Materials Science Forum
ISSN: 1662-9752, Vol. 1050, pp 115-123

Submitted: 2021-08-12
Revised: 2021-08-15
Accepted: 2021-08-18
Online: 2022-01-18

Recycling of Waste Medical Plastic Syringes in Manufacturing Low-Cost Structural Sections

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Keywords: Waste, Recycling, low-cost structures, plastic syringes, unsaturated polyester adhesive.

Abstract. Particles of waste from plastic medical syringes (WPMS) are recycled with a polymeric adhesive from unsaturated polyester resin (UPS) to manufacture structural profiles at the lowest cost, and that could be used in various applications such as buildings, furniture manufacturing, toys, etc. The manual molding method was used in preparing the models for testing with the following volumetric fractions (0%, 30%, 40%, 50%, 60%, 70% and 80%), and with a granular size of (0.45mm) of (WPMS). Some tests were performed on the prepared samples, including mechanical ones, tests included are (tensile test, bending test, and hardness test), in addition to the physical test, which is (thermal conductivity),The results of the mechanical tests showed an increase in the values of mechanical properties of (tensile strength (27MPa), the flexural modulus (3.42GPa), and hardness (69 N/mm^2)) as the volumetric ratios of Waste plastic medical syringes (WPMS) particles increased. Whereas, the thermal conductivity (2.14W/m.°C) values decreased as the volumetric ratios of Waste plastic medical syringes (WPMS) particles increased. Given that this is the first time that this type of waste is used in manufacturing structural profiles at a low-cost in exchange for less harms to the environment.

1. Introduction

Composite materials have received increasing attention in the current era as a basic engineering material, because of its excellent properties, and its success has emerged in many specialties and uses, like: (medical industries, military and civil industries, furniture industry, toys), and in our daily life. All of that is because of its unique properties which makes it the number one choice over all other materials. Its use increased in many technological and industrial applications, because of its specifications that replaces traditional materials, such as metals and alloys, which have durability and strength but lack high density and polymers, which are being low in density, but need way more strength and durability. So, composite materials have become the trend [1], because of their effective role and distinctive properties, such as (light weight, hardness, and high strength). These properties made the composite materials to be the source of attraction for investors and engineers in various industrial branches [2-4]. The composite materials can be defined as the materials coming from mixing two or more substances with different properties to produce new ideal properties that are different from the properties of the materials included in the composition process, even if it is a single substance [5]. Polymeric Composites can be prepared from various stiffeners and specific fillers to produce distinct properties that have widely used in various applications [6]. The emergence of polymers as a result of the requirements of the current era, which is witnessing a remarkable development in various life fields, has led to the common thinking that the world without polymers is impossible, because of their excellent properties that keep pace with the scientific development that is occurring, compared to other materials like (metals, ceramic), which are easy to manufacture, resistant to oxidation and corrosive solutions, such as acid and base solutions, let alone that they are prone to discoloration [7]. Plastic waste is different and diverse, as plastic is used in various medical fields, which results in enormous plastic waste that must be utilized Single-use, especially [8]. Plastic materials create a major cumulative problem over time, which generates thousands of tons of waste after its use [9].Waste is generally known as materials that have lost their value, for example, medical waste, which includes plastic waste [10]. Medical waste is a part of environmental waste arising from various medical practices and activities, including plastic medical syringes (WPMS) [11], and sources of such waste are government and private hospitals, laboratories, blood banks, sample collection operations, and various health sectors and centers [12]. This is in addition to meeting the needs of researchers and the ease of formation and modification of plastic properties, which, in turn, led most world countries toward recycling plastic materials in the industrial and construction field. Thus, and because of the industrial and environmental requirements, this prompts us to recycle Waste plastic medical syringes (WPMS), and reduce environmental damage on the one hand, and produce a composite material used in industrial applications on the other as a substitution of raw materials for two major reasons. First, to preserve the natural resources for the longest possible period of time, and second, to reduce the damage arising as a result of burying and burning the waste. Recycling has become one of the most important pillars which many industries rely upon today [13-15]. The research aims at recycling the waste of medical plastic syringes (WPMS) to manufacture low-cost structural profiles which could be molded with multiple thicknesses and sizes, use them in many applied and industrial fields, and reduce the harms of environmental pollution resulting from these wastes, because they compose gradually and slowly in the environment, and need large landfill places. Let alone that burning these wastes produces toxic gases which are very harmful to the people and the environment in general.

