The Commercial Roofing Industry: New Directions in Construction Quality

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Abstract

This paper provides an overview of quality management initiatives in the construction industry and compares these efforts with specific achievements in one segment of the industry: commercial roofing. The level of quality improvement achieved in commercial roofing is identified, and the factors leading to this improvement are explored. The paper advances the hypothesis that quality improvement in commercial roofing has been advanced primarily through the efforts of subcontractors and materials suppliers, industry participants who have been frequently overlooked in previous research in construction quality.

The Total Quality Management Approach to Quality

Before exploring the status of quality initiatives in the construction industry, it is first necessary to review current theory and practice regarding quality. During the last half of the twentieth century, Total Quality Management (TQM) has emerged as a broad term to describe the attitudes and processes considered by many practitioners to be essential for the attainment of quality by modern organizations. Moorhead and Griffin (1995) describe TQM as “a fundamental change in the organization’s culture to one that includes a focus on the customer, an environment of trust and openness, formation of work teams, breaking down of internal organizational barriers, team leadership and coaching, shared power, and continuous improvement” (p. 186). Sashkin and Kiser (1993) state that “TQM means that the organization’s culture is defined by and supports the constant attainment of customer satisfaction through an integrated system of tools, techniques and training (which) involves the continuous improvement of organizational processes, resulting in high quality products and services” (p. 39).

From these and other definitions, a number of common principles regarding quality can be identified. First and foremost is a definition of quality. In TQM, quality is from beginning to end defined by the customer. And because the customer’s wants and needs constantly change, quality must be viewed as a continuous process rather than a numerical quota or fixed standard. TQM also requires the active participation of everyone involved in the production and consumption of a good or service. Every manager, worker, supplier, and customer must be involved. As a consequence, a culture that fosters openness, trust and respect among all participants is necessary to attain quality. Barriers that block communication and trust must be removed. Finally, quality is a process that must be learned. Accordingly, all participants must be trained in the use of effective tools, techniques and skills. These four broad principles - quality as defined by the customer, quality as the responsibility of all participants, quality as a culture of openness and trust, and quality as a process requiring training and tools - will be used in this paper to review quality management in the construction industry.

Current Research and Opinion in Construction Quality

Within the current body of quality research directed at the construction industry, a number of common themes can be observed. First, the construction industry all too frequently defines quality in traditional, mechanistic terms that predate the use of TQM. While industries embracing TQM have begun to view quality in broad terms of customer satisfaction, the construction industry still appears to cling to a narrow definition of quality as the "conformance-to-requirements" (Seymour & Sui-Pheng, 1990). Conformance-to-requirements defines quality as the satisfaction of a set of construction specifications rather than the satisfaction of the customer. This definition assumes that specifications will in fact meet the customers needs and wants, but as Tobica and Stroh (1999) state:

> In many cases this quality paradigm has been proven inadequate. There is ample evidence that construction is not immune of technically incomplete and unsound designs and specifications, since they come to be viewed as a neutral touchstone against which quality is assessed. Another limitation of conformance-to-requirements … is that it assumes that we can get stable and complete requirements; it ignores the potential mismatch between what is specified and what the customer needs or wants. In fact, customers may not know or care how well a constructed facility conforms to specifications; they want their needs and expectations to be met. The crucial task is how to establish design requirements and specifications that best reflect their needs and expectations. This is particularly problematic for non-technical requirements, such as aesthetics, comfort and convenience, which usually are not completely addressed by specifications. (p. 316)

While many industries have embraced a variety of TQM processes to measure quality, everyday practice in the construction industry also appears to lag behind. A poll of construction firms conducted by *Engineering News Record* ("TQM," 1995) found that the majority of companies said they have difficulty even making a baseline assessment of their quality. Even when attempts are made to measure quality, the measurement criteria fall far short of modern TQM practice. Sommerville (1994) observes that much of what passes for TQM in the construction industry is frequently nothing more than traditional Quality Assurance (QA) commonly employed in many sectors of the economy prior to the introduction of TQM. As a consequence, common TQM processes such as continuous improvement and quality circles are frequently ignored in favor of more traditional approaches emphasizing rigid product standards, fixed contractual relationships and after-the-fact inspection. As Sommerville states:

> The focus in the construction industry is directed towards the more mechanistic aspects of quality attainment…. The reliance on the mechanistic viewpoint, of course, misses the crux of the matter, namely that TQM is a philosophy not just a set of guiding principles (Sommerville, 1994, p. 291)

