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Araştırma Makalesi / Research Article

The Importance of GRP Composite Material in Liquid Fertilizer Tanks and Production Optimization of the Tanks

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Öz

Kompozit malzemeler sahip oldukları üstün özelliklerden dolayı imalat sektöründe birçok alanda oldukça yaygın kullanılmaktadır. Bu çalışmada cam elyaf takviyeli plastik (CPT) kompozit malzemeden tarım sektöründe sıvı gübrelerin taşınmasında kullanılan tanker imalatı ve optimizasyonu çalışılmıştır. Özellikle bitkilerin gelişiminde organik gübre kullanımına önem verilmektedirler. Gübre içeriğinde bulunan azot, fosfor, potasyum, kalsiyum, magnezyum, kükürt, demir, manganez, bakır, çinko ve bor gibi büyük miktarlardaki elementler taşıma kapları ile kimyasal reaksiyona girebilir. Bu kimyasal reaksiyonları gözlemlemek amacı ile deney kapları hazırlanmıştır. Bu kaplarda yoğunlaştırılmış farklı sıvı gübre çeşitleri oluşturulmuştur. Bunlar için uygun zaman aralıkları seçilerek pH dereceleri masa tipi "ohaus AB23PH-F" ölçülmüştür. Hazırlanan tavuk gübresinin pH değeri 8,44 küçükbaş hayvan gübresinin pH değeri 8,34 güvercin gübresinin pH değeri 7,54 ve büyükbaş hayvan gübresinin pH değeri 9,03 olarak ölçülmüştür. Bununla birlikte sıvı gübreler 20 °C de kapalı yalıtımlı kap içerisinde bekletilip nem oranları %58 olarak belirlenmiştir. Deney kaplarında sıvı gübre içinde bekletilen ST37 çelik numuneler ve CTP nin SEM, XRD ve optik görüntüleri ve kütle kayıpları değerlendirilmiştir. Korozif ortamlardaki CTP numunelerinde korozyona rastlanmamıştır. İki faklı malzemeden $10m^3$ hacminde tanker tasarımı yapılmıştır. Sonlu elemanlar analizi sonucunda güvenli olarak kullanılabilecek CPT tankerin et kalınlığı 12mm bu tankerin ağırlığı 702 kg olarak hesaplanmıştır. Aynı hacim ve 3 mm kalınlıkta tasarlanan ST37 çelik tankerin ağırlığı 3504 kg olmaktadır. Korozyona karşı dirençli ve yaklaşık 5 kat daha hafif olması CPT kompozit malzemeden imal edilen tankerlerin uygun olacağı düşünülmüştür.

Anahtar Kelimeler
Korozyon, Kompozit, Sıvı gübre tankeri, Sonlu Elemanlar, CTP.

Abstract

Due to their superior features, composite materials are commonly used in many various fields in production industry. In this study, the production and optimization of the tanks which are made of Glass Fiber Reinforced Plastic (GRP) composite materials and used in transporting liquid fertilizers in agricultural industries were studied. The application of organic fertilizers is particularly important in plant growing. Elements which are present in fertilizers, such as nitrogen, phosphor, potassium, calcium, magnesium, sulfur, iron, manganese, copper, zinc and boron may chemically react with container drums. Experimental containers were prepared in order to observe these chemical reactions. Various types of condensed liquid fertilizers were composed in those containers. PH values were measured via benchtop "Ohaus AB23PH-F" at predesignated time intervals. The pH values were measured as following: 8.44 for chicken manure, 8.34 for small cattle manure, 7.54 for pigeon manure and 9.03 for cattle manure. In addition to that, liquid manures were kept at 20 °C in an isolated container and humidity was measured 58%. SEM, XRD and optical images of St37 Steel specimens which were kept in liquid fertilizers in experiment containers and GRP and mass loss were evaluated.

eywords
Corrosion, Composite, Liquid fertilizer tanks, Finite Elements, CTP.

No corrosion was observed in GRP in corrosive environment. Users prefer those materials due to the fact that they have high corrosion resistance, and they are light material. A $10m^3$ tank was designed out of those materials which are very common in production industry. The method of finite elements was used in the design and their weights were compared. As for the results of finite elements analysis, the wall thickness of the GRP tank for safe use was calculated to be 12mm and the weight of that tank was calculated to be 702kg. The weight of the St37 steel tank of the same volume and 3mm thickness is 3504kg. It was thought that tanks made of GRP composite material would be convenient due to the fact that they are corrosion resistant and 5 times lighter.