2. Experimental Work:

2.1 Recycled materials: The waste from plastic medical syringes (WMPS) were recycled after being cutting and grinded using high-quality technical methods to obtain particles of (0.45mm) in size.

2.2 Adhesive Material: In preparation of the current work, an adhesive material from (UPS), which is manufactured by the Saudi Company for Specific Industrial Resins (SIR) with quality (SIROPOL-8341), which has a transparent viscous liquid form at room temperature with a density of approximately (1.2 g/cm^3). It is the type of resins that harden with heat, to increase the speed of solidification. Methyl ethyl ketone peroxide (PMEK), which is also manufactured by the same company, it is a transparent liquid that is added to the unsaturated polyester resin at a ratio of (2g) per (100g) at room temperature, to increase the hardening speed.

2.3 Sample preparation: The manual molding method was used to prepare samples from (WPMS) particles after cleaning them from contaminants, drying them completely, then cutting and grinding them, and using them in volumetric proportions of (30% 40%, 50%, 60%, 70% and 80%).

(WPMS) were mixed with the adhesive substance (UPS) gradually and slowly in order to obtain a complete homogeneity between the particles of (WPMS) and the adhesive material (UPS). The mixing continues slowly so as not to cause bubbles that affect the consistency process, and the mixing is done in all directions to ensure the uniformity process for a period of (2min). All of that in order not to have clumpy mixture which will be poured into the special molds, after ensuring consistency and no lumps in the mixture, the liquid mixture is placed in the mold carefully and is left for approximately (30minute) at room temperature. Once it is frozen, it is placed in an electric oven at a temperature (50 C°) for (1 hour), and remains in the (electric oven) after turning it off at this temperature until it cools- down. Thus, obtain the best interlocking between the polymeric chains and achieve the best solidification, and then, we take it out of the mold. We repeat the process with the same steps for all samples, according to the volume ratios of the recycled (WPMS) particles.

2.4 Mechanical tests:

Tensile tests: Tensile samples were prepared according to the required standard dimensions, in accordance with the approved American specifications (ASTMD638-03) [16], using a tensile testing machine, specifically (LARYEE Testing Solutions). The machine stretches the sample from the upper and lower side and then applies stress force on the sample (load) until it collapses (until failure), and the reading process begins for the diagram of the samples prepared for this test, and through the interface graph we obtain (stress - strain) curves. Through which, we calculate the properties of (tensile strength). Figure (1) represents the standard dimensions of tensile samples according to international specifications, and figure (2) represents the tensile test samples.

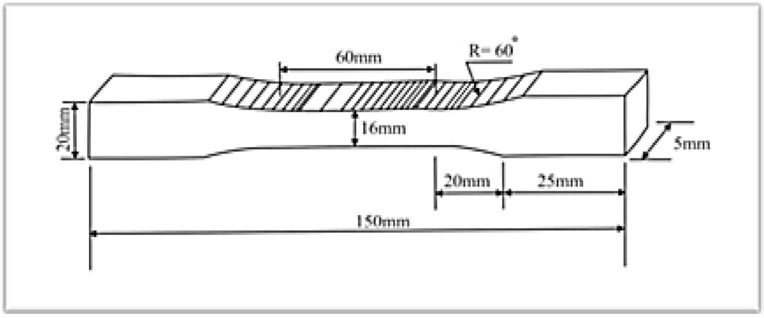

Figure (1) Scheme of tensile samples according to International Standards (ASTM).

