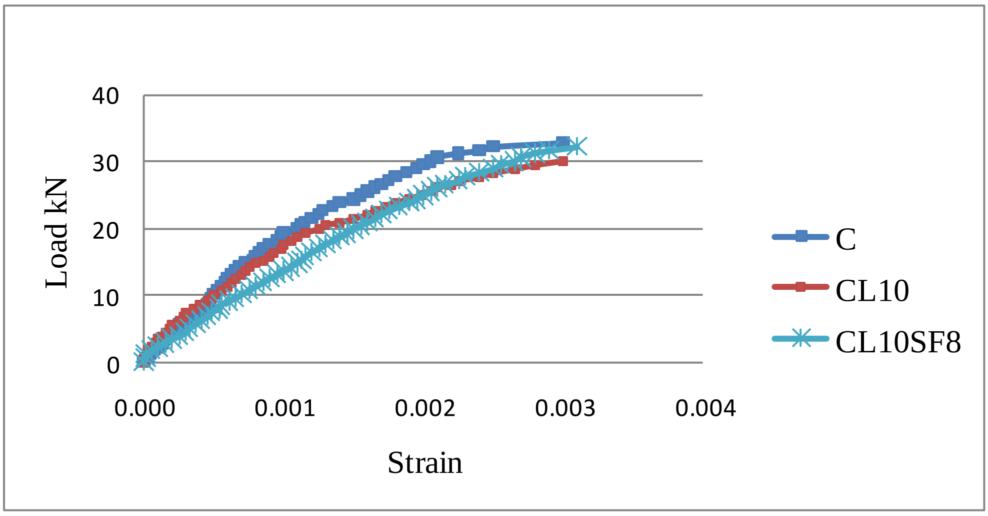

Figure 3: Stress Strain Curve

Table 5: Elastic Modulus at 28 days

S.No	Mix	Elastic Modulus N/mm^2
1	C	33333
2	CL10	26666
3	CL10SF8	22857

Scanning Electron Microscopy (SEM) Test:

The specimens used for the SEM were 28 days of age. The conventional concrete, LMC and Latex modified concrete with silica fume were oven dried at 105 degree Celsius for 24 hours, then they were cooled at room temperature in an air tight container. The specimens used for the investigation were obtained from the fracture surface of the concrete just before placing the specimen into the microscope**.** Figure 5-8 show the SEM images of concrete surfaces were taken at the magnification of approximately 1500 times.

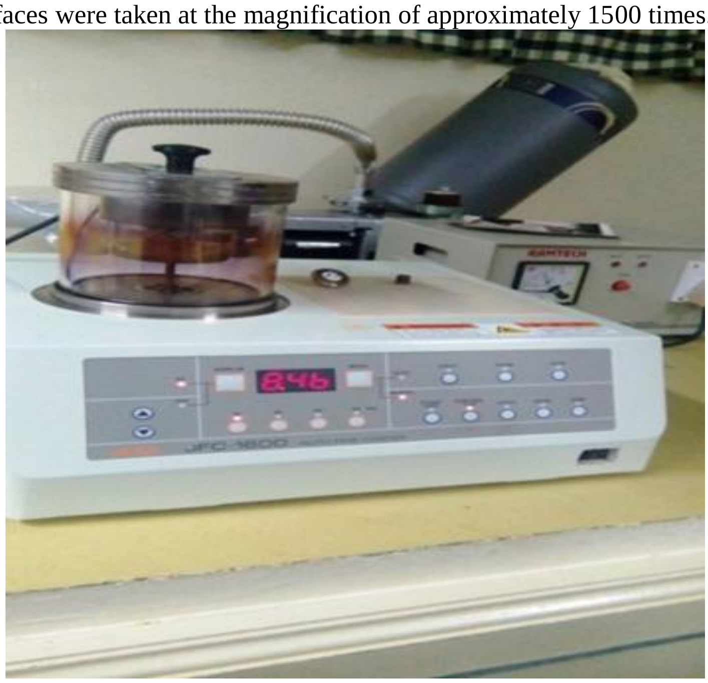

Figure 4: SEM Coating Machine

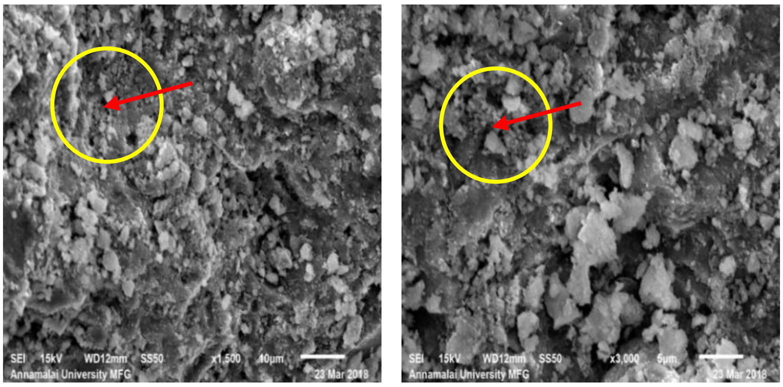

Figure 5: SEM-Test for Control (M30)

