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# A COMPARATIVE STUDY OF MODIFIED CONCRETES

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# A COMPARATIVE STUDY OF MODIFIED CONCRETES

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A study is presented on the behaviour of modified concretes in comparison to normal concrete having similar mix proportions, aggregates, net water cement ratios and same curing cycles with a view to know their performance as a structural concrete. The polymer, which has been used for the modification purposes, was SBR (Styrene Butadiene Rubber) latex with polymer dispersions of 10% and 20%. The specimens cast for various tests were 4"x4"x4" cubes and 4"x4"x20" prisms for both modified concrete and companion normal concrete. It is known that the properties of this type of hardened modified concrete depend to a large extent on the type of curing cycle used. Therefore three different curing cycles have been used for the measurement of parameters mentioned. The curing cycles used in the study were largely based on ACI requirements for latex modified concretes and those recommended by Prof. Ohama of Japan and Prof. Fowler of USA, the authority research workers on polymer concretes. Temperature and relative humidity had also been monitored during the investigation. The parameters studied include compressive strength, indirect tensile strengths, workability and water absorption, a parameter which enjoys greater importance when viewed from durability point of view. This study was aimed at assessing the possibilities of using this type of concrete modifiers in structural concretes although these modifiers are famous for some other properties like greater bond strength specially between older concrete and fresh concrete surfaces, for minimizing the pore sizes, improving surface finish of concrete, for improving freeze –thaw resistance and surface texture etc. The results of study are indicative of reduced compressive strength with increased polymer dispersions in modified concretes, higher workability, lower indirect tensile strengths and minimized water absorption in comparison to normal concrete companion specimens cast, cured and tested under similar conditions. However the reduction in compressive strength of modified concrete can be offset by imaginative use of lower water – cement ratios.

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## BRIEF HISTORY AND INTRODUCTION

The first patent of the present day polymer latex modified system appears to be generated by Lefebure in 1924 who used natural rubber latex by mix proportioning method. Latex modified concrete (LMC) is defined as portland cement and aggregate combined at the time of mixing with organic polymers that are dispersed in water. This dispersion is called a Latex. The organic polymer is substance composed of thousands of simple molecules known as monomers and the reaction that combines the monomers is called as polymerization. The latexes currently used with hydraulic cements are produced by a process known as emulsion polymerization. The basic process involves mixing the monomer with water, a surfactant and an initiator. The initiator generates a free radical that causes the monomers to polymerize by chain additions [1].

Ohama, 1973 [2] has studied extensively the properties and proportioning of polymer modified mortars. The same author [3] deals with the systems in both mortars and concretes.

Latex modification usually consists of two processes namely cement hydration and Latex coalescence. It is believed that cement hydration occurs first and as the cement particles hydrate and the mixture sets and hardens the latex particles become concentrated in void spaces. With continuous water removal by cement hydration, evaporation or both, the latex particles coalesce into a polymer which is interwoven in the hydrated cement and is present in the interstitial voids. Because of the fact that latex particles are greater than 100 nm diameter, they are not able to penetrate small capillaries, present in the cement paste, which roughly have a size of 1 nm. Therefore, it is the larger capillaries and voids wherein latex can be most effectively accommodated after polymerization. In the initial stages the latex modified mortars and concretes are more sensitive to plastic shrinkage and cracking than unmodified mortar or concrete [4].

The latexes are normally used to improve workability, surface texture, freeze - thaw resistance, bonding of old concrete with new concrete and reduced permeability or water absorption etc [5,6,7].