1. Introduction

Composite materials continue to play an important role in human history, from the first civilizations to today's innovations. Compared to fully dense materials such as steel and aluminum, composites offer several advantages such as lightweight, high strength and stiffness, excellent vibration-damping properties, design flexibility, and resistance to corrosion and wear. These unique properties have made composite materials ubiquitous every day, from household goods to complex fields such as biomedical, sports, marine, agricultural implements, and construction industries. Additionally, some critical applications, such as aircraft and spacecraft, would be impossible without composite materials. Today, the composites industry continues to evolve, with major growth focused on renewable energy. (Weiland, K. at all 2021, S.; Alammar, S. At all 2020, Fedosyuk, R.L. at all 2021, Friedrich, K., Almajid, A. A., 2013). Many experiments have been carried out to increase the mechanical properties of composite materials. A new test configuration was proposed to measure the transverse compressive strength of unidirectional composite layers by three-point bending and was examined with cross-ply test specimens. Cross-ply carbon/epoxy with different thicknesses were tested by three-point bending until failure. Transverse compression damage area, as found in the literature it was found to be in good agreement with the studies. Tensile stresses are lower than bending stresses in 90° laminates, maximum tensile stresses are lower than longitudinal tensile stresses in 0° laminates, but the maximum It was determined that the tensile stress was very close to the tensile stress. Composite materials are used in various fields such as space and aeronautics industry, food and medical industry, building and construction industry, technology industry and in manufacturing the machines which help people cater for their needs. The production of these materials in different areas such as agricultural tools, automotive and aviation industries is due to the differences in their thermal and mechanical properties (Hollaway at all 2004)One of the sectors where those materials are widely used is agricultural machines and tools. They actively play a role in transporting clean water to the consumer, in irrigation tools and equipments in agricultural industry, and in storing and transporting products such as petroleum and fertilizers. Some of the most determining factors in product design, particularly in storing and transporting, are that human health is taken into consideration, that the product being carried is not spoiled and that the container is not damaged. Tanks used in agricultural field for fertilizing and applying agricultural pesticide are important in that regard. Minimizing the chemical effects of substances stored or carried on the tank material and maintaining long-lasting tools are required qualifications. In the study conducted in order to determine mechanical properties of composites, reinforced and extended fiber length and ratio are under the effect of tensile and flexural strength. (Demircioğlu 2006, Demirer, Aydın, 2016). In the studies carried out; The impact strength of glass fiber/epoxy composites containing different orientations with different impact energy values was examined experimentally. For the impact test, samples measuring 150 mm x 100 mm consisting of 8 and 12 layers were created and tested at increasing impact energy values of 10 J, 20 J, and 30 J (Öndürücü, A., & Karacan 2004). In studies examining the behavior of fiber orientation and layer thickness against impact, it was observed that the amount of collapse increased despite increasing impact energy and that the sample with the highest collapse for 30J impact energy was the sample with [0°/30°/60°/0°] fiber alignment. High corrosion, high hardness, high specific strength, and light weight properties of composite materials. More efficient than traditional materials Allows structural design. Basically, polymer composites have more than one phase materials and at least one phase is a polymer matrix (K.P. Ashik and R.S. Sharma 2015). A study was conducted on the resistance properties and corrosion resistance of fiber glass reinforced epoxy composite materials. It was observed that Boric acid addition of reinforcement phases caused a decrease in corrosion resistance and, along with that, size of reinforced abrasive particles and the changes in various fiber directions caused remarkable changes in corrosion rate(Bağcı 2010). In the study conducted on mechanical properties of GRP composites, it was determined that, along with the increase in number of layers in the structure and the resin density, there was an increase in mechanical values, however, there was no changes in mechanical properties after a certain number of fiber glass layers (Türkmen, Köksal 2012). It was indicated that size and geometry of the ceramic powder mixtures which was added into matrix ceramic in epoxy matrix fiber glass reinforced composites significantly affected physical and mechanical properties (Asi, Gün, Asi, 2018). It was indicated in the study that the ratio of fiber volume of elastic modules in GRP composite materials increases (Turhan 2007). In the study conducted on fatigue life behavior of GRP composites, it was demonstrated that reinforced fibers abandoned matrix phase and the polyester resin matrix was degraded (Aydınlı 2021). They studied the behaviors of GRP composite materials in conditions in different environmental medium. They analyzed the corrosion resistance in environmental conditions such as salty water environment, acid environment and accelerated aging (Korku 2021). A bending simulation on laminated composites was developed to investigate the effects of placement. The results of the FEA (Finite Element Analysis) simulation revealed in-plane normal stresses in the cross-edged laminate and in-plane shear stress in the angled laminate near the free edge region. These transverse normal stresses are not taken into account in traditional laminate theory (Carbajal, N., & Mujika 2001). Many experimental and theoretical studies have been carried out. Two different composites the force-displacement behavior of the material was compared experimentally and numerically with the ANSYS finite element method. As a result of these studies, numerical solution and experimental solution gave similar results (Meng, M., at all 2015). In the analysis of GRP composite structures with finite elements, they determined approach methods with finite elements on the effects of reinforcement phases directed differently in matrix phase, in order to demonstrate the potential which the structure had (Aydın and Kefal 2020).

In this study, the weight and corrosion resistance features of liquid fertilizer tanks used in agricultural industry today. Cattle and small cattle manures, pigeon manures and chicken manures are used in plant development in agricultural field. Experiment specimens were prepared, which were made from those materials used in the production of the tanks. After the materials to be used in the experiment were sized 25x40x2mm, kept in resting container in 60gr fertilizer and rinsed with distilled water once in every ten days, their weight changes were measured by 0.00001g precision scale. SEM analysis was applied on those specimens and the structures formed on them were examined. 10m3 tanks were designed and the thickness of the material was determined for the manufacturing, in accordance with the safety conditions. In the event that GRP composite materials are used for the production of the tanks, the weight of the tanks might decrease, and it would lower the carbon emission and help us have longer-lasting tanks without corrosion.

2. Material and Method

2.1 Materials

The structure and properties of GRP composite materials and reinforcement phases which are added into matrix phase affect the mechanical properties (tensile strength, bend strength and impact strength) and increase them in the composite structure that is formed (Asi 2018). The duty of the matrix phase in these composite materials is to transfer the tension coming from external effects to reinforcement phase and maintain the structural integrity. GRP composite material is favorable, due to its significantly low density, its suitability for design variety, its relatively high heat resistance, its high specific strength, its resistance to corrosion, its moulding flexibility, its suitability for colorization during production, its high resistance to chemicals, its resistance to inflammation due to flame retardants added into matrix phase, its optional transparency, its better mechanical properties than steel due to optional various layers.

Table 2.1: Mechanical properties and components of GRP composite material

PROPERTIES	GLASS TYPE			
	A	C	E	S
Specific weight (g/cm^3)	2,5	2,49	2,54	2,48
Elasticity Module (GPa)	-	69	72,4	85,5
Tensile strength (MPa)	3033	3033	3448	4585
Thermal expansion coefficient	8,6	7,2	5	5,6
Softening temperature (°C)	727	749	841	970
Admixture Materials (%)				
SiO_2	72	64,4	52,4	64,4
$Al_2O_3Fe_2O_3$	0,6	4,1	14,4	25
Cao	10	13,4	17,2	-
MgO	2,5	3,3	4,6	10,3
$Na_2O_1K_2O$	14,2	9,6	0,8	0,3
B_2O_3	-	4,7	10,6	-
Bao	-	0,9	-	-

The other material which was used in the study is St37 Steel material. The tensile strength of this steel material is 37kg/mm2 and has 0.2% carbon ratio. It has been widely used due to the fact that it is high weldable and easily machinable.

