LIABILITY OF ENGINEERS FOR STRUCTURAL DESIGN ERRORS: STATE OF THE ART CONSIDERATIONS IN DEFINING THE STANDARD OF CARE*

JOHN C. PECK†
WYATT A. HOCH‡

Based on their delineation of four distinct strata of knowledge within the engineering profession, the authors propose a standard of care for engineers that reflects advances in knowledge and design theory but that stops short of strict liability.

I. INTRODUCTION

IN 1970, MAD Magazine's "Scenes We'd Like to See"[1] featured a three frame cartoon entitled "The Ribbon Cutting Ceremony." The first frame depicts a new suspension bridge over a harbor, an assembled crowd, and a tuxedo-clad mayor preparing to cut the ceremonial ribbon. The second frame catches the mayor carefully cutting the ribbon. The third frame portrays disaster as, to everyone's horror, the bridge collapses—the implication being that the ribbon alone had supported the entire structure.

MAD Magazine's satirical poke at the design profession and construction industry bears a double-edged truth: the cartoonist's suspension bridge, with its long structural spans, high strength materials, and infinite public access, symbolizes the triumphs of twentieth century engineering and technology; new structures continue to span greater distances with less material and more aesthetic grace. Yet, during the past decade, some cata-

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† Professor of Law, University of Kansas. B.S., Civil Eng'g, Kansas State University, 1968; J.D., University of Kansas, 1974. Member, Kansas Bar.

‡ Associate, Foulston, Siefkin, Powers and Eberhardt, Wichita, Kansas. B. Arch., Kansas State University, 1980; J.D., University of Kansas, 1983. Member, Kansas Bar.

1. MAD MAGAZINE July 1970.

strophic failures have occurred. Those at Kansas City's Kemper Arena,[2] Hartford's Civic Center Coliseum,[3] and Boston's John Hancock Tower[4] resulted in enormous economic loss. The Kansas City Hyatt Regency walkway[5] and the Harbour Cay condominium[6] collapses caused human injury and loss as well. Failures such as these, occurring both during construction and after initial occupancy or use, have focused public and professional attention on the myriad potential hazards in large structures that shelter thousands of people and represent millions of dollars in capital investment.

These and other less spectacular structural failures also have provided the legal system with the opportunity to refine the scope and degree of the engineer's duties. Ironically, however, large failures create such overwhelming economic loss that most damage suits are settled by the parties prior to trial, leaving a dearth of reported court opinions on the engineer's responsibilities.

Any structural failure may embody numerous and often con-

2. Part of Kemper Arena's 324-foot clear-span roof collapsed to the floor during an intense rain and wind storm on June 4, 1979. Subsequent investigation revealed that high-strength bolts subjected to dynamic loading conditions fatigued under recurrent movement, precipitating the collapse. *See Rocking That Fatigued Bolts Felled Arena Roof*, ENGINEERING NEWS REC., Aug. 16, 1979, at 10-12.

3. The 360' x 300' steel space frame roof of Hartford's Civic Center Coliseum collapsed on January 18, 1978, after several days of heavy snow, rain, and freezing temperatures. Although the $30 million building was heavily damaged, no injuries were reported. *See* AMERICAN INSTITUTE OF ARCHITECTS, TOWARDS SAFER LONG-SPAN BUILDINGS 3 (1981) [hereinafter cited as AIA]; Smith & Epstein, *Hartford Coliseum Roof Collapse: Structural Collapse Sequence and Lessons Learned*, CIVIL ENGINEERING—ASCE, Apr., 1980, at 59-62.

4. Foundation, structural steel, and glass curtainwall problems have plagued the 60 story, rhomboid-shaped John Hancock Tower in Boston. Curtainwall glass breakage caused by unanticipated wind loading, minute inclusions or defects in the glass, and possibly inadequate structural stiffness delayed the building's occupancy for five years and prompted replacement of all 10,344 glass units on the tower. *See* J. O'BRIEN, CONSTRUCTION DELAY 348-56 (1976).

5. The walkway's spectacular collapse on July 17, 1981, claimed 114 lives, the most ever in an American structural failure. Two 117-foot long "skywalks," which spanned a five-story atrium area of the hotel, failed under 53% of the minimum load capacity required by the Kansas City Municipal and Uniform Building Codes. After extensive destructive testing on specimens obtained from the walkway debris, the National Bureau of Standards concluded that the most probable cause of failure was insufficient load capacity in the suspended walks' supporting connections. *National Bureau of Standards, Investigation of The Kansas City Hyatt Regency Walkway Collapse* 249, 251 (1982).

6. On March 27, 1981, 11 construction workers were killed when the entire five-story structure in Cocoa Beach, Florida, collapsed. A National Bureau of Standards report cited insufficient punching shear capacity in the fifth floor reinforced concrete slab, which failed during a concrete pour, as the cause of the accident. *See Florida Collapse Blamed on Design*, ENGINEERING NEWS REC., June 18, 1981, at 39.

current causes outside the design professional's[7] control. These include defects in materials, improper member fabrication, inadequate inspection or supervision during construction, and loads exceeding design loads. Engineering design error, however, is a major contributing cause which is wholly within the engineer's control. The advent of more complex structural systems, such as the space frame,[8] the use of high-strength weldable metals,[9] the increased magnitude and types of structural loadings,[10] and the industry's reliance on minimum-cost systems[11] may have expanded the engineer's responsibilities and in turn heightened his liability exposure.[12]

Additionally, the continuing force of empirical research may

7. The terms "design professional," "architect" and "engineer" are used interchangeably throughout this article to designate individuals responsible for design services on a construction project.

8. Space frames or space frameworks are "[t]hree-dimensional structures composed of a number of bars hinged together in such a manner as to form a rigid framework." C. NORRIS & J. WILBUR, ELEMENTARY STRUCTURAL ANALYSIS 116 (2d ed. 1960). Space frames have been defined alternatively as "three-dimensional structural systems composed of interconnected members, other than bearing walls, and laterally supported to function as a complete, self-contained unit, with or without the aid of horizontal diaphragms or floor bracing systems." STANDARD HANDBOOK FOR CIVIL ENGINEERS § 15-12 (F. Merrit 3d ed. 1983). One commentator has described the design advantages of space frames in the following way:

> Space frames possess a positive aesthetic quality by having a molecular-type structure which tends to duplicate nature. Structural materials are utilized efficiently, since space frames span in more than one direction. With the use of high-strength materials, larger column-free spans can be attained, thereby providing a greater flexibility of usage within the structure. Space frames provide great rigidity and inherent redundancy, which results in an increased safety factor. Most space frame systems utilize extensive prefabrication in the shop, thereby eliminating the need for highly skilled field labor. Many space frames can be assembled on the ground, thus resulting in increased construction safety and further reduction in skilled labor. Space frames possess a versatility of shape and form, and can utilize a standard module to generate flat grids, barrel vaults, domes, and free-form shapes.

Cuoco, *State-of-the-Art of Space Frame Roof Structures*, in AMERICAN SOCIETY OF CIVIL ENGINEERS SYMPOSIUM ON LONG SPAN ROOF STRUCTURES 1 (Oct. 26-30, 1981).

9. Recent accident investigations have uncovered a direct correlation between high-strength steel and catastrophic failures of buildings, aircraft wings, and other steel products. Although alloyed steel offers the engineer added strength, durability, and cost saving over conventional steel, "[i]ts flaws are all the more pernicious because designers specify its use in precisely those applications where the margin for error is the slimmest." *High-Strength Steel Is Implicated as Villain in Scores of Accidents*, Wall St. J., Jan. 16, 1984, at 1, col. 6.

10. *See* Rolfe & Hall, *Fracture Mechanics, Fracture Criteria, and Fracture Control in Structures*, in STRUCTURAL AND GEOTECHNICAL MECHANICS 70 (1977).

11. *See id.*

12. *See id.* at 70-71.

affect the engineer's duties.[13] Recent advances in the understanding of fatigue failure,[14] stress concentrations,[15] and brittle fracture[16] in steel members—the staple of most large structures—have created new design considerations. Yet knowledge and technology are not easily assimilated into practice.[17] Determining an engineer's liability is thus becoming more complicated, because of both this increased knowledge and the incorporation of novel design theories into structures performing at the cutting edge of the profession.

This article attempts to define the liability limits of structural engineers. Part II describes the engineering field of knowledge by way of a stratification of knowledge levels. Part III examines the various standards of care used by appellate courts in civil damage actions to judge an engineer's design performance. Using this framework, Part IV advocates that courts adopt a higher standard of care, one that reflects advances in knowledge and design theory but that stops short of strict liability. Part IV concludes by identifying practices and alternatives available to the

13. For a discussion of the structural design engineer's standard of care under present law, see *infra* notes 69-115 and accompanying text.

14. The American Society for Testing and Materials (ASTM) defines fatigue as "the process of progressive localized permanent structural change occurring in a material subjected to conditions which produce fluctuating stresses and strain. . .and that may culminate in cracks or complete fracture after a sufficient number of fluctuations." AMERICAN SOCIETY FOR TESTING AND MATERIALS, COMPILATION OF ASTM STANDARD DEFINITIONS 249 (4th ed. 1979) [hereinafter cited as ASTM STANDARD DEFINITIONS]. In manufactured steel products, fatigue failures are the inevitable consequence of cyclical live load design stresses. The touchstone of liability for such fatigue failures is the reasonableness of the length of the product's service life. Allen, *Fatigue Failure in Products Liability Actions*, 28 ALA. L. REV. 575, 581, 584 (1977). In the area of structural design, by contrast, fatigue failure must be prevented because of the enormous risk and capital investment involved in a building collapse.

15. Stress concentration is defined as

> [a] condition in which a stress distribution has high localized stresses. A stress concentration is usually induced by an abrupt change in shape of a member. In the vicinity of notches, holes, changes in diameter of a shaft, or application points of concentrated loads, maximum stress is several times greater than where there is no geometrical discontinuity.

13 ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY 219 (5th ed. 1982). Local stress concentration "may be due to poorly made welds, small holes, and rough or damaged edges resulting from the fabrication processes of shearing, punching, or poor-quality oxygen cutting." B. JOHNSTON, F. LIN & T. GALAMBOS, BASIC STEEL DESIGN 33 (2d ed. 1980).

16. A brittle fracture occurs when a structural member fractures perpendicular to the direction of loading without obvious, uniform cold drawing. ASTM STANDARD DEFINITIONS, *supra* note 14, at 78.

17. For a discussion of how new research, knowledge, and technological advances are assimilated into the structured design engineering process, see *infra* notes 36-40 and accompanying text.

engineer to limit his liability exposure and to reduce the risk of catastrophic structural failures.

II. THE STRUCTURAL ENGINEERING STATE OF THE ART

An engineer's level of skill depends upon his training, experience, and savvy. The gamut of expertise held by members of the profession extends from that of a new structural engineering graduate, to that of a newly-certified professional, to that possessed by a venerable pro with thirty years of experience. The law of structural engineering liability, however, is not clearly defined—at least not as clearly defined as products liability law. In products liability, a product not designed to the "state of the art"[18] can create liability for its manufacturer.[19] No such parallel state of the art for engineers exists. Rather, the law has protected structural engineers who have designed at the minimum professional level of competence but not necessarily at the state of the art.[20] If our proposed new standard of care were accepted,[21]

18. *See* Note, *Products Liability—Strict Liability—Elimination of "State of the Art" Defense*, 41 TENN. L. REV. 357 (1974). "State of the art" is defined as the extent to which a product could have been safely designed given the scope of knowledge and experience of the industry at the time of manufacture and sale. *Id.*

19. Compliance with the state of the art standard may operate as an affirmative defense. *See, e.g.*, Moorer v. Clayton Mfg. Corp., 128 Ariz. 565, 569, 627 P.2d 716, 720 (1980) (noting Arizona statute that allows the state of the art defense in product liability cases), *cert. denied*, 454 U.S. 866 (1981); Heath v. Sears, Roebuck & Co., 123 N.H. 512, 530, 464 A.2d 288, 299 (1983) (recognizing an affirmative defense to product liability actions based on discoverability of the risk as measured by the state of the art at the time of distribution or sale); Day v. Barber-Coleman Co., 10 Ill. App. 2d 494, 508-10, 135 N.E.2d 231, 238-39 (1956) (permitting state of the art defense, including consideration of reasonableness of defendant's design choice, in a negligence action against a manufacturer for defective design of an overhead vertical door).

