Development of Reinforced Recycled Plastic Lumber Post for Agriculture Fencing

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled “**Development of Reinforced Recycled Plastic Lumber Posts for Agriculture Fencing”** is a *bonafide* record of project work done by us during the course of academic programme in the Kerala Agricultural University and that the report has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title of any other university or society.

Place :Tavanur
Dated: 05-02-2015

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CERTIFICATE

Certified that this project report entitled **“Development of Reinforced Recycled Plastic Lumber Posts for Agriculture Fencing”** is a bonafide record of project work jointly done by Geethu Krishnan *(Admn. No. 2011-02-020)*, Greeshma K. *(Admn. No 2011-02-021)**,** *and* Mirshad M *(Admn. No 2011-02-026)* under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship, associateship, or other similar title of any other University or Society to them.

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ABSTRACT

Plastic solid waste (PSW) presents challenges and opportunities to societies regardless of their sustainability awareness and technological advances. During the 1990s, a number of technologies emerged to utilize recycled plastics in products designed to replace dimensional wood lumber. Since that time, recycled plastic umber (RPL) products have proven to be effective alternatives for many applications, offering high durability and requiring little maintenance. Plastic lumber products are resilient, weather-resistant, and impervious to rot, mildew, and termites. They do not require painting or staining.

The first applications of plastic lumber products were in non-structural applications such as picnic tables and benches. As the industry has matured through the years, innovative research and development work by the plastic lumber industry and universities has fostered the development of superior performing products which in turn has begun to establish new and demanding structural applications for these products. Much of the work has involved the application of composites technology to the reuse of post-consumer and post-industrial materials in plastic lumber products. This evolution, from non-structural applications to structural application is achieved by reinforcing plastic lumber with glass fibres, steel and iron rods etc. In the present study we used LDPE recycled plastic lumber with and without reinforcement to compare its mechanical properties with wood and concrete as fencing posts and also plastic coating is given to bamboo to prevent it from termite and rodent attack.

ABBREVIATIONS

ASTM	American Standard Testing Machine
ATR-FTIR	Attenuated Total Reflectance Fourier Transform Infrared
DSC	Differential Scanning Calorimetric
EPA	Environmental Protection Agency
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
MSW	Municipal Solid Waste
PE	Polyethylene
PET	Polyethylene Tetreaphalate
PL	Plastic Lumber
PP	Polypropylene
PS	Poly styrene
PVC	Poly Vinyl Chloride
PU	Polyurethane
RPL	Recycled Plastic Lumber
SEM	Scanning Electron Microscope

USDA	United States Agriculture Department
UTM	Universal Testing Machine
UV	Ultra Violet
WPC	Wood Plastic Composite
XPS	X-ray Photoelectron Spectroscopy

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INTRODUCTION

Pollution prevention is an integral part of the management of the nation's municipal solid waste (MSW). Integrated management of MSW involves source reduction, recovery and recycling of materials, composting, and environmentally sound disposal of waste streams through combustion and/or landfills. Of these alternatives, source reduction and materials recycling are the preferred options.

One significant component of the waste stream is discarded plastic products and packaging, which continues to be a growing portion of the MSW. As detailed in a recent EPA (Environmental Protection Agency) report, plastics contribute 22.4 million tons (20 x 106 metric tons) (or 10.2 percent) to the total waste stream with only five percent of this total currently recovered. More importantly, due to its low density, the volume of plastics in landfills reaches almost 25 percent of the total volume. And the amount of plastics being discarded annually is not expected to decrease any time in the foreseeable future.

Plastics are inexpensive, lightweight and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications. Around 4 per cent of world oil and gas production, a non-renewable resource, is used as feedstock for plastics and a further 3–4% is expended to provide energy for their manufacture.

Recycling is one of the most important actions currently available to reduce these impacts and represents one of the most dynamic areas in the plastics industry today. Recycling provides opportunities to reduce oil usage, carbon dioxide emissions and the quantities of waste requiring disposal. While plastics have been recycled since the 1970s, the quantities that are recycled vary geographically, according to plastic type and application.

Figure 1-Plastic wastes

1.1 Recycled Plastic Lumber

RPL is a wood-like product made from recovered plastic or recovered plastic mixed with other materials, which can be used as a substitute for concrete, wood, and metals. At the present time, RPL has only been used in a few structural applications. Although in recent years great attention has been given to the production of objects using recycled plastic materials, the poor quality of objects made from mixed recycled plastics, and the costs associated with processes capable of reducing impurities, place considerable constraints on the economic viability of recycling of plastics in general. Most low density polyethylene (LDPE) coming from solid urban waste is processed by means of a process called the "in-meld extrusion", or "intrusion" process. The products obtained by this technology are used to replace wood in outdoor applications, owing to their better resistance to environmental degradation. These materials are usually referred to as "recycled plastic lumber" (RPL), and are widely used in marine and high humidity environments. The poor compatibility of the different polymers present in plastic waste, together with the contamination by non-polymeric materials (above all paper), results in products with poor mechanical properties.

Usually, RPL is used for the production of high aspect ratio beams, subjected to one-directional bending forces. Under such conditions, a very efficient reinforcement of the beams can be attained by the introduction of rigid rods near the upper and lower surfaces of the beam, which can be readily achieved in continuous extrusion processes through introduction of the appropriate features in the die, and continuously feeding of the reinforcing rods. Recently, it was demonstrated that a similar approach can be readily adapted to the in mould extrusion process, as well as to other closed mould processes, such as rotational moulding. The resulting product is characterized by a strong anisotropy, since the reinforcing elements are placed in the zones of the beam subjected to the higher stresses. The process has therefore been adapted for the production of reinforced RPL beams on an industrial plant. Thus reinforced RPL lumber can be used as an alternative to conventional fencing posts.

A few years ago, the total RPL production was approximately 16 million board-feet (38 000 m^3), which is equivalent to about 40 million pounds (18 000 metric tons) of waste plastics. The current annual growth rate for this industry has been around 40 percent. Today it is estimated that the total RPL production is over 300 million pounds (136 000 metric tons) or about 120 million board-feet (280 000 m^3). Assuming a 50 percent recycling rate for all waste plastics, the total production of RPL is estimated to reach 25 billion board feet (59 x 106 m^3) per year as this industry matures to its full potential. In comparison, the current consumption of softwood lumber is about 34 billion board feet (80 x 106 m^3) annually. Therefore, the importance of the RPL industry in recycling of plastics cannot be overemphasized.

1.2 Conventional Fencing Posts

1.2.1 Concrete

Concrete fence posts are typically sturdier than any other variety and from this you can take peace of mind that your fence is now robustly supported. With a more robust fence post also comes the knowledge that you won't have to replace them any time soon. A concrete fence post can last for decades if kept in good condition. There is little you'll need to do to keep a concrete fence post in good condition as it doesn't need as much attention once it's been put in place.

With all of the advantages which concrete posts can bring there is the disadvantage of them being slightly more expensive than other post types. Concrete is obviously one of the weightiest materials and because of this it makes concrete posts slightly more difficult to install – usually taking more than one pair of hands.

1.2.2 Wood

Wood or timber can often be perceived as being more stylish and warmer when it comes to creating an attractive garden. It can often compliment additional features such as trees and decking. Fence panels can be affixed to wooden fence posts which can eliminate the rattle in high winds which concrete fence posts might give if not securely fixed.

With any wooden material there is a far greater risk of splitting and rotting when it's exposed to the elements. While this might not matter for panels quite as much it's important that the posts are sturdy enough to ensure the whole fence serves its purpose**.** Wooden posts often seem a little simple and basic looking, creating a bland perimeter around your garden**.** Just as with your panels, your wooden fence posts will need more maintenance than a concrete post. Wood needs to be treated consistently to ensure it can stand up to the elements and last longer. Weathering occurs on all materials but if you live in an area where your garden is exposed to high winds and lots of water or sea spray then your wooden posts will deteriorate a lot quicker. This means yet more expense when replacing posts more frequently.

1.2.3 Stone

Stone fences are practically immune to even the most disastrous forces of nature. Rain, wind, sleet, snow and summer heat will have little to no effect on a stone fence. They don’t rot. Insects like termites, ants and other creepy crawlies don’t disturb the sanctity of the structure of a stone fence. If you have a fire, it may discolor the stone fence, but it won’t destroy it.

1.3 Properties of RPL

It is interesting to note that a comparison of woods mechanical properties along the grain with plastic and plastic lumber indicates that the lower modulus of plastic is a much bigger issue than any strength comparison. Incidentally, wood is several times less stiff and strong when measured orthogonal to the growth axis as compared to along the growth axis. Most any plastic lumber compares rather favourably in terms of both stiffness and strength in this situation. The materials that are typically used in plastic lumber are viscos-elastic in terms of their mechanical properties. This means that there is a time-dependence to their mechanical properties In other words, if structure is loaded to a certain load level and the deflection of that structure is measured right after the load is applied, the deflection is expected to increase by some value for each increment of time as the load remains applied. To further complicate matters, the deflection will increase more during the first day than the second. The deflection will occur each day at ever decreasing rates, unless a crack opens up in the material. This effect can be minimized by design with lower levels of stress.

