Quest Journals
Journal of Architecture and Civil Engineering
Volume 8 ~ Issue 9 (2023) pp: 27-35
ISSN(Online) : 2321-8193
www.questjournals.org

Research Paper

"Study of the properties of wood manufactured from wood waste"

Hassan Hamouda[a,]*,Sherif Mohamed[a], Mohamed Elnabrawy[a], Mohamed Amin[a]
[a]*Civil and Architectural Construction Department, Faculty of Technology and Education, Suez University, Egypt.*
Corresponding author

ABSTRACT
Wood industries are essentialindustries in which the economy of many countries, especially developing countries, is based. Still, wood industries produce wood waste in large quantities, which must be used positively. In Egypt, large amounts of wood waste are produced disposed of by burning, burial, dumping in rivers, lakes, and canals, or burying in the soil.This waste is generally considered a national wealth. By recycling it, 30% of theimported wood can be saved, which will benefit the national economy, theenvironment, and public health by properly disposing of wood and plastic waste. Incorrect waste wood disposal in the environment impacts both aquatic and terrestrial ecosystems. Burning discarded wood also emits greenhouse gases into the environment, leading to various health problems.In this study, Wood Plastic Composites (WPCs) of the vast wood and plastic wastesproduced from the wooden and plasticindustries.Thirteen differentmixes wereexperimented withand subjected to mechanical and physical measurements.The mixture proportions containing nano-clay designated and presented in this investigation.The wood and recycledplasticbasedon polypropylene(PP)or polyethylene(PE)have been obtainedas waste fromwood and plastic factories in industrialand urban regions,DamiettaFurniture City,Egypt. The result analysis of the recycled polymer type effects on the mechanical properties, virgin and recycled WPC (V-WPC and R-WPC) rely on wood flour (WF) and maleic anhydride (MAPP or MAPE).

***R**eceived 03 Sep, 2023; **R**evised 12 Sep., 2023; **A**ccepted 14 Sep., 2023*

I. Introduction

Egypt is an economically developing country, but it depends onimporting raw materials to a large extent. One of the essential industries in Egypt is the wood industry. Egypt imports 90% of natural and manufactured wood fromabroad, and Egypt's imports of timber arrived according to the report issued by CentralPackaging Agency, statistics for 2019 and 2020 reached $ 134 million, increasingannually by 9%, and the wood industries produce vast quantities of wood waste suchas sawdust powder. And other wood waste and wood industries in Egypt areessential industries that characterize many regions in Egypt, such as DamiettaGovernorate and many industrial zones in Egypt, and the national project established in 2019, which is the city of furniture in Egypt. Damietta and otherfederal projects. With the increase in the production of wood products resulting fromtheenormousfactories andsmallworkshops, largequantities ofwoodand plasticwastearebeingproducedfromthesemanydifferent industries.It is a national treasure if appropriately used and sustainably. These wastes can be recycled,and the wood manufactured from them can be produced by combining wooden andplastic wastes after processing them, which saves the state from importing natural andmanufactured wood from abroad. Accurate furniture saves 30% of wood importsannually,andwoodandplasticwastemustbecollectedbyuniquemethodsandtreated before it is incorporated into the manufacture of processed wood due to thedifferent properties and physical dimensions. Theproject's objective is to valorizebulky waste with modern innovative techniques, one of which being wood-plastic composites. It is estimated that about nineteen million ton of furniture,upholstery, mattresses, textiles, and plastic gardenwaste, in addition among others in eachyear in the European countries, end up in the waste, while about 60% of which goes to landfills. Based on, the plastic materials from bulky waste are a loss of a vital resource that can be exploited, and to contribute to the sustainable environment and the economy by the greening strategy in Europe [1], WPCs were primarily producedwithmediumand low wood content.