In some jurisdictions, compliance with the state of the art may be offered only as evidence of the defendant manufacturer's reasonableness in the design and manufacture of its product. *See, e.g.*, Rodriguez v. Compass Shipping Co., 456 F. Supp. 1014, 1024 (S.D.N.Y. 1978) (adherence to the usual practice of an industry is not, in itself, a complete defense to a charge of negligence); Gelsumino v. E.W. Bliss Co., 10 Ill. App. 3d 604, 608, 295 N.E.2d 110, 113 (1973) (evidence of conformity to the state of the art is not conclusive as to nonnegligence, but may be considered along with other evidence in determining reasonableness of defendant's conduct).

Determination of the state of the art is a question of fact and is proven by expert testimony at trial. *See* Chown v. U.S.M. Corp., 297 N.W.2d 218, 222 (Iowa 1980); Chandler v. Neosho Memorial Hospital, 223 Kan. 1, 5, 574 P.2d 136, 139 (1977); Hancock v. Paccar, Inc., 204 Neb. 468, 478, 283 N.W.2d 25, 35 (1979). Few reported appellate decisions have attempted to define state of the art in either strict liability or negligence actions based on defective products. *See* Note, *supra* note 18, at 357-59. For a further discussion of state of the art in products cases, see *infra* notes 22-35 and accompanying text.

20. *See infra* notes 69-115 and accompanying text.

courts would have to take steps to define the structural engineering state of the art. A brief examination of the state of the art in products cases will be helpful to the process of formulating a definition for structural engineers.

A. *State of the Art in Products Cases*

State of the art originated as a defense to negligence claims founded on defective products.[22] If the manufacturer's product design conformed to the industry standard, the manufacturer could escape liability for injuries sustained from use of the product.[23]

The advent of strict products liability diminished the role of the state of the art definition. Under the theory of strict liability defined in section 402A of the Second Restatement of Torts, a manufacturer is liable for injuries caused by his product if the product is both defective and unreasonably dangerous.[24] This rule implicitly creates a high standard of care because compliance with industry custom, in and of itself, is inadequate to avoid

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21. *See infra* notes 135-52 and accompanying text.

22. *See* Day v. Barber-Colman Co., 10 Ill. App. 2d 494, 135 N.E.2d 231 (1956). In *Day*, the Illinois Court of Appeals articulated its standard and rationale for the state of the art defense as follows:

> [I]t is not of itself negligence to use a particular design or method in the manufacture or handling of a product or doing a job which is reasonably safe and in customary use in the industry, although other possible designs, whether in use in the industry or not, might be conceived which would be safer, and evidence as to what is thought by some to be a safer design or method or product is not admissible.

Id. at 508, 135 N.E.2d at 238. *See also* Olson v. Arctic Enters., 349 F. Supp. 761 (D.N.D. 1972) (permitting state of the art defense in a negligent design action against a snowmobile manufacturer).

23. *See* Comment, *The State of the Art Defense in Strict Products Liability*, 57 MARQ. L. REV. 649 (1974).

24. RESTATEMENT (SECOND) OF TORTS § 402A (1965). Section 402A provides as follows:

> (1) One who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or to his property, if
>
> (a) the seller is engaged in the business of selling such a product, and
>
> (b) it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.
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> (2) The rule stated in Subsection (1) applies although
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> (a) the seller has exercised all possible care in the preparation and sale of his product, and
>
> (b) the user or consumer has not bought the product from or entered into any contractual relation with the seller.

Id.

liability.[25]

Nonetheless, many courts continue to acknowledge the relevance of state of the art in product liability actions,[26] but differ in their definition and analytical application of the term "state of the art." Some jurisdictions define state of the art as scientific knowledge at the time of manufacture or construction that can be incorporated into the product in an economically and practically feasible manner.[27] Under this definition, the manufacturer is held to a higher standard than in negligence cases. Other jurisdictions follow the negligence definition of state of the art as "conformity with industry-wide practice," yet effectively refuse to apply this standard by considering expert testimony as to whether the design was reasonable.[28] Still other courts, while focusing on whether a risk of harm from use of a product is unreasonable, have considered factors such as the availability, cost, practicality, and technological feasibility of alternative designs to establish the state of the art.[29] Recently, some courts have even injected reasonableness into the equation by holding that the law does not require manufacturers to be prescient, to recognize and utilize all art and science everywhere, or to create the ultimate in design and safety.[30]

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25. *See, e.g.*, Voss v. Black & Decker Mfg. Co., 59 N.Y.2d 102, 450 N.E.2d 204, 463 N.Y.S.2d 398 (1983). *But see* Caterpillar Tractor Co. v. Beck, 593 P.2d 871 (Alaska 1979); Gelsumino v. E.W. Bliss Co., 10 Ill. App. 3d 604, 295 N.E.2d 110 (1973).

26. *See* O'Donnell, *Design Litigation and the State of the Art: Technology, Practice and Reform*, 11 AKRON L. REV. 627 (1977-78) (citing Spurlin v. General Motors Corp., 528 F.2d 612 (5th Cir. 1976); Hoppe v. Midwest Conveyor Co., 485 F.2d 1196 (8th Cir. 1973); Schneider v. Chrysler Motors Co., 401 F.2d 549 (8th Cir. 1968); Holmgren v. Massey Ferguson, Inc., 394 F. Supp. 910 (D.N.D. 1974) (other citations omitted); Raleigh, *The "State of the Art" in Product Liability: A New Look at an "Old" Defense*, 4 OHIO N.U.L. REV. 249 (1977); *Strict Products Liability and State of the Art Evidence in Texas*, 45 J. AIR. L. COM. 711 (1980).

27. *See* Chown v. USM Corp., 297 N.W.2d 218, 221 (Iowa 1981); Boatland of Houston, Inc. v. Bailey, 609 S.W.2d 743, 745 (Tex. 1980).

28. *See* 2 L. FRUMER & M. FRIEDMAN, PRODUCTS LIABILITY § 16A[4][i] (1980); Weinstein, Twerski, Piehler & Donaher, *Product Liability: An Interaction of Law and Technology*, 12 DUQ. L. REV. 425, 450 (1974).

29. For examples of strict liability cases in which courts have permitted consideration of technical feasibility, cost, practicality, and effect on the utility of the product in defining state of the art, see Raney v. Honeywell, Inc., 540 F.2d 932, 935 (8th Cir. 1976); Caterpillar Tractor Co. v. Beck, 593 P.2d 871, 887 (Alaska 1979); Kerns v. Engelek, 76 Ill. 2d 154, 162-63, 390 N.E.2d 859, 864 (1979); Gelsumino v. E.W. Bliss Co., 10 Ill. App. 3d 604, 609, 295 N.E.2d 110, 113 (1973).

30. *See* Mitchell v. Machinery Center, Inc., 297 F.2d 883, 886 (10th Cir. 1961); Garst v. General Motors Corp., 207 Kan. 2, 20, 484 P.2d 47, 61 (1971). *But see* Beshada v. Johns-Manville Sales Corp., 90 N.J. 191, 447 A.2d 539 (1982)

The proposed federal products liability act offers yet another definition of the state of the art in products cases.[31] The act, which is designed to preempt all state product liability actions,[32] would impose liability on manufacturers for harm caused by "unreasonably dangerous" products[33] when a means to eliminate the danger is within "practical technological feasibility."[34] The bill defines "practical technological feasibility" as "the technical, medical, and scientific knowledge . . . which, at the time of production . . . was developed, available and capable of use in the manufacture of a product, and economically feasible for use by a manufacturer."[35]

B. *A Practical Formulation of the State of the Art for Structural Engineers*

Although the products state of the art might be applicable by analogy to structural failure cases, it is preferable to define a state of the art for structural design based on the development, acceptance, and dissemination of new structural design theories. Four horizons of structural engineering knowledge can and should be identified by courts as guidelines in defining the state of the art and in formulating an appropriate standard of care for design professionals.[36]

The top stratum represents "cutting edge" research on new hypotheses and design solutions proposed by research engineers for professional institutes,[37] university professors, and a few prac-

(holding defendant manufacturer to the level of all knowledge scientifically discoverable as of the time of trial).

31. S. 44, 98th Cong., 1st Sess. (1983). *See* Kircher, *Federal Product Legislation and Toxic Tort: The Defense Perspective*, 28 VILL. L. REV. 1116 (1983); Phillips, *The Proposed Federal Product Liability Statute from the Toxic Tort Plaintiff's Perspective*, 28 VILL. L. REV. 1156 (1983); Schwartz & Means, *The Need for Federal Product Liability and Toxic Tort Legislation: A Current Assessment*, 28 VILL. L. REV. 1088 (1983); Note, *Proposed Federal Product Liability Legislation—A Summary and Analysis*, 1 J. PROD. L. 103 (1982).

32. S. 44, 98th Cong., 1st Sess., § 3(c) (1983). The federal act would eliminate all state products, negligence, and breach of express or implied warranty actions for damages caused by a manufactured product.

33. *Id.* § 4(a).

34. *Id.* § 5(b).

35. *Id.* § 2(8).

36. Conversations with Stanley R. Rolfe, Ross H. Forney Distinguished Professor of Engineering, Chairman of the Department of Civil Engineering, University of Kansas (1983 and 1984).

37. For example, the American Institute of Steel Construction (AISC), the Concrete Reinforcing Steel Institute (CRSI), the American Society of Civil Engineers (ASCE), and the American Society for Testing and Materials (ASTM) all participate in ongoing structural research.

ticing engineers. Some of this research, like the development of the space frame, may transcend fundamental structural concepts. Other research refines accepted principles or demonstrates the need to consider alternative or additional design factors. This advanced research is typically the subject of professional research symposia, but usually would not be found in innovative structural design.[38]

Once cutting edge research is proven and generally accepted by professional associations, it becomes part of the second, "open literature" horizon. Typically the research engineer will present a paper formalizing his findings at a professional society meeting. Many new theories are submitted to the American Society for Civil Engineers (ASCE) committees, which review the underlying research. Papers deemed worthy are then published.[39] By publishing the research, the professional society impliedly gives the findings its "stamp of approval."

Publication of a new proposal, however, does not yet signify total acceptance by the profession. For this reason, professional journals encourage, solicit, and print responses to published papers as a medium for active dialogue between researchers and practitioners. Moreover, contrary articles may appear in the journals. It is only after a period of maturation following publication and testing in the literature, then, that the third horizon of "professionally accepted knowledge" arises. Proof of acceptance is inferred from publication of corroborating articles as well as from the absence of effective refutation. This third level defines the upper limit of knowledge employed by quality structural engineers who keep abreast of advances in the profession.

Finally, the fourth and bottom level of knowledge, the "undergraduate" horizon, encompasses the design information necessary to complete a competent (by current legal standards), traditional structural design. Presumably, all engineers holding a bachelor of science degree in civil engineering have a basic grasp of statics, dynamics, strength of materials, basic design concepts, and industry design manuals.[40] They do not, however, have

38. "A construction project should not be a design professional's laboratory . . . ." Rubin & Goldberg, *Foundation Failures and Rehabilitation*, 3 CONSTR. LAW. 10 (1982).

39. For examples of ASCE Publications, see CIV. ENGINEERING; J. STRUCTURAL ENGINEERING; J. ENGINEERING MECHANICS; and J. CONSTRUCTION DIVISION.

40. *See* AMERICAN CONCRETE INSTITUTE, ACI MANUAL OF CONCRETE PRACTICE (1984); AMERICAN INSTITUTE OF STEEL CONSTRUCTION, MANUAL OF STEEL CONSTRUCTION (8th ed. 1980); AMERICAN SOCIETY FOR TESTING & MATERIALS,

either the actual design experience or understanding of new concepts displayed by a licensed professional engineer practicing at the forefront of available knowledge.