Table 2.2: Mechanical Properties of St37 Material

Properties	ST37
Density (Kg/M3)	7,7
Elasticity Module (Mpa)	210000
Extension (%)	15
Poisson Ratio (0,3)	0,3
Tensile Strength (Mpa)	1158
Fluxion Strength (Mpa)	1034
Thermal Conductivity (W/M.K)	42,7
Specific Heat (J/Kg.K)	477
Thermal Expansion (K)	17
Fusion Temperature (°C)	1370

2.2 Method

2.2.1 Experimental Setup and Equipments Used

In parallel with the developments in composite material industry, liquid fertilizer tanks are designed which are commonly used in agricultural industry today. The important and specific properties desired in those tanks are their weights are corrosion resistance. Cattle and small cattle manures, pigeon manures and chicken manures are commonly used in plant development in agricultural field. Experiment specimens were prepared out of the materials used in the production of tanks. (Figure 2.2) After those materials were sized as 25x40x2mm, kept in 60gr of manure for 10 days -as seen in Figure 2.1-, rinsed with distilled water; the changes in their weight were measured by using a precision scale with 0.00001g sensitivity. SEM analyses were applied and structures that formed on the surface were evaluated. 10 m^3 tanks were designed and their compliance with security standards for the manufacturing process were evaluated using the finite elements analysis and the thickness of the materials were determined.

The manures were placed into the containers as exhibited in Figure 2.1. Those manures were different types of manures which had 58% humidity and were kept at 20 °C in closed and insulated containers. pH values of those manures were measured with benchtop Ohaus AB23PH-F pH meter. pH values the manures were measured as 8.44 for chicken manure, 8.34 for small cattle manure, 7.54 for pigeon manure and 9.03 for cattle manure.

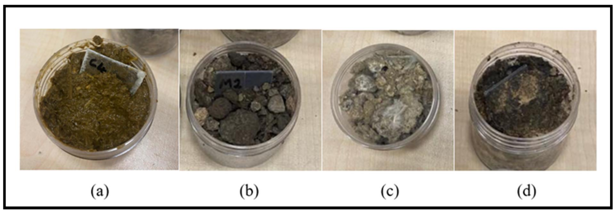

Figure 2.1: *(a) Cattle manure, (b) Small cattle manure, (c) Pigeon manure, (d) Chicken manure*

Those values are close to the previous pH values which were obtained through the other studies conducted on liquid fertilizers. (Sezen 1984). In Figure 8, test specimens were prepared using GRP composite and St37 steel materials in dimensions of 25x40x2mm. Their mass loss values were calculated with Bel Engineering M214Ai model precision scale before and after the experiment. In order to capture the images from the same angles, diagonal and perspective lines were drawn on the specimens. Microscopic images were obtained with Skygo 500x 8 Led microscopes with mounted endoscopic camera. In addition to those, as shown in Figure 3.2, other test specimens were prepared using GRP and St37 materials with the dimensions of 10x102mm for EDS and XRD experiments. Scanning electron microscope analysis was applied on those specimens and, later, phase analysis was conducted with energy distribution spectrum (EDS) images and X-ray diffraction (XRD) methods. Since GRP material is not electrical conductor, the images were obtained after gold coating process. In Figure 2.2, "C" represents coated GRP and "M" represents coated St37 materials.

