World Survey of Civil Engineering Programs on Fiber Reinforced Polymer Composites for Construction

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Abstract: The Editorial Board of the American Society of Civil Engineers *Journal of Composites for Construction* (Lawrence C. Bank, Editor) sponsored a survey of the civil/structural engineering programs around the world on the subject of fiber reinforced polymer (FRP) composites, excluding the traditional steel–concrete composite construction and fiber reinforced concrete. This paper summarizes the main results from the survey. During the last decade, considerable focus has been devoted to the use of FRP composites in construction. The main driving force is the need for revitalizing the aging infrastructure with innovative materials and structural systems that last longer and require less maintenance. As the construction industry embraces FRPs in the field, the need for educating civil engineers with background on the subject has become more evident. Despite a significant number of field applications and laboratory research, the survey shows that FRPs have not yet been fully implemented in the engineering curricula, and the classrooms are still lagging behind. To improve this situation, civil engineering and their extension programs must provide sufficient training on unique features of FRPs so that engineers could design or specify them in construction. This survey should be repeated as a gauging tool again at the end of this decade.

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Introduction

Fiber reinforced polymer (FRP) composites have been used as structural materials since World War II, when they were first used in the construction of the British Spitfires. They consist of stiff fibers of around 10 μm diameter embedded in a thermoset or thermoplastic polymer resin. In the 1950's, the boating industry began using glass fiber reinforced thermosets with the hand lay-up process. Carbon fibers were introduced in the early 1960's, and because of their superior strength and stiffness properties soon became the fiber of choice for advanced composite applications in the aerospace industry. The research and development of the last four decades have made FRP composites quite competitive in the aerospace industry. The uptake of FRP composites in civil engineering has been much slower. In the 1970's, a number of building structures were cladded or domed with FRP panels using the hand lay-up technique (Hollaway and Head 2001).

During the last 25 years, there have been significant developments in composite processing methods such as pultrusion, filament winding, resin transfer molding, and resin infusion molding. These methods use different fiber reinforcement systems for different applications.

Driven by the need for revitalizing the aging infrastructure with innovative materials and structural systems that last longer and require less maintenance costs (Bakis et al. 2002), considerable focus has been devoted to the use of FRP composites. Higher quality FRP materials are now available in shapes and forms more attractive to civil engineers. The challenge is to make them more cost effective for large civil engineering structures.

Often with the support from governments and the composite and construction industries, educational institutions have led the way in carrying out research on FRPs and developing design guidelines and specifications. As the construction industry embraces these structural materials in the field, the need for educating civil engineers with background on the subject has become more evident.

Background on FRP Education

In the mid 1980's, the Technical Committee on Composite Materials of the American Society of Mechanical Engineers Applied Mechanics Division sponsored a survey on the educational and research programs in composite materials available at schools in the U.S. (Bank and Dvorak 1987; Sierakowski and Vinson 1986). The survey identified 44 institutions with a combined total of 410 faculty members, 1213 undergraduates, and 877 graduate students. A program of average size was found to have nine faculty members, 28 undergraduates, and 20 graduates.

Karbhari et al. (1992) took an overall view of composites to identify the key factors that would affect their growth and com-

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A World Survey of Civil Engineering Programs
On Composites for Construction

Purpose

During the last decade, considerable focus has been devoted to the use of fiber reinforced polymer (FRP) composites in construction. Educational institutions have led the way in carrying out research on FRP composites. As the construction industry begins to apply FRP composites in the field, the need for educating civil engineers with background on the subject has become more evident. The Editorial Board of the American Society of Civil Engineers (ASCE) Journal of Composites for Construction (Lawrence C. Bank, Editor) has sponsored a survey of the civil/structural engineering programs around the world on the subject of FRP composites. The traditional steel-concrete composite construction and fiber reinforced concrete (FRC) are not the focus of this survey. Please take a few minutes to respond to this survey. The department chairs are encouraged to seek input from the faculty members intimately involved with the subject. We apologize in advance, if you get multiple copies of this email, as different mailing lists have been used. All respondents will receive completed survey results and discussion paper.

