Recycled HDPE Plastic Lumber: Performance Characteristics & Applications
Description: Provides an overview of recycled HDPE plastic lumber and includes discussions on manufacturing processes, comparisons to wood lumber and wood/plastic composite lumber, and the composition and construction of different types of recycled HDPE plastic lumber as well as their performance attributes and applications.

Purpose: Provides an overview of recycled HDPE plastic lumber and includes discussions on manufacturing processes, comparisons to wood lumber and wood/plastic composite lumber, and the composition and construction of different types of recycled HDPE plastic lumber as well as their performance attributes and applications.

Learning Objectives:

At the end of this program, participants will be able to:

• define plastic lumber and list the types of materials used in its composition

• outline three processes used to manufacture recycled HDPE plastic lumber and the differences between their end products

• compare recycled HDPE plastic lumber to wood lumber and other composite lumber along various performance attributes

• describe the composition and construction of different types of recycled HDPE plastic lumber and relate these to their performance and applications.
# Table of Contents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Lumber Overview</td>
<td>7</td>
</tr>
<tr>
<td>Recycled HDPE Plastic Manufacturing Processes</td>
<td>20</td>
</tr>
<tr>
<td>Recycled HDPE Plastic Lumber vs. Wood/Composites</td>
<td>30</td>
</tr>
<tr>
<td>Types of Recycled HDPE Plastic Lumber</td>
<td>38</td>
</tr>
<tr>
<td>Green Building Programs and Testing Standards</td>
<td>57</td>
</tr>
<tr>
<td>Case Studies</td>
<td>61</td>
</tr>
<tr>
<td>Summary</td>
<td>68</td>
</tr>
</tbody>
</table>
Plastic Lumber Overview
What Is Recycled Plastic Lumber?

Recycled plastic lumber is defined as formed plastic supplied in traditional dimensional lumber sizes and manufactured using at least 50% recycled materials.
Many types of plastic are recycled; however, not all recycled plastics are suitable for plastic lumber. The highest quality plastic lumber utilizes #2 HDPE—high-density polyethylene.

<table>
<thead>
<tr>
<th>Recycling Number</th>
<th>Alternate Image</th>
<th>Abbreviation</th>
<th>Polymer Name</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PETE</td>
<td>PETE or PET</td>
<td>Polyethylene terephthalate</td>
<td>Polyester fibers, thermoformed sheet, strapping, and soft drink bottles</td>
</tr>
<tr>
<td>2</td>
<td>HDPE</td>
<td>HDPE</td>
<td>High-density polyethylene</td>
<td>Bottles, grocery bags, milk jugs, recycling bins, agricultural pipe, base cups, car stops, playground equipment, and plastic lumber</td>
</tr>
<tr>
<td>3</td>
<td>PVC</td>
<td>PVC or V</td>
<td>Polyvinyl chloride</td>
<td>Pipe, fencing, shower curtains, lawn chairs, and non-food bottles</td>
</tr>
<tr>
<td>4</td>
<td>LDPE</td>
<td>LDPE</td>
<td>Low-density polyethylene</td>
<td>Plastic bags, six-pack rings, various containers, dispensing bottles, wash bottles, tubing, and various molded laboratory equipment</td>
</tr>
<tr>
<td>5</td>
<td>PP</td>
<td>PP</td>
<td>Polypropylene</td>
<td>Auto parts, industrial fibers, food containers, and dishwasher</td>
</tr>
<tr>
<td>6</td>
<td>PS</td>
<td>PS</td>
<td>Polystyrene</td>
<td>Desk accessories, cafeteria trays, plastic utensils, toys, video cassettes and cases, clamshell containers, packaging peanuts, and insulation board and other</td>
</tr>
<tr>
<td>7</td>
<td>OTHER</td>
<td>OTHER or O</td>
<td>Other plastics, including acrylic, acrylonitrile butadiene styrene, fiberglass, nylon, polycarbonate, and polylactic acid</td>
<td>Bottles, plastic lumber applications, headlight lenses, and safety shields/glasses</td>
</tr>
</tbody>
</table>
Thermoplastics Triangle

The two categories of thermoplastics are semi-crystalline and amorphous. Their properties are shown to the right.

Commodity plastics are produced at high volume and low cost for the most common disposable items and durable goods, while engineered plastic properties are tailored to specific applications and are produced at low volume and higher cost.

HDPE is a semi-crystalline commodity plastic that is durable and economical.
Source Plastics: High-Density Polyethylene

High-density polyethylene (HDPE) is defined as a stiff plastic resin used extensively by the food industry to mold bottles and trays. This resin is resistant to most chemicals and absorbs almost no moisture, making it an excellent building material.