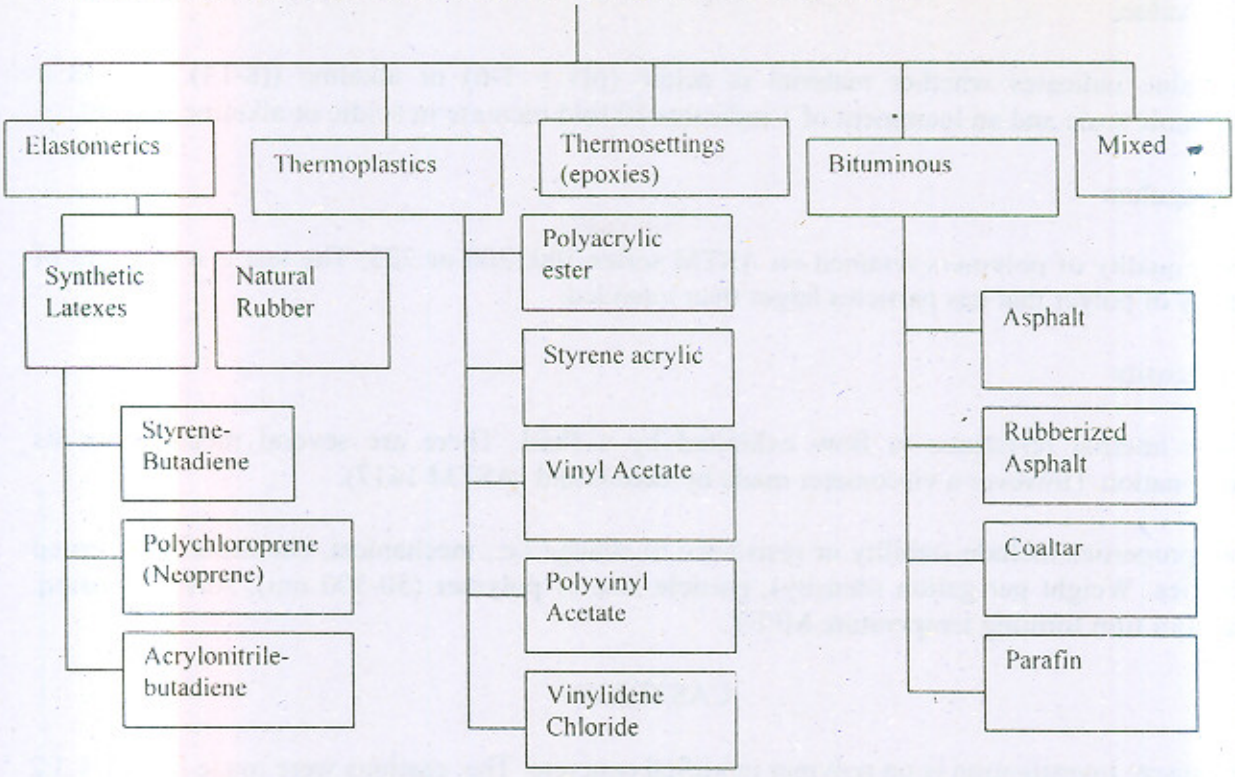
Styrene-Butadiene latexes have been used in a variety of applications with portland cement mixtures ranging from concrete bridge deck overlays to thin mortar coatings on swimming pools. They have also been used as overlays for parking garage decks and for repair works etc. [8,9,10,11].

In addition, polymer dispersions are added to mortars and concretes to improve certain desired properties of the final product including improved bond strength to concrete substrates, increased flexibility (ductility), impact resistance, improved resistance to penetration by water, dissolved salts and improved resistance to frost action. [12].

## LATEXES USED FOR MODIFICATION

The following latexes are used for the modification of mortars and concretes.

Polymer latexes used for modification of hydraulic cement systems




Most of the latexes used with portland cement are stabilized with nonionic (no charge) surfactants for requisite stability. Higher Styrene-Butadiene ratios give higher compressive strengths in case of Styrene-Butadiene co-polymer latexes. Surfactants are also called as stabilizers, soaps, and protective colloids are chemicals whose particles attach themselves to the surface and latex particles. Some substances known as compounding ingredients are added after the completion of polymerization to improve properties of product. These properties include resistance to chemical or physical attacks. These compounding ingredients maybe bactericides, anti-oxidants, anti foaming agents and ultraviolet particles. Surfactants can also improve workability, provide stability to freezing and thawing and reduce water-cement ratios.

