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Polymeric Fiber based Composite Coatings

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Abstract: Environmental friendly products are becoming popular and acceptable in industries due to the global limitation to the amount of volatile organic compounds (VOCs) released into the atmosphere. Low VOC compounds and technologies are also becoming a choice in the coatings and paint industry. Coatings can be made from water or solvent. In coatings from water, we use water as the solvent, therefore coating called waterbased coating and in the case of solvent-borne coatings, we used organic or inorganic compounds as solvents, therefore this coating called as solvent borne coating. Among all different types of solvents water is the greatest choice among these low VOC technologies for usage as a solvent to manufacture chemical compounds and Paints and coatings. because water is often recognized as a low-cost, safe, non-toxic, easily availabl sand ecologically friendly solvent. Also nanomaterials is new field in research and development of material science field. Materials can be one dimensional such as small paricles, materilas can be two dimensional such as fibers. Therefore in two-dimensional materials such as fibers (micro and nanofibers) use in many different applications such as medical, composites, aerospace, Bulding constructions etc. Nanofiber has the advantage of high surface area to volume ratio hence to decrease the coating defects. micro and nanofibers should be incorporated inside the coating matrix. This way one can improve the properties of water-based coatings. Hence low VOC solvent water with high surface area fiber is becoming a trend in composite coating and nanotechnology in fibers. This review provides information on Composite coatings, distinct fibers used in coatings and their applications, effects of different sizes of fibers such as micro and nanofibers on coatings.
Keywords: Microfibers, Nano Fibers, Polymeric fibers, Water-based Coatings, Composite Coating

I. MATERIALS

Fibers: Polypropylene fibers are purchased from Xatex industries Pvt Ltd. Mumbai and Jogani fibers, Mumbai
Coating: additives such as wetting and dispersing agent, ammonia solution 25%, thickner, defoamer, anti-freezing agent, Coalescing agent purchased from SD fine chemicals Pvt. Ltd., Pigments and extenders such as Titanium dioxide (TiO_2), Calcium Carbonate ($CaCO_3$) and Talc are purchased from Amrutlal Bhrabhai Mumbai, Binder such as Acrylic emulsion from Pidilite industries.

II. METHODS

A. Water-based Exterior Decorative Coating

Water-based exterior decorative paint without fibers is made in a high-speed disperser by using three steps as Premixing, grinding, and letdown, pigment volume concentration was 31.67 %.

Fig. 2.1 High speed disperser for paint formation

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In the premixing step ammonia 25%, defoamer, wetting, and dispersing agents are added to water one by one, and thickner such as hydroxyl ethyl cellulose is added slowly in a mixing chamber or cylinder and stirred by using a stirrer at 700 to 800 rpm for 15 min. In the grinding step TiO2, Talc, and CaCO3 Pigments and extenders are added and grinded at 1200 to 1500 rpm for 45 min for proper dispersion of pigments. To check the fineness of the grind hegman gauge is used. after 45 min. the small quantity of water, coalescing agents, and anti-freezing agents such propylene glycol added. After grinding pure acrylic emulsion, rheology modifiers and defoamer is added and stirred at 600 to 700 rpm for 15 min. after that liquid paint is taken for testing such as Viscosity, density, and weight per liter etc.

Table 2.1: Formulation for Exterior decorative emulsion Paint

Raw Materials	Density	Wt%
Solvent (distilled water)		20
PH maintainer		0.3
Defoamer		0.4
Wetting and Dispersing agent		1
Thickner		0.80
Pigment	4.5 gm/cc	15.8
Extender	2.71 gm/cc	8.00
Extender	2.76 gm/cc	6.5
Solvent		4
Coalescing Agent		1
Antifreezing Agent		0.9
Binder	1.02 gm/cc	38.00
Rheology Modifier		0.7
Defoamer		0.2
Solvent (Distilled water)		3
Total		100

B. Composite / Reinforced Coating:

Reinforced / Composite Water-based exterior decorative paint is made in a high-speed disperser by using three steps as Premixing, grinding, and letdown, and pigment volume concentration was 31.67 %. In the premixing step ammonia 25%, defoamer, wetting, and dispersing agents are added to water one by one, and thickener such as hydroxyl ethyl cellulose is added slowly in a mixing chamber or cylinder and stirred by using stirrer at 700 to 800 rpm for 15 min. In the grinding step TiO2 pigment, Talc and CaCo3 and Polypropylene fibers (of different diameters and lengths) are added in different concentrations such as 0.5%, 1%, 1.5%, and 2 % and grind at 1200 to 1500 rpm for 45 min for proper dispersion of pigments. To check the fineness of the grind hegman gauge is used. after 45 min. the small quantity of water, coalescing agents, and anti-freezing agents such propylene glycol added. After grinding pure acrylic emulsion, rheology modifiers and defoamer is added and stirred at 600 to 700 rpm for 15 min. after that liquid paint is taken for testing such as Viscosity, density, and weight per liter etc.