HDPE is more rigid and harder than LDPE, with a tensile strength four times that of LDPE. Its compressive strength is three times that of LDPE.

It is commonly found in: milk jugs and juice bottles; butter and yogurt tubs; shampoo bottles; industrial containers; agricultural (water) tanks; and motor oil bottles.

Source a manufacturer who does not knowingly use recycled HDPE that has come in contact with petroleum or agricultural/industrial chemicals.
Low-density polyethylene (LDPE) is a widely used plastic, especially in the manufacturing of various containers, dispensing bottles, wash bottles, and tubing. It is translucent to opaque, robust enough to be virtually unbreakable, and at the same time, quite flexible.

LDPE is a tough material that is weldable and machinable. It has very good chemical resistance, good clarity and excellent electrical/chemical use in low heat.

It is commonly found in: flexible bottles; milk jug caps; bread, frozen food, shopping and clothing bags; some carpeting; and chemical containers. It is not often recycled through curbside programs, but some do accept it.

Plastic lumber manufacturers do not intentionally procure LDPE material but may accommodate what LDPE is acquired.
Source Plastics: Specific Weight

It is difficult to separate recycled HDPE from recycled LDPE because of their specific weights.

Water, by definition, has a specific weight of 1.0 g/cc. When immersed in water, more dense plastics will sink (red in chart) and less dense plastics float (blue in chart). Because HDPE and LDPE have very similar specific weights, and both float, they are not easily separated, which is why most manufacturers will use what little LDPE they have acquired.

Note that the exact specific weight depends on the plastic formula used, and on the additives used. Therefore, the given values in the chart are only approximated values.
Source of Recycled Plastics: Post-Industrial

Post-industrial waste is generated during the manufacturing process of upstream plastic products. This can be from virgin producers, molding plants, and many other plastic products.

Examples of post-industrial waste include milk jug scraps from manufacturing plants, plastic lumber scraps, and the plastic lumber manufacturer’s own scraps.

Post-industrial versus post-consumer content used in the manufacture of plastic lumber varies based on what the raw material availability is. Plastic for recycling is a very opportunistic buying industry.
Source of Recycled Plastics: Post-Consumer

Post-consumer waste is recovered from the consumer supply chain. Post-consumer waste is any item that served its original use and has been diverted from disposal in a landfill.

Typical examples of recycled post-consumer HDPE include milk jugs, detergent bottles, and shampoo bottles.

Most of the cost of plastic lumber is for raw materials. The more supply out there, the lower the cost. Depending on the product, significant plastic content is used.
Contamination

Post-industrial waste is considered “less green” than post-consumer waste; however, it is typically a “cleaner” plastic material to use due to less contamination and mixed content.

Post-consumer recycled plastic is often a more contaminated supply versus post-industrial waste; it is more likely to contain cardboard, aluminum, paper fiber, other plastics, etc. A plastic lumber manufacturer may landfill as much as 5 to 20% of the “purchased” recycled plastic off of the sorting line.
Composite Materials

Where are we in the composite materials world?

The term “composite” is an umbrella term in the materials and construction arena. One needs to be more specific on the type of composite being referenced. Let us start with some definitions:

• According to the Oxford Dictionary, a composite is simply defined as “made up of various parts or elements.”¹

• According to Wikipedia, composite materials are “materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components.”²

• Beams constructed of two or more different materials are referred to as composite beams.

Composite Materials

Every day we encounter composite materials, which can range from low-tech to very high-tech.

Engineered composites in the building and construction arena can be broken down into two categories:

1. Composite Building Materials
   a) Examples: concrete, cement, steel reinforced concrete, composite wood beams

2. Reinforced Plastics – which can be sub-categorized by the plastic matrix*
   a) Thermosets – once cured, they cannot be re-melted
      i. Examples: carbon-fiber car parts, steel braided car tires or hose, fiberglass boat hulls, fiberglass grating, and fiberglass rebar
   b) Reinforced thermoplastic – when heated, they become soft and formable
      ii. Examples: reinforced plastic lumber belongs to this category

*Matrix - the original plastic material without fiber reinforcement
Composite Materials

Reinforced thermoplastics can be broken down further into two categories based on the reinforcement material.

1. Organic Reinforcement or Natural Fiber Reinforced
   a) Wood-plastic composite (WPC) uses wood fiber/flour (including sawdust scrap) as reinforcement
      i. Low-cost material
      ii. Common “composite lumber” found in home improvement megastores
   b) Other plant-derived, cellulose-based fiber options: flax, hemp, jute, rice hulls  Organic reinforced plastic lumber faces the challenge of encapsulating and protecting the organic material from deterioration due to moisture and UV light.