These four horizons illustrate the movement of a new design concept or advance in knowledge from the time of its inception at the cutting edge, through its publication in open literature, its acceptance by the profession, to final promulgation in design codes and undergraduate curricula. Each state embodies successes, failures, and refinements. It is from this continuum that the crucial legal issue flows: *when* in the development of structural knowledge is an engineer expected to know, understand, and incorporate new design principles or methodologies into his structures?

Historically, the law has required the engineer to exercise only "ordinary and reasonable skill usually exercised by one of that profession" in order to avoid liability for professional negligence.[41] This standard, commonly known as "the professional standard,"[42] corresponds to the "custom" definition of state of the art found in negligence-based products liability actions. It requires only that the engineer use the expertise found at the undergraduate horizon. Thus, the structural engineer can defend a negligence action by proving that he designed at the level of the average practitioner, which may only require proof that his design incorporated industry-standard design codes and undergraduate-level expertise. By contrast, the strict products liability definition of state of the art would encompass all structural knowledge and expertise practically and technically feasible for any design. Knowledge of this sort would be drawn from the middle two horizons of our scheme.

As an alternative to the foregoing, our suggested four-tiered stratification would place the "state of the art" for the structural engineer at the third, "professionally accepted knowledge" horizon, one step up from the lowest, undergraduate level. In our definition, state of the art incorporates scientific and engineering advances known to result in better and safer structures. Our pro-

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1984 ANNUAL BOOK OF ASTM STANDARDS; CONCRETE REINFORCING STEEL INSTITUTE, CRSI HANDBOOK (2d ed. 1975).

41. Major v. Leary, 241 A.D. 606, 606, 268 N.Y.S. 413, 414 (1934). *See* Seiler v. Levitz Furniture Co., 367 A.2d 999, 1007-08 (Del. 1976) (standard of "reasonable and ordinary diligence"). *See also* Conklin v. Cohen, 287 So. 2d 56, 61 (Fla. 1973); Bodin v. Gill, 216 Ga. 467, 472, 117 S.E.2d 325, 330 (1961).

42. *See* J. SWEET, LEGAL ASPECTS OF ARCHITECTURE, ENGINEERING, AND THE CONSTRUCTION PROCESS 833-38 (2d ed. 1977) (applicability of the "professional" standard of care to design professionals).

posal would require engineers to be cognizant of, and to incorporate into their designs, advances which had reached the level of professionally accepted knowledge. Before explaining our rationale for this proposal, a general review of the context and results of litigation against design engineers is appropriate.

III. CIVIL ACTIONS AGAINST THE ENGINEER

The typical building project is initiated by a prospective owner, who contracts with an architect for the development of the project's design.[43] The architect will then subcontract with various specialty engineers, including the structural engineer.[44] Together they develop the project drawings and specifications which form the basis for the contractor's bid for construction on an entirely separate contract with the owner. The successful bidder also subcontracts for specialty labor and materials. Thus the owner stands at the apex of a triangular contractual relationship, one leg of which represents the architect's design contract, and the other leg of which represents the general contractor's construction contract. In projects not involving an architect, the structural engineer occupies the architect's position on the triangle.[45]

Design-induced structural failure may result in engineer liability. The owner, with whom the engineer may or may not be in contractual privity, may have a cause of action to recover for economic loss.[46] An injured worker or bystander, with whom there is clearly no contractual privity, may have a claim for economic loss and personal injury.[47] The injured party's choice of remedy will depend on appropriate evaluation of contract law, tort law,[48] and statutes of limitations.[49]

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43. 2 AMERICAN INSTITUTE OF ARCHITECTS, ARCHITECT'S HANDBOOK OF PROFESSIONAL PRACTICE, Document B-141 (1977 ed.) [hereinafter cited as AIA].

44. 2 AIA, *supra* note 43, Document C-141, art. 1 (1979 ed.); NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, Document 1910-10 (1980 ed.).

45. Architects usually design buildings and are not involved in bridge, offshore drilling rig, and television tower design.

46. For a discussion of the design engineer's potential liability to the owner, see *infra* notes 50-67 and accompanying text.

47. For a discussion of the design engineer's potential liability to third parties such as injured bystanders, see *infra* note 68 and accompanying text.

48. *See infra* notes 50-68 and accompanying text.

49. In the late 1960's, the AIA, the NSPE, and the Associated General Contractors lobbied state legislatures for the enactment of special statutes of limitation or repose for builders of structures on real property. *See* Comment, *Recent Statutory Developments Concerning the Limitations of Actions Against Architects, Engineers, and Builders*, 60 KY. L.J. 462, 464 (1972); Comment, *A Defense Catalogue for the*

A. *Choice of Remedy*

1. *Engineer in Privity with Owner*

The law is well settled that a project owner in contractual privity with the structural engineer can sue for economic loss arising from a breach of contract.[50] In order to ascertain whether there has been such a breach, however, the factfinder must determine what the engineer was contractually obligated to do. Without express contractual language to guide them,[51] the courts' interpretations of the engineer's contractual duty have been "infected" with a tort standard.[52]

Although the engineer's design responsibility arises purely as

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Design Profession, 45 UMKC L. REV. 75, 91-96 (1976). Forty-six state legislatures eventually passed or amended statutes with limitations ranging from three to twenty years, although twelve statutes were later held unconstitutional. For an accurate accounting of the statutes and their current status, see *Statutes of Limitation for the Design Professions*, A/E Legal Newsletter (V.O. Shinnerer Co. Jan. 1983 Special Supp. No. 1, 3).

Special statutes of limitations for engineers, architects and builders generally run from the time of substantial completion of construction, not from final performance of the contractual duties or the date of injury. *See, e.g.*, COLO. REV. STAT. § 13-80-127 (Supp. 1983) (suits against engineers and architects must commence within two years of the time the claim arises and "in no event . . . more than ten years after the substantial completion of the improvement"). Where traditional tort statutes apply, the statute will generally run from the date of substantial injury. *See, e.g.*, KAN. STAT. ANN. § 60-513 (1983) (tort actions must be brought within two years from the date of substantial injury).

50. *See* RESTATEMENT (SECOND) OF CONTRACTS § 347 (1981). Section 347 embodies the accepted legal principle that a party to a contract injured as a result of a breach of the contract has a right to damages based on his expectation interest as measured by:

> (a) the loss in the value to him of the other party's performance caused by its failure or deficiency, plus
> (b) any other loss, including incidental or consequential loss, caused by the breach, less
> (c) any cost or other loss that he has avoided by not having to perform.

Id.

51. Although the AIA and NSPE standard contract documents between owner and design professional carefully define those *duties* of the architect or engineer, neither attempts to define the *manner* of performance in more than vague terms. For example, the architect is charged with becoming "generally familiar with the progress and quality of the [w]ork" in determining if the work is proceeding in accordance with the contract documents. *See* AIA, *supra* note 43, Document B-141, ¶ 1.5.4; NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, Document 1910-1 ¶ 1.6.2 (1979 ed.) [hereinafter cited as NSPE]. Neither contract requires the professional to use standard design manuals or formulae; minimum competence is assumed.

52. Note, *Architectural Malpractice: A Contract-Based Approach*, 92 HARV. L. REV. 1075, 1089 (1979) (citing Straus v. Buchman, 96 A.D. 270, 273, 89 N.Y.S. 226, 228 (1904), *aff'd mem.*, 184 N.Y. 545, 76 N.E. 1109 (1906); White v. Palley, 119 Or. 97, 99-100, 247 P. 316, 317 (1926)).

a matter of contract, a majority of jurisdictions uphold liability in tort for breach of a contractual duty whenever it involves a foreseeable, unreasonable risk of harm to the interests of the owner:[53]

> If a defendant may be held liable for the neglect of a duty imposed on him, independently of any contract, by operation of law, *a fortiori* ought he to be held liable when he has come under an obligation to use care as the result of an undertaking founded on a consideration. Where the duty has its roots in contract, the undertaking to observe due care may be implied from the relationship . . . .[54]

Thus, the owner in privity of contract with the engineer usually has available to him both contract and tort remedies.

2. *Engineer Not in Privity with Owner*

Although the owner may contract directly with the engineer, it is more probable that he will contract with an architect and allow the architect to execute independent contracts with structural and mechanical engineers as well as interior and landscaping consultants.[55] In such a case, the owner's lack of privity with the engineer raises an impediment to actions both in contract and in tort. Under traditional contract law, the owner, absent privity, cannot sue for breach of contract unless he is an intended third party beneficiary[56] of the engineer's agreement with the architect.[57]

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53. *See generally* PROSSER AND KEETON ON THE LAW OF TORTS § 92, at 55 (W. Keeton 5th ed. 1984) [hereinafter cited as PROSSER AND KEETON].

54. Flint & Walling Mfg. Co. v. Beckett, 167 Ind. 491, 498, 79 N.E. 503, 505 (1906).

55. *See supra* notes 43-45 and accompanying text.

56. *See* Waterford Condominium Ass'n v. Dunbar Corp., 104 Ill. App. 3d 371, 432 N.E. 2d 1009 (1982) (condominium owners who were not in privity with the developer could not bring suit in contract or implied warranty unless they could demonstrate that they, as subsequent purchasers, were the intended beneficiaries of the developer's contract with the original purchaser).

The Second Restatement of Contracts defines a beneficiary of a promise as an intended beneficiary if recognition of a right to performance in the beneficiary is appropriate to effectuate the intention of the parties and the circumstances indicate that the promisee (architect) intends to give the beneficiary (owner) the benefit of the proposed performance. RESTATEMENT (SECOND) OF CONTRACTS § 302 (1981). *See also* J. CALAMARI & J. PERILLO, CONTRACTS § 17-2 (1982).

57. *Cf.* Holiday Dev. Co. v. J.A. Tobin Constr. Co., 219 Kan. 701, 549 P.2d 1376 (1976) (subcontractor or materialman may obtain a personal judgment against owner where there was privity of contract or a direct promise to pay the subcontractor in the owner's contract with the architect). *See generally* 4 A. CORBIN, CORBIN ON CONTRACTS § 774 (1964).

Moreover, some courts will not recognize a tort action for economic injury absent privity of contract.[58] Although the landmark *MacPherson v. Buick Motor Co.*[59] decision and its progeny have abrogated the privity doctrine for personal injuries,[60] most project owners will not suffer personal injury as a result of structural failure. Thus, the owner not in privity with the engineer might be left without a tort cause of action for negligent performance of the engineer's contractural duties.

A growing number of jurisdictions,[61] however, refuse to recognize privity as a defense to economic injury actions arising from a design professional's conduct unless the plaintiff is beyond the foreseeable scope of harm.[62] The owner's position at the apex of the construction project triangle clearly places him within this

58. *See, e.g.*, Peyronnin Constr. Co. v. Weiss, 137 Ind. App. 417, 208 N.E.2d 489 (1965) (complaint by contractor against engineers for economic loss suffered as a result of engineers' negligence did not state a cause of action because the contractor failed to show a contractual relation between itself and the engineers); Delta Constr. Co. v. City of Jackson, 198 So. 2d 592 (Miss. 1967) (denying recovery for economic loss in the absence of privity of contract).

59. 217 N.Y. 382, 111 N.E. 1050 (1916).

60. *See* Montijo v. Swift, 219 Cal. App. 2d 351, 353, 33 Cal. Rptr. 133, 134-35 (1963) (privity of contract not required in an action to recover damages for physical injuries); Paxton v. Alameda County, 119 Cal. App. 2d 393, 259 P.2d 934 (1953) (without discussing issue, court affirmed recovery for injuries despite lack of privity); Inman v. Binghamton Hous. Auth., 3 N.Y.2d 137, 144, 164 N.Y.S.2d 699, 703, 143 N.E.2d 895, 898-99 (1957) (those who plan and build a defective improvement on real estate are liable for physical injuries resulting from the defect, regardless of privity of contract). *See generally* Note, *Liability of Architects and Engineers to Third Parties: A New Approach*, 53 NOTRE DAME LAW. 306, 307-09 (1977).