Plasticmaterials wasteis one ofthe major elementsof global municipal solid materials waste. It represents promising rawmaterials from plastic/wood composites, mainly due to their large size and low cost. Recycled plastics to manufacture fiber-reinforced recycled plastic material composites have been investigated. Woodwork (WPCs) by several authors [2-3].Many researchers have discovered the capabilityofadditives to improve adhesion and thus enhance mechanical properties, such as the flexuralandtensile strength of these composites[4-5].The polymer, wood, and additives are the main factors that measure the mechanical and physical properties of WPC.The wood surface modification and coupling agent enhance the polar wood and non-polar polymer mix with WPC. Then, using compatibilizer during prepares WPC.The bonding between wood and polymer depends on compatibilizers, including polar wood and non-polar groups [6–7].Bütün et al. [6] produced the WPC using the disintegration method's wood waste of the medium density fiberboard (MDF). Chaharmali et al., determining water absorption as a physical measurement of WPCs. Nowadays, numerous building external elements depend on natural fiber-plastic composites, which contain thermoplastic and polyethylene. These are considered significant amounts in the wastes and high resistance to a severe environment.Many researchers are interested in utilizing plastic waste as a by-product material [8]. The researchers obtained the recycled high-density polyethylene from the post-consumer milk bottles was not vastly different from pure resin, thus could be utilized for different applications [9].Recycled plastic is more economical than the source form. Also, the wood waste is accumulated through the wood industry process, which is largely destined for landfills.The recycled plastic includes waste polymers to prepare high-performance natural fiber elements. The recycled plastic materials utilized for the WPCs manufactured have been studied by several authors [10–11].Some applications include a parquet wood floor, wastepaper, flower vases, park benches, plastic lumbers, and picnic tables.Hybridization is a suitable technique for producing natural fiber composites with high performance. However, hybridization is defined as a material made using various fiber types in a standard matrix.Hybridization of short fibers such as wood flour and fibers is available with different lengths and diameters.

II. Materials and Methods

Figure (1) shows aswood waste was reached from Furniture City, Damietta Governorate, and the national furniture project in Egypt. The waste was sawdust from sawing andpolishing wood during thin furniture and wooden architecturalartifacts.

Sifting with a diagonal vibrating screen was used to select the wood fibers. Meshes 16–30 (i.e., 1.2–0.6 mm), 30–50 (i.e., 0.6–0.3 mm), 50–100 (i.e., 0.3–0.15 mm), and more than mesh 100 (i.e., 0.15 mm) were used to separate fiber into four different sizes. (75, 225, 450, and 900 mm, respectively) were the average length dimensions. The wood fibers were then separated, air-dried for a few days, anddried again at 102°C for 24 hours to reduce the moisture content to less than 3%.

Figure (2) shows asRecycled polyethylene was obtained from plastic waste from one of the nationalfactories(Al-SafaFactory)to recycle plasticwaste processed togethigher quality plastic grades. The treatment included scaling, washing, fixing, metalfracture removal, re-grinding, and dust removal.

Table (1) lists the recycled polymers offered by the VEC, which are classified by melt flow indicators (high, medium, or low MFI), polymer type (PP, PE, or mixed PO), and field of application (garden part) (PPFGF) or artificial grass (LLDPEgrass). PPFGF is made of 10.7% by weight as filler. A local plastic recycling company supplied the waste polymer polypropylene (PP) in pelletswith amelt flowindex of 8g/10 min(230°C2160 g)and a densityof 0.92g/cm^3.

Maleic anhydride grafted polypropylene (MAPP) with a density of 0.91 g/cm^3 was obtained from (Aldrich Chemical Company). At 190°C, it has a molecular weight of 9100 and a Brookfield viscosity of 40,000 cP.

The nano-clay material was obtained from the Center for Structural Research andStudies in Cairo, with some mechanical and physical properties of the samples [16-20].

Fig.1.Detailingthemanufacture ofsawdust fromwoodwaste.

Finesawdust **RecycledPP** **Mixingmachine** **Mixturepressuremachine**

Fig.2.Generalmanufacturingprocessforwoodmanufacturedfromwoodand plasticwaste.

Fig.3.Applications.

