ISSN 2278-7763

Performance of Styrene Butadiene Rubber as a Concrete Repair Material in tropical climate

R.Radhakrishnan[1], Syam Prakash.V[2], and C.K.Prasad Varma Thampan[3]

[1,3] Associate Professors, Department of Civil Engineering, N.S.S.College of Engineering, Palakkad, India [2] Professor, Department of Civil Engineering, College of Engineering, Thiruvananthapuram, India
Email: rrmanjeeram@gmail.com[1], dr_syamprakash@yahoo.co.in[2], and ckpvarma@gmail.com[3] .

ABSTRACT

Deterioration of Concrete due to variety of reasons like corrosion of steel, inferior quality of materials as well as workmanship and exposure to aggressive environment like thermal cycling affect the performance or damage a number of Reinforced cement concrete structures. In order to repair these structures for enhancing the service life, number of methods and materials are available. But the degree of success of any repair in concrete depends mainly on the correct choice and the method of application of repair materials. This paper discusses the details of an experimental investigation on the performance of Styrene – Butadiene Rubber (SBR) as a concrete repair material in tropical climatic conditions. Resistance to water penetration and tensile cracking are two important performance criteria for any repair material. Cement mortar cubes of mix proportion 1:3 with SBR added at the rate of 20% of the weight of cement, and control specimens without SBR were made. Compressive strength and sorptivity values of the cubes were determined. Shear Bond strength (by slant shear test) and splitting tensile strength of the repaired cylinder specimens of standard dimensions, in which SBR used as a bonding agent were determined. These values were compared with the values obtained for the similar specimens, in which the bonding agent applied was conventional cement slurry. The influence of thermal cycling on the properties of repaired concrete specimens were also studied. A comparison has also been made with the values required to meet the standard specifications of a repair material.

Keywords : concrete repair, Styrene butadiene Rubber, bonding agent, thermal cycling

1 INTRODUCTION

Construction Industry has been showing considerable growth, for the last two decades, to meet the growing demands of the new infrastructure of various countries around the world. At the same time, the proportion of deteriorated concrete structures, which needs repair and rehabilitation, is ever increasing. In order to make these structures functional during the remaining years of service life, suitable repairs are made possible with the help of various repair techniques which utilizes the new generation concrete repair materials. Commercially available materials for concrete repair can be conveniently categorised as follows

- Resinous materials: epoxy mortar, polyester mortar, Acrylic mortar mixtures, polyurethane grouts.
- Polymer-modified cementitious materials: SBR (styrene butadiene rubber) modified, magnesium phosphate modified, acrylic modified, ethyl vinyl acetate cementitious materials.
- Cementitious materials: OPC-Sand mortar, High Alumina Cement (HAC) mortar, HAC and OPC mixed mortar, expansion producing grout, flowing grout.

The selection of an appropriate repair material is an important task which determines the effectiveness of a repair. The various factors to be considered for selection of a repair material are: type of concrete to be repaired and its age, magnitude and thickness of repairs, compatibility (dimensional, chemical, electrochemical and permeability), nature of environment in which the structure is situated, availability, cost and ease of application The development of adequate bond between old concrete (substrate) and the repair material is also one of the essential requirements to be satisfied, in order to realize a successful repair. During the process of repair of concrete structures, the application of bonding agents (bond improving agents) on substrate surface is an essential step before applying repair material in the form of mortar or concrete. Different types of bonding agents are available in the market, viz., SBR, acrylic and epoxy based bonding agents. The performance of bonding agents and the proposed repair materials need to be evaluated, before selecting one of them for a particular application. This paper discusses the details of an experimental study conducted on the performance of SBR as a bonding agent and as well as mortar modifier for the purpose of repair. This preliminary study is a part of the ongoing research study on the performance evaluation of various concrete repair materials. The performance was evaluated by laboratory tests to determine the compressive strength, bond strength, splitting tensile strength and sorptivity of the test specimens. Tropical climate is characterized by Heat-cool cycles and good rainfall, whih may accelerate the process of degradation.Therefore the influence of thermal cycles on the properties of repaired concrete specimens were also studied.

