**Bedford Technology® LLC Design Guide**
**Recycled Plastic Lumber (RPL) and Structural Grade Recycled Plastic Lumber (SGRPL)**

## Background

Due to the unique characteristics of recycled plastic lumber, this design guide has been written, in "layman's" terms to assist the designer or builder when choosing these alternative building materials, and to promote the safe and practical use of plastic lumber.

## Terminology

- Recycled Plastic Lumber (RPL) – Recycled plastic lumber is defined as molded plastic supplied in traditional dimensional lumber sizes and manufactured using at least 50% recycled materials. It should be noted that Bedford Plastic Lumber contains between 90-95% recycled materials.

- High Density Polyethylene – (HDPE) – 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. Bedford Recycled Plastic Lumber is manufactured using recycled HDPE, which is widely available.

- Structural Grade Plastic Lumber (SGPL) – Structural Grade Plastic Lumber is primarily standard recycled plastic lumber, with fiberglass strands and rebar rods added to increase structural strength. It should be noted along with increased strength, added benefits of (SGPL) are reduced creep deformation and reduced expansion and contraction due to temperatures changes.

- Bedford Select™ plastic lumber – Select™ plastic lumber contains between 90-95% recycled HDPE as the base material. Ultraviolet ray (UV) inhibitors, foaming agents and colorants are added to enhance and protect the finished product.

- Bedford FiberForce® plastic lumber – FiberForce® plastic lumber is the same composition as Select™ lumber with fiberglass strands added to strengthen the product.

- Bedford BarForce® plastic lumber – BarForce® plastic lumber is the same composition as Select™ lumber with fiberglass strands added, plus fiberglass reinforced polymer rebars (FRP) added to further strengthen the product.

- Creep – 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. Recycled plastic lumber, when loaded properly within the design limits, will deform slightly at the onset and minimally thereafter. For a creep comparison between Bedford Select™, FiberForce® and BarForce® materials **(See Figure #2).** Note the creep deformation is drastically reduced in Bedford FiberForce® and BarForce® products. Also creep increases as temperature increases, see temperature correction factor **(Table 1)**.

- Υ Modifications to modulus of elasticity E to account for long term (10 yr) creep are defined in (**Table 2)**

## CALCULATIONS

- **Expansion & Contraction due to temperature changes** - Plastics in general expand and contract dramatically due to changes in temperature, therefore these design considerations must be taken into account when building with recycled plastic lumber. For example the coefficient of thermal expansion of Bedford FiberForce® Recycled Plastic Lumber is 0.00003 Inch/Inch/Degree F. The expansion can be calculated as follows:

Thermal Expansion = Board length (in) x 0.00003 x Temperature change in degrees Fahrenheit (F)

**Example:** A 10 ft long "FiberForce®" plastic board will change length from, 10 degrees F to 70 degrees F by how much? (That's a 60 degree F temperature change) (10 ft = 120 inches)

**Answer:** Thermal expansion calculation = 120 inch X 0.00003 x 60 F = 0.20 inch

Co-efficient of Thermal Expansion for Bedford Select™ Lumber = 0.000055 inch/inch/degree F

Co-efficient of Thermal Expansion for Bedford FiberForce® & BarForce® Lumber = 0.00003 inch/inch/degree F

- **Moisture Absorption** – Moisture absorption of Bedford Select™ lumber is 0.06% by weight Bedford plastic lumber absorbs very minimal amounts of moisture.

**Example:**
How much moisture will a 2 x 4 x 10 ft Bedford Select™ plastic lumber absorb when immersed in water for an extended period of time? (First convert 0.06% to decimal = 0.0006)

**Answer:** The 2 x 4 x 10 ft long board weighs approximately 20 lbs. 20 lb x 0.0006 = 0.012 lb

- Dead load - Dead load is defined as a load permanently applied to a structure.

- Live load – Live load is defined as a load temporarily applied to a structure, examples include; snow load, wind load, rain, objects and people.

- **Flexibility of Plastic Lumber due to temperature changes** – The flexibility of plastic lumber increases as the temperature rises therefore a temperature correction factor ($C_t$) **(See Table 1)** is included to correct the standard beam deflection formula. Deflection = $5WL^4/384\ E\ I\ (C_t)$.
- Testing to determine $C_t$ was conducted at 74 F, therefore $C_t$ at 74 F = 1.00. Note deflection decreases for temperatures below 74 F and increases above 74 F.

**Example:** Deflection changes due to temperature:

Assume a 2 x 6 FiberForce® board 60" long, supported at both ends, is loaded at 1.3 lbs/inch. Note the board weight must be added to the loading. A (2 x 6) weighs 0.292 lb/in, therefore the load W = 0.292 + 1.3 = 1.592 lb/in

Board is placed in "joist" mode with the 2" dimension horizontal.

What would the deflection, at the board midpoint, be at both 90 F and 74 F? Temperature

correction factor $C_t$, From (**Table 1**), $C_t$ = 1.00 @ 74 F, Ct = 0.82 @ 90 F Calculate

deflection at both temperatures using the following formula:

Deflection = $5WL^4/384$ E I ($C_t$)

Where;
L = 60" (board length)

I (2x6) (polar moment of inertia), calculated from I = $bh^3/12$ = 19.7 $in^4$ b = 1.5" (base), h = 5.4"(height)

E = 306500 psi (modulus for the material, in this case FiberForce®)(note this modulus hasn't been corrected for creep)

**Answer:**
The calculated deflections are, deflection = 0.045" at 74 F, and deflection = 0.054" at 90 F

Therefore the plastic lumber board will deflect more at higher temperatures.