61. E.C. Ernst, Inc. v. Manhattan Constr. Co., 551 F.2d 1026 (5th Cir.) (architect liable for economic injury to contractor), *reh'g denied in part and granted in part*, 559 F.2d 268 (5th Cir. 1977), *cert. denied*, 434 U.S. 1067 (1978); Detweiler Bros., Inc. v. John Graham & Co., 412 F. Supp. 416 (E.D. Wash. 1976) (privity of contract not necessary in order for contractor to maintain a tort action against architect); Cooper v. Jeune, 56 Cal. App. 3d 860, 128 Cal. Rptr. 724 (1976) (right of recovery against negligent architect by those not in privity of contract with him extends to economic loss); A.R. Moyer, Inc. v. Graham, 285 So. 2d 397 (Fla. 1973) (third party general contractor has right of recovery in tort against architect or engineer despite lack of privity); Redarowicz v. Ohlendorf, 95 Ill. App. 3d 444, 420 N.E.2d 209 (1981), *aff'd in part*, 92 Ill. 2d 171, 441 N.E.2d 324 (1982) (builder liable to subsequent purchasers for economic loss resulting from latent defects in construction); Kristek v. Catron, 7 Kan. App. 2d 495, 644 P.2d 480 (1982) (purchaser of a residence may recover damages for economic loss caused by negligence of builder despite lack of privity); Craig v. Everett M. Brooks Co., 351 Mass. 497, 222 N.E.2d 752 (1967) (privity is not a requirement for recovery for economic loss caused by contractor's negligence in performing his duty); McMillan v. Brune-Harpenau-Torbeck Builders, 8 Ohio St. 3d 3, 455 N.E.2d 1276 (1983) (privity of contract is not a necessary element in negligence action for economic injury).

62. *See* J. SWEET, *supra* note 42, at 730.

scope, thus providing a negligence cause of action for personal and economic injury in some states.

In most suits against structural engineers, a tort remedy will be more advantageous to the injured owner than a contract remedy. Under the widely accepted rule of *Hadley v. Baxendale*,[63] contract damages are limited to those that are foreseeable, either because the result followed in the ordinary course of events or because the party had reason to know of the result at the time the contract was formed.[64] Thus, whether reconstruction costs and loss of use of the property are recoverable under a contract depends upon whether they are foreseeable.[65] By contrast, in tort the owner may recover all damages proximately caused by the tortfeasor's negligence[66] and sometimes even punitive damages are awarded.[67]

3. *Injured Workers and Bystanders*

The employee of the contractor or subcontractor injured during construction, the tea dance participant paralyzed by a failing skywalk, the professional hockey team relocated from a damaged municipal arena, or the corner business showered by a skyscraper's glass might sue the structural engineer but would have no option but to proceed in tort. Absence of privity with the engineer will bar most contract suits[68] and possibly some negli-

63. 156 Eng. Rep. 145 (1854). *See* RESTATEMENT (SECOND) OF CONTRACTS § 351 (1981) (adopting *Hadley v. Baxendale's* forseeability limitation).

64. 156 Eng. Rep. at 151.

65. *See* English Village Properties, Inc. v. Boettcher & Lieurance Constr. Co., 7 Kan. App. 2d 307, 316, 640 P.2d 1282, 1290 (1982) (the cost of repair rule is the proper measure of damages). *See generally* 5 A. CORBIN, *supra* note 57, § 1007 (1964); Note, *Economic Loss in Products Liability Jurisprudence*, 66 COLUM. L. REV. 917, 918 (1966). Punitive damages are not recoverable for breach of contract. Kemper v. Rohrich, 508 F. Supp. 444, 449 (D. Kan. 1980). *See* 5 A. CORBIN, *supra* note 57, § 1077, at 438.

66. Crisci v. Security Ins. Co., 66 Cal. 2d 425, 58 Cal. Rptr. 13, 426 P.2d 173 (1967) (injured party may recover all damages proximately caused by a defendant's conduct, whether or not the damages were foreseeable or anticipated); Enlow v. Hawkins, 71 Kan. 633, 81 P. 189 (1905) (tortfeasor liable for all damages which are natural and probable results of his conduct). *See generally* PROSSER AND KEETON, *supra* note 53, § 41.

67. Generally, only a finding of willful, wanton, or reckless conduct will justify an award of punitive damages in tort actions. Atkinson v. Orkin Exterminating Co., 5 Kan. App. 2d 739, 747, 625 P.2d 505, 511 (not a construction case), *aff'd*, 230 Kan. 277, 634 P.2d 1071 (1981). *See generally* PROSSER AND KEETON, *supra* note 53, § 2.

68. The injured worker might want to proceed against the engineer because workers' compensation benefits are the exclusive remedy against his employer/contractor. Recent amendments to some state workers' compensation statutes bar an action against design professionals for injuries on the construc-

gence actions for economic injuries where the plaintiff's harm is outside the scope of foreseeable damage and only weakly connected to the structural failure. Like the owner, however, the injured worker or bystander can generally maintain a cause of action in tort for personal injuries.

B. *The Engineer's Standard of Care*

Unless the engineer's professional services contract with the owner or architect establishes a minimum measure of performance,[69] the law imposes the same standard of care in both contract and tort actions; judicial deference towards professionals interjects a tort standard of care into the contract interpretation.[70] Four distinct measures of the engineer's implied standard of care have evolved, three by judicial definition and one by regulatory action.

1. *The Professional Malpractice Standard*

The seiminal American case, *Coombs v. Beede*,[71] established the early standard of care for architects:

> The undertaking of an architect implies that he possesses the skill and ability . . . sufficient to enable him to perform the required services at least ordinarily and reasonably well . . . . But the undertaking does not imply or warrant a satisfactory result. . . . An error of judgement is not necessarily evidence of a want of skill or care, for mistakes and miscalculations are incident to all the business of life.[72]

The Second Restatement of Torts incorporates the *Coombs* statement into its general standard for all professions, including engineers:

> Unless he represents that he has greater or less skill or knowledge, one who undertakes to render services in the

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tion site unless responsibility for safety is specifically assumed by contract or the injury is caused by negligent preparation of design plans or specifications. *See* Kansas H.B. 2084 (1985) (amending KAN. STAT. ANN. §§ 44-501,-508 (1981 and Supp. 1984)); OKLA. STAT. ANN. tit. 85, § 12 (West Supp. 1984).

69. *See supra* note 51.

70. *See supra* notes 51-52 and *infra* notes 71-83 and accompanying text.

71. 89 Me. 187, 36 A. 104 (1896).

72. *Id.* at 188-89, 36 A. at 105. *See also* T. CLARK, ARCHITECT, OWNER AND BUILDER BEFORE THE LAW 28 (1905); J. WAIT, ENGINEERING AND ARCHITECTURAL JURISPRUDENCE 751 (1898).

> practice of a profession or trade is required to exercise the skill and knowledge normally possessed by members of that profession or trade in good standing in similar communities.[73]

This standard includes the "performance of skills necessary in coping with engineering and construction problems" outside the knowledge of ordinary laymen.[74] It does not, however, set the standard at either the level of the most highly skilled or even the average practitioner, since those below the average may be competent and qualified nonetheless.[75]

Although a majority of jurisdictions have clearly adopted this "professional" standard for architects and engineers,[76] only a

73. RESTATEMENT (SECOND) OF TORTS § 299A (1965).

74. Bartak v. Bell-Galyardt & Wells, Inc., 629 F.2d 523, 529 (8th Cir. 1980). *See also* Aetna Ins. Co. v. Hellmuth, Obata & Kassabaum, 392 F.2d 472, 477 (8th Cir. 1968).

75. *See* RESTATEMENT (SECOND) OF TORTS § 299A comment e (1965). The Restatement drafters emphasized that competence was the critical factor.

> In the absence of any such special representation, the standard of skill and knowledge required of the actor who practices a profession or trade is that which is commonly possessed by members of that profession or trade in good standing. It is not that of the most highly skilled, nor is it that of the average member of the profession or trade, since those who have less than median or average skill may still be competent and qualified.

Id.

76. *See, e.g.*, Bartak v. Bell-Galyardt & Wells, Inc., 629 F.2d 523, 529 (8th Cir. 1980) (standard of care for architects is similar to that for other professionals); General Trading Corp. v. Burnup & Sims, Inc., 523 F.2d 98, 101 (3d Cir. 1975) (standard of reasonable care which applies to architects is the same as the standard which applies to other professionals who furnish skilled services for compensation); Karna v. Byron Reed Syndicate, #4, 374 F. Supp. 687, 689 (D. Neb. 1974) (architect's duty is to exercise care ordinarily exercised by members of his profession); Huber, Hunt & Nicols, Inc. v. Moore, 67 Cal. App. 3d 278, 313, 136 Cal. Rptr. 603, 625 (1977) (architect is required to perform in accordance with a professional standard of care); Yarbro v. Hilton Hotels Corp., 655 P.2d 822, 828 (Colo. 1982) (architect's inspection, supervision and observation of construction involve individual judgment and expertise, which is not susceptible to the quality control standards of a factory); Seiler v. Levitz Furniture Co., 367 A.2d 999, 1007-08 (Del. 1976) (standard of care applicable to professional persons providing services is also applicable to architects and engineers); Morrison v. MacNamara, 407 A.2d 555, 560-61 (D.C. 1979) (one who has special knowledge or skills is required to exercise his superior ability in a manner reasonable under the circumstances); Shepard v. City of Palatka, 414 So. 2d 1077, 1078 (Fla. Dist. Ct. App. 1981) (engineers and architects are to exercise their professional skill and judgment in a reasonable manner and without neglect); H. Elton Thompson & Assocs. v. Williams, 164 Ga. App. 571, 572, 298 S.E.2d 539, 540 (1982) (professionals are obligated to exercise a reasonable degree of care, skill, and ability as is ordinarily exercised by their profession); Lukowski v. Vecta Educ. Corp., 401 N.E.2d 781, 786 (Ind. Ct. App. 1980) (architect required to exercise his special skill and knowledge and use his best professional judgment); Schlitz v. Cullen-Schlitz & Assocs., 228 N.W.2d 10, 17 (Iowa 1975) (architect

handful have adhered to the Restatement's locality rule.[77] The Restatement compares the engineer's performance with that of others in similar "communities," leading to the conclusion that a New York City engineer could be held to a standard different from that of a Lawrence, Kansas, engineer.[78] Judicial reluctance to adopt the locality rule may be due to a desire to apply a national standard when appropriate and to the difficulty of finding competent expert witnesses from a similar practice in a similar locality.[79]

Few appellate courts have identified probative evidence for

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obligated to furnish design and specifications prepared with a reasonable degree of technical skill); Klein v. Catalano, 386 Mass. 701, 715, 437 N.E.2d 514, 525 (1982) (architect does not impliedly guarantee his work is fit for its intended purpose, but rather that he has exercised the level of skill and care required of a member of his profession); Tiffany v. Christman Co., 93 Mich. App. 267, 286, 287 N.W.2d 199, 207 (1979) (architects and engineers held to the level of ordinary skill and care common to their professions); City of Eveleth v. Ruble, 302 Minn. 249, 253, 225 N.W.2d 521, 524-25 (1974) (professional is under a duty to exercise such care, skill, and diligence as others in his profession ordinarily exercise under like circumstances); State *ex rel.* Risk Management Div. of Dep't. of Fin. & Admin. v. Gathman-Matotan Architects & Planners, Inc., 98 N.M. 790, 792-93, 653 P.2d 166, 169 (1982) (professional required to exercise the reasonable skills of his profession); Van Ornum v. Otter Tail Power Co., 210 N.W.2d 188, 201 (N.D. 1973) (architect obligated to exercise the level of learning, skill and care ordinarily exercised by others of his profession); Waggoner v. W & W Steel Co., 657 P.2d 147, 149 (Okla. 1982) (architect does not guarantee perfect results, but rather is liable only for failure to exercise reasonable care and professional skill); Surf Realty Corp. v. Standing, 195 Va. 431, 442-43, 78 S.E.2d 901, 907 (1953) (architect must possess and exercise the degree of care of those ordinarily skilled in his profession); Hull v. Enger Constr. Co.,15 Wash. App. 511, 515, 550 P.2d 692, 695 (1976) (architect held to a professional standard of care); A.E. Inv. Corp. v. Link Builders, 62 Wis. 2d 479, 488-89, 214 N.W.2d 764, 769 (1974) (architect's duty is to exercise the level of care ordinarily exercised by members of his profession). *See also* Coburn v. Lenox Homes, Inc., 186 Conn. 370, 381, 441 A.2d 620, 626 (1982) (a builder is under a duty to exercise that degree of care which a skilled builder of ordinary prudence would have exercised).

