

<b>UTC Project Information</b>	
Project Title	MPC 416 – Development and Testing of Crashworthy Ipe Bridge Rails
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Brief Description of Research Project	<p>Bridge and guard rails are extraordinarily common along roads and highways around the world (Ritter et al. 1999, Wacker and Smith 2001). Even the most low-traveled rural bridge likely has rails installed for safety, and of course interstate highway systems have rails that can vary from concrete along bridges to cable lines across medians and metal railings at shoulders. Various types of railing have been studied for decades, and excellent design guidelines exist for nearly every class of railing. Typical types of railing can include formed steel in the shape of convex shell structures, simple solid wood timbers spliced with lap joints, hollow steel or other metal tubing that can be arrayed in either its strong or weak direction to adjust the stiffness at impact, glu-lam beams attached to solid wood posts, and cable “rails”. Representative configurations for these types of railings are shown below in Figure 1.</p> <p>Clearly, there are massive differences in cost and effectiveness between various barriers, and there are only limited numbers of studies that have attempted to compare the various types of railing (Shankar et al. 2000, Plaxico et al. 2000). In this study, we will complete a thorough review of all previously published studies of guardrails (including both performance and cost) throughout the United States along with collecting data on guard rail events in Colorado. But the primary emphasis of this work is exploring the use of an extremely durable and tough alternative structural material: the hardwood commonly known as ipe, also known as Brazilian walnut (<i>ocotea porosa</i>). Ipe has tremendous benefits compared to existing alternatives and has yet to be used in conjunction with transportation structures. In fact, there are almost no studies related to its structural performance. This is in part because it is an imported wood, and has a slightly higher cost than common structural wood species. But it appears to have excellent potential for use in applications where</p>

durability, environmental stability, and strength/stiffness are paramount.

There are some limits to current practice, and rail testing appears to possess a mildly ambiguous standard. Even systems that are FHWA accepted to specified NCHRP Report 350 test levels may have passed a relatively low number of crash tests. In extreme cases, this could be as little as a single test. By far the most common guardrails are either treated or untreated metal railing. These usually appear as w-beam sections and have relatively low cost and high strength. However, they usually suffer permanent deformation after a crash and also lose much of their structural capacity. There have been a number of other designs proposed for so-called “aesthetic” barriers that modify the surface of usual crashworthy barriers in design patterns, but physical testing by Caltrans has shown that even slight modifications from crashworthy surfaces have resulted in barrier failure.

In Figure 2, several real-world rail failures/repairs are shown that indicate the wide variability in failure mode and material type. There is not a common mode of failure such as would occur, say, in pure beam bending. Instead, there can be a combination of post/rail failure or a local foundation collapse. Performing a full study of failure modes is beyond the scope of this study. Instead, we focus on local impact behavior of ipe rails compared to other material candidates. There have been several numerical models performed for bridge railing systems (Atahan and Cansiz 2005, Liu et al. 2011), and these results will also be incorporated into an assessment of existing methods.

This project focuses on the design and performance of ipe bridge rails in an application that is similar to the lower right picture of Figure 2. Ipe is one of the densest hardwoods that is commercially available in the United States. It has the same fire rating as both steel and concrete, with an ability to resist flames much longer than softer woods. It has a natural oil that repels insect infestation and is also resistant to mildew and decay, raising the possibility of its use in coastal or humid environments. In terms of durability, we quote from the online database at [www.wood-database.com](http://www.wood-database.com): “Ipe is among the most durable lumbers on earth, with exceptional resistance to decay, rot, and insect attack. Ipe was reportedly used for the boardwalk along the beach of New York City’s Coney Island, and was said to have lasted 25 years before it needed to be replaced: an amazing lifespan given the amount of traffic and environmental stresses put upon the wood.” Its properties are compared with competitors in Table 1.

The primary disadvantage is related to cost. It is approximately 30 percent more expensive than cedar or pine. Additionally, ipe is difficult to work with. Holes must be pre-drilled, cutting can lead to a blunting of blades, and gluing surfaces can be somewhat challenging.

	<p>On a cautionary note, a side objective of this work is to return some integrity to the study (and marketing) of ipe. If one does a quick electronic search of ipe, it does not take long to discover the following comment, repeated on countless web sites: “Testing by the <i>US Navy</i> in a 1962 Panama Canal study showed ipe to be one of the top performers in resistance to decay, termites, and borers.” The principal investigator of this proposal cannot find any evidenced to back this claim. There was an excellent and comprehensive study made of various types of wood species with the intent of using wood as pier material in the Panama Canal (Southwell et al. 1962), but it never included ipe.</p> <p><b>Research Objectives:</b> The objectives of this project are to:</p> <ol style="list-style-type: none"> <li>1. Completely characterize ipe specimens in terms of the full elasticity stiffness tensor components <math>C_{ij}</math> for use in engineering structural applications.</li> <li>2. Complete impact tests on prototype ipe bridge rails to determine dynamic toughness under standard conditions. These will include basic rail configurations and sandwich-type structures that soften the apparent rail structure while maintaining the ultimate strength. These will be completed for varying angles of attack of the oncoming vehicle, with visual inspection used to detect and quantify levels of damage.</li> <li>3. Quantify these rail structures in terms of performance metrics compared to more standard metal and large-wood railing systems composed of other wood species.</li> </ol>
<p>Describe Implementation of Research Outcomes (or why not implemented)</p> <p>Place Any Photos Here</p>	<p>Ipe can perform just as well as W-beam rails. To obtain a similar performance to W-beam rails, the cost for Ipe would run approximately 5 times as much for the configurations used in this study. Realistic implementation of Ipe barriers would be more beneficial for roads with lower speed limits, resulting in less required material thus lowering the cost. Lower speeds showed more flexibility, which could result in less damage to the impacting vehicle. Implementation of carbon fiber reinforced polymers did not increase the performance of the railings enough to justify its cost.</p>
<p>Impacts/Benefits of Implementation (actual, not anticipated)</p>	<p>Ipe can be used in areas with specific speed ranges but at slightly higher costs. Environmental benefits and lower costs could make this a viable alternative.</p>
<p>Web Links</p> <ul style="list-style-type: none"> <li>• Reports</li> <li>• Project Website</li> </ul>	<p><a href="https://www.ugpti.org/resources/reports/details.php?id=894">https://www.ugpti.org/resources/reports/details.php?id=894</a></p>