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Building Structural Failures – Their Cause and Prevention

Défaillances structurales en génie civil – causes et prévention

Versagensfälle im Bauwesen – Ursachen und Verhütung

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SUMMARY

This article outlines the major conclusions of a conference on building structural failures held in November 1983 under the sponsorship of the Engineering Foundation. Over 60 leaders from all facets of the construction process in the USA met to discuss measures to reduce the incidence and severity of building failures. The conclusions of the conference listed herein have been endorsed by a number of major building industry groups within the USA.

RÉSUMÉ

La contribution présente les principales conclusions d'une conférence sur les défaillances structurales en génie civil, tenue en novembre 1983. Plus de 60 spécialistes représentant tous les aspects de la construction aux Etats-Unis ont discuté des mesures propres à réduire la fréquence et la sévérité des cas de ruine des constructions. Les conclusions de la conférence ont été approuvées par les principaux groupes de l'industrie de la construction aux Etats-Unis.

ZUSAMMENFASSUNG

Der Beitrag berichtet über die wichtigsten Schlussfolgerungen einer Konferenz über Bauschäden, die im November 1983 stattfand. Über 60 Fachleute aus allen Sparten des Bauwesens der USA trafen sich, um über Massnahmen zur Reduktion von Häufigkeit und Schwere von Bauschäden zu diskutieren. Die hier dargestellten Schlussfolgerungen der Konferenz werden von führenden Gruppen der Bauindustrie der USA unterstützt.

1. INTRODUCTION

Recent years have seen a marked increase in public concern with building structural failures. Many recent collapses of U.S. buildings have occurred both during construction and following occupancy. Public attention has been captured by several spectacular failures with attendant major losses of life and property. Indications of this increased attention include reports in the professional press, discussions at professional meetings, appointment of special committees on failure prevention by the design societies, and Congressional hearings on the subject. This Engineering Foundation Conference has been planned to examine whether the perception that there have been more major structural failures is supported in fact, to look at contributing causes, and to develop recommendations for their mitigation.

The conference, Building Structural Failures—Their Cause and Prevention, was held in Santa Barbara, California, November 6-11, 1983, under the auspices of the Engineering Foundation. The conference program was planned in detail by a steering committee, with the program being devoted to examining the nature and magnitude of failures, the relationship of such failures to the building design, construction, and regulatory processes, and the examination of specific case studies as a learning experience and a point of departure for discussion. The conference was attended by a broad cross section of 65 people representing most areas of concern and responsibility for structural performance of buildings.

The conference was intended to encourage open and free discussion with the understanding that sensitive issues could be openly discussed in a nonlitigious environment. It was agreed that the conference discussion would be off the record, so these summary notes include no direct quotes and do not attribute specific comments or recommendations to individuals. Specific presentations are not reported on; but highlights, issues discussed and points of view are provided. Where there was apparent general agreement, such is identified.

This set of summary notes is divided into INTRODUCTION, RECOMMENDATIONS, NATURE AND MAGNITUDE OF THE PROBLEM, THE DESIGN PROCESS, THE CONSTRUCTION PROCESS, LEGAL IMPLICATIONS, and THE REGULATORY PROCESS. A brief CONCLUSION follows. The case studies are not discussed individually, but points of view brought out in the discussion of the case studies are included as they relate to the various sections.

2. RECOMMENDATIONS

The following recommendations were developed in open session as consensus recommendations of this conference with the proposition that they would be presented to the building community for further consideration and action. In considering each recommendation, a hand ballot was taken with between 90% and 100% affirmative votes cast.

2.1 Structural Integrity

The overall structural integrity of buildings should be improved by use of design concepts and details which provide ductility, continuity, and redundancy. Nonredundant structures, where necessary, should be designed and detailed with a full understanding of their performance and constructed with extra care to ensure compliance with the contract documents. Standards and codes development organizations should recognize the need for higher safety factors for nonredundant structures.

2.2 Life Safety Assurance

The design professionals must be responsible for assuring that the completed building is safe for occupancy. This responsibility includes the safety of the basic design, the structural details, checking shop drawings, field inspection and verification of structural safety related matters. The design professionals should certify that, to the best of their knowledge, all safety requirements have been met before a certificate of occupancy is issued.

2.3 Peer Review

All buildings above a certain threshold level should have a comprehensive review of the structural design and details by an independent professional. The threshold level will vary according to the building occupancy, size and uniqueness. Peer review may be provided by the cognizant building department if it includes a thorough structural review by a professional engineer.