77. *See, e.g.*, Clark v. City of Seward, 659 P.2d 1227, 1230 (Alaska 1983) (engineer has duty to exercise that degree of learning and skill ordinarily possessed by engineers practicing in the same locality and under similar circumstances); Nauman v. Harold K. Beecher & Assocs., 24 Utah 2d 172, 179, 467 P.2d 610, 615 (1970) (architects held to the standard of care possessed by architects in their locality). *See also* Seaman Unified Sch. Dist. No. 345 v. Casson Constr. Co., 3 Kan. App. 2d 289, 292-95, 594 P.2d 241, 245 (1979) (applying a community standard to determine whether expert testimony is required). *But see* Paxton v. County of Alameda, 119 Cal. App. 2d 393, 406, 259 P.2d 934, 942 (1953) (deviation from the practice normally followed in a community does not necessarily indicate negligence).

78. *See supra* note 73 and accompanying text.

79. *See* Swan v. Lamb, 584 P.2d 814 (Utah 1978). In this medical malpractice action, the Utah Supreme Court reversed a trial court's refusal to admit expert testimony on a national standard of care. *Id.* at 818. The concurring judge stated that if the critical issue in a case relates to a generally known and

defining the engineer's standard of care. In *Burran v. Dambold*,[80] however, the United States Court of Appeals for the Tenth Circuit established one litmus paper test by holding that a structural engineer's failure to design reinforced concrete picnic shelters in compliance with the New Mexico state building code constituted negligence *per se*.[81] Under *Burran*, then, evidence of a violation of a state statute or municipal ordinance may entitle the plaintiff to a directed verdict without consideration of the standard of care.[82] By contrast, the violation of a private safety code or design manual, such as the National Fire Code or National Electric Code, is admissible but *not* conclusive evidence of negligence.[83] Despite its advantage of predictability, the *Burran* rule establishes a relatively low standard of care since design codes often run five to seven years behind the publication of new knowledge.

2. *An Intermediate Standard—Duty to Stay Informed*

Several courts, either in direct holdings or dicta, have hinted at a higher standard of care for professionals than that of the Restatement by requiring consideration of advances in the profession.[84] First suggested in a medical malpractice case in 1853,[85]

accepted practice, then a "national" standard can be properly applied. *Id.* at 818-19 (Crockett, J., concurring specially).

80. 422 F.2d 133 (10th Cir. 1970) (applying New Mexico law).

81. *Id.* at 135.

82. *Id. See* PROSSER AND KEETON, *supra* note 53, § 36. *See also* Henry v. Britt, 220 So. 2d 917, 920 (Fla. Dist. Ct. App.) (evidence of violation of a statute constituted *prima facie* evidence of negligence), *cert. denied*, 229 So. 2d 867 (Fla. 1969). *See generally* RESTATEMENT (SECOND) OF TORTS § 288C (1965).

83. Evans v. Howard R. Green Co., 231 N.W.2d 907, 913 (Iowa 1975).

84. *See, e.g.*, Miller v. DeWitt, 59 Ill. App. 2d 38, 111, 208 N.E.2d 249, 284 (1965), *modified*, 37 Ill. 2d 273, 226 N.E.2d 630 (1967) (architect must "keep abreast of the improvements of the times"); Brune v. Belinkoff, 354 Mass. 102, 109, 235 N.E.2d 793, 798 (1968) (requiring physician to "tak[e] into account the advances in the profession"); Hansen v. Pock, 57 Mont. 51, 58-59, 187 P. 282, 284 (1920) (physician must recognize and use "the condition of medical or surgical science" at the time); Banner v. Town of Dayton, 474 P.2d 300, 307-08 (Wyo. 1970) (engineer required to be familiar with current developments in his field). *See also* National Cash Register Co. v. Haak, 233 Pa. Super. 562, 335 A.2d 407 (1975). In deciding the negligence of an architect for faulty design of dry wells, the appellate court in *Haak* reversed to allow a geology professor to testify that none of the professor's geologist colleagues, either at the college or elsewhere, would have designed the well system as the architect had, and that he knew this from discussions at meetings with those colleagues. *Id.* at 574, 335 A.2d at 412.

85. McCandless v. McWha, 22 Pa. 261 (1853) (mandating consideration of "the advanced state of the profession at the time" in determining the degree of skill to which a physician should be held). Expanding on the idea of a physician's duty to stay current, the *McCandless* court observed:

Discoveries in the natural sciences for the last half-century have exerted

and repeated in cases concerning malpractice of physicians who failed to use X-rays for diagnoses,[86] the notion of a duty to stay informed has also appeared in a few engineering liability cases. For example, in *Chapel v. Clark*,[87] the architect brought suit to recover professional fees, and the owner counterclaimed for additional construction costs incurred because of the architect's errors or omissions.[88] The Michigan Supreme Court refused to impose an implied warranty on the architect's work and held only that "[t]he law requires the exercise of ordinary skill and care, in the light of *present knowledge*."[89]

Similarly, the Wyoming Supreme Court, in *Banner v. Town of Dayton*,[90] fully reviewed both the standard of care and the sufficiency of evidence in reversing a summary judgment in favor of a consulting engineer. The city had hired the engineer to design and supervise installation of a new city water main. The main subsequently developed numerous leaks from electrolysis-induced corrosion.[91] The supreme court, finding that electrolysis was a "common subject of discussion among the profession at the time" as evidenced by articles in professional journals,[92] held that the engineer failed to meet the minimum standard of care.[93]

This higher standard recognizes *sub silentio* Judge Learned Hand's reasoning in *The T.J. Hooper*,[94] in which the United States Court of Appeals for the Second Circuit held tugboat owners liable for losses incurred during a storm because the tugs were not equipped with radios that would have warned against the impend-

> a sensible influence on all the learned professions, but especially on that of medicine, whose circle of truths has been relatively much enlarged. And besides, there has been a positive progress in that profession resulting from the studies, the experiments, and the diversified practice of its professors. The patient is entitled to the benefit of these increased lights. The physician or surgeon who assumes to exercise the healing art, is bound to be up to the improvements of the day. The standard of ordinary skill is on the advance; and he who would not be found wanting, must apply himself with all diligence to the most accredited sources of knowledge.

Id. at 269.

86. For citations to these cases and a comprehensive discussion of the duty to stay informed in medical malpractice cases, see McCoid, *The Care Required of Medical Practitioners*, 12 VAND. L. REV. 549, 575-81 (1959).

87. 117 Mich. 638, 76 N.W. 62 (1898).

88. *Id.* at 638-39, 76 N.W. at 62.

89. *Id.* at 640, 76 N.W. at 62 (emphasis added).

90. 474 P.2d 300 (Wyo. 1970).

91. *Id.* at 301.

92. *Id.* at 307 n.7.

93. *Id.* at 308.

94. 60 F.2d 737 (2d Cir.), *cert. denied*, 287 U.S. 662 (1932).

ing storm.[95] Noting that an entire profession cannot hide behind "customary" but negligent practices,[96] Judge Hand wrote that

> [t]here are, no doubt, cases where courts seem to make the general practice of the calling the standard of proper diligence . . . . Indeed in most cases reasonable prudence is in fact common prudence; but strictly it is never its measure; a whole calling may have unduly lagged in the adoption of new and available devices. . . . [T]here are precautions so imperative that even their universal disregard will not excuse their omission.[97]

3. *A Strict Liability Standard*

Strict liability provides a second alternative to the "professional" standard of care for structural engineers. Injured owners or third parties could conceivably recover under two strict liability theories: (1) a products liability claim based on a defective condition in the structure; or (2) a warranty claim based on representations made by the engineer. Few courts, however, have allowed recovery against design professionals under either theory.

Strict liability for defective products imposes liability on "sellers" of "products" without fault.[98] Under section 402A of the Second Restatement of Torts, the injured party need only establish that the product exhibits a condition of safety below that imposed by operation of law and that it was expected to and did reach the consumer substantially unchanged.[99] It makes no difference that the seller exercised all possible care in preparing the product.[100] In the construction context, the application of this theory could raise the specter of liability of the structural engineer in two ways, *assuming* that an engineer sells some finished product.

First, if the structural engineer's "product" is the finished building, then he would be liable to the owner for any injury caused by either design or construction errors. The complexity of building projects, the sheer number of construction partici-

95. *Id.* at 739-40.

96. *Id.* at 740.

97. *Id.* (citations omitted).

98. RESTATEMENT (SECOND) OF TORTS § 402A (1965). For a discussion of § 402A and strict liability in products cases, see *supra* notes 24-30 and accompanying text.

99. RESTATEMENT (SECOND) OF TORTS § 402A (1965).

100. *See id.* Section 402A focuses on the safety of the product, not on the conduct of the manufacturer.

pants, and the inherent inability of the engineer to control the construction progress militate against such a broad definition of product. By contrast, if the engineer's "product" is a completed design embodied in drawings and specifications, he could be strictly liable for all injury or loss caused by design error, absent superseding acts of negligence by the general contractor or subcontractors.[101] Under this theory, even if the engineer uses state of the art design knowledge, he could be liable if the structure fails on account of design error.[102]

Despite the intuitive appeal to the public of the products liability approach, courts have unanimously refused to apply the doctrine to engineers[103] unless the engineer participates in the assembly or manufacture of a structure or building component.[104] Courts have recognized that owners or architects hire engineers to provide services, not insurance on the exercise of their professional judgments.[105]

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101. *See* Comment, *Architect Tort Liability in Preparation of Plans and Specifications*, 55 CALIF. L. REV. 1361, 1380 (1967).

102. For example, a design engineer could be strictly liable for the collapse of a novel 1250 foot cylindrical television tower where the design undertaken was "beyond the frontiers of knowledge." *See* Stanton & Dugdale, *Design Responsibility in Civil Engineering Work*, 131 NEW L.J. 583, 585 (1981). Such a case occurred in England where the collapse was due to icing of the stay ropes and "vortex shedding," which is air turbulence creating random pressure on the structure. The unreported opinion of the House of Lords is described in the Stanton and Dugdale article.

103. *See, e.g.*, LaRossa v. Scientific Design Co., 402 F.2d 937, 941-43 (3d Cir. 1968) (distinguishing professional services from consumer goods and refusing to apply strict liability standards to the former on policy grounds); K-Mart Corp. v. Midcon Realty Group, Ltd., 489 F. Supp. 813, 819 (D. Conn. 1980) (doctrine of strict liability does not extend to design and development of buildings); Swett v. Gribaldo, Jones & Assocs., 40 Cal. App. 3d 573, 575-76, 115 Cal. Rptr. 99, 101 (1974) (engineers not liable in the absence of negligence or intentional conduct); Castaldo v. Pittsburgh-Des Moines Steel Co., 376 A.2d 88, 90-91 (Del. 1977) (strict tort liability not imposed against defendants who have provided only professional services); City of Mounds View v. Walijarvi, 263 N.W.2d 420, 424-25 (Minn. 1978) (architectural errors better handled under a cause of action for professional negligence rather than strict liability); Queensbury Union Free Sch. Dist. v. Jim Walter Corp., 91 Misc. 2d 804, 398 N.Y.S.2d 832 (Sup. Ct. 1977) (no action in strict liability for damages resulting from an architect's services).

104. *See* Abdul-Warith v. Arthur G. McKee & Co., 488 F. Supp. 306, 310-11 (E.D. Pa. 1980) (engineering firm both designed and built skip bridge for steel blast furnace), *aff'd mem.*, 642 F.2d 440 (3d Cir. 1981).

