B-2-5 Study of cost effective weather resistant water repellent acrylic polymer emulsion on porous hardboard, concrete and metal substrate under uncontaminated environment and contaminated environment with sodium chloride

Tarak Vora
Balaji Industries, Vice President, Product Development and application Center, Bangalore, India.
balajiindustry10@gmail.com

Meet Vora
Balaji Industries, Vice President, Product Development and application Center, Bangalore, India.
balajiindustry10@gmail.com

Jalashree Vora
Balaji Industries, Vice President, Product Development and application Center, Bangalore, India.
balajiindustry10@gmail.com

ABSTRACT: The key function of water repellent polymer is to change surface properties of substrate on which it is applied. Deterioration and degradation will greatly reduce if the porosity on surface of substrate is blocked by a weather resistant polymer coating which will not allow moisture to penetrate through the substrate due to capillary action. A novel UV resistant acrylic aqueous polymer emulsion has been developed, which not only blocks the pores on the surface but effectively alters surface property of the substrate. This results in substantial increase in hydrophobic character and decrease in deterioration due to hostile weather and thermal shocks. A study has been conducted on untreated porous hardboard, Concrete and iron piece; and coated hardboard, Concrete and iron piece. The substrates were placed under uncontaminated and contaminated environment with sodium chloride in salts spray corrosion cabinet in humid and hostile environment over a prolonged period. The substrates were also subjected to thermal shocks. The effectiveness of coated samples were compared with uncoated samples for change in porosity, change in contact angle and deterioration of samples when subjected to uncontaminated and contaminated environment with sodium chloride in salt spray cabinet and under thermal shocks. The results show substantial improvement for coated samples in decrease in porosity, increase in hydrophobic character and decrease in surface deterioration when subjected to prolonged period of uncontaminated and contaminated environment with sodium chloride and thermal shocks.

KEY-WORDS: Acrylic polymer emulsion, water repellent.

INTRODUCTION

Recent innovations in the area of polymer colloids and hybrid materials offer new opportunities to develop novel coating formulations having better hydrophobicity and barrier properties [1]. The film forming process of latex is complex mechanism that includes four different stages, schematically shown in Fig.1.These stages are: 1) the concentration of latex dispersion; 2) particle contact; 3) particle deformation; and 4) the inter-diffusion of polymer chains across the boundaries, which is necessary to form a mechanically stable film.

The end-use properties of the latex (mechanical and optical properties to mention a few) are strongly influenced by the film formation process. Typically, only the outer shell of the polymer particles takes part in the fourth stage, namely the inter-diffusion of the polymer chains into the neighbouring particles. Therefore, this outer layer is largely responsible for proper film formation. This last stage of the film forming process is of paramount importance to obtain coatings with good early water-spot resistance.

Although this film formation is facilitated by lower molecular weight and lower glass transition (Tg) polymers, a certain hardness of the polymer film is necessary in order to assure good barrier properties and durability. Unfortunately, an increase in hardness either via higher content of hard monomers (such as styrene) or cross linking (using functional monomers) has usually a negative influence on the film formation, in particular on the inter-diffusion of polymer chains across the particles boundaries. This leads to poor early water-spot resistance and too early failure of coatings under the corrosive environments.

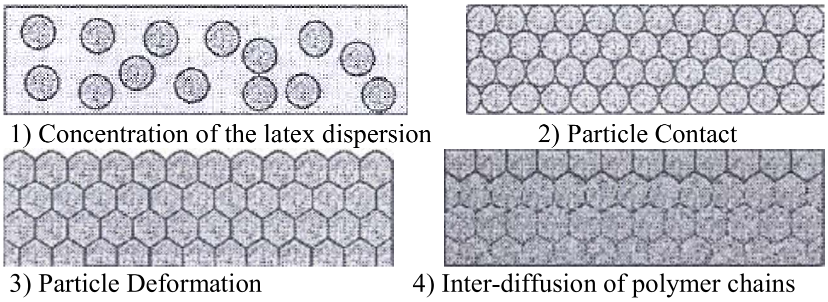


Fig.1. Schematic representation of the different stages during the film forming process

By choosing appropriate technology, it is possible to design acrylic binders with improved water repellency, low water uptake and improved anti-corrosive properties. One way to get coatings with good barrier properties and hydrophobicity is the use of structural polymer particles made by two stage polymerization process with optimum ratio of monomers and cross-linking agents, and minimum use of surfactants. Molecular weight distribution, polymer composition, branching and cross-linking density, particle morphology and particle size distribution are of paramount importance. Proper choice of monomers and cross-linking agents in optimum ratio, minimum quantity of proper surfactants and strict control of polymerisation conditions can provide polymer emulsions with better barrier properties, anti corrosive properties, higher water resistance, good water repellency and aging properties.

