

Chemicals Used in Polymeric Material Coated Waste Paper Composites

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Abstract

In this research, at different quantities as fillers, Boric Acid, Calcite (CaCO_3), SPT (Sodium Perborate Tetrahydrate) and as coupling matters, 3%, MAPE (Maleic Anhydride Grafted Polyethylene), Titanate and Silanyl (Vinyltriethoxysilane) were added waste paper. Composite boards were pressed and cut in $1 \times 30 \times 30$ cm. In order to identify some properties of the produced boards, experimental works were applied according to the standards. In conclusion, bending stress reduced with filler materials and chemicals was reduced even more than the bending stress except for some experimental groups. In addition, it was observed that the coupling chemicals increased the bending strength and modulus of elasticity compared to the fillers.

Keywords

Matching Chemicals, Paper Composites, Filling Materials, Polymers, Coupling Agents, Paper Fibers

1. Introduction

Today, polymer materials consisting of paper, plastic and aluminum have a wide range of use as packaging materials, especially beverage cans. These materials are converted into composite materials thanks to additives and are brought to the industry as products with new different usage areas. Recycling waste materials without harm is an increasingly important issue. Plastic and paper raw materials, which are among the leading recycling materials, are essential components of composite products [1]. They can have unique advantages over solid materials such as high resistance, high hardness, low density, long durability life, high thermal stability, insulation and transmission [2].

The composite material structure consists of fibers and matrix. Matrix of these

materials does not dissolve by putting a different fiber or particulate material into it. Fibers are responsible for providing mechanical strength as reinforcement elements in composites. The matrix provides the stress transfer between the fibers. This affects the mechanical durability and chemical external effects, and forms the main structure of composite materials [3]. It protects the fibers against various chemical effects. Fiber-compatible matrixes significantly affect the harms in composite boards [4].

Application areas where composite materials are generally used are as follows, space technology, marine industry, medicine (manufacturing of medical devices), instruments industry, construction and construction industry, and automotive industry [5]. The thermoplastic material in Tetra Pak is holding the fibers together by acting as a matrix. Tetra Pak box components made of paper plastic and aluminum material are shown in **Figure 1** [6].

Raw materials affect the process and the material properties of the manufacturing of composites affect the cost. These are the fillers and matching chemicals used.

In this research, the physical and mechanical waste paper ratios, reinforcing filler ratios, and the ratios of different adapting agents on composite materials produced from the waste paper were investigated. Various proportions of coupling chemicals and fillers have been used to bind polar paper material and nonpolar thermoplastic polymers together. Considering that there are tons of waste paper will be evaluated in Türkiye, this study is important. The silane binding mechanism is shown in **Figure 2**.

2. Materials and Methods

Plastic and various chemical matching substances added to Tetra Pak materials in the production of composite materials as follows, plastic material (polyethylene), Calcite, Boric Acid, Sodium Perborate Tetrahydrate (SPT), Titanate, Acetic Acid,

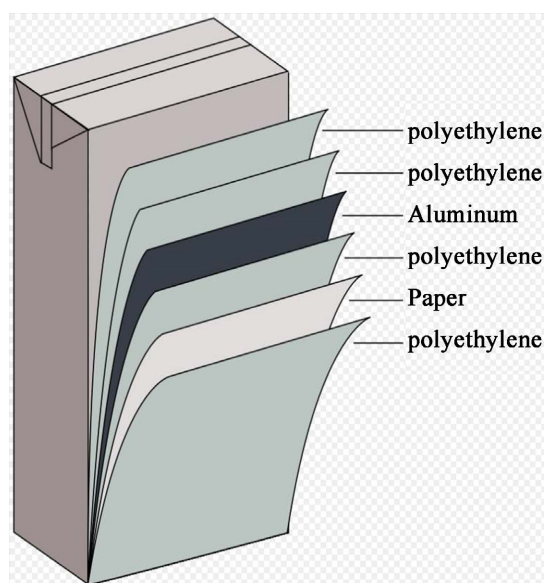


Figure 1. Layers Tetra Pak.

Maleic Anhydride Grafted Polyethylene (MAPE), Vinyltriethoxysilane (Silanyl). Filling materials, matrix and matching chemicals in the composite material produced in the study are shown in **Figure 3**.

2.1. Tetra Pak (TP)

Paper products supplied in small pieces were shredded in a 1 mm shredder machine and made suitable for production.

2.2. Polyethylene (PE)

Waste High Density Polyethylene (HDPE) used as polymer was obtained from commercial sources. Waste Polyethylene was preferred in this study. It is a easy to find and inexpensive material to supply.

