DEMONSTRATION INSTALLATIONS OF RECYCLED-PLASTIC LUMBER FOR BRIDGES, MARINE PILINGS, AND RAILROAD TIES

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Abstract

Over the last ten years, recycled-plastic lumber (RPL) and related recycled plastic products have been used in various projects that demonstrate their structural capabilities and versatility in different construction applications. Projects of significance include an all-plastic recreational pier, a RPL bridge designed to carry light vehicles, and large staging platforms at a ski run. RPL materials are not limited to common dimensional lumber sizes but can be fabricated as marine pilings and railroad crossties. Use of RPL and related products in demonstration constructions is helping to develop a performance history for these materials. This process will, in turn, help further the general acceptance and use of these materials by the construction industry.

Introduction

The plastic lumber industry in the United States has its origins in the mid-1980's by making use of post-consumer plastics that would otherwise be destined to a landfill [Ref. 1]. While fabricated in typical dimensional lumber sizes, recycled-plastic lumber (RPL) has some mechanical properties much different than the wood materials they are to replace [Ref. 2]. For example, typical RPL materials have an elastic modulus (stiffness) at least an order of magnitude less than natural woods. In recent years, advances in technology and processing have enabled the manufacture of "structural- grade" RPL with a modulus of two to three times that of "standard-grade" materials [Ref. 3]. Several standard test methods have been developed by the American Society for Testing and Materials[1] (ASTM) to characterize the mechanical properties of plastic lumber [Ref. 4]. However, design engineers still show reluctance to specifying these new products for construction applications due to limited experience and performance history of constructed facilities made from RPL materials.

In response to this identified need, several projects were initiated to demonstrate the application of RPL in outdoor structures with a particular emphasis to incorporate RPL as structural elements besides the non-structural components of the constructed facilities. This paper

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describes some of these projects. In most instances, the projects were undertaken as cooperative ventures between government, academia, and many of the RPL manufacturers.

Recycled-Plastic Lumber Demonstrations

Tiffany Street Pier

The first all-plastic lumber civil structure of major significance was the Tiffany Street Pier located at the end of Tiffany Street in the Bronx in New York City. This roughly 125 meter (410 ft) long by 15 meter (49 ft) wide recreation pier (Figure 1) was designed by the New York City Department of General Services. The structure incorporates recycled-plastic pilings, timber joists, decking, and railings. Unfortunately, a fire significantly damaged the outer one third of the pier when lightening struck the structure less than a year after it was put into service [Ref. 5]. Repairs to the damaged portion are currently underway and the pier is expected to again be available for public use in the near future.

Plastic Lumber Bridge At Ft. Leonard Wood

While the Tiffany Street Pier showed that a large all-plastic structure could be built, the structural design of the pier was not very optimal in materials usage. An existing wood timber bridge at Ft. Leonard Wood, Missouri, was selected to demonstrate applications of “structural-grade” plastic lumber. The 7.6 meter (25 ft) long by 7.8 meter (26-1/2 ft) wide plastic lumber bridge sits on six steel girders that had supported the original wooden bridge. Although the bridge is used primarily for pedestrian traffic, the replacement plastic lumber bridge was designed to carry light vehicular traffic. Figure 2 shows a sport utility vehicle crossing the plastic lumber bridge.

M. G. McLaren Consulting Engineers, New York, designed the bridge structure using protocol developed for plastic lumber as part of the ASTM standards development for these materials. The safe capacity of the new bridge is more than 30 tons over the entire structure. Structural-grade RPL 3x12 boards, incorporating polystyrene for added stiffness, were used as the main support joists over the steel girders. The decking was also 3x12 RPL but a standard-grade material. In all, materials from four different manufacturers were used in the structure. The bridge was constructed with standard wood working power tools and hardware (e.g., fasteners).

RPL expands and contracts to a greater extent with changes in temperature than does wood or steel. Design features were, therefore, incorporated to allow the plastic lumber bridge structure to move differentially relative to the steel members and the bridge abutments during such changes in temperature. These features included slotted connections between the plastic lumber joists and the steel girder to which they were attached, to accommodate side-to-side movement, and a floating deck at the bridge abutments to accommodate end-to-end movement.