- **Beam deformation "deflection" due to long term loading & temperature**

**Example:** Using the same example above, what would the deflection, at the board midpoint, be after 10 yrs?

Assume a 2 x 6 FiberForce® board 60" long, supported at both ends, is loaded at 1.3 lbs/inch. Note the board weight must be added to the loading. A (2 x 6) weighs 0.292 lb/in, therefore the load W = 0.292 + 1.3 = 1.592 lb/in (Note: Board "weight" is found in **Table 3**) Board is

placed in "joist" mode with the 2" nominal dimension horizontal. What would

the deflection, at the board midpoint, be at 90 F?

Temperature correction factor $C_t$, From (Table 1), $C_t$ = 0.82

Calculate deflection using the following formula: Deflection =

$5WL^4/384$ E I ($C_t$)

Where;
L = 60" (board length)

I (2x6) (polar moment of inertia), calculated from I = $bh^3/12$ = 19.7 $in^4$ b = 1.5" (base), h = 5.4"(height)

E = 101,000 psi **(See Table 2)** (Modified modulus for FiberForce® beam loaded for 10 yrs)

**Answer:**
The calculated deflection, deflection = 0.165"
Therefore the plastic lumber board deflects more over a longer period of time.

Finally the "L/360 deflection for long term creep" is checked. Where L = board length. Therefore

Deflection maximum allowable = L/360 = 60"/360 = 0.17"

In the above example the long term creep = 0.165" < 0.17", so the design works.

### Table (1) Temperature Correction Factors

| Temperature (F) | Temperature (C) | Temperature Correction Factor ($C_t$) |
|---|---|---|
| 14 | -10 | 1.64 |
| 32 | 0 | 1.42 |
| 59 | 15 | 1.13 |
| 74 | 23 | 1.00 |
| 90 | 32 | 0.82 |
| 122 | 50 | 0.48 |

### Table (2) Modified Modulus (E)

| Time (yrs) | Time (months) | FiberFoce® Correction factor | Fiberforce® Modified Modulus (E) | BarForce® Correction Factor |
|---|---|---|---|---|
| 0.00 | 0 | | 306,500 | |
| 0.01 | .12 | 0.70 | 214,706 | 0.82 |
| 0.02 | .24 | 0.66 | 203,117 | 0.79 |
| 0.03 | .36 | 0.65 | 198,603 | 0.79 |
| 0.04 | .48 | 0.63 | 192,715 | 0.78 |
| 0.05 | .60 | 0.61 | 186,191 | 0.78 |
| 0.07 | .84 | 0.60 | 182,857 | 0.78 |
| 0.08 | .96 | 0.59 | 179,641 | 0.77 |
| 0.09 | 1.08 | 0.57 | 176,101 | 0.78 |
| 0.12 | 1.44 | 0.55 | 169,425 | 0.77 |
| 0.18 | 2.16 | 0.54 | 166,272 | 0.76 |
| 0.25 | 3.0 | 0.53 | 161,030 | 0.75 |
| 0.27 | 3.24 | 0.52 | 160,308 | 0.75 |
| 0.33 | 4 | 0.51 | 157,483 | 0.75 |
| 1.90 | 23 | 0.42 | 130000 | 0.71 |
| 10.00 | 120 | 0.33 | 101000 | 0.67 |

## Table (3) Weight Pounds per Inch

| **Weight in pounds per in (lb/in)** | | | | |
|---|---|---|---|---|
| Size | Select™ | FiberForce® | BarForce® | No. Of Bars |
| 2 x 4 | 0.167 | 0.183 | N/A | 0 |
| 2 x 6 | 0.267 | 0.292 | N/A | 0 |
| 2 x 8 | 0.325 | 0.350 | N/A | 0 |
| 2 x 10 | 0.417 | 0.450 | N/A | 0 |
| 2 x 12 | 0.50 | 0.542 | N/A | 0 |
| 3 x 4 | 0.258 | 0.283 | N/A | 0 |
| 3 x 6 | 0.392 | 0.425 | N/A | 0 |
| 3 x 8 | 0.542 | 0.583 | N/A | 0 |
| 3 x 10 | 0.675 | 0.742 | 0.833 | 2 |
| 3 x 12 | 0.833 | 0.90 | 1.00 | 2 |
| 4 x 4 | 0.367 | 0.40 | N/A | 0 |
| 4 x 4 TR | 0.425 | 0.492 | N/A | 0 |
| 4 x 6 | 0.558 | 0.60 | N/A | 0 |
| 4 x 8 | 0.758 | 0.817 | N/A | 0 |
| 4 x 12 | 1.15 | 1.25 | 1.375 | 2 |
| 5 x 5 | 0.583 | 0.633 | N/A | 0 |
| 6 x 6 | 0.808 | 0.958 | N/A | 0 |
| 6 x 8 | 1.20 | 1.333 | N/A | 0 |
| 6 x 12 | 1.792 | 2.083 | N/A | 0 |
| 8 x 8 | 1.625 | 1.833 | 2.00 | 4 |
| 8 x 10 | 2.058 | 2.333 | N/A | 0 |
| 8 x 12 | 2.417 | 2.75 | 3.00 | 4 |
| 10 x 10 | 2.75 | 3.333 | 3.50 | 4 |
| 10 x 12 | N/A | 4.00 | N/A | 0 |
| 12 x 12 | 3.833 | 4.667 | 5.00 | 4 |
| 12 x 16 | N/A | 6.417 | N/A | 0 |
| 10 RND | 2.183 | 2.358 | 2.667 | 6 |

**Figure (2) Creep Comparison Chart**