Table 2.2: Formulation for composite /reinforced exterior decorative emulsion Paint

Raw Materials	Density	Wt%
Solvent (distilled water)		20
PH maintainer		0.3
Defoamer		0.4
Wetting and Dispersing agent		1
Thickner		0.80
Pigment	4.5 gm/cc	15.8
Extender	2.71 gm/cc	8.00

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Extender	2.76 gm/cc	6.5
Polypropylene fibers	0.92 gm/cc	0.5-2
Solvent		4
Coalescing Agent		1
Antifreezing Agent		0.9
Binder	1.02 gm/cc	38.00
Rheology Modifier		0.7
Defoamer		0.2
Solvent (Distilled water)		3
Total		100

III. CHARACTERIZATION TECHNIQUES

A. *Characterization of fibers*

Fourier transform infrared spectroscopy (FTIR) of Polypropylene fiber was conducted on a Bruker instrument to identify the functional groups present. An Olympus BX41 polarized optical microscope (POM) and scanning electron microscopy (SEM) were employed to observe the diameter of polypropylene fiber. The thermal properties like melting and crystallization point of polypropylene fiber were carried out by using differential scanning calorimetry (TA Q100 DSC analyzer; T.A. instrument, USA). The heating and cooling cycle were between 40-250˚C under a nitrogen atmosphere at heating and cooling rate of 10˚C/min. also for specific gravity test for confirmation of polypropylene fibers.

B. *Characterization of Paint*

1) *Gloss:* The standard paint and paint with adding fibers of different concentration of fibers were applied to a leneta paper with wet film thickness of 200 µm and air dry for 24hr as per ASTM D 523. Gloss is measured at angle of 60° by digital gloss meter.
2) *Water Resistance:* The standard paint and paint with adding fibers of different concentration were applied on glass panel and dried for the 7 days. After that panels are placed in enclosed chamber containing water and air mixture at temperature of 38˚C at 100% relative humidity as per ASTM D 870. The paint applied has 200μm wet film thickness. The presence of water acted upon the surface of paint and helps to determine the resistance of paint to water. After 12, 24, 48, 96 hr the panels are evaluated for colour change, blistering. Skinning of coating.
3) *Alkali Resistance:* The standard paint and paint with adding fibers of different concentration applied on glass panel and dried for the 7 days. After that panels are immersed in alkali solution (30 gm of NaOH into water to prepare to 1 liter solution) as per ASTM D 1647. The paint applied has 200μm wet film thickness. The presence of water acted upon the surface of paint and helps to determine the resistance of paint to alkali media. After 12, 24, 48, 96 hr the panels are evaluated for film whitening and blistering or loss of adhesion
4) *Wet Abrasion Scrub Test:* Wet abrasion Scrub test use to determine washing and scrubbing resistance and cleanability of dispersion paints (wall paints). To test wet abrasion resistance the paints were applied to Scrub black test panels (Leneta Co. size 17.32 in. × 6.69 in.) by using an applicator of 200 µm. 5 panels for each sample 1-panel paint without fiber and 4 panels paint with fibers of different concentration such as 0.5%, 1%, 1.5%, 2%) were applied and drying time 1 week at room temperature. The panels were placed in a scrub machine (Raj scientific company wet abrasion scrub tester), which uses a scrubbing brush (Nylon) that moves back and forward at a constant rate (stroke rate of 38 ± 2 cycles/min. and stroke length 300 ± 5 mm) force over a substrate. A scrub paste consisting of water, thickener, sand and detergent (10 g) was added to the brush as well as 5 g of water. The abrasion is measured by how many cycles have been performed before a thin black line covering the entire film can be seen.
5) *Stain Resistance:* The prepared paint such as standard paint and paint with fibers are applied to leneta paper and allow to dry for 7 days. Stain like Pencil, Pen, Sketch pen, lipstick, Oil, Ink, Coffee, Tea was applied on dry paint film and allowed to rest for 1 hr on the paint film and then washed with abrasive and non-abrasive media as per ASTM D 3450. The greater the ease of stain removal with a min. pf film erosion, the greater the useful service life is expected.

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IV. RESULTS AND DISCUSSION

A. Polarized Optical Microscope (POM)

An Olympus BX41 polarized optical microscope (POM) was employed to observe the diameter of polypropylene fiber.