2 TESTING PROGRAMME

2.1 General

The following tests were conducted in the laboratory on specimens as per the standard procedures given in ASTM/EN literature to assess

- Compressive strength
- Bond strength (ASTM C 1042-99)
- Splitting tensile strength (ASTM C 496)
- Sorptivity (EN 13057)

2.2 Materials used

Portland Pozzolana Cement conforming to Indian standards (IS 1489-1991), Fine aggregate of Zone II grading as per Indian standards (IS 383), Coarse aggregate – crushed granite aggregate 12 mm graded satisfying Indian standards were used.

The Repair material used was commercially available SBR latex (40% solids) of a reputed manufacturing company.

3 TESTING

3.1 Compressive Strength

Cement mortar cubes of face area 50 square centimetres each were made with the following mixes

(1) Cement mortar of mix proportion 1:3 with a water to cement ratio by weight (w/c ratio) of 0.55 providing desirable workability as judged by an experienced mason (A practice internationally accepted among researchers, as reported in literature to simulate site conditions)

(2) Cement mortar of mix proportion 1:3 with SBR added at the rate of 20 % of the weight of cement. A w/c ratio of 0.30 was used based on the judgement of the mason for adequate workability.

Cubes were tested in a compression testing machine for determining the compressive strength values after 28 days of water curing in a tank/wet spray chamber curing as specified by the manufacturer of the repair material.

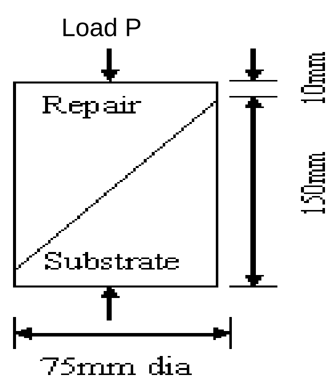

Figure 1. Dimensions of repaired specimen

3.2 Slant Shear Test (ASTM C 1042-99)

The specimen used in the test consisted of two parts (two halves of a cylinder) as shown in Fig.1, the first portion being the concrete substrate (grade M25), and the second portion the repair material. The substrate part of the specimen as shown in Fig. 1 was cast using the mould as shown in Fig. 2 and cured for 28 days by immersing in water.

Figure 2. Mould of specimens used for slant shear test

The interface surface was thoroughly cleaned and the SBR bonding agent was applied by brushing as per the instruction given by the manufacturer. The repair concrete (grade M25) was cast by keeping in the cylindrical mould and the curing continued for another 28 days in a water spray chamber. The repaired test specimens of diameter 75 mm and 160mm height were subjected to compression test and thus the shear bond strength values were determined (Fig. 3). The test was also done on specimens prepared as per the above procedure, with conventional cement slurry used as a bonding agent, all other conditions remaining the same.

Figure 3. Specimen subjected to slant shear test

3.3 Splitting Tensile Strength Test (ASTM C496)

Composite cylinders were constructed with one half as substrate (old concrete) and the other half as repair material (new

ISSN 2278-7763

concrete) cast after the surface cleaning and application of the bonding agent. Two sets of composite cylinders (150 mm diameter 300 mm high – one set consisting of 3 numbers) were made viz., (i) with cement slurry as bonding agent and (ii) with SBR as bonding agent. These cylinders were subjected to splitting test in a compression testing machine, after 28 days of water spray curing (Fig.4).

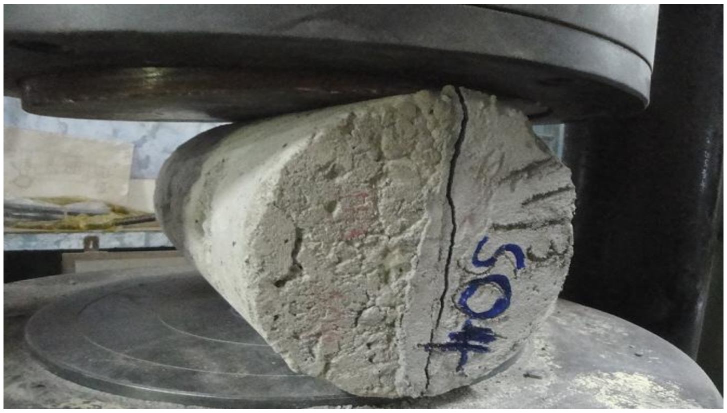

Figure 4. Splitting tensile strength test on Repaired cylinder

3.4 Sorptivity Test

A set of six cement mortar cubes of face area 50 square centimetres (7.07 cm X 7.07 cm sides) each, made with the same mixes as in the case of testing compressive strength, were used for sorptivity test.