2. Inorganic Reinforcement
   a) Fiberglass reinforcement
   b) Metal reinforcement
   c) Other inorganic reinforcement options: basalt, other plastics
Inorganic reinforced plastic lumber generally does not have environmental deterioration exposure issues.
Recycled HDPE Plastic Manufacturing Processes
Single stage extrusion (also called continuous extrusion) is a profile extrusion process in which the molten plastic material with additives is driven through a die. The die actually forms the molten plastic to net shape as it comes out of the extruder. Downstream equipment then supports and refines the shape of the plastic extrudate during cooling. Single stage extrusion involves a single extruder machine producing a single extrudate material. Usually, the product is extruded horizontally.

The major advantage of this process is the economical cost for high volume production runs. Also, any length of the profile can be manufactured.
Multiple stage extrusion, also known as co-extrusion, involves two or more extruder machines, each producing one extrudate material. The multiple materials are channeled through a single die. This usually produces a skin of material on the product surface, which is different from the material at the core of the final product.
The molded (or hard tool) process is similar to injection molding. The molten plastic material with additives is forced, under pressure, through channel runners and gates into a mold. The resin cools in the mold until it is solid. Larger molds take hours to cool, so the molds are disconnected and rotated around to the extruder between the fill, cool, and part removal steps.

The major advantage of this process is that some lower value material may be used, yet it can produce higher product strengths. The process is economical at low order quantities, down to one.
Custom Molded Plastic Lumber

The molded process can produce plastic parts of thick rectangular cross-section (linear). Here, mold length determines the maximum length of product that can be made. The molding process can also produce thick, non-rectangular (custom) parts when coupled to molds similar to typical injection molds. Thick wall parts mean a heavier weight, which makes them more stable and easier to fasten and connect to.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Injection Molding</th>
<th>Rotational Molding</th>
<th>Vacuum Forming</th>
<th>Custom Molded (Hard Tool Process)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Wall Thickness</td>
<td>Thin Only</td>
<td>Thin to Medium</td>
<td>Thin Only</td>
<td>Medium to Thick</td>
</tr>
<tr>
<td>Production Speed</td>
<td>Fast</td>
<td>Slow</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Tooling Cost</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low to Medium</td>
</tr>
<tr>
<td>Large Parts</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Recycled Plastic as Source Material</td>
<td>Limited</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Semi-Crystalline Plastic Friendly</td>
<td>Yes</td>
<td>Yes</td>
<td>Limited</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Custom Molded Process/Product Comparisons

**Injection Molding**
This is one of the prime processes for producing plastic articles. It is a fast process and is used to produce a large number of identical items. High pressures in the mold require precision tooling. The product is designed with thin walls for fast processing. A very large injection molded part would weight 12 lbs.

**Rotational Molding (Rotomolding or Rotamolding)**
Hollow plastic bodies are formed by resin powder (instead of pellets) plastic material in heated molds. The molds are rotated simultaneously in two planes perpendicular to each other. Operational pressures in the mold are low, offering lower cost tooling. Common products are containers, tanks, and big and small toys.

**Vacuum Forming (Thermoforming)**
The typical process involves heating a plastic sheet until soft and then draping it over a mold. A vacuum is applied, sucking the sheet to the mold. This process commonly utilizes amorphous type plastic material for its easy formability characteristic. Chemically resistant semi-crystalline plastic can be utilized, but with more constraints on product design and/or mold temperature control.
## Molded vs. Extruded HDPE Plastic Lumber

<table>
<thead>
<tr>
<th></th>
<th>Molded</th>
<th>Single/Multiple Stage Extrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recycled HDPE Plastic Lumber, Structural Recycled HDPE Plastic Lumber,</td>
<td>Recycled HDPE Plastic Lumber, Structural Recycled HDPE Plastic Lumber,</td>
</tr>
<tr>
<td></td>
<td>Reinforced Structural Recycled HDPE Plastic Lumber</td>
<td>Multiple Stage Reinforced Structural Recycled HDPE Plastic</td>
</tr>
<tr>
<td></td>
<td>Most structural use</td>
<td>Limited structural applications (single stage only)</td>
</tr>
<tr>
<td></td>
<td>Medium and large profiles</td>
<td>Small and medium profiles (single stage only)</td>
</tr>
<tr>
<td></td>
<td>Medium rough texture</td>
<td>Smooth finish</td>
</tr>
<tr>
<td></td>
<td>Maximum length – depends on profile</td>
<td>No maximum length limit</td>
</tr>
<tr>
<td></td>
<td>Any order size</td>
<td>Minimum order quantity specific to manufacturer</td>
</tr>
<tr>
<td></td>
<td>Inconsistent end cut appearance</td>
<td>Consistent end cut appearance</td>
</tr>
<tr>
<td></td>
<td>Some contamination</td>
<td>More pure material</td>
</tr>
</tbody>
</table>
Appearance: Texture

Texture is the roughness of a surface. More texture hides imperfections and gives more mechanical grip. This mechanical grip provides good traction for walking, but it is not desirable if trying to slide something. Rougher textures are not desired in marine constant water contact surfaces.