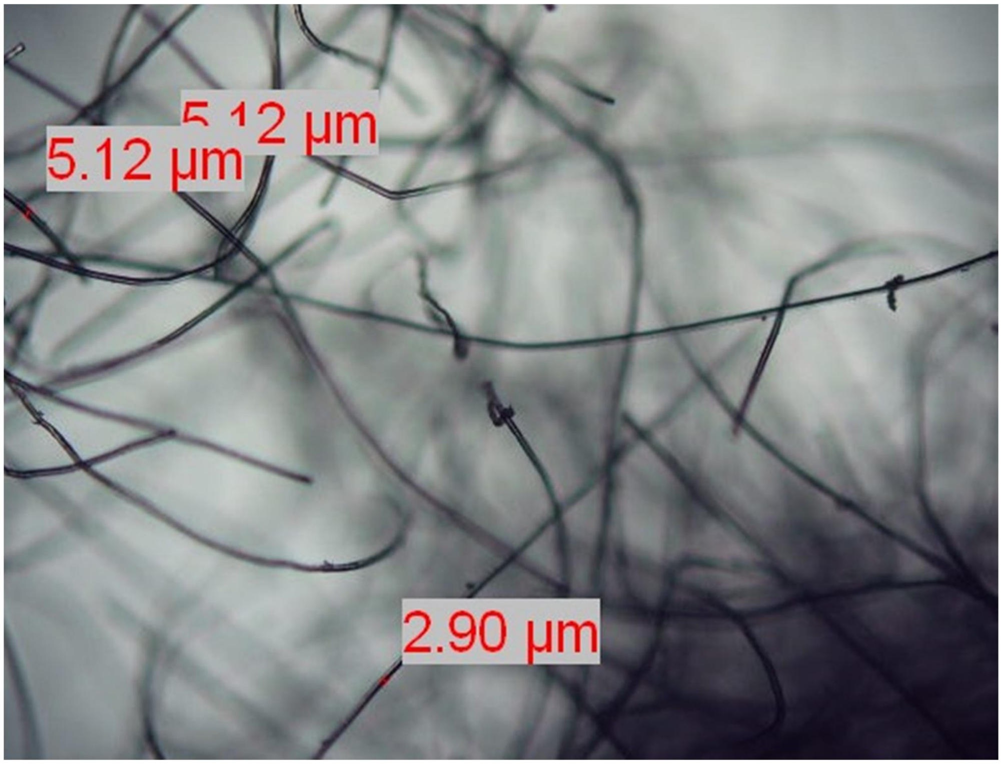

Fig. 4.1: OM image of 0.5 -1mm length polypropylene fibers

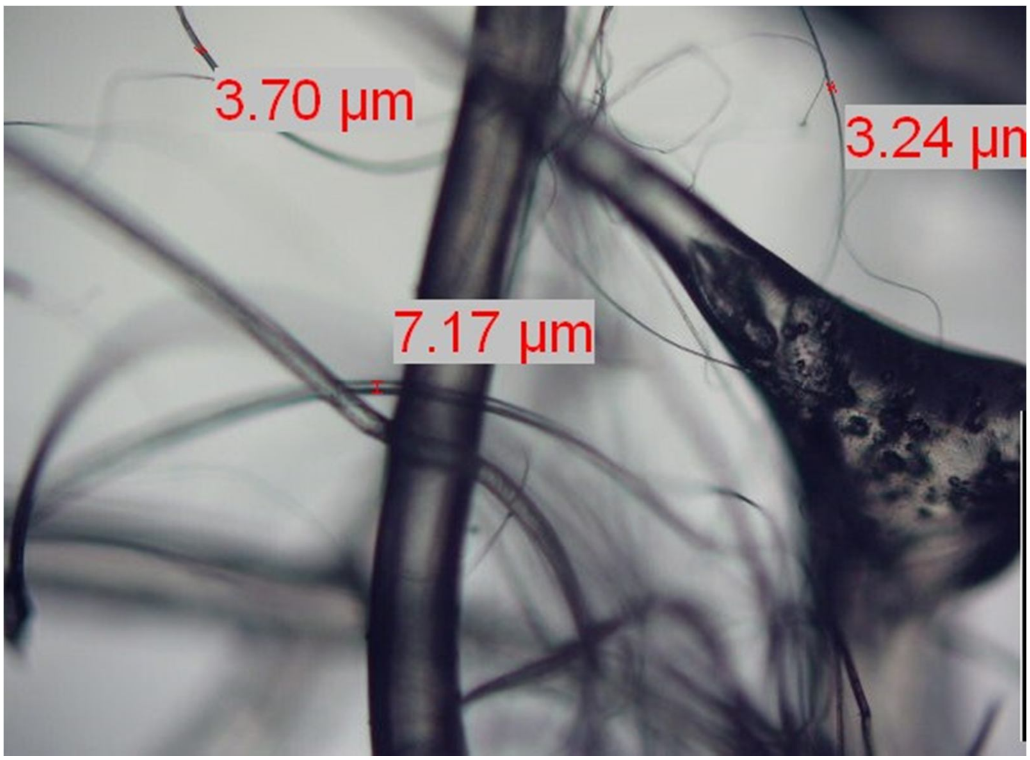

Fig. 4.2: OM image of 3 mm length polypropylene fibers

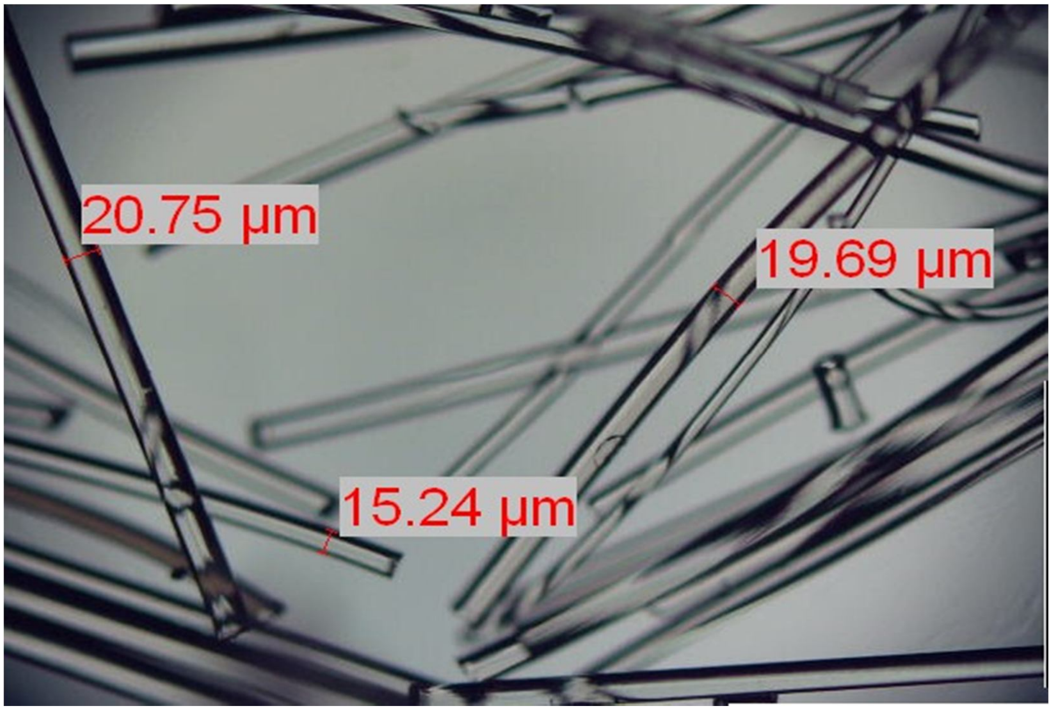

Fig. 4.3: OM image of 6 mm length polypropylene fiber

B. Scanning Electron Microscopy (SEM)

Scanning Electron microscopy was employed to observe the morphological structure of the polypropylene fiber. Hence morphology of fibers at 20 kv