1. Casting and sample processing

After gathering the sawdust, it is drying in an oven-dry at 100 °C, where the drying rate is a slow drying system. Then the sawdust has analyzed using sieve analysis as shows Figure (4). Table (1) shows the typical polypropylene, Nano clear, and formaldehyde quantities. The dimensions of the wooden mold were 50 cm in length, 12 cm in width, and 22 mm inthickness. The mixture is cast and placed underthepiston by thermal-hydraulicpressureforfive minutes at 200 bars.

Fig.4.Casting and sample processing.

2. Mixing process

Figure (5) as shows Polyethylene (PE) and polypropylene (PP) formulations are mixed at 170 °C and 190 °C, respectively (Table 1). The mix sequence was as follows: first, add polymers to the mix; second, add sawdust and mix for 11 minutes.

Fig.5.Recycledpolypropylene.

3. Preparation of the specimens

After the mixing process, the specimens were performed after being pressed using a hydraulic pressure machine to reduce the voids inside the samples. The specimen nominal dimension was 20 mm thickness, 120 mm width, and 500 mm length.Melamine was added to the outer surfaces on three samples of each type of mixture to increase its efficiency in bearing(A). Also, an outer layer of natural peelextractedfrom thepeonytreewasadded for comparisonwith theotheraddition of melamine(B).

TabIe1. Shows the typical polypropylene, Nano Clay, and formaldehyde quantities.

Code	Fiber	p.p	Fiber	Agenttoheating	Nano clay
	Woodenwastes	Polypropylene	cellulose	Ureaformaldehyde	Nc
G1	50%	50%	0%	0%	0%
G2	45%	50%	5%	0%	0%
G3	40%	50%	10%	0%	0%
G4	50%	47.5%	0%	2.5%	0%
G5	50%	45%	0%	5%	0%
G6	45%	47.5	5%	2.5%	0%
G7	45%	47.5	5%	5%	0%
G8	40%	47%	10%	2.5%	0%
G9	40%	45%	10%	5%	0%
G10	50%	44.5%	0%	2.5%	0%

G11	50%	42%	0%	5%	3%
G12	45%	44.5%	5%	2.5%	3%
G13	45%	42%	5%	5%	3%

4. Mechanical tests

Tensile, flexural, and impact tests were carried out as part of this investigation, according to ASTM standards D 638, D 790, and D 256. An Instron Universal machine test (model 1186) was used to perform tensile and bending tests at 1.5 and 2 mm/min. All tests were performed at room temperature (25°C) and constant relative humidity(65%).Six samples have been experimentedwith for each mix.Five specimens for each mix were tested in flexural by a three-point bending testwith dimensions mentioned previously accordingto ASTM D790 [13]. The specimens were maintained at 20°C and 65 percent relative humidity for three days to minimize residual processing stresses. Each specimen's dimensions, such as length, width, and thickness, were examined before testing. A computer-controlled MTS 858 Mini Bionix system was used to conduct a three-point bending test with a span of 50 mm. The crosshead's speed setup is 1.3 mm/min. The data is recording using a computer-controlled acquisition.

5. Mechanical Properties

The type and rate of polymer recycling, molecular weight, and processing conditions all influence the mechanical properties of recycled polymers. Filters and additives of various types are also included in recycled polymers. In addition, the style, shape, and many filters and additives used each affected the mechanical properties of recycled polymers. During the recycling process, mixing different types of incompatible polymers hurts the polymers' mechanical characteristics. The quality and integration of products made from recycled polymers rely heavily on classifying plastic waste by source. The mechanical findings of this study describe the impacts of the previously specified parameters on the mechanical properties, water absorption properties, and density of recycled WPCs, followed by a comparison analysis.

5.1 Compressive strength

Figure (6) shows the effect of the sawdust ratios with recycled propylene on the strength by about 23%,and improving the bond strengthbetween glyccellulose filler and the matrix polymer due to using material enhancing the bond. The tensile strength and modulus are noticeably developing with adding MAPP to the mixand mixing with the high ratio of bonding agents. The effective ratio of thebonding agent is 5% wt.,which increase the tensile strength due to improvingthe chemical bond between the fiber and PP polymer chains, as shown in Figure (6).

The results demonstrated that altering the fiber surface improves the compatibility of a hydrophobic polymer with hydrophilic cellulose fibers. The tensile modulus trended in the same direction as the tensile strength trend.