The two basic problems that unreinforced plastic lumber have in some substitution applications for wood are, lower modulus and even lower modulus when loaded over a long time.

The two key advantages that these materials have are that they are not subject to degradation (perhaps unless filled with a high percentage of wood), and that they do not leach harmful chemicals into the soil or groundwater

It should be mentioned that some very successful applications for plastic lumber types of products have been developed for which concrete or other materials are the traditional material to be used. These include construction curbs, removable speed bumps, parking lot stops, bollards, and others. Many structurally more demanding applications have been attempted, and all have met with some level of success. Applications have included joists, railroad ties, marine pilings, and vehicular bridge substructures. These all required some type of reinforcement in order to achieve the properties necessary success. The development of ASTM test methods to evaluate the properties of plastic lumber and compare them has opened up real possibilities to engineer structures with these materials

1.4 Reinforced plastic lumber

The first plastic company that recognized this situation was Tri-max, back in 1989-90. They developed a continuous extrusion process which utilized 20-30 % fibreglass and foaming to produce stiffer product than would be obtainable with the same composition without fibreglass. Glass is about three times the density of the polymer component, so foaming was desirable to keep the weight down. The polymer component was originally washed curb side tailings, but they found that washing wasn't necessary and was costly. Products produced to date include sheet pilings, structural plastic lumber, and marine pilings

Rutgers University researchers also recognized that plastic lumber ought to be reinforced in order to enter structural markets, and developed a polymer-polymer composite with high stiffness and high strength in 1988-89.This process utilized unwashed curb side tailings and up to 35% recycled polystyrene, depending upon the properties desired. This technology is currently licensed to Plywood, Inc., where it is being utilized for a number of structural plastic lumber applications, including the substructure for decks and the first vehicular bridge made from plastic lumber. Later, in 1994-95, the same group found that short glass fibres were capable of being oriented in a curb side tailings matrix, requiring only about 10-12% present fibreglass to obtain high strength and stiffness values. This technology is currently licensed to US Plastic Lumber, Inc., where it is being utilized for railroad ties

Development of products utilizing continuous glass fibber reinforcement held together with traditional thermosetting plastic (in the shape of rods) moulded with HDPE. In this interesting design, the fibreglass members act as rears supporting the less rigid thermoplastic material. The fibreglass rods are placed strategically and symmetrically about the central axis. This technology has been used to produce marine pilings and walers. Plastic pilings with a steel pipe core have been produced by Plastic Pilings Inc. and Hammer's Plastic Recycling, Inc. A four inch layer of HDPE is moulded onto the outside of several sizes of steel pipe.

1.5 Types of RPL

1.5.1 High Density Polyethylene (HDPE) RPL

This type of RPL consists of up to 95 percent of HDPE (The same material used to make plastic milk jugs).Its advantage is that it is in many colours. Well suited for decking and landscape applications. The main disadvantages include much lower stiffness than wood. Also, material sorting increases labour costs. This cost can be reduced by using automated sorting technology instead of hand sorting.

1.5.2 Commingled RPL

Commingled RPL is made from mixed recovered thermoplastic. It primarily consists of 80-90% polyethylene (PE).It costs less because sorting is eliminated and is well suited for decking and landscaping applications. Its stiffness is much lower than wood.

1.5.3Fibre-Reinforced RPL

Fibre-reinforced RPL consists of plastic mixed with chopped or continuous strands of glass fibber. They are stiffer than other plastic lumber. Well suited for support structures but less flexible than other plastic lumber, and may irritate skin.

1.5.4 Wood-Filled RPL

Wood-filled RPL is made of plastic mixed with sawdust or other recycled fibber, usually a mix of 50 percent polyethylene (primarily low-density polyethylene or LDPE) and 50 percent sawdust or other recycled fibber. Its advantages includes fewest voids, best traction, best paintability, greater surface roughness and disadvantages are it can absorb moisture, may have poor impact strength under low temperatures, may not be completely insect resistant, may become discoloured in outdoor applications, may contain metal contaminants, much lower stiffness and strength than wood, can degrade, poor flexibility.

1.6 Mechanical Properties of Plastic Lumber

1.6.1Density

The design engineer needs to know the density of the material in order to calculate the dead load of the structure. The plastic lumber tested has a higher density than wood, and so the dead load will be higher than for wooden deck boards of the same shape. Density of the plastic lumber was tested in accordance with ASTM D792. This test uses the
Archimedes principle to calculate density, and the plastic lumber was less dense than water, so weights had to be used to submerge the lumber and make the density measurements.

1.6.3 Compressive Strength and Modulus

Compression tests were conducted in accordance with ASTM D695.Tests were conducted at -23°C AND 40.6°C to simulate winter and summer conditions.

1.6.4 Flexural Strength and Modulus

The tests were conducted in accordance with ASTM D790. The flexure modulus for this material is higher than either the compression modulus or tensile modulus, which is unusual. For most materials the flexure modulus is less than or equal to the tensile and compression modulus. The reason for this is that the dense outer layer of this plastic lumber has a higher modulus than the porous core material. The flexure test for measuring modulus gives more weight to the material near the top and bottom surfaces and less weight to the core material. The tensile and compression tests give equal weight to both materials. So because of the way the plastic lumber is manufactured, it has a higher ‘‘apparent’’ modulus in flexure than intension or compression.

1.6.5 Tensile Strength and Modulus

Tests were conducted in accordance with ASTMD638.

1.6.6 Shear Strength

Punch tests in accordance with ASTM D732 were conducted to measure the shear strength of the plastic lumber .Shear strength is very important in holding the nails and screws and making secure structural connections. The results of the shear strength tests are a good indication that the connections in plastic lumber structures will be as strong as or stronger than similar connections in wooden lumber structures. This conclusion is further supported by the pull-out and lateral load tests conducted on nails and screws below.

CHAPTER 2

REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work done by various research workers related to the present studies that gives the general information on plastic lumber, wood plastic composites, recycled plastic lumber and its mechanical properties.

2.1Plastics

2.1.1History of plastics

The first man-made plastic was created by Alexander Parks who publicly demonstrated it at the 1862 Great International Exhibition in London. The material called Parkesine was an organic material derived from cellulose that once heated could be moulded, and retained its shape when cooled (Marry bellis, 2005)

2.1.2Production of plastic

As a material, plastic has existed for just over a century (Gorman 1993), and mass production began in earnest in the 1950s (Beall 2009). By 1988, 30 million tons of plastic products were produced annually (O’Hara et al. 1988), reaching 265 million tons by2010 (PEMRG 2011) and accounting for 8% of global oil production (Thompson et al. 2009). Most plastic products are lightweight, inexpensive, and durable. These defining characteristics make plastics a convenient Material for the manufacture of everyday products.

2.1.3Recycling of plastic

Cemal Meran (2008) reported that due to the advantages of plastic material during the last decade their use has increased greatly, both in areas of application and in actual quantities employed. Because it is impossible to avoid plastic consumption, which parallels the development of new technology, realistic solution have to be searched for the problems arising from the growing use of plastic. That is recycling methods and ways of evaluating these recycled materials must be found. In addition recycling refused plastic materials is an essential part of national economy.

Recycling, being one of the strategies in minimization of waste, offers three benefits (Edwards, 1999): i) reduce the demand upon new resources; ii) cut down on transport and production energy costs; and iii) use waste which would otherwise be lost to landfill sites

Dtuart Ross and David (2003) examined whether reuse and recycle strategy for a plastic-based packing that substantially reduces the quantity of waste to land fill would also reduce the overall environmental burden. The results revealed that recycle and reuse strategies for plastic based products can yield significant environ mental benefits.

Jefferson Hopewell (2009) reported that recycling is one strategy for end-of-life waste management of plastic products. It makes increasing sense economically as well as environmentally and recent trends demonstrate a substantial increase in the rate of recovery and recycling of plastic wastes.

2.2 Plastic lumber

2.2.1 Origin of Plastic Lumber

Klobbie (1974) reported that plastic lumber industry (based on thermoplastic materials) originated in Japan and Europe, where patent applications for newly designed equipment to make large cross-section materials were filed in the early to mid-1970

2.2.2 Unreinforced Plastic Lumber

Forster (1994) reported that the popularity of plastic lumber worldwide were hindered by the limited and uncertain supply of raw materials, a lack of certifiable performance, a significantly lower modulus as compared to wood along the growth axis, and a plentiful supply of wood. The two main advantages of plastic lumber were most apparent when compared to chemically treated wood, and these are that the material is benign to the environment and that it will not degrade readily when used outdoors.