2.3. Filling Materials

Calcite (CaCO_3), used as a filler material, is abundant in nature and is used as a filling substance, paint and plastic industries. It has been preferred because it is cheap and has the significant volume to fill the gap between the reinforcement material and the polymer matrix. Boric Acid (H_3BO_3) is not a flammable substance

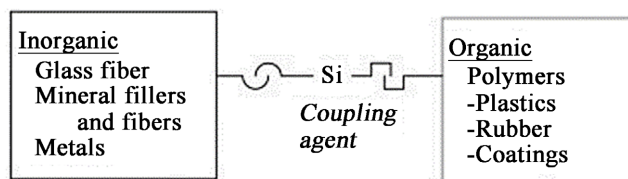


Figure 2. Binding silane mechanism [7].

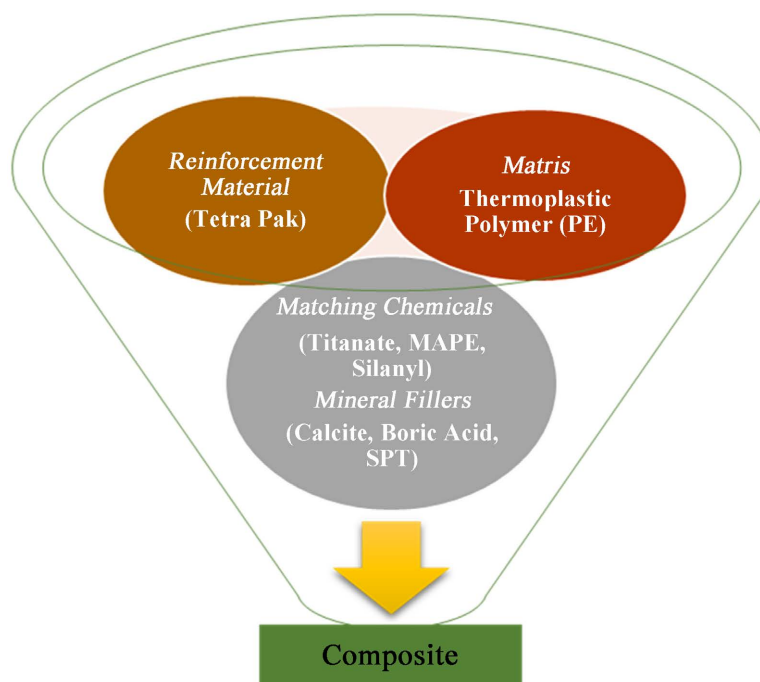


Figure 3. Representation of the composite material content produced.

and has flame retardant properties.

In this research, it was preferred to prevent possible burns on composite sheets to be produced under hot press.

SPT (Sodium Perborate Tetrahydrate/ $\text{NaBO}_3 \cdot 4\text{H}_2\text{O}$) is in the form of powder. To reinforcement materials used, a more economical and robust material will be obtained.

2.4. Matching Chemicals

Titanate improves hydrophobicity and eliminates air pockets. MAPE (Maleic Anhydride Grafted Polyethylene) used as a compatibilizer, MAPE has been applied to improve interfacial adhesion between high density polyethylene and fiber [8]. Silanyl (Vinyltriethoxysilane $\text{C}_8\text{H}_{18}\text{O}_3\text{Si}$) is used to bond organic polymers and inorganic reinforcement materials due to its surface tension adjustment feature [9].

A total of 38 different recipes were used in different groups as Tetra Pak (TP), TP + plastic (PE), Tetra Pak + plastic (PE) + matching chemical/filler. In the laboratory environment, in a press (hot) at 200 bar pressure, at 170°C for approximately 10 minutes. It was pressed and produced in $1 \times 30 \times 30$ cm dimensions. One panel was produced for each recipe. The mixing percentages of the composite panels are shown in **Table 1**.

Table 1. Composite panels types and percentages

Composite Panels Types	Tetra Pak (TP)	MAPE (%)	Titanate (%)	Silanyl (%)	Calcite (%)	Boric Acid (%)	SPT (%)
TP	100	-	-	-	-	-	-
TP + PE	90 + 10	-	-	-	-	-	-
TP + PE + Calcite	95	-	-	-	5	-	-
TP + PE + Calcite	85	-	-	-	15	-	-
TP + PE + Calcite	75	-	-	-	25	-	-
TP + PE + Boric Acid	95	-	-	-	-	5	-
TP + PE + Boric Acid	85	-	-	-	-	15	-
TP + PE + Boric Acid	75	-	-	-	-	25	-
TP + SPT + PE + (AA)	95	-	-	-	-	-	5
TP + SPT + PE + (AA)	85	-	-	-	-	-	15
TP + SPT + PE + (AA)	75	-	-	-	-	-	25
TP + PE + Titanate	100	3	-	-	-	-	-
TP + PE + Boric Acid + Titanate	95	-	3	-	-	5	-
TP + PE + Boric Acid + Titanate	85	-	3	-	-	15	-
TP + PE + Boric Acid + Titanate	75	-	3	-	-	25	-
TP + PE + Calcite + Titanete	95	-	3	-	5	-	-
TP + PE + Calcite + Titanete	85	-	3	-	15	-	-