The reluctance of construction organizations to embrace modern quality management principles also has been documented by Schriener and Angelo (1995), who state this reluctance is typified by a commonly-held industry view that the costs of TQM outweigh the benefits. Sommerville (1994) asserts that this attitude can be attributed in some part to the legal framework of typical construction contracts. Almost all construction contracts contain provisions for the "making good of defects" (p.292), and the traditional process by which such defects are "made good" can encourage the participants to view quality as a cost. Sommerville illustrates this attitude in a discussion of a typical final inspection of a construction project:

> This … final walk-through inspection of the building [is conducted] to ensure a degree of acceptability; note that the building will not be defect free nor of the highest possible quality, but only acceptable to the persons inspecting. The contractor is … placed under a financial obligation to make good these defects in order that retained monies be released. Many contractors fail to return to make good the defects, simply writing off the retained sums off as being lower than return costs. This practice reinforced the perception that quality attainment has costs associated with it. (Somerville, 1994, p. 292)

Reluctance toward TQM is also likely a reflection of the general atmosphere of contentiousness and distrust within the construction industry. As evidenced by the high frequency of litigation in construction, especially in the United States and Great Britain (Carlisle & Kanji, 1998), it is obvious that disputes are common and frequently resolved only through the courts. Carlisle and Kanji also observe that this contentiousness permeates almost all aspects of the construction process. After conducting in-depth interviews with over 2000 construction workers and managers in the UK, they observe that "the typical site atmosphere is one of divisions, suspicion and a lot of argument" (Carlisle & Kanji, 1998, p. 28).

While TQM requires the participation of all parties involved in a quality process, the preponderance of construction research is focussed on the quality practices of a single participant, the *general contractor*. Based on a review conducted by the author of 40 recent research articles addressing construction quality, the focal point of the research in 28 of the studies was the general contractor. In the remaining articles, either the project owner (6) or the project designer (6) was identified as the primary focus. While this brief review allows no statistical conclusion regarding the relative importance of each party, it should be noted that almost no attention is paid to two very important participants in the construction process: the *subcontractor* and the *building materials manufacturer*.

While the general contractor certainly plays a pivotal role in establishing and monitoring quality at a construction site, the lack of attention paid to subcontractors and material manufacturers is disturbing. This paucity of attention is especially troubling when the economic inputs of these two groups are taken into consideration. In a study of construction practice in Hong Kong, Wong and Fung (1999) assert that 82% of total construction costs are represented by the materials and services contributed by subcontractors and suppliers. Based on the author's own experience in the construction industry, this percentage is reasonably accurate for all countries in the developed world. If subcontractors and material suppliers provide over 80% of all goods and services incorporated into a construction site, why is so much attention focussed on the general contractor? This is a particularly troubling question since effective TQM requires the cooperation and effectiveness of all participants in the process.

The atmosphere of contentiousness in the construction industry is also reflected in common industry perceptions of subcontractors and material manufacturers. Although these two groups supply the lion's share of goods and services, industry leaders frequently discount their contributions. In regard to subcontractors, Wong and Fung (1999) describe what is too often a common industry perspective:

> In general, … subcontractors are smaller in size and financially not strong. Works carried out on construction sites are labour-intensive and control of workers is difficult. It is often difficult to hold subcontractors responsible for problems. Policy and procedures in small firms are normally not well established and provide little or no guarantee of quality and professional competence. (p. 203)

While subcontractors are perceived to be small, weak and somewhat disorganized, material suppliers are frequently treated even more harshly. Reporting on the state of modern construction to the insurance industry, architects Butt and Clinton (1996) state:

> … new building products are often crash marketed and highly promoted without adequate testing. The promise of reduced construction costs has enticed developers as well as builders into some incredibly expensive, product-related construction failures in the last decade. Flash-in-the-pan materials … have become the stuff of legend for construction failure investigators and have cost their manufacturers and their manufacturers' insurers hundreds of millions of dollars in claims-related losses. (p. 4)

Current Approaches to Quality Management in Construction

Just as research in construction quality has focussed disproportionately on the general contractor, initiatives to enhance quality also typically place the general contractor as the key figure in quality improvement. Ferreira and Rogerson (1999) suggest that changes in the construction contract documents issued by building owners and general contractors can improve quality management. Kanji and Wong (1998) and Wong and Fung (1999) recommend the implementation of Supply Chain Management (SCM), while Fung & Wong (1995) promote the benefits of ISO 9000 certification for general contractors. Gentile (1993) reviewed the application of TQM tools such as Pareto Charts to improve the handling of design change requests during the construction process. Boyle (1993) recommends that general contractors, owners and architects apply TQM principles during the punchlist process, while Ahmed (1994) proposed a quality function deployment (QFD) model designed for the construction industry. While all of these proposals certainly can improve the effectiveness of the general contractor (and to some extent, building owners and designers), they do not fully engage the resources of subcontractors and building material manufactures to improve construction quality.