Respondent Information
Please fill out the following information for future contact:
Name ______ Position ______
University ______ Telephone ______
Department ______ Fax ______
City, State, Zip ______ E-mail ______
Country ______ Web Site ______

Undergraduate Education
Do you have any Civil Engineering undergraduate course on FRP composites? YES ☐ NO ☐
If so, indicate the name of the course(s):
How often is the course offered?
On average, how many students are enrolled in the course?
At what level is the course offered? (Junior or Senior) Jr. ☐ Sr. ☐
Do you cover any of the following topics in traditional Civil Engineering courses?
Material properties of FRP composites YES ☐ NO ☐
Anisotropy and laminate theory YES ☐ NO ☐
Use of non-metallic FRP reinforcement YES ☐ NO ☐
Strengthening with FRP composites YES ☐ NO ☐
FRP composites as construction materials YES ☐ NO ☐
Please provide any additional information, e.g., course syllabus, as electronic attachment.

Graduate Education
Do you have any Civil Engineering graduate course on FRP composites? YES ☐ NO ☐
If so, indicate the name of the course(s):
How often is the course offered?
On average, how many students are enrolled in the course?
Do you have a Civil Engineering laboratory for FRP composites? YES ☐ NO ☐
Do your students take courses on composites from other departments, such as mechanical engineering, aerospace engineering, materials engineering, etc.? YES ☐ NO ☐
Do you discuss FRP composites in any of the following Civil Engineering courses? (Mark only if applicable)
Bridge engineering YES ☐ NO ☐
Reinforced concrete YES ☐ NO ☐
Construction materials and techniques YES ☐ NO ☐
Please provide any additional information, e.g., course syllabus, as electronic attachment.

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Professional/Continuing Education
Does any Civil Engineering faculty offer any short course on FRP composites? YES ☐ NO ☐
If so, indicate the name of the course(s):
How often is the course offered?
On average, how many students are enrolled in the course?
Please provide any additional information, e.g., course syllabus, as electronic attachment.

Research
How many Civil Engineering faculty carry out research on FRP composites?
How many Civil Engineering MS theses on FRP were awarded in the last 3 years?
How many Civil Engineering PhD theses on FRP were awarded in the last 3 years?
Please provide any additional information, e.g., thesis titles, as electronic attachment.

Additional Information/Comments
Please provide below your general comments and any other educational and training initiatives concerning FRP composites that your Civil Engineering department is involved with.

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Please email the completed survey to the contact person in your geographic area:

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Middle East and Africa
Send to USA contact person.

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Fig. 1. Questionnaire survey

petitiveness. They considered the challenge facing composites technology as to not only develop the market in nonaerospace applications, but to educate the future engineers in specifying the composites for construction.

Kukich et al. (1992) considered the current focus of the composites industry on aerospace and automotive applications as the primary reason for the lack of curricula and training for engineers using composites and advanced materials for offshore applications. They discussed the education needs of engineers using composites in the offshore industry. They recommended formulating a multidisciplinary composites program based on the diverse educational needs of undergraduate- and graduate-level aca-

Table 1. List of Respondents in U.S.

1. Auburn University	22. University of Akron
2. Bucknell University	23. University of California, Davis
3. Carnegie Mellon University	24. University of California, San Diego
4. Catholic University of America	25. University of Florida
5. Clarkson University	26. University of Iowa
6. California Polytechnic State University	27. University of Maine
7. California State University, Chico	28. University of Massachusetts, Amherst
8. Florida Atlantic University	29. University of Michigan, Ann Arbor
9. Florida State/Florida A&M University	30. University of Minnesota, Twin Cities
10. George Mason University	31. University of Missouri, Rolla
11. Georgia Institute of Technology	32. University of New Hampshire
12. Idaho State University	33. University of New Mexico
13. Iowa State University	34. University of New Orleans
14. Johns Hopkins University	35. University of South Carolina
15. North Carolina State University	36. University of South Florida
16. Oregon State University	37. University of Toledo
17. Pennsylvania State University	38. University of Wyoming
18. Purdue University	39. University of Wisconsin, Madison
19. Rice University	40. Villanova University
20. Rowan University	41. West Virginia University
21. Tulane University	

Table 2. List of Respondents in Canada

1. Dalhousie University
2. University of Alberta
3. University of Calgary
4. University of Manitoba
5. University of Saskatchewan
6. University of Sherbrooke
7. University of Toronto

demic programs as well as the continuing education needs of practicing engineers. They emphasized the integration of materials science, processing, mechanics, durability, and design. They further identified the need to establish a cooperative program between academe and industry to provide the appropriate educational tools for future engineers. Valenti (1996) has also emphasized the importance of the interdisciplinary programs in composites to train future engineers.