The differences in the control samples used in the study in terms of various matching chemicals were evaluated by One-way analysis of variance (One-Way Anova test). If there was a statistically significant difference at the $P = 0.05$ significance level between the composite groups in terms of mechanical properties as a result of the analysis of variance, the Tamhane T2 test, one of the Post-Hoc (Multiple comparison) tests, was used to determine the different composite groups.

3. Results and Discussion

Since the significance level is $P < 0.05$ in the Anova table, it is seen that there is a statistically significant and significant difference between the groups in terms of the flexural strengths examined. The differences between the mean values of the groups were determined by Tamhane T2 test. It was checked by the Tamhane T2 test which composite groups were different in terms of flexural strength. It is shown in **Table 2**.

When **Table 2** is examined, it has been determined that there is a significant difference between the groups with an asterisk (*) next to them in terms of the

Table 2. Tamhane T2 test results of flexural strength values of composites.

Composite Types					
(I) Composite	(J) Composite	I-J	Standard Error	Significance Level	
Tetra Pak + Plastic	% 5/15/25 Calcite	3.038ns.	1.703	0.98	
	% 5/15/25 Boric Acid	3.842ns.	1.181	0.16	
	% 5/15/25 SPT + Aa	5.935ns.	1.558	0.07	
	Tetra Pak + PE + % 3 Titanate	5.501ns.	1.649	0.60	
	% 5/15/25 Boric Acid + %3 Titanate	8.638***	1.099	0.00	
	% 5/15-/25 Calcite + %3 Titanate	6.451***	1.052	0.00	
	% 5/15 SPT + AA + % 3 Titanate	7.544***	1.206	0.001	
	% 5/15 Boric Acid + % 3 Mape	8.548***	0.963	0.00	
% 15/25 Boric Acid + % 3 Silanyl	% 15/25 Boric Acid + % 3 Silanyl	6.636***	1.115	0.001	
	Tetra Pak + Plastic	-3.038ns.	1.703	0.98	
	% 5/15/25 Boric Acid	0.804ns.	1.723	1.00	
	% 5/15/25 SPT + Aa	2.897ns.	2.001	1.00	
	Tetra Pak + Plastic + % 3 Titanate	2.463ns.	2.072	1.00	
	% 5/15/25 Calcite	% 5/15-/25 Boric Acid + %3 Titanate	5.599ns.	1.668	0.16
	% 5/15/25 Calcite + %3 Titanate	3.413ns.	1.638	0.91	
	% 5/15 SPT + AA + %3 Titanate	4.505ns.	1.740	0.58	
% 5/15 Boric Acid + % 3 MAPE	5.510ns.	1.582	0.16		
% 15/25 Boric Acid + % 3 Silanyl	3.598ns.	1.679	0.88		

