PERCEPTIONS OF RECREATIONAL BRIDGE DECKING MATERIALS BY U.S. ARCHITECTURAL AND ENGINEERING FIRMS

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ABSTRACT

This paper examines recreational bridge decking material specifiers to better understand substitution opportunities for wood/natural fiber-plastic composites (WPCs). The WPC industry in the United States has enjoyed success in several residential construction applications including decking/railing, doors, and windows. As new WPC technologies and advancements evolve, potential exists to expand into an array of new products, including structural components for housing, marine, and transportation infrastructure applications. Specifically, this research investigates the perceptions of U.S. architectural and engineering (A&E) firms regarding the industrial infrastructure materials used in recreational bridge decking.

Through various exploratory methods, private U.S. A&Es were identified as key decision-makers in the recreational bridge construction industry and were subsequently examined via email/Internet surveys. A&Es indicated their highest level of influence in the recreational bridge decking process was in Project Design (4.14) followed by Material Selection (3.53) (5-point scale). Architects and engineers average self-rated Knowledge Of and Experience With WPCs were 2.10 and 1.48, respectively, well below the neutral point (3.0) on the 5-point scale. The two most important and most appealing recreational bridge decking material/service attributes were Low Maintenance and Decay Resistance. A&Es identified Decking and Marine Applications as the top two applications where WPCs could be used as a wood substitute. The Internet, Trade/Industry Journals, Conferences/Seminars, and Word of Mouth were the most important methods used by A&Es to learn about new industrial infrastructure materials.

Keywords: Recreational bridges, material perceptions, product/market development, specifiers, wood-plastic composites.

INTRODUCTION

To better understand opportunities for new industrial infrastructure products and/or materials, it is essential to identify key decision-makers and then gain insight into their product and material perceptions. For many industrial markets, these tasks may be particularly challenging and complex since a project's material selection may be more or less influenced by a wide array of professionals including, but not limited to, governmental administrators, engineers, and architects; trade association members; and private architects and engineers (Smith et al. 1998; McGraw and Smith 2007).

Smith and Bush (1994, 1996) found private consulting engineering firms to be important de-

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cision-makers in the use of materials for vehicular bridges, particularly in the timber bridge industry. Moreover, in the process of exploring the recreational bridge decking market from the perspectives of Forest Service bridge engineers, Professional Trailbuilder Association members, and recreational bridge manufacturers, McGraw and Smith (2007) identified private architectural and engineering (A&E) firms as key decision-makers in the material selection. Additionally, Brueggeman (2004) indicated that an important segment of the recreational bridge market consists of "engineered" trail and golf course bridges. These relatively complex and long-spanned structures typically require the use of an A&E firm, further underscoring the importance of A&E firms within the recreational bridge material decision process.

In addition to their role in the selection of industrial infrastructure materials, architectural and engineering (A&E) firms have also been identified as specifiers playing a key role in the material selection process in nonresidential construction markets. As Kozak and Cohen (1997) pointed out, "to understand why a building material is or is not used in certain [nonresidential construction] structural applications, one must query those responsible for their specification: namely, architects and engineers."

Architects and engineers are often viewed as trendsetters in the adoption and utilization of wood products (Johnson 1998). Though there is no current research examining A&E firms within the recreational bridge market, some research is available concerning these firms within the industrial infrastructure and nonresidential construction industries (Bright and Smith 2002; Smith and Bright 2002; Kozak and Cohen 1997; 1999; O'Connor et al. 2004; Wagner and Hansen 2004). Smith and Bright (2002) concentrated on two separate infrastructure components of waterfront facilities, decking and fendering, while surveying U.S. port authorities and private engineering firms. In addition Bright and Smith (2002) investigated component specific decking and piling material attributes for U.S. marina decision-makers.

Bridge markets and materials

Recreational bridges include state and federal government owned trail bridges, rails to trails bridges, and golf course bridges; however, exact numbers on this market are lacking and very little has been documented regarding the materials used or the decision-making process employed in the design, specification, and construction of recreational bridges. Anecdotal expert testimony suggests this market may be substantial. In research conducted by McGraw and Smith (2007), the recreational bridge market includes an estimated 5,000+ USDA Forest Service trail bridges (Eriksson 2004), and perhaps up to 12,000 rails-to-trails bridges and 60,000 golf course bridges in the U.S. (Sexton 2005; Beckwith 2004).