Taly (1998) referenced the accelerated pace of using FRPs by the defense, aerospace, aircraft, and sporting goods industries, in comparison with the slow progress in applications in the mainstream civil engineering structures. He attributed this to a number of reasons including lack of available textbooks, design manuals, and design codes, and also on account of unfamiliarity of the vast number of civil engineers with these materials. He suggested that to improve this situation, it would be imperative that effective steps be taken to disseminate knowledge of composites in the civil engineering community. This goal, Taly added, could be achieved through teaching composites design and application in engineering schools, in the form of lecture and laboratory work, beginning at the undergraduate level, similar to other design courses.

The National Science Foundation (NSF) has sponsored a number of integrated research and educational programs, with a few focusing on developing undergraduate and graduate courses on FRP composites in civil engineering curricula (Davalos and Qiao 2001). Also, there are a number of NSF supported engineering research centers and industry/university cooperative research programs on composites. The educational component of these centers is often quite strong. For example, Hawley et al. (2001) presented the educational impacts of the NSF Industry/University Cooperative Research Center of polymer composites processing at Michigan State University. The Center developed course materials, compact disk read-only memory (CD-ROM) design manuals, and workshop materials on the state of the art of thermoplastics design knowledge. The educational developments consisted of new and existing engineering courses, experiments for a new teaching laboratory, workshops, videotaped instructional modules, interactive web-based simulations and tutorials, and knowledge-based software.

Sponsored by the Editorial Board of the American Society of Civil Engineers (ASCE) *Journal of Composites for Construction* (Lawrence C. Bank, Editor), this paper summarizes the results of a survey of the civil/structural engineering programs around the world on the subject of FRP composites, excluding the traditional steel–concrete composite construction and fiber reinforced concrete. Despite a significant number of field applications and laboratory research on FRP, the survey shows that the research results have not yet been fully translated into teaching curricula, and civil engineering graduates for the most part are not sufficiently trained to design or specify FRPs for construction projects.

Survey Results

To evaluate the current trends in the FRP education, a survey of universities around the world was carried out between November 2001 and February 2002. Fig. 1 shows the survey questions. The survey included a brief explanation of the purpose, information on the respondent, and the four specific areas of interest, as follows:

1. Undergraduate education: to determine whether and to what extent new courses have been developed that exclusively discuss FRP composites, and also whether the concept of FRPs as a construction material is at all covered in any of the traditional civil engineering courses;
2. Graduate education: to determine whether graduate programs have a specific civil engineering course on FRPs, whether students are directed to take courses on mechanics and fabrication of FRPs in any other engineering department, and also whether FRPs are discussed in any of the traditional civil engineering graduate courses;
3. Professional and continuing education: to determine if the educational institutions are making the effort to train practitioners through extension services such as short courses and seminars on FRP materials; and
4. Research: to determine whether and to what extent the faculty and graduate students are exposed to and engaged in research on FRPs, and, therefore, determine by comparison whether the laboratory and field research is in fact delivered into the classrooms for the benefit of undergraduate and graduate students and practitioners.

The survey was distributed to all civil engineering departments (approximately 250) in the U.S. through the ASCE electronic mailing list, and to the extent possible by the efforts of the au-

Table 3. List of Respondents in Europe

1. Cranfield University	12. University of Lecce, Italy
2. Demokritus University of Thrace, Greece	13. University of Manchester, U.K.
3. ETH/Zurich and EMPA Duebendorf, Switzerland	14. University of Naples, Italy
4. RWTH Aachem, Germany	15. University of Newcastle, U.K.
5. Technical University of Dresden, Germany	16. University of Nottingham, U.K.
6. Technical University in Prague, Czech Republic	17. University of Patras, Greece
7. Swiss Federal Institute of Technology, Lausanne, Switzerland	18. University of Sannio, Italy
8. University of Bath, U.K.	19. University of Sheffield, U.K.
9. University of Cambridge, U.K.	20. University of Southampton, U.K.
10. University of Cardiff, U.K.	21. University of Surrey, U.K.
11. University of Lancaster, U.K.	22. University of Warwick, U.K.