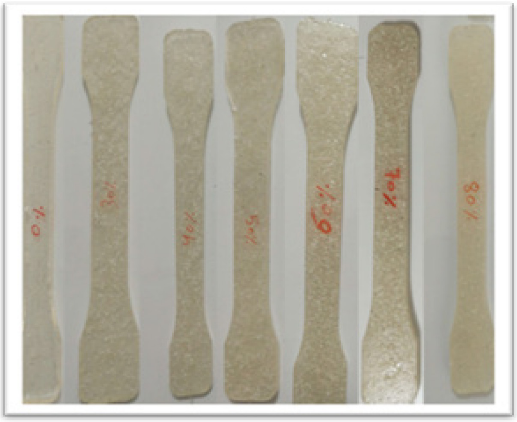

Figure (2) Tensile test samples

Bending test: The bending samples were prepared according to the American specifications made for testing materials (ASTM D790) [17], with the dimensions (4.8X10X100mm^3). A three Point Bending Test was performed for these samples, where the sample is installed between the two supports braces of the device, and then, load is applied to the middle of the sample until it fails. The interface graph starts reading the test samples through which we obtain the stress-strain curves and from those curves we calculate (the modulus of elasticity of bending). Figure (3) represents the standard dimensions diagram for the test samples according to the international specifications ASTM, whereas figure (4) represents Bending Test Samples.

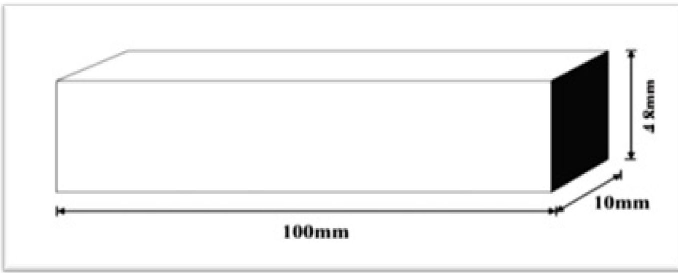

Figure (3) The standard dimension diagram of the test samples according to International Standards (ASTM).

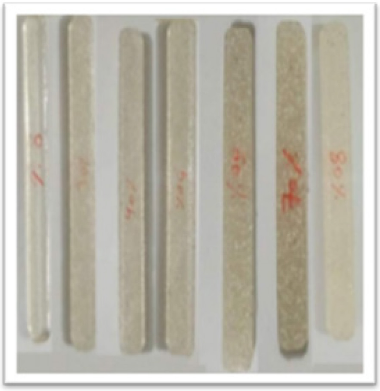

Figure (4) Bending Test Samples

Hardness Resistance Test: The samples for this test were prepared according to the international specifications of the device (ASTM-D2240) [18], and according to Shore D hardness measurement method, because this method is suitable for polymeric materials that harden with heat, samples with a thickness of (4mm) and a diameter (40mm) were used in order to be suitable for measurement when conducting the examination. Figure (5) shows a diagram of the hardness test samples. We put the test sample in the designated place, and then we take the readings for all proportions directly after testing them with the hardness measuring device that contains a needle installed which penetrates the surface of the sample. Figure (6) shows the hardness test samples.

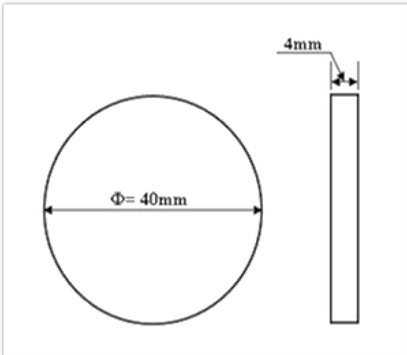

Figure (5) Diagram for the measures and dimensions of hardness samples according to international specifications (ASTM-D2240).

Figure (6) Hardness Test Samples.