2.4 Definition and Assignment of Responsibility

A document should be developed which sets forth the many areas of responsibility necessary for the design and construction of buildings. This document could be used as a checklist to assure that responsibilities for all life safety considerations are assigned and understood by all parties to the construction process. Since the assignment of responsibilities may vary from project to project, several models need to be developed. This document should be prepared by and agreed upon by a committee with representatives from the national societies and associations representing the major participants in the construction process including owners, designers, regulators, and contractors.

2.5 Unified Risk Insurance

The insurance industry should develop a blanket, all-purpose risk policy which simultaneously will insure all members of the project team under a single umbrella. The policy should cover design, construction, and occupancy of the building. Such a combined policy would greatly help restore cooperation and teamwork in the overall construction process. It would remove current impediments to communication between members of the building team.

2.6 Other

In addition to the recommendations above, there was discussion and general agreement on the need to strengthen the building departments of the Nation in order to carry out the necessary regulatory functions. It was recognized that there is need to provide additional financial support so that the process of regulation, the regulations themselves, and the professional personnel to carry out the regulatory functions can be strengthened. Also, there was a recommendation offered which would require contractors and subcontractors to obtain state licenses. Although there was considerable support for this proposal, a consensus was not reached.

3. NATURE AND MAGNITUDE OF THE PROBLEM

3.1 Introduction

Structural failures, as considered by the conference, include those failures which occur during the construction of a building prior to its occupancy and those which occur after a building has been completed and is occupied. The conference speakers and participants did not provide hard data on the total number of major structural failures nor on the magnitude as related to direct dollar loss or by total costs to society including injury and loss of life. Limited data available from the Architecture and Engineering Performance Information Center at the University of Maryland at this time do not indicate a major increase in the number of structural failures.

Major structural collapses have occurred throughout recorded history. In fact, collapses historically have been the primary physical tests to better understand structural performance and have contributed much to the art and science of building design and construction. While there is no strong evidence to indicate a large increase in frequency of occurrence of structural failures, it appears that the magnitude of individual failures, as measured by loss of life and costs per incident, has increased in recent years.

3.2 Causes of Failures

Case studies and discussion indicated that the causes of major structural failures vary, and usually, but not always, are due to more than a single factor when a failure occurs. Design errors can and do occur. These errors can result from use of inappropriate design methods, overlooking critical factors and lack of attention to design requirements; e.g., lack of understanding of dead and live loads and load combinations which may occur during construction and following occupancy.

Construction errors include the misinterpretation of design drawings and specifications and the lack of carrying out the design intent as shown in the contract documents. A further problem, particularly related to the primary structural members, includes poor workmanship in placing, connecting, and protecting materials and members.

Materials deficiencies can also contribute, but probably to a lesser extent than design and construction errors. Failures were cited where the materials did not meet the specification or the specification itself was deficient in not addressing some property or characteristic of the materials.

3.3 Effects of Technical Advancements

The rapidly advancing increase in computational capability has provided mixed blessings. On one hand there are opportunities for improvements such as the conduct of more complex analyses in greater depth and accuracy. Computers allow designers and constructors to look at more options as a solution to a given problem. They permit more sophisticated analysis of structural details. At the same time, this increased computational capability presents further opportunities for errors, both in the development of design and carrying out the construction. There is no standard or well-recognized way to validate a given design computer program to assure full compliance with the intent of the design standard. With greater dependence on computers for detailed design and drafting, building regulation, and construction scheduling and management, there is a tendency for those involved to have less "feel" for the building as it is designed and constructed. With less "hands-on" involvement because of the computer, obscuration of the building process can occur.

New materials and advancements in understanding of structural properties of traditional materials can contribute indirectly to disastrous errors. As these new structural properties are being exploited, frequently, insufficient attention is devoted to the other materials properties. New uses of old materials and increased uses of plastics, high strength metals, and particularly high strength concretes, increase the spans and heights to which structures can be constructed. Extensions in the use of and structural understanding of wood and masonry present new problems. There is increased evidence of chemical and physical incompatibility of structural materials, particularly with greater use of chemical additives and structural adhesives. There appears to be a lack of appreciation of secondary effects such as corrosion, atmospheric attack, and differential movement. Differential movement problems are compounded due to reduction in mass, higher stresses which contribute to elastic and plastic deformations, and an increase in moisture shrinkage and expansion. Increased and varied uses of insulation influence thermal movements. With decreased mass there is increased differential movement and vibration with second order effects which influence the performance of the structure.