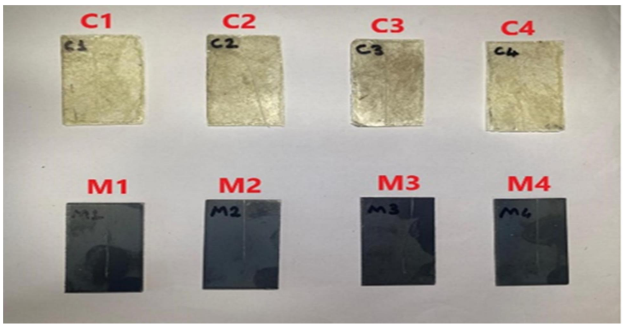

Figure 1.2: 25x40x2mm CTP and St37 test specimens

3. Experimental Findings

3.1 Microstructure Optical Image Analysis

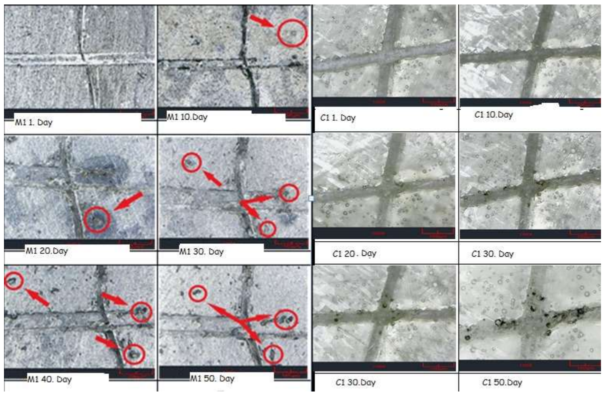

Figure 2.3: 100X images of GRP and St37 specimen kept in chicken manure

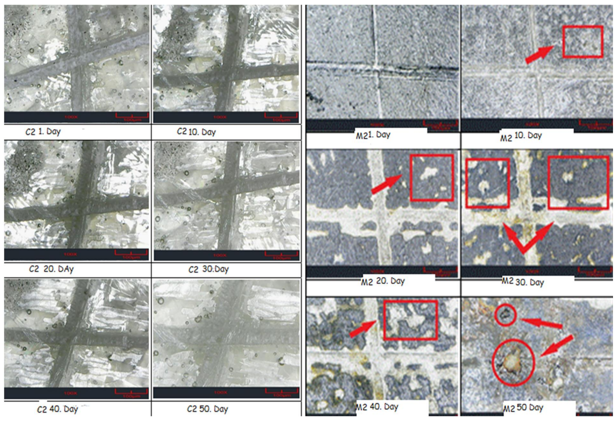

Figure 3.4: 100X images of GRP and St37 specimen kept in small cattle manure

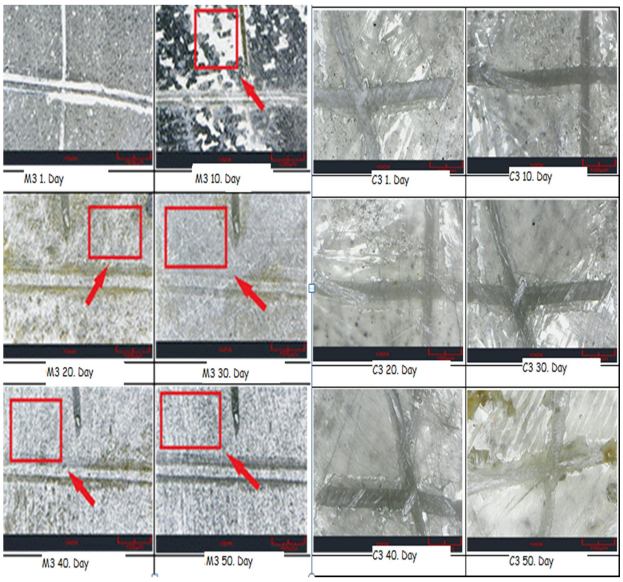

Figure 4.5: 100X images of GRP and St37 specimen kept in pigeon manure

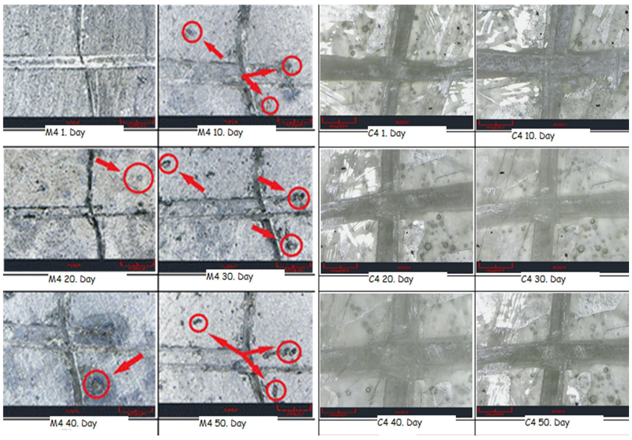

Figure 5.6: 100X images of GRP and St37 specimen kept in cattle manure

Table 2.3: Mass changes of specimen kept in different types of manures for 1200 hours (1)

SPECIMEN NAME	DAY 1(G)	DAY 10(G)	DAY 20(G)
C1	2,7994	2,7998	2,8011
C2	2,7704	2,7711	2,7722
C3	2,8354	2,8356	2,8378
C4	2,8456	2,8465	2,8492
M1	24,0681	24,0671	24,0626
M2	23,9994	23,9596	23,9376
M3	24,0687	24,0183	23,9616
M4	23,9904	23,9783	23,9671

Table 2.3: Mass changes of specimen kept in different types of manures for 1200 hours (2)

SPECIMEN NAME	DAY 30(G)	DAY 40(G)	DAY 50(G)
C1	2,8023	2,8045	2,8043
C2	2,7738	2,7746	2,7729
C3	2,8411	2,8456	2,8476
C4	2,8508	2,8501	2,8538
M1	24,0585	24,0583	24,0572
M2	23,9235	23,9116	23,8945
M3	23,9377	23,9257	23,9191
M4	23,9598	23,9483	23,9349

It was observed that St37 steel material was obviously affected by the liquid manure it contained and, as exhibited in the optical images, there were significant mass losses due to corrosion as a result of chemical reactions which the manure had on the material; on the other hand, there were no chemical reactions on the GRP but there was slight mass gain. The reason for this is that as the GRP material stays longer in humid environment, its weight increases and it was thought that there could be a mass gain due to the water absorption property of reinforcements phases present in matrix phases (İlhan and Feyzullahoğlu 2019).