Due to the dearth of available research on the recreational bridge market, previous research on vehicular bridges was examined to gain insight and perspective. Traditionally, lumber/timber dominated the vehicular bridge materials market. However, in recent times, concrete, both prestressed and reinforced, and steel have become the dominant materials in vehicular bridges. The Federal Highway Administration (FHWA 2003) classifies and quantifies the total U.S. vehicular bridge material market by number of bridges as reinforced concrete (41%), steel (33%), prestressed concrete (21%), and wood (5%). In the decision process for vehicular bridge materials, local highway officials, state department of transportation officials, and private consulting engineers rated Life Span of the material most important followed by Past Performance and Maintenance Requirements (Smith and Bush 1996).

In addition to the more traditional highway bridge materials of concrete, steel, and wood, new bridge materials are starting to be utilized in bridge design and construction. Among these materials are new concrete and cement products, metals and intermetallic alloys, and fiber reinforced polymers (FRPs). As new, innovative bridge materials penetrate the vehicular bridge market, engineered wood products such as plywood, laminated veneer lumber, wood I-joists, oriented strandboard, and glulam beams are also gaining market share from traditional solid wood products in a variety of industrial infrastructure and residential markets[1] (Smith and Wolcott 2006; Adair 2004; Bright and Smith 2002; Eastin et al. 2001; Guss 1995).

Woodfiber-plastic composites

The U.S. WPC market was estimated at $1 billion in 2005 with decking and railing accounting for nearly two-thirds of this, though WPCs are finding their way into other residential applications such as window lineals, door stiles and rails, mouldings, fencing, siding, and trim (Smith and Wolcott 2006). From 1997 to 2005, the market share for WPC decking and railing products grew from 2 percent to an estimated 18 percent (Smith and Wolcott 2006).

As Smith and Wolcott (2006) state, "Wood/natural fiber-plastic composites (WPCs) are a unique development in the wood products industry, an emerging renewable material class based on performance, process, and product design innovation. The emerging material class combines the favorable performance and cost attributes of wood (and non-wood agricultural fibers) with the processability of thermoplastic polymers." WPCs first captured market share in applications such as landscape timbers, picnic tables, playground equipment, benches, fencing and trash receptacles (Smith and Wolcott 2005a). Early wood plastic composites were designed as direct lumber substitutes, but were criticized for their low mechanical properties and poor creep resistance (Wolcott 2003). These materials have found favor, in part, because they can function in exterior environments without the use of chemical preservatives. This is especially important as environmental concerns and the threat of lawsuits against treated wood manufacturers increase (Smith and Wolcott 2006). For decades composites of wood and plastic have been used in the automobile and door industries, though WPCs are fairly new products that have seen tremendous market growth (Smith and Wolcott 2005b). The increased use of WPCs can be primarily attributed to several factors such as life cycle cost, environmental issues, builder acceptance, and marketing communications (Smith and Wolcott 2006).

WPCs can now be produced for use as structural elements with complex cross-sections using polymer extrusion techniques (Wolcott 2001), suggesting their potential to compete in the industrial infrastructure market. Smith and Wolcott (2006) propose that improving material performance has created greater acceptance of WPC material solutions in residential, commercial, and industrial applications and that exterior structural applications such as waterfront and other industrial infrastructure applications are possible future markets for WPCs.

Objectives

The general objective of this study is to examine opportunities for WPCs within the recreational bridge market by surveying key specifiers, namely private architectural and engineering (A&E) firms. The specific goals of this research were to examine: (1) the role of A&E firms in the recreational bridge project decisions; (2) A&E's self-rated knowledge of and experience with WPCs; (3) recreational bridge decking material/service attribute importance; (4) WPC substitution potential; and (5) communication tools used by A&Es.

