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UNIVERSITY OF GAZİANTEP
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NATURAL & APPLIED SCIENCES

EFFECT OF OLIVE POMACE ON THE MECHANICAL PROPERTIES OF POLYMER COMPOSITE MATERIAL

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Effect of Olive Pomace on the Mechanical Properties of Polymer Composite Material

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Assoc. Prof. Dr. Ahmet ERKLİĞ

By

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Effect of Olive Pomace on the Mechanical Property of glass fiber reinforced epoxy composites.

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This is to certify that we have read this thesis and that in our consensus opinion; it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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Ahmed Shihan ABBOOD

ABSTRACT

EFFECT OF OLIVE POMACE ON THE MECHANICAL PROPERTIES OF POLYMER COMPOSITE MATERIAL

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This work aims to study the effect the mixing natural particles micro-size olive pomace (OP) on the tensile and flexural properties of glass fiber reinforced polymer composite (GFRP). Hence, mechanical behavior of recycled olive pomace filled glass fiber reinforced epoxy composites was studied in order to develop an engineering material for industrial applications. The modifying of GFRP was conducting by adding six weight fractions of olive pomace (0.5, 1, 2, 5, 10, and 15%) with a grain size of 75 μm. The composite specimens were prepared by hand lay-up technique and cut according to ASTM standards. It has found the higher values of flexural and tensile strength occur at 5 %wt. of OP filler. In addition, the tensile test results showed that with more addition of OP above 5% the elongation at the break decreased. Maximum damping ratio is obtained from 10 % wt addition of OP to glass/epoxy. the consequence of addition OP, Damping ratio is increased from 0.407 value and 70 % higher than full glass/epoxy composite.

Keywords: Glass fiber, olive pomace, polymer composite, Hybrid composite.

ÖZET

ZEYTİN PİRİNA KATKISININ POLİMER KOMPOZİT MALZEMENİN MEKANİK ÖZELLİĞİNE ETKİSİ ÜZERİNE ARAŞTIRMA

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Bu çalışma, mikro boyutlu zeytin çekirdeği doğal parçacıklarının (OP) cam elyaf takviyeli polimer kompozitin (GFRP) çekme ve eğilme özelliklerine olan etkisini incelemeyi amaçlamaktadır. Bu nedenle, endüstriyel uygulamalar için bir mühendislik malzemesi geliştirmek için geri dönüştürülmüş zeytin çekirdeği dolgulu cam elyaf takviyeli epoksi kompozitlerin mekanik davranışı incelenmiştir. GFRP'nin modifikasyonu, zeytin çekirdeği (75 µm) tane boyutu ile altı ağırlık fraksiyonu (0.5, 1, 2, 5, 10 ve% 15) eklenerek gerçekleştirildi. Kompozit numuneler el yatırma tekniği ile hazırlanmış ve ASTM standartlarına göre kesilmiştir. Eğilme ve gerilme mukavemetinin en yüksek değerlerinin ağırlıkça% 5 oranında olduğu tespit edilmiştir. OP dolgu maddesinin % 5'ten fazla eklenmesiyle çekme deneyindeki kopma uzamasının azaldığını göstermiştir. Maksimum sönüm oranı, cam/epoksi için ağırlıkça% 10 oranında OP eklenmesinden elde edilmiştir. Damıtma oranı, saf cam/epoksi kompozitinden % 70 daha yüksek bir seviyeye yükseltilmiştir.

Anahtar Kelimeler: Cam elyafı, zeytin çekirdeği, polimer kompozit, hibrit kompozit

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LIST OF SYMBOL

GFRP	Glass fiber reinforcement polymer
OP	Olive pomace
δ	logarithmic decrement
A_0	maximum magnitude of first cycle
A	maximum magnitude of nth cycle
I	moment of inertia of specimen
A	cross-section of the specimen
ρ	density of specimen
L	free length of specimen
E′	storage modulus
E’’	loss modulus
ω_1	natural frequency of the first mode
$\omega_1 - \omega_2$	bandwidth
ω_n	natural frequency of plate in radian

CHAPTER 1

INTRODUCTION

1.1 Preview of Composite Materials

Natural fibres like sisal, banana, jute, oil palm, kenaf, recycled jute and coir have been utilized as a reinforced composite for advanced usage such as aircraft and aerospace structures and for ordinary applications like consumer goods, furniture and civil structures.

The collection of strong fibres in smooth matrices can lead to new materials with outstanding mechanical characteristic include the features of both the fibre and matrix [1]. Composite materials which consist of fibers in their structure are light and strong in weight in which brittle, strong and hard fibers are available in ductile softer and matrix. This character permits the matrix to convey the loads applied to the composite to the fibers that are embedded within the matrix that result in enhanced mechanical characteristic if compared with un-reinforced matrix materials. [2].

The request for firmer, more strong and more lightweight materials was gradually growing from the beginnings of 1960s to be utilized in the industries of construction, transport and aerospace. Recently, natural fibers appear to be the outstanding material, which has emerged as a viable and many substitutes for the high cost and non-renewable synthetic fiber.

The creation of new and better materials such as composite materials and extensive research occurred as a result of high-performance requests on new materials that are used in constitutional purposes of engineering. The low densities of such materials result in high force to weight and high hardness to weight rates if likened with the features of traditional materials in engineering. Besides, these composite materials are attractive to users as they have high fatigue damage tolerance and high fatigue strength to weight ratio [3]. Composite materials have five groups such as metal matrix composites, ceramic matrix composites, alloy matrix composites, carbon composites and polymer matrix composites (PMCs). The main attention of this investigation is to develop PMCs. There are either thermoset or thermoplastic matrix within PMCs which act as a conductor of the load that is applied to the fibers from the composite additionally to binding the enhance fibers together. Thermosets can be defined as plastics that when cured and set cannot be liquefied and consist of resins such as phenolic, polyesters and epoxies. From other side, thermoplastics are plastics that can be melted repeatedly, so they have the ability to be recycled. Thermoplastics that are frequently used include polyethene, polypropylene and polyvinyl chloride (PVC). PMCs contain either short or continuous reinforcing fibers, with enhanced mechanical characteristic as a consequence of continuous fibre reinforcement in the direction of fibre alignment. Aramid or carbon with high-performance such as (e.g. Kevlar™) fibres are primarily utilized to reinforce continuous fibre composites. These composites are often used in fields such as aircraft composites where the extraordinary fibre characteristic can be entirely exploited.

Hand lay-up, filament winding and pultrusion and compression molding are some commonly used methods for processing of continuous fibre composite. Collected fibers such as graphite, cellulose and glass are firstly used to strengthen short fibre composites. In applications where medium to low strength and stiffness demanded, these kinds of composites are easier to fabricate and cheaper and are well established. Short fibre composites if compared to continuous fibre composites, are simply handled in alike way to the matrix. Compression moulding is a mass-production of short fibre composites with a thermoset matrix [4].

The mechanical property and dispersal of the fibers and matrix in addition to the efficiency of load between the two parts are substantially influenced composite mechanical characteristic. When designing composite products, a mechanical characteristic like stiffness and strength of great value and can be expected for short fiber composites with various degrees of accuracy via means of mathematical foretelling models. It is so difficult to expect the mechanical characteristic of short fiber composites as compared with that of continuous fiber composites. This is because of the difficulties of determining parameters like orientation and geometry (aspect ratio) of the fibers within the composites, fiber dispersion, fiber and matrix volume fractions and the interfacial shear strength through the fibers and matrix [5].

Olives are considered as one of the most extensively cultivated fruit crops in the world. The complete world production of olives and virgin olive oil was reported to be 20.8 and 3.28 million tones, respectively, for the year 2010 [6]. Olive cultivation is fundamentally common throughout the Mediterranean region and takes on a significant role in its economy, regional historical past and environment safeguard. The olive-producing states are present in the Mediterranean and Middle Eastern regions, providing 98% of the overall cultivated area, and 99% of the entire olive berries preparation [7].

Turkey is ranked through the leading olive/oil producers, with over 180 million olive trees grown on 0.7 million hectare cultivation areas and an average annual production amounting to 500 thousand metric tonnes table olive production annually and olive oil production annually. A major problem which significantly impacts the environmental sustainability of this gardening activity is the fingertips of residues made from the vocational squeezer of olive oil [8].

In recent times, many studies were dealt with utilising cellulose fillers like palm nucleus shell, olive pomace, blueberry leaf, wood, coconut covering as fillers within organic & natural polymers. Therefore, the synthetic fillers were replaced through utilisation of natural fillers as reinforcement in thermoset polymer and thermoplastic composites in an effort to increase productivity, minimize the cost and improve the mechanical characteristic of the product [9]. Fillers and fibres such as olive pomace, oil palm empty fruit, kola nitride furious fibre, as well as several fillers such as rice husk, were a necessity as reinforcing agents for other thermoplastic and thermosetting plastic resins [10, 11]. There is a vast attention in filler and natural fibre reinforced polymers owing to their ease of processing and low cost as some of these fillers are regarded as waste. When epoxy/eggshell particulate composites develops, the hardness and density readings of the epoxy/eggshell particulate composites increased steadily when eggshell addition increases, compressive, flexural strengths plus impact energy increased [12]. The impact of treated and untreated coconut shell strengthened unsaturated polyester composites was studied and there was increase in the mechanical and thermal characteristic of unsaturated polyester/coconut- shell composites [13].

1.2 Natural Fiber Reinforced Thermoset Composites

The charm of utilized synthetic fibers in polymer composites are fading because they are costly, non-brittle and shell cause environment Pollutions . Availability of cheap lignocellulosic fibers in tropical countries delivers a sole chance of discovering the likelihood of their exploitation for the artificial of inexpensive biodegradable composites for different uses. Where high stiffness, extraordinary strength and low density are demanded, the most commonly utilized reinforcements for composites are high performance carbon and aramid (e.g. Kevlar^{TM}) fibers. Glass fibers are cheaper alternatives for them to be used commonly in industry as they are costly for use in general uses. The utilization of such alternatives (Glass fibers) has numerous advantages, such as relative ease of production and low cost, in addition to having moderate strength and stiffness to weight ratios. Though, beside the advantages, they also have many drawbacks [14]. They are dangerous to work with as they tend to be abrasive, as well as on processing machinery there are increasing in the wear. More importantly, there are health hazards to those who are working on glass fibers. The difficulty of getting rid of them at the end of their lifetime is the huge problem with synthetic fibers such as glass fibers. There are also problems with recycling of composite reinforced with glass fibers as these fibers break during processing procedures and they cannot be burned as the remnants have a movement to injury the furnace. Discarding the waste in landfills is the only way of disposal, which is becoming further costly in much countries with introduction of landfill excises [15].The characteristic of natural fiber as compared to those of E-glass are explain in Table 1.1.

Table 1.1 Properties of natural fibers in relationship to those of E/glass

Fiber	Density (g/cm^3)	Strength (MPa)	Modulus (GPa)
Indian grass	1.25	264	28
Hemp	1.29	695	42-70
Kenaf	1.4	284-800	21-60
Henequen	1.57	372	10
Pineapple leaf fiber	1.44	413-1627	35-83
Jute	1.3-1.45	393-773	13-27

Natural fibers require well small energy to produce, and because they possess high calorific values, can be burned it when their lifetime ends for energy recovery. Each of plant-derived fibers use carbon dioxide when they are grown and can be considered CO_2 natural, meaning that at the end of their lifetime they can be burned without further CO_2 is was being freed into the atmosphere [17]. Instead, glass fibers are not CO_2 natural and to deliver the energy wanted for manufacture it needs the burning of fossil fuels. Vast amounts of CO_2 released into the atmosphere as a result of the burning of fossil fuel-based products and this phenomenon is thought to be the chief reason of the greenhouse impact and the climatic changes that are being witnessed in the world today [14]. The characteristic and geometry of natural fibers depend, for instance, on the species, growing environments, cambium age, harvesting and processing circumstances. As cellulose fibers have the likelihood to display an extensive array with both poor and strong bonding to polymer matrix materials, depending on fiber-matrix modification and compatibility, the best interface is typically thereabouts through the two extreme cases. For instance, when the interface is so strong, the composite material can become too brittle, utilize a notch-sensitive material with low strength, since stress focused defects are unavoidable [22]. There are different benefits of utilizing natural fibers such as thermoset composites reinforced via natural fibers in numerous fields from household to automobiles articles. These benefits of utilize natural fibers over synthetic ones are high specific strength, renewability, low price, light weight and biodegradability [17]. By many factors have identified mechanical & physical properties. The chemical and physical composition that determine the characteristic include the structure of the fibers, cellulose content, micro-febrile angle, cross section, and the grade of polymerization. Although, the natural fibers have some drawbacks mainly the absorption of moisture utilize swelling of the fibers, which consequence in a delicate bond in the fiber resin interface in the composites. Strength, stiffness, fiber length and cross sectional area of natural fibers differs from plant to plant leads to different characteristic of the fibers. Such differences can eventually result in problems in the design of composite plus expectations of its performance. Thermal stability is also a drawback of natural fibers as they are restricted to working and processing temperatures of 200°C if compared with synthetic fibers. Finally, regarding natural fibers, they are hydrophilic (absorb water) and polar in nature which is also a drawback [23]. Whereas polyester resin which is a common thermoset matrices are non-polar and hydrophobic (do not absorb water).