According to the USDA Wood handbook, pines and oaks typically have moduli of at least, and strengths of 2,400 and 3,500 respectively, when measured along the axis. The performance of wood is complicated due to the fact that wood has knots, and wood has properties that deteriorate when left outside, unpainted. Despite chemical treatment, wood also rots eventually and must be replaced.

In Modern Plastic Encyclopedia it is given that the mechanical properties of unreinforced polyethylene based plastic lumber understandably had properties similar to polyethylene, with virgin polyethylene as an upper bound (modulus of 1.1GPaand ultimate strength of 24.13MPa).

The reason for this is that cooling a large cross-section, semi crystalline polymer product creates voids in the interior. In most cases, these voids possess an apparently random size and shape.

R.J. Ehrig*et al* (1992) stated that impurities in these materials represent material inclusions. To address this problem, many manufacturers practice foaming to reduce the maximum size of voids. This can be done a small amount without affecting properties, but a high level of foaming can significantly reduce stiffness and strength, while increasing the thermal expansion coefficient. It is interesting to note that a comparison of woods mechanical properties along the grain with plastic and plastic lumber indicates that the lower modulus of plastic is a much bigger issue than any strength comparison. Incidentally, wood is several times less stiff and strong when measured orthogonal to the growth axis as compared to along the growth axis. Most any plastic lumber compares rather favourably in terms of both stiffness and strength in this situation.

2.2.3Mechanical Properties of Plastic Lumber

In July 1993, the ASTM Subcommittee D20.20.01 on Manufactured Recycled Plastic Lumber and Shapes was formed to develop the needed test methods and specifications for plastic lumber materials. The nucleus of this group was comprised of academic and government researchers, private sector engineers, non-profit research organizations, and plastic lumber manufacturing representatives, all of whom had been working cooperatively to further the commercialization and applications of RPL materials. The newly formed Plastic Lumber Trade Association (PLTA) coordinated its meetings with the ASTM D20 meetings to maximize the interaction of the association membership with the standards development activities of the ASTM plastic lumber subcommittee. This cooperative spirit has led to work with a focus on developing test methods, specifications, and building code acceptance criteria. Each of these is detailed next.

Test Methods

The ASTM D20 activities in recycled-plastic lumber and shapes have led to the establishment of seven test methods to date. These include:

- D 6108, Standard Test Method for Compressive Properties of Plastic Lumber and Shapes;
- D 6109, Standard Test Method for Flexural Properties of Unreinforced and Reinforced PL
- D 6111, Standard Test Method for Bulk Density and Specific Gravity of PL and shapes by displacement.

- D 6112, Standard Test Methods for Compressive and Flexural Creep and Creep-Rupture of PL Shapes;
- D6117, Standard Test Methods for Mechanical Fasteners in PL and Shapes;
- D6341, Standard Test Method for Determination of the Linear Coefficient of Thermal Expansion of PL and PL shapes between -30ºF and 140ºF (-34.4ºC and 60ºC) and
- D 6435, Standard Test Method for Shear Properties of PL and PL Shapes.

2.2.4 RPL Specifications

Simultaneously with the development of test methods, ASTM Committee D20 also undertook the development of purchasing and distribution specifications for RPL. For each end application of RPL in structures, such as decking board, joists, marine fender piles, pallets, etc., a separate specification needed to be developed per the end-use and performance requirements. Since residential decking boards from RPL promised to be the most significant market, the first of these specifications was targeted toward this market. ASTM D 6662, Standard Specification for Polyolefin-Based Plastic Lumber Decking Boards was completed and published in March of 2001. As is done for plastic piping for water, gas, and sewer applications, manufacturers can now use an “ASTM stamp” on plastic lumber decking boards that meet the specifications. In the development of D 6662 several major issues concerning the use of RPL in decking boards were resolved. These included the following:

Dimensional Tolerances: Acceptable tolerance for dimensional RPL was not available. Tolerance limits that would meet industry requirements and performance consideration were developed.

Creep: The most significant difference between wooden lumber and RPL is sensitivity to elevated temperature. As stated earlier, the visco-elastic nature of RPL makes it susceptible to creep at sustained loads at elevated temperatures. A methodology was developed to use creep data per ASTM D 6112 to define design limits to avoid excessive deflection and creep in the decking boards.

Flammability: The question of plastic lumber’s ignitability properties was also addressed. The fire test method described uses a small ignition source, which is appropriate for expected sources on a deck such as hot charcoal briquettes from a tipped over barbecue grill.

Allowable Material Properties for Structural Design: A complete methodology is presented in the standard to determine allowable maximum span lengths for decking boards based on the material properties determined from the test methods listed above. This is analogous to having a design guide or a handbook that is available for other construction materials such as steel, wood, or concrete.

Douglas R.Caroll *et al.*(2001)conducted a study on structural properties of recycled plastic/sawdust lumber decking planks. In this research effort, standard 2×6 plastic lumber planks were tested for many different structural properties. The plastic lumber tested was a blend of recycled plastic and sawdust. The tests were conducted at −23.3°C to simulate winter conditions, and at 40.6°C to simulate summer conditions. In all cases the high temperature strength and stiffness was lower than at low temperature, so the high temperature values would determine the allowable strength and stiffness for design. The high temperature modulus of the plastic lumber was 5.79, 1.03, and 1.12 GA in compression, flexure and tension respectively. High temperature strength values were 16.8, 12.0, and 1.45 MPa in compression, flexure and tension respectively. The high temperature shear strength of the plastic lumber was 5.31 MPa. Strength tests were also performed for nail and screw connections typically used with lumber, and the pull-out and lateral load were comparable to wooden lumber. The plastic lumber performed well under sustained load tests at high temperature. Slip resistance tests were performed, and it was found that the plastic lumber is more slippery than wooden lumber, but probably does not represent a safety hazard. The conclusion was that the plastic lumber is a good structural material, but it is not appropriate to simply substitute plastic lumber for wooden lumber pieces of the same dimension in structural applications. Plastic lumber structures must be designed using the structural properties of the plastic lumber.

Vincent T.Breslin*et al.*(1998) conducted a study on long-term engineering properties of recycled plastic lumber used in pier construction. Plastic lumber manufactured using post-consumer waste plastic has been proposed as an acceptable material for use in the construction of docks, piers and bulkheads and is touted to outlast conventional wood products due to its strength, durability and resistance to rot. Plastic lumber profiles were used in the decking of a pier built in West Meadow Creek, Old Field, NY during December 1995. Samples of plastic lumber were removed from the deck of the pier periodically over a two-year period and returned to the laboratory for testing. Results of engineering tests showed the in-plane compression modulus (260±30 MPa), dimensional stability and the Shore D surface hardness (60±2) of plastic lumber removed from the pier remained similar to or greater than their pre-placement values. In contrast, significant changes in the modulus of elasticity of plastic lumber were measured with prolonged weathering. The modulus of elasticity of plastic lumber initially decreased from 1370 Pa to 750 Pa following 12 months weathering, a decrease equal to 45% of its pre-placement value and then increased during the second year to close to its initial value. The high variability in the modulus of elasticity should restrict the use of plastic lumber profiles to non-load bearing structural applications.

Kamal B.Adhikary *et al.*(2008) investigated the stability, mechanical properties, and the microstructure of wood–plastic composites, which were made using either recycled or virgin high-density polyethylene (HDPE) with wood flour (*Pinusradiata*) as filler. The result of the study revealed that tensile and flexural properties of the composites based on recycled HDPE were equivalent to those based on virgin HDPE and also dimensional stability and strength properties of the composites can be improved by increasing the polymer content or by addition of coupling agent.

Krishnan Jayaraman *et al.*(2004) Studied about mechanical performance of wood fibre waste plastic composite materials. The study revealed that the tensile and flexural moduli increased with fibber content.

2.2.5 Reinforced Plastic lumber

S.D.George*et al.* (2000) conducted a study on Recycled fibreglass composite as reinforcing filler in post-consumer HDPE plastic lumber. The study concluded that Recycled fibreglass composite increases the stiffness of recycled HDPE more effectively than wood flour with no significant effect on tensile strength. However, the use of recycled fibreglass composite results in a significant decrease in impact strength. In addition, there was a synergistic effect on stiffness between recycled glass fibber and wood flour, suggesting that the use of the two together provides better performance than either alone. These data suggest that recycled fibreglass composite may be economical reinforcing filler for use in HDPE plastic lumber.