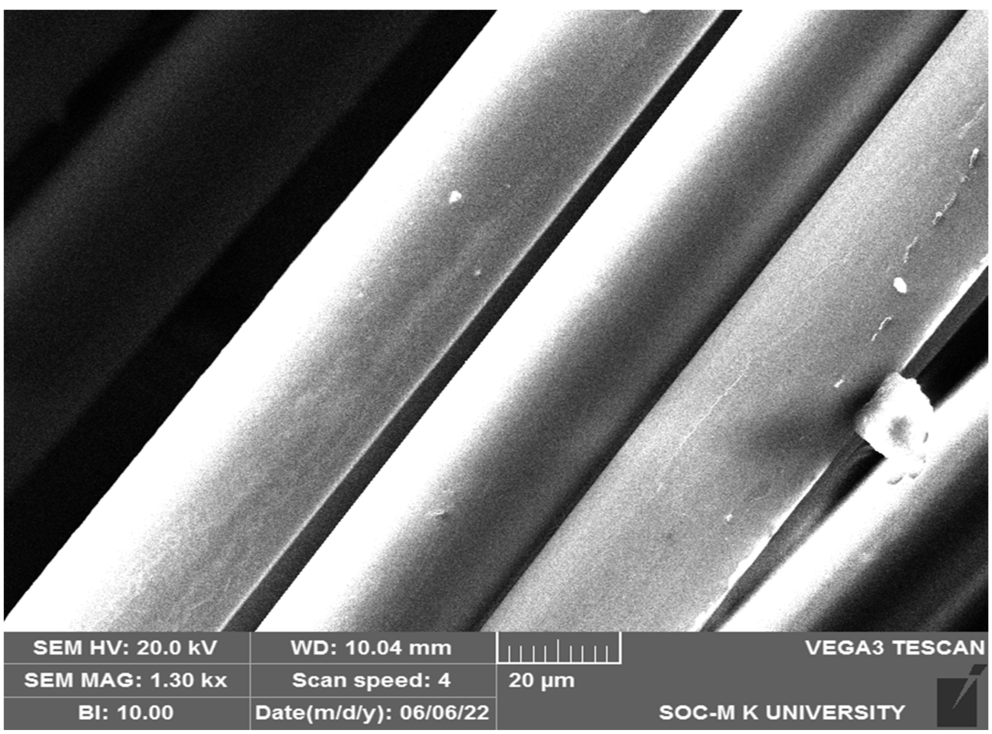

Fig. 4.4: SEM image of 0.5 -1mm length polypropylene fibers

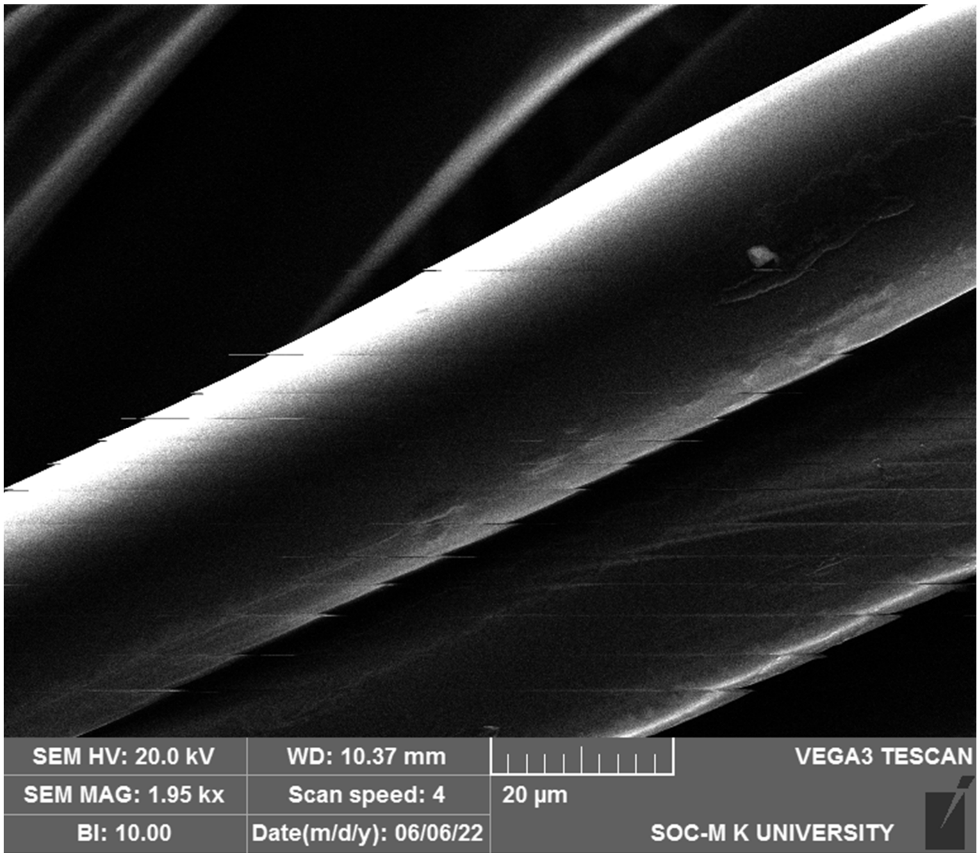

Fig. 4.5: SEM image of 3 mm length polypropylene fibers

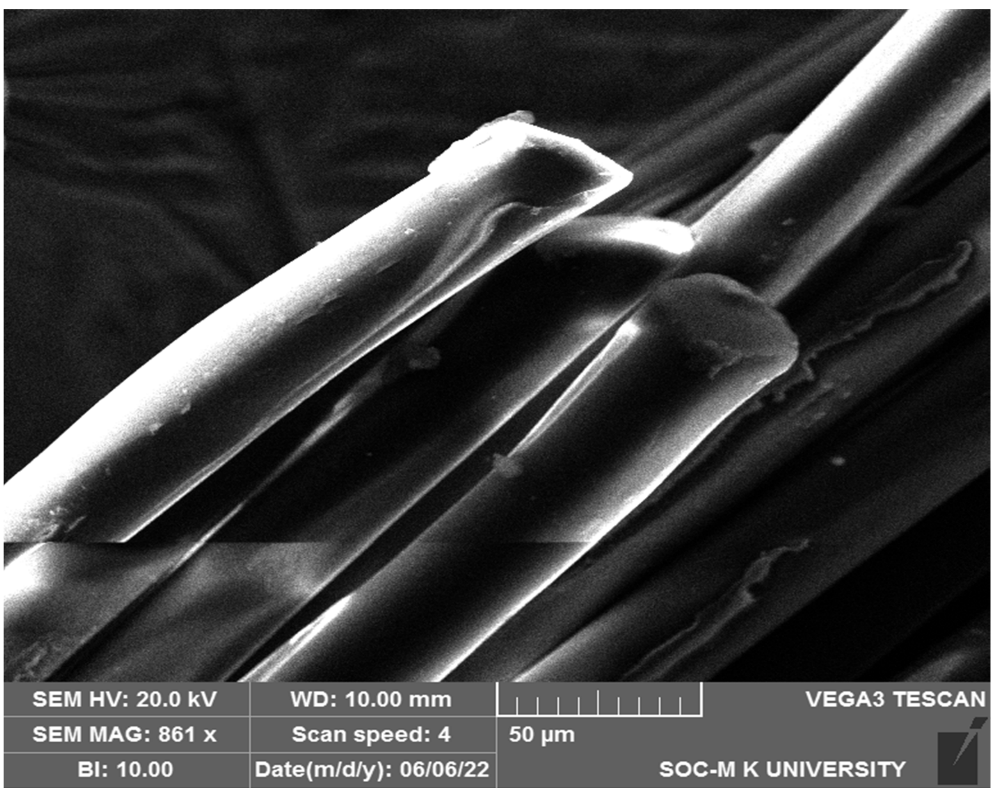

Fig. 4. 6: SEM image of 6 mm length polypropylene fiber

C. Confirmatory Tests (Specific Gravity of Fibers)

Confirmatory tests such as the Specific gravity of fibers give us confirmation about whether the fibers used are polypropylene fibers or another fiber. As we know that polymers with a