The cubes were water cured for a period of 28 days and pre conditioned in an oven at 105 degree Celsius, until it reaches a constant mass, before measurements of capillary sorption were carried out. The lower areas on the sides of the specimen were coated with epoxy paint to provide a water tight seal to achieve unidirectional flow (Fig. 5).

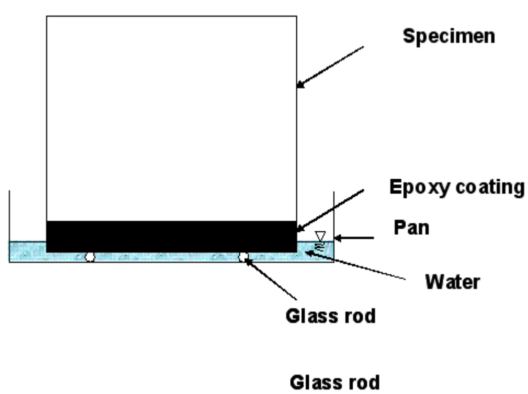

Figure 5. Schematic diagram of Sorptivity Test Set up

The cubes were exposed to water on the plane of 7.07 cm x 7.07 cm by placing it in a pan (basin). During the experiment, the water level in the pan was maintained at about 5 mm above the base of the specimen. The mass of the specimen was measured using an electronic balance of accuracy 0.001 g, then the amount of water absorbed was calculated and normalized with respect to the cross sectional area of the specimens exposed to water at various durations such as 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121 and 1440 minutes from the first contact of the specimen with water. A graph was drawn with square root of time on X-axis and water intake kg/square metre on Y-axis (Fig. 6). The slope of the linear fit provides the sorptivity coefficient.

3.5 Influence of Thermal cycles

The influences of thermal cycles on the strength characteristics and sorptivity were investigated by exposing the repaired concrete specimens to 50 thermal cycles, (heating the specimens in an electric oven to a temperature of 50^{o}C maintained for 8 hours and then allowing to cool for 16 hours constitute one thermal cycle) and at the end of thermal cycles, conducting the tests to determine the splitting tensile strength, shear bond strength and sorptivity.

4 RESULTS

The values of compressive strength, bond strength, splitting tensile strength and moisture sorption for various specimens are given in Tables 1, 2, 3 and 4. The influence of themal cycles on the properties of repair materials are presented in Table 5 and Figure 7.

TABLE 1 COMPRESSIVE STRENGTH VALUES OF CUBES

Type of specimen	Serial no.	Compressive strength MPa	Average MPa
Cement mortar 1:3	1 2 3	14.00 15.20 14.50	14.60
SBR modified cement mortar 1:3	1 2 3	12.50 14.00 12.20	12.90

TABLE 2 REULTS OF SLANT SHEAR TEST

Type of speci-men	Serial No.	Shear Bond strength MPa	Average MPa
Monolithic (control)	1 2 3	14.65 10.90 12.31	12.62
Cement slurry used as bond-ing agent(CO)	1 2 3	7.14 7.69 6.81	7.21
SBR as bonding agent(SO)	1 2 3	8.35 9.12 9.45	8.97

TABLE 3 SPLITTING TENSILE STRENGTH TEST RESULTS

Type of specimen	Serial No. No.	Splitting tensile strength MPa	Average MPa
Monolithic (control)	1 2 3	1.98 2.15 2.37	2.17
Cement slurry used as bonding agent (CO)	1 2 3	1.12 0.82 0.96	0.97
SBR as bonding agent(SO)	1 2 3	1.18 1.51 1.37	1.35