1.3 Application of the Natural Fiber Composites

It is becoming hard to ignore the substantial role of natural fiber composites in advanced technology. Because of the environmental issues, many natural fiber composites are used nowadays at the highest levels of materials technology, allowing their usage in sophisticated fields such as internal parts of automotive and building structures. The usage of natural fibers, such as kenaf, flax, or sisal to reinforce plastic body panels for automotive industries is being introduced for car interior trim parts such as door and window panels, hat shelves, and roofing, as shown in Figure 1.1. The panels that are made up of natural fibers have good mechanical characteristic and are lighter than glass fiber reinforced panels, As a result, lower fuel exhaustion and hence cost saving. Moreover, as a renewable product, natural fibers have a greater environmental interest than oil-based plastics. In the last years, plant fibers have also been used in exterior composite components: the engine and transmission covers of a Mercedes-Benz Travego. In 2002, the overall consumption of plant fibers was about 17,000 tones, and the average value of fibers per vehicle was (10 kg – 15 kg). The industrial use of plant fibers is not only driven via reductions in cost, but also by issues related to environmental awareness. In Europe, the EU “end of life vehicle” directive imposes that 85 % of the weight of all vehicle components should be recyclable by 2005 which should be increased to 95 % via 2015 [24]. Concerning plant fiber composites, the expression recyclable is somewhat unresolved [25]. Plant fibers are fully recyclable via combustion, in addition to being fully biodegradable, but the same cannot be implied for the residual synthetic polymeric matrix.

Finally, natural fibers are better than glass fibers because they can be recycled and reused. In latest years, there has been an growing interest in proving the plant's suitability for use in building materials particle boards of several densities, thicknesses, with adsorbents, blaze and insects resistance, cattle feed, weaving and fibers in new and recycled plastics [injected molded and extruded] [27]. Natural fiber composites are utilized in various fields not only in Vehicles industry. For instance, for the American markets, wood fiber reinforced thermoplastic decking is produced by at least 20 manufacturers [28]. Also wood fiber reinforced polymers are used by door and window profile producers from another enormous industrial section [23]. Besides, natural fiber composites are utilized in other different fields such as louvers, flooring, walls, and outdoor and indoor furniture [29]. Finally, so as to use them to their full extent in industry, it is important to develop the strength and hardness of these composites, in addition to confronting case such as water absorption and thermal instability.

Figure 1.1 Mercedes-Benz 20% weight saving achieved with flax/sisal thermoset door panels [26]

1.4 Classification of Natural Fibers

Natural fibers are classified based on their origins: animal fibers, mineral fibers and vegetable fibers (Figure 1.2). In this thesis, vegetable fibers are considered like as granular form. Typical and mostly used natural fibers are shown in Figure 1.3.

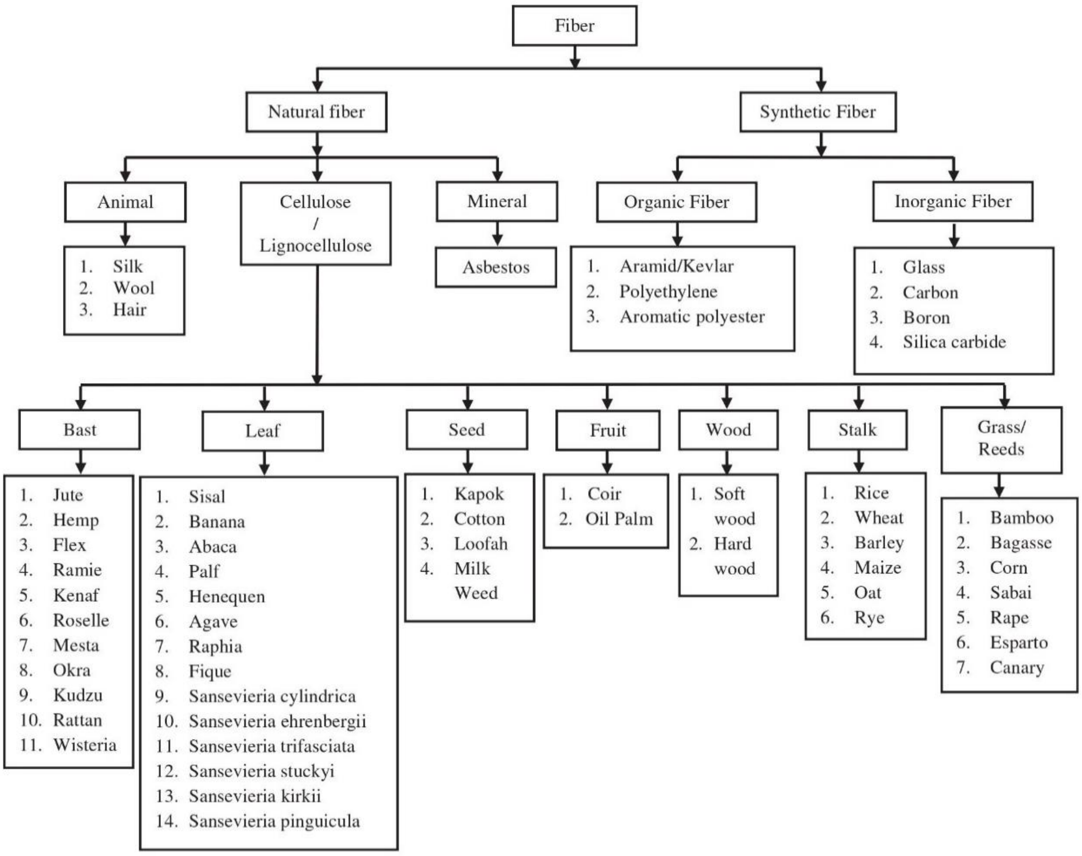


Figure 2.2 Classification of Natural Fibers [30].

Figure 3.3 Pictures of Several Natural Fiber [31].

1.5 Advantages of Natural Fiber Composites

The some of the advantages of a natural fiber are:

- Higher specific strength and stiffness than glass fiber because it has Low specific weight.

- It is a renewable source, the production needed little energy, and CO_2 is utilized while oxygen is given back to the environment.
- It is an interesting product because it is a low investment at low cost.
- Healthier working condition, reduced wears of tooling, and no skin irritation.
- Thermal recycling is possible for natural fiber.
- It has an acoustic insulation and good thermal characteristic.

1.6 Definition of Hybrid Composite

Hybrid composites are the systems in which an example of reinforcing materials combined in a mix of different matrices, or maybe or reinforcing & filling materials are present in a single matrix or both approaches are combined.

Hybridization is commonly utilized for growing the mechanical characteristic and for lowering the expenditure of standard composites. There are various kinds of hybrid composite classified in line with the way in which the component materials are incorporated:

1. Sandwich: when one material is placed between layers of another.

2. Interplay: alternate levels of several materials are stacked in a orderly manner.

3. Literally: Series of more constituents are concerted in a regular or randomly manner.

4. Intimately: blended: constituents are mixed as much as potential so that no concentration of either kind is present in the composite materials.

1.7 Definitions of Tensile and Flexural Strength

Tensile strength is a measure of the amount of stress on the material when they arrive at the point of collapse, which then shatter or lose cohesion, which is the maximum stress material can hold out without collapsing. The tensile strength is the property does not change with the amount of material being tested, but it depends on the test sample preparation and the temperature, who made the test. This property is one of the most important standards in the field of construction and in the fields of generally engineering and is often used for materials in the form of cords or wires, construction rods. Some of the material when it happens to break out be a sharp break be a sharp break is not occurs to material constitute a thermoplastic during tensile strength, called "fragile collapse. While other materials are ductility, which are often most metals, which happens to material the case constitutes born as a result of tensile strength.

Flexural strength is the border of a material to endure flexural stress without failure. If an object is exposure to flexural stress, it will subject both compression and tension behavior as a result of bending moment. Flexural strength of any material will depend on its compressive strength or tensile strength, whichever is lighter.

1.8 Vibration, Damping in Composite Materials

Is becoming more and more significant in advanced engineering systems for enhanced vibration, noise control, dynamic stability plus fatigue and impact resistance. There is a mainly sturdy necessary for information for refinement methods of damping in lightweight structural composite materials. So that they may be more impactively utilised in the design of high-performance machines, tool and structures [32].

1.9 Importance of the Study

Progress in technology requirement materials with unique property series that cannot be achieved with conventional metal alloys, ceramics, or polymeric materials. This is chiefly true for applications that necessitate durability under extreme circumstances such as automobile, aerospace, and infrastructure industries.

Superior chemical, mechanical and physical characteristic are achieved utilize composites and hybrid composites. The main advantages that drive the usage of composites are weight reduction, corrosion resistance, wear resistance, part-count reduction, easy of handling, excellent damage tolerance and impact resistance great specific strength (high strength with less weight or more generally, it has high stiffness with less weight), low thermal extension and reinforce fatigue life.

Many studies have been conducted on the laminated composite structures as given in the next chapter (literature survey) due to the fact that composite structures have lots of application areas such as aerospace industry, automotive industry, marine applications, sporting goods industry, construction and civil structures and healthcare industry (like biomedical). In others words, they are used nearly all of the engineering based applications

Less flexural affected materials and more durable can be obtained with the usage of the hybrid composite material. In layers, material distribution required knowing the number of layers to avoid flexural can be specified. In this way, the benefits of hybrid laminated composites can be determined specially for automotive and aircraft industry.

1.10 Outline of the Study

Hybrid composites were produced by GFRP and olive pomace particles as reinforcements and matrix (epoxy resin) respectively. After that samples for flexural, vibration, and tensile tests were created from produced hybrid composite laminates according to dimensions in ASTM standards.

The study has been made up five chapters.

Definitions and general introduction on composite materials, natural fiber composites and hybrid composites, tensile and flexural strengths, vibration, damping are introduced in the first chapter. The first chapter also comprises the significance of the study and its outline.

Chapter 2 consists of literature review. Chapter 3 presents raw materials used in this research, and to clarify the characteristic and general characteristics also includes devices used and the method of testing models and measurements carried out Information about designed and production methods of the composite. Also mechanical characteristic, standards and test methods to determine these mechanical characteristic are given in this chapter.

Chapter 4 contains experimental results of tensile, flexural, damping, and natural frequencies of plates. Tables and figures were conducted to see impacts of adding the olive pomace particles on the hybrid configurations on these characteristic.

In chapter 5, contains general conclusions and upcoming works.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

A lot of studies have been conducted during the past years on conventional synthetic fiber to substitute them with natural fiber composites. For example, jute, broom, flax, cotton, sisal and hemp are the most frequently fibers used as reinforcements for polymers. Besides, fibers (bamboo, sisal, jute, coir, oil palm, grist and linen straw, waste silk and banana) had achieved to be effective and good as strengthening in the thermoplastic and thermoset matrices. Composites, made from non-traditional materials, obtained instantly from various sources (agro-wastes like coir fiber, coconut pith, jute sticks, groundnut husk, rice husk, reed, and straw) get a lot of attention of the researchers.

Mohammed [33] studied the effect of data seeds (DS) and olive seeds (OS) particles filled epoxy resin on tensile and impact characteristic. When date and olive seeds powders were added to the epoxy matrix at weight fraction (0, 8, 13, and 18 wt. %) with grain size (300- 450 & 600μm), it's found the higher value of modulus of elasticity and tensile strength happened at 18% wt. and grain size 300μm for samplings reinforced with olive seeds powder, but acquired the lower percentage of elongation at fracture, impact strength and fracture toughness at this value. In addition, the mathematical model outcomes show that the weight fraction of powder has higher impact than grain size on characteristic.