specific gravity of greater than 1gm/cc goes down or settle in water whereas polymers with a specific gravity of less than 1gm/cc float on the surface of the water.

polypropylene fibers have a specific gravity of 0.91gm/cc and water has 1gm/cc therefore PP fibers floats on the surface, Therefore from fig.4.7 we confirm that the fibers that we are using are Polypropylene fibers.

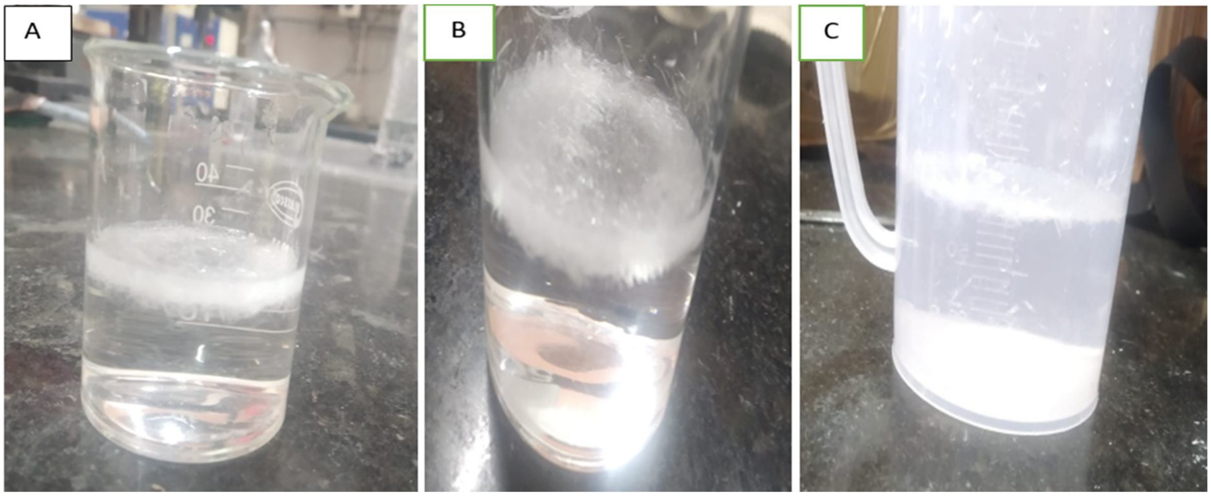

Fig. 4.7: Confirmation test (Specific gravity of Fibers) A - 0.5 – 1mm PP fibers, B – 3 mm PP fibers, C - 3mm PP fibers