2.3 Wood Plastic Composite

Pritchard (2004) reported that WPC was born as a modern concept in Italy in the 1970s, and popularized in North America in the early 1990s. By the start of the 21st century it was spreading to India, Singapore, Malaysia, Japan and China. Gupta *et al*. (2007) WPCs may be one of the most dynamic sectors of today's plastic industry with an average annual growth rate of approximately 18% in Northern America and 14% in Europe. It has been reported that 460 million pounds of WPCs were produced in 1999. Statistics show that the production of these composites in 2001 has increased to 700 million pounds.

Panthapulakkal*et al*. (2006) .The term WPCs refers to any composites that contain plant (including wood and non-wood) fibres and thermosets or thermoplastics. Thermo sets are plastics that, once cured, cannot be melted by repeating. These include resins such as epoxies and phenolics, plastics with which the forest products industry is most familiar. Thermoplastics are plastics that can be repeatedly melted. This property allows other materials, such as wood fibres, to be mixed with the plastic to form a composite product. Polypropylene (PP), polyethylene (PE) and polyvinyl chloride (PVC) are the widely used thermoplastics for WPCs and currently they are very common in building, construction, furniture and automotive products WPCs are normally produced by mixing plant fibber with polymer, or by adding wood fibber as filler in a polymer matrix, and pressing or moulding under high pressure and temperature. Additives such as colorants, coupling agents, stabilizers, blowing agents, reinforcing agents, foaming agents and lubricants help tailor the end product to the target area of application

Alireza Ashori (2008) conducted a study on wood–plastic composite (WPC) and found that it is a very promising and sustainable green material to achieve durability without using toxic chemicals. The term WPCs refers to any composites that contain plant fibber and thermo sets or thermoplastics. In comparison to other fibrous materials, plant fibres are in general suitable to reinforce plastics due to relative high strength and stiffness, low cost, low density, low CO_2 emission, biodegradability and annually renewable. Plant fibres as fillers and reinforcements for polymers are currently the fastest-growing type of polymer additives. Since automakers are aiming to make every part either recyclable or biodegradable, there still seems to be some scope for green-composites based on biodegradable polymers and plant fibres. From a technical point of view, these bio-based composites will enhance mechanical strength and acoustic performance, reduce material weight and fuel consumption, lower production cost, improve passenger safety and shatterproof performance under extreme temperature changes, and improve biodegradability for the auto interior parts.

Xun Xu *et al.*(2008) reported that natural fibres such as sisal, flax, jute and wood fibres possess good reinforcing capability when properly compounded with polymers and hence can be used in wide array of applications in building and construction, automobile industry.

Dillman *et al.*(2000) conducted a study on properties of adding ground recycled fibber glass composite in combination with wood flour to HDPE lumber thus providing better performance. Even though recycled fibber glass composite alone increases stiffness of HDPE but impact strength decreases.

F.P.La Mantia *et al.*(2007)Studied about the effect of maleate adhesion promoters to polypropylene-wood floor composite and revealed that there is a decrease in water uptake and mechanical properties such as elastic modulus, tensile strength and impact strength are increased.

Johannes Ganster *et al.*(2005) stated that cellulose spun fibres are suited for reinforcing thermoplastic polymers such as PE, PP, PS.

2.4 Weathering

Mark Mankowski*et al.* (2000) investigated the ability of white and brown rot fungi to colonize wood-plastic composites were investigated by measuring weight loss and anatomical changes three composite materials were evaluated. The material containing a 70/30 wood-high density polyethylene (HDPE) mixture was most susceptible to fungal attack, while two different 50/50 wood-HDPE composites experienced little or no attack. Scanning electron microscopic (SEM) examination of samples not exposed to fungus revealed the presence of voids between the wood and HDPE in all three material. Similar examination of decayed samples of the composite with a higher wood content revealed that the fungi had thoroughly colonized the particles, particularly near the point of initial fungal exposure. Fungal hyphae were also prevalent in the voids deeper in the composite. The two composites containing higher HDPE levels had little evidence of fungal attack, despite the presence of voids

Chatree Homkhiew *et al.*(2014) reported that weathering sharply changed lightness and discoloration and slightly reduced flexural strength and modulus of the composite.

J.L.Lopez *et al.*(2004) revealed that relative humidity highly affected the modulus of rupture and modulus of elasticity and had a greater effect than temperature and UV exposure.

Nicole M.Stark *et al.* (2007) conducted an eperiment to study the characterization of weathered wood–plastic composite surfaces using FTIR spectroscopy, contact angle, and XPS. In this study, wood flour filled high-density polyethylene (HDPE) composites were manufactured through either injection moulding or extrusion. A set of extruded composites were also planned to remove the extruded surface. Composites were weathered in a xenon-arc weathering apparatus. Scanning electron microscopy (SEM) was used to characterize the morphology of the composite surface. Attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy was useful in showing the loss of wood particles from the surface after weathering. Contact angle was higher for the extruded and planed composites compared with the injection moulded composites, and was shown using X-ray photoelectron spectroscopy (XPS) to be due to lubricant used as a processing aid**.**

2.5 Plastic coating for bamboo

H.Kumar*et al* (2005) studied the chemical and tensile properties of PU/PS coated bamboo fibres. The tensile strength and chemical resistance were measured on alkali treated and untreated fibres with or without polymer coating. The PU and PU/PS (50/50) IPN (inter penetrating polymer network) coated bamboo fibres showed improvement in tensile behaviour and chemical resistance

CHAPTER 3

MATERIALS AND METHODS

3.1Plastic

Plastic has been considered as one the commonly used materials in our daily life due to its unique properties such as light in weight, flexibility and durability. However, it has bad side; the effect of plastic wastes on the environment is a huge problem that people face. The plastic wastes affect the environment in three ways; air, land and water pollutions

3.1.1Types of Plastic

Plastics are divided into two main types according to how they behave when heated:

- **Thermosetting plastics**

Thermosetting plastics undergo relatively weak molecular motion but once softened by heat and treated they undergo a chemical reaction which causes them to form a high molecular weight 3D matrix structure. This means that once they have set they cannot be softened again by heat. Uses include food containers, circuit boards for electrical equipment, shafts for golf clubs and tennis rackets, and fibber-reinforced plastic boats.

- **Thermoplastic plastic**

Thermoplastic plastics undergo strong molecular motion when heated, which causes them to soften. They harden when cooled, and repeated heating and cooling allows them to be moulded into a variety of different shapes. Uses include containers and packaging material (film, sheet, and bottles), daily necessities, household appliances and automobiles. Hence thermoplastics can be used for recycling.

Major thermoplastics used include:

1) Polyethylene:

Low density polyethylene (LDPE), Linear Low Density Polyethylene (LLDPE) and High density Polyethylene (HDPE) are the three types of Polyethylene plastic. Polyethylene has a density range of 918-965kg/m3 depending on the type. It is a soft, tough and flexible and transparent material. LDPE is used in the application of making bottles, bowls, buckets, film plastic

Bags, tubing or pipes, electric or telephone insulators etc. on the part of HDPE, it is slightly tougher and stiffer than LDPE. It is used in manufacturing of dustbins, bottles crates, pipes and fluid containers.

2) Polystyrene:

Polystyrene (PS) is a thermoplastic material that is obtained by polymerisation of monomer styrene extracted as liquid from petroleum. It is a brittle, transparent material and it is solid at room temperature and softens to liquid at temperature above 100°C. Polystyrene is produced in the form of either as solid or foamed plastic and use in the application such as electrical thermal insulation, window panels, food cutlery, battery case, food box etc. It is resistant to heat, oil, acids, alcohols etc.

3) Polypropylene:

Polypropylene (PP) is a thermoplastic material made from monomer propylene and properties such as rigidity, chemical resistance, stiffness and excellent fatigue. In terms of its applications, it is used to make pipes, crates, chairs, tool handles, TV cabinets, machine parts, carpets, bottles etc.

4) Polyvinyl chloride:

One of the most used plastic materials is polyvinyl chloride (PVC). The plasticized and unplasticised are the forms of polyvinylchloride. Polyvinyl chloride has flexibility rigidity, resistance to weathering, hardness, toughness and electrical insulation as its properties depending on the form of polyvinylchloride concern. Polyvinylchloride is used in applications such as floor tiles, raincoats, water pipes, window frames, water hose, gloves, toy balls etc

Figure 2-Plastic resign codes

3.2 Plastic Processing

3.2.1 Extrusion

Extrusion is a process that can be compared to squeezing toothpaste out of a tube. Thermoplastic granules are forced through a heated barrel and the fused polymer is then squeezed through a die that is the profile of the extruded component. The extrusion is cooled by water or air as it leaves the die and is finally cut tothe required length. The shape of the die can be varied from a simple hole witha centrally supported core to produce tubes such as pipes, to very complex sections for curtain tracks or hollow window frames.