3.2 Microstructure SEM and EDX Analysis

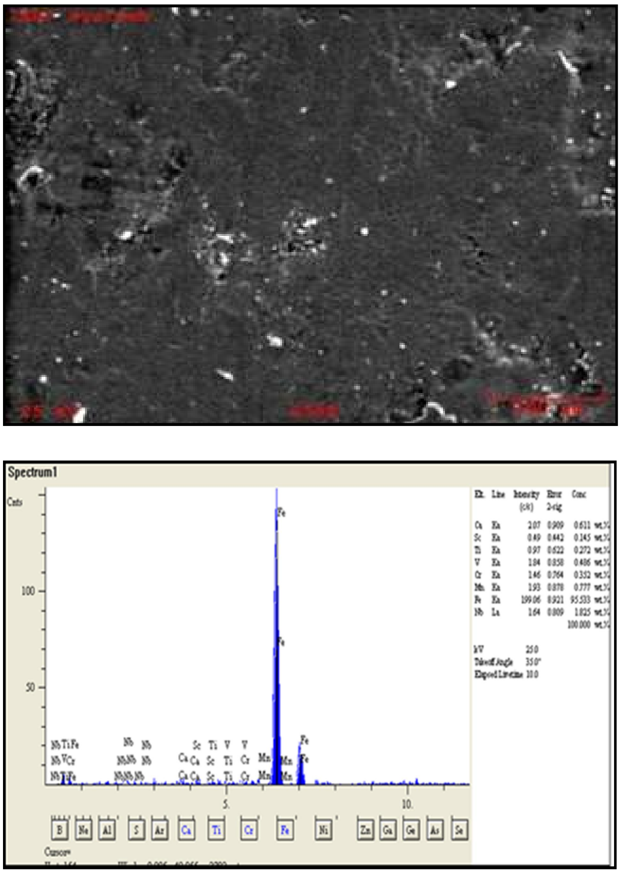

Figure 3.1: SEM and EDX images for St37 steel specimen

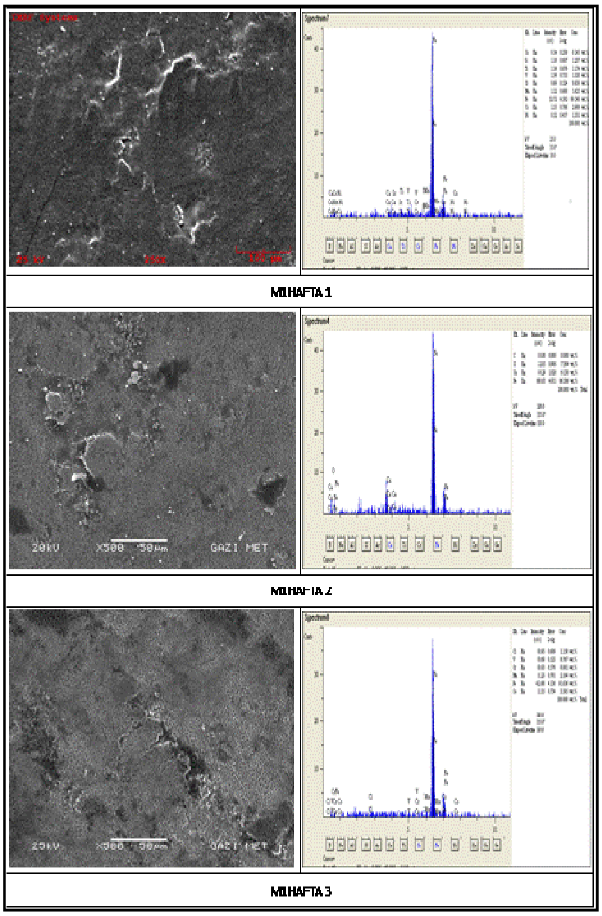

Figure 3.2: SEM and EDX images of St37 steel specimen kept in chicken manure

Oxide compounds that could cause corrosion on St37 steel material that stayed in chicken manure for 7/14/21 days form craters on the surface of the material. The existence of those craters leads to mass loss. The existence of iron oxide peaks which increases depending on the holding duration, as seen in SEM images, exhibits that there could be more oxidation. It can be understood from the SEM images given in Figure 3.5 that St37 steel specimen kept in cattle manure reach maximum corrosion on the day 21. Besides, as seen from M4 values given in Table 2.1, it was measured that those specimens had a greater mass loss. When the SEM images of the specimens kept in other manures are analyzed, it can be seen that St37 steel material had corrosion.

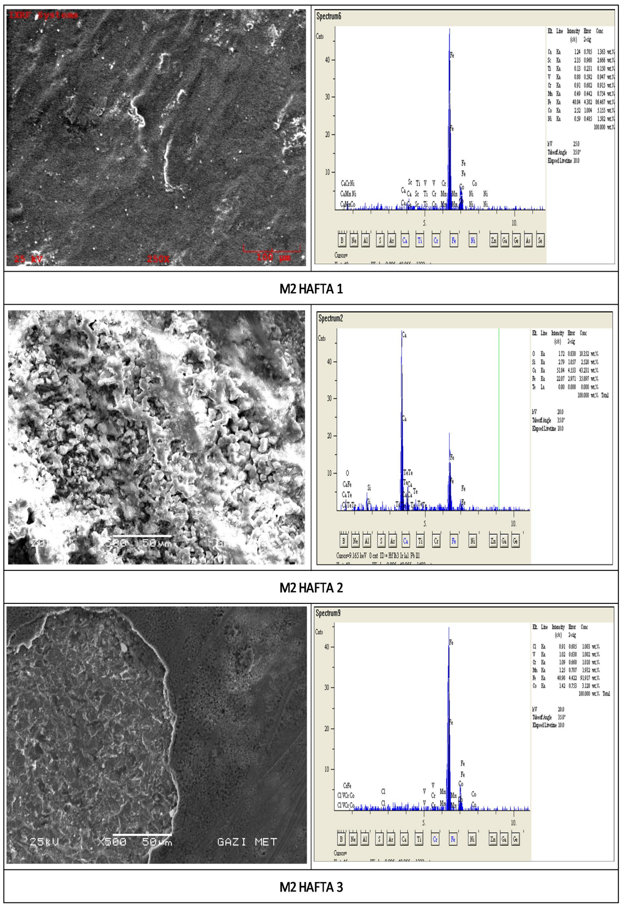

Figure 3.3: SEM and EDX images of St37 steel specimen kept in small cattle manure