V. RESULTS AND DISCUSSION OF REINFORCED COATING

The composite / reinforced coatings were formed by adding three different diameters of Polypropylene fibers as 5µm, 20µm, 50µm, and three different lengths of fibers such as 0.5 to 1mm, 3mm, 6mm in different concentrations such as 0.5% to 2 % during the formation of paints and were checked to find out the effect of different diameters and different lengths of polypropylene fibers on properties of reinforced coating (by comparing with standard paint).

figure 4.8 shows that reinforced coating with 3mm length of fibers and 20µm diameter of fibers gives good texture and as we increase or decrease the length of fibers and diameters of fibers, the fibers get accumulate and did not get the good texture to the coating. Therefore in the below experiments I only show the results of reinforced coating with 3mm length of fibers and 20µm diameter of fibers because it gives good texture and properties.

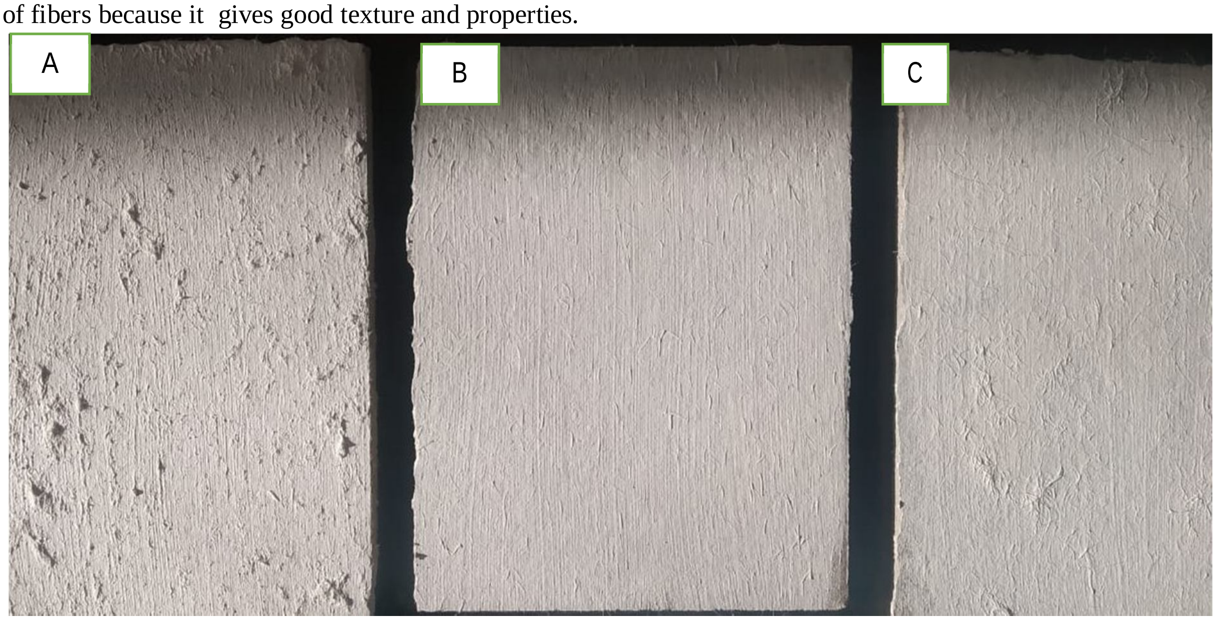

Fig. 5.1: Texture of reinforced coatings with A - 0.5-1mm length fibers and 20µm diameter fibers, B- 3mm length fibers and 20µm diameter fibers, C – 6mm length fibers and 50µm diameter fibers.

A. Water Resistance

The standard paint and paint with adding fibers of different concentrations were applied on a glass panel and dried for 7 days. After that panels are placed in an enclosed chamber containing a water and air mixture at a temperature of 38˚C at 100% relative humidity as per ASTM D 870. The paint applied has 200μm wet film thickness. The presence of water acted upon the surface of the paint and helps to determine the resistance of paint to water. After 12, 24, 48, and 96 hr the panels are evaluated for the color change, and blistering. Skinning of coating

Table. 5.1 Water Resistance - Blister formation on the surface

Time interval	color change and size of the blister				
	Standard Paint	0.5 % PP Fibers	1% PP Fibers	1.5 % PP Fibers	2% PP Fibers
12 hours	nil	nil	nil	nil	nil
24 hours	nil	medium	medium	nil	nil
48 hours	medium	medium	medium	medium	nil
96 hours	dense	dense	dense	medium	medium

B. Alkali Risistance

The standard paint and paint with adding fibers of different concentration applied on glass panel and dried for the 7 days. After that panels are immersed in alkali solution (30 gm of NaOH into water to prepare to 1 litre solution) as per ASTM D 1647. The paint applied has 200μm wet film thickness. The presence of water acted upon the surface of paint and helps to determine the resistance of paint to alkali media. After 12, 24, 48, and 96 hr the panels are evaluated for film whitening and blistering or loss of adhesion. Here we can see that as we increase the concentration of fibers in the coating, the results get satisfied.