## IMPORTANT PROPERTIES OF LATEXES

The following polymeric properties are usually tested to ensure quality control.

1. Total solids or nonvolatile content

This is the polymer content of a latex along with any ingredient of latex which is non-volatile at test temperature. This is simple to determine by weighing a representative sample of latex, drying it under specific conditions at 70°C for 16 hours or 125°C for 0.5 hours and weighing the residue and expressing as a %age of original weight (Total solid content).

2. pH value.

This value indicates whether material is acidic (pH = 1-6) or alkaline ((8-14). This is a logarithmic scale and an increment of 1 indicates 10 fold increase in acidic or alkaline content.

3. Coagulum

This is quality of polymers retained on ASTM series 100, 200 or 325. The test is a measure of quantity of polyer that has particles larger than intended.

4. Viscosity

This is internal resistance to flow exhibited by a fluid. There are several methods for its determination. However a viscometer made by Brookfield (ASTM 1417).

Other properties include stability or resistance to change i.e., mechanical, chemical and thermal stabilities. Weight per gallon (density), particle size of polymer (50-500 nm), surface tension, minimum film forming temperature MFFT.

## CASTINGS

The present investigation is on polymer modified concrete. The castings were made from 1:1.3:2 concrete mix having net w/c ratio of 0.38. The sand was Hero sand with fineness modulus of 2.6 on BS sieve 100 and Margallah crush stone having fineness modulus of 6.6 on the same sieve.

Polymer cement doses included 10% and 20% of the weight of SBR coplymer latex. The composition of copolymer latex is as follows:

| | |
|---|---|
| pH value | = 10.5 |
| Specific gravity | = 1.01 |
| Mean particle size | = 0.17 nm |
| Butadiene content | = 40% by weight of polymer |
| Styrene/butadiene ratio | = 6/4 =1.5 |
| Total solids | = 47% |

## CURING CYCLES

Three curing cycles were used

### 1ST CURING CYCLE

1) After casting specimens are to be demoulded after 24 hours.
2) After demoulding specimens are to be put in a curing room at 80% relative humidity for 3 days.
3) After that, specimens are to be put in water at 20°C for 5 days.
4) After that, there are air cured and tested at specified ages.

## 2ND CURING CYCLE.

1) After casting specimens are to be demoulded after 24 hours.
2) After demoulding specimens are to be put in curing room at 100% relative humidity for 24-48 hours.
3) After that, specimens are to be put in 50% relative humidity at room temperature for the rest of the time for air curing till they are tested at specified ages.

## 3RD CURING CYCLE

1) After casting, specimens are to be immediately put in a curing room at 100% relative humidity for 24-48 hours.
2) Demoulding is to be carried out in curing room.
3) After that, specimens are to be put in 50% relative humidity at room temperature for air curing till the time the specimens are tested at specified ages.

## CASTING SPECIMENS SIZES

The specimens were cast at room temperature of 34°C and relative humidity of 55%. The specimens consisted of 4" x 4" x 4" cubes for compression testing and 4" x 4" x 20" beams for modulus of rupture test. The coarse aggregate (specific gravity being 2.63) passing BS sieve number ¾" and retained on 3/8" were taken 80% of the total weight of coarse aggregate and the remaining 20% consisted of coarse aggregate passing 3/8" and retained on 3/16".

Mix proportions for concrete were 1:1.3:2 with net w/c ratio of 0.38. The sand portion consisted of 70% by weight of Haro sand (with a fineness modulus of 2.6 on BS sieve 100) and remaining 32% Chenab sand (with a fineness modulus of 1.7 on BS sieve 100).