Continued

	Tetra Pak + Plastic	-3.842ns.	1.181	0.16
	% 5/15/25 Calcite	-0.804ns.	1.723	1.00
	% 5/15/25 SPT + Aa	2.093ns.	1.581	1.00
	Tetra Pak + PE + % 3 Titanate	1.659ns.	1.671	1.00
% 5/15/25 Boric Acid	% 5/15/25 Boric Acid + % 3 Titanate	4.795*	1.131	0.01
	% 5/15/25 Calcite + % 3 Titanate	2.609ns.	1.085	0.69
	% 5/15 SPT + Aa + % 3 Titanate	3.701ns.	1.235	0.30
	% 5/15 Boric Acid + % 3 MAPE	4.70616**	0.999	0.009
	% 15/25 Boric Acid + % 3 Silanyl	2.794ns.	1.146	0.67
	Tetra Pak + PE	-5.935ns.	1.558	0.07
	% 5/15/25 Calcite	-2.897ns.	2.001	1.00
	% 5/15/25 Boric Acid	-2.093ns.	1.581	1.00
	Tetra Pak + PE + % 3 Titanate	-0.434ns.	1.955	1.00
% 5/15/25 SPT + Aa	% 5/15/25 Boric Acid + % 3 Titanate	2.702ns.	1.520	0.99
	% 5/15/25 Calcite + % 3 Titanate	0.515ns.	1.487	1.00
	% 5/15 SPT + AA + % 3 Titanate	1.608ns.	1.599	1.00
	% 5/15 Boric Acid + % 3 MAPE	2.612ns.	1.425	0.98
	% 15/25 Boric Acid + % 3 Silanyl	0.701ns.	1.532	1.00
	Tetra Pak + PE	-5.501ns.	1.649	0.60
	% 5/15/25 Calcite	-2.463ns.	2.072	1.00
	% 5/15/25 Boric Acid	-1.659ns.	1.671	1.00
	% 5/15/25 SPT + Aa	0.434ns.	1.955	1.00
Tetra Pak + Plastic + % 3 Titanate	% 5/15/25 Boric Acid + % 3 Titanate	3.136ns.	1.613	0.99
	% 5/15/25 Calcite + % 3 Titanate	0.949ns.	1.582	1.00
	% 5/15 SPT + Aa + % 3 Titanate	2.042ns.	1.688	1.00
	% 5/15 Boric Acid + % 3 MAPE	3.046ns.	1.524	0.99
	% 15/25 Boric Acid + % 3 Silanyl	1.135ns.	1.624	1.00
	Tetra Pak + PE	-8.638***	1.099	0.00
	% 5/15/25 Calcite	-5.599ns.	1.668	0.16
	% 5/15/25 Boric Acid	-4.795*	1.131	0.01
	% 5/15/25 SPT + Aa	-2.702ns.	1.520	0.99
% 5/15/25 Boric Acid + % 3 Titanate	Tetra Pak + Plastic + % 3 Titanate	-3.136ns.	1.613	0.99
	% 5/15/25 Calcite + % 3 Titanate	-2.18630ns.	0.995	0.83
	% 5/15 SPT + Aa + % 3 Titanate	-1.09401ns.	1.156	1.00
	% 5/15 Boric Acid + % 3 MAPE	-0.089ns.	0.900	1.00
	% 15/25 Boric Acid + % 3 Silanyl	-2.001ns	1.061	0.97

Continued

	Tetra Pak + PE	-6.451***	1.052	0.00
	% 5/15/25 Calcite	-3.413ns.	1.638	0.91
	% 5/15/25 Boric Acid	-2.609ns.	1.085	0.69
	% 5/15/25 SPT + Aa	-0.515ns.	1.487	1.00
% 5/15/25 Calcite + % 3 Titanate	Tetra Pak + PE + % 3 Titanate	-0.949ns.	1.582	1.00
	% 5/15/25 Borik Asit + % 3 Titanate	2.186ns.	0.995	0.83
	% 5/15 SPT + Aa + % 3 Titanate	1.092ns.	1.112	1.00
	% 5/15 Boric Acid + % 3 MAPE	2.096ns.	0.842	0.64
	% 15/25 Boric Acid + % 3 Silanyl	0.185ns.	1.013	1.00
	Tetra Pak + Plastic	-7.544**	1.206	0.001
	% 5/15/25 Calcite	-4.505ns.	1.740	0.58
	% 5/15/25 Boric Acid	-3.701ns.	1.235	0.30
	% 5/15/25 SPT + Aa	-1.608ns.	1.599	1.00
% 5/15 SPT + Aa + % 3 Titanate	Tetra Pak + Plastik + % 3 Titanate	-2.042ns.	1.688	1.00
	% 5/15/25 Boric Acid + % 3 Titanate	1.094ns.	1.156	1.00
	% 5/15/25 Calcite + % 3 Titanate	-1.092ns.	1.112	1.00
	% 5/15 Boric Acid + % 3 MAPE	1.004ns.	1.028	1.00
	% 15/25 Boric Acid + % 3 Silanyl	-0.907ns.	1.172	1.00
	Tetra Pak + PE	-8.548***	0.963	0.00
	% 5/15/25 Calcite	-5.510ns.	1.582	0.16
	% 5/15/25 Boric Acid	-4.706**	0.999	0.00
	% 5/15/25 SPT + Aa	-2.612ns.	1.425	0.98
% 5/15 Boric Acid + % 3 MAPE	Tetra Pak + Plastik + % 3 Titanate	-3.046ns.	1.524	0.99
	% 5/15/25 Boric Acid + % 3 Titanate	0.089ns.	0.900	1.00
	% 5/15/25 Calcite + % 3 Titanate	-2.096ns.	0.842	0.64
	% 5/15 SPT + AA + % 3 Titanate	-1.004ns.	1.028	1.00
	% 15/25 Boric Acid + % 3 Silanyl	-1.911ns.	0.920	0.92
	Tetra Pak + PE	-6.636**	1.115	0.001
	% 5/15/25 Calcite	-3.598ns.	1.679	0.88
	% 5/15/25 Boric Acid	-2.794ns.	1.146	0.67
	% 5/15/25 SPT + Aa	-0.701ns.	1.532	1.00
% 15/25 Boric Acid + % 3 Silanyl	Tetra Pak + PE + % 3 Titanate	-1.135ns.	1.624	1.00
	% 5/15/25 Boric Acid + %3 Titanate	2.001ns.	1.061	0.97
	% 5/15/25 Calcite + % 3 Titanate	-0.185ns.	1.013	1.00
	% 5/15 SPT + Aa + % 3 Titanate	0.907ns.	1.172	1.00
	% 5/15 Boric Acid + % 3 MAPE	1.911ns.	0.920	0.92