METHODOLOGY

To examine potential industrial infrastructure applications for structural WPCs, an innovative data collection approach was employed. First, the secondary literature concerning industrial infrastructure materials and markets was thoroughly examined to provide a foundation for this research. Additional exploratory research, including Internet searches and personal communications with individuals involved in various industrial infrastructure projects, provided a clearer picture of this market. Key personnel in the Pennsylvania Department of Transportation (PennDOT) (Christie 2004) and the Pennsylva-

[1] Markets include marine and transportation infrastructure, and non-residential construction.

nia Department of Conservation and Natural Resources (PA DCNR) (Eppley 2004 and Di-Carlantonio 2004) were interviewed in the spring of 2004 to examine the potential use of structural WPCs as a bridge decking material. Moreover, attendance at the 17th National Trails Symposium in Austin, Texas, October 21–24, 2004, provided the research team with valuable insight regarding recreational bridge decking applications, materials, and decision-makers. These exploratory activities led to the identification of United States Department of Agriculture Forest Service bridge engineers, Professional Trailbuilders Association members, bridge manufacturers (McGraw and Smith 2007), and private consulting A&E firms as key links in the material selection process for recreational bridge decking.

Sampling and sampling design

The American Council of Engineering Companies (ACEC) online directory was used to identify all relevant A&E firms. The ACEC is the "the only national organization devoted exclusively to the business and advocacy interests of engineering companies" (ACEC 2004a). The ACEC directory includes over 5,500 member firms nationally (ACEC 2004b). Bridge engineering firms were selected online by setting the search criteria to "bridges" in the box labeled "area of interest" (ACEC 2004b). This generated a list of 1,540 U.S. firms.

To properly obtain a geographically representative sample from this population, we stratified the bridge engineering firms by census region[2]. A final, regionally representative, stratified sample of 638 "Bridge" A&E firms was developed. This sample size was calculated[3] to achieve the required number of respondents involved in recreational bridge projects (Mendenhall et al. 1986).

Of these 638 firms, 83 were undeliverable, mainly due to invalid email addresses, and an additional 52 responded that the survey was not applicable to their firm. From an adjusted population of 503 A&E firms, 165 firms responded resulting in an adjusted response rate of 33 percent for our initial contact.

These 165 respondents were asked to indicate (by checking a box) whether their "*firm was involved in a recreational bridge project(s) in the last five years (2000 thru 2004).*" Of the 165 "Bridge" A&E respondents, 112 indicated their firm was recently involved in recreational bridge decking projects resulting in a more targeted sample frame of 112 recreational bridge A&E firms. A complete questionnaire was administered to the 112 firms.

Research instrument

Internet questionnaires were used to collect primary data as questionnaires are considered an effective and cost-effective means of collecting data from a geographically diverse group (Dillman 2000). As Schonlau et al. (2002) state, "Internet-based surveys, although still in their infancy, are becoming increasingly popular because they are believed to be faster, better, cheaper, and easier to conduct than surveys that use more-traditional telephone or postal methods." The use of an Internet survey was selected for this population for several reasons: (1) A&Es generally spend much of their workday on a computer, so a computer-based survey is a logical way to reach them; (2) Internet surveys have a quicker response time as they are instantly submitted and received through the website instead of being mailed; (3) email seems to provide a greater sense of urgency versus mailed correspondences; (4) follow-up efforts can be expedited because there is no need to wait for surveys to arrive via traditional mail; and (5) the use of Internet surveys eliminates the chance of the response being lost in the mail. Questionnaire constructs addressed demographics, proj-

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[2] Based on the four U.S. Bureau of Census regions shown in Fig. 1.

[3] It was calculated that we would need approximately 100 responses to be within a bound on the error of estimation of 10% at the 95% confidence level (Mendenhall et al. 1986). Taking this number into account, and assuming a response rate of 25 percent a final sample size of approximately 600 was deemed necessary.

ect influence, WPC knowledge, experience, appeal and substitution potential, decking material attribute importance, and information sources. The questionnaire was thoroughly pretested by industry experts and university personnel in order to refine the questionnaire for effectiveness in obtaining the desired information.

Data collection and response rates

Survey implementation generally followed the method described in Dillman (2000) and Schonlau et al. (2002) and is outlined as follows:

- A detailed cover letter was emailed to convey the importance of the respondent's participation with links to the voluntary questionnaire and to relevant background information.
- A second email and questionnaire link was sent to nonrespondents one-and-a-half to two-and-a-half weeks after the first mailing.
- A third and final email and questionnaire link was sent to remaining nonrespondents one-and-a-half to two-and-a-half weeks following the second mailing.