105. *See* Swett v. Gribaldo, Jones & Assocs., 40 Cal. App. 3d 573, 576, 115 Cal. Rptr. 99, 101 (1974); Gagne v. Bertran, 43 Cal. 2d 481, 489, 275 P.2d 15, 21 (1954) ("Those who hire [experts] are not justified in expecting infallibility, but can expect only reasonable care and competence. They purchase service, not insurance."). *But see* Comment, *supra* note 101, at 1386 (most building owners simply "assume that the architect's plans will not be defective," and "[t]he

The second basis for strict liability could arise from an engineer's express or implied representations that the structure will be fit for its intended purpose. Although the implied warranty action has gained support as an additional form of consumer protection in residential construction,[106] very few courts have allowed the doctrine to operate absent the engineer's actual knowledge of unique performance criteria. For example, in *Bloomsburg Mills, Inc. v. Sardoni Construction Co.*,[107] the contract between the owner and architect specified temperature and high humidity requirements necessary to the owner's weaving business.[108] The architect specified a built-up roof with a vapor barrier to protect against roof-surface condensation, but the barrier failed and the roof had to be replaced.[109] The Pennsylvania Supreme Court, while expressly adopting the professional standard, stated: "While an architect is not an absolute insurer of perfect plans, he is called upon to prepare plans and specifications which will give the structure so designed reasonable fitness for its intended use, and he impliedly warrants their sufficiency for that purpose."[110] The implied warranty theory could bode an ominous standard for design-build projects,[111] where in-house "professional" engineering work merges with construction into a finished product.

4. *A Regulatory Standard—Gross Negligence*

The Environmental Protection Agency (EPA) has promul-

law should protect those 'thoughtless' clients from their own lack of foresight" by imposing strict liability on the design professional).

106. *See* Kristek v. Catron, 7 Kan. App. 2d 495, 644 P.2d 480 (1982) (purchaser of a residence may recover property damage resulting from builder's conduct under theory of implied warranty); Weeks v. Slavik Builders, Inc., 24 Mich. App. 621, 180 N.W.2d 503 (implied warranty of fitness for use extends to purchaser of a new residential dwelling), *aff'd*, 384 Mich. 257, 181 N.W.2d 271 (1970); Schipper v. Levitt & Sons, Inc., 44 N.J. 70, 207 A.2d 314 (1965) (plaintiff asserting claim against builder of residential dwelling on theory of implied warranty has burden of proving existence of a defect at the time of sale).

107. 401 Pa. 358, 164 A.2d 201 (1960).

108. *Id.* at 359, 164 A.2d at 202.

109. *Id.*

110. *Id.* at 361-62, 164 A.2d at 203. *See also* Chrischilles v. Griswold, 260 Iowa 453, 460, 150 N.W.2d 94, 99 (1967) (architect bound to produce a building of the kind called for, without marked defects in character, strength, or appearance); Tamarac Dev. Co. v. Delamater, Freund & Assocs., 234 Kan. 618, 622-23, 576 P.2d 361, 365 (1984) (duty of architect "gives rise to an implied warranty of workmanlike performance").

111. *See* J. SWEET, *supra* note 42, at 700 ("[S]ometimes design and construction are combined. This can be accomplished by a large firm which supplies both functions.").

gated regulations that establish a special federal standard of care for consulting engineers on new waste water treatment plant funded under the Clean Water Act.[112] The EPA encourages owners to incorporate new "innovative" methods of sewage treatment in EPA-funded plants.[113] In return, the consulting design engineers are given contractual immunity from liability for innovative designs in the absence of gross negligence.[114] This lower standard has not been adopted in other agency design contracts and remains an unlikely candidate for projects involving great safety risks to the public.[115]

IV. DEFINING AN APPROPRIATE STANDARD OF CARE

Identification of the four horizons of engineering design knowledge and information prompts the pressing question of whether the courts are applying the appropriate standard of care to engineers. As Judge Hand recognized in *The T.J. Hooper*, courts will not permit an entire profession to absolve itself from liability by adopting negligent methods as its industry standard.[116] Certainly no American court has gone as far toward immunizing the engineer as one English court did in 1853:

> [I]f the building is of an ordinary description, in which [the engineer] has had abundance of experience, and it proved a failure, this is evidence of want of skill or attention. But if the building is out of the ordinary course, and you employ him about a novel thing, . . . if it has not had the test of experience, *failure may be consistent with skill.*[117]

A court's choice between strict liability and liability based on the engineer's negligence reflects a decision to evaluate either the fin-

112. 33 U.S.C. §§ 1251-1376 (1982). The act authorizes the EPA to finance construction of waste treatment works, and to promulgate standards for their construction. *See* 40 C.F.R. §§ 35.900-.970 (1982).

113. 40 C.F.R. § 35.908(a) (1983).

114. 40 C.F.R. § 35.900 app. C-1 § 2(d) (1983). This immunity extends only to the use of innovative processes or techniques, not to standard design and construction processes. *Id.*

115. *See* Clovis Heinsath & Assocs., NASA B.C.A. No. 180-1 ¶ 16,133 (1983) (adopting the "locality" rule, a standard different from the innovative design immunity proposed by the EPA for an engineering design error case).

116. For a discussion of the *Hooper* decision, see *supra* notes 94-97 and accompanying text.

117. Turner v. Garland & Christopher, 2 Hudson's B.C. 127 (1853), *quoted in* W. BALL, THE LAW AFFECTING ENGINEERS 53 (1909) (emphasis added).

ished product or the process employed in the design.[118] The following discussion suggests a rationale for adopting a negligence theory of liability for engineers and proposes an appropriate standard of care.

A. *A Rejection of Strict Liability*

Despite the forceful arguments of two student commentators,[119] courts have correctly refused to apply either absolute or strict liability to design professionals.[120] Both legal and policy arguments support this position. First, a supplier of services is expressly outside the scope of section 402A.[121] Even those courts that recognize strict liability in the residential construction context, thus blurring the fine line between buildings and consumer products, continue to distinguish the engineer's service contract from the design-build contract.[122] Second, a negligence standard is more consistent with the reasonable expectations of the owner and engineer because of the engineer's inherent inability to control the entire construction process.[123] By contrast, an automobile manufacturer typically has absolute control of the component assembly process from frame to custom interior.

Third, the policy bases underlying strict products liability generally do not apply to structural engineers. For example, the product owner's difficulty in proving a manufacturer's negligent design of a mass-produced product is not present when a single structural engineering firm designs a single structure for a known

118. *See* J. SWEET, *supra* note 42, at 111-12.

119. Comment, *supra* note 101 at 1379-91 (current means of shifting risk of loss, such as contractual arrangements or insurance, are inadequate to protect the rights of the injured); Note, *Products and the Professional: Strict Liability in the Sale-Service Hybrid Transaction*, 24 HASTINGS L.J. 111, 129-131 (1972) (advocating strict liability in hybrid transactions as a way of balancing the tremendous benefits which accrue to professionals against their responsibility to those harmed by their failure to perform).

120. *See supra* notes 103-10 and accompanying text. In the construction context, absolute liability would render an engineer liable for *any* structural failure, even one caused by the negligence of a third party—like a steel erector leaving a critical connection unbolted. By contrast, the erector's intervening act would supersede an engineer's liability under a general products liability theory. *See generally* PROSSER AND KEETON, *supra* note 53, § 102.

121. RESTATEMENT (SECOND) OF TORTS § 402A, comments e & f (1965). *See* Abdul-Warith v. Arthur G. McKee & Co., 488 F. Supp. 306, 310 & n.3 (E.D. Pa. 1980) (§ 402A does not extend to parties who provide only services), *aff'd mem.*, 642 F.2d 440 (3d Cir. 1981).

122. For an explanation of the design-build contract, see *supra* note 111 and accompanying text.

123. *See* Note, *Liability of Design Professionals—The Necessity of Fault*, 58 IOWA L. REV. 1221, 1246 (1978).

owner. Similarly, although the threat of strict products liability may encourage manufacturers of mass-produced products to develop safer manufacturing processes, it has little effect on an engineer with no direct control over fabrication and construction methods.[124] Too, products liability's policy of spreading the risk of injuries among numerous purchasers by incremental additions to product costs is inappropriate in the structural engineering context. As one court observed:

> If every facet of structural design consisted of little more than the mechanical application of immutable physical principles, we could accept the rule of strict liability which the city proposes. But even in the present state of relative technological enlightenment, the keenest engineering minds can err in their most searching assessment of the natural factors which determine whether structural components will adequately serve their intended purpose. Until the random element is eliminated in the application of architectural sciences, we think it fairer that the purchaser of the architect's services bear the risk of such unforeseeable difficulties.[125]

Although the *owner* may be strictly liable for defects in his building premises,[126] he also gets the direct benefits of the building. The engineer does not have numerous purchasers among whom the risk may be spread; the risk of structural failure can be passed only to the owner in the form of increased design fees.

A fourth reason courts have not applied strict or absolute liability is that mass-produced products, even automobiles and aircraft, can be effectively modeled before production to predict

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124. The engineer's slipping grasp on construction practices is perhaps most evident in structural steel detail design and fabrication. As limited design funds force more detail work from the engineer's board squarely onto the fabricator, fast track scheduling and persistent construction managers concentrate the engineer's connection review time. Concurrently, however, engineers have adopted review stamps that disclaim or obfuscate responsibility for connection design and strength. Dallaire & Robison, *Structural Steel Details: Is Responsibility a Problem?* CIV. ENGINEERING—ASCE, Oct. 1983, at 51.

125. City of Mounds View v. Walijarvi, 263 N.W.2d 420, 424 (Minn. 1978) (footnote omitted).

126. *See* Memorandum of Law in Support of Plaintiffs' Motion for Partial Summary Judgment, at 28, *In re* Federal Skywalk Cases, No. 81-0945 (W.D. Mo., filed May 4, 1983). *See also* Ursin, *Strict Liability for Defective Business Premises—One Step Beyond* Rowland *and* Greenman, 22 UCLA L. REV. 820, 823 (1974) (strict liability for owners serves the policy of spreading the risk of accident losses because the owner can insure against the risk of loss and then pass the cost of insurance on to his customers).

accurately all operational characteristics. This is not so in the case of structures. While some testing is possible, the sheer size of buildings and other structures make impossible the destructive testing of all connections, components, and interfaces between the structure and building fabric.

Finally, the formulation of the products liability state of the art defense demonstrates the doctrine's inapplicability to design engineers.[127] Commentators define the product's state of the art in terms of economic considerations like cost, utility, and ease of assembly, in addition to technological factors like strength of materials and availability of alternative designs.[128] For buildings, however, those same economic factors must be accommodated without sacrificing the integrity of the structure and imperiling the public; cost considerations cannot compromise the structural integrity of a design.[129]

B. *A Rejection of the Professional Standard*

The "professional" standard,[130] established by reference to care exercised by other engineers, is likewise an inappropriate measure of the engineers' performance. This objective standard, keyed to the knowledge and skill "ordinarily possessed and exercised," establishes only the minimum professionally acceptable conduct.[131] Under the "reasonable man" concept, negligence law requires prudent conduct—a standard somewhat above average.[132] Yet for professionals, the courts apparently consider a "prudent" standard too high.[133] This may be so because proof of

127. For an explanation of the various formulations of the state of the art defense, see *supra* notes 27-30 and accompanying text.

128. *See generally* O'Donnell, *supra* note 26; Raleigh, *supra* note 26.

129. *See Behind All Those Roof Collapses*, Christian Science Monitor, Jan. 31, 1978, at 1, col. 5. This article states that structural engineers are angry at being blamed for collapses they feel are traceable to "[c]ost-cutting caused by competitive bidding at design, materials, construction, and maintenance stages." *Id.* The article continues:

> [T]he fact is that in a competitive business, buildings are designed to cope with 1-in-20 year conditions, not 1-in-50, or 1-in-100 . . . . Faults show up particularly, say engineers, in the bulk-ordered roofs used by discount supermarket chains which count every penny to make their operations pay.