Accordingly, three aqueous styrene acrylic polymer emulsions have been developed as under.

1. WP 981: 50% Styrene acrylic emulsion.
2. WP 985: 50% Styrene acrylic emulsion with 2% siloxane.
3. WP 990: 50% Styrene acrylic emulsion with 3% siloxane.

These emulsions are formulated without using Alkoxy phenol Ethylene oxide, ammonia and formaldehyde. They also do not contain any volatile organic compound having boiling point below 250°C.They do not emit any harmful chemical or organic volatile chemical during storage or after application which affect the human being or environment adversely.

These emulsions are environmental friendly because of the above criteria.

EXPERIMENTAL SECTION

Two coats of 25 microns each of WP 981, WP 985 and WP 990 were applied on the following substrates.

1. Paper Board
2. Wooden Plate
3. Clay tile
4. Mild Steel Plate

Mild Steel Plates were coated with 25 microns Acrylic Primer (WP 550) prior to coating with the emulsions.
The coated samples were also immersed in 5% salt solutions for seven days at 30°C.

The following values were observed for uncoated and coated samples.

A. The hydrophobic behaviour of coated samples was determined by water contact angle (Sessile Drop method) using commercial video based software controlled contact angle analyzer DSA 210 of Kruss GmbH.
B. The coated samples were kept in 5% salt solution for seven days. The hydrophobic behaviour was determined by water contact angle (Sessile Drop Method).
C. The hydrophobic behaviour of coated samples was once again determined after 1 month by water contact angle (Sessile Drop Method) to study the effect of aging.

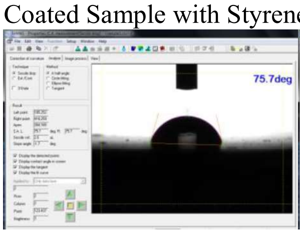
D. The Samples were weighed before and after immersing in water for 5 minutes. The difference in weight was used to calculate uptake of water.
E. This exercise was repeated after coating with all the three polymer emulsions namely WP 981, WP 985 and WP 990 for all the substrates.

Table 1. Samples Tested

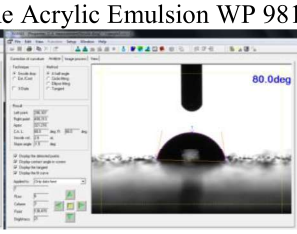
Sample No.	Substrate	Styrene Acrylic Emulsion (25-micron double coated samples)	
2.1	Paper Board	WP 981	Coated
7.1	Wooden Plate	WP 981	Coated
12.1	Clay Tile	WP 981	Coated
17.1	Mild Steel Plate	WP 981	Coated
2.2	Paper Board	WP 981	Coated and immersed in 5% salt solution for 7 days
7.2	Wooden Plate	WP 981	Coated and immersed in 5% salt solution for 7 days
12.2	Clay Tile	WP 981	Coated and immersed in 5% salt solution for 7 days
17.2	Mild Steel Plate	WP 981	Coated and immersed in 5% salt solution for 7 days
2.3	Paper Board	WP 981	Coated and tested after 1-month aging
7.3	Wooden Plate	WP 981	Coated and tested after 1-month aging
12.3	Clay Tile	WP 981	Coated and tested after 1-month aging
17.3	Mild Steel Plate	WP 981	Coated and tested after 1-month aging
3.1	Paper Board	WP 985	Coated
8.1	Wooden Plate	WP 985	Coated
13.1	Clay Tile	WP 985	Coated
18.1	Mild Steel Plate	WP 985	Coated
3.2	Paper Board	WP 985	Coated and immersed in 5% salt solution for 7 days
8.2	Wooden Plate	WP 985	Coated and immersed in 5% salt solution for 7 days
13.2	Clay Tile	WP 985	Coated and immersed in 5% salt solution for 7 days
18.2	Mild Steel Plate	WP 985	Coated and immersed in 5% salt solution for 7 days
3.3	Paper Board	WP 985	Coated and tested after 1-month aging
8.3	Wooden Plate	WP 985	Coated and tested after 1-month aging
13.3	Clay Tile	WP 985	Coated and tested after 1-month aging
18.3	Mild Steel Plate	WP 985	Coated and tested after 1-month aging
4.1	Paper Board	WP 990	Coated
9.1	Wooden Plate	WP 990	Coated
14.1	Clay Tile	WP 990	Coated
19.1	Mild Steel Plate	WP 990	Coated
4.2	Paper Board	WP 990	Coated and immersed in 5% salt solution for 7 days
9.2	Wooden Plate	WP 990	Coated and immersed in 5% salt solution for 7 days
14.2	Clay Tile	WP 990	Coated and immersed in 5% salt solution for 7 days
19.2	Mild Steel Plate	WP 990	Coated and immersed in 5% salt solution for 7 days
4.3	Paper Board	WP 990	Coated and tested after 1-month aging
9.3	Wooden Plate	WP 990	Coated and tested after 1-month aging
14.3	Clay Tile	WP 990	Coated and tested after 1-month aging
19.3	Mild Steel Plate	WP 990	Coated and tested after 1-month aging