In addition, a research summary was offered as an incentive to improve response rates. Through these efforts, a response rate of 62 percent (69/112) was achieved (Fig. 1).

Study bias

In order to assess nonresponse bias, those who responded to the first emailed questionnaire (n = 18) were considered early respondents while those responding to follow-up efforts (n = 51) were considered late respondents. Late respondents are generally believed to be more like nonrespondents (Pearl and Fairley 1985). Analysis of variance (ANOVA) was used to compare the responses of the early versus late respondents across an array of questions. No significant differences among their mean perceptions of attribute importance and rank, WPC appeal, and/or communication factor importance were found (at the 0.05 level) between the two groups, thus allowing concerns of nonresponse bias to be put aside.

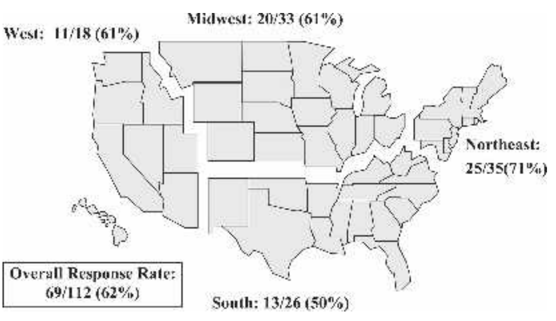

FIG. 1. ACEC response rates by U.S. Bureau of Census regions.

RESULTS

Descriptive statistics were used to summarize the collected data. In some instances one-way analysis of variance along with a Mann-Whitney U-test were used in order to detect differences among means based on certain demographic variables. For the qualitative data collected on the open-ended questions, understanding was limited to the researcher's interpretation of the responses provided.

Respondent profile

Respondents consisted of ACEC member firms that were involved in at least one recreational bridge project from 2000 through 2004. The median firm size was 220 employees, with an average of 987, a minimum of 2, and a maximum of 25,000. The regional breakdown of firms based on the four U.S. Bureau of Census regions was as follows: Northeast = 36 percent, Midwest = 29 percent, South = 19 percent, and West = 16 percent (Fig. 1). Respondents also indicated that they had a mean of 20 years of engineering experience with a range of 4 to 40 years. Responding firms were involved in a total of 454 recreational bridge projects from 2000 through 2004 with a mean of 7 and median of 4 projects per firm (with a minimum of 1 and a maximum of 50). Of these projects, the number that were timber/lumber decked ranged from 0 percent to 100 percent with a mean of 40 per-

TABLE 1. *Mean number of recreational bridge projects and percent lumber decked by firm size.*

	Overall		Firm size (No. of employees): Small (1–100)		Medium (100–499)		Large (500+)			
2000–2004	n	Mean	n	Mean	n	Mean	n	Mean	Sig.[1]	Significant differences among sizes[2]
# Recreational Bridge Projects	69	6.58	25	6.48	22	3.68	22	9.59	0.97	
% Lumber Decked	69	40.07	25	59.08	22	34.68	22	23.86	**0.008**	**1 > 2, 1 > 3**

[1] Based on ANOVA, bold = significant at the 0.05 level.
[2] Based on nonparametric Mann-Whitney U-Test with 1 = Small, 2 = Medium, and 3 = Large, bold = significant at the 0.05 level.

cent. New construction projects averaged 6 over this 5-year time period with repair/replacement projects accounting for an average of 1 project.

Analysis of variance showed that the number of recreational bridge projects did not differ significantly at the 0.05 level by firm size (number of employees). However, Large firms (500+ employees) and Small firms (1–100 employees) appeared to be involved in a greater number of recreational bridge projects than were Medium firms (100–499 employees) (Table 1). Also, as seen in Table 1, Small firms (1–100 employees) had a significantly higher mean usage of lumber/timber as a decking material than did both Medium and Large firms.

Project influence

Respondents were asked to rate their self-reported level of influence compared to bridge owners and contractors on a 5-point Likert scale with 1 = No Influence, 2 = A Little Influence, 4 = Much Influence, and 5 = The Most Influence. Overall respondents indicated that they had the most influence over the Project Design (mean = 4.14) followed by Material Selection (3.53), Project Construction (2.99) and Material Purchase (1.79) (Table 2).