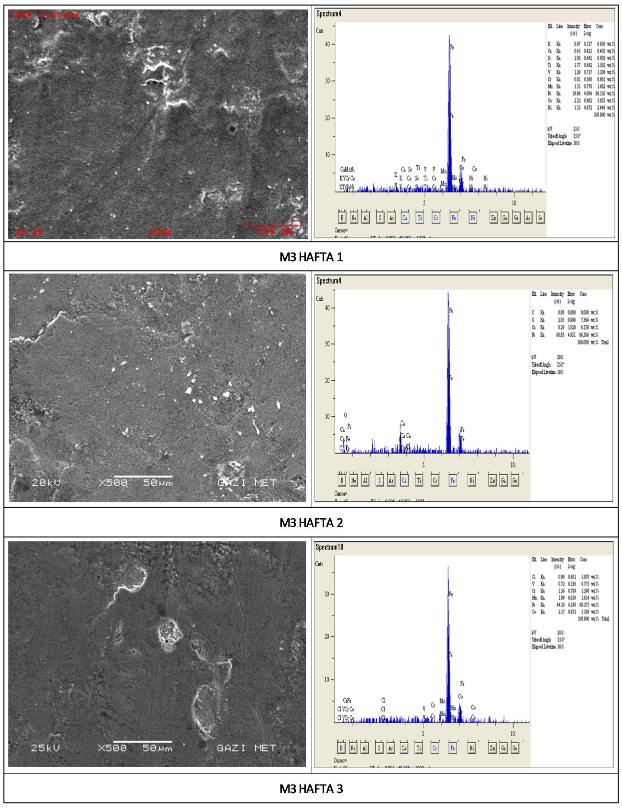

Figure 3.4: SEM and EDX images of St37 steel specimen kept in pigeon manure

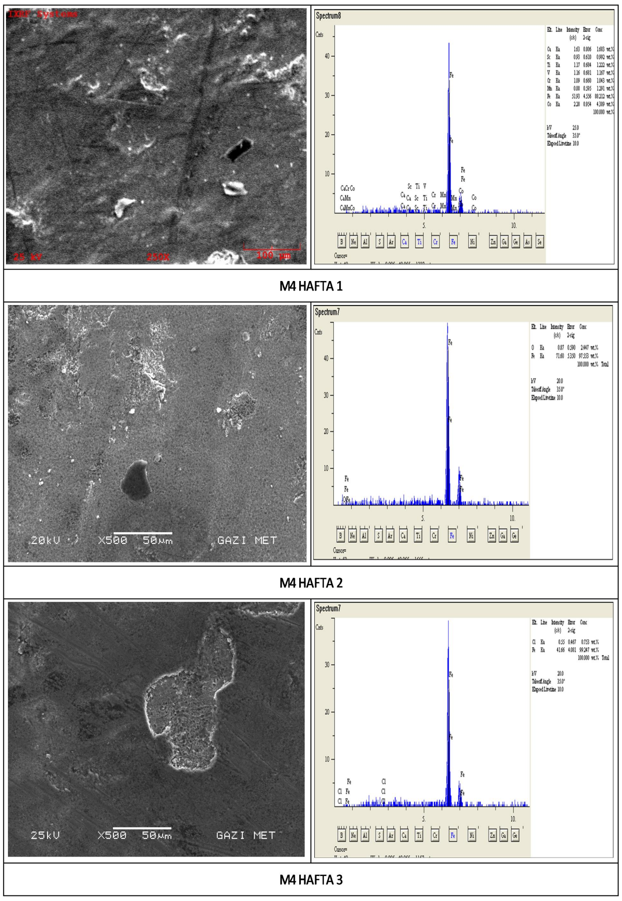

Figure 3.5: SEM and EDX images of St37 steel specimen kept in cattle manure

There were no oxide compounds that may cause corrosion or craters on material surface on the GRP St37 composite material kept in liquid manures for 7/14/21 days. It can be seen in Table 2.1 where mass loss values are given.