Molded lumber has more texture, while extruded lumber has a smoother finish.

The image on the upper right shows a wood grain embossed lumber look that is very common for use on walking surfaces or finished surfaces.

The image to the bottom right depicts a knurled texture that can be used when additional surface grip is needed in an application.
Appearance: Color

Color is the visual perceptual property in humans corresponding to the categories called red, green, blue, and others.

Unlike length or weight, there is no physical scale for measuring color. Specifications of color are associated with light source, light absorption, reflection, texture, background difference, directional difference, observer difference, and even size difference.

Colorimeters or spectrophotometers numerically assign values to three or four of these aspects. These devices only look at a tiny sample surface.

The best way to color match is by shipping an actual color sample to the client and viewing in natural outdoor sunlight. HDPE plastic lumber is available in a wide variety of colors, as seen in the samples to the left.
Appearance: End Cut

As shown on the upper right, extruded HDPE plastic lumber products have a consistent end cut appearance. The density does not vary based on the board segment position as it does with molded HDPE plastic lumber.

To the bottom right, the molded HDPE plastic board, when cut into four pieces on the blue lines, will yield eight cut surfaces. Two of the cut surfaces appear as solid plastic while six other cut surfaces have the foamed core exposed.
Recycled HDPE Plastic Lumber vs. Wood/Composites
Plastic vs. Wood: Traits

Recycled HDPE plastic lumber:

- loses stiffness as the temperature rises; the temperature of a board in sunlight will be much greater than the air temperature.
- expands in all directions as the temperature rises; it expands the most in length in its longest direction.
- contracts in all directions as the temperature cools; it shrinks the most in length in its longest direction.
- creeps over time. Creep is defined as the deformation of a product, due to the weight of the board plus any load placed upon it, for an extended length of time. This is more often than not the sizing factor of a board in a dead load application. Recycled HDPE plastic lumber, when loaded properly within the design limits, will deform slightly at the onset and minimally thereafter.

All materials (including wood) have these traits, but not nearly as predominantly as with plastic lumber.
Plastic vs. Wood: Decking Orientation

Because plastic lumber expands and contracts the most distance along its length, its preferred decking orientation is to have the decking boards run the shortest length across a platform. This minimizes the expansion/contraction concern.

This is not required, and can be abated by a proper board gapping and fastening system.
Deflection is the degree to which a structural element is displaced under a load. Flexural modulus is the slope as determined by stress over strain in the elastic region of the force vs. deflection curve. Flexure testing gives us an idea of how resistant the material is against deflection. From this modulus, you can calculate and predict the deflection of a known shape and orientation.

The flexibility of plastic lumber increases as the temperature rises. Therefore, a temperature correction factor is used to correct the standard beam deflection formula. Deflection decreases for temperatures below 68°F and increases above 68°F.

Customers cannot always use plastic lumber for a structure designed for wood components. Plain recycled HDPE plastic lumber is not recommended for structural applications; however, there is structural HDPE plastic lumber available that may be suitable for these projects.
Plastic vs. Wood: Energy Absorption and Strength

The energy absorption and strength for recycled HDPE plastic lumber, structural recycled HDPE plastic lumber, and reinforced structural recycled HDPE plastic lumber is significantly greater than wood.
Plastic vs. Wood: Cost Comparison

Recycled HDPE plastic lumber lifetime costs are much lower due to the low maintenance costs relative to wood. There are cost savings over the life of the product due to no rotting, chipping, splintering, and no painting or sealing, and it is recyclable at the end of its useful life. Comparisons with timber structures show the break-even point is around six years.
Plastic vs. Wood: Indoor / Outdoor

Relative to outdoor use, recycled HDPE plastic lumber has several key advantages over wood. Plastic lumber is moisture resistant, does not require painting, is UV light resistant, and is impervious to insects. The rough cut look and appearance is also better suited to the outdoors. Plastic lumber has a higher purchase price (initial cost) than wood, but lasts longer than wood in outdoor environments.