Commercial Roofing: A Case Study

In order to expand the understanding of the role of subcontractors and material manufacturers, this paper provides an overview of current quality practice in one particular segment of the U. S. construction industry -- commercial roofing -- where subcontractors and manufacturers appear to have made important contributions to construction quality. In addition, the paper identifies underlying quality management principles and processes that could be tested in future research.

The U. S. Commercial Roofing Industry: Historical Background

In order to conduct an effective review of the commercial roofing industry, a brief historical review is required. Although roofing has experienced its share of change over the past hundred years, the modern commercial roofing industry has been shaped in many ways by a singular event. This event was the emergence of the flat or low-slope buildings that now dominate the urban landscape. Although low-slope roofs can be found throughout the history of architecture, the modern preference for flat roofing can be attributed primarily to the Bauhaus school of design, founded in 1921 by architect Walter Gropius. The architecture of the Bauhaus, later called the International Style, emphasized rectangular structures framed with steel columns and beams and covered with concrete and glass facades. The roof surface was flat, making drainage difficult. Frequently the vertical facades extended above the roofline to form a continuous parapet, making it even more difficult to move water off the roof.

The popularity of the flat roof was accelerated by an industrial society that required ever-larger buildings to house the factories, warehouses and shopping centers needed to serve the expanding consumer market. What started out as an architectural style quickly became an economic necessity. Although even an elementary understanding of the Law of Gravity would lead to the conclusion that flat roofs will tend to hold water, and thus be more susceptible to leakage than sloped roofs, overall economic value favors the flat roof. As stated by Griffin and Fricklas (1996),

> Steeply sloped roofs on the large, sprawling buildings that dominate today's construction would dramatically cut the costs of reroofing, repair and litigation … but they would raise construction costs by a far greater amount through the costs for additional building volume. Low-sloped roofs will maintain their predominance in commercial roofing for a simple economic reason: the costs of steeply sloped roofs over the vast acreages covered by shopping centers and other modern buildings are simply too high a price to pay to avoid the problems posed by low-slope roof systems. (pp. 1-2)

With the advent of the low-slope roof favored by modern architecture, the basic function of the roof system changed. On steeply pitched roofs, the function of the roof is to *shed* water, while a low-slope roof must be *resist* the intrusion of water. As a result, many of the traditional materials of roofing, such shingles made of slate, wood or metal, have been replaced by moisture-proof materials originally developed for waterproofing rather than roofing.

The origins of roofing practice designed to accommodate the demands of low-slope roofing can be dated to the middle of the nineteenth century. In the 1840s, a flat roofing method was developed using materials originally employed to waterproof ships. The system was called *built-up roofing* (BUR), referring to the redundancy of separate layers that are installed to assure resistance to water entry. Each layer of the built-up roof was composed of two basic materials: *bitumen* and *felts*. Typically composed of petroleum asphalt or coal tar, bitumen serves both as an adhesive and as a waterproofing agent, while the felts (typically made from organic or mineral fibers) stabilize and strengthen the layers of bitumen, acting in a manner similar to steel reinforcing mesh in concrete. In a typical BUR, four separate layers of felts and bitumen are applied. Frequently, the layers of bitumen and felts are covered with a gravel surfacing; thus the origin of the phrase "tar and gravel roof."

For over a century, built-up roofing dominated the commercial roofing market and provided a satisfactory barrier to water entry into buildings. The success of BUR over this long time period can be attributed to the redundancy of its design as well as application standards and methods that were understood and shared by all members of the roofing community.

The dominance of built-up roofing, however, was shattered by a number of events starting in the 1970s. The OPEC Oil Embargo significantly raised the price of roofing asphalt, opening the door for previously more expensive synthetic materials. It is also very likely that the quality of roofing asphalt changed as well during this period. Asphalt is literally the "bottom of the barrel" in a petroleum refinery, and rising oil prices spurred refiners to find new ways to extract more of the higher value products from crude oil. As a result of refiners' efforts, the remaining asphalt possessed fewer light fractions to provide the elasticity and workability needed by the roofing contractor.