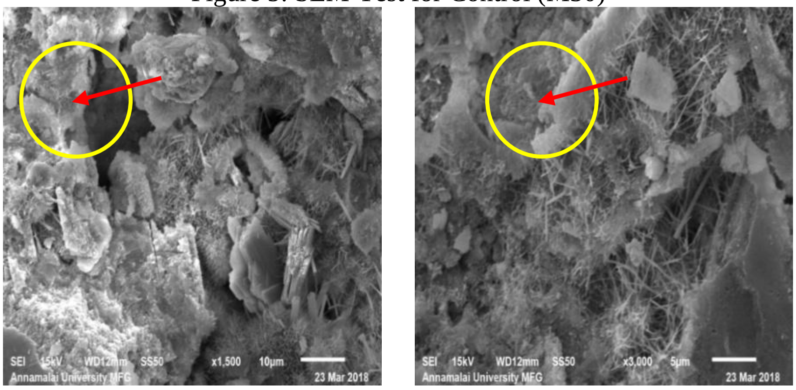

Figure 6: Control Latex

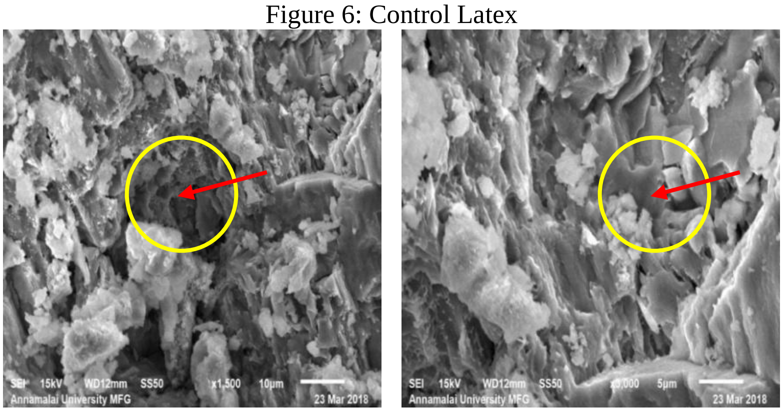

Figure 7: Control + Silica Fume

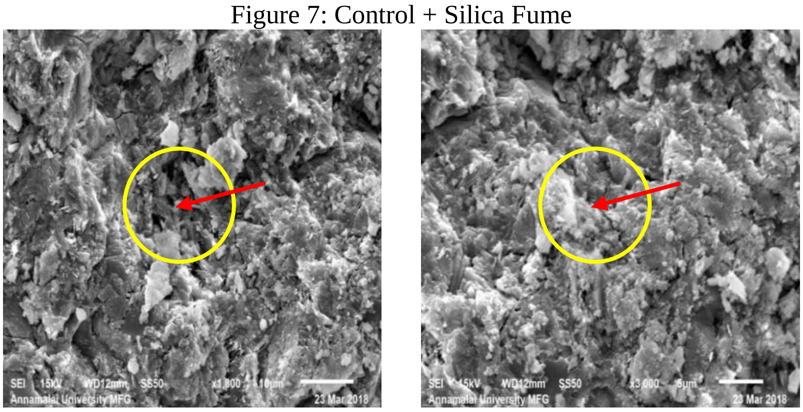

Figure 8: Control +Silica Fume+ Latex

Result and Discussion:

Slump Test: Slump test were performed on both control and latex modified concretes. However percentage of water content was adjusted (decreased), from the results it was observed that the addition of SBR improves workability (slump) of concrete. This shows that SBR latex particle has ball bearing action and 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 silica fume 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 silica fume showed average compressive strength of order 36.74 N/mm^2, 34.65 N/mm2, 32 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 silica fume decreased 4.94%, 10.35%, 17% 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%, 6.23%, 10.26% and 15.14% compressive strength reduction were observed at the latex content of 5%, 10%, and 15% of latex for LMC and LMC with silica fume respectively with respect to 56 days control specimens. The compressive strength reductions at 90 days were 8.4%, 12.80, 20.77%, 3.46%, 7.42% and 13.75% for LMC and LMC with silica fume 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 silica fume improved the compressive strength of concrete compared to latex modified concrete. Physical interaction occurred due to the fineness of silica, its large specific surface and that its 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 3.78%, 4.28%, and 5.87 % by the addition of silica fume 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 silica fume showed an improvement of 10% ,21%, and 26% 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%, 11.66%, 23.75% and 31.25% flexural strength improvement were observed at the latex content of 5%, 10%, and 15% of latex for LMC and LMC with silica fume respectively. The flexural strength developments at 90 days were 9.2%, 15.25, 25%, 13%, 27.40% and 34% for LMC and LMC with silica fume 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.

Elastic 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 silica fume 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 silica fume showed 20%, 31% 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.

Scanning Electron Microscopy (SEM) Test:

The Latex modified concrete is characterized by a dense microstructure compared to that of conventional concrete. The polymer latex was observed to form a polymer film which is well dispersed throughout the cement matrix forming a dense network which is interwoven with the cement matrix as shown in Figure. Also great reduction was observed in the size of the crystals formed throughout the polymer cement matrix, such as calcium hydroxide crystals, indicating a denser microstructure than that of the conventional concrete. The structure is relatively homogeneous with fewer pores in the mix with silica fume and latex than that with conventional concrete. The reason is the pozzolanic reaction between the cementitious phase of silica fume and latex. Indicating that silica fume aids in pore refinement when its reaction is almost completed. Most of the pores were found to be filled with the polymer latex and silica fume. The micro cracks observed in the LMC were found to be bridged with the polymer film and also exhibited a smaller width compared to those of micro cracks found in the conventional concrete. The polymer film seems to form a connecting phase between the aggregate and the cement matrix and develops the bond between the aggregate and the polymer-cement co-matrix. This can be noticed in noticed in the increase in the tensile strength of the Latex modified concrete over

Conclusions:

Latex modified concrete and latex modified concrete with silica fume was developed focusing on the workability and strength development. This study showed the effect of latex modification on the mechanical property of latex modified concrete. The main variables were latex content 5% to 15% and silica fume content of 8%. The conclusions were as follows.

- ✓ Latex addition allows w/c ratio to fall by 0.05 to 0.15 without affecting the workability in all cases studied. It was 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 was 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.
- ✓ The reducing effect of latex addition on compressive strength of latex modified concrete could be attributed to incorporation of soft rubbery, low elastic material in the matrix. Maximum reduction of compressive strength (22.87%, 17%) at 28 days was observed at 15% latex addition in LMC and LMC with silica fume respectively. The compressive strength reduction were 8.4%, 12.8%, 20.77%, 3.46%, 7.42% and 13.75% for 90 days cured LMC and LMC with silica fume specimens respectively with respect to the control specimens. The strength reduction was found to decrease with the addition of silica fume content and hence silica fume can be used for partially compensating the compressive strength reduction due to addition of latex.
- ✓ Flexural strength increased with the increase of polymer binder ratio. Maximum increase of flexural strength was 21% and 26% at 15% latex addition for LMC and LMC with silica fume respectively for 28 days cured specimens. The flexural strength improvement were 9.2%,15.2%,25%,13%,27.4%, and 34% for 90 days cured LMC and LMC with silica fume specimens with respect to the control specimens. The latex content has the potential of improving the flexural strength of latex modified concrete and latex modified concrete with silica fume. Addition of latex binds the cement hydrates together to form a monolithic network in which the latex interpenetrates throughout the hydrate phase and bridges crack propagation and enhances the flexural strength of latex modified concretes.
- ✓ The elastic modulus reduced by 20 to 30 percent for LMC and LMC with silica fume compared with control concrete at 28 days. The decreasing tendency of elastic modulus was due to increased strain and deformability of latex modified concrete over unmodified concrete. The deformability and elastic modulus of the latex modified concrete tend to increase and decrease, with the addition of latex
- ✓ The micro structural analysis either due to compositional variation (Cement, SF, Latex) significantly increase the flexural strength compare to conventional concrete.
- ✓ The polymer concrete was found to have a dense microstructure, smaller discontinuous pores, less porous transition zone, better bond between the aggregate and the cement matrix, and bridged micro cracks with respect to the conventional concrete.

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