Indoor fit and finish standards are higher than those of outdoor standards. Indoor wood building material can be planed down to near perfectly flat, whereas plastic lumber surfaces could be 1/10\textsuperscript{th} as flat as wood. It is not possible to plane down plastic lumber and make the surface look appealing. In addition, freshly cut plastic lumber emits an odor that may not be pleasant indoors; when used outdoors, the odor disperses much faster.

In terms of building codes and flame spread ratings, structural recycled HDPE plastic lumber performs better than non-structural plastic lumber.
Plastic vs. Wood/Plastic Composites

Plastic lumber made from recycled polyethylene, reinforced with chopped glass fiber or GRP (glass reinforced plastic) rebar, does not rot, split, or chip. It is also ideal for long-term immersion in water.

Wood/plastic composites (WPCs) are wood in a plastic matrix. They overcome some disadvantages of natural wood, but composites will still decay and rot over time, particularly when damp. Newer composite products include an extra layer of plastic on top to try to better encapsulate the wood from the environment. However, when you cut the board to length, the cut surface exposes those wood particle fibers to the environment.

<table>
<thead>
<tr>
<th></th>
<th>Wood</th>
<th>Composite (WPC)</th>
<th>Recycled HDPE Plastic Lumber</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-year warranty (depending on the manufacturer)</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Insect and borer resistant</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Rot and decay resistant</td>
<td>✓*</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Load bearing and structural</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Non-splintering</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Low friction</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Maintenance free</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Color stability</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Non-leaching/toxin-free</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Recycled feedstock</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Recyclable</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Long-term aesthetics</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

*Chemical treatments required
Types of Recycled HDPE Plastic Lumber
Recycled HDPE Plastic Lumber

Composition
Recycled HDPE plastic lumber utilizes high-quality HDPE to create a long-lasting product. Recycled HDPE plastic lumber is available in a wide variety of colors with color consistency throughout the cross-section. The addition of ultraviolet stabilizers provides resistance to color fading in outdoor applications.

It can be manufactured by either process mentioned earlier, continuous extrusion or molded. Each process provides unique product characteristics to fit a wide range of applications. Recycled HDPE plastic lumber is a product that requires low maintenance, has a long life expectancy, provides flexibility in applications, and is best suited where there are low load bearing requirements.
Recycled HDPE Plastic Lumber

Sample Installation Considerations (refer to manufacturer’s guidelines)

1. **Structural Ability:** Recycled HDPE plastic lumber is not recommended for structural use; therefore, the substructure must be constructed of another structural grade material. Due to its increased flexibility (as compared to wood), recycled HDPE plastic lumber requires more support. Refer to manufacturer’s span tables to determine support requirements based on live load and ambient temperature.

2. **Expansion/Contraction:** Recycled HDPE plastic lumber expands and contracts along its length. A 10' (3.048m) length will expand and contract up to 3/8" (1cm). Therefore, it should be run along the shortest length with the joists running the long direction. Also, lighter colors do not heat up as much in sunlight and are therefore preferable when installing in a sunny location.

3. **Fastening:** To withstand the expansion and contraction as well as to maintain a long-lasting, beautiful looking deck, stainless steel deck screws should be used. Each deck board should be fastened with at least two screws per joist, at least 3/4" (2cm) from the edge or end of the board. Screws must be pre-drilled and should be counter-sunk.
Recycled HDPE Plastic Lumber

Coating the screws with a lubricant, such as a silicone caulk, or soap will ease installation. The best fastening solution allows for thermal expansion/contraction.

4. **Butt Joints:** When butting recycled HDPE plastic lumber against any wall, fixed surface, or other boards (if necessary), they should be securely fastened to the nailer or double joist with a gap allowing for expansion. The size of gap should be determined based on weather conditions at the time of installation—the closer the temperature is to the usual high temperature for the year, the smaller the gap. The project should be designed to minimize the butt joints. However, in the event that joints are required, a double joist underneath the butt joint should be used. Boards should be securely fastened with a row of screws on each side of the joint 3/4" (2cm) from end of the board. Always keep deck boards out 3/8" (1cm) from permanent structure.