Table 4. List of Respondents in Asia

1. Chalalongkorn University, Thailand
2. Dalian University of Technology, People's Republic of China
3. Fuzhou University, People's Republic of China
4. Guangdong University of Technology, People's Republic of China
5. Hokkaido University, Japan (Civil and Architectural Engineering)
6. Hong Kong Polytechnic University, Hong Kong, People's Republic of China
7. Indian Institute of Technology, Bombay, India
8. National University of Singapore
9. Kyoto University, Japan (Architectural Engineering)
10. Sirindhorn International Institute of Technology, Thammasart University, Thailand
11. University of Tokyo, Japan
12. Yonsei University, Korea

Table 5. List of Respondents in Middle East and Africa

1. Ain Shams University, Egypt
2. Israel Institute of Technology, Technion, Israel
3. Suez Canal University, Egypt
4. Stellenbosch University, South Africa

thors, to civil engineering programs around the world, including 15 in Canada, 100 in Europe, 35 in Asia, 15 in the Middle East and Africa, and 10 in South and Central America. Tables 1–5 present lists of all universities that participated in the survey from different regions of the world, including 41 schools in the U.S., seven in Canada, 22 in Europe, 12 in Asia, and four in the Middle East and Africa, respectively. No response was received from schools in South and Central America.

It should be emphasized here that the lack of response from any institution or region may not necessarily mean their lack of an FRP program. While the disproportionate rate of return from different regions understandably makes the survey less than "scientific," it may still serve as an informative gauging or "polling" tool of the current state of FRP education.

The list of respondents is still quite extensive and provides a representative cross section of the civil engineering programs in the U.S. and abroad. Of the responding schools in the U.S., 75% were state universities and 25% were private. The majority of the respondents offer graduate programs in civil engineering. Engineering technology programs were not included in the list of respondents. The low number of respondents in the Middle East and Africa made it difficult to gauge the efforts in that region, and therefore, they were not included in the comparative study.

Table 6 summarizes the responses on the undergraduate education. It appears that compared to the other regions, European schools are more aggressive in incorporating a special course on FRPs in their undergraduate curriculum. The FRP course, when offered, appears to be on a biannual basis in the U.S., annual in Canada and Europe, and every term in Asia. The enrollment in Asia and Europe is almost twice that in the U.S. and Canada. Furthermore, schools in the U.S. and Canada tend to offer such a course in the senior year, whereas European and Asian schools may offer this course in the spring of the junior year. Of the FRP topics covered in other undergraduate courses, the material properties and the use of FRPs as construction materials rank highest in almost all regions. There are some schools that discuss the use of FRPs as reinforcement and strengthening in undergraduate concrete courses, but fewer teach laminate analysis in the undergraduate curriculum.

Table 7 summarizes the responses on the graduate education. Canadian schools are the most aggressive in incorporating a special course on FRPs in their graduate curriculum. On the other hand, two out of five respondents in the U.S. and Europe offer such courses. In Asia, the offerings of undergraduate and graduate courses on FRPs are the same, at only one out of 12. Generally, graduate courses on FRPs are being offered once a year with good enrollments. It appears that FRP courses in the U.S. and in Asia are more lecture oriented, whereas in Europe and to some extent in Canada, the focus is more on the laboratory courses. Civil engineering programs in the U.S. and to some extent in Canada seem keen on sending their students to mechanical or aerospace engineering departments to take courses on FRP composites. Of other graduate courses, FRPs are discussed most frequently in traditional reinforced concrete courses as an alternative reinforcement.

Table 8 summarizes the responses on professional/continuing education. Quite surprisingly, schools in the U.S. are least engaged in such activities. On the other hand, one out of every two Canadian schools boasts an extension program on FRPs. The courses or workshops, when offered, are generally once a year. Enrollments in Europe are very significant, indicating the high interest in FRPs among practitioners in that continent.