Abessalam [34] studied the usage of powdered olive pits as a new filler material as a new series of sustainable reinforced polymer composite materials to be used with epoxy resin. Moreover, the effect of the loading (weight fraction) of treated and untreated powder on the void content and the mechanical properties of the composites were studied. It was found that the mechanical features of composites reinforced with treated olive pits were significantly improved as compared with that of composites reinforced with untreated olive pits.

Briones et al.[35] investigated valorization of some lignocellulosic agro-industrial remains to gain bio-polyols. The valorization of renewable and much resources (date seed, olive stone, corncob, rapeseed cake and apple pomace) from industrial activities was achieved by mild liquefaction utilize polyhydric alcohols to get bio-polyols that create an interesting optimal for industrial divisions specially polyurethanes. The results found demonstrated the possibility of utilize polyhydric alcohol liquefaction to create bio-based polyols, thus opening new avenues of exploitation of these via-products.

Koutsomitopoiulou et al. [36] studied the effect of (PLA-matrix) strengthened with olive pits powder. This study is concentrated on recycling potential of some discarded materials, such as olive pits, i.e. the solid phase derived from an olive oil mill, mixed with thermoplastic polymers and used for the making of new materials useful in manufacturing containers and formworks. The olive pit powders then are considered and well-defined. Then the powder is presented in a bio-based and biodegradable matrix (polylactic acid, PLA) at numerous proportions.

Hamma et al. [37] investigated the mechanical characteristic, thermal and morphology of polypropylene (PP) composites by adding of date stone flour (DSF) on in the presence and absence of ethylene/butyl acrylate-glycidyl methacrylate (EBAGMA) utilized as the coupling agent. Scanning electron microscopy analysis displayed by this study that (EBAGMA) compatibilizer enhanced the wettability and the dispersion of DSF in the PP matrix. Thermogravimetric analysis (TGA) indicated a small reduction in the decomposition temperature at onset (Tonset) for all composite materials compared to PP matrix, but the rate of thermal degradation were slower. The fusion temperature of PP in the composite materials continue almost unaffected which is discovered via differential scanning calorimetry (DSC) data. However, the compatibilizer reduced the nucleating influence of DSF. Furthermore, the incorporation of DSF leads to an increase of stiffness of the PP composites goes together with a important reduction in both the stress and strain at break. The adding of EBAGMA to PP/DSF composites enhanced considerably the ductility due to the elastomeric impact of EBAGMA.

Ahmed [38] prepared the composite materials from unsaturated polyester resin with diverse sorts of flakes (wood flour and rice husk), also a hybrid was prepared utilize the two kinds that mentioned above, with the almost the same volume fraction. Results exhibited that the composite materials of (wood flour) have improved mechanical characteristic compared with others, the hybrid gained better thermal insulation compared with rice husk and wood flour composite.

Zabihzadeh et al. [39] studied the impact of filler loading on the flexural and physical properties of the natural/filled thermoplastic polymer composite panels. Test results showed that the elasticity modulus and flexural strength were basically affected by the filler content, and the flexural strength was appeared to decrease with an increase in the filler content, while the flexural modulus rising in consideration.

Sanaa[40] studied the diverse volumetric portions effects from short chopped fibers and sawdust on the mechanical characteristic of unsaturated polyester composite then these findings were compared with the characteristic of saw-dust fiber filled composites immersed for various phases in a salt solution. The addition of wood volume fractions vol% 20, 30, 50 to unsaturated polyester was studied. It showed an enhancement in their mechanical characteristic for all reinforced composites (only there was a decrease in the impact) and mainly at higher values of volume fractions, hence, hardness exhibited an increment of (15%), compressive strength was clearly improved by (38%), with saw-dust reinforcement of (50 vol%), the impact resistance decreased by (16%). When the stuffs were immersed in a salt solution for (60 days), the above mentioned readings were reduced.

Karmaker and Schneider [41] made composites by the use of jute, kenaf fiber and polypropylene resins. They stated that the mechanical characteristic of jute fibre is best than that of kenaf fibre.

Ichazo et al. [42] noticed that the addition of saline treated wood flour to PP produced a sustained increase in the tensile strength and the tensile modulus of the composite.

Mishra et al. [43] studied the composites and their tensile stress-strain performance when fiber loading is 40% via weight. There was about 22% increase in tensile strength for alkali treated (5%) sisal polyester bio composite.

Mishra et al. [44] investigated the polyester hybrid composites reinforced with Bio-fiber/glass and their mechanical performance. Adding of slight quantity of glass fibers in the pineapple leaf fiber and sisal fiber reinforced polyester was found to have positive hybrid impact, which improved the mechanical properties of those composites.

Thwe and Liao [45] investigated the mechanical characteristic of polypropylene matrix hybrid composites (BGRP) reinforced with bamboo-glass fiber before and after environmental aging. They found that before environmental aging, both modulus and strength in tension and flexural tests increased with incorporation of glass fiber, while after environmental aging, the mechanical characteristic reduced. They strongly suggested that hybridization of glass fiber could improve durability of bamboo fiber reinforced polypropylene (BFRP). They also exhibited that the fiber length, orientation and distribution in the composites were important variables on the mechanical characteristic of the composites.

Gharbi et al [46] examined the result of the incorporation of the olive nuts flour up to 60% loading in unsaturated polyester on the flexural characteristic, impact strength, thermo-mechanical characteristic and water absorption performance. The exhausted solid olive oil mills were used to create olive nuts flour after mechanical grinding treatment. A steady enhancement in the flexural modulus was noted via the olive nuts flour incorporation. So, to produce cheapest composite laminates, the use of glass fiber in a natural particulate-filled polymer having varied uses and good characteristic like high stiffness, strength, thermal stability and resistance to chemical upset.

Hassan et al. [47] concerned with usage of waste natural particles as a filler in a natural fiber reinforced composites The intensity and hardness values of the polyester/eggshell particulate composites increased gradually during the development of polyester/eggshell particulate composites, with the increasing compressive strength, eggshell addition, impact energy and flexural strength increased.

Husseinsyah and Mostapha [48] studied the outcome of reinforcement of unsaturated polyester composites with untreated and treated coconut shell. It was obvious that the mechanical and thermal characteristic of unsaturated polyester/coconut shell composites were clearly enhanced.

Osabohien and Egboh [49] researched for usage of cellulose fillers (coconut shell, wood, pineapple leaf, palm kernel shell, etc.) as fillers so as to exchange the synthetic fillers via utilize of reinforcement or natural fillers in thermoset polymer and thermoplastic composites trying to lessen the cost, enhance the mechanical characteristic of the product and increase its productivity.

Alvarado et al. [50] investigated the influence of mingling numerous proportions of olive stone in a polyester resin matrix on the chemical, physical and mechanical properties. The results showed a heterogeneous distribution within a matrix, a reason for which the characteristic displayed via these materials are not good enough to be used in the plastic making industry.

Khoathane et al. [51] investigated the Young’s modulus and tensile strength of composites reinforced with bleached hemp fibers. Properties of composites with hemp fibers improved amazingly, when fiber packing increases. Mathematical modelling were too mentioned. It was revealed that the rule of mixture (ROM) expected and experimental tensile strength of diverse natural fibres reinforced HDPE composites were right close to each other. The most effective equation in expecting the Young’s modulus of composites encompassing diverse kinds of natural fibers was Halpin-Tsai equation.

Sathishkumar et al. [52] studied the tensile characteristic of snake grass fiber and compare them with that of other natural fibers that are commonly available. The mixed chopped snake grass fiber strengthened composite was created utilize polyester. The experimental evidence too displays that the volume fraction increases the flexural, tensile, and modulus of the snake grass fiber reinforce composite.

Deli [53] demonstrated experimental and numerical study of natural frequency and mechanical characteristic for natural fiber reinforced composite materials. The experimental works encompassed study of vibration and the mechanical characteristic of composite materials are made of date Palme fiber, natural fiber, and polyester resin materials with different border conditions. The outcomes revealed the date Palme fiber causes increasing the modulus of elasticity of composite materials, then, it causes growing the natural frequency of composite plate when the fiber volume fraction increased. Also, due to low density of natural fiber, the strength to weight ratio increased with the use of natural fiber.

Zuhri et al. [54] investigated of the mechanical properties of epoxy (OPF/epoxy) composites reinforced with short random oil palm fiber. Empty fruit bunch (EFB) was chosen as the fiber and epoxy as the matrix. Composite plate with four various volume fractions of oil palm fiber were fabricated. Hand-layup technique was used for fabrication. There was a decrease drift in the tensile and flexural characteristic when the fiber loading was increased.

Bachtiar et al. [55] studied outcomes of alkaline treatment on the flexural characteristic of epoxy composites reinforced with sugar palm fiber. 10% weight fraction of the fibers was utilized to reinforce the composites. Sodium hydroxide (NaOH) with 0.25 M and 0.5 M concentration solution for 1hour, 4 hours and 8 hours soaking time were used to treat fibers. The interfacial bonding between matrix and fiber surfaces was improved as a result of alkali treatment of fibers.

Chaithanyan et al. [56] investigated the hybrid composites of natural fibers in isophthalic polyester resin. Natural fibers (sisal and coir fibers) mixed with isophthalic polyester in magnitude fraction basis of 0.4 , 0.5. Hand layup process was used to manufacture this composite. Tensile, flexural, impact tests determine the mechanical characteristic of each composite. The tensile strength of the coir-glass composite was lesser than that of sisal-glass composite. The flexural strength and impact strength of sisal-coir-glass hybrid composite was proved to be better than the residual two combinations of composites.

Alhumdaany et al. [57] developed an isotropic hyperactive composite resin material. The botanical materials were reinforced by two kinds of brief fiber and powder. Thus, it is consisted of three items, powder and short glass fiber in the mixture of cup or date palm almonds as two reinforcements and polyester resin material. The composite structure was looked at to evaluate the mechanized characteristic (modulus of suppleness E, yield stress y) experimentally and analytically, as the natural frequencies were approximated theoretically, experimentally and numerically. The results display that, when utilize the particular date palm nuts powder, the yield stresses and the essential natural frequency are increased. This encourage utilize this kind of composite plate safely in the engineering uses where high loads are experienced in an comprehensive blend of operating frequencies.

Agunsoye et al. [58] and Pradhan et al. [59] studied polyester composite reinforced with coconut shell and their flexural and tensile characteristic. This composite was created via utilize coconut layer powder as filler (0, 15, 30, 45, and 60% via weight). Their very own result indicated better flexural and tensile strength of polyester-made composites compared to un-reinforced samples.

Naidu et al. [60] studied the combination natural and synthetic fibres in the same matrix (unsaturated polyester) to make Sisal-Glass fibre hybrid composites and evaluation of the compressive and impact characteristic of these hybrid composites. There was a significant refinement in the compressive and impact characteristic of (Sisal/Glass fibre) hybrid composites. Furthermore, the impact of Chalk powder on compressive and Impact characteristic of these hybrid composites was studied via addition of the Chalk powder to the resin (unsaturated polyester) in proportions of 1%, 2%, 3% by weight of resin respectively and via utilize this resin to study, Sisal-Glass fibre hybrid composites were prepared. It is also noticed that the compressive and impact characteristic decrease as the chalk powder amount increases.

Dixit and Verma [61] investigated the hybridization and its impacts on mechanical characteristic on coir and jute reinforced polyester composite (CJRP), coir and sisal reinforced polyester composite (CSRP), jute and sisal strengthened polyester composite (JSRP) were assessed experimentally. Compression moulding method was utilized to fabricate composites. It was proven that the mechanical characteristic of composites were considerably improved utilize hybridization. The tensile and flexural characteristic of hybrid composites are considerably improved as compared to non-hybrid composites.

Shehu et al. [62] studied the particle size impact on the characteristic of the composites to create polyester/ palm kernel shell (PKS) particulate composites. The palm kernel shell particles were varied thus; 0, 10, 20, 30 and 40 wt. % at three different particle sizes; 75µm, 150µm and 300µm. Polymerization reaction was initiated utilize cobalt accelerator and Methyl-ethyl Ketone catalyst and therefore accelerates the reaction. The palm kernel shell particles and particle size impact on mechanical and physical properties of polyester was investigated. The results showed a better interaction of polyester and palm kernel shell particles at 300µm sieve size with density, water absorption, ultimate tensile strength and impact energy increasing when percent palm kernel shell particles increases while only hardness decreases.

Kütük and Oguz [63] investigated experimentally the mechanical characteristic of particle filled composite material by utilize the sewage sludge ash. Consequences appear that the flexural strength impact resistance decreases and tensile strength increase if the rate of the sewage sludge ash in the composite was increased.