At the same time economic pressures affected the price and the nature of roofing asphalt, similar disruptions were occurring with roofing felts. From the 1920s until the early 1970s, felts made of asbestos fibers dominated built-up roofing. These felts not only provided high strength to assure long-term resistance against splitting but also offered a degree of flexibility that made them easy to handle and install. When asbestos was eliminated due to heath dangers, the industry fell back on organic felts comprised primarily of cellulose fibers. Not only are organic felts a little more rigid than asbestos felts, but they also tended to absorb moisture much more easily. This tendency to absorb moisture undoubtedly contributed to an increase in the reports of blistering in built-up membranes (Griffin and Fricklas, 1996, p. 240), a condition where the layers of the roof separate due to heating of entrapped moisture.

To an industry reeling from numerous economic and regulatory shocks, fresh answers came quickly – perhaps too quickly. In response to the apparent shortcomings of organic felts, glass fiber felts, originally introduced in the 1940s, were used with increasing frequency. From the coated fabrics industry came a variety of reinforced plastic roofing sheets originally developed for tarps and awnings. Tire and automotive manufacturers offered a number of synthetic rubber membranes. Liquid coatings, both asphaltic and polymeric, also proliferated. New roofing technologies were also imported from Europe, including large unreinforced sheets of PVC plastic and rolls of bituminous roofing modified with plastic and rubber polymers. According to some industry estimates, over 100 new manufacturers of roofing products emerged during the ‘70s and early ‘80s, each offering the “miracle” answer for roofing performance.

The Quality Challenge in Roofing

With each of these new products also came unique application techniques. Glass felts are less flexible than asbestos felts, making it difficult for roofers to properly lay and align each layer of material. Plastic sheets had to be welded together on the roof with solvents or heat welders. Rubber membranes were seamed together with adhesives that required extensive cleaning and priming of the membrane surface. Coatings required proper mixing and careful substrate preparation. Polymer modified asphalt membranes had to be placed in a layer of hot asphalt or torched to the roof surface with propane torches. For the most part, all of these techniques were new to the roofing contractor and each required new skills and considerable practice. All of these techniques also had their weaknesses as well. Surfaces could be improperly or inadequately prepared, welds and adhesives could be misapplied, and torches could burn down buildings.

In addition to the challenges of new application techniques, many of these new roofing products were insufficiently tested and, as a consequence, performance problems increased. Some plastic membranes, especially the unreinforced varieties, became brittle over time, leading to fracture and splitting. Other synthetic membranes exhibited amounts of shrinkage that often overwhelmed their securements. Some coatings and adhesives absorbed moisture, leading to premature failure.

For the roofing contractor, however, economic reality offered little choice: either install these new roofing systems or lose business. So contractors began using these new products – and using them extensively. In 1980, non-BUR roofing systems accounted for less than 10% of the low slope roofing market, with BUR commanding over 90%. By the mid-1990s, this proportion was almost reversed, with new roofing membranes accounting for nearly 70% of the commercial roofing market (Griffin and Fricklas, 1996, p. 193). As can easily be imagined, this proliferation of new materials supplied by literally dozens of new suppliers lead to even more disruption in the roofing business and a continuing decline in roofing quality.

All of these dramatic changes in commercial roofing lead to increased dissatisfaction, both by building owners as well as roofing contractors. According to data published by the National Roofing Contractors Association (Cullin, 1988), problems associated with the new roof membrane systems introduced in the 70s and 80s quickly proliferated. The most telling statistic is that during this same period, roofing disputes accounted for over half of all commercial construction litigation, even though roofing accounted for less than 5% of a typical building's construction costs (Good, 1995, p. 32).

Responses to the Quality Challenge

Government and Academia

Any response to a problem naturally will require resources, and the availability of useful and adequate resources is a critical issue for the roofing industry. Government laboratories have conducted a number of important research studies concerning the performance of roofing materials, but recent changes in federal funding have drastically reduced the role of such facilities in roofing research. Academic research in roofing is also minimal. Currently, only a handful of colleges and universities conduct research or offer seminars in roofing technology. Due to the dearth of research activity, the roofing industry can support no more than one research symposium every other year, producing on the average no more than several dozen peer-reviewed research articles annually. Given that the current sales volume of the commercial roofing industry is over $10 billion annually, the amount of available professional research is pitifully small.