Table 9 summarizes the responses on research. On average, almost two faculty members carry out research on FRPs in every school in the U.S. that responded to the survey. This number is slightly higher in Asia, but is close to four in Canada and in Europe. This translates into a similar proportion of masters and doctoral students in various regions. It seems, however, that, in the U.S., research activities on FRPs have not been taken into the classrooms quite as extensively as in Europe for undergraduate students or in Canada for graduate students. Civil engineering programs in the U.S. have also shied away from active extension

Table 6. Average Survey Responses on Undergraduate Education

Category		U.S.	Canada	Europe	Asia	Middle East/Africa	World-wide
Exclusive course on FRP	Offering	24%	14%	59%	8%	50%	31%
	Frequency (per year)	0.6	1.0	1.0	3.0	1.0	0.9
	Enrollment	18	15	30	50	35	26
	Level	4	4	3–4	3–4	3–4	3–4
Topic coverage	Material properties	41%	57%	77%	31%	50%	53%
	Anisotropy and laminate theory	27%	29%	32%	0%	25%	24%
	As reinforcement	32%	43%	50%	23%	0%	34%
	For strengthening	24%	29%	59%	38%	25%	36%
	As construction material	39%	43%	59%	23%	25%	41%

Table 7. Average Survey Responses on Graduate Education

Category		U.S.	Canada	Europe	Asia	Middle East/Africa	World-wide
Exclusive course on FRP	Offering	43%	71%	41%	8%	25%	38%
	Frequency (per year)	0.7	0.9	0.9	0.5	2.0	0.9
	Enrollment	12	8	19	20	35	14
FRP laboratory course		30%	57%	73%	23%	0%	40%
FRP course from other departments		85%	57%	28%	23%	0%	55%
Course inclusion	Bridge engineering	27%	29%	50%	23%	0%	31%
	Reinforced concrete	51%	57%	50%	46%	25%	49%
	Construction materials	29%	43%	68%	46%	25%	43%

Table 8. Average Survey Responses on Professional/Continuing Education

Category		U.S.	Canada	Europe	Asia	Middle East/Africa	World-wide
Short course or seminar	Offering	12%	57%	28%	23%	50%	23%
	Frequency	1.0	1.0	0.8	0.7	0.8	0.9
	Enrollment	19	18	76	24	10	33

Table 9. Average Survey Responses on Research

Category		U.S.	Canada	Europe	Asia	Middle East/Africa	World-wide
Research on FRP	No. of faculty	1.8	3.9	3.5	2.2	3.8	2.5
	No. of MS theses	2.6	4.1	3.0	2.2	1.5	2.7
	No. of PhD theses	0.8	1.4	1.5	0.5	0.5	1.0