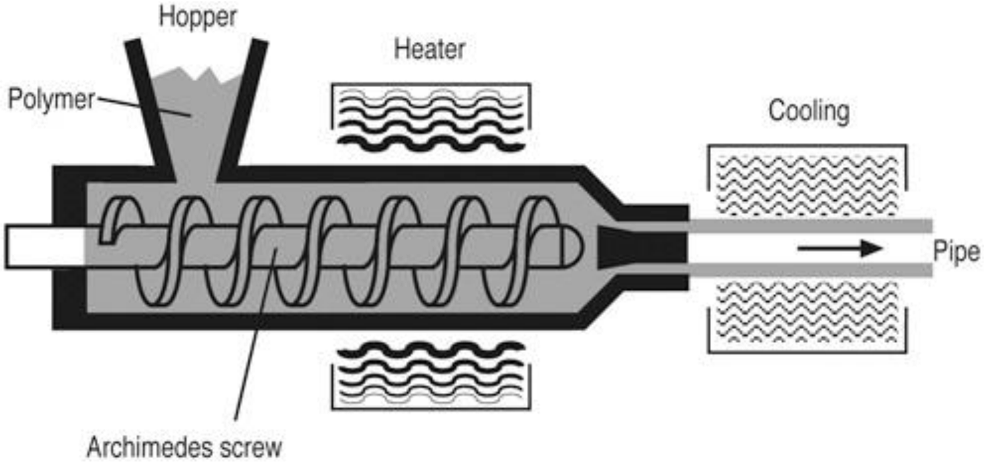


Figure 3-Extrusion moulding

3.2.2. Injection Moulding

This process is one of the most common of all plastics manufacturing processes. The polymer, in granule form, is heated until fused and forced into a closed mould. Because of the viscous (thick, syrupy) nature of the fused polymer, very high pressures are needed to make it flow, which means that the machine and mould have to be very strong to withstand the forces involved.

A typical industrial injection moulding machine uses a screw to force the granules along a heated barrel, and when the granules become fused the screw is used as a plunger to force the polymer into the mould. The moulds are usually made from high-grade steel to withstand the forces involved and must also be highly polished to produce a very good finish on the product, as any Scratches will show up in the moulded plastic surface. Because of the ability of the plastic to show even the smallest of marks very fine detail can be cut into the surface of the mould, for example in the form of trademarks, lettering ortextures.

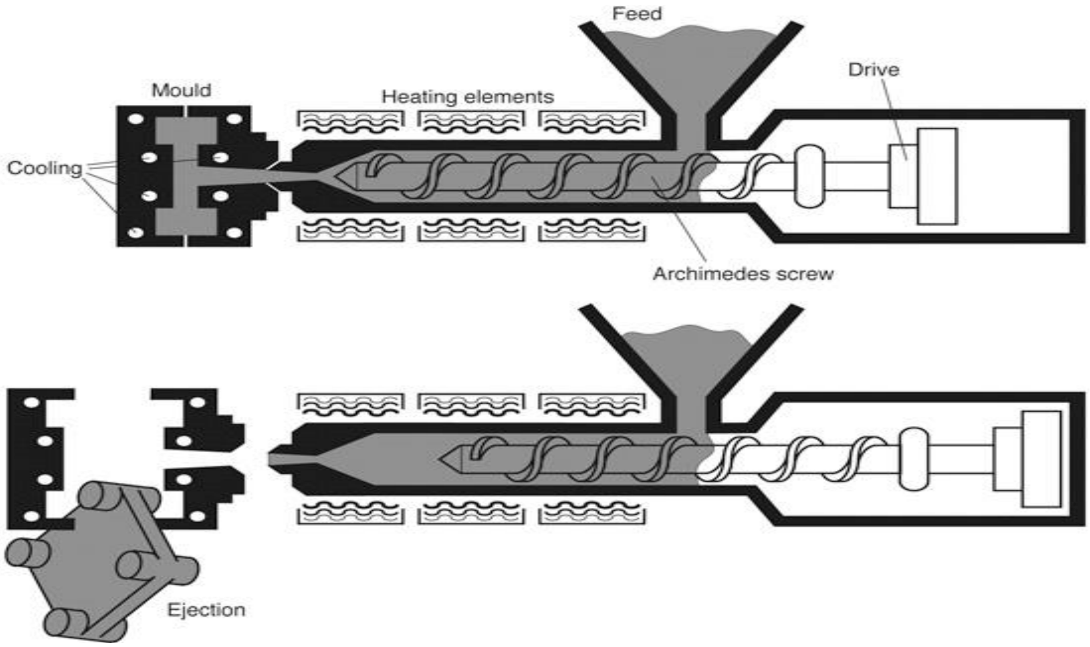


Figure 4-Injection moulding

3.2.3 Blow moulding

Blow moulding is a simple process where compressed air is introduced underneath a warmed sheet of thermoplastic material forcing the material into a mould cavity, or allowing it to expand freely into the shape of a hemisphere. It is a good way of forming large domes, which when made out of clear acrylic sheet is often used in shop displays.

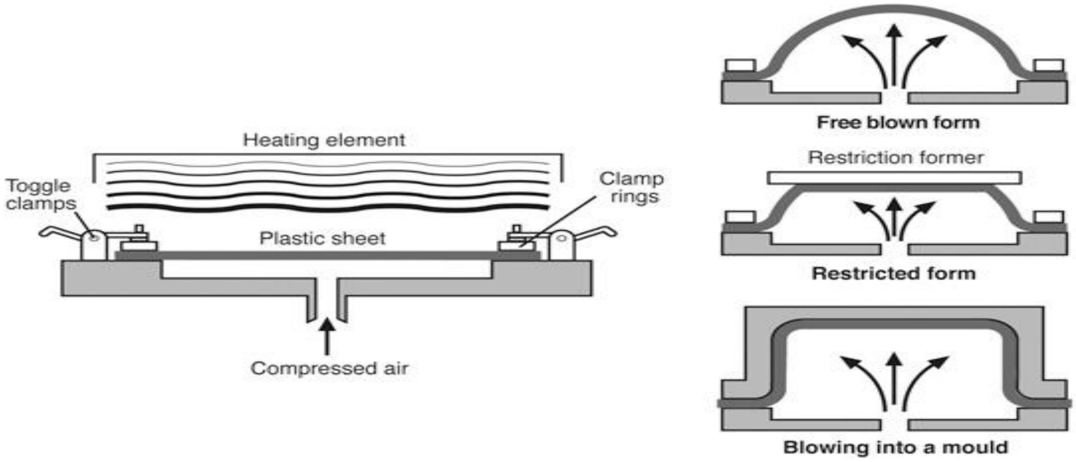


Figure 5-Blow moulding

3.2.4 Vacuum Forming

This is a very common manufacturing process used, for example, to make a range of plastics packaging. Think of the boxes sandwiches come in, or the inner in a chocolate box, or your acrylic bath. It is really the opposite of blow moulding. Instead of the warmed plastic sheet being forced into a mould by air pressure, in vacuum forming the air is drawn out from under the softened plastic sheet, so it is forced over or into a mould by atmospheric pressure. Vacuum forming is a very common and effective way of producing complex shapes in thermoplastic sheeting.

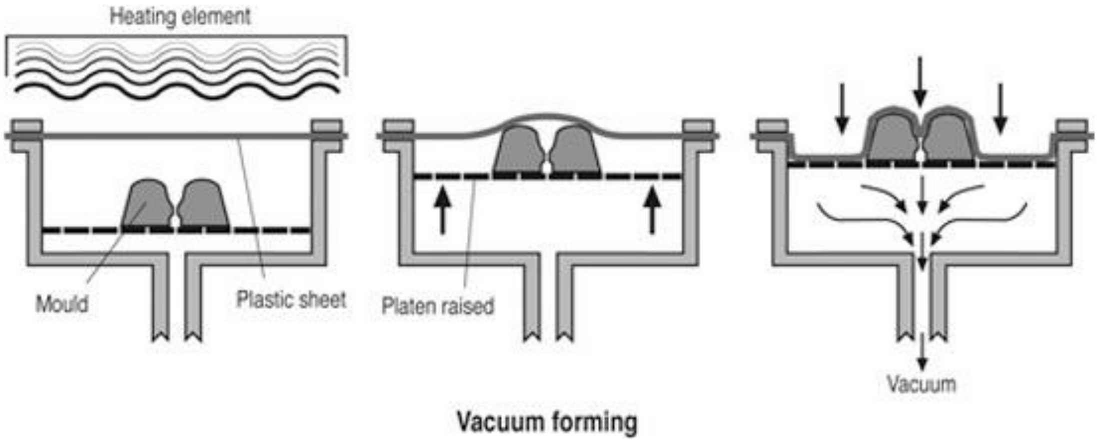


Figure 6-Vacuum moulding

3.3 METHODOLOGY

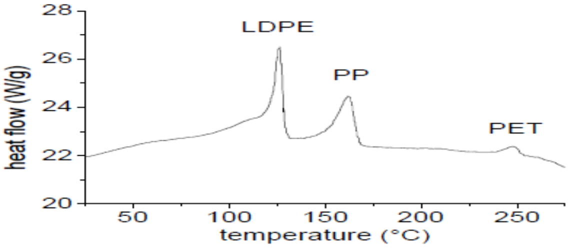
3.3.1 Material Collection

The polymer material used in the present work is a recycled plastic coming from solid urban waste. The LDPE is obtained by manual sorting of plastics from solid urban waste. After removal of PET, HDPE and PP bottles, and of films of PP and PE bigger than about 20 × 30 cm, all the residues, mainly consisting of films of small dimensions, are collected as a mixed plastic. Such material mainly contains flexible and rigid PE and PP, but also small percentages of PET, escaped from the sorting stage.