effect of chemical substance types on the bending strength of composite materials formed with various chemicals and binding agents. According to Tamhane T2 test results, on the modulus of elasticity in bending of Tetra Pak + PE group: Tetra Pak + PE + BA + Titanate, Tetra Pak + PE + Calcite + Titanate, Tetra Pak + PE + SPT + AA + Titanate, Tetra Pak + PE + BA + Mape, Tetra Pak + PE + BA + Silanyl groups determined that showed significant differences. It has been observed that the effect of the type of coupling chemical added to the composites on the flexural strength of Tetra Pak + PE composites generally makes a difference. It was determined that there was no significant difference between the calcite added composite groups and the other groups in terms of flexural strength. It was determined that there was a significant difference between the groups with Boric Acid added to the Tetra Pak + PE mixture with the composite groups with Boric Acid + Titanate and Boric Acid + MAPE added in terms of bending strength. It was determined that there was no significant difference between the flexural strength of the SPT + AA added composite group with the other chemical added composite groups.

Statistical findings of modulus of elasticity (MOE) in bending:

Since the significance level is $P < 0.05$ in the Anova table, it is seen that there is a statistically significant and significant difference in terms of the elasticity modulus examined between the groups. The differences between the mean values of the groups were determined by Tamhane T2 test. It was checked by the Tamhane T2 test which composite groups differed in terms of elasticity modulus.

When Tamhane T2 test results of modulus of elasticity values of composites is examined, it has been determined that there is a significant difference between the groups with an asterisk (*) next to them in terms of the effect of chemical substance types on the modulus of elasticity in bending of composite materials formed with various chemicals and binding agents. According to Tamhane T2 test results, on the flexural modulus of elasticity of Tetra Pak + PE group, Tetra Pak + PE + Calcite, Tetra Pak + PE + Titanate, Tetra Pak + PE + Calcite + Titanate, Tetra Pak + PE + SPT + AA + Titanate, Tetra Pak + PE + SPT + AA + MAPE, Tetra Pak + PE + It was determined that there were significant differences in the BA + Silanyl groups. It has been observed that the effect of the type of coupling chemical added to the composites on the flexural modulus of elasticity of Tetra Pak + Plastic composites generally makes a difference. However, it was determined that Tetra Pak + PE group showed similar modulus of elasticity with Tetra Pak + PE + BA + MAPE and Tetra Pak + Plastic + Calcite + MAPE groups and did not create a significant difference.

4. Conclusions

In the study, silanes, one of the bonding agents or coupling chemicals, are used to match the composite material components to each other. They are the binding agents used to combine polymer and mineral fibers.

According to a study, they reported that EPOLENE E-43, a type of MAPP

with low component effects, was successful as a binder in polypropylene PP and thermomechanical pulp composites [10].

It has been used in our country because of its easy and abundant availability and cheapness. Since Boron production in Türkiye is sufficient for our country, there is no import [11].

According to a study, the known types of titanate binding agents are very effective in improving the mechanical properties of composites [12]. According to another study, the incorporation of the titanate binding agent resulted in a decrease in yield stress and flexural strength [13].

Thanks to the covalent bond between the matrix and the fiber obtained by adding silane, swelling of the fibers is prevented [14]. Another binder, maleic agents, which are used to modify the surface, positively affect the interfacial connection and mechanical properties [15].

The right binding agent creates a water-resistant bond at the interface between inorganic and organic materials. The silane binding agent has a unique chemical and physical property to increase bond strength. Even though the elasticity modules of the composite materials made from waste papers sometimes show very low values with the effect of added plastic material and various chemicals. It can be shown as a good alternative to wood material in terms of both waste evaluation and less deflection by showing high values.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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