Manohara et al. [64] studied the tensile performance of composites reinforced with sea shell-jute fabric. The preparation of composites was done utilize sea shell powder as filler material in jute fabric reinforced with epoxy composite. The study of the tensile behaviors of this composite was accomplished via changing the sea shell filler percentage. It was proved that maximum tensile strength of 8400N with less distortion was delivered utilize 5% sea shell filler in jute fabric reinforced composite. The results were supported with SEM analysis. The current study of an exciting filler material (sea shell) on jute fabric reinforced composite.

Padal et al. [65] created jute nanofibre reinforced composite. The composites were prepared with 50 wt.% of glass fibre and 50 wt.% of epoxy resin content. The nanofibres are reinforced in various weight percentages (1wt.% - 5wt.%) with epoxy matrix to make (nano-fibre) composites. After that, mechanical characteristic of the nanofibre composites were compared with the base composite to see the results. It was found that the tensile strength of nanocomposite were increased to 96% with the 3wt.% nanofiber reinforcement as compared to the base composite. Besides, their suitability for high damping uses was proved as the damping parameters of the nanofiber composites were found to be much higher than that of the base composites.

Sanjay and Yogesha [66] studied the impact of composites that make of jute-E-Glass-fibers. This test displayed that hybrid composite of jute/ E-glass fiber has extreme superior characteristic if compared with that of jute fiber composite. However, it was proved that the strength of hybrid composite is better than that of jute fiber composite fabricated separately with glass fiber.

Zhang et al. [67] investigated interfacial and tensile characteristic of hybrid composites reinforced with unidirectional flax/glass fiber. It was found that the tensile characteristic of the flax/glass fiber reinforced hybrid composites were enhanced accompanied with the increasing of glass fiber content. The interlaminar shear strength and fracture toughness of GFRP were lower than those of hybrid composites reinforced with flax/glass fiber.

Sapuan et al. [68] increased impact, tensile and flexural characteristic of glass/sugar palm fibers, glass/sugar palm composites occurs due to increasing fiber content and the weight ratio of the composites.

Sarki et al. [69] worked on the effect strength to some extent decreased as compared with pure epoxy resin. the increase of coconut shell particles content in epoxy resin composite strengthened with a coconut shell leads to increase of tensile modulus and tensile strength values.

Idicula et al. [70] investigated the dynamic behavior of randomly oriented mixed short banana/sisal hybrid fiber strengthened polyester composites. Besides dynamic behavior of composites such as damping and storage modulus, static and impact characteristic were handled properly. Banana and sisal fibers were preferred for hybridization to select high performance and low cost composites.

Kenny and Marchetti [71] studied the nonlinear behavior of composite laminates, developed a micromechanical model including the plastic behavior of the matrix. They exhibited that there is an association between the plastic deformation and the increase of damping at high stresses.

Hwang and Gibson [72] made the micromechanical modeling of both damping and hardness in composite offered a strain energy approach including the fiber/matrix interface.

Singh and Kishore [73] worked on damping based design with composite materials highlighted the desirability of including damping as a restraint. The case studies result in lower weight configurations, improved dynamic performance, higher strength and stiffness of the composite structure.

2.2 Conclusion on Literature Review

As a conclusion on the summarized literature, the effect of fillers on the composite material can be clearly seen. Weight rate or volume rate of additive materials affect almost all properties of the composite material. Type of additives may affect with different weight rate/volume rate of olive pomace (additive) or different filler type. Also, the Mathematical model results show that the weight fraction of particle has a higher effect than grain size on the physical and mechanical properties of composite materials. The success of combining natural particulate fillers with polymer matrices results in the improvement of mechanical properties of the composites compared with the matrix materials. These fillers can be acquired from renewable sources and easily recyclable. Despite their little strength, they can produce composites with superior specific strengths.

CHAPTER 3

EXPERIMENTAL STUDIES

PRODUCTION OF COMPOSITE PLATES AND DETERMINATION OF MECHANICAL CHARACTERISTIC

3.1 Introduction

This chapter includes a presentation of raw materials used in this research, and to clarify the characteristic and general characteristics also includes devices used and the method of testing models and measurements carried out.

3.2 Raw Materials

Raw materials that have been used in the research could be divided into two parts, first, the matrix Materials is epoxy resin (Momentive-MGS L285) the second section is The Reinforcing Materials are glass fibres (E-Glass) and olive pomace particles. In the production of composite specimens, The composites achieved for this study via adding olive pomace particles filler in epoxy with six various weight fractions as 0.5, 1.0, 2, 5, 10 and 15 wt. % with a grain size of (75 μm).

3.3 The Matrix Materials

3.3.1 Epoxy resin

Epoxy resin was utilized in the research, which is in the liquid state it is possible to turn it into a solid state with adding hardener. The hardener is liquid blue colour Figure 3.1, added to the epoxy resin via a stoichiometric ratio of (100:40).

Epoxy resin allows an extensive range of characteristic and capabilities of the operation. Epoxy resin shows little contraction and high adhesion with fibre, it is also used in many applications, starting from space devices and ending sports equipment. The physical properties of epoxy resin is given in the table 3.1.

Figure 3.1 Epoxy Resin and Hardener

Table 3.1 Physical characteristic of the epoxy resin

Young Modulus	Compressive Strength BS 6319	Flexural Strength BS 6319	Specific Gravity	Viscosity
4.5 GPa	> 73 N/ mm^2	> 60 N/ mm^2	1.04	1.0 Poise

3.4 The Reinforcing Materials

3.4.1 Glass fiber

Glass fiber is a material consisting of numerous extremely fine GFRP. (Silica sand, limestone, boric acid) etc. GFRP is the main form of reinforcement the polymeric materials in general because it gives good binding strength and high toughness. Higher stiffness and rigidity can be obtained from other kinds of fibers such as fibers Kevlar and carbon, but they are expensive than the GFRP. Some advanced composite materials utilize GFRP kind (S) to obtain special mechanical characteristic, but the most common kind for use in the composite material is fiberglass kind E and the cause for this is it cost of low-lying. Table 3.2 shows some of the physical characteristic of the GFRP.

Figure 3.2 Glass fibre

Table 3.2 Characteristic of glass fibre.

Fiber kind	**σ* (GPa)**	**α (10-6k-1)**	**Density (g/cm^3)**	**E (GPa)**	**T max (C°)**	***K* (Wm-1k-1)**
E-glass	3.45	4.9	2.58	76.0	550	13

3.4.2 Olive pomace

Among the natural fibres, which generally consist of natural via-products, plant seeds have an important place. The olive pit is a good example for this. Olive pits are obtained, during the processing of fresh olives for oil. The olive tree is hard to cultivate and only grows in a constricted region in the world due to its needs a special soil and terrain. Mediterranean countries have these specialties and in the olive, the industry has become an important industrial branch in these countries. As one of them, in Turkey olive cultivation is common in Marmara and Aegean regions. In a classic olive oil manufacturing process the fresh olives in colours pink, green and black, are milling to extract the oil. pomace (Figure 3.3 shows olive pomace powder). Olive pomace has a lignocellulosic structure with its cellulose, lignin, uric acid, and polyphenol content. Table 3.3 shows the chemical composition of olive pomace.

Figure 3.3 Olive pomace powder.

Table 3.3 Chemical composition of olive pomace.

Crude protein	**Crude fiber**	**Crude fat**	**Soluble carbohydrates**	**Ash**
5.6%	57.5%	3.2%	20.7%	13.0%

3.5 Production of Composite Laminates

In order to manufacture composite specimens, plain woven Glass fiber having areal density of 200 g/cm² was utilized as a strengthened material in the composite laminate. Momentive-MGS L285 apoxy resin and Momentive-MGS H285 hardener with a stoichiometric ratio of 100:40 used in the matrix. The GFRP composite manufactured by utilizing six weight fractions of olive pomace as 0.5, 1, 2, 5, 10, and 15% with a grain size of (75 μm). Composite laminates were produced by hand lay-up method. Olive pomace was mixed with epoxy resin by mechanical stirrer with a 900 rpm rotation speed for 20 minutes then hardener added (Figure 3.4). Finally, the mixture applied to the all 8 glass layers one by one. Composite laminates were manufactured with the dimension of (250 mm ×200 mm) using hot press under 0.1 MPa pressure for 1 h curing time with 80^0C temperature (Figure 3.5). After curing of composites in a mold, produced laminates were leave to reduce its temperature to room temperature under the applied pressure. Produced specimens are seen in Figure 3.6.

(a) (b)

(c)

Figure 3.4 (a) Mixing, (b) Laying of olive pomace/epoxy resin, (c) Molding

Figure 3.5 Manufacturing unit.

Figure 3.6 Examples of produced composite and hybrid composite plates.

Table 3.4 Thickness and density of specimen.

Wt%	**t (mm)**	**ρ(Kg/m³)**
0	1.7	1.628
0.5	1.7	1.648
1	1.9	1.657
2	1.9	1.678
5	1.9	1.706
10	2	1.712
15	2	1.751

3.6 Mechanical Tests

Tensile test specimens and bending specimens were cut from hybrid composite plates in accordance with ASTM standards with CNC. ASTM D63810 [74] standard is used for tensile specimens and ASTM D-790 [75] standard is used for bending specimens. The thickness of the cut samples is 1.85 mm. The cut specimens are given in Figure 3.7. Figure 3.8 shows the measurements of tensile and flexural specimens.

The tests were conducted using universal testing machine (300 kN capacity Shimadzu Corporation, made in Japan) as shown in Figures 3.10- 3.11. Sample sizes are 165x13 mm for drawing and 200x12.7 mm for bending test. A 32: 1 ratio was used in the bending test. Three samples were produced and tested for each experiment. Averages of the results were presented in tabular form. The cross head speed was 2 mm/min and 3 mm/min for the tensile and the bending tests respectively.

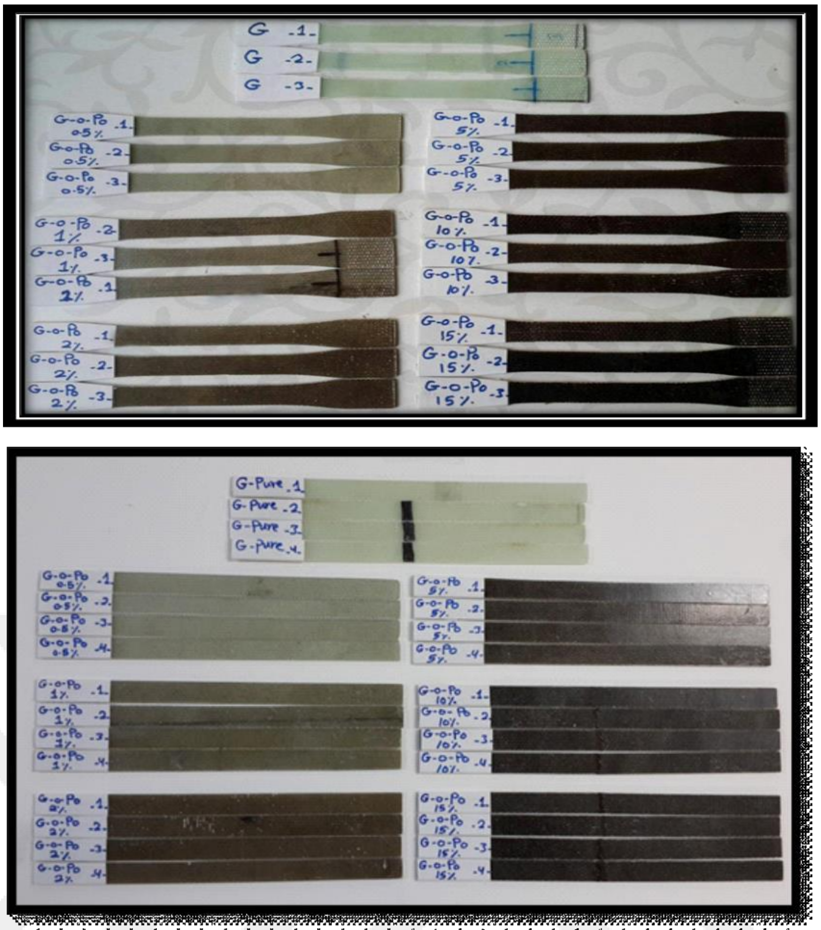


Figure 3.7 (a) Tensile & (b) flexural test specimens. Determination of tensile characteristic

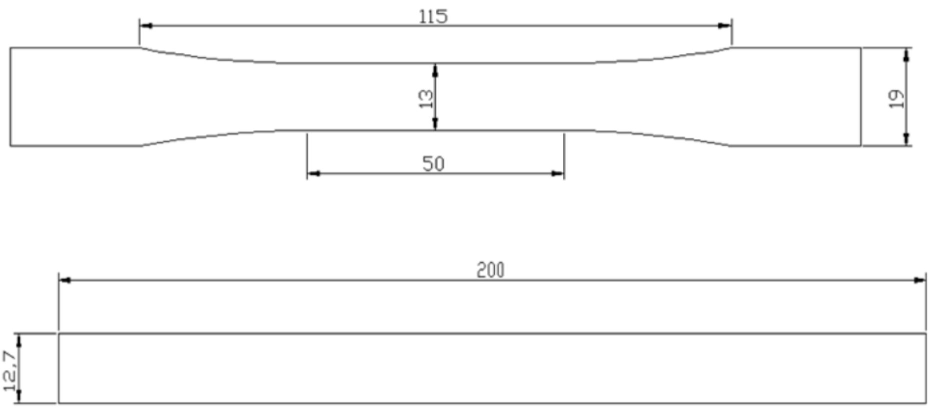


Figure 3.8 (a) Tensile and (b) flexural test dimensions. (All dimensions are in mm)

Figure 3.9 (a) tensile test set-up, (b) specimen under test.