2.5 Physical tests:

Thermal conductivity test: This test was performed through the use of hot disk analysis, where the sample is placed inside the device, and this device is considered one of the most common techniques to read (thermal conduction) properties. This is heated via an electrical connection with a capacity (0.022W) with resistance (11.56Ω). The sensor works as a heat source as it heats up by passing an electric current for a limited period of time, and at the same time the temperature is recorded for the sample being used. It is necessary that the sample is larger than the sensor diameter to ensure that the thermal energy is not dissipated. Figure (7) shows Thermal conductivity test samples.

Figure (7) Thermal conductivity test samples.

3. Results and Discussion

3-1. Results and discussion of tensile strength test: Figure (8) on this page shows an increase in the tensile strength values reaching the volumetric ratio of (50%) by (27MPa), then it started to gradually decrease as the volumetric ratios increased for particles from (WPMS) with the adhesive material (UPS), and this is because of the (WPMS) particles that possesses tensile impedance and have good elasticity. Particles penetrate into the adhesive content, especially when the particle size is appropriate, which leads to a gradual reduction of defects in the cavity of the adhesive used [19]. In addition to that, composite materials reinforced via the formed particles, do not necessarily depend on the qualities and properties of the components of the composite materials, but there is a fundamental role for the nature of the interface between the two components, as well as the geometric shape and the proportions of the granular size of the particles being used [20]. We notice with the increase of the quantity of (WPMS) particles as well as its increasing volumetric percentages, the tensile strength values decrease gradually till it fails collapses, and that is due to the small interface area between the adhesive material (UPS) and the number of particles obtained from the increase of volumetric ratios of the particulate matter. This leads to weakening the forces that bind the superimposed materials (WPMS) and the adhesive material (UPS), and this leads to the collapse of the overlaying material with the least load applied. That is especially true if the amount of particles is large, making it difficult to penetrate into the cavity of the adhesive material, and a number of internal defects may arise that cause the collapse of the overlaying material with the least load applied [21].

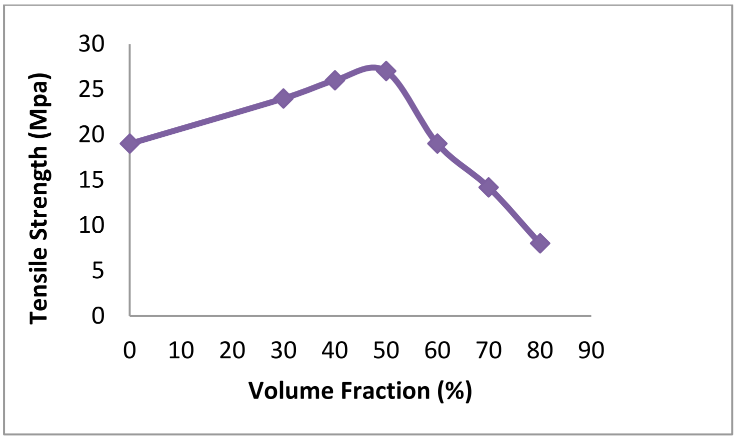

Figure (8) Tensile Strength (WPMS) and (UPS).

3.2 Results and discussion of the Flexural Modulus Test: Figure (9) shows that the values of the Flexural Modulus Test start to increase when we add (WPMS) particles until it reaches the highest percentage (30%) which is equivalent to (3.42GPa), and this is due to the nature of the particles and the great flexibility they have in the composite material, and its ability to adhere the (WPMS) particles and the adhesive material (UPS). These particles penetrate the adhesive material, which increases the entanglement and durability of the overlay material, and that consequently increases the Flexural Modulus. Then, the Flexural Modulus starts to decrease gradually whenever there is an increase in the amount of (WPMS). Although, it remains higher than the Flexural Modulus of Polymer particles (UPS). This is due to the weak bonding in the composite material when increasing the number of particles, and the cracks that are formed around (WPMS) particles may merge with each other while applying load to it. Thus, because of the presence of cracks occurring inside and on the outer surface of the sample, this would decrease the Flexural Modulus.