TABLE 4. SORPTION TEST RESULTS

Time in min	Moisture Penetration for Cement mortar (kg/m²) (1:3)	Moisture Penetration for Cement Mortar Cubes modified with SBR (20%) (kg/m²)	Moisture Penetration of SBR modified cube after Thermal cycling (kg/m²)
1	0.267	0.100	0.13
4	0.400	0.100	0.135
9	0.600	0.133	0.15
16	0.934	0.133	0.195
25	1.000	0.167	0.22
36	1.067	0.200	0.286
9	1.200	0.200	0.295
64	1.467	0.200	0.34
81	1.600	0.200	0.366
100	1.667	0.233	0.387
121	1.801	0.233	0.42

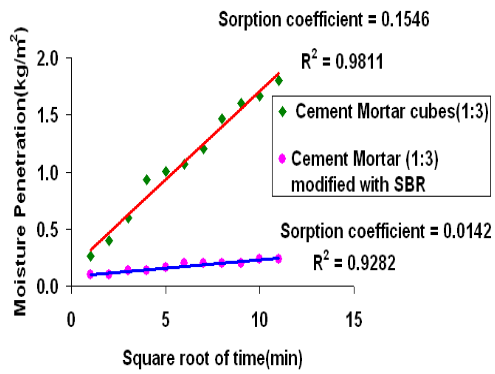

Figure 6. Sorptivity Characteristics of repair materials

Table 5. Influence of thermal cycling on bond strength

Specimen Code	Shear Bond Strength (MPa)		Bond Strength (MPa) by splitting cylinder test	
	Specimen Without Thermal Cycles	Specimen With Thermal Cycles	Specimen without Thermal Cycles	Specimen Subjected to Thermal Cycles
CO	7.68	2.81	1.12	0.40
	6.80	5.59	1.15	0.40
	7.13	5.81	0.96	0.42
	Average = 7.20	Average = 4.74	Average = 1.08	Average = 0.41
SO	8.34	7.13	1.19	1.20
	7.35	5.48	1.27	0.71
	7.24	5.05	0.86	0.85
	Average = 7.64	Average =5.89	Average = 1.11	Average = 0.92

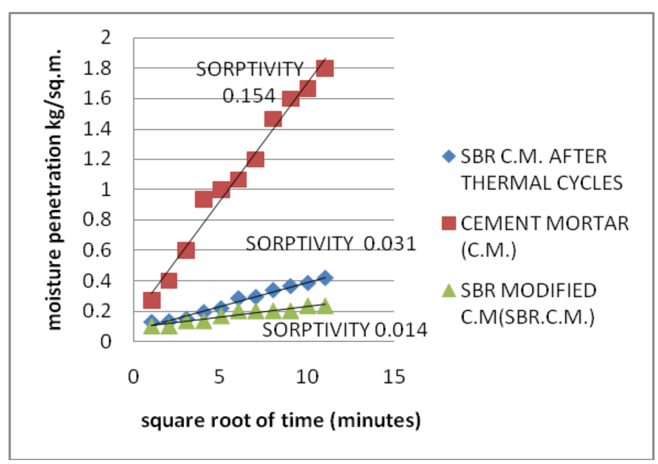

Figure 7. Influence of Thermal cycling

Compressive strength values of the SBR modified mortar cubes were slightly less than that of cement mortar cubes. This is in agreement with an earlier study [5]. As per [5], though the compressive strength values of the SBR modified mortar cubes were slightly less during the initial months, the SBR modification increased the flexural and tensile strengths. The results of sorptivity test of this study showed that addition of SBR at the rate of 20 % of the weight of cement in cement mortar cubes of 1:3 proportion, gave substantial reduction (91%) in the sorptivity value. The average value of sorptivity coefficient obtained for SBR modified cement mortar cubes was 0.0142 kg/m^2 / $min^{0.5}$. Also, the sorptivity value of SBR modified cement mortar subjected to thermal cycling was 0.031 kg/m^2 / $min^{0.}$5. This satisfies the requirement of capillary absorption property as per the compliance criteria of the European Standard EN 13057 for non-structural repair products (0.064 kg/m^2 / $min^{0.5)}$. The bond strength values obtained for the specimens with SBR as bonding agent satisfied the requirement of bond strength as per ASTM specifications The values obtained were higher compared to the values obtained for specimens in which cement slurry was used as a bonding agent. SBR as a bonding aid restored 72% of the capacity of monolithic specimen whereas the use of cement slurry gave 57% of the capacity of monolithic specimen. The results of splitting tensile strength test showed that SBR as a bonding agent provided 40% enhancement in tensile strength, compared to the use of cement slurry for the same purpose.