A typical treated wood bridge structure at this site would need to be replaced every 15 years with biannual inspections and maintenance to replace deteriorated boards and loose fasteners. The RPL bridge is expected to last 50 years with minimal maintenance. While the plastic lumber materials cost more than double what they would be for a replacement treated wood bridge, a lifecycle cost analysis showed the RPL bridge would begin to pay for itself in less than 8 years. An added benefit is the fact that the plastic lumber bridge used some 5,900 kg (13,000 lb) of waste plastics [equivalent to approximately 78,000 3.8-liter (one-gallon), high-density polyethylene (HDPE) milk jugs and 335,000 237-milliliter (8-oz) molded polystyrene coffee cups] that had otherwise been destined for landfills. The bridge will not require any application of protective coatings or preservatives that can emit environmentally damaging volatile organic compounds into the atmosphere.

Boardwalk and Observation Platform at Ft. Belvoir

Another opportunity to design and construct an all-plastic structure presented itself as the Army Installation at Ft. Belvoir, VA, was planning to renovate a popular wetlands area on post. Part of this restoration included the construction of a 7.3 meter (24 ft) long boardwalk leading to a 3.7 meter (12 ft) deep by 4.3 meter (14 ft) wide observation deck overlooking the wetlands area. Some major benefits of using plastic lumber are its resistance to moisture, rot, and insects. And, unlike wood, no toxic treatments, preservatives, or coatings are needed for the plastic lumber to maintain these properties. These features make plastic lumber ideal for applications in environmentally sensitive areas such as a wetlands refuge.

Initial designs for the boardwalk and observation deck had been completed as a wood design. A project goal was to make maximum use of the plastic lumber materials. This included the supporting substructure to eliminate the potential for rot and decay that would normally occur with a wooden structure in a damp wetlands environment. In converting the design from a wood structure to a RPL structure, roughly 5,300 kilogram (11,700 lb) of waste plastics were used to construct the facilities at this wetlands site. Installation personnel estimate that a minimum $60,000 savings will be realized over the life of the structure due to reduced maintenance and replacement costs. The renovated refuge was dedicated during a 1999 Earth Day ceremony. Figure 3 shows the observation deck being used by a group of teachers and preschoolers.

Staging Platforms at Lake Placid

The latest large-scale project showcasing the structural use of RPL was completed for the 2000 Winter Goodwill Games in Lake Placid, New York. Three staging platforms, made from RPL, are part of a newly constructed luge/bobsled/skelton run. This is the first time RPL has been used in a commercially loaded platform, carrying 4.8 kilopascals (100 lb/square ft)) of live load (Figure 4). New York State engineers worked with the Olympic Regional Development Authority on the design and material requirements.

The platforms total over 557 square meters (6,000 square feet) and the RPL used for these structures represents about 1 million recycled HDPE milk jugs and detergent bottles. As with the bridge at Ft. Leonard Wood, the design of the platforms had to account for the RPL material's tendency to expand and contract more than wood. This was especially important since construction was completed in the winter months with air temperatures at times as low as minus 34^{o}C (minus 30^{o}F).

Recycled-Plastic Pilings

Over the last 20 years, tougher water pollution regulations have lead to cleaner coastal rivers and harbors. The cleaner waters have resulted in a dramatic increase in the marine borer population, which in turn has caused an increased attack on wooden pilings so commonly used in marine/waterfront facilities. Pollution regulations have also raised concerns about the use and disposal of creosote or chemically treated wooden piles. To address the need for a non-polluting and marine borer-resistant pile, recycled-plastic pilings were developed.

Three different methods of reinforcement were used to increase the overall stiffness of the fabricated plastic pilings (and thus increasing their utility as a replacement for a wooden pile): (1) a heavy-walled steel pipe core; (2) steel or glass fiber reinforced rebars placed near the outer circumference of the piling; and (3) dispersed chopped-glass fibers. All of these piling types were used in the construction of the previously described Tiffany Street Pier (Figure 1).