Building Owners

Although some building owners have in-house capabilities for roofing research and development, such programs require an extensive inventory of buildings to justify the cost of in-house expertise. Even for companies with a large inventory of buildings, however, the trend toward corporate downsizing in the 1980s frequently has lead to the elimination or outsourcing of such services.

Building Designers

Instead of developing in-house expertise in roofing design, architects and engineers also frequently depend on outsourcing from independent roof consultants. The rising importance of roof consultants in the construction process during the 1980s to the present can be illustrated by the growth in the membership of the Roof Consultants Institute (RCI), a professional organization for roofing consultants. From an initial membership of fewer than 100 members in 1986, this organization has now grown to over 1000 members. Roof consultants now carry much of the burden for designing and specifying roofing systems for both architects and owners.

While it is likely in the future that roofing consultants will play a greater role in roofing quality research in the future, their professional organization is still in its infancy. Within the past few years, however, roofing consultants have made significant strides in developing a variety of forums for roofing research. These resources include a monthly professional publication (*RCI Interface*), an annual symposium on roofing research and an extensive electronic data bank of roofing research articles.

For many building designers and owners, however, the roofing consultant provides a different service than the design and specification of roof systems. Consultants provide the lion's share of inspection services for owners and architects, both as a QA function during construction and as a forensic function in the event of a roof failure. In these two roles, the roof consultant's activities reflect the fundamental conservatism and contentiousness of the construction industry, with its emphasis on inspection instead of continuous improvement and litigation instead of cooperation.

General Contractors

The response of general contractors to the challenges of roofing quality has been virtually non-existent. Although (as previously mentioned) roofing claims account for over half of construction litigation, very little effort has been exercised by general contractors or their trade associations to address this issue in a proactive way. At the present, almost all organized efforts on the part of general contractors continue to focus on ever-restrictive legal subcontracts to separate themselves from the consequences of roof system problems.

Roofing Contractors and Roofing Manufacturers

This leaves the two remaining participants – roofing contractors and roofing manufacturers – to address the problems of roofing quality. Fortunately, these two groups appear to possess both the resources and the determination to take proactive steps. Because over 75% of roofing involves the repair or retrofit of existing roofs, roofing contractors have a significant economic interest in roofing quality due to the long-term customer relationships they establish with building owners. Likewise, because of the $10 billion size of the roofing industry, a number of materials manufacturers have achieved the economies of scale to make quality research both affordable and necessary.

The Roofing Contractor and Roofing Quality

In order to understand how roofing contractors have responded to the disruptions in materials and processes that have impacted the industry since the 1970s, it is first necessary to gain some insight into their values and behaviors. As might be expected in an industry with a long history of craftsmanship, today's roofing contractors are still shaped by values long associated with traditional building trades. For the most part, roofing contractors take pride in their capabilities and accomplishments, value the importance of their customers, and see themselves as a part of a larger community. These values are effectively summarized in a study conducted for the National Roofing Foundation (1990):

> A rather serious and professional approach identifies one of the top values of [the successful roofing contractor]. He has a strong work ethic. He perseveres. He expects and appreciates performance. He is geared to results. He has an enthusiastic willingness to work…. He values honest dealing, delivery of good service, and says so many times in the survey, often in different ways. He tends to avoid fads, yet believes it is important to be ready to accept constructive change. He is a people person. He values his employees and his customers…. It is fascinating how often [the successful roofing contractor] is involved in community and service activities…. Not only doe they encourage participation, they personally value such participation and they get out and do it! (p. 23)

The NRF survey clearly identified that, in addition to traditional values of hard work and professionalism, roofing contractors also tend to be involved in activities outside the workplace. Frequently, this activity revolves around roofing trade associations, which have been active for over 100 years. Because of this propensity for involvement, the National Roofing Contractors Association (NRCA) has been able to develop an impressive presence in the construction industry. While few roofing contractors have the individual resources to effectively research and respond to the broad array of quality issues presented by the proliferation of roofing products during the 1980s, they have been able to join forces and fund an organization that has established an impressive track record.