Figure 7-LDPE Plastic covers

DSC (Differential Scanning Calorimetry) analysis, reported in Fig confirms that the material is mainly composed of LDPE, which melts in the range between 100 and 130 °C. Significant amounts of PP are also highlighted by the melting peak around 160 °C, as well as small traces of PET, which melts around 250 °Before extrusion, the material is simply milled to a size of about 8mm, and then pelletized. No washing stage is foreseen

Figure 7. DSC analysis of RPL.



3.3.2 Plastic Granulator

A plastic granulator is a machine used for size reduction, an essential step in plastic recycling. They have the ability to quickly breakdown plastic products. In a plastic granulator cutting knives are mounted on an open rotor spun to high speeds by an electric rotor. This rotor is encased in a cutting chamber where stationary knives are mounted .As the plastic scrap enters this cutting chamber; the rotating knives come into contact with the stationary knives cutting the plastic into little pieces. A large screen with many holes is placed at the bottom .The plastic will continue to mix and be cut by the knives until it is small enough to fall through the screen.

Figure 8-Plastic granulator

Figure 9-Plastic granules

3.3.3 Melting of Thermoplastic

Extruder Specification

Heater - 1150 W

Heating temperature - 320ºC (consist of 7 chambers)
(200ºC,220ºC,240ºC,260ºC,280ºC,300ºC,320ºC)

Motor hp - 20 hp

Figure 10-Plastic Extruder

Working

The purpose of the screw extruder is to simply mix, homogenize and melt the material. Higher back pressures may be generated in single screw extrusion machines compared to injection moulding machines and the screws may be longer for better mixing.

In combination with the barrel, the purpose of the screw is to convey solid material to the melt zone, melt, and mix and pump material to the die in an efficient manner. The screw design and length of screw will depend on the polymer being processed as well as the application.

3.3.4 Forming

Discharge or force the molten mixture into a mould, cool the mould in a water bath, and eject the finished product

Figure 11-Die and Mould arrangement

Mould

A rectangular mould of 8*8 cm cross-section and 60cm height is made from mild steel. It is an open able mould with nut and bolt arrangement. The mould is placed vertically with its bottom closed.

Location of Manufacture of Recycled Plastic Lumber

Star Polymers
UTC Compound
Muzhppilangad P.O
Kannur-670 622

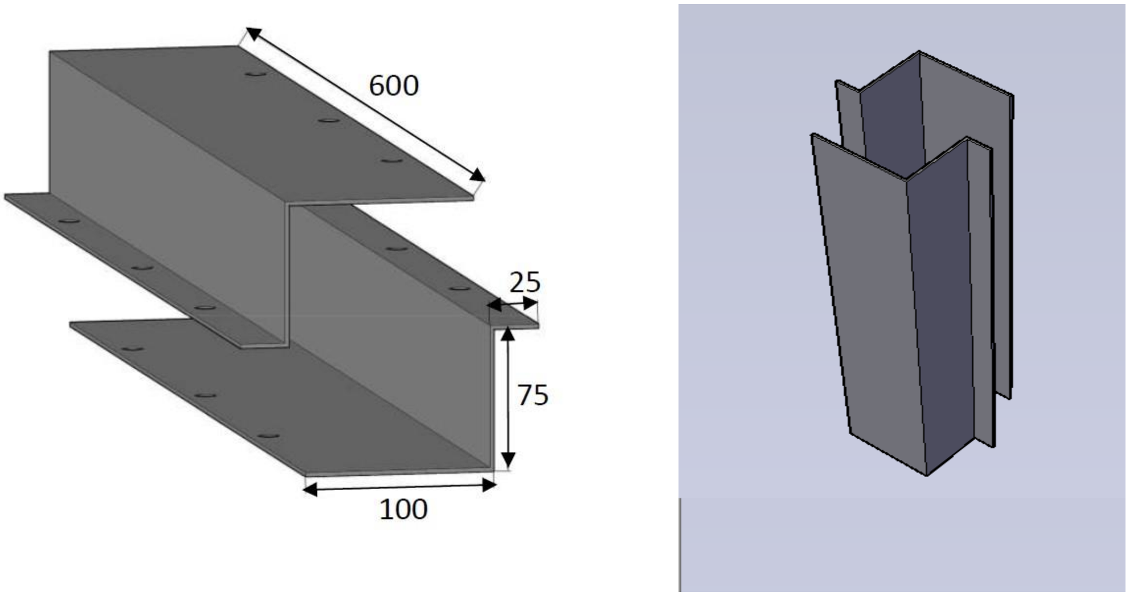


Figure 12-Autocad drawing of mould

Figure 13-Mould and plastic lumber

Reinforcement

Four mild steel rods of 6mm diameter and 60cm long are made in the form of a rectangular block and are kept in the centre of mould.

3.4 Concrete Fencing Posts

Figure 14-Concrete post

Prepare a concrete mix of 1:2:4 ratios with 0.3 water cement ratio (8 Kg of coarse aggregate, 4 Kg of fine aggregate, 2 Kg of cement and 0.6 Kg of water).Mix the cement and sand first and then mix it with the coarse aggregate. Then add water and thoroughly mix it to form a mixture of uniform colour. With a shovel keep on mixing the concrete, so as the concrete folds over again and again. Keep on adding water until you achieve a smooth mixture. To test the concrete, use the blade and try to cut a channel through it. Make sure the concrete is not too dry, if it is, the walls will be crumbly. Pour the concrete mix thus obtained in the mould. Four corrugated mild steel bars of 60 cm length, in the form of rectangular bar having 3.5*3.5 cm^2 cross section is kept as reinforcement. Wait overnight for the concrete to dry. The concrete fence post is kept for 14 days as such for curing.

3.5 Plastic Coating for Bamboo

Figure 15-Plastic coated bamboo and normal bamboo pole

LDPE plastic bags were collected and is subjected to melting at around 150ºC.Then bamboo poles are dipped in molten plastic. Thus plastic coated bamboo poles were obtained .Plastic coating helps to prevent the deterioration of bamboo from termites and mites.

Normal bamboo pole and plastic coated bamboo pole were subjected to termite attack in the field for about 3 months and it was found that plastic coated bamboo poles were more resistant to rodents and termites than normal bamboo pole.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Universal Testing Machine (UTM)

20 tonne UTM consist of the testing machine and control panel mounted on the foundation and interconnected by oil piping. Testing machine is provided with hydraulic transverse drive to the movable cross rail and mechanical drive to lower grip. Mechanical drive to the lower grip is necessary only for adjusting this position of the grip .This is controlled by “up and down” push button on the right hand column.

Movable cross rail represents the upper grip .it is provided with the levers for clamping the test specimen. Load is applied to the specimen by hydraulic pressure. The machine is driven by the pumping unit. The control lever mounted over the central cabinet is used for coarse adjustment. The load will be applied when the lever is moved along the longitudinal slot towards the operator and moved when lever is in opposite direction. Fine adjustments can be made by turning the knob clockwise to apply load and anticlockwise to remove load. The changes of pressure in the power cylinder are transmitted to the pendulum load weighing device plunger through oil piping and is transferred to the load dial by means of a pointer. Pendulum load weighing device compresses a rod with weights .one weight is attached to the rod at all time while other four loads ranges 2.5 tonne,5 tonne,10 tonne and 20 tonne to get a particular range, keep the corresponding weight on the pendulum and adjust the load dial for that range.

Pump and load weighing device motors are controlled by “start” and “stop” buttons. The portion above the cross rail can be used for bending and compression test whereas that below the cross rail can be used for tension test.

Figure 16-Universal Testing Machine

4.2 Compression Test

Procedure

Measure the length and width of sample and calculate approximate crushing load .Select the scale and pendulum load for this crushing load. Place the sample over cross rail, between two plywood sheets each of thickness 3 mm with flat face of sample facing upwards. Carefully centre the sample between platforms of testing. Apply load axially at uniform rate till failure. This crushing load divided by area of lumber gives the crushing strength. Repeat the test with three other samples and find average crushing load.