Contact angle measurement (Sessile Drop Method)

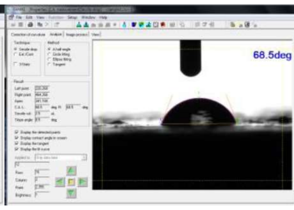
Coated Sample with Styrene Acrylic Emulsion WP 981



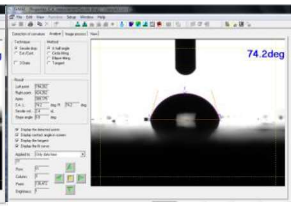
Paper Board 2.1
Fig. 2.



Wooden Plate 7.1
Fig. 3.

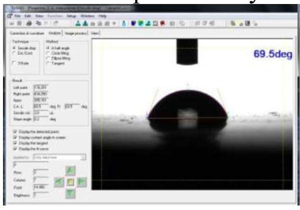


Clay Tile No 12.1
Fig. 4.

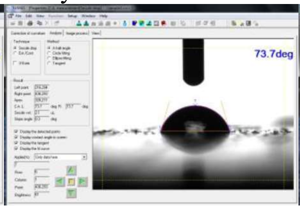


Mild Steel Plate No 17.1
Fig. 5.

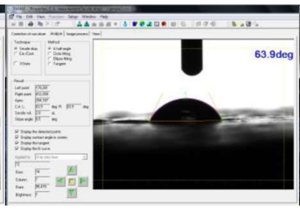
Coated Sample with Styrene Acrylic Emulsion WP 981 & Immersed in 5% Salt Solution



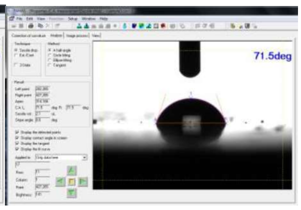
Paper Board 2.2
Fig. 6.



Wooden Plate 7.2
Fig. 7.

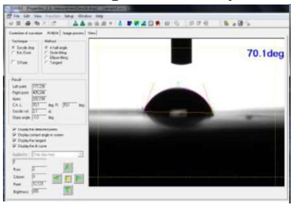


Clay Tile No 12. 2
Fig. 8.

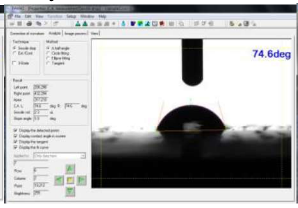


Mild Steel Plate No 17.2
Fig. 9

Coated Sample with Styrene Acrylic Emulsion WP 981 with 1 month aging

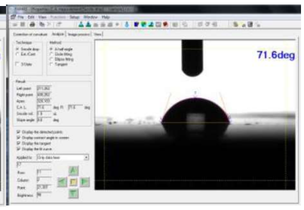


Paper Board 2.3
Fig. 10.