There is a tendency to build taller and span wider; in other words, to exploit the high strengths by doing more with less. This is not always accompanied by appropriate analysis and understanding of all conditions present and the material properties. With better structural understanding of materials, there has been a move to reduce load factors and factors of safety. Design and construction methods and procedures have not always kept up with the advances in materials and their exploitation.

While there were a limited number of concerns expressed about the lack of known technology, it was noted that knowledge is lacking in some areas, e.g., wind engineering is not mature. There was discussion on the need for redundancy, especially for some loading conditions, such as drainage and ponding, even if the redundancy simply consists of permitting the water to flow off the roof edge as a means of escape. It was suggested that redundant systems not only shift forces to other receiving members, but also provide warning signs. They "talk to you" during periods of distress. Such features are sometimes termed "fail-safe" concepts.

Professional education today has very strong emphasis on theoretical and fundamental understanding of the sciences. This necessarily is at the expense of gaining practical knowledge to help young architects and engineers understand and effectively contribute to practice early in their careers. Without the practical experience of hand drafting and computation, understanding of the practical aspects of building, such as details, codes, and specifications, is more difficult to obtain.

3.4 Pressures of Time

The use of fast-track methods of construction, construction management, design-build approaches and other techniques to reduce the total elapsed time required from the decision to build to occupancy has had a deleterious effect on structural performance of buildings. These pressures on total elapsed time have been brought about by the high cost of money and high rates of inflation.

The use of such techniques requires greater team effort and coordination. It was noted over and over that it's not always clear who-is-in-charge-of-what under such construction processes. These techniques increase the number of change orders, which increase the chance for error. Such activities complicate team cooperation and frequently contribute to adversarial relationships between subcontractors, general contractors, designers, owners, and construction managers. Under nontraditional processes, such as fast tracking, at times there is an unrealistic push to meet deadlines, with insufficient time for the construction participants to carry out their roles in a thorough and responsible manner.

The changes in the construction process from the traditional relationship of owner, designer, regulator, constructor (each knowing and understanding the responsibilities and the work of the other) have created new relationships and new problems; in particular, with the question of who has responsibility for what at the construction site. Examples include quality control of construction, code compliance, and approval of shop drawings.

4. THE DESIGN PROCESS

4.1 Introduction

In the traditional design and construction process, the owner makes basic decisions as to what he wants to build and under what conditions. He takes the business risk and expects profits consistent with that risk. He hires the architect who traditionally has professional engineers on his staff or contracts with other consulting professionals. Under various schemes in use today, the owner frequently assumes other roles as well, such as the developer, and in some cases the construction manager. In the past, an owner, using a traditional process, expected a high quality building, delivered on time, and within the budget which was established at the beginning of the project. He expected all professionals to be competent and assumed that all building codes and regulations were complied with. He helped develop and approved the building program. His other principal functions included approval of the recommendations of his manager, "the architect." He approved the preliminary and final design and signed the contract with the contractor. Under some of the more recent approaches, these relationship are less clearly defined and followed, so responsibilities vary from project to project.

In the traditional process, the architect was not only responsible for design, but for control and managing the process, keeping in balance the functional requirements, the aesthetic considerations, and the budget. The structural engineer and other engineering consultants performed their work under the overall coordination of the architect.

4.2 New Roles of Designers

In the various newer methods of conducting the building process, the architect may be the prime design contractor, or an engineer may be the prime design contractor, the owner or owner/developer may subcontract design and construction himself, or these functions may be controlled by a construction manager. It was opined by some that more frequently than in the past engineers are now assuming the management role for building projects rather than the architect. Under this arrangement, an architect performs the architectural design, plan preparation, and construction inspection of architectural features; but the project is managed by engineers. It was noted that complex, highly technical building projects today may involve 60 to 80 percent engineering man-hours and 20 to 40 percent architectural man-hours. As a result, more and more design contracts are being performed by engineering-architectural firms. It was felt by some that this trend will reduce structural and other engineering problems in buildings. These variations have contributed to the confusion and disagreement related to responsibilities.

It was also made obvious that, while specifications are indeed an integral part of the design process and the contract documents, they are frequently neglected. The specifications cover the quality of materials and equipment and their installation. Therefore, the specifications themselves become a very important part of the quality control program for the project. Further, it should be noted that where there is a conflict between the specifications and drawings the specifications usually prevail.

Another related point is that designers often look at codes and standards not as minimum requirements but as optimum design criteria. Building codes need to be considered by designers as minimum requirements only.