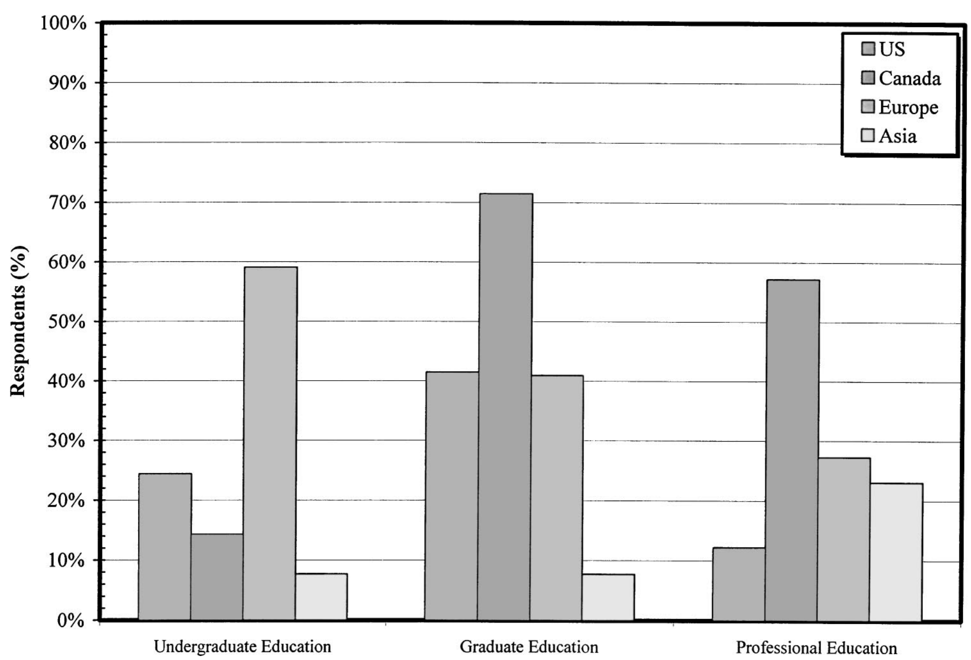

Fig. 2. Comparison of FRP course offering in various regions

programs on FRPs. This point is well demonstrated in Fig. 2, where undergraduate, graduate, and professional education of FRPs are compared among various regions.

Conclusions

A survey of the civil/structural engineering programs around the world was carried out on the subject of fiber reinforced polymer (FRP) composites. The survey consisted of questions on undergraduate, graduate, and professional/continuing education, as well as research on FRPs. The following conclusions were made:

- European schools are more advanced in incorporating a special course on FRPs in their undergraduate curriculum. The course offering is more frequent in Europe and in Canada. The enrollment in Asia and Europe is almost twice that in the U.S. and in Canada.
- Canadian schools are most aggressive in incorporating a special course on FRPs in their graduate curriculum.
- FRP courses in the U.S. and in Asia are more lecture oriented, whereas in Europe and to some extent in Canada, the focus is more on the laboratory teaching.
- Canadian schools are more involved in seminars and workshops for practitioners, while Europe boasts the largest class sizes for professional education.

In general, FRPs have not yet been fully implemented in the engineering curricula, and the classrooms are still lagging behind. To improve this situation, civil engineering and their extension programs must provide sufficient training on unique features of FRPs so that engineers could design or specify them in construction. This survey provides a benchmark to gauge the progress in this field, and may be repeated again at the end of this decade.

Acknowledgments

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References

Bakis, C. E., Bank, L. C., Brown, V. L., Cosenza, E., Davalos, J. F., Lesko, J. J., Machida, A., Rizkalla, S. H., and Triantafillou, T. (2002). ‘‘FRP composites for construction: State-of-the-art review.’’ *J. Compos. Constr.*, 6(2), 73–87.

Bank, L. C., and Dvorak, G. J. (1987). ‘‘Composite materials education in the United States: A survey.’’ *Mech. Eng. (Am. Soc. Mech. Eng.)*, 109, 64–67.

Davalos, J. F., and Qiao, P. Z. (2001). ‘‘Innovative teaching guides for composite materials in civil engineering curricula.’’ *Proc., ASEE North Central Regional Conf.*, Cleveland (CD-ROM).

Hawley, M., Jayaraman, K., Sticklen, J., Moore, B., Drzal, L., and McCullough, R. L. (2001). ‘‘Impact of the NSF State/Industry/University Cooperative Research Center on low-cost, high-speed polymer composites processing on the research and educational programs at Michigan State University.’’ *Composites, Part A*, 32(8), 1175–1179.

Hollaway, L., and Head, P. R. (2001). *Advanced polymer composites and polymers in the civil infrastructure*, Elsevier Science, Amsterdam, The Netherlands.

Karbhari, V. M., Henshaw, J. M., Wilkins, D. J., and Munson, M. S. (1992). ‘‘Composites: Design, manufacturing, and other issues: A view towards the future.’’ *Int. J. Mater. Prod. Technol.*, 7(1), 13–37.

Kukich, D. S., Karbhari, V. M., and Gillespie, J. M., Jr. (1992). ‘‘Composites for offshore applications: A multidisciplinary education program for the marine industry.’’ *Proc., Int. Conf. on Civil Engineering in the Oceans*, ASCE, New York, 953–967.

Sierakowski, R. L., and Vinson, J. R. (1986). ‘‘On education in composite materials in North America.’’ *Proc., 3rd Japan/U.S. Conf. on Composite Materials*.

Taly, N. (1998). ‘‘Structural design with FRP composites.’’ *Proc., Int. SAMPE Symp. and Exhibition*, Covina, CA, 43(2), 1229–1237.

Valenti, M. (1996). ‘‘Teaching tomorrow’s engineers.’’ *Mech. Eng. (Am. Soc. Mech. Eng.)*, 118(7), 64–69.