Two factors increase the compression properties, the pressure coefficient of melamine and peel installation and using3%nano-clay[17],asshowninFigure (6). The compression properties are significantly increased due to cellulose, formaldehyde, and nanoclear portions. Table (2) present the stress results.

Table.2Compressive strength results forsamplesmeasuring50*12*2 cm.

Code	Group(A)MPa	Group(B) MPa
G1	0.30	0.20
G2	0.35	0.30
G3	0.40	0.35
G4	0.45	0.40
G5	0.50	0.45
G6	0.44	0.35
G7	0.50	0.42
G8	0.45	0.39
G9	0.50	0.45
G10	0.47	0.35

G11	0.55	0.48
G12	0.62	0.58
G13	0.68	0.59

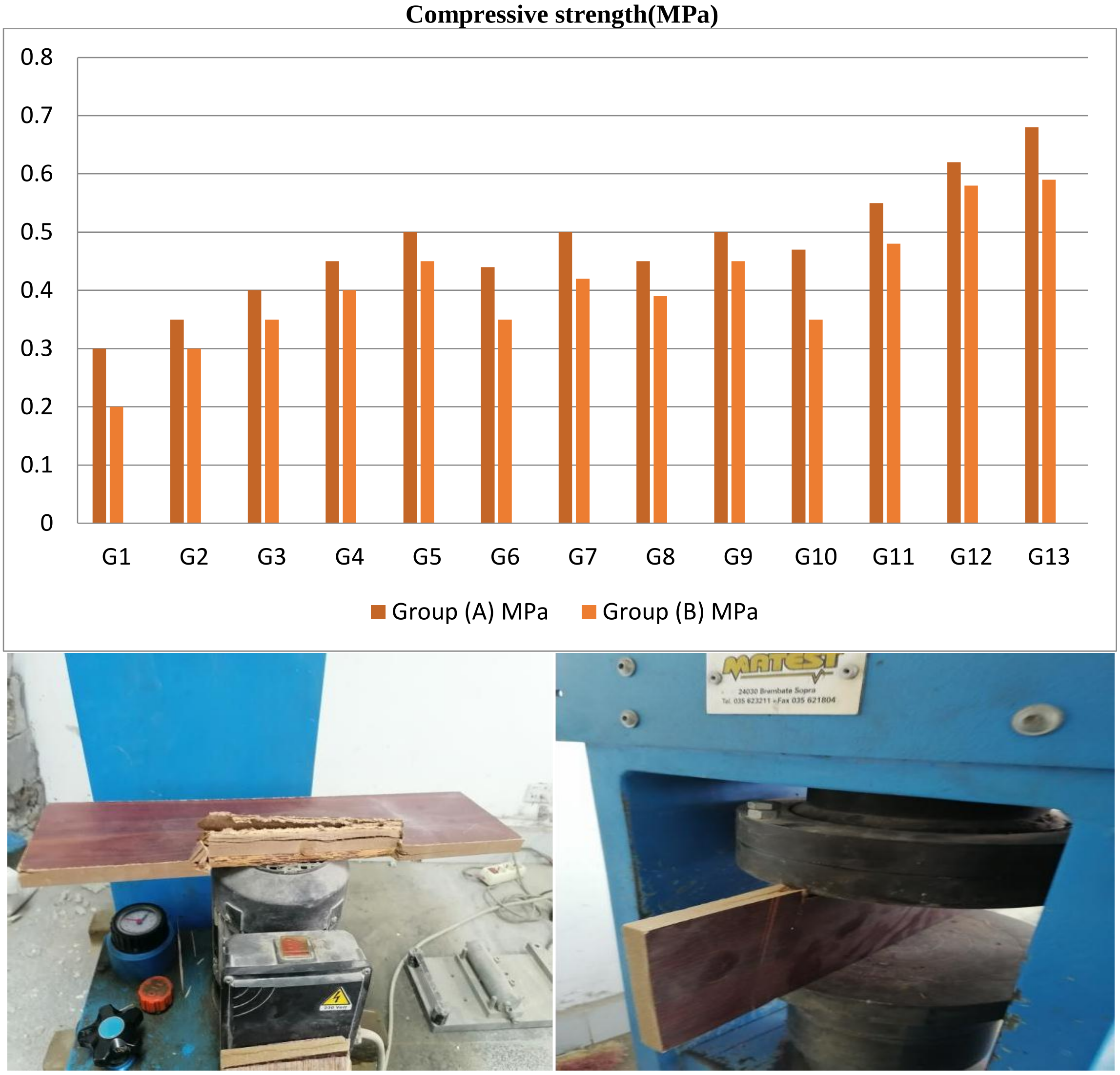

Fig.6 Compressive strength results forsamplesmeasuring50* 12*2cm.

5.2 Flexural strength

Figure (7) shows the flexural strength and modulus of the mixes. The highest flexural strength of pure PP is between 11.3 and 3.13 MPa, whereas the lowest flexural strength is 2.3 MPa. For MAPP, MCC, and NC, the flexural properties of the mixes differ wildly.The mix MCCshowedthehigheststrengthandflexural moduluscompared with a purePP mix,asshowninFigure (7).Flexural strength wasperformedondifferentmixture samples and divided into two groups. Group (A) had a higherbendingcoefficientthangroup(B).It can be noticed that each mixture of cellulose, formaldehyde, and nanoparticles had higher bending stress than poor mixtures of these materials.Theexternal melamine layer significantly affected the bending stress compared to the compression stress.The bending stress of mixes g11, g12, and g13 were higher than the samples containingcellulose and formaldehyde g1,g2, and g3. Figure(7) indicates that the flexural strength improve, components'sense and proportions, as shown in Table (3).

Table 3.Flexural strength results for samples measuring 50 * 12 * 2 cm.

Code	Group(A)MPa	Group(B) MPa
G1	3.13	2.3
G2	3.9	3.13

G3	5.5	3.9
G4	4.7	3.75
G5	4.7	3.3
G6	7.8	7.2
G7	8.12	7.5
G8	8.75	8.12
G9	9.4	9.2
G10	9.1	8.4
G11	10.8	9.4
G12	10.9	10.2
G13	11.3	10.8

Flexural strength(MPa)