5. **Rip Cutting:** Rip cutting is not recommended on any plastic lumber. In the event that rip cutting is needed, please refer to the manufacturer’s guidelines.
Recycled HDPE Plastic Lumber

Features and Applications

Performance features of recycled HDPE plastic lumber include:

- Low maintenance
- Long life expectancy
- Various lengths
- No rotting
- No splintering
- No painting or staining
- Cuts, drills, and secures just like wood

- Available in multiple profiles
- Available in a variety of colors
- Textured surfaces
- Continuous piece construction
- Environmentally friendly
- Resistant to marine borers, termites, fungus, salt, and oils

Recycled HDPE plastic lumber has been used for many unique applications. Some of the more common uses have been benches, outdoor furniture, decking, docks, boardwalks, parking curbs, trim work, signs, and playground equipment.
Recycled HDPE Plastic Lumber
Composition

Structural recycled HDPE plastic lumber is a high-performance structural product manufactured from high-quality HDPE, ultraviolet stabilizers, colorants, and fiberglass strands to increase rigidity. This added rigidity creates characteristics suited for many structural applications where a wider span, dimensional stability, increased flexural strength, or higher rigidity is required. Due to the increased strength and its resistance to environmental elements, structural recycled HDPE plastic lumber is well suited for exterior applications where structural support or load bearing is required. It is manufactured in many different profiles and lengths.
Structural Recycled HDPE Plastic Lumber

Sample Installation Considerations (refer to manufacturer’s guidelines)

1. **Structural Ability**: Structural recycled HDPE plastic lumber is recommended for structural use, but care needs to be used in the design of the structure. In most cases, the deflection will control the needed size of boards. Refer to the manufacturer’s span tables to determine support requirements based on live load and ambient temperature.

2. **Expansion/Contraction**: Structural recycled HDPE plastic lumber expands and contracts along its length based on temperature. A calculation of change in length in inches can be done by using the formula supplied by the manufacturer. This expansion and contraction on short lengths is minimal, but if you are using longer lengths, and are in a climate with large temperature change, you need to take into account the expansion/contraction of the board in the design.

3. **Fastening**: Same as for recycled HDPE plastic lumber.
4. **Butt Joints**: Same as for recycled HDPE plastic lumber.
5. **Rip Cutting**: Same as for recycled HDPE plastic lumber.
Structural Recycled HDPE Plastic Lumber

Features and Applications

Performance features of recycled HDPE plastic lumber include:

- Low maintenance
- Long life expectancy
- Various lengths
- No rotting
- No splintering
- No painting or staining
- Cuts, drills, and secures just like wood
- Available in multiple profiles
- Available in a variety of colors
- Textured surfaces
- Continuous piece construction
- Environmentally friendly
- Resistant to marine borers, termites, fungus, salt, and oils

Examples of applications suitable for structural recycled HDPE plastic lumber are retaining walls, fencing, decks, large equipment mats, light commercial, and many industrial, agricultural, and marine applications.
Structural Recycled HDPE Plastic Lumber
Reinforced Structural Recycled HDPE Plastic Lumber

Composition
Reinforced structural recycled HDPE plastic lumber is manufactured in a process utilizing blended glass fiber and recycled plastic HDPE, which encapsulates full-length fiberglass reinforcement rods. This process establishes uniform structure and composition throughout the product. In addition to superior rigidity and strength, it features high impact resistance, and energy absorption. It can be manufactured using the molded or extruded process and is available in various bar diameters and quantities. It is best suited for projects that require long spans, structural loading, and impact resistance.
Reinforced Structural Recycled HDPE Plastic Lumber

Sample Installation Considerations (refer to manufacturer’s guidelines)

1. **Cutting:** It is recommended to use a chain saw with a carbide tipped chain. Use a chain saw with a rated horsepower of at least 7HP and with a 20" bar length. Use a carbide tipped chain to fit a 20" bar length. Carbide tips are brittle; any contact with the ground or other objects may shatter or dull the tips. Saws and chain should be kept clean between cuts. Blowing out residue from the cut and the saw cavities helps prolong chain life.

2. **Drilling/Counter Boring:** It is recommended to drill a through hole of sufficient diameter for easy passage of the mounting hardware. If it is desired to recess the head or nut and/or washer of the hardware below the surface of the timber, a counter bore bit of sufficient diameter to make the recessed hole should be used. Most counter bore bits will require drilling a pilot hole, and the use of a counter bore bit with a pilot attached that fits the diameter of the pilot hole to guide the boring. The pilot hole can be of sufficient diameter for use with the mounting hardware. Standard high-speed steel twist drills are suitable for drilling most through holes or pilot holes for the mounting hardware. Avoid drilling through rebar if possible.
Reinforced Structural Recycled HDPE Plastic Lumber

Features and Applications

Performance features of reinforced structural recycled HDPE plastic lumber include:

- Continuous single piece construction
- Color consistency throughout entire cross-section and length
- Superior UV and abrasion resistant protection
- Textured exterior provides high-end finish
- High impact resistance and energy absorption characteristics offered in reinforced and non-reinforced products to fit application strength requirements
- Resistant to extreme marine environments, e.g., temperature variations and salt water
- Marine borer resistant
- Environmentally friendly requiring no chemical preservatives
- Standard construction tools used for installation and machining
- Standard marine colors (yellow and black) and custom colors available

Reinforced structural recycled HDPE plastic lumber is suitable for retaining walls, pedestrian bridges, guide walls, marine fenders, wales and piles, etc.
Reinforced Structural Recycled HDPE Plastic Lumber
Multiple Stage Reinforced Structural Recycled HDPE Plastic Lumber

Features and Applications

Performance features of multiple stage reinforced structural recycled HDPE plastic lumber include:

• Low life cycle cost
• Will not rot, corrode, or decay
• Unaffected by marine borers
• Choice of flexural modulus to suit different applications
• Can be pile driven, sawn, and drilled
• Low friction coefficient
• Ultra-low maintenance
• Custom colors available
• Unlimited lengths (depending on manufacturer)

Multiple stage reinforced structural recycled HDPE plastic lumber is suitable for many marine applications such as fender piles and systems, structural piles, bridge protection, guide walls and locks, corner fenders, dolphins, navigation markers, walings, and bullrails.
Dolphins, or groups of piles, are placed near piers and wharves to guide vessels into their moorings, to fend them away from structures, or to serve as mooring points. Compared with timber, considerably fewer piles are needed to absorb the same impact energy.

Piles are used extensively as vertical fenders set out in front of a marine structure. During the berthing of a ship, fender piles act as a buffer to absorb and dissipate the impact energy of the ship. They also provide a barrier to prevent vessels from going underneath the pier.

Piles are used to support the loads of light-duty piers and wharves. Structural piling generally uses bracing between piles to increase the strength and stiffness of the foundation for the structure.
Single piles and dolphins are used to support lights, day beacons, fog signals, and radar beacons.

Piles and dolphins are widely used to create protective structures for bridge piers, and to guide vessels into the channel and away from bridge supports. Three-pile clusters are used in impact zones, single piles in less vulnerable areas.
Multiple Stage Reinforced Structural Recycled HDPE Plastic Lumber
Multiple stage reinforced structural recycled HDPE plastic lumber piles and timbers have good energy absorption characteristics through system deflection at a given load, having the ability to bounce back from repeated impacts, when compared to wood, concrete, and steel. When tested to ultimate load, multiple stage reinforced structural recycled HDPE plastic lumber piles and timbers absorb 15 times the energy of southern yellow pine. This means less damage, maintenance, and downtime, leading to a lower lifecycle cost.
Green Building Programs and Testing Standards
The standard criteria of “green” building products specify the use of materials that are durable, made by a resource efficient manufacturing process, have an identifiable recycled content, are recyclable themselves, and have low to no negative impact on environmental quality.

LEED rating systems are groups of requirements for projects that want to achieve LEED certification. Within each of the LEED credit categories, projects must satisfy prerequisites and earn points. The number of points the project earns determines its level of LEED certification.

LEED credit requirements cover the performance of materials in aggregate, not the performance of individual products or brands. Therefore, products that meet the LEED performance criteria can only contribute toward earning points needed for LEED certification; they cannot earn points individually toward LEED certification.

Recycled HDPE plastic lumber can contribute to points earned on a project in several categories of LEED v4.
The Living Building Challenge™ is currently the most stringent sustainable design protocol. The protocol sets 20 imperatives which compel building owners, designers, operators, and tenants beyond the current USGBC LEED rating levels. To be certified under the Challenge, projects must meet a series of ambitious performance requirements (imperatives) categorized under seven “Petals”: Site; Water; Energy; Health; Materials; Equity; and Beauty.

Recycled HDPE plastic lumber products fall under the “materials” petal.

Source a plastic lumber manufacturer who can provide proof of a Living Building Challenge Certificate.
ASTM Testing

ASTM tests applicable to recycled HDPE plastic lumber include:

- ASTM D6111 Standard Test Method for Bulk Density and Specific Gravity of Plastic Lumber and Shapes by Displacement
- ASTM D6341 Standard Test Method for Determination of the Linear Coefficient of Thermal Expansion of Plastic Lumber and Plastic Lumber Shapes Between –30 and 140°F (–34.4 and 60°C)
- ASTM D6117 Standard Test Methods for Mechanical Fasteners in Plastic Lumber and Shapes
- ASTM D6662 Standard Specification for Polyolefin-Based Plastic Lumber Decking Boards
Case Studies
Manjack Trace Pedestrian Walkway, South America

**Project Objective:** Design, fabricate, and install a single-span pedestrian walkway to replace an old wooden one. The desire was to utilize a green material, such as a recycled product, for the structure.