Table 1-Compression test observations

Sl.no	Length (cm)	Breadth (cm)	Area (A) (cm^2)	Crushing Load(P) (Kg)	Compressive strength(P/A) (Kg/cm^2)
1	7	7	49	12160	248.16
2	7	7	49	10640	217.14
3	7	7	49	8624	176

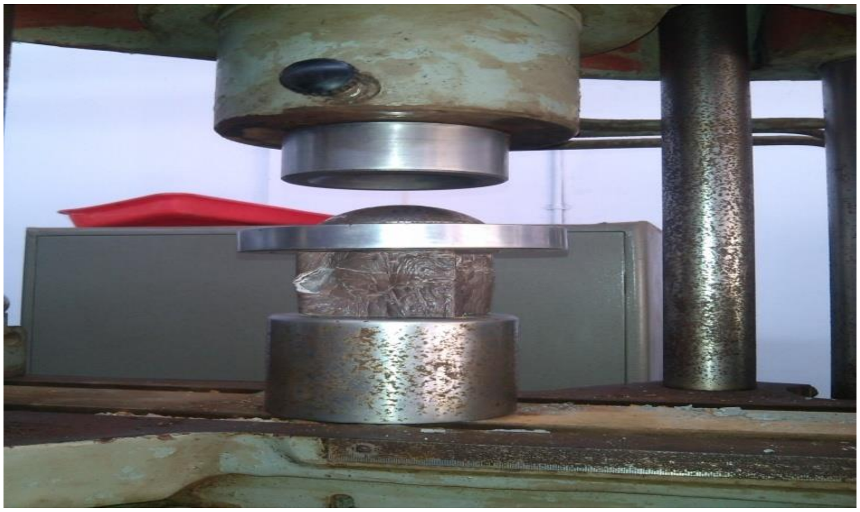


Figure 17-Specimen subjected to compression in UTM

4.3 Static Bending Test

Procedure

Note the width and depth of the specimen. Mark the span length. Then support the specimen over the rail. Proper loading device is attached to the UTM. Assuming maximum fibber stress of 1000 Kg/cm² .Calculate the maximum central load the specimen can carry M=Wl/4=fz Hence select a suitable loading range and adjust the machine for that range. Start the motor and slowly open the inlet valve until the ram is floated. Adjust the pointer to zero reading. Raise the cross head so that central loading device just touches the top of the beam specimen. Fix the dial gauge beneath the specimen to note the deflection. Adjust the deflection dial to zero. Now slowly load the specimen opening the inlet valve and note the deflection corresponding to load (w) at regular intervals. Also note down the load at yield point and ultimate load. Draw the load deflection curve and from the graph obtain average value (w/d).Then young's modulus $E=wl^3/48Ed$. Also calculate the fibber stress at limit of proportionality and fibber stress at ultimate

Stress at ultimate load (Modulus of Rupture).

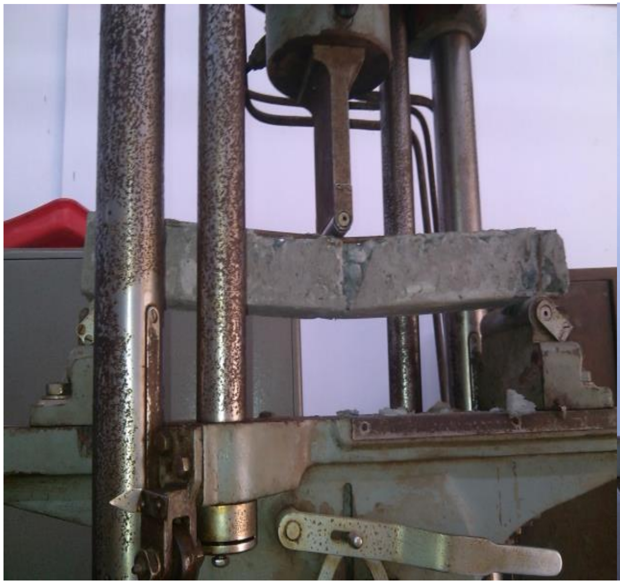


Figure 18-Concrete post subjected to tension

Figure 19- RPL subjected to bending test

Table 2-Bending test result in RPL

Load	50	100	150	200	250	300
Deflection	0. 70	1.30	2.55	2.85	3.10	3.30

Width of the specimen, b = 7.25 cm

Depth of the specimen, d = 7.5 cm

Span, l = 55 cm

<u>Load by calculation</u>

$M/I = \sigma/y$

$(Wl/4)/ (bd^3/12) = \sigma / (d/2)$

$(W\times55\times12)/ (4\times7.25\times (7.5)^2) = 50/ (7.5/2)$

$W = 247$ Kg

Modulus of elasticity, $Z = bd^2/6 = 67.986\ \text{cm}^3$

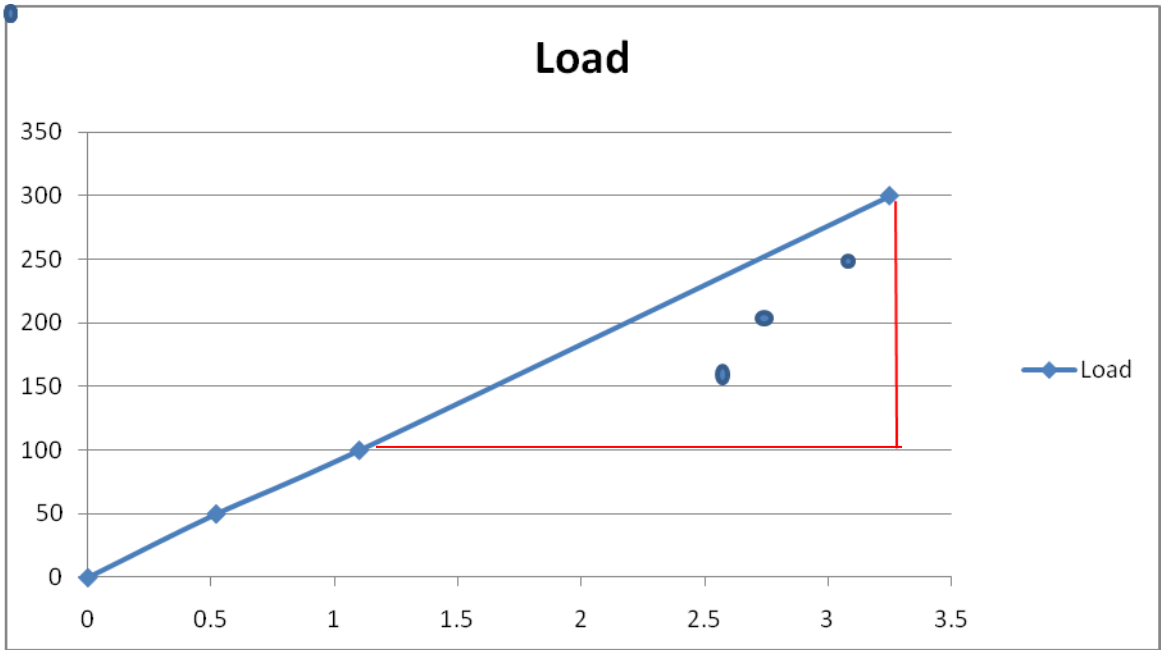
Moment of inertia, I = $bd^3/12$ = 254.88 cm^4