The influence of thermal cycles on the bond strength and sorptivity are shown in Table 5 and Figure7 respectively. The reduction in shear bond strength by slant shear test, due to thermal cycles was 34% for cement slurry- bonded specimens where as only 22% for SBR bonded specimens. The reduction in split tensile strength, due to thermal cycles was 62% for cement slurry bonded specimens and only 17% for SBR bonded specimens. The sorptivity of SBR modified cement mortar subjected to thermal cycling was 0.031 kg/m^2 / $min^{0.5}$. This satisfies the requirement of capillary absorption property as per the compliance criteria of the European Standard EN 13057 for non-structural repair products(0.064 kg/m^2 / $min^{0.5}$). Therefore the performance of SBR latex modified cement mortar is good and conforms to the standards.

5 CONCLUSION

1. The results of sorption test showed that the conventional weathering coat of cement mortar of 1:3 proportion did not possess adequate water penetration resistance, to function as water proofing agent. Therefore a modifier is essential to make the repairs durable.

2. SBR modified cement mortar possess very good water penetration resistance and can be used as a repair material in the case of spalled roof slabs with exposed steel reinforcement.

3. The results of splitting tensile strength test showed that SBR as a bonding agent possess good tensile strength compared to cement slurry. Thus SBR is better choice in repairing/resurfacing concrete in tension zone of a flexural member.

4. The bond strength values obtained for the specimens with SBR as bonding agent satisfied the requirement of bond strength as per ASTM specifications.

5. The performance of SBR, as a modifier to cement mortar, and as a bonding agent, satisfied the requirements stipulated by the standards.

6. Since the SBR based repair material presented better performance after thermal cycling, the results of the study upholds the use of SBR latex, as a modifier to cement mortar repair and being mixed with cement slurry as a bonding agent in tropical climate.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support for this research work from Kerala State Council for Science Technology and Environment(KSCSTE), Thiruvananthapuram, India and the infrastructure support from N.S.S.College of Engineering, Palakkad -678 008, Kerala, India .

REFERENCES

[1] J. Abdel –Zaher.A and Ambalavanan.R (1998). "Development and Behaviour of Repair Mortars for RC components", Indian Concrete Journal, December, 669-675.

[2] ASTM C 1059-99, ,"Standard specifications for latex agents for bonding fresh to hardened concrete"

[3] ASTM C496, "Test method for splitting test for concrete cylinders." ASTM, Philadelphia.

[4] ASTM C1042-99, "Test method for bond strength of latex systems used with concrete by slant shear."" ASTM, Philadelphia.

[5] Cabrera, J G and Ai-Hassan A S (1997). "Performance Properties of Concrete Repair Materials." *Construction and Building Materials*, 11(5-6), 283-290.

[6] Maria Sofia Sousa Riberio, Arlindo Freitasb Goncalves and Fernando Antonio Baptista Branco, "Styrene - butadiene polymer action on compressive and tensile strengths of cement mortars", Materials and Structures (2008) 41:1263-1273.

[7] European Standard EN 13057 for non-structural repair mortar.

[8] R.Radhakrishnan , Dr.V.Syam Prakash and Dr.C.K.Prasad Varma Thampan.(2010), "Performance of Styrene-Butadiene-Rubber in Concrete Repair –An Experimental Study"–Paper presented in the international conference ICTT 2010, 25-27 November 2010, College of Engineering Trivandrum, India.