Popular composite materials containing cellulose components were not considered, due to their poor performance in tropical climates. In addition, it is widely known that most composites do not perform well in structural applications. Therefore, a structural-grade HDPE product was utilized.

Because of the length of the span, it was determined that a truss design was best suited to serve as the primary spanning members, while providing the structural capacity with the least amount of deflection. The walkway is in a residential area, serving as a heavily used access point for residents to cross over a storm channel.

**Scope:** 85-PSF Pedestrian Walkway, 5' Overall Width (4'-4" Clear Width) x 38' long.

**Site Conditions:** The walkway is to span over a concrete-lined storm channel 15' deep.

**Design:** Single-span, truss design.

**Material:** Recycled plastic (HDPE), structural grade.

**Abutments:** Concrete, designed by client’s engineer, constructed by client’s contractor, were to be built immediately adjacent to the outside of the channel sidewalls.
The project was upgraded to two walkways, so the trusses were fabricated and loaded into shipping containers, along with joists and decking, for shipment to South America.

Working with recycled plastic is very similar to working with wood; however, it weighs somewhat more than wood, and that should be taken into consideration during the design and building phases.
Once the materials arrived, they were unloaded and set up on a flat surface. The joists were attached to help bind the trusses together. Wood blocking was added to stabilize the structure en route to the job site.

The walkway assembly was set on the awaiting abutments and secured with anchor bolts. The decking and additional rails were installed and additional material was added in the field to allow the concrete path to abut directly to the structure.
Santa Cruz Harbor, CA

**Challenge**: On Friday March 11, 2011, a magnitude 8.9 earthquake struck Japan; five hours later, the earthquake’s effects were felt on the West Coast of the United States.

Santa Cruz Harbor, shown here, was dramatically affected by the surge of the tsunami. Starting at about 7:45 a.m., the tsunami-related surge entered the harbor and severely damaged several docks and dozens of boats. The harbor is just south of the Santa Cruz Boardwalk and is marked by the Santa Cruz Breakwater Lighthouse. The damage estimate to the harbor alone, according to city officials, was over $2 million.
Santa Cruz Harbor, CA

**Solution:** Redesign and rebuild the 6,300 square feet of docks and finger piers using structural recycled HDPE plastic lumber. Given the experience that the Harbor had with the tsunami, the focus was on building a very tough, long-lasting system that could withstand a 2' wave. Designed by Ashton Engineering and constructed by the team at Bellingham Marine, the new docks at Santa Cruz are supported by floats, similar to a traditional timber dock system. Installation of the new docks was started the last week of July and completed August 16, 2011. The structural recycled HDPE plastic lumber product used came with a 50-year limited warranty made from recycled plastic material. This is an HDPE product that is inert in the environment and can withstand years of heavy-duty use and wave action.
Port Aransas, TX

Multiple stage reinforced structural recycled HDPE plastic lumber is loaded via railcar and shipped to Port Aransas, Texas. These plastic lumber piles will be joined together into dolphin clusters used to guide ferry barge traffic between the Port Aransas terminals. Both plastic lumber piles and timbers are used throughout marine applications worldwide as bridge protection fenders, dolphin clusters, guide walls, wales, navigation markers, bullrails, and various other applications. Multiple stage reinforced structural recycled HDPE plastic lumber is manufactured using recycled plastic put through a multiple extrusion process and has superior energy absorption characteristics.
Summary
Recycled HDPE plastic lumber products are available in a wide variety of sizes, shapes and colors, from standard lumber sizes to custom shapes.

The single stage extrusion process allows for flexibility in shapes and long lengths with a smooth surface appearance and feel, which is ideal for OEM (original equipment manufacturer) applications requiring long lengths and unique profiles.

The molded process produces a product with a textured look and feel, which is ideal for standard lengths and manufacturing specialty profiles for many different project applications.

Recycled HDPE plastic lumber products have a very long life that virtually eliminates maintenance and replacement costs, outperforming wood and wood/plastic composites. Selecting recycled HDPE plastic lumber will ensure you have the highest quality end product on the market.
Conclusion

©2014, 2015 Bedford Technology®, LLC. The material contained in this course was researched, assembled, and produced by Bedford Technology®, LLC. and remains its property. Questions or concerns about the content of this course should be directed to the program instructor.

For additional knowledge and post-seminar assistance, click on the Ask an Expert link below.

Questions?

Ask an Expert – sales@bedfordtech.com