Modulus of rupture = $(P_u \times l)/4Z$

$= (1.18\times10^3\times55)/ (4\times67.968)$

= 238.715 Kg/cm^3

Load - Deflection curve of plastic lumber



X Axis: Deflection; 1unit=0.5 mm

Y Axis: load; 1 unit= 50 Kg

From graph ,

Modulus of elasticity, E = $(P/\delta) \times (l^3/48I)$

$= (200/0.215) \times (55^3/ (48\times254.88))$

= 12647.1Kg/cm^2

= 1.24GPa

Figure 20-RPL after bending test

4.3.2 Concrete

Table 3-Bending test result in concrete

Load	50	100	150	200	250	300	350
Deflection	0.20	0. 28	0.33	0.40	0.50	0.60	0.70

Width of the specimen, b = 8cm

Depth of the specimen, d = 7.5cm

Span, l = 54cm

<u>Load by calculation</u>

$(Wl/4)/ (bd^3/12) = \sigma/ (d/2)$

$(W\times54\times12)/ (4\times8\times (7.5)^3) = 50/ (7.5/2)$

$W = 277.7Kg$

Modulus of elasticity, $Z = (bd^2)/6 = 75cm^3$

Moment of inertia, $I = (bd^3)/12 = 281.25cm^4$

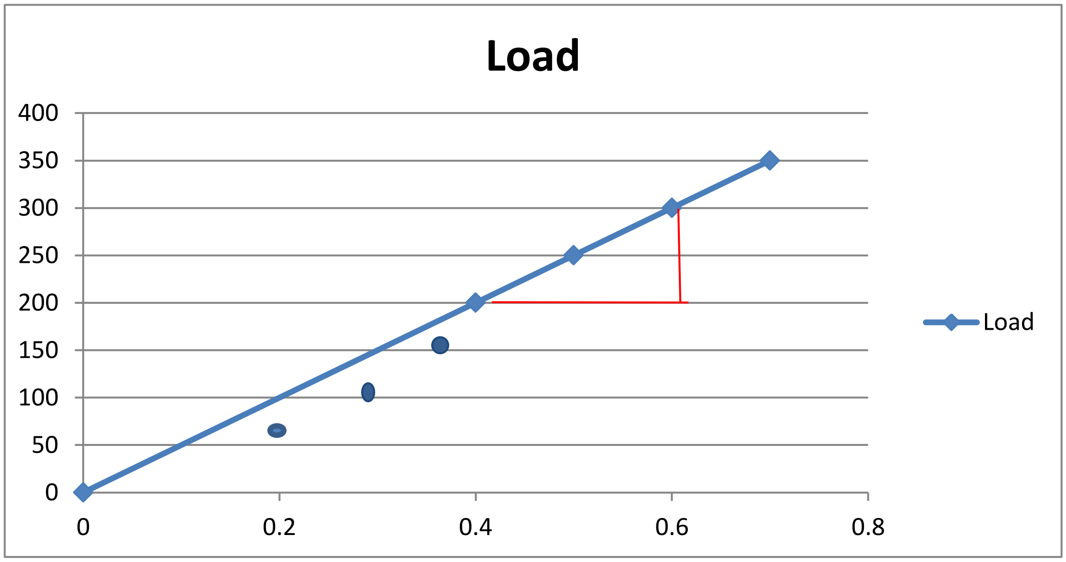
Ultimate load, $P_u = 0.65\times10^3Kg$

Modulus of rupture $= (P_u\times l)/ (4\times Z)$

$= (0.65\times10^3\times54)/ (4\times75)$

$= 117Kg/cm^2$

Load –Deflection curve of concrete



X Axis: Deflection; 1unit = 0.1 mm

Y Axis: Load; 1unit = 50Kg

From graph,

Modulus of elasticity, E $= (P/\delta) \times (l^3/48I)$

$= (100/0.020)*(54^3/ (48*281.25))$

$= 58320 Kg/cm^2$

$=5.83 GPa$

Figure 21-Concrete post after bending test

4.3.3 Wood

Table 4-Bending test results in wood

Load (P)	100	200	300	400
Deflection (δ)	1.8	3.3	4	6.1

CALCULATION

Width of the specimen = 7 cm

Depth of the specimen = 7cm

Length of the specimen = 50cm

Modulus of section, z = $(bd^2)/6 = 57.16$ cm^3

Moment of inertia, I = $(bd^3)/12 = 200.08$ cm^4

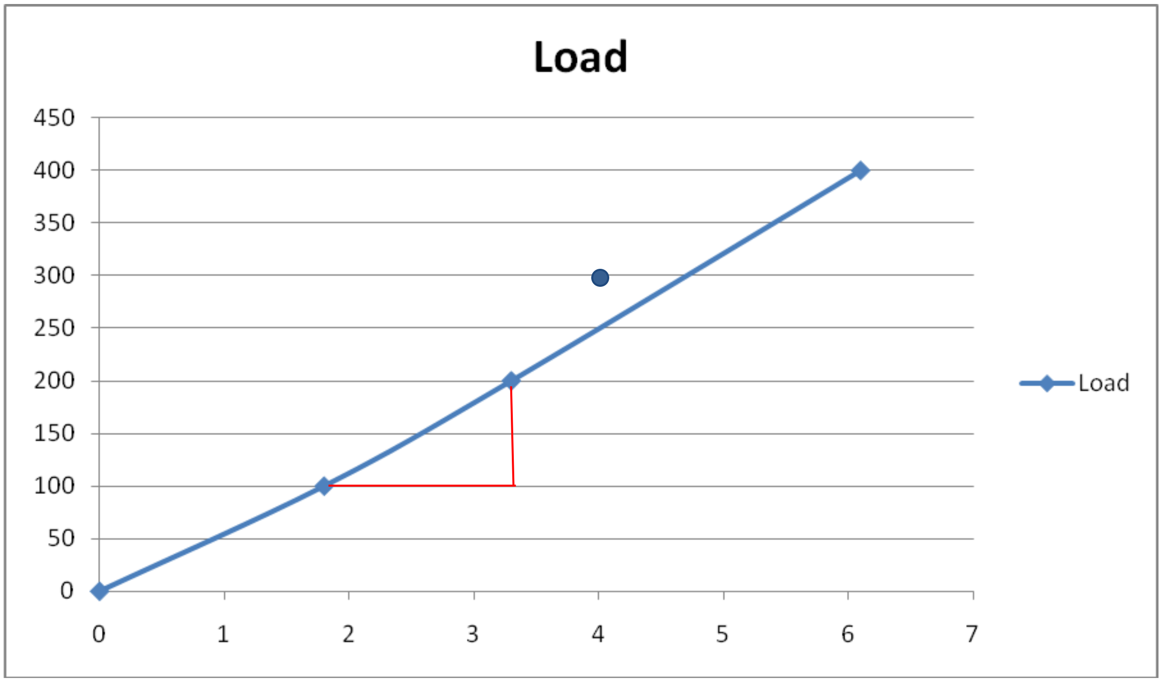
Ultimate load, P_u = 1010kg

Modulus of rupture = $(P_u \times l)/(4 \times Z)$

= $(1010 \times 50)/(4 \times 57)$

= 221.4 Kg/cm^2

Load-Deflection curve of wood post



From the graph,

P/δ =100/.15 = 66.66

Modulus of elasticity = (P×l^3)/ (48×I×δ)

= (666.6v50^3)/ (48×200.08)

= 867.838 Kg/cm^2

= 0.85GPa

SUMMARY AND CONCLUSION

Plastic recycling has become a new focus throughout the globe because of the need to recover plastic and reuse them. In this study attempt has been made to produce plastic lumber from recycled LDPE plastic. The lumber can be used as an alternative to conventional fencing posts. In order for lumber to be used and sustain certain load, the mechanical properties of the lumber (pure LDPE lumber) have to be examined through experimental procedures. Theexperiments that are carried out to evaluate mechanical property were bending and compression test.

Flexural strength, also known as modulus of rupture, which is defined as a material's ability to resist deformation under load for concrete, wood and recycled LDPE plastic lumber are 10.78MPa,21.67MPa and23.48MPa respectively.

From the bending test result, the recycled LDPE lumber has more elastic nature making it to be ductile and not tube broken easily during bending loading resulting in young’s modulus of about 1.24GPa .The wood is more brittle and is easily broken when it’s exposed to bending load since it poses a young’s modulus of about 0.85GPa.However concrete fencing post is having the largest modulus of elasticity ie, 5.8GPa.

Compression test of specimens for recycled LDPE lumber is found to be 23.35MPa. For the concrete post and wood it may vary from 7Mpa to25MPa depending upon the variation in composition and type of the wood. Thus the RPL has almost same energy absorbing capacity when compared to the concrete and wood.

From the above results it can be concluded that recycled LDPE plastic can replace traditional fencing posts having high modulus of rupture and compression strength. The resistance to load failure varies with plastic type and will much more for HDPE recycled plastic lumber. Moreover the cost of RPL will be much less as compared to concrete and wood fencing post.

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ABSTRACT

Plastic solid waste (PSW) presents challenges and opportunities to societies regardless of their sustainability awareness and technological advances. During the 1990s, a number of technologies emerged to utilize recycled plastics in products designed to replace dimensional wood lumber. Since that time, recycled plastic umber (RPL) products have proven to be effective alternatives for many applications, offering high durability and requiring little maintenance. Plastic lumber products are resilient, weather-resistant, and impervious to rot, mildew, and termites. They do not require painting or staining.

The first applications of plastic lumber products were in non-structural applications such as picnic tables and benches. As the industry has matured through the years, innovative research and development work by the plastic lumber industry and universities has fostered the development of superior performing products which in turn has begun to establish new and demanding structural applications for these products. Much of the work has involved the application of composites technology to the reuse of post-consumer and post-industrial materials in plastic lumber products. This evolution, from non-structural applications to structural application is achieved by reinforcing plastic lumber with glass fibres, steel and iron rods etc. In the present study we used LDPE recycled plastic lumber with and without reinforcement to compare its mechanical properties with wood and concrete as fencing posts and also plastic coating is given to bamboo to prevent it from termite and rodent attack.