Wooden Plate 7.3
Fig. 11.

Clay Tile No 12.3
Fig. 12.



Mild Steel Plate No 17.3
Fig. 13.

The contact angle of uncoated substrates has not been measured as the substrates are totally hydrophilic except mild steel plate. Coating with WP 981 indicates an increase in contact angle. The percentage decrease in value of contact angle after immersion in 5% salt solution for seven days and after aging for one month is as under.

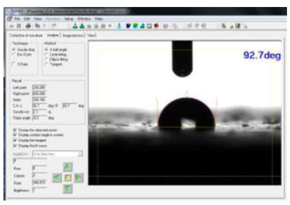
Table 2. Observations

	Contact angle	% decrease on immersion	% decrease on aging
Paper board	75.7	8.19%	7.39%
Wooden Plate	80.0	7.87%	6.75%
Clay tile	68.5	0.60%	0
Mild steel Plate	74.2	3.63%	3.5%

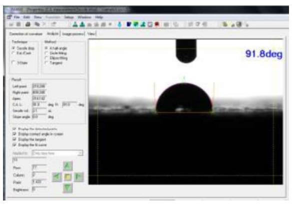
Coated sample with styrene acrylic emulsion WP 985

Coated Sample with Styrene Acrylic Emulsion WP 985

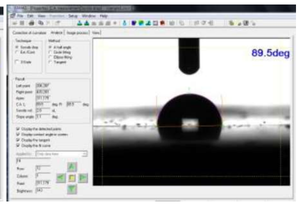
Paper Board No 3.1
Fig. 14.



Wooden Plate No 8.1
Fig. 15.

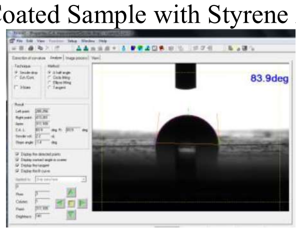


Clay Tile No 13.1
Fig. 16.

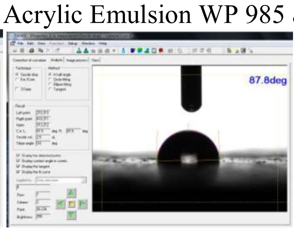


Mild Steel Plate No 18.1
Fig. 17.

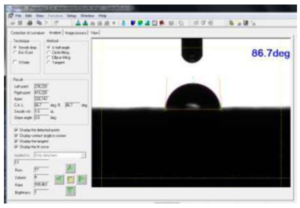
Coated Sample with Styrene Acrylic Emulsion WP 985 & Immersed in 5% Salt Solution



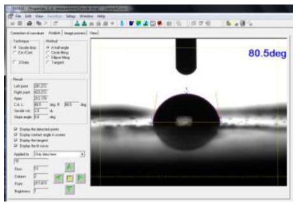
Paper Board No 3.2
Fig. 18.



Wooden Plate No 8.2
Fig. 19.

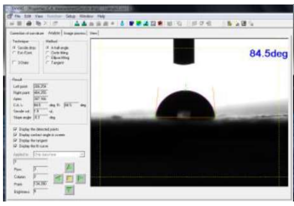


Clay Tile No 13.2
Fig. 20.

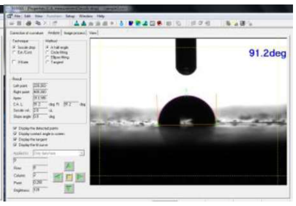


Mild Steel Plate No 18.2
Fig. 21.

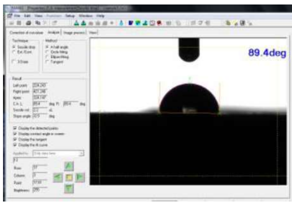
Coated Sample with Styrene Acrylic Emulsion WP 985 with 1 month aging



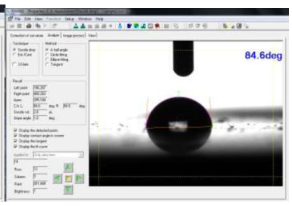
Paper Board No 3.3
Fig. 22.