Id. at 22, cols. 1-3.

130. *See supra* notes 71-83 and accompanying text.

131. Curran, *Professional Negligence—Some General Comments*, 12 VAND. L. REV. 535, 538 (1959). *See also* RESTATEMENT (SECOND) OF TORTS § 299A comment b (1965).

132. Curran, *supra* note 131, at 538.

133. *See supra* notes 71-83 and accompanying text.

compliance or noncompliance with acceptable practice is difficult, and because the expert is required to testify as to general practices in a profession without clear guidelines.[134]

C. *A New Standard: The Informed Engineer*

The missing element in present formulations of the professional standard of care for engineers is the place of scientific advances in the engineer's designs. Many design professionals disdain new techniques, unless the technique either lowers project and design costs or enables award-winning cutting-edge designs. This same conservatism exists in other professions as well. A pioneer doctor put it this way:

> Researchers should be quarantined both for their own good and for the good of the student. . . . The fact should be recognized that the average doctor never does catch up with what the researcher is doing. We doctors should be spared the agony of the scientific delivery room and should be allowed to hold the baby only after the nurse has him all polished up and dressed.[135]

So too, practicing engineers may disdain newborn theories until they are polished up and dressed in an undergraduate textbook cover. Dean Prosser, however, suggests that the law should take a different position:

> [A]s scientific knowledge advances, and more and more effective tests become available, what was excusable ignorance yesterday becomes negligent ignorance today.[136]

In the field of medical practice, for example, one court imposed upon physicians a general duty to stay informed of present day scientific knowledge.[137] Another court required physicians to read journals, solicit product data from manufacturers' representatives, listen to tape recorded digests of current literature, and

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134. For a discussion of the difficulties involved in expert testimony to establish a standard of care in a professional negligence case against a design professional, see Annot., 3 A.L.R. 4th 1023 (1981).

135. A. HERTZLER, THE HORSE AND BUGGY DOCTOR 46 (1938).

136. PROSSER AND KEETON, *supra* note 53, § 32 (footnote omitted).

137. *See* Swan v. Lamb, 584 P.2d 814, 817 (Utah 1978). *See also* McCoid, *supra* note 86, at 575-81.

attend postgraduate courses and professional seminars.[138] Such jurisdictions essentially have abrogated the locality rule, modified the professional standard, and prevented the professional from practicing in an out-of-date vacuum. Although dicta of some courts indicate a willingness to adopt an "informed engineer" standard,[139] all courts should expressly recognize and apply this higher standard of care to structural engineers. The engineer should be expected to incorporate into his designs applicable advances in the profession that have reached the "professionally accepted" horizon of knowledge.[140]

Under this standard the engineer is not held responsible for cutting-edge research or technology that is not widely disseminated to practitioners, but only for accepted techniques published in professional journals and accepted by the profession after a period of time.[141] This national standard of the informed engineer avoids the pitfalls of strict liability, but at the same time prevents wholesale engineering practice at the "undergraduate" horizon of minimum acceptable professional conduct.[142] The "informed" standard provides a demonstrable level of conduct provable by objective facts.

The advent of the Architecture and Engineering Performance Center (AEPIC)[143] at the University of Maryland and the vast dissemination of structural research support the notion of changing the standard. AEPIC opened in 1982 to collect, analyze and disseminate information on the performance of structures in an effort to prevent perpetuation of past design and construction errors. The goal of AEPIC is to provide practicing engineers access to a computer database of case files on successful and unsuccessful structures, photographic files, and hard-bound dossiers before they commence a similar design.

Judicial adoption of this new, informed standard would not, of course, be without problems. Defendant engineers, their lawyers and insurers will certainly make two arguments that test our proposed standard. First, the level of "professionally accepted

138. Pederson v. Dumouchel, 72 Wash. 2d 73, 78-79, 431 P.2d 973, 977-78 (1967).

139. *See supra* notes 84-97 and accompanying text.

140. *See supra* text following note 39.

141. *See supra* note 39 and accompanying text.

142. *See supra* note 40 and accompanying text.

143. AEPIC is an educational branch of the Schools of Architecture and Civil Engineering at the University of Maryland. The National Science Foundation provides funds for additional research and analysis.

knowledge" is never clear and possibly incapable of proof. Numerous journals publish matters relating to structural engineering practice;[144] one might ask which of these should be surveyed to determine acceptance of a theory by the profession? In case of conflicting theories, which should be accorded more weight?[145] Furthermore, problems of courtroom proof that the engineer's design either did or did not measure up to the "informed engineer" standard remain as difficult as the problems of proof under the current professional standard.[146]

A second, fundamental objection to our standard arises on a philosophic plane. Even with proof that a theory is accepted by the profession at the time the disputed design was conceived, that theory is not necessarily a rigid immutable law for all times. The

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144. *See supra* note 39 and accompanying text. Recent developments may also be reported in AM. WATERWORKS A.J., J. ENGINEERING MECHANICS, and PUB. WORKS. Construction material trade associations, such as the American Iron and Steel Institute, the American Institute of Steel Construction, the American Concrete Institute, and the Portland Cement Association, also publish professional journals.

145. The absence of published contradictory articles is only implied support for a theory; if incorrect, a theory remains incorrect whether refuted or not, and many incorrect theories are published. One observer of the scientific method has stated:

> The second continuum is the scale of scientific competence. It also has its extremes—ranging from obviously admirable scientists, to men of equally obvious incompetence. . . . Scientific journals today are filled with bizarre theories. . . . If anything, scientific journals err on the side of permitting *questionable* theses to be published, so they may be discussed and checked in the hope of finding something of value.

Gardner, *In the Name of Science*, in SCIENCE: METHOD AND MEANING 34-37 (S. Rapport & H. Wright eds. 1963) (emphasis in original). Thus it would not be wise for courts invariably to draw the inference from an absence of contradictory literature that a published theory is correct and has been accepted by the profession as a whole.

146. One commentator has criticized the professional standard because of problems of proving what is "ordinarily exercised in the profession":

> [E]ven where we are able to obtain professional witnesses for the plaintiff, what is their function? We ask these witnesses to give an "expert opinion" . . . [in court] . . . on whether the defendant's action was in conformity to the skill and learning "ordinarily exercised in the profession," or, whether it was "professionally acceptable conduct." Does any one practitioner know the answer to this? Is there really an answer? Perhaps by some consensus or statistical study answers *might* be obtained. . . . Witnesses . . . who give "opinions" act individually and in an uncontrolled way. Their opinions may not be representative. They represent themselves, really, not "the profession." I wonder if we don't actually have *individuals* judging the defendant and *not* the profession . . . .

Curran, *supra* note 131, at 539 (emphasis in original). Under our proposed standard the problems will remain in proving what constitutes "professionally accepted knowledge."

history of science shows that even in the proclaimed exact sciences such as physics, the principles and laws accepted at any given time are subject to change.[147] As stated by Poincare:

> [N]o particular law will ever be more than approximate and probable. Scientists have never failed to recognize this truth; only they believe, right or wrong, that every law may be replaced by another closer and more probable, that this new law will itself be only provisional, but that the same movement can continue indefinitely, so that science in progressing will possess laws more and more probable, that the approximation will end by differing as little as you choose from exactitude and the probability from certitude.[148]

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147. *See* M. GOLDSTEIN & I. GOLDSTEIN, HOW WE KNOW—AN EXPLORATION OF THE SCIENTIFIC PROCESS (1978). Goldstein and Goldstein use Newton's theorems as an example:

> [Newton's] laws [of motion] could be written in the form of mathematical equations on half a page, and they governed all motions in universe as well as on earth . . . In this century Newton's laws were found to fail when bodies move at very high speeds approaching the velocity of light. New laws that apply to these high speeds were formulated by Einstein. The results of Newton's laws became in turn a special case—the special case when things move slowly.

Id. at 198-99. Another commentator has observed that "the fact is that every theory, however majestic, has hidden assumptions which are open to challenge and, indeed, in time will make it necessary to replace." J. BRONOWSKI, THE ASCENT OF MAN 240 (1973).

148. H. POINCARE, THE FOUNDATIONS OF SCIENCE 341 (1913). *See also* J. BRONOWSKI, *supra* note 147; B. RUSSELL, RELIGION AND SCIENCE 14-15 (1935) (science is always tentative, expecting that modifications in its present theories will sooner or later be found necessary); Weaver, *Imperfections of Science*, in SCIENCE: METHOD AND MEANING 23-24 (S. Rapport & H. Wright eds. 1963) (perfect accuracy is unattainable in any measurement and certainty is impossible in any prediction).

Recent writers in the legal literature seem to find more exactness in engineering and science than do the philosophers of science. For example, the Kansas Supreme Court recently stated:

> [I]t can be said certain professionals, such as doctors and lawyers, are not subject to such an implied warranty. However, an architect and an engineer stand in much different posture as to insuring a given result than does a doctor or lawyer. *The work performed by architects and engineers is an exact science*; that performed by doctors and lawyers is not. A person who contracts with an architect or engineer for a building of a certain size and elevation has a right to expect an exact result.

Tamarac Dev. Co. v. Delamater, Freund & Assocs., 234 Kan. 618, 622, 675 P.2d 361, 365 (1984) (emphasis added). And a recent *American Bar Association Journal* article noted a "cultural difference" between technology and law:

> Both legal and physical precedents are changeable, the first by courts themselves or by legislatures, the second by confirmation of subsequent, differing theory.
>
> Another frequently cited difference in the two cultures turns on

Changes and progressions of scientific understanding affect engineering[149] in two ways: the "laws" of science change, and the methods engineers use to apply science change. Recognizing this, so the argument might go, the law of professional malpractice should not pretend to acknowledge a body of accepted structural engineering knowledge as forever valid. The current "professional standard" may be somewhat arbitrary and difficult of proof, the argument would continue, but at least it is admittedly arbitrary. By contrast, the proposed "informed engineer" standard pretends to embody current knowledge, but such knowledge is admittedly subject to change. The structural engineer, then, who has not incorporated current "accepted knowledge" should not be penalized since today's "accepted" theory may be modified or disproved tomorrow.

A corollary to this second argument arises when a structural design incorporates "accepted" knowledge and practice, but the structure collapses because what was accepted was in fact invalid.[150] Similarly, there are already suggestions in the literature that use of computer-aided design techniques are hurting overall design quality because the structural engineer loses the "feel" for structures and materials.[151] These concerns raise a larger dilemma of whether the law should actively promote progress or suggest restraint in keeping abreast of progress.

Despite these arguments, we adhere to our contention that courts should require the structural engineer to use currently ac-

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concepts of "fact" and "truth." A scientist or engineer must attach a very high probability, say 90-plus percent, to a phenomenon before being willing to move it from the realm of speculation to fact.

The litigation process . . . normally requires only a preponderance of evidence, perhaps something more than 50%, to find "facts" necessary to the resolution of a dispute.

Nyhart & Jones, *What You Don't Know About Technology Can Hurt You*, 69 A.B.A. J. 1667, 1667 (1983).

149. Engineering is defined as "the application of science and mathematics by which the properties of matter and sources of energy in nature are made useful to man in structures, machines, products systems, and processes." WEBSTER'S NEW COLLEGIATE DICTIONARY 375 (1981).

150. The medical literature reports cases where doctors followed recent medical advances too well, only to learn later, for example, of side effects of a particular drug which were not known at the time of use. *See* McCoid, *supra* note 86, at 549, 580-81.

151. AIA, *supra* note 3, at 10 (use of computers hinders engineers' ability to determine whether there was an error in the assumptions upon which calculations are based); Thornton, *Lessons Learned from Recent Long Span Roof Failures*, in LONG SPAN ROOF STRUCTURES 89, 91 (ASCE 1981); Kansas City Star, Oct. 28, 1981, at A-4, col. 6 (statements by chairman of ASCE Commission on Failed and Damaged Buildings).

cepted theories and practices in designing structures. The recent plethora of structural failures, some with loss of life, dictates that the law, like science, should move in the direction of progress. Courtroom proof of liability is difficult under the current standard, but it should be no more difficult or uncertain under our proposal. An objection based on the absence of rigid, immutable scientific laws could be raised against any legal standard. Even design principles taught in undergraduate curricula could be superseded eventually. To concede that scientific theories are never fixed is not to say each is not an improvement over its predecessor.[152]

D. *Defensive Measures*

A review of alternative defensive measures for the practitioner is appropriate, lest engineers and their counsel reject the "informed" standard out of hand as patently unreasonable. Six "office practice" suggestions and one possible legal solution are proposed as available alternatives to limit the impact of the "informed" standard of care.