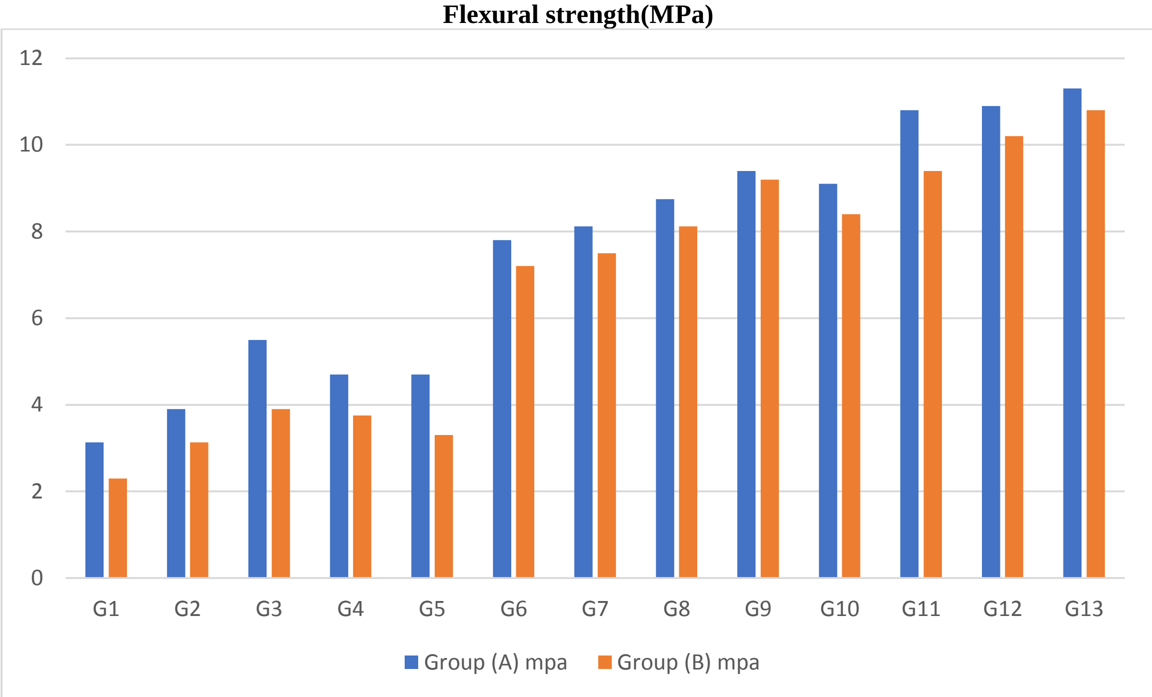

Fig.7 Flexural strength results forsamplesmeasuring50* 12*2cm.

6. Water absorption and density of WPCs compounds

WPCs samples water absorption (wt%) and thickness swelling (%) have been selected by measuring thickness dimension and the mass weight according to Eq. (1). The WPCs samples were submerged in water at room temperature for 24 h after drying four times. Then, the wet specimens are extracted and then measured.
Where,W_d is dry mass andW_w is wet mass of samples, respectively. The same equations were used to determine

$$\text{Water sorption } \% = ((W_w - W)_d / W_d) \times 100$$

thickness swelling (%) instead of mass values. A helium pycnometer was used to determine the density of WF (Quantochrome Instruments, Ultrapycnometer 1000). The software "Pycwin Version 1.10" was used to calculate the average theoretical density of WF with standard deviation. The true densityofWFwas foundas 1.5637 ± 0.0024 g/cm³. The results show that the mixtures containing nano-clay (g11,g12, and g13) have less water absorption. Furthermore, the samples (g1:g6) containing high ratios of mulch had revealedanti-puffiness,as presented inTable(4) and Figure (8).

Table 4.Water absorbency test results for samples measuring 50 * 12 * 2 cm.

Code	Weightbeforetesting (g)	Weightaftertesting (g)	Absorptionratio (g)
G1	0.275	0.455	0.180
G2	0.250	0.400	0.150
G3	0.245	0.375	0.130
G4	0.285	0.445	0.160
G5	0.295	0.445	0.150
G6	0.278	0.418	0.140
G7	0.269	0.369	0.100
G8	0.255	0.395	0.140
G9	0.240	0.390	0.150
G10	0.250	0.400	0.145
G11	0.310	0.380	0.070
G12	0.315	0.395	0.080
G13	0.310	0.410	0.100

7. Density of wood made from waste and propylene

Samples were prepared with 12.5 × 12.5 × 2.5 cm dimensions and weighed on a digital weight scale. The samples were from the following models (G1, G5, G10, and G13). After dried, the samples' weights ranged between 0.225 and 0.320 kg, and the average density was 675 kg/m^3.