Table. 5.2 Alkali Resistance -Blister formation on the surface

Time interval	Color change and size of the blister				
	Standard Paint	0.5 % PP fibers	1% PP fibers	1.5 PP fibers	2% PP fibers
12 hours	nil	nil	nil	nil	nil
24 hours	medium	medium	medium	medium	nil
48 hours	medium	medium	medium	medium	medium
96 hours	dense	dense	dense	medium	medium

C. Gloss

The standard paint and paint with adding fibers of different concentrations the paints were applied to a leneta paper with a wet film thickness of 200 µm and air dry for 24hr as per ASTM D 523. Gloss is measured at an angle of 60° by a digital gloss meter. Results show that as we increase the concentration of fibers the gloss is reduced we can see from the table that 0.5 % of fibers have high gloss compared to 2% fibers.

Table. 5.3 Results of Gloss test

Concentration	Gloss value
Standard Paint	9.6
0.5 % PP Fibers	8.9
1 % PP fibers	8.5
1.5 % PP fibers	8.3
2 % PP fibers	8.1

D. Wet Abrasion Test

Abrasion testing was performed using 5 panels (Fig.1 paint without fiber and fig. 2 to fig. 5 are painted with fibers of different concentrations such as 0.5%, 1%, 1.5%, 2%) and drying time 1 week at room temperature and the effect of different concentration of polypropylene microfiber on abrasion resistance is calculated. As the concentration of fibers increases the cycle time also increases (Table) and abrasion resistance increase. The number of scrub cycles required for the standard paint is less compared to the paint with fibers. Strong increases in wet abrasion resistance over time were seen for the paint with 2% fibers It is possible that because of polypropylene has excellent water resistance. The figure shows the abrasion resistance of paint without fibers and paints with different concentrations of fibers such as 0.5%, 1%, 1.5%, and 2%.

Table. 5.4 Results of wet scrub abrasion test

Sr. No.	Sample	No. of cycles required
1	Standard Paint	>4000
2	Paint + 0.5 % fibers	>4300
3	Paint + 1 % fibers	>4600
4	Paint + 1.5 % fibers	>4800
5	Paint + 2 % fibers	>5000

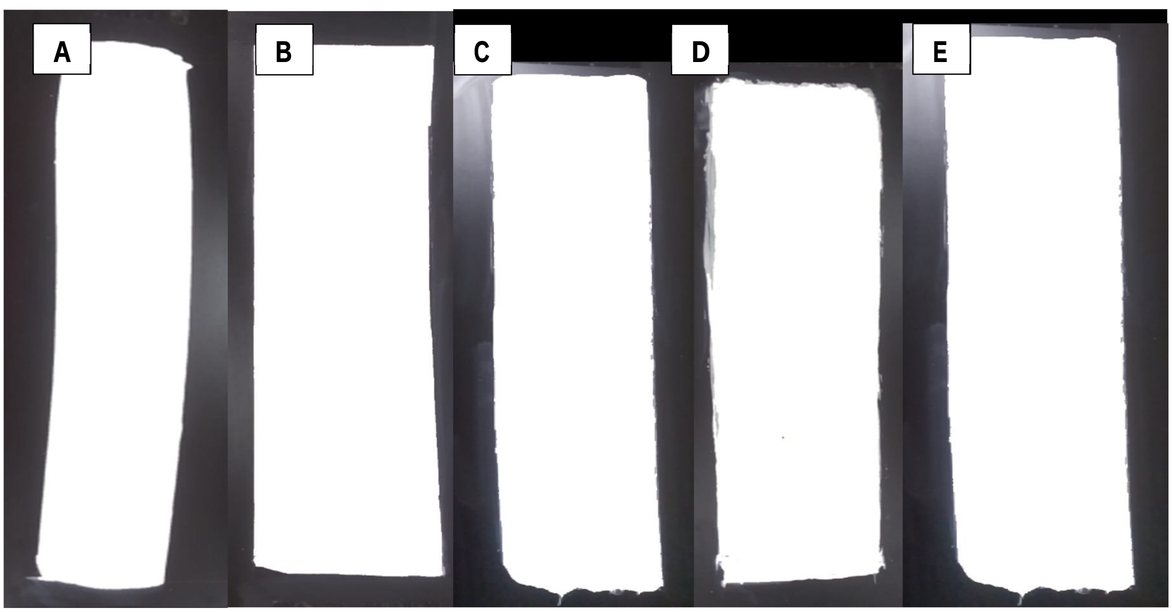

Fig. 5.2 : Wet abrasion scrub test A standard Paint, B. Paint + 0.5gm PP fibers, C. Paint + 1 gm PP fibers, D. Paint + 1.5gm fiber, E. Paint + 2 gm fiber

E. Stain Resistance

The coated panels (standard paint and paint with adding different concentrations of fibers) were subjected to various stains and practice to remove the stain from the coated panels were studied and rated as 1 to 10 for ease to remove the stain within a maximum of 50 rubs with cloth and the value " 1" for Poor and " 10 "for Excellent. The results of all panels such as (standard paint and paint with adding different concentrations of fibers) are summarized in the table 4.5.