Analysis of variance along with the Mann-Whitney U-test were used to determine if there were any significant differences in the influence of the different stages of a recreational bridge project based on the number of projects respondents were involved in between 2000 and 2004. Respondents were categorized into three groupings, Few (1–3 projects), Some (4–9 projects), and Many (10+ projects).

As shown in Table 2, there were significant differences at the 0.05 level between the groups for the stages of Project Design, Project Construction, and Material Selection. Both the Some and the Many had significantly more influence in their recreational bridge Project Design and Material Selection than did the Few firms. The Many (involved in 10+ projects) indicated they had a significantly greater influence in their recreational bridge Project Construction than did the Few firms (involved in only 1–3 projects).

TABLE 2. *Mean self-rated influence of ACEC firms relative to bridge owners and contractors on bridge activities in the past 5 years by number of recreational bridge projects.*

	All respondents		No. recreational bridge projects (2000–2004): Few (1–3)		Some (4–9)		Many (10+)			
Influence	n	Mean rating[1]	n	Mean rating	n	Mean rating	n	Mean rating	Sig.[2]	Significant differences among sizes[3]
Project Design	69	4.14	28	3.82	28	4.36	13	4.38	**0.006**	**2 > 1, 3 > 1**
Project Construction	68	2.99	28	2.64	27	3.11	13	3.46	**0.023**	**3 > 1**
Material Selection	68	3.53	28	3.18	27	3.74	13	3.85	**0.024**	**2 > 1, 3 > 1**
Material Purchase	68	1.79	28	1.64	27	1.85	13	2.00	0.408	

[1] Mean rating on a 5-point scale of 1 = No Influence to 2 = A Little Influence to 4 = Much Influence to 5 = The Most Influence.
[2] Based on ANOVA, bold = significant at the 0.05 level.
[3] Based on nonparametric Mann-Whitney U Test with 1 = Few, 2 = Some, and 3 = Many, bold = significance at the 0.05 level.

TABLE 3. *Self-rated knowledge of WPCs and experience with WPCs by number of recreational bridge projects.*

	All respondents		No. recreational bridge projects (2000–2004)							
			Few (1–3)		Some (4–9)		Many (10+)			
	n	Mean rating[1]	n	Mean rating	n	Mean rating	n	Mean rating	Sig.[2]	Significant differences among sizes[3]
Knowledge	69	2.10	28	1.86	28	2.04	13	2.77	**0.016**	**3 > 1, 2**
Experience	67	1.48	27	1.33	28	1.36	12	2.08	**0.005**	**3 > 1, 2**

[1] Mean rating on a 5-point scale of 1 = No Knowledge/Experience to 5 = Much Knowledge/Experience.
[2] Based on ANOVA bold = significant at the 0.05 level.
[3] Based on nonparametric Mann-Whitney U Test with 1 = Few, 2 = Some, and 3 = Many, bold = significant at the 0.05 level.

WPC knowledge and experience

Respondents were asked to rate their Knowledge Of and Experience With woodfiber-plastic composites on a 5-point Likert scale from 1 = No Knowledge/Experience to 5 = Much Knowledge/Experience. Overall, respondents rated their Knowledge Of WPCs (mean = 2.10) higher than they did their Experience With WPCs (mean = 1.48) although both self-ratings were below the neutral point of the scale (Table 3).

ANOVA was used to determine if there were any significant differences in the Knowledge Of and Experience With WPCs based on the number of recreational bridge projects a firm had been involved in over the past five years. A Mann-Whitney U-test determined that respondents who were involved in 10+ projects from 2000–2004 had significantly higher mean self-ratings for both Knowledge of WPCs and Experience with WPCs than those involved in 1–3 and 4–9 projects (Table 3).

Attribute importance and WPC appeal

In order to better understand the material needs of these industrial infrastructure specifiers, respondents were asked to rate the importance of 15 recreational bridge decking material and service attributes on a 5-point Likert scale from 1 = No Importance to 5 = Critically Important (Table 4). Attributes were selected based on discussions with industry experts and reviewed literature.