Wooden Plate No 8.3
Fig. 23.



Clay Tile No 13.3
Fig. 24.



Mild Steel Plate No 18.3
Fig. 25.

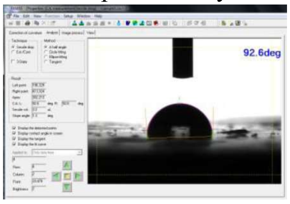
The coating with WP 985 has improved the hydrophobic character of the substrates. The percentage decrease in value of contact angle after immersion in 5% salt solution seven days and after aging for one month is as under.

Table 3. Observations

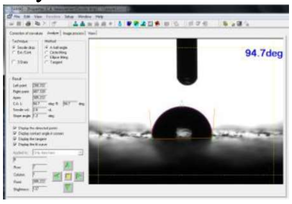
	Contact angle	% decrease on immersion	% decrease on aging
Paper board	85.2	1.5%	0.8%
Wooden Plate	92.7	5.2%	1.6%
Clay tile	91.8	5.5%	2.68%
Mild steel Plate	89.5	10%	5.5%

Coated sample with styrene acrylic emulsion WP 990

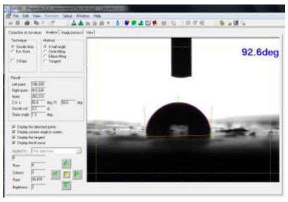
Coated Sample with Styrene Acrylic Emulsion WP 990



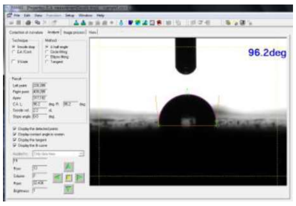
Paper Board No 4.1
Fig. 26.



Wooden Plate No 9.1
Fig. 27.

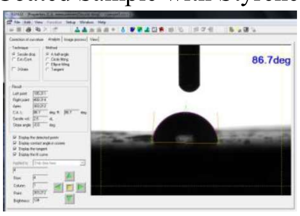


Clay Tile No 14.1
Fig. 28.

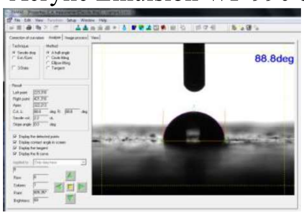


Mild Steel Plate No 19.1
Fig. 29.

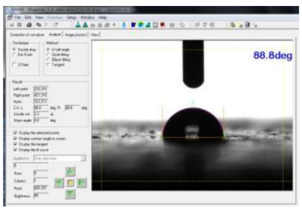
Coated Sample with Styrene Acrylic Emulsion WP 990 & Immersed in 5% Salt Solution



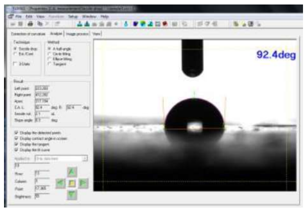
Paper Board No 4.2
Fig. 30.



Wooden Plate No 9.2
Fig. 31.

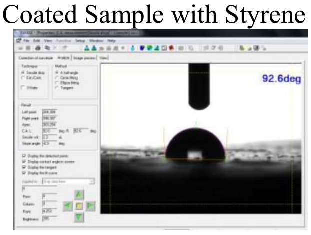


Clay Tile No 14.2
Fig. 32.

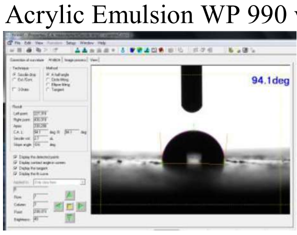


Mild Steel Plate No 19.2
Fig. 33.

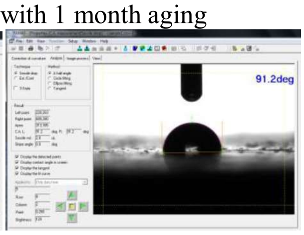
Coated Sample with Styrene Acrylic Emulsion WP 990 with 1 month aging



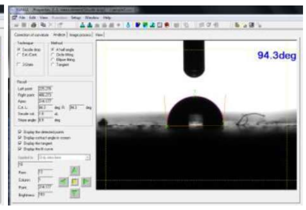
Paper Board No 4.3
Fig. 34.