As we increase the concentration of fibers in coating it gives excellent properties compared to less concentration of fibers

Fig. 5.3 : stain resistance test before and after

Table 5.5 stain resistance of different stains over coated paint samples and their rating

Sr. No.	Paint types	Pencil	Pen	Sketch pen	Lipstick	Oil	Ink	Coffee	Tea
1	Standard Paint	9	7	7	6	9	6	10	10
2	Paint + 0.5 % fibers	9	7	7	6	9	6	10	10
3	Paint + 0.5 % fibers	9	7	7	7	9	7	10	10
4	Paint + 0.5 % fibers	10	6	6	8	9	8	10	10
5	Paint + 0.5 % fibers	10	5	5	9	9	9	10	10

VI. CONCLUSION

In this paper we are adding polypropylene micro fibers in paint with different length of fibers (0.5-1mm, 3mm, 6mm) and different diameters of fibers (4 micron, 20 micron, 35 microns) in different concentration such as (0.5%, 1%, 1.5 %, 2%) . As per the results the 3mm length fibers with 20 micron diameter give best results among all different fibers therefore in this paper we only showing results of fibers with diamers 20 microns and length of 3mm.

VII. RESULS

As we increase the diameter and length of fibers (l/d- 6mm/35microns) the fibers get coagulate on paint films during applying paint also As we decrease the diameter and length of fibers(l/d- 0.5-1mm/4microns) the fibers get coagulate on paint films during applying paint and not get uniform film.

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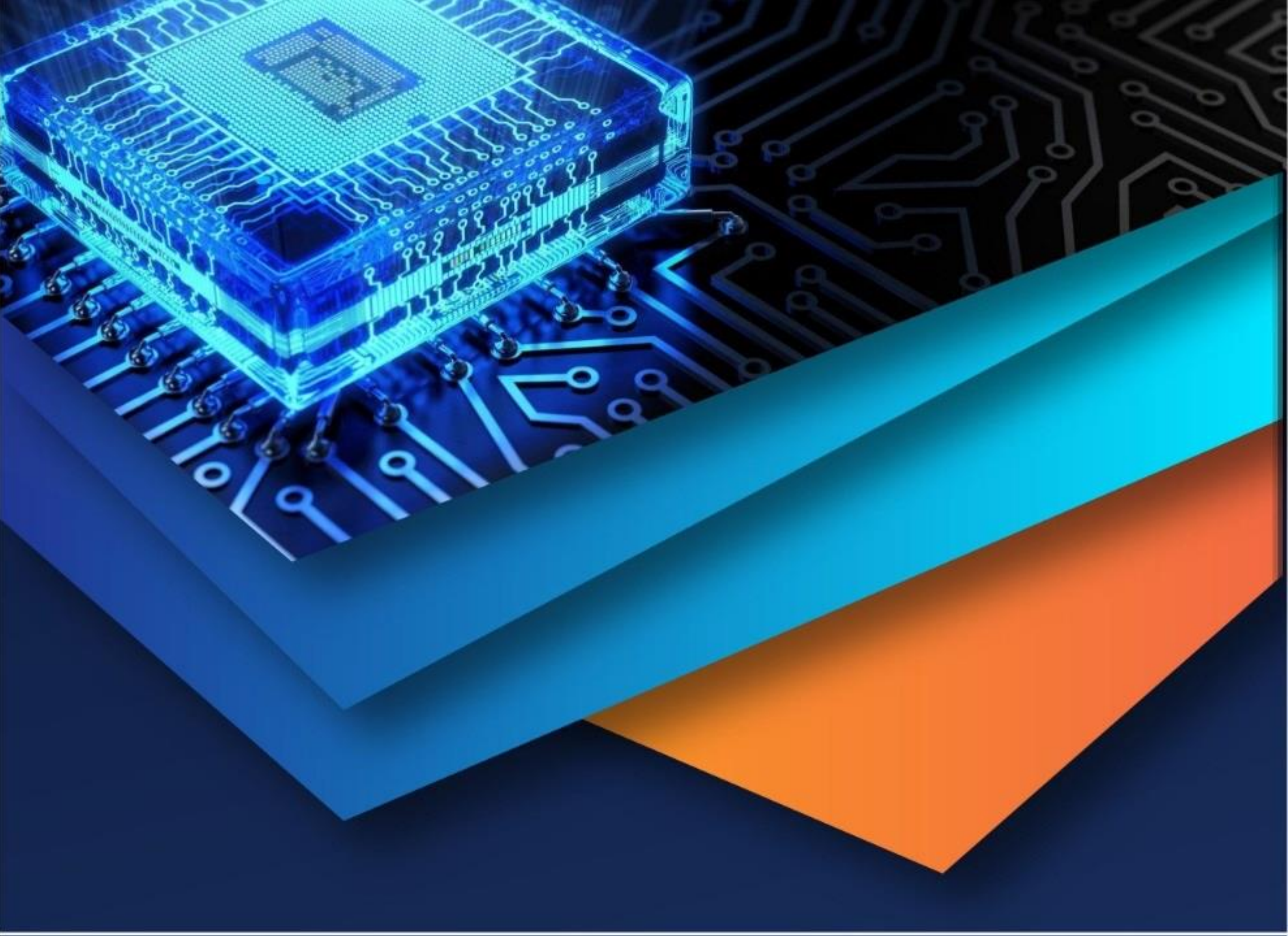

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