Respondents rated Low Maintenance (mean = 4.24) as the most important attribute for a rec-

TABLE 4. *Mean rating of importance and WPC appeal of recreational bridge decking material attributes in ACEC firm's material selection decision.*

Recreational bridge decking material attribute	"Importance"		"WPC appeal"		Difference	
	Mean rating[1] (n = 67)	Standard deviation	Mean rating[2] (n = 66)	Standard deviation	Mean	Sig.[3]
Low Maintenance	4.24	0.65	4.14	0.86	0.08	0.533
Decay Resistance	4.22	0.73	4.38	0.80	−0.15	0.228
Initial Cost	4.06	0.85	3.52	1.08	0.53	**0.002**
Slip Resistance	3.99	0.81	3.65	0.85	0.33	**0.015**
Life-Cycle Cost	3.91	0.85	3.77	0.82	0.12	0.363
Availability	3.83	0.83	3.47	0.93	0.38	**0.008**
Proven Track Record	3.81	0.80	3.50	1.05	0.30	0.074
Wear Resistance	3.78	0.73	3.88	0.79	−0.11	0.366
Aesthetics	3.61	0.65	3.52	0.86	0.11	0.340
UV Resistance	3.49	0.96	3.44	0.86	0.05	0.742
High Strength	3.07	0.72	3.39	0.84	−0.32	**0.006**
Fire Resistance	3.01	0.99	3.37	0.80	−0.38	**0.004**
Low Weight	2.82	0.67	3.58	0.70	−0.76	**0.000**
Thermal Expansion	2.61	0.74	3.30	0.66	−0.70	**0.000**
Chemical Free	2.48	0.89	3.20	0.66	−0.73	**0.000**

[1] Mean rating on a 5-point scale of 1 = No Importance to 5 = Critically Important.
[2] Mean rating on a 5-point scale of 1 = No Appeal to 5 = Very Appealing.
[3] Based on paired t-test, bold = significant at the 0.05 level.

reational bridge decking material followed by Decay Resistance (4.22), Initial Cost (4.06), and Slip Resistance (3.99) (Table 4). Rated lowest were Chemical Free (mean rating = 2.48), Thermal Expansion (2.61), Low Weight (2.82), and Fire Resistance (3.01) (Table 4).

In order to assess the A&Es opinions concerning wood-plastic composites, they were asked to rate the appeal of WPCs as a recreational bridge decking material ("WPC Appeal") for the same 15 attributes on a 5-point Likert scale where 1 = No Appeal to 5 = Very Appealing (Table 4). Decay Resistance (mean = 4.38) was rated as the attribute for which WPCs are most appealing as a recreational bridge decking material followed by Low Maintenance (4.14), Wear Resistance (3.88), and Life-Cycle Costs (3.77). WPCs were rated as least appealing as a recreational bridge decking material on the attributes of Chemical Free (mean = 3.30), Thermal Expansion (3.20), Fire Resistance (3.37), and High Strength (3.39) (Table 4).

It is interesting to note that the rank orders of the ratings for both "Importance" and "WPC Appeal" follow a similar order with the top two most important recreational bridge decking material attributes also being the top two most appealing WPC attributes for use as a recreational bridge decking material. Also worth noting, the results for "WPC Appeal" deviated less from the neutral point of the scale than the ratings for "Importance."

Differences between "Importance" and "WPC Appeal" were explored using a paired t-test. Significant differences (at the 0.05 level) were found for eight of the fifteen attributes (Table 4). "Importance" was rated higher than "WPC Appeal" for Initial Cost, Slip Resistance, and Availability, while ratings of "WPC Appeal" for the bottom five attributes were higher than their corresponding "Importance" ratings.

WPC substitution potential

Respondents were asked in an open-ended question to indicate the top three industrial infrastructure applications where they believed WPCs could be used as a wood substitute. Due to the qualitative nature of the information collected, analysis of the data consisted of obtaining frequencies of the responses and grouping them into "catch-all" categories to better organize and present the results of this research in the process of organizing the "same family of terms" (Hoonaard 1997). Categories were then assigned a weighted ranking of 1 through 3 points based on Substitution Potential with "Best Substitution Potential" receiving a score of 3, "2nd Best Substitution Potential" = 2, and "3rd Best Substitution Potential" = 1. By nature, the qualitative data collected through open-ended questions are subject to interpretation by the researchers (Mariampolski 2001). This interpretation may differ from researcher to researcher; our interpretations were based upon previous research as well as inherent knowledge of this project.