Many of the important joint research efforts in the roofing industry, conducted by government laboratories as well as independent researchers, have been made possible only through NRCA funding. In fact, as some research facilities have lost public funding, the NRCA has taken on more and more of the burden of research. Examples of research funding include the sponsorship of national and international roofing research symposia, industry studies funded by the National Roofing Foundation, and most recently the establishment of an industry-wide Alliance for Progress. The Alliance is funded with an over $9 million endowment and is charged with the sponsorship of research and programs that anticipate and address the issues affecting the roofing industry. All told, the NRCA is involved in millions of dollars of technical research each year.

In regard to education and quality management initiatives, the NRCA has also established a significant presence. The organization was instrumental in the establishment of the Roofing Industry Education Institute (RIEI), an educational outreach that provides professional training seminars for all members of the roofing community, including building owners, designers, manufacturers and contractors. Since its inception in 1984, RIEI has provided roofing education for over 40,000 members of the roofing and construction industries. In conjunction with Northwestern University, the NRCA has also established a Total Quality Management program for roofing contractors, and over 200 contractors from across North America have participated in this program and implemented TQM practices in their operations (Good, 1995, Puniani, 1997).

The Roofing Manufacturer and Roofing Quality

The response of roofing manufacturers to roofing quality issues has been influenced by a number of factors. First, even though dozens of new manufacturers entered roofing during the 1970s and early ‘80s, the industry consolidated quickly (Midwest Roofing Contractors Association, 1989). As a result of this consolidation, a number of firms have emerged with the size necessary to fund extensive research and development efforts. Although information regarding the exact amount research funding is not available, industry experts estimate that the annual level of R & D spending by the ten largest manufacturers is at least $10 million.

During the middle and late 1980s, many of these firms embarked on extensive programs to address fundamental quality concerns, both in the materials they produced and the application procedures they endorsed. Two of the largest BUR manufacturers, Johns-Manville and Owens-Corning, conducted extensive research to improve the workability of glass fiber felts. In the rubber-roofing sector, Carlisle and Firestone invested heavily in the development of new moisture-resistant adhesives to extend the life of roof seams and new anchorage details to resist environmental and dimensional forces. While many manufacturers of thermoplastic and modified asphalt membranes lacked the size of the BUR and rubber roofing companies, they were able to draw upon the experience of European companies that originally developed these technologies. All in all, the manufacturing sector of the roofing industry responded with a significant investment of time and money to help improve roofing quality.

Although the resources to engage in extensive research efforts were available to these manufacturers, several other forces motivated and shaped this response. Probably the most important was the introduction of the *roofing warranty*, initiated by a rubber roofing manufacturer in 1972 (Griffin & Fricklas, 1996, p. 22). Manufacturers' warranties typically provide for the repair of leaks for periods from 10 to 20 years. These repairs are usually limited by a number of exclusions, but typically cover failures either in the materials supplied or the workmanship used to install these materials. Although the value of warranties is hotly debated within the roofing industry (Griffin & Fricklas, chap. 21; Springborn, 1992, Chap.11), the issuance of warranties carries a significant financial and accounting burden for roofing manufacturers. Because the term of these warranties runs anywhere from 10 to 20 years, reliable estimates of warranty pay-outs must be developed, appropriate reserves must be established, and these reserves and pay-out forecasts must be reviewed by independent external auditors before a company's financial statement can be issued. Without debating the marketing merits of issuing warranties, the principle effect of warranties on the manufacturer was to direct extensive management resources to respond to warranty claims and reduce the potential for pay-outs. In a review of the effects of roofing warranties on quality management at one roofing manufacturer, Hoff (1998) illustrates how this information has been used to direct ongoing quality improvement efforts:

> Because the majority of roof systems ... receive a written leak warranty… the company had accumulated an extensive data base that included substantial information regarding the original installation, including detailed technical information, the identity of the installing contractor, and the date of installation. In addition, because building owners experiencing a roof leak must call [the manufacturer] in order to obtain warranty service, the data base also contained detailed information regarding the timing, type and extent of repair required. The information in this database was analyzed to identify the primary causes of roof leaks, including specific construction components, regional climatic conditions and variations among different contractors. Based on this analysis, [the manufacturer] was able to determine that the great majority of leak events could be related to a few key roofing details. (p. 19)

Although formal warranty programs with all of their financial and contractual implications certainly provided an incentive for quality improvement, a second factor also directed the quality efforts of roofing manufacturers. Because the leading suppliers of roofing materials in the United States are for the most part operating divisions of large and broadly diversified manufacturing corporations, many already had established extensive Total Quality Management (TQM) programs in their factories (Hoff, 1998).