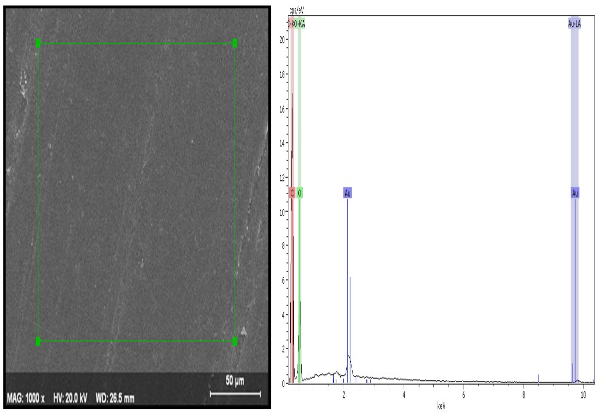

Figure 3.6: SEM and EDX images of GRP composite specimen

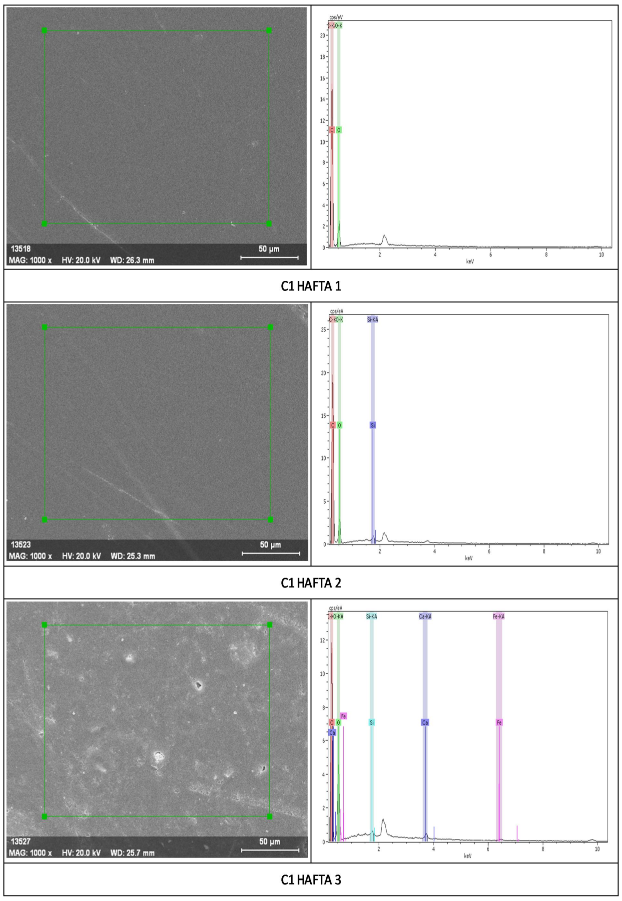

Figure 3.7: SEM and EDX images of GRP composite specimen kept in chicken manure

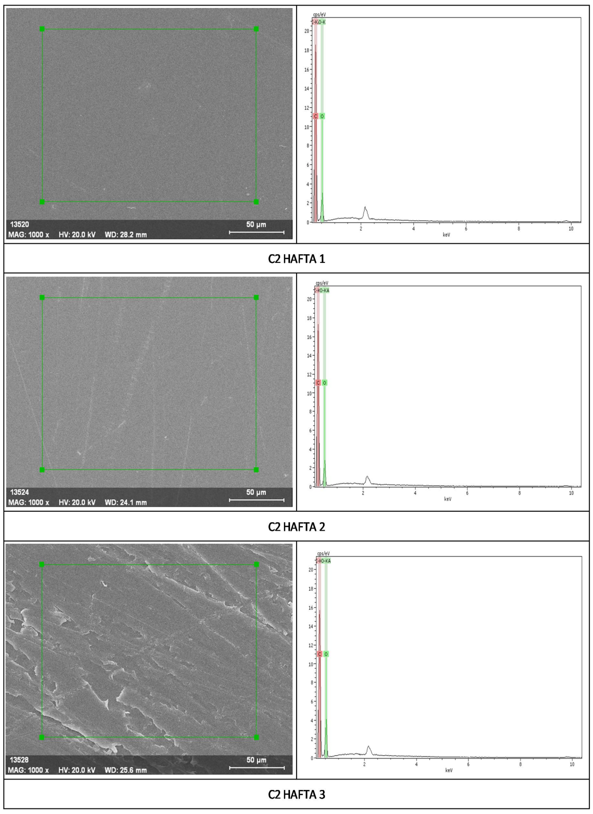

Figure 3.8: SEM and EDX images of GRP composite specimen kept in small cattle manure

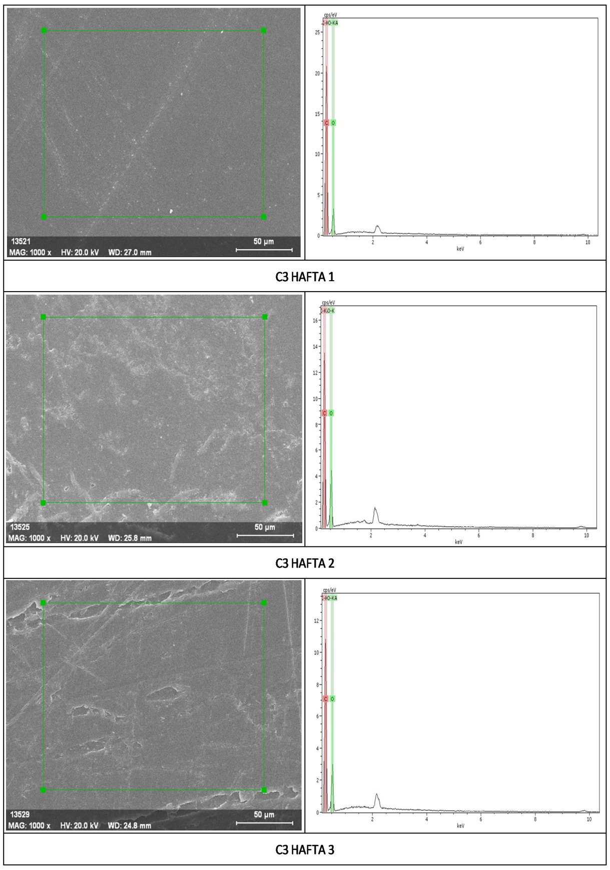

Figure 3.9: SEM and EDX images of GRP composite specimen kept in pigeon manure

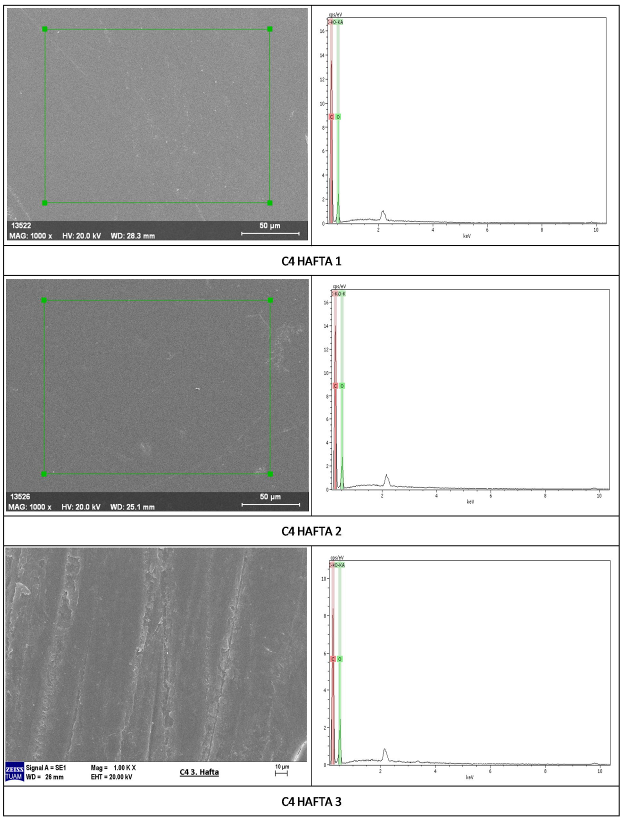

Figure 3.10: SEM and EDX images of GRP composite specimen kept in cattle manure

4. Discussion and Conclusion

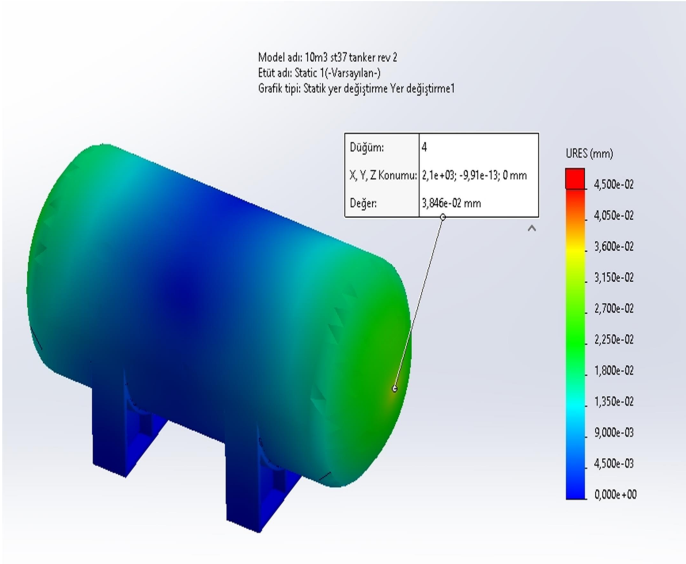

Figure 4.1: Static analysis of 10m^3 tanks made of St37 material with 3mm thickness