4.3 The Structural Designer Today

Structural engineering for buildings is being practiced in many ways. In the traditional practice of structural engieering for buildings the structural engineer of record was responsible to the architect. The practice today is so varied that in some cited projects as many as four different structural engineers had partial responsibility plus a fifth party with a professional engineering staff had quality control responsibility. This instance included a structural engineer for the foundation, another for the frame, another for structural details, and another for secondary structural elements such as walls. This arrangement suggests that no single structural engineer is an important and integral member of the design team. Under these conditions, who is the engineer of record?

In order to participate in a professional manner, it was agreed that the structural engineer needs to be involved early in the design and should have full responsibility centered in one firm. Piecemeal responsibility causes erosion of the design quality and professionalism itself. The erosion of clear structural engineering responsibility was lamented by the conference participants. The structural engineers felt a strong need to reassert their professional responsibility to provide the public with safe buildings. It was suggested that the design structural engineer should have construction quality control and onsite inspection responsibility. It was recommended that engineers insist on an appropriate position on the design team or not accept the assignment. There was general agreement that the structural engineer should be responsible for shop drawings meeting the design intent, whether prepared by him or others, also for the quality control of materials. However, it was also noted that the fee-structure generally provided today is insufficient to cover the cost of shop drawing preparation.

There is need to get better, more accurate information on structural failures promptly published in order to share investigation findings with other professionals. There has been a broad reluctance by professional engineers to share information on failures, particularly in response to legal restraints and threats of litigation. Most failures have not been widely discussed openly due to the reluctance of engineers to call attention to problems.

It was noted that value engineering may be helpful, especially when the project comes in over budget; however, a great deal of attention and analysis needs to be devoted to proposed alternate solutions. The conference appeared to be skeptical of fast-track methods without a clear understanding of professional and contractual responsibilities at the outset. It was generally agreed that there is need for clear definition of responsibilities and that the related fee-structure must provide for carrying out these responsibilities. Architects and engineers must reestablish their professional worth and regain the public trust.

5. THE CONSTRUCTION PROCESS

5.1 Introduction

The actual construction process is normally led by a general contractor (GC). Even under the various new approaches to increasing the speed and reducing the cost of construction, including the use of construction managers and fast-track methods, most onsite work is still done under the direction of the general contractor.

The characteristics of a successful GC include a good understanding of his strengths and limitations based upon experience. The GC must have sufficient resources in staff, capital, materials, and equipment to carry out the work. The GC needs to understand the responsibilities for any particular contract including his obligations as well as those of others which he should not assume. Some of the problems of general contractors include being left out as part of the construction team when decisions are made that affect the GC, his profits, and ability to perform. Accepting deficiencies and ambiguities in contract documents is another problem. Some general contractors do not properly schedule and manage the construction, leaving it up to the subcontractors to "run the job."

There was much discussion about the merit of licensing contractors, with very different opinions as to the merit of such licensing. In some areas, licensing includes verification of technical competence, while in others it is primarily a means of assuring financial responsibility and business capability. There has been formed an American Institute of Contractors which encourages licensing and has as one of its objectives to raise the level of contractor professionalism.

5.2 Onsite Responsibilities

The project architect needs to better inform owners of what is expected of the general contractor, his subcontractors, and what is the contractual relationship. The architect and engineer should not take responsiblity for job safety; this is the responsibility of the contractor. Because of the increase in litigation, some designers are purposely staying away from the project while under construction to mitigate potential liability. It was suggested by some that design/build contractors may work better and deserve more consideration because they remove some of the reasons for the adversarial relationships of the parties involved.

Materials suppliers have responsibility during construction as well. They are responsible to see to it that the materials delivered to the job site are as specified and that they are properly placed and protected as required. If the materials supplier is responsible for shop drawings, these need to be started immediately following notice of award. On the other hand, the contractor and the design professionals have responsibility to the materials supplier to review and approve shop drawings promptly so as to meet the requirements of the project schedule. This applies particularly to producers and suppliers of structural materials.

5.3 New Onsite Roles

In an attempt to deliver better buildings faster, a number of new roles and relationships are being tried. These roles include: scheduling engineers, materials engineers, QA-AC organizations, inspection agencies, and materials laboratories. When such organizations are used, their roles need to be specifically spelled out for the particular project so their responsibilities are clear to all affected parties. Typically, such agencies report to and are paid directly by the owner. If was noted that the role of such agencies appears to be expanding with decreased A&E inspection. In selecting such firms, the most important criteria should be experience and past performance. Today, more than ever, the owner should hire high quality laboratories and other third party consultants to assist in quality control of such items as concrete strength, reinforcing steel placement, and welding.