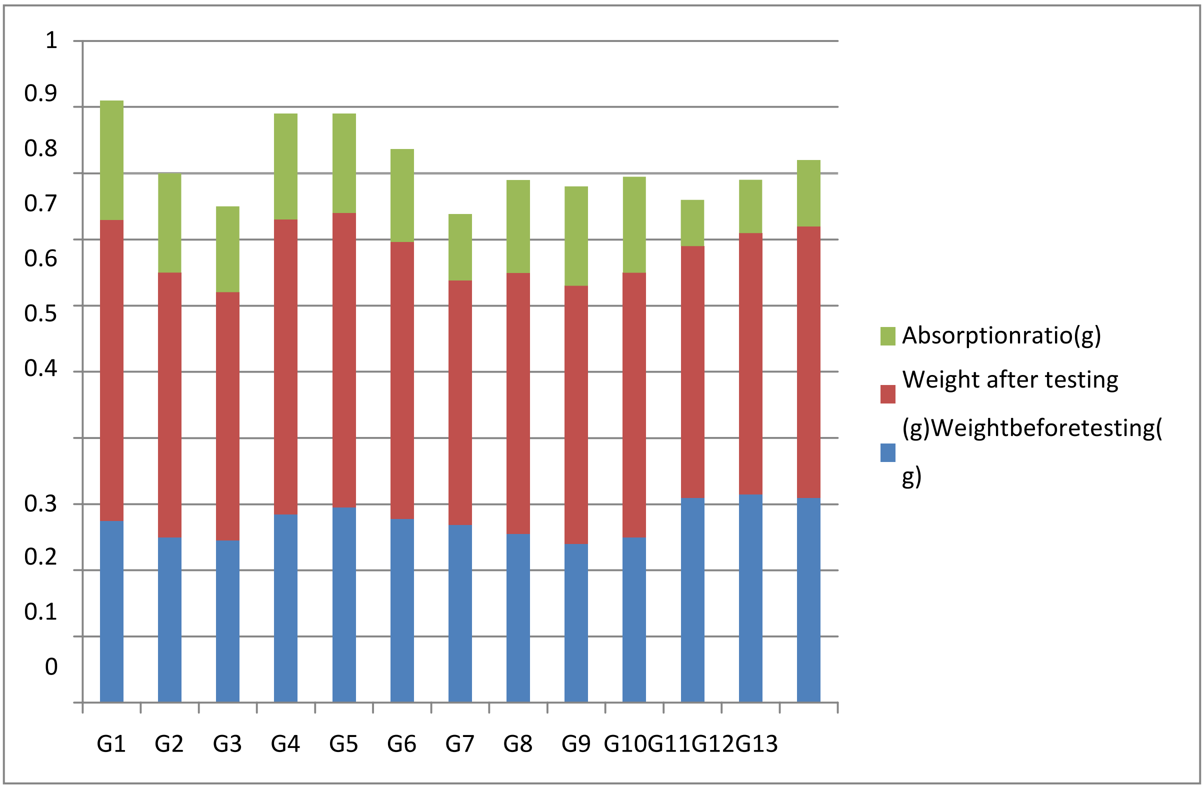

Fig.8 Water absorption percentage in grams.

III. Conclusions

The following conclusions were obtained based on the results of this investigation:-

1. The mixture of sawdust with propylene enhanced the cohesion of the samples. The high proportion of propylene improves the compression resistance.
2. The high ratio of urea-formaldehydeis developing the compression strength.
3. Also, nano-clay material significantly improved compression properties, water absorption, and workability.
4. It can be observed that the wood containing sawdust and propylene shows excellent hardness and cohesion when cutting.This property makes it good in fine works likeproducing delicate home furniture such as wooden libraries and tables.
5. Sawdust and propylene can manufacture wooden boards.Nano-clay reduces permeability and water absorption.Moreover, secondarily using these boards with natural wood in wood industries.
6. This type of timber is not compatible with tensile and flexural strength due to its weak resistance.

REFERENCES

[1]. Malinauskaite, J., Jouhara, H., Czajczynska, D., Stanchev, P., Katsou, E.,Rostkowski, P., Thorne, R.J., Colon, J., Ponsa, S., Al-Mansour, F., Anguilano,L., Krzyzynska, R., Lopez, I.C., Vla-sopoulos, A., Spencer, N.: Municipal solidwaste management and waste-to-energy in the context of a circular economyandenergy recyclingin Europe. Energy 141,(2017),2013–2044.

[2]. Drouglas, R. C.Structural Properties of Recycled Plastic/Sawdust LumberDeckingPlanks,Resources,ConserveandRecycling,31(3),(2001),241–251.

[3]. Bakraji, E. H. and Salman, N.Properties of Wood–Plastic Composites:EffectofInorganicAdditives,RadiationPhysicsandChemistry,66(1),(2003),49–53.

[4]. Oksman, K. Improved Interaction Between Wood and Morphology ofImpact ModifiedPolypropylene-wood Flour Composites,Applied PolymerScience,67(9),(1998),1503–1513.

[5]. Lu, J. Z. and Wu, Q. L.Chemical Coupling in Wood Fiber and PolymerComposites: A Review ofCoupling Agents and Treatments,Wood Science andTechnology,32(1),(2000),88–104.