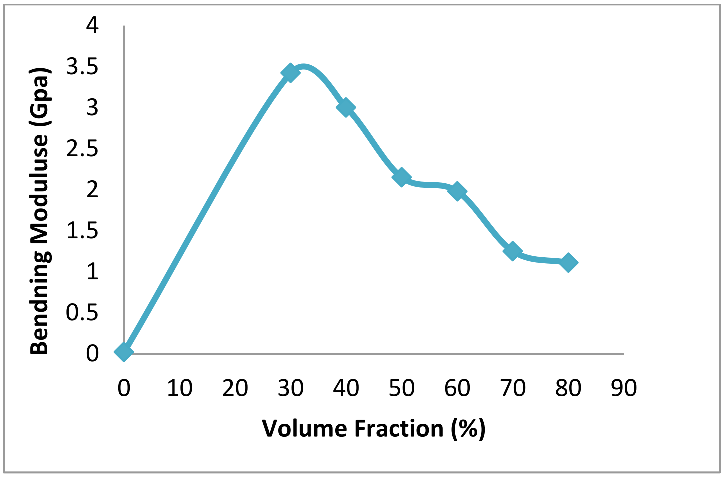

Figure (9) Flexural Modulus of (WPMS) and (UPS).

3.3 Results and discussion of Hardness Test: Most plastics are used in various applications, which may generally be subjected to scratches and cracks. Therefore, the hardness test is considered one of the basic tests that are very important [22]. Figure (10) shows the values of hardness for all samples prepared from the composite materials. Hardness values are improving gradually for all samples when we increase (WPMS) particles. The highest value with volumetric ratios of (80%) reached (69 N/mm^2), and this is due to the homogeneity between the (WPMS) particles and the adhesive material (UPS). In addition to the quality, size, and shape of the particles and their ability to penetrate inside the expansions occurring inside the polymeric chains, and this contributes to the increase in the binding force between those polymeric chains and (WPMS) particles. The increase in the pressing force works on slowing-down the movement of polymeric particles, where the dimensions between the polymeric chains are small, which reinforce its resistance to scratching or penetration [6]. which increases their resistance to plastic deformation. Because the forces that work to connect between atoms or molecules, as well as the distance between the polymeric chains are what Hardness mainly relies upon. As the hardness values rise when the bonding forces are large, as well as the reasons that led to the increase in hardness is that those (WPMS) particles take over the largest amount (space) within the adhesive material (UPS), which will lead to a better and more efficient fragmentation of the applied load.

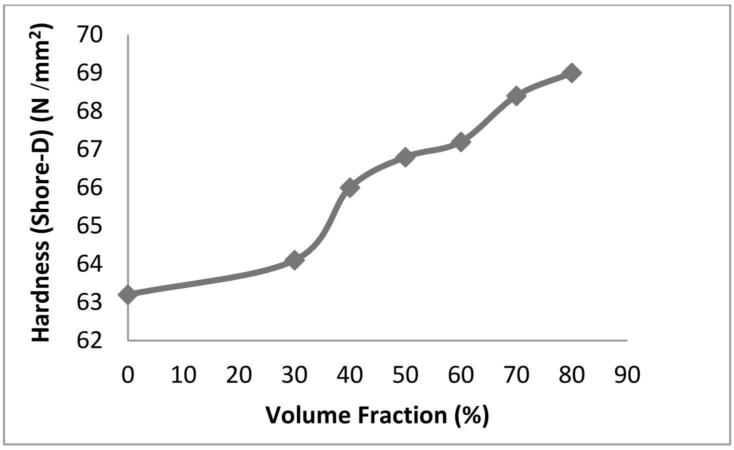

Figure (10) Hardness of (Shore-D) (UPS) and (WPMS).