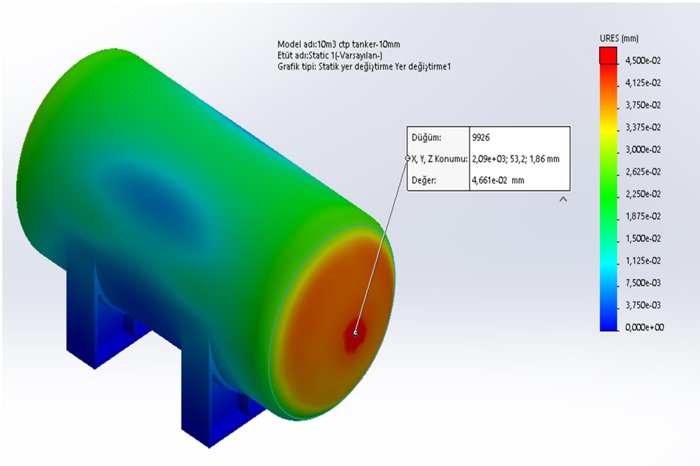

Figure 4.2: Static analysis of 10m^3 tanks made of GRP material with 10mm thickness

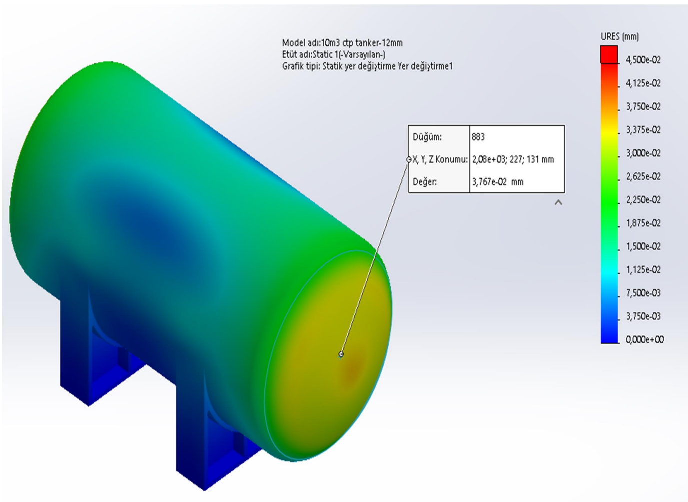

Figure 4.3: Static analysis of 10m^3 tanks made of GRP material with 12mm thickness

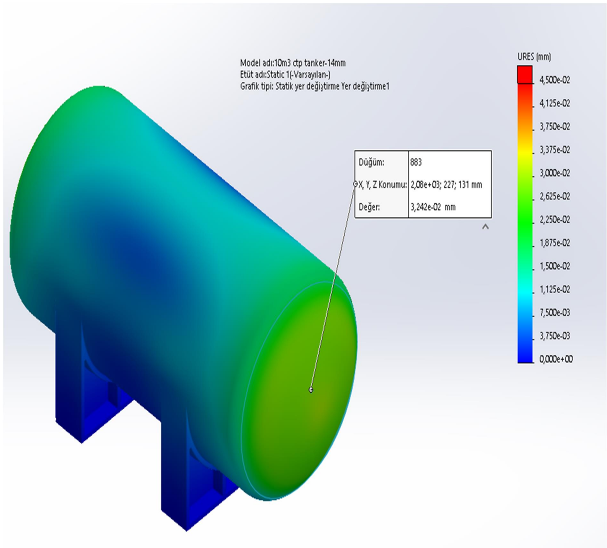

Figure 4.4: Static analysis of 10m^3 tanks made of GRP material with 14mm thickness

When the Freedom of Design, weight of the tank, corrosion resistance and manufacturability optimization parameters are taken into consideration, tanks which will be manufactured by using GRP composite material has a great advantage due to not having any limits in manufacturing with moulding procedure. On the other hand, steel material has limitative parameters in manufacturing process such as having limited moulding options, having to have welded connection in manufacturing, having standard size of sheet metal used as raw material. Today, GRP material is used in manufacturing wings and fan blades in space and aeronautics industry, in manufacturing mudguards and automobile doors in automotive industry, in construction industry, in manufacturing guard rails on highways, greenhouse panels and waterslides, in manufacturing sport automobiles, bicycles and helmets, in treatment facilities for products which needs corrosion resistance, in manufacturing water pipes and industrial tanks, in printed circuit panels in electric and electronic industry, in manufacturing electric poles and lamp posts, in manufacturing helicopter bodywork, weapon and rocket parts in military industry, in manufacturing sailboats and canoes in maritime industry (Sibel 2021, Korku, Feyzullahoğlu, İlhan, 2022). Based on the optical images and SEM analysis, when St37 steel material was used, physical changes were observed on the surfaces of contact with the manure resulting from the mass loss occurring with corrosion. However, those negative effects were not observed when GRP composite material was used. In the study Can İpek conducted, he observed that abrasion resistance of steel specimen in dry environment is low, compared to corrosive environment, and that composite material has higher abrasion resistance in both dry and corrosive environments. It was observed that while the specimen with the highest corrosion rate was St37 specimen kept in cattle manure, the specimen with the greatest mass loss was St37 specimen kept in pigeon manure. It is thought that the reason for this is that the high amount of nitrogen in the chemical compound of pigeon manure speeds up the corrosion and increases the mass loss. With the finite elements analysis conducted on the 10m^3 tanks with St37 and GRP material designs, instead of a St37 tank with 3mm thickness, a GRP tank with 12mm thickness has almost the same replacement under the same weight and force. Gözde Demircioğlu remarked in her study that increasing fiber length and ratio affect the tensile and flexural strength of the composites more and more. Also, between the tanks designed with equal capacity, the tank which is made of GRP material with 12mm thickness has a weight of 702kg, while the tank which is made of St37 material with 3mm thickness 3504kg. Based on these data, the tank which will be made of GRP material has certain advantages.

5. References

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