In cooperation with the Port Authority of New York & New Jersey, several plastic pilings, representing reinforced types two and three described above, were installed in a fendering system at Port Newark, New Jersey (Figure 5). Cracking failures were reported at the bolt attachment locations on the installed pilings reinforced with chopped glass fibers. These failures were mainly a result of improperly designed attachments rather than material deficiencies. Additional information on this particular demonstration project as well as general information on the development of plastic pilings and can be found in reference [Ref. 6]. Recycled-plastic fender pilings have now been installed at several U.S. ports and Navy installations. Specifications and standards for plastic pilings are currently under development by ASTM Committee D20.20.04, Systems for Marine/Waterfront Applications.

Recycled-Plastic Composite Railroad Ties

Railroads in the United States typically replace between 10-15 million wood railroad (RR) crossties annually. Considering each tie is 2.6 meters (8-1/2 ft) long, if laid end-to-end, 15 million ties would extend almost 38,600 kilometers (24,000 miles). Engineered recycled-plastic composite RR ties have been developed to meet the load requirements of even the most demanding applications of mainline, heavy-haul railroads [Ref. 7]. Plastic ties installed at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center, Inc, in Pueblo, Colorado, have been subjected to accumulated traffic loadings of up to 272 billion gross kilograms (300 million gross tons) with no material failures (Figure 6).

A 2.6 meter (8-1/2 ft) long by 19 centimeter (7 in) high by 23 centimeter (9 in) wide RR tie contains an average of 77 kilograms (170 lb) of recycled plastic. With even a modest acceptance and use of plastic ties by the railroads as a replacement for wood ties, many kilograms (pounds) of waste plastics could be diverted from landfills. Since plastic ties are inherently resistant to insects, rot and moisture, plastic ties also eliminate the concerns about the use of creosote or other chemical treatments that are needed with wood ties.

In December 1998, plastic ties were installed in a #10 turnout (switch) at the Naval Surface Warfare Center in Crane, Indiana [Ref. 7]. This installation was the first use of plastic ties in a turnout. A variety of track fastening hardware was employed to assess their performance with the plastic ties. Guidance on the use of plastic RR ties is currently being developed by the American Railway Engineering and Maintenance of Way Association (AREMA)[2].

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Conclusions

The United States plastic lumber industry has advanced significantly from its early beginnings in the 1980's. Structural RPL materials now make possible the once unattainable all-plastic and composite structures. Much more work is still required in order to generate data required to show expected lifetimes and to generate needed lifetime cost information. Each new project using RPL as well as plastic pilings and RR ties will help to advance this knowledge and expand the possibilities of new applications and innovations in materials processing and structural designs.

References

1. Ehrig, R.J., ed., *Plastics Recycling – Products and Processes,* Chapter 9, "Commingled Plastics," Munich, Germany; Carl Hanser Verlag, 1992.

2. Lampo, R., and T. Nosker, "Development and Testing of Plastic Lumber Materials for Construction Applications," USACERL Technical Report 97/95, June 1997, pp 29-39.

3. Nosker, T., and R. Renfree, "Recycled Plastic Lumber: From Park Benches to Bridges," Approved for Proceedings of R'2000 5th World Congress, Toronto, Canada, June 5-9, 2000.

4. Lampo, R., P. Krishnaswamy, and A. Robbins, "Development of Industry Consensus Standards for Recycled-Plastic Lumber," Approved for Proceedings of R'2000 5th World Congress, Toronto, Canada, June 5-9, 2000.

5. Same as 2, pp 69-76.

6. Lampo, R., et al, "Development and Demonstration of FRP Composite Fender, Loadbearing, and Sheet Piling Systems," USACERL Technical Report 98/123, September 1998.

7. Lampo, R., T. Pinnick, and T. Nosker, "Development, Testing, and Demonstration of Recycled-Plastic Railroad Crossties," Proceedings of Transportation Systems 2000 Workshop, San Antonio, TX, Feb-Mar 2000, pp183-192.

Figure 1. RPL Tiffany Street Pier in New York City.

Figure 2. Sport utility vehicle driving over RPL bridge.

Figure 3. RPL observation deck at wetlands area.

Figure 4. RPL platforms being constructed at Lake Placid.

Figure 5. Recycled plastic pilings installed at Port Newark.

Figure 6. Recycled-plastic RR crossties being installed at test track in Pueblo, CO.