1. *Office Practices*

First, as a cardinal rule, an engineer must know the limits of his or her capabilities and never undertake more than he or she can professionally—not merely competently—complete.[153] Sec-

152. The interface between law and scientific or technological advances is discussed in a series of articles developed by the National Conference of Lawyers and Scientists and published in the *American Bar Association Journal*. *See* Green, *Should Technology Assessment Guide Public Policy?*, 69 A.B.A. J. 930 (1983) (assessment of the risks, benefits, and costs of technical advancements should be based on democratic principles); Jasanoff & Nelkin, *Science, Technology, and the Limits of Judicial Competence*, 68 A.B.A. J. 1094 (1982) (traditional processes of adjudication are inadequate to handle technological litigation); Markey, *Science and the Law: A Dialogue on Understanding*, 68 A.B.A. J. 154 (1982) (scientific questions should be capable of definitive answers before expert testimony is admitted; courts should not attempt to determine scientific truth); Myrick & Sprowl, *Patent Law for Programmed Computers and Programmed Life Forms*, 68 A.B.A. J. 920 (1982) (development of laboratory life forms underscores the necessity of flexibility in the law regarding scientific advances); Nyhart & Jones, *supra* note 117 (legal decisions are not the best answers to technical questions); Ramo, *Regulation of Technological Activities: A New Approach*, 67 A.B.A. J. 1456 (1981) (all factors, not just harm to the environment, must be considered before regulations are promulgated); Thornton, *Uses and Abuses of Forensic Science*, 69 A.B.A. J. 288 (1983) (the law frequently errs in deeming science a product rather than a process).

153. The codes of ethics of various professional engineering societies adhere to the same rule. For example, the code of the American Society of Civil Engineers says that "[e]ngineers shall perform services only in areas of their competence." AMERICAN SOCIETY OF CIVIL ENGINEERS, CODE OF ETHICS Canon

ond, at least one member of the firm should continually review the professional journals and periodically attend seminars to acquire knowledge of advances prior to their inclusion in design manuals.[154] Third, each design should incorporate a review of all available information on the performance of similar structures based on data obtained through AEPIC or other sources.[155] Fourth, the structural engineer should retain an independent proof engineer to analyze all major designs, not just to check mathematical computations.[156] Fifth, the engineer might request scale model strength tests of innovative designs, components, or member-critical systems like the space frame. Even full-scale testing might be done in some cases.[157] Sixth, the owner and engineer should consider full-time engineering supervision during the erection of critical elements of systems to ensure proper construction sequencing and procedures.[158] This suggestion is made de-

2 (1980). Section 6 of the Code of Ethics of the National Society of Professional Engineers states: "The Engineer will undertake engineering assignments for which he will be responsible only when qualified by training or experience; and he will engage, or advise engaging, experts and specialists whenever the client's or employer's interests are best served by such service." NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, ETHICS FOR ENGINEERS. CODE OF ETHICS § 6. Breach of one of the duties under an ethical code can lead to expulsion from the Society.

154. *See supra* notes 39 & 144.

155. For a discussion of the role AEPIC can play in facilitating dissemination of advances in the engineering field, see *supra* note 143 and accompanying text.

156. *See* Thornton, *supra* note 151, at 91.

157. For example, engineers load tested the space frame roof of the Gerald R. Ford Presidential Museum in Grand Rapids, Michigan, prior to application of the roof deck. Total cost: $40,000, or 1.3% of the building's total $3,000,000 cost. *Space Frame Safety Issue Sparks Full-Scale Load Test*, ENGINEERING NEWS REC., Sept. 18, 1980, at 39.

158. Support for this proposition comes from the profession itself. *See, e.g.*, AIA, *supra* note 3, at 8, 12 (by supervising construction, engineers put themselves in a better position to discover defects in the work); Thornton, *supra* note 151, at 89, 90, 94-95.

Full time supervision may; however, create liability for construction site accidents. *See* Balagna v. Shawnee County, 233 Kan. 1068, 668 P.2d 157 (1983); Hanna v. Huer, Johns, Neel, Rivers & Webb, 233 Kan. 206, 662 P.2d 243 (1983); Comment, *Architects' Liability for Construction Site Accidents*, 30 U. KAN. L. REV. 429 (1982) (architect must contractually assume control of contractor's methods and procedures before a duty to protect workers arises).

In 1983, the Florida legislature enacted a law that requires employment of a full-time, qualified inspector during the erection of structural components of all major buildings. FLA. STAT. ANN. § 553.79(5)(A) (West 1983). Any structure that exceeds 25,000 square feet in floor area, that is greater than two stories or twenty-five feet in height, that has an assembly occupancy greater than 5,000 square feet, or is of unusual design or construction technique triggers the inspector provision. *Id.* § 553.71(6). Residential structures of three stories or less are exempt from the inspection requirement. *Id.*

spite changes in the AIA and NSPE standard contract documents that have moved the design professional away from project supervision into periodic inspection.[159] Compliance with the first three suggestions satisfies the engineer's duty to stay informed, while the review involved in the last three should help eliminate negligent procedures and result in a safe, suitable structure. Moreover, design review, testing, and supervision costs are all directly chargeable to the project owner.

2. *A Contractural Alternative: Indemnity Clauses*

A crucial but unspoken issue underlying the structural engineer's liability is which of the parties should bear responsibility for developmental risks?[160] In economic terms, the engineer can either increase precautions against failure by providing design redundancy, thus increasing construction costs, or, if his bargaining position is strong enough, seek indemnification from the owner for any resulting liability.[161] Either alternative has the effect of allocating the risk of liability and/or the costs of avoiding liability to the project owner.[162] Owners' agreements to indemnify engineers for negligent performance of design responsibilities are strictly construed but generally upheld[163] unless prohibited by

159. AIA, *supra* note 43, Document A-201, ¶ 2.2.3 (1976 ed.) (architect shall visit construction site at intervals appropriate to the stage of construction to familiarize himself with the progress and quality of work); NSPE, *supra* note 51, Document 1910-1, ¶ 1.6.2 (1979 ed.). *See also* Wheeler & Lewis v. Slifer, 195 Colo. 291, 577 P.2d 1092 (1978) (contractual authority of architect to stop work to assure proper execution of contract did not impose a duty on architect to see that work was performed safely); Brown v. Gamble Constr. Co., 537 S.W.2d 685 (Mo. Ct. App. 1979) (architects under no duty to supervise construction unless they expressly agree to do so).

160. *See* Stanton & Dugdale, *supra* note 102, at 585.

161. When owners have the bargaining edge, they might insist on just the opposite, i.e., that the engineer indemnify the owner. One commentator notes that

> [d]uring the past five years, architects and engineers have increasingly been besieged with demands from their clients for indemnification provisions in professional services agreements requiring the architect or engineer to indemnify their clients. This recent trend, which started on the west coast, has now swept the country.

P. Purcell, Dangers of Hold Harmless and Indemnification Agreements: Legal Liability and Insurability 1, Presentation at 24th Annual Meeting of Invited Attorneys, Savannah (May 10, 1985) (available at *Villanova Law Review* office).

162. *Id. See* Coase, *The Problem of Social Cost*, 3 J. LAW & ECON. 1, 10-11 (1960).

163. *See* Batson-Cook Co. v. Industrial Steel Erectors, 257 F.2d 410, 413-14 (5th Cir. 1958); DeFelice v. English, 91 Misc. 2d 1109, 399 N.Y.S.2d 417 (1977) (a tortfeasor may not be denied indemnification because his negligence was active), *aff'd*, 63 A.D.2d 976, 406 N.Y.S.2d 702 (1978); *see also* RESTATEMENT (SECOND) OF CONTRACTS § 192 comment b (1981) (a promise to indemnify is

statute[164] or against public policy.[165] If the owner clearly and unequivocally agrees to indemnify the engineer, the engineer's liability exposure to the owner is significantly reduced.[166] Alternatively, the parties can agree that the owner will purchase insurance to cover an anticipated risk, which has the effect of indemnifying the engineer against his own negligence.[167]

V. CONCLUSION

Today, the structural engineer occupies an unenviable position in the design profession. As project owners demand that architects create novel, innovative solutions to old space enclosure or spanning problems, the engineer must use proven methodologies to design the structure within the architect's aesthetic parameters. He has some room for innovation, but ultimately he must recognize the impact of statics, dynamics, and strength of materials on such diverse structures as a television tower, a 4,000 foot-long suspension bridge, or a simple warehouse roof. Long span designs with fewer redundant elements, lessened resistance to member buckling, and greater threat to human life increase the engineer's design responsibilities.[168] Structural failures in cutting edge designs like space frame roof structures are most often caused by gross design negligence or construction errors rather than by deficiencies in materials or fabrication.[169]

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unobjectionable if the tortious act is only an undesired possibility and the promise does not tend to induce its commission).

164. *E.g.*, CAL. CIVIL CODE § 2782 (West 1984); DEL. CODE ANN. tit. 6, § 2704 (1974). *See also Anti-Indemnification Statutes*, in XIII GUIDELINES FOR IMPROVING PRACTICE, ARCHITECTS & ENGINEERS PROFESSIONAL LIABILITY No. 8 (V.O. Schinnerer & Co. 1983).

165. *See* Tunkl v. Regents of Univ. of Cal., 60 Cal. 2d 92, 98-100, 383 P.2d 441, 445-46, 32 Cal. Rptr. 33, 36-38 (1963) (invalidating exculpatory provisions found in contracts where indemnitee provides an essential service).

166. By entering into an indemnification agreement with the engineer, the owner indemnitor deprives his insurer of the right to subrogation and may forfeit his liability insurance. *See* Liberty Mut. Ins. Co. v. Altfillisch Constr. Co., 70 Cal. App. 3d 789, 131 Cal. Rptr. 91 (1977). *But see* Great N. Oil Co. v. St. Paul Fire & Marine Ins. Co., 291 Minn. 97, 99, 189 N.W.2d 404, 406 (1971) (in the absence of an express prohibition in the insurance policy against entering into exculpatory indemnity agreements, an insured owner may release a contractor for negligently causing a loss); Insurance Co. of N. Am. v. Universal Mortgage Corp., 82 Wisc. 2d 170, 262 N.W.2d 92 (1978).

167. Tuxedo Plumbing & Heating Co. v. Lie-Nielson, 245 Ga. 27, 262 S.E.2d 794 (1980); South Tippecanoe Sch. Bldg. Corp. v. Shambaugh & Son, Inc., 182 Ind. App. 350, 395 N.E.2d 320 (1979).

168. AIA, *supra* note 3, at 3-4, 12. *See* Christian Science Monitor, *supra* note 129.

169. *See* Cuoco, *supra* note 8.

The rapid development of new design theories and solutions demands redefinition of the engineer's standard of care, based on verifiable and comprehensible criteria. Our suggested solution follows a theory's chronological development from inception at the cutting edge, publication in trade journals, acceptance after a period of maturation and refinement, and eventual inclusion in design standards and undergraduate texts. Once a theory is accepted by the profession, the engineer should have a duty to inform himself of that theory and apply it in practice. The practicing engineer should read the journal literature and attend professional seminars to acquire knowledge of these advances prior to their inclusion in design manuals. Current topics in structural engineering open literature include design considerations for steel fatigue, brittle fracture, and stress concentrations. Public safety demands that the law recognize successive improvements and hold engineers responsible for recognizing and incorporating them as well. Project owners deserve the latest design to extend the longevity of their investment. The public deserves protection from deficient structures. The engineer owes himself decreased liability exposure arising from structural failures.