Combining the accounting requirements and financial incentives posed by large warranty reserves with established capabilities in TQM and similar quality programs, it was only natural that many roofing manufacturers would apply their management resources to address external quality issues in the same way these issues were resolved in their factories.

The incentive of the roofing warranty to improve roof performance also motivated many roofing manufacturers to view roofs from a *systems* perspective. Griffin and Fricklas (1996) observe:

> The low-slope roof system is an assembly of interacting components designed, as a part of the building envelope, to protect the building interior, its contents, and its human occupants from the weather. It is one of many other building subsystems … each similarly designed for a specific function. (p. 9)

Because of this systems perspective, roofing manufacturers began to integrate both vertically and horizontally to minimize risk and maximize profitability. For the larger roof membrane manufacturers, vertical integration was achieved through the addition of roofing substrates such as insulation and decking, either through acquisition or joint venture. Several prominent rubber roofing and BUR manufacturers also pursued horizontal integration by expanding their product lines to include a wide variety of roofing membrane types. This integration undoubtedly strengthened the value of the roofing warranty, since more and more elements of the roofing system could now be included in the warranty.

A final aspect of the roofing warranty that should not be overlooked is how this warranty brought a new relationship into the construction industry. While typical construction contracts relegate material suppliers to a subcontract or even sub-subcontract relationship to the general contractor, long-term roofing warranties established a direct relationship between the roofing manufacturer and the building owner. Long after the general contractor has demobilized the construction site, the owner and the manufacturer are tied in a relationship centered on the performance of the roof. This relationship also extends to the roofing contractor, since most roofing manufacturers employ the services of roofing contractors to respond to service requests.

The Results of Industry Initiatives

In terms of measuring quality improvement in the roofing industry, the Fourth International Symposium on Roofing Technology held in Gaithersburg, MD, in 1997, was a seminal event. During this seminar, research studies covering almost every major product segment were presented, and these papers clearly pointed to significant improvement in roof system performance. Cash (1997) presented data indicating that the glass fiber felts currently used in the overwhelming majority of BUR roofs are providing a significant level of improvement over the organic felts used previously. According to Cash's data based on the survey of 430 roofing professionals throughout the United States, built-up roofs using glass felts were expected to achieve a mean service life of 16.6 years, as compared to 14.1 years for roofs using organic felts. In addition, the current estimated service life for glass felt BUR had improved by over one year from a previous 1995 survey conducted by Cash. Drawing from a database of over 21,000 roofs in place, Schneider & Keenan (1997) also noted significant improvements in BUR performance from 1992 to 1995.

In regard to rubber roofing systems, Schneider & Keenan (1997) observed a high baseline of performance, with the average service life for rubber roofs in their data base varying from 16.8 to 18.4 years, depending on the specific type of application. Using data from the warranty records of a large roofing manufacturer, Hoff (1997) reported a significant reduction in warranty repair costs for rubber roofs installed between 1985 and 1991. Hoff also illustrated how these repair cost reductions were driven both by product improvements achieved by the manufacturer's TQM programs and by alignment of the manufacturer's warranty program with a base of professional, well-trained and quality-oriented roofing contractors.

Recently, information linking the value of roofing warranties to customer satisfaction has become available. In a study of customer satisfaction among roofing contractors, Hoff (2000) discovered that companies with extensive roof warranty programs and large numbers of roofing projects under warranty received higher overall satisfaction ratings than companies with smaller warranty programs. Although the contractor respondents did not attach a high value to the warranty itself, they did tend to attach high values to the services companies offered as a consequence of these warranties.

Discussion

Roofing Manufacturers and Product Quality

Over the past two decades, roofing manufacturers appear to have achieved significant quality improvements in the products and systems they supply to the roofing industry. Based on the nature of these improvements and the common practices of many roofing manufacturers, a number of hypotheses can be advanced to explain this improvement in terms of common TQM principles:

1. Effective measurement tools. Accounting rules for corporate warranty reserves provide an incentive for improvement while warranty repair records provide a useful database for statistical analysis.
2. Removing barriers. Management processes required to administer the warranty provide a critical link between the factory and the field, while the warranty itself establishes a new and ongoing relationship between the building owner and the manufacturer.
3. Systems perspective. Systems integration, both horizontally and vertically, increases both the resources available to the manufacturer to address overall quality issues, while adding even more value to the warranty for the building owner.
4. Past TQM success. Manufacturer's in-plant experience with TQM can provide the tools necessary to transform the relationships between the factory, field and building owner into an effective quality management program.