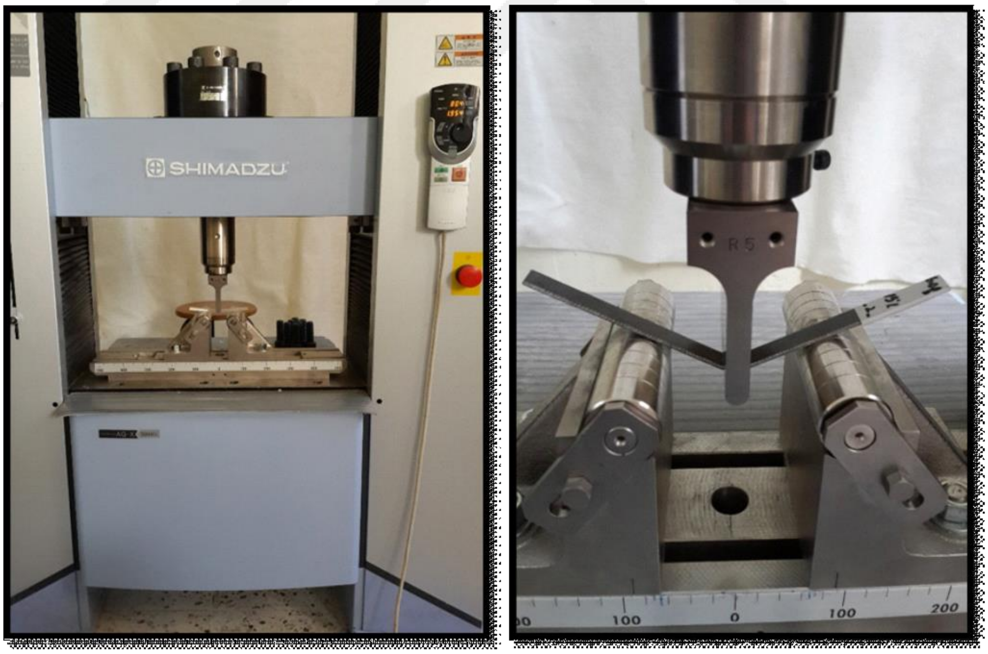


Figure 3.10 (a) flexural test method, (b) specimen under test.

3.7 Vibration Test

Vibration testing is an effective tool for nondestructively measuring the effect of any damage on the mechanical properties of composite materials according to ASTM E756 [76]. Half-power bandwidth method was used to get natural frequencies of the hybrid composite samples (Figure 3.11). The sample preparation and testing them on the device shown in Figure 3.12. The size of the vibration test is 200 × 12.7 mm and samples were fixed by supports. Produced samples exposed to excitation for by impact hammer to obtainable dynamic characteristic.

3.8 Damping Ratios for Composite

Damping ratios of hybrid composites were determined using half-power bandwidth method. This method is based on a time domain technique which shows exponential decay characteristic of the free response of the structure in order to obtain the knowledge of damping ratio [17]. The damping ratio in composite materials is essential to avoid failure in the mechanical parts that are exposed to the vibration and it necessary to calculate the damping time because it helps us to extend the life of these mechanical parts.

$$\delta = \frac{1}{n} \ln \frac{A_0}{A} \ldots\ldots\ldots\ldots\ldots \; (3.1)$$

δ = the logarithmic decrement, A_0 = the maximum magnitude of first cycle and

A= the maximum magnitude of nth cycle. Damping ratio= (ξ)

$$\xi = \frac{1}{\sqrt{1+\left(\frac{2\pi}{\delta}\right)^2}} \ldots\ldots\ldots\ldots\ldots (3.2)$$

The Euler-Bernoulli beam theory [76] as:

$$\omega_1 = \frac{1.875^2}{2\pi L^2} \sqrt{\frac{E' I}{\rho A}} \ldots\ldots\ldots\ldots\ldots (3.3)$$

The loss E''& storage modulus E' is expressed in Eq. (3.4):

$$E''(\omega) = 2E'(\omega)\xi(\omega) \ldots\ldots\ldots\ldots (3.4)$$

$$\xi = \frac{\omega_2 - \omega_1}{2\omega_n} \quad (3.5)$$

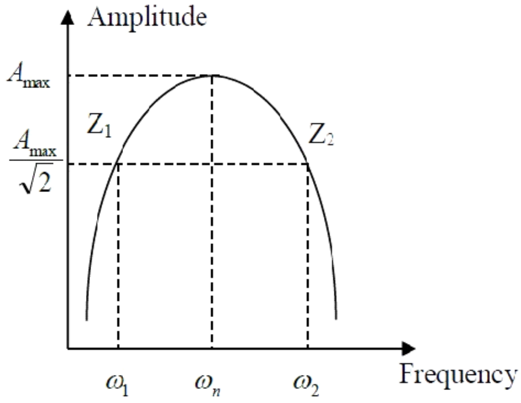
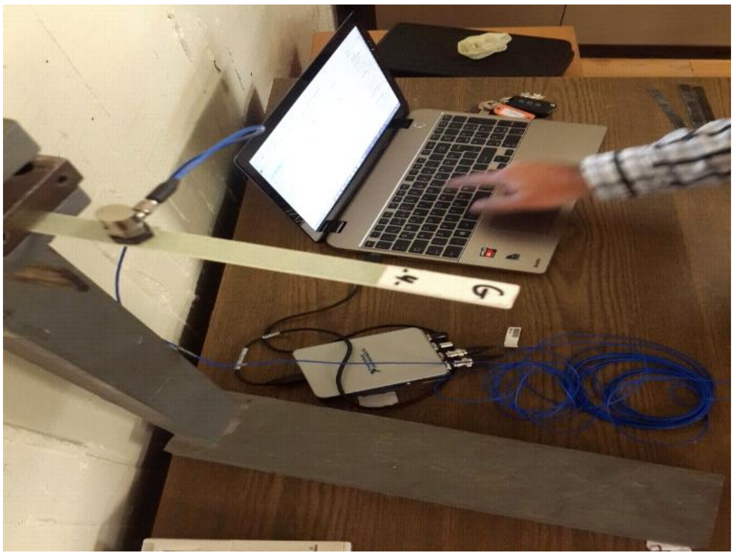


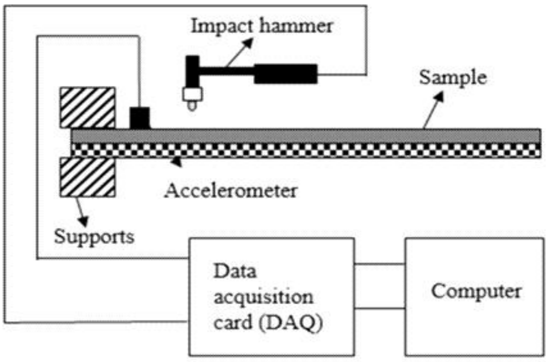
Figure 3.11 Half-power bandwith method

3.9 Experimental Set-up

The experimental method for specimens analysis used to calculate damping ratios and natural frequencies of GFRP composite. Accelerometer for output signal acquisition, impact hammer for stimulus force signal, data acquisition card device and the specimen analysis explain in Figure 3.12. Dynamic characteristics of composite laminates were measured using an experimental set-up. In the experiments, a general purpose ceramic shear ICP ® accelerometer (PCB 352C03), general purpose modal impact hammer (PCB 086C03) and a National Instrument product NI 9234 with LABVIEW software were used for output signal acquisition, stimulus force signal and data acquisition, respectively.



(a)



(b)

(c)

Figure 3.12 (a) Computer (b) schematic set-up (c) Experimental set-up

CHAPTER 4

EXPERIMENT RESULTS AND DISCUSSION

This chapter contains experimental results to determine tensile, flexural, damping, and natural frequencies of the specimen, which were conducted to see impacts of adding the olive pomace particles on the mechanical characteristics of GFRP composites.

4.1 Tensile Characteristic

This section discusses the results obtained for tensile characteristics of GFRP and GFRP-OP composites for various olive pomace contents.

Table 4.1 displays the tensile characteristic of GFRP and GFRP-OP composites for various olive pomace contents. As shown in Figure 4.1 and 4.2 and corresponding data in Table 4.1, the tensile strength of unfilled GFRP composite is decreased then increased gradually with adding olive pomace particles that the maximum reinforcement is 16.63% at particle content of 5 wt%, after this content the tensile were reduced. The elongation at break (followed same behavior of strength) that also was decreased then increased with addition of olive pomace particles then decreased. Hence, the elongation at fracture reached maximum amplitude with an increasing of 22.6% at OP content of 5 wt%. All the specimens were broken without any nicking and the fracture surfaces were flat (Figure 4.3), that means the specimens fractured in a brittle style during a tensile test. There was no effective decreasing in the cross-sectional area of the specimens and the specimens of GFRP/OP composites appear a brittle style. In addition, whether it was filled or unfilled with olive pomace particles, the tensile samples were failed at higher stress. the tensile samples were failed at higher stress.

Table 4.1 Tensile characteristic of GFRP-OP

Specimen	Wt.	Max. Stress (MPa)	Average Tensile Stress (MPa)	Average Tensile Strain %
GFRP -1 GFRP -2 GFRP -3	0%	303.28 320.43 334.78	319.50	2.99
GFRP-$OP_{0.5}$-1 GFRP-$OP_{0.5}$-2 GFRP-$OP_{0.5}$-3	0.5%	253.91 254.38 251.57	253.28	3.16
GFRP-OP_{1}-1 GFRP-OP_{1}-2 GFRP-OP_{1}-3	1%	267.73 278.96 277.91	274.86	3.10
GFRP-OP_{2}-1 GFRP-OP_{2}-2 GFRP-OP_{2}-3	2%	319.49 314.66 270.15	295.17	2.91
GFRP-OP_{5}-1 GFRP-OP_{5}-2 GFRP-OP_{5}-3	5%	365.60 378.23 374.11	372.65	2.80
GFRP-OP_{10}-1 GFRP-OP_{10}-2 GFRP-OP_{10}-3	10%	190.58 207.17 233.67	210.48	3.22
GFRP-OP_{15}-1 GFRP-OP_{15}-2 GFRP-OP_{15}-3	15%	175.76 177.03 196.26	183.02	3.28

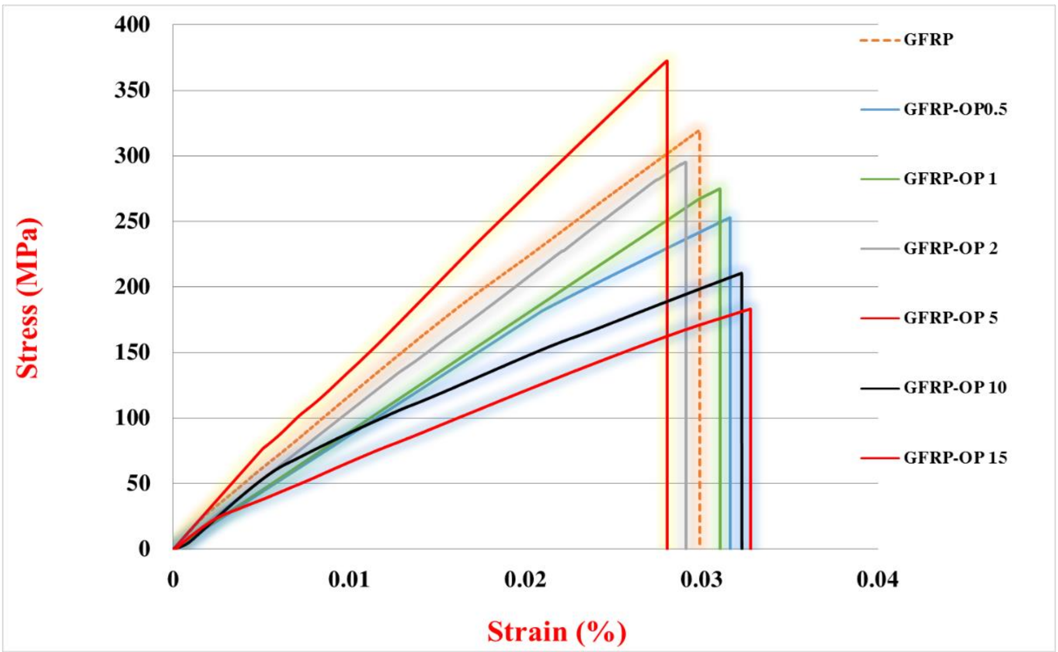


Figure 4.1 Tensile stress-strain curves of the glass fibre reinforced epoxy composite filled with olive pomace.