TABLE 1: Bulk densities of constituent materials

| Material | Loose State ($lb/ft^3$) | Rodded State (lb/ft3) |
|---|---|---|
| 100% Chenab Sand | 85 | 94 |
| 100% Haro Sand | 89.5 | 99 |
| Blended Stage (30% Chenab) Sands | 90 | 99.5 |
| Coarse aggregate (80% ¾" - 3/8") | 88.53 | 99.6 |
| Cement | 89.6 | - |

TABLE 2: Results of workability test.

| Test | Normal Concrete | Modified Concrete 10% | Modified Concrete 20% |
|---|---|---|---|
| Slump Test | (½") | (3/4") | (3/4") |
| Compacting Factor Test | 0.81 | 0.85 | 0.86 |

TABLE 3: Compressive Strength Results

| | Time (Days) | Normal concrete (psi) | Modified concrete 10% (psi) | Modified concrete 20% (psi) |
|---|---|---|---|---|
| 1st Curing Cycle | 3 | 5180 | 2170 | 1020 |
| | 7 | 5355 | 2415 | 1400 |
| | 28 | 7700 | 4200 | 2275 |
| 2nd Curing Cycle | 3 | 4900 | 2380 | 1330 |
| | 7 | 5320 | 3010 | 1680 |
| | 28 | 5705 | 4300 | 2268 |
| 3rd Curing Cycle | 3 | 4550 | 2695 | 1820 |
| | 7 | 5040 | 3360 | 2380 |
| | 28 | 6020 | 4500 | 2940 |

TABLE 4: Results of modulus of rupture

| Curing cycle | Normal Concrete 10% (psi) | Modified Concrete 10% (psi) | Modified Concrete 20% (psi) |
|---|---|---|---|
| 1st | 780 | 445 | 335 |
| 2nd | 510 | 410 | 400 |
| 3rd | 550 | 490 | 450 |

TABLE 5: Results of split cylinder test

| Curing cycle | Modified concrete 10% (psi) | Modified concrete 10% (psi) | Modified Concrete 20% (psi) |
|---|---|---|---|
| 1st | 227 | 263 | |
| 2nd | 277 | 258 | 188 |
| 3rd | 317 | 238 | 227 |

TABLE 6: Results of 24 hour water absorption.

| % Absorption of water | Normal Concrete (%) | Modified Concrete 10% (%) | Modified Concrete 20% (%) |
|---|---|---|---|
| 1st Curing cycle | 2.33 | 2.21 | 1.55 |
| 2nd Curing cycle | 3.27 | 2.76 | 1.40 |
| 3rd Curing cycle | 3.22 | 3.06 | 1.90 |

In an earlier investigation [13], the water absorption of different concrete mixes was obtained as under in table 7. This is also a function of micro structure of concrete [14]. Coarse aggregate %ages were similar to that of table 6. During literature survey stage, good quality material relevant to the topic was consulted [15,16,17,18,19].

TABLE 7: Water absorption reported in an earlier investigation

| Mix Proportion | W/C ratio | Test | Plain | Modified concrete 10% | Modified concrete 15% |
|---|---|---|---|---|---|
| 1:2:3 | 0.64 | Slump | 6.3 | 4.5 | 3 |

## CONCLUDING REMARKS

1. After testing 3 series of different concrete mixes with different w/c ratios and polymer dispersions, it is established that compressive strength of concrete decreases with an increase in polymer dispersion.
2. Water absorption of concrete reduces with increase in polymer dispersions.
3. This type of Latex is good for repairing mortar and concrete surfaces and can be used with ease and care as a good bonding agent.
4. Permeability and durability of concrete specially in terms of pore sizes and freeze-thaw resistances are improved.
5. Considering three days strength, effect of curing cycle is same for all types of concretes.
6. Considering seven days strength, rate of strength developed for normal concrete starts reducing while for modified concretes it remains the same.
7. Considering twenty eight days strength rate of strength development for normal concrete reduces considerably. However, rate of strength development for modified concrete reduces by an insignificant amount.
8. First curing cycle gives higher strength for normal concrete while third curing cycles give higher strengths for modified concretes.

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