3.4 Results and discussion of the Thermal Conductivity Test: Figure (11) shows that these values gradually decrease for all the prepared samples, and that the lowest value of thermal conductivity has volumetric ratios of (80%) reaching (2.14W/m.°C). This is due to the (WPMS) particles which are inside the composite material are tangled and irregular, which obstructs the passage of heat in one direction from one end to another. Also, it is divided in different directions, which leads to heat dissipation to inside the prepared sample, and also due to the structure of the adhesive material (UPS). Which is random and irregular, obstructing the thermal conductivity, has low thermal conductivity rating, as well as the irregular and asymmetric structural composition of the adhesive material. This leads to random waste of energy, as well as irregularity of (WPMS) particles while bonding with the adhesive material (UPS), which increases the thermal energy dissipation, and reduces thermal conductivity. The higher thermal conductivity of (UPS) is due to the interference between the polymeric chains, which leads to a decrease in crosslinking, which gives great freedom of movement for the thermal energy. This in turn increases vibration inside the material significantly, due to the nature and form of the actual material [23].

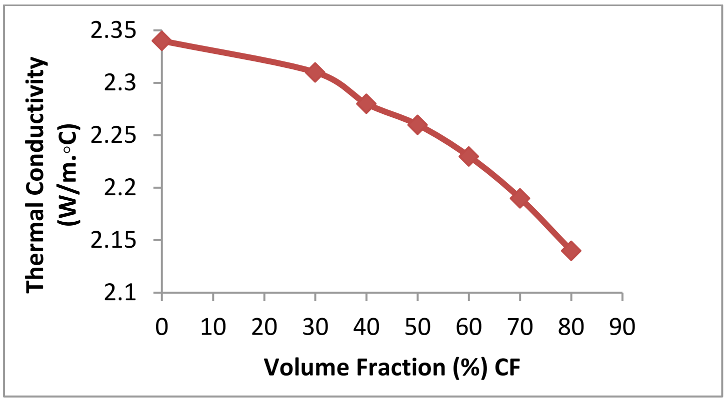

Figure (11) The Relationship between the Thermal Conductivity Values of the Adhesive Material (UPS) And (WPMS) Particles.

Summary

From the results obtained, when Waste plastic medical syringes (WPMS) particles are used with the adhesive material unsaturated polyester resin (UPS), we conclude the following:

1- There is an improvement in some mechanical properties (tensile strength, flexural modulus, and hardness) when the volumetric ratios of Waste plastic medical syringes (WPMS) particles is increased.

2- There is a decrease in the values of the physical property, which is (thermal conductivity), whenever we increase the volume ratios of Waste plastic medical syringes (WPMS) particles.

References

[1] H. H. Thanoun, N.A. Hussain, “Mechanical and physical properties of epoxy and polyester compositions Unsaturated is fortified with glass fibers and Alumina nanopowder”, Journal of Education and Science, Vol. 28,No. 1 , (2019).

[2] E. S. Al-Ameen, J. J. Abdulhameed, F. A. Abdulla, A. A. F. Ogaili, and M. N. M. Al-Sabbagh, “Strength characteristics of polyester filled with recycled GFRP waste,” J. Mech. Eng. Res. Dev., vol. 43, no. 2, pp. 178–185, 2020.

[3] Kareem A. Jasim, Rihab Nassr Fadhil, Auday H. Shaban, Harith I. Jaafar, Bushra K.H. Maiyaly, Suad H. Aleabi, Ebtisam M-T. Salman, The effects of copper additives on the glass transition temperature and hardness for epoxy resin, PIE, Progress in Industrial Ecology – An International Journal, Vol. 13, No. 2, pp: 163-172, 2019.

[4] S. I. Salih , A. R. Jabur and T.A. Mohammed" The Effect of PVP Addition on the Mechanical Properties of Ternary Polymer Blends"IOP Conf. Series: Materials Science and Engineering 433 (2018) 012071 doi:10.1088/1757-899X/433/1/012071.

[5] W. Bdaiwi and S. M. Hashim, “Investment of environmental waste to promote materials used in industrial products Inversión de residuos ambientales para promover,” pp. 66–73, 2019, doi: 10.4206/aus.2019.n26.2.8/.

[6] M. T. Yaseen, M. A. M. Al Saadi, A. I. Hussein, and W. Bdaiwi, “An Investigation of the Mechanical Properties of PMMA-based Composites Reinforced with PZT Ternary Nanoparticles,” vol. 18, no. 2, pp. 56–61, 2020, doi: 10.14704/nq.2020.18.2.NQ20125.