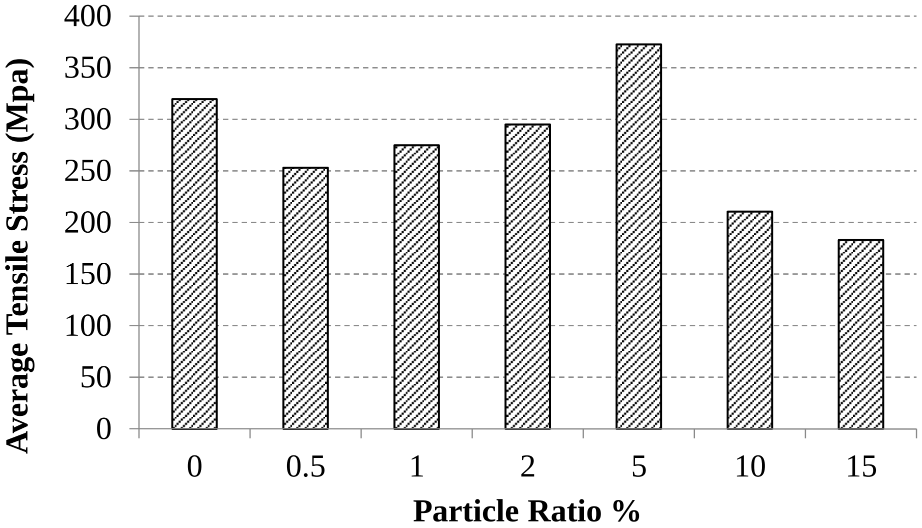


Figure 4.2 Tensile stress- Particle content (wt. %) diagram of the glass fibre reinforced epoxy composite filled with olive pomace.

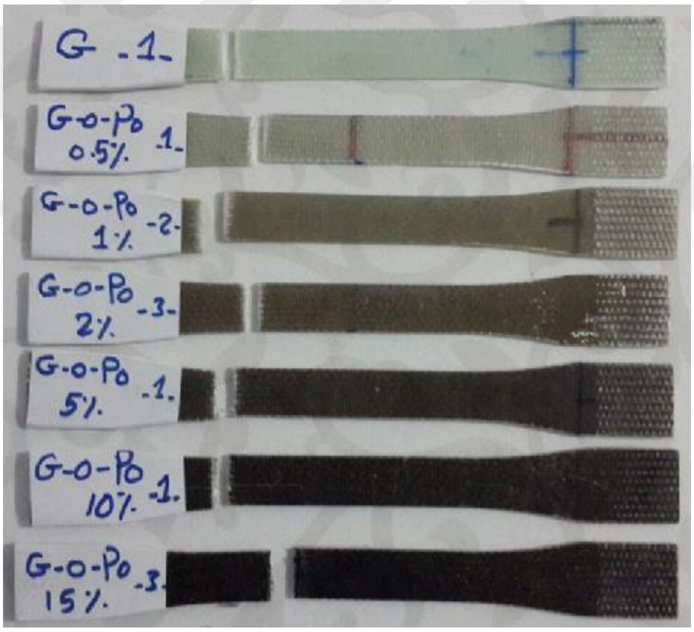


Figure 4.3 Failure form in tensile specimens after testing.

4.2 Flexural Results

This section presents experimental studies on the flexural tests of GFRP and GFRP-OP composites for various addition of olive pomace contents. Flexural load and displacement values are listed Table 4.2. After experiments, flexural stress and flexural modulus values were calculated according to equations in ASTM standard and calculated values are given in Table 4.3.

As shown in Table 4.3 and Figures 4.4 and 4.5, flexural strength was improved by the OP particles addition to the GFRP. The composite flexural strength was rise from 465.56 MPa for neat GFRP to 630.90 MPa with OP content of 5 wt%, after that flexural stress follows the reducing trend up to 291.81 MPa at content of 15 wt%. The highest flexural strength was obtained at 5 wt% content of OP with maximum increment of 35.5 %. The flexural tests was appear a linear response of the stress-strain curves (Figure 4.4) of the composites, then the fracture was happened and the flexural load decreased suddenly. It is also seen from Table 4.3 the failure strain was decreased with the increase of olive pomace particle ratios.

Additionally, the flexural modulus enhanced with addition organic particle of OP, which modulus was increased from 17.84 GPa for unfilled GFRP to 24.24 GPa at OP particles of 5 wt%, then decreased to 18.41 GPa at OP particles of 15 wt% (Fig. 4.6). The maximum increment of flexural modulus was 35.9%.

As shown in Figure 4.7, the specimens fractured at the middle by bending load, then failure was acquired with matrix cracking then fibers breakage and Glass/epoxy layers delamination between compression and tension sides.

To sum up, this refinement of tensile and flexural characteristic attributed to the chemical compatibility of the olive pomace particles with epoxy resin and E-glass fibers in the composite laminate system. Furthermore, the tensile and flexural characteristic were degraded when olive pomace particles content exceeded 5 wt. percentage and that may be ascribed to the particle aggregation phenomena which forming weaknesses in composite laminate and decreasing flexural strength.

Table 4.2 Flexural load-displacement of GFRP

Pomace Particles (wt%)	Load (N)	Displacement (mm)
0	193	7.6
0.5	190	5.5
1	263	7.4
2	280	7.6
5	294	7.8
10	199	6.1
15	145	4.4

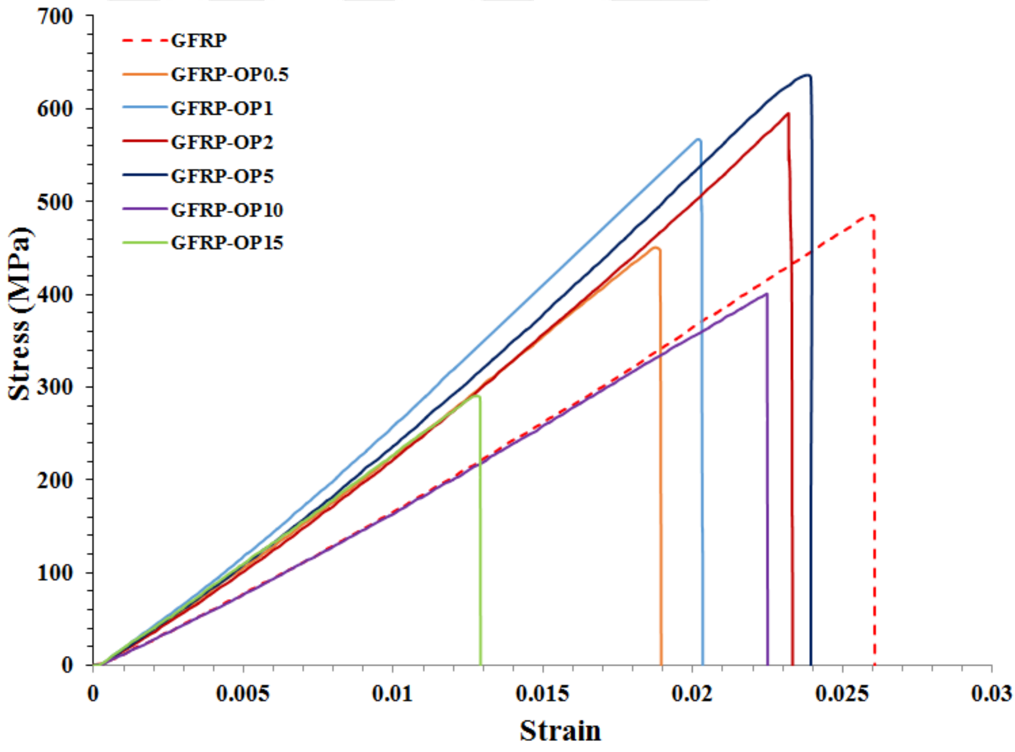


Figure 4.4 Flexural stress-strain curves of the glass fiber reinforced epoxy composite filled with olive pomace.

Table 4.3 Flexural characteristic of GFRP-OP

Specimen	Wt. (%)	Max. strain	Max. Stress (MPa)	Average Flexural Stress (MPa)	Flexural modulus (GPa)
GFRP -1		0.0223	405.14		14.42
GFRP -2	0	0.0169	505.46	465.56	16.71
GFRP -3		0.015	486.09		16.38
GFRP-$OP_{0.5}$-1		0.0187	450.98		22.51
GFRP-$OP_{0.5}$-2	0.5	0.0193	412.44	468.82	21.26
GFRP-$OP_{0.5}$-3		0.0232	543.02		19.42
GFRP-OP_{1}-1		0.021	594.65		24.21
GFRP-OP_{1}-2	1	0.0225	566.67	553.21	24.81
GFRP-OP_{1}-3		0.0206	498.32		23.52
GFRP-OP_{2}-1		0.0217	613.75		24.71
GFRP-OP_{2}-2	2	0.0223	595.77	602.09	24.82
GFRP-OP_{2}-3		0.0233	596.76		23.18
GFRP-OP_{5}-1		0.0225	612.87		25.1
GFRP-OP_{5}-2	5	0.024	648.95	630.9	23.93
GFRP-OP_{5}-3		0.0234	630.88		23.68
GFRP-OP_{10}-1		0.0231	401.8		16.23
GFRP-OP_{10}-2	10	0.0215	395.26	405.51	17.42
GFRP-OP_{10}-3		0.0225	419.47		18.15
GFRP-OP_{15}-1		0.0222	297.79		17.55
GFRP-OP_{15}-2	15	0.022	291.49	291.81	18.20
GFRP-OP_{15}-3		0.0211	286.15		14.08

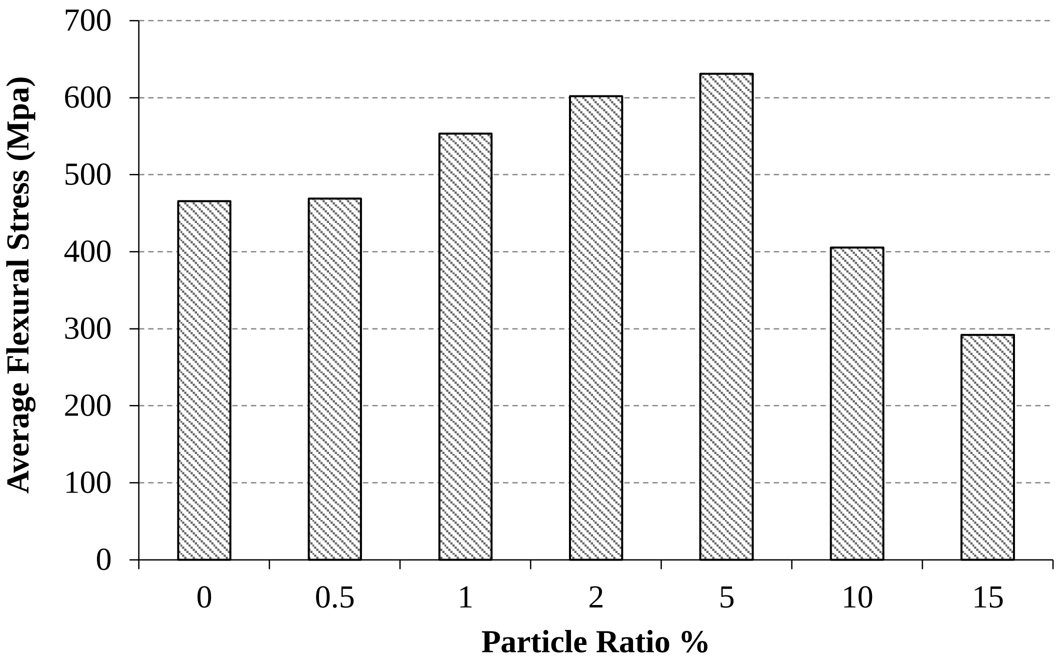


Figure 4.5 Flexural stress– Particle content (wt. %) diagram of the glass fibre reinforced epoxy composite filled with olive pomace.