As seen in Table 5, Decking (weighted ranking = 301) was ranked as the top application for WPC substitution followed by Marine applications (71). Although numerous applications were suggested in response to this question, many of them were only mentioned one or two times and were therefore grouped into an "Other" category.

TABLE 5. *WPC substitution potential for lumber/timber per application by weighted ranking.*

Application	Weighted ranking[1]
Decking (includes bridge decking)	301
Marine (includes docks, piers, fendering)	71
Flooring	17
Harsh Environments	15
Fencing	12
Forms	12
Applications Sensitive to Chemical Treatments	12
Retaining Wall	11
Railing	8
Posts	7
Roofing	6
Railroad Ties	5
Other (includes beams, guardrails, siding)	45

[1] Weighted Ranking by assigning a score of 3 for application listed as "Best Subsitution Potential", "2nd Best Substitution Potential" = 2, and "3rd Best Substitution Potential" = 1.

Information sources

In order to understand the sources of information used by A&E firms to learn about new materials, respondents were asked to rate the importance of six communication sources that they use to learn about new industrial infrastructure materials on a 5-point Likert scale from 1 = No Importance to 5 = Critically Important. The Internet (mean = 3.59) was rated as the most important information source followed closely by Trade/Industry Journals (3.57), Conferences/Seminars (3.55), and Word of Mouth (Vendors & Peers) (3.53). Rated as the least important sources were Direct Mail (mean = 2.87) and Government/University Research (2.97) (Table 6). It is interesting to note, however, that all six sources of information used by A&E firms to learn about new materials were clustered close to the mid-point of 3.0.

CONCLUSIONS AND RECOMMENDATIONS

This study investigated the recreational bridge market regarding A&E firms' material perceptions and the possible use of WPCs as a recreational bridge decking material. The findings of this study indicate that A&E respondents exert considerable influence (relative to bridge owners and bridge contractors) in the Project Design and Material Selection of recreation bridge projects. A&Es perceived Low Maintenance and Decay Resistance as the most important material/service recreational bridge attributes as well as the most appealing WPC attributes for use in this industrial infrastructure application.

TABLE 6. *Mean ratings for information sources in learning about new industrial infrastructure materials.*

Information source	n	Mean rating[1]	Standard deviation
Internet	69	3.59	0.91
Trade/Industry Journals	68	3.57	0.90
Conference/Seminars	66	3.55	0.84
Word of Mouth (Vendors & Peers)	68	3.53	0.80
Government/University Research	68	2.97	0.77
Direct Mail	68	2.87	0.81

[1] Mean rating on a 5-point scale of 1 = No Importance to 5 = Critically Important.

This research employed a blend of exploratory and confirmatory methods to investigate material perceptions of A&E firms within the recreational bridge market. This methodology not only identified the population of interest, but it also delineated key issues for researching this industrial infrastructure market. Additionally, Internet/email surveys proved to be useful in communicating with A&Es throughout the United States, collecting primary data, and expediting response times resulting in an overall response rate of 62%.

It must be noted that WPCs are not yet commercially available for specification by A&Es for use in this application. If/when these materials are commercially introduced, marketing efforts will need to overcome the lack of knowledge and experience with WPCs as indicated by the respondents. Though the findings show that A&E specifiers feel that WPCs would be a viable substitute material for use as a recreational bridge decking material, marketing approaches will need to highlight the strengths of WPCs that are consistent with key material attributes. Additionally, consumer education regarding emerging WPC material developments will be essential. This would be best accomplished by utilizing the communication sources found most useful by A&Es such as the Internet, trade journals, and conferences. Specifically, direct mail to "Recreational Bridge" A&E firms, with links to technical websites and upcoming conferences, coupled with technically oriented trade journal articles and advertisements represent potential mechanisms to reach these key specifiers and to increase their knowledge and awareness of these new technologies/materials/products.

This research supplements the current research concerning industrial infrastructure markets, materials, and the specifiers who select these materials. This research followed the example of previous research by utilizing component-specific questions about recreational bridge decking in order to understand the specific application of this material within the entire recreational bridge project. This study will be valuable to both product and marketing managers in further developing the recreational bridge market, as well as other industrial infrastructure markets for emerging WPC materials.

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