[7] E. Habeeb, “Study of Etiquettes Behavior and Some Physical and Mechanical Properties of a Polymeric Basic Composite,” no. 4, pp. 58–65, 2019.

[8] C. Godswill and C. Gospel, “Impacts of Plastic Pollution on the Sustainability of Seafood Value Chain and Human Health,” Int. J. Adv. Acad. Res. | Sci., vol. 5, no. 11, (2019), pp. 2488–9849.

[9] A.M.Ahmed,A.N.Mahmood,R.M.Yousu,“Physical Thermal Effect Test for Treatment of Polystyrene Plastic Waste”,Rafidain Journal of Science,Vol.29,No.4,(2020),pp.32-43.

[10] Hasan, A. S., Mohammed, F. Q., & Takz, M. M. (2020). Design and Synthesis of Graphene Oxide-Based Glass Substrate and Its Antimicrobial Activity Against MDR Bacterial Pathogens. Journal of Mechanical Engineering Research and Developments.

[11] Karimbnada, “Development of methods of treatment of medical waste in the hospitals of Baghdad health Department / (Rusafa survey)”, Journal of Economics and Administrative Sciences, Vol.25, No.113, (2019), pp.252-278.

[12] I. Idowu, B. Alo, W. Atherton, and R. Al Khaddar, “Profile of medical waste management in two healthcare facilities in Lagos, Nigeria: A case study,” Waste Manag. Res., vol. 31, no. 5, pp. 494–501, 2013, doi: 10.1177/0734242X13479429.

[13] Hind A. Mahdi, Kareem A. Jasim, Auday H. Shaban, Manufacturing and improving the characteristics of the isolation of concrete composites by additive Styrofoam particulate, Energy Procedia, Vol.157, pp:158-163, 2019

[14] Jalal, Noor M.; Jabur, Akram R.; Hamza, Mohammed S.; Allami, Shrok" Preparation, Microstructure and Morphology of Electrospun Sulfonated Polystyrene Films for Proton Exchange Membrane Hydrogen Fuel Cell" Jan 2019 in Energy Procedia. DOI:10.1016/J.EGYPRO.2018.11.314

[15] H. B. Ali, "Effect Of Reinforced by Coconut Fiber Core on The Mechanical Properties for Un-Saturated Polyester Matrix Composite", Material, Engineering and Technology Journal, Vol. 31. No. 17,(2013).

[16] Astm, D. 638, Standard Test Method for Tensile Properties of Plastics. ASTM, West Conshohocken, PA. (2003).

[17] Astm International, "Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. D790," Annu. B. ASTM Stand., no. January, pp. 1–12, 2002.

[18] Annual Book of ISO Standard. , "Standard Test Method for Unnotched Izod Impact Testing of Plastics", ISO (180), (2006), pp. 1-2.

[19] K. K. Chawla, "Composite Materials" springer-verlag , NewYork , Inc, (1987).

[20] Jask. R. Vinson, Tsv-Wei Chou "Composite Materials & their Use in Structure", publisher by LTD, (1975).

[21] M. A.sadik, H. A. Sallal , K. k. kahlol, " Effect the grain size on the polymer matrix composites reinforced by Reenia particles" Al-Khwarizmi Engineering Journal, Vol. 9, No. 2,(2013), P.P. 94 -102.

[22] H. A. Albakry, " Studies of the Mechanical Properties of Unsaturated Polyester Composite Reinforced by Randomly Woven Fiber Glass and Effect of Acidic Solutions on some of its Physical Properties", Al-Rafidain Science Journal,Vol. 23 ,No.1, (2012),pp.114-129.

[23] S.I.Salih, W.B.Salih, H.S.Hamad ,"Characterization of thermo-physical and hardness properties of unsaturated polyester resin hybrid nano composites." Iraqi Journal of Physics (IJP) 16.37 (2018): 136-148.