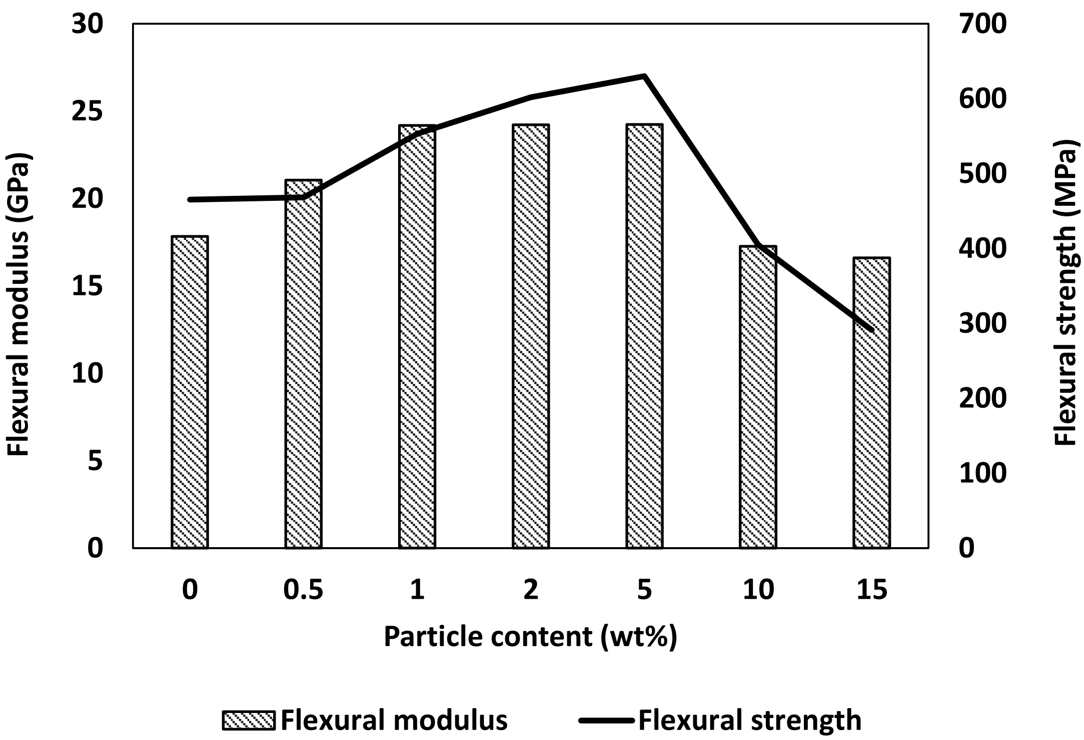


Figure 4.6 Flexural strength and modulus of the glass fiber reinforced epoxy composite filled with olive pomace.

(a) (b)

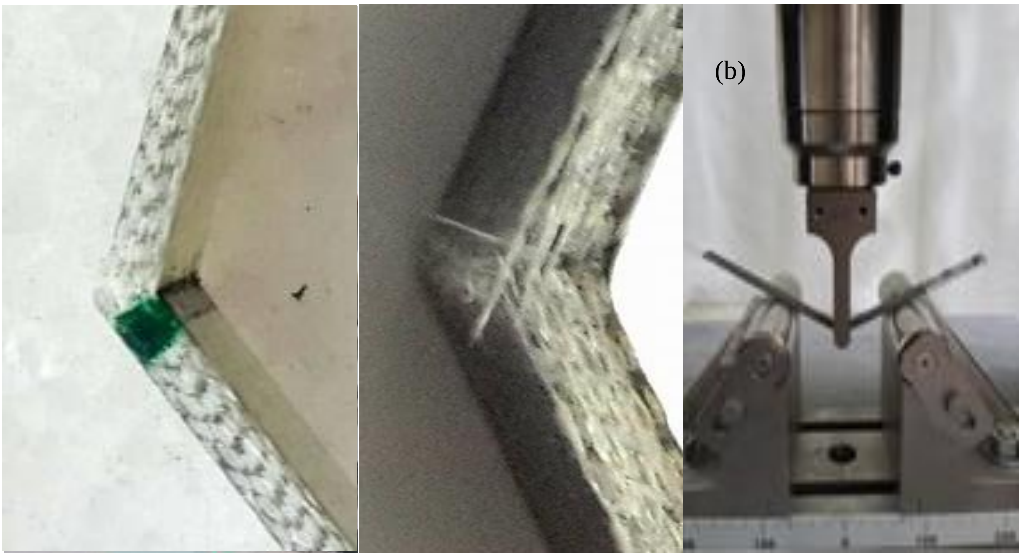


Figure 4.7 (a) Flexural specimens after testing**, (b)** Flexural specimen under test

4.3 Vibration Damping Results

Change of first mode frequency values according to damping properties of composite laminates In Table 4.8, the frequency response is shown in Figure 4.8. Time response curves are given in Figure 4.9. The results imply that the increase in stiffness causes a trend of increase in the natural frequency [79]. However, increase in stiffness may not lead to increase in the damping ratio, since the damping characteristic of the structures strictly depend on viscoelastic characteristic, which means the better absorption of vibration energy and good storage modulus [80]. According to experimental results, the increase of particle ratio is nearly same affecting the first mode natural frequency of glass/epoxy composite. In this context, first mode natural frequency of the composites was not affected by the particle ratio.

Damping ratio of composite samples was determined using half-power bandwidth method. Damping ratio of the olive pomace/glass/epoxy composite is similarly dependent to the interfacial interactions of polymer/filler system. There are both increasing and decreasing trends in damping ratio for particle modified GE composite specimens. With addition of 15 wt.% of olive pomace, damping was increased by 23.8%.

It is clear that the addition of olive pomace particles significantly improves the storage modulus about by 13.84% for GFRP-OP_5 composite, while loss modulus increases about by 74.21% for GFRP-OP_{10} composite. This means that addition of olive pomace particles enhances the energy dissipation capacity of the structure followed by a decrease of the stiffness.

In order to figure out the damping properties of particle filled composite laminates, loss and storage modulus of all composite laminates were identified using dynamic modal analysis. It is clearly shown in Table 4.4 that variation of filler content do not give any definite correlation with loss modulus. There are both increasing and decreasing trends in the results of loss modulus for particulate composite specimens. The addition of 5 wt.% of olive pomace improves the storage modulus about by 13.8 % and 10 wt.% of olive pomace addition improves loss modulus about by 68.8 %.

Table 4.4 Vibration results of the glass fiber reinforced epoxy composite filled with olive pomace.

wt%	W_N	ξ	E'' (GPa)	E' (GPa)
GFRP	37.98	0.239	8.17	17.08
GFRP-$OP_{0.5}$	44.59	0.185	8.82	23.83
GFRP-OP_1	36.33	0.250	6.36	12.73
GFRP-OP_2	39.63	0.271	8.30	15.34
GFRP-OP_5	44.59	0.278	10.97	19.74
GFRP-OP_{10}	44.59	0.407	14.57	17.88
GFRP-OP_{15}	42.94	0.296	7.86	13.27

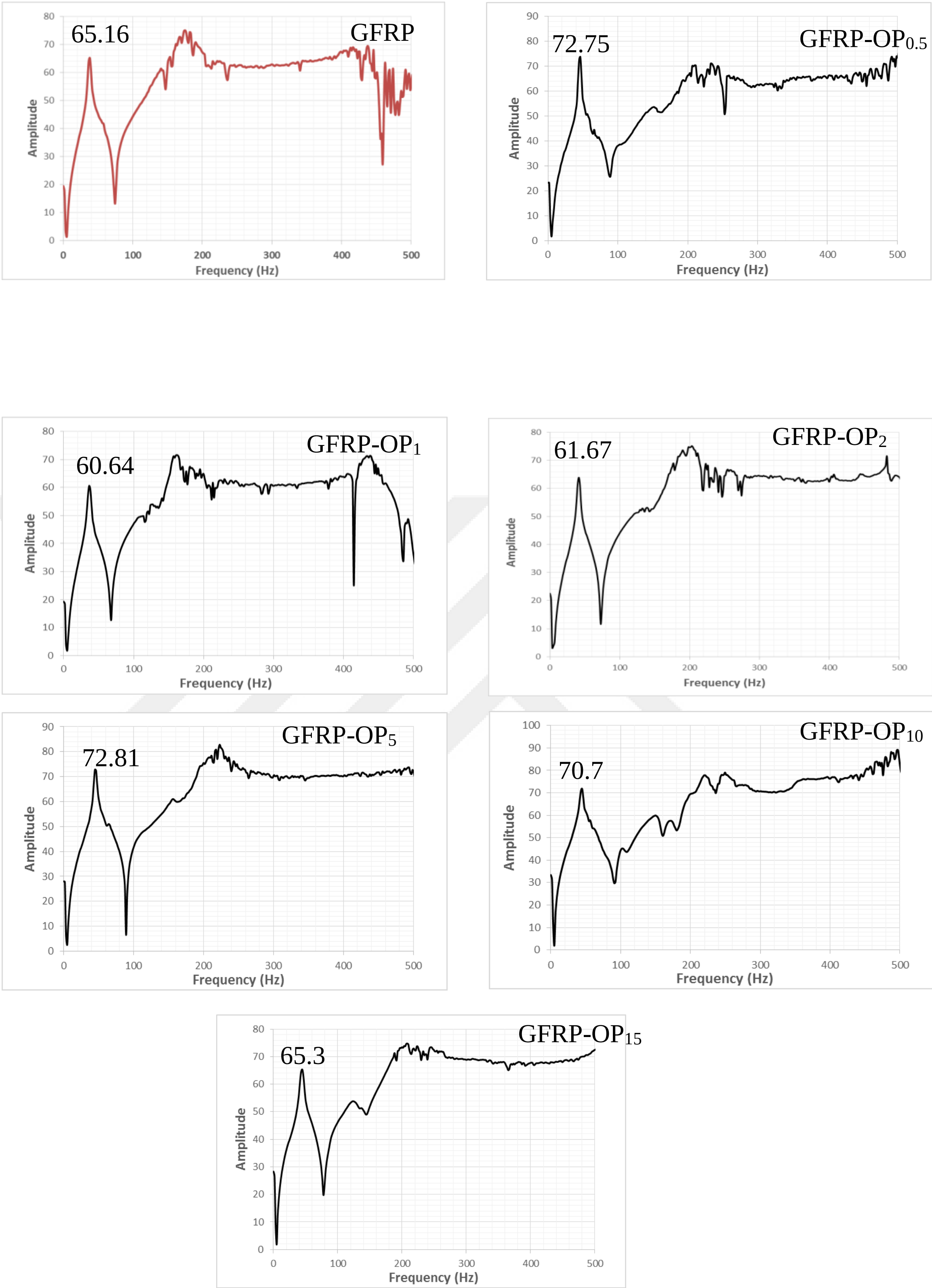


Figure 4.8 Frequency response diagram of the glass fibre reinforced epoxy composite filled with olive pomace of samples.