<u>Roofing Contractors and Roofing Quality</u>

Although it is more difficult to quantify the contribution of roofing contractors as compared to roofing manufacturers, it is important to note that through the NRCA, roofing contractors have consistently engaged all participants of the roofing community and challenged them to achieve constant quality improvements. In addition, data regarding the contractor's contribution to roof system performance as presented at the Fourth International Roofing Symposium indicate that the mutual partnership of dedicated roofing contractors and quality-oriented roofing manufacturers has made a significant and positive difference in roof system quality.

Implications for the Construction Industry

Based on the information contained in this paper, it would appear that quality improvement requires many different disciplines and resources not normally available to the building owner, general contractor, architect or engineer. At least in the roofing segment of the construction industry, it appears that significant quality improvement requires a scope of resources, a coordination of those resources and a strategic focus that can best be provided by an integrated building systems manufacturer in partnership with a well-trained and professional installer base. Hopefully, this quality improvement paradigm in can be further demonstrated in future research and eventually employed successfully in other segments of construction.

In regard to applicability of the manufacturer/subcontractor quality paradigm outside of roofing, it is important to note the commercial roofing industry differs from many other segments of construction. Because approximately 75% of all roofing is performed on existing buildings (Paulson & Smith, 1998), the great majority of roofing work is performed separately from the larger coordinated construction effort required for new construction projects. It is possible, therefore, that the apparent success of manufacturer / subcontractor collaboration as illustrated in commercial roofing may not offer the same opportunity for other segments of the industry that require greater integration into the complexities of new construction.

Opportunities for Future Research

With the advent of recent research to better quantify the technical performance of roofing systems over time, measurement of quality in terms of conformance-to-requirements has advanced significantly. But additional research is needed to understand quality in terms of *customer satisfaction*. A recent study of roofing contractor satisfaction (Hoff, 2000) provides a start, but this research must be expanded to include all participants in the industry – including roof designers and consultants, general contractors, and most importantly, building owners. This research also should identify the key factors or performance dimensions that drive customer satisfaction as well as measure the perceived performance of all industry participants in terms of these performance dimensions.

While customer satisfaction research will help to clarify the measurement of quality in commercial roofing, research should also be undertaken to better understand the culture of the industry. This is especially important since many of the research articles referenced in this paper rely on professional opinion rather than empirical research to identify attitudes and processes in the industry. As an example, some researchers have identified that industry participants frequently believe the costs of modern quality management to outweigh the benefits, but these researchers offer no definitive information from which to conclude how strongly and how widely this belief is held. Perceptions of contentiousness in the construction industry as also lack empirical definition and quantification. In order to understand better the culture of the industry, empirical research is required. First, this research should include all industry participants, including subcontractors, material suppliers, general contractors, design professionals and building owners. Secondly, this research should focus on two key areas of inquiry: 1) participant attitudes regarding quality management, and 2) participant perceptions regarding the roles and responsibilities of other industry participants. In regard to attitudes and perceptions as related to TQM, Zeitz, Johannesson and Richie (1997) have developed a survey instrument that measures 23 attitudinal dimensions related to quality management processes in manufacturing firms, and this instrument could easily be adapted to measure these attitudes in the construction industry. In addition to providing a baseline of quality attitudes and perceptions held by industry participants, such research could also be combined with customer satisfaction research to identify important areas of conflict within the industry.

Ultimately the results of satisfaction and attitudinal research could be applied to develop a more comprehensive understanding of the relationships and interactions necessary for the industry to achieve ongoing success. Sommerville, Stocks, and Robertson (1999) have recently advanced an interesting example of how such research could be applied. These authors have proposed a *polar plot model* for mapping key organizational and cultural parameters in the British construction industry. The model incorporates both process dimensions of organizations as well as the cultural dimensions of the participants in the construction process. For each of these dimensions, the authors have also identified measurement variables. By mapping these process and cultural dimensions in a hierarchical polar plot, starting with the overall industry and moving down through all participant organizations and sub-units, Sommerville, Stocks and Robertson will attempt to identify important areas of opportunity and conflict within the industry in order to develop effective change strategies. With additional research regarding the values of all participants within U.S. commercial roofing, such a polar plot model could be used to develop similar change strategies for the roofing industry.

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