Wooden Plate No 9.3
Fig. 35.



Clay Tile No 14.3
Fig. 36.



Mild Steel Plate No 19.3
Fig. 37.

The coating with WP 990 has shown further increase in the hydrophobic character of the substrates. The percentage decrease in value of contact angle after immersion in 5% salt solution seven days and after aging for one month is as under.

Table 4. Observations

	Contact angle	% decrease on immersion	% decrease on aging
Paper board	92.6	6.3%	0
Wooden Plate	94.7	6.2%	3.69%
Clay tile	92.6	4.1%	1.5%
Mild steel Plate	96.2	3.95%	1.97%

Table 5. Observations

Substrates		Sample No.	Contact Angle	TWU	WP 981			WP 985			WP 990		
					Sample No.	Contact Angle	TWU	Sample No.	Contact Angle	TWU	Sample No.	Contact Angle	TWU
Paper Board	Uncoated	1	NA	54.89%									
	Coated				2.1	75.7		3.1	85.2		4.1	92.6	
	Coated & Immersed				2.2	69.5		3.2	83.9		4.2	86.7	
	Coated & Aging				2.3	70.1	1.18%	3.3	84.5	0.60%	4.3	92.6	0.30%
Wooden Plate	Uncoated	6	NA	6.13%									
	Coated				7.1	80		8.1	92.7		9.1	94.7	
	Coated & Immersed				7.2	73.7		8.2	87.8		9.2	88.8	
	Coated & Aging				7.3	74.6	0.60%	8.3	91.2	0.28%	9.3	94.1	0.18%
Clay Tile	Uncoated	11	NA	23.40%									
	Coated				12.1	68.5		13.1	91.8		14.1	92.6	
	Coated & Immersed				12.2	63.9		13.2	86.7		14.2	88.8	
	Coated & Aging				12.3	68.5	0.74%	13.3	89.4	0.30%	14.3	91.2	0.20%
Mild Steel Plate	Uncoated	16	NA	0.003%									
	Coated				17.1	74.2		18.1	89.5		19.1	96.2	
	Coated & Immersed				17.2	71.5		18.2	80.5		19.2	92.4	
	Coated & Aging				17.3	71.6	0.005%	18.3	84.6	0.002%	19.3	94.3	0.002%

CONCLUSIONS:

1. Normally Styrene Acrylic Emulsions will have only limited water resistance but no water repellency because of presence of hydrophilic surfactants which form integral part of the coating. They attract water and deform the coating. However, WP 981 Styrene Acrylic Emulsion, because of the novel formulation has shown substantial increase in the hydrophobic character as indicated by Contact Angle measurement and total water uptake.

2. WP 985 and WP 990 show further increase in hydrophobic character. WP 990 is able to retain hydrophobic character even after the substrates are immersed in 5% salt water for seven days and after one month of aging.

3. Addition of small quantity of siloxane (2% to 3%) at the formulation stage under proper conditions has resulted in increase in the contact angle of the coating by more than 20%.

4. Barrier properties of all the coatings show very less total water uptake. This property is retained even after immersion in 5% salt solution for seven days and after one month aging. This can work very well in

protecting all the substrates namely Wood, Exterior of buildings, Concrete surfaces and Mild steel structures from hostile weather conditions.

5. These Styrene Acrylic emulsions are very cost effective compared to water repellent coatings based on silicone compounds which are being widely used. Apart from being cost effective, these emulsions are environmental friendly because they do not emit any harmful chemical or organic volatile chemical during storage or after application which affect human being or environment adversely.

REFERENCES

[1] O. Elizade, S. Amthor, C. Moore. *Closing the gap between water and solvent-borne anti-corrosion coatings via new binder concept*. JCT Coatings Tech. 7(2010): 22-31.

[2] M. Aamodt. *High –performance water borne coatings for heavy-duty corrosion protection*. In Corrosion, (2004). NACE International.

[3] R. Satguru, J. C. Padget, P. J. Moreland. *The relationship between film formation and anticorrosive properties of latex polymers in film formation in waterborne coatings*. ACS Symposium Series - Chapter 22. (1996): 349-358.