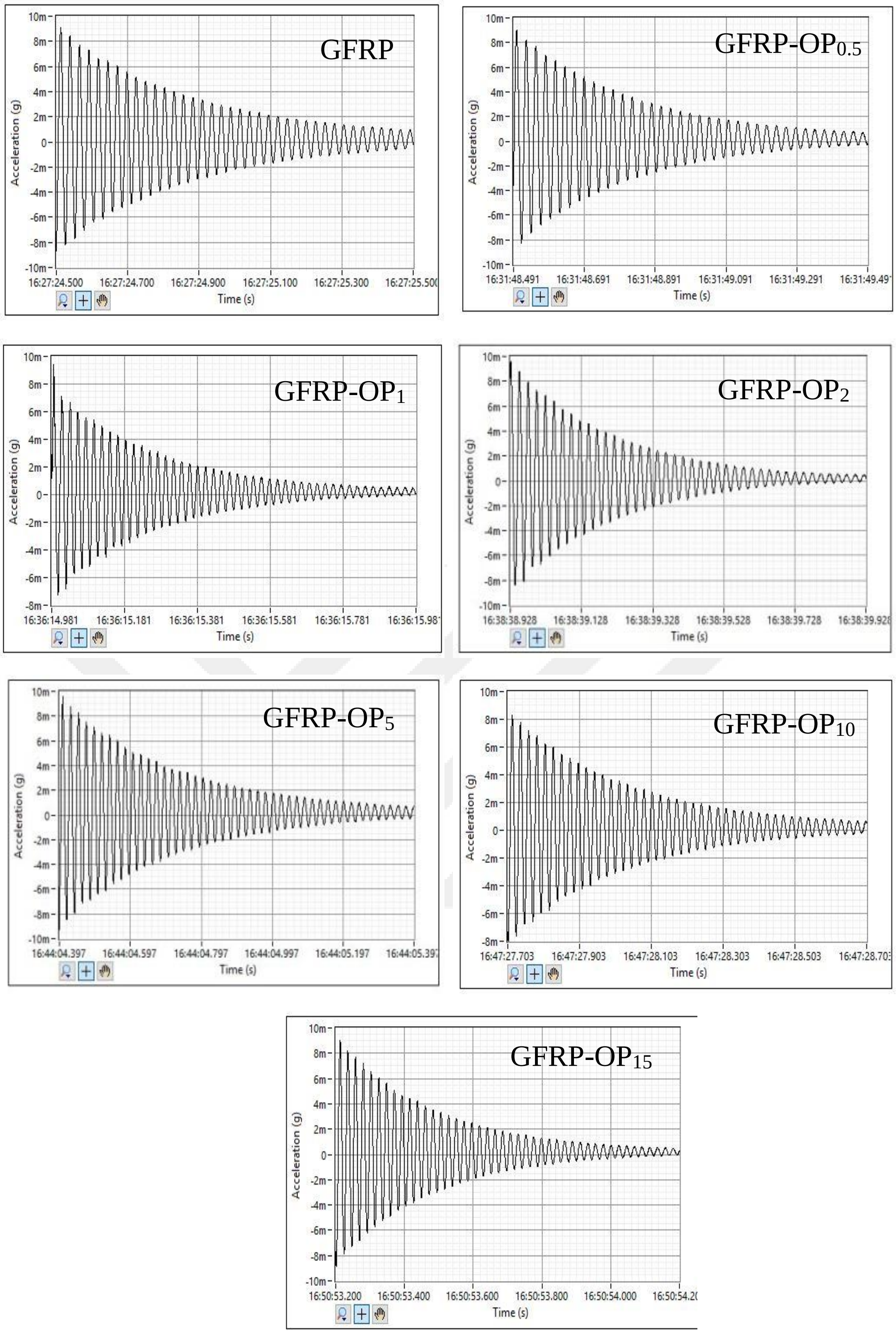


Figure 4.9 Time responses of samples.

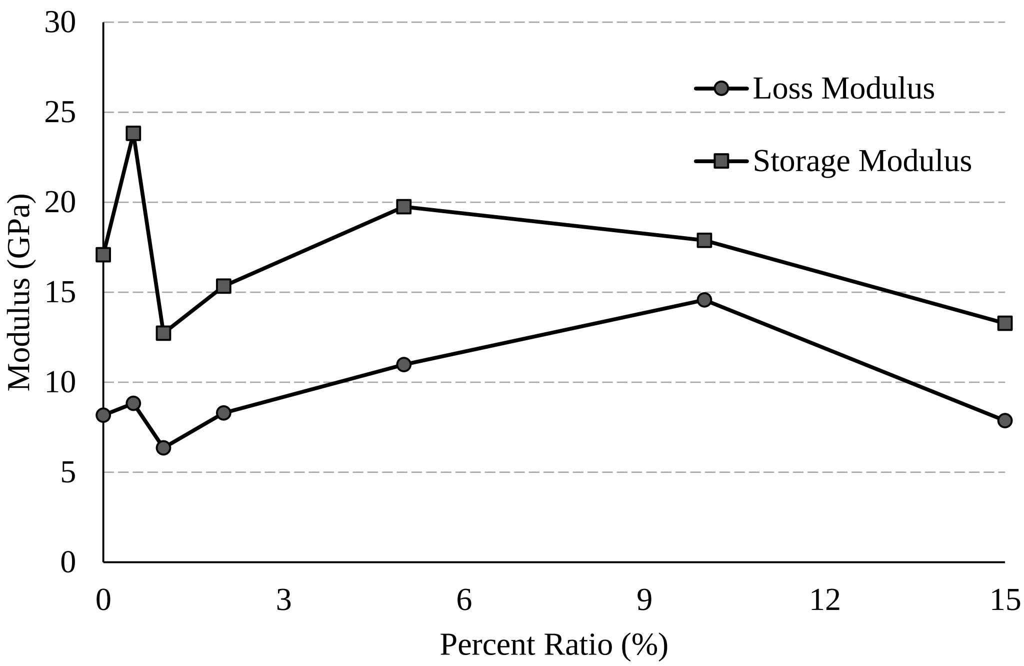


Figure 4.10 Storage and loss modulus - Particle content (wt. %) diagram of the glass fibre reinforced epoxy composite filled with olive pomace.

4.4 SEM Micrographs

The fractured surface of the tensile specimens was observed using SEM micrographs for OP particle contents of 0.5, 2, 5, 10 and 15 wt%, as presented in Figure 4.11 SEM images indicate the bonding of OP particle, epoxy and glass fiber. The samples of 5 wt% OP is exhibited good adhesion of the OP/epoxy and the glass fibers (Figure 4.11c). As shown in Figure 4.2(a), and (b) for the samples of 0.5, and 2 wt% of OP particles, respectively, the interface bonding is weak between the OP/epoxy and glass fiber, which these images show the fiber pull-out at low OP content of the glass fiber composite systems.

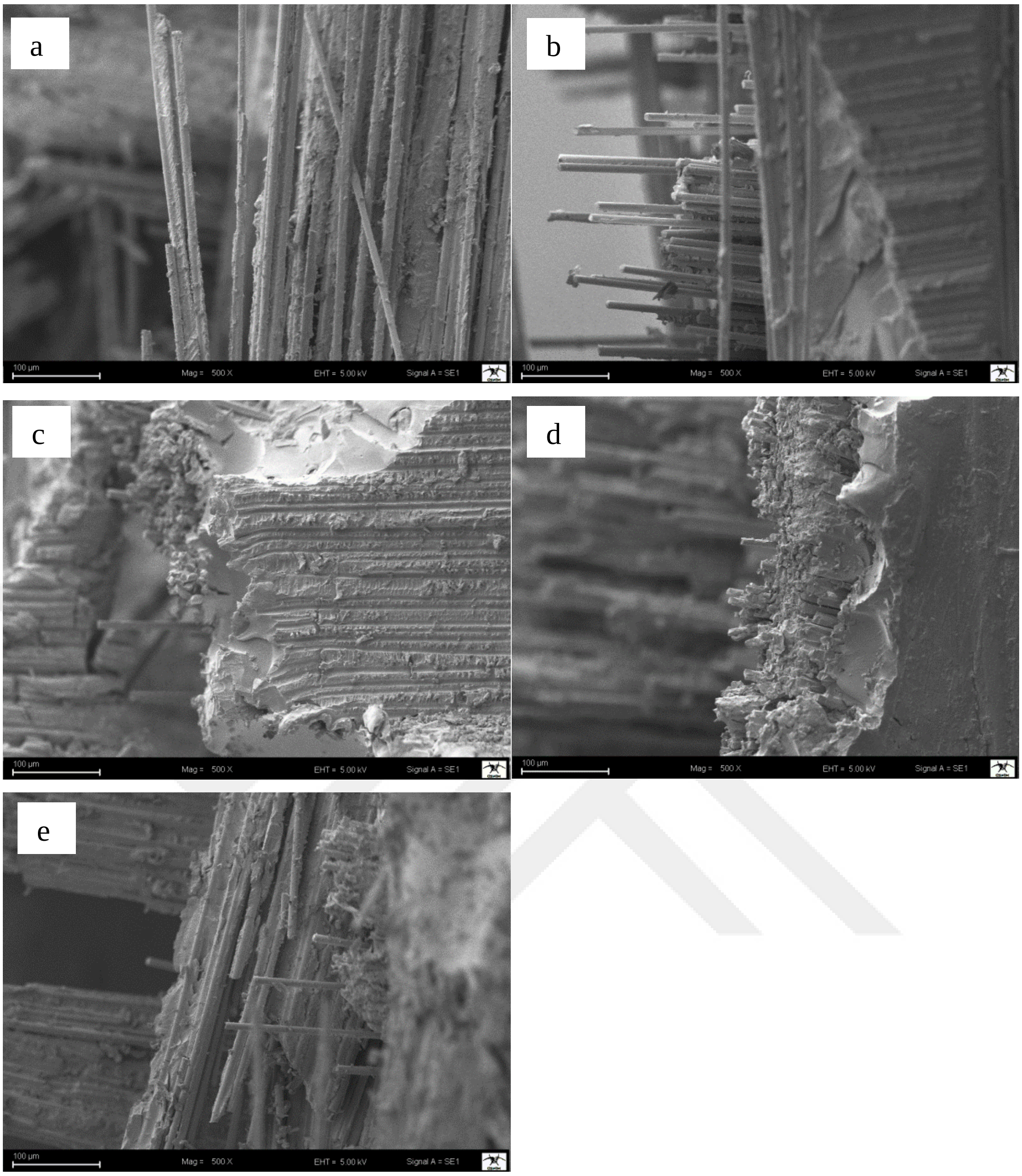


Figure 4.11 SEM micrographs of (a) 0.5 wt% (b) 2 wt% (c) 5 wt%, (d) 10 wt% and (e) 15 wt% olive pomace filled glass fabric/epoxy composite samples.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

Main conclusions from this study can be drawn as follows:

The effects of olive pomace particle content on tensile and flexural and variation (natural frequencies and damping properties) characteristic of the glass/epoxy composites were inspected. The main conclusions from this study can be drawn as follows:

- The following conclusions can be obtained from the present study:
- The SEM images indicated good distribution of OP particles was obtained for OP particle content of **5** wt%. In addition, particle aggregation occurs at content above ~**5** wt%.
- For tensile test results, the adding OP particle improved the tensile strength nearly **16.63%** (319.50 Mpa - 372.65 Mpa) from neat epoxy with **5** wt% OP content.
- The elongation at break was increased by **22.6%** (3.45-4.23) at **5** wt% compared to unfilled epoxy matrix.
- For flexural test results, the adding OP particle improved the flexural strength nearly **35.5%** (465.56 Mpa - 630.90 Mpa)from neat epoxy with **5** wt% OP content.
- The flexural modulus was gradually improved up to OP particle content of **5** wt% with highest increment of **35.9**% (17.84 Gpa – 24.24 Gpa).

- Maximum damping ratio is obtained from **10** % wt addition of olive pomace to Glass/epoxy. Damping ratio was increased by **70%** (0.407) higher than Glass/epoxy composite.

- Finally, It is clear that the addition of OP improves the storage modulus about by **39.51%** (23.83 Gpa) for GFRP-OP0.5 composite, while loss modulus increases about by **78.33%** (14.57 Gpa) for GFRP-OP10 composite.

- Even though some loses in mechanical properties can be found at high particle content, fabricating environmentally friendly and low price particulate polymer composite can be regarded as benefits of using OP as particulate filler.

5.2 Future Works

- The lightness of weight composite materials reinforced with natural fibers made it possible to use a substitute for composite materials reinforced industrial fibers. But there is still a lack of it can be used in difficult environmental conditions, so it must find new ways to get the size grain smallest fiber for the purpose of obtaining a homogeneous mixture, which leads to not be grouped hinder the distribution of loads over fibre ,as well as increase the strength of adhesion between the fiber and the matrix and therefore get the best mechanical characteristic has therefore been limited so far to use applications such as internal plates in cars, trains, furniture, tools and sports entertainment.
- Study the phenomenon damping the mechanical vibrations in composites reinforced fibre, As a way to learn about the role of fiber in the loss of energy out on the mass of composites And the extent of the role play it the mechanical characteristic of the composite materials in the process of damping the vibration or loss of energy.

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