[6]. Bütün, F.Y., Sauerbier, P., Militz, H., Mai, H.: The effect of fibre-board (MDF)disintegration technique on wood polymer compos-ites (WPC) produced withrecoveredwoodparticles.Compos.A.118,(2019), 312–316.

[7]. Nidiaye, D., Matuana, L.M., Morlat-Therias, S., Vidal, l, Tidjani, A., Gardette, J.L.:Thermal and mechanical properties of poly-propylene/wood-flour composites. J. -Appl.Polym.Sci.119(6),(2011),3321–3328.

[8]. Ahmad, I., Abu Bakr, D. R., Mokhilas, S. N. and Raml, A.Direct Usage ofProducts of Poly(Ethylene Terephthalate) Glycolysis for Manufacturing of RiceHusk/UnsaturatedPolyesterComposite,Iran.J.Polym.Sci.Technol., 16,(2007),233–239.

[9]. Kazemi, N. S., Tajvidi, M. and Hamidinia, E.Effect of Temperature, PlasticType and Virginity onthe Water Uptake of Sawdust/Plastic Composites,Holz. Roh.Werkst. 65,(2007),377–382.

[10]. Youngquist, J. A., Myers, G. E. and Harten, T. M.Emerging Technologies forMaterials andChemicals from Biomass, American Chemical Society, Washington,DC. ACS Symposium Series, 476,Chapter 4. Proceeding of the ACS Symposium,(1990),August26–31.

[11]. Kazemi, N. S., Hamidinia, E. and Tajvidi, M.Mechanical Properties ofComposites from Sawdustand Recycled Plastics,J. Appl. Polym. Sci., 100,(2006), 3641–3645.

[12]. Annual book of ASTM standards. American Society for Testing andMaterials,100BarrHarborDr.,WestConshohocken,(1999),PA19428,UnitedStates.

[13]. ASTM D790. Standard Test Methods for Flexural Properties of Unreinforced andReinforced Plastics and Electrical Insulating Materials. American Society forTestingandMaterials.

[14]. ASTM D256. Standard Test Methods for Determining the Izod Pendulum ImpactResistanceofPlastics.AmericanSocietyforTesting andMaterials.

[15]. Kazayawoko, M., Balatinecz, J. J. and Matuana, L. M.Surface Modificationand Adhesion . Mechanisms in Wood Fiber-polypropylene Composites,Journal ofMaterialScience,34(24), (1999),6189–6199.

[16]. Solomon MJ, Lu Q. CurrOpin Colloid Interface Sci 2001;6:430–7.Krishnamoorti R,Yurekli K. CurrOpin Colloid Interface Sci 2001;6:464–70. Mitchell CA,Krishnamoorti R. J PolymSci Part B: PolymPhy 2002; 40:1434–43. Ren J, Silva AS,KrishnamoortiR.Macromol-ecules2003; 4443:4451.

[17]. LanT, KaviratnaPD,PinnavaiaT. JChemMater1995, 7:2144–50.

[18]. Kojima Y, Usuki A, Kawasumi M, Okada A, Kurauchi T, KamigaitoO, Kaji K. J PolymSci, Part B: PolymPhys 1994;32:625–30. NohMH, Lee WJ, Lee DC. J ApplPolymSci2003, 179:188.

[19]. GalgaliG,RameshC,LeleA.Macromolecules2001, 34:852–8.

[20]. LeleA, MackleyM,GalgaliG,RameshC. JRheol2002, 46:1091–110.

[21]. Gasan,J.andBledzki,A.K.ThermalDegradationofFlaxandJuteFibers,JournalofApplied PolymerScience,82,(2001),1417–1422.

[22]. Annual book of ASTM standards, American Society for testing andmaterials,100BarrHarborDr., WestConshohocken,(1999), PA19428,UnitedStates.

[23]. Meyrs EG, Chahyadi IS, Gonzalez C, Coberly CA. Wood fibres/polymercomposites: fundamental concepts, processes, and material options. ForestProductSociety,(1993),Madison,USA.