The biggest problem in onsite construction is the lack of communication. Thorough project planning and scheduling would be of much assistance in onsite communication. Preconstruction meetings were also recommended as a means to gain understanding and to air problems and differences before they impact construction progress and quality.

Contractors indicated that a major problem is with broken promises, particularly related to time commitments and schedules, even when people know better. Some professional developer/owners have started to use a special "scheduling engineer" to assist in project planning and schedule maintenance.

It appeared that most contractors prefer that architects and engineers provide onsite inspection which would assist in expediting the work where technical decisions are needed during construction. Items requiring A&E decisions include changes in conditions, interpretation of contract documents, and correction of errors in design documents. Some of the structural engineers felt that it would be best if the materials engineers, QA-QC firms, inspection agencies, and material laboratories were directly responsible to the professional structural engineer of record. Also the design structural engineer should be responsible for onsite structural inspections. When the structural design firm is not located convenient to the construction site the onsite inspection can be provided by temporary reassignment of inspectors, frequent travel, or by associating with a local firm.

While it was recognized that some engineers stay away from the construction site to mitigate their liability, the primary reason that engineers don't provide onsite inspection is the lack of adequate fees to pay for these services.

6. LEGAL IMPLICATIONS

6.1 Introduction

There was strong agreement that there has been a substantial increase in litigation where large sums of money are at stake. Unfortunately, the U.S. court system provides for lay people to make decisions for placement of blame regardless of the extremely complex technical and construction process issues at hand. A general feeling was present concerning dissatisfaction with the U.S. legal system's ability to adequately and fairly deal with financial exposure and blame for structural failures. This appears to have the effect on the professionals involved to want to limit their exposure and thus avoid involvement when responsiblitiy is not clear.

The increase in building related litigation involves not only major failures but minor failures and unsatisfactory building performance as well. It was noted that the climate for litigation is very favorable today, with high monetary awards frequently being given. As a result of litigation, usually all parties concerned get hurt--the owner/developer, the A&E, the contractor, and other parties involved. Frequently legal awards do not relate well to parties at fault but are often based upon who has the "deep pocket." The high cost of liability insurance is a matter of much concern. In the case of failures, property losses are paid off early, but personal injury claims drag on much longer and are more costly.

There was a general feeling that increased litigation will be experienced over the foreseeable future, as there has been a continuing increase in litigation through the period of 1950 to present. Contributing causes include: older buildings are wearing out, new buildings under construction are failing, architects and engineers are developing more innovative designs, and the public is more litigious today.

Needs were identified to improve the process of litigation, including judicial reform to reduce frivolous suits, many of which are filed by third parties. Such are found to be time consuming, costly, and annoying; but currently there is no ready means for avoidance. It was suggested that contingency fees breed frivolous lawsuits, that innovative designs need to be treated differently, and when peers are called upon for review, they should be protected and held harmless from lawsuits.

6.2 Legal Responsibilities

In spite of many problems identified and attributed to the lawyers and to insurance companies, it was agreed that the major problem relates to a lack of clearcut responsibility for design and construction.

From a legal viewpoint, when responsibility is not clear, it doesn't make any difference who is boss, who assumes responsibility/risk, and who has the contract. All of the purveyors, the designers (A/E's), owners, developers, and contractors are subject to suit; and all will get hurt. The deep pocket theory tends to prevail. Just because a designer did not have sufficient fees, or didn't have time to review shop drawings due to a tight schedule, does not protect him from lawsuits. He can be sued anyway. Litigation is designed to establish fault, but this objective is not always met. It was generally agreed that legal costs will increase, that costs of professional liability insurance will increase, and all purveyors will continue to be involved in litigation. The only real protection is to design and build so that the buildings stand up and perform properly. Some argued the way to do this is to place all responsibilities in one firm to provide all design, construction, inspections, and construction management services. Questions were raised about the lack of clarity on the statue of limitations as applied to design and construction, also in respect to the moral obligations of designers and builders.

Because of the increase in lawsuits, there has been a proliferation of professional engineering firms specializing in investigations and diagnostics for litigation. These firms frequently do excellent work, but the results are not widely disseminated nor made public. There is need for prompt release of accurate information as to the causes and circumstances of structural failures in order to reduce reoccurrences.

In former times, there were fewer structural failures and little or no insurance. It was suggested by some that, when the insurance companies started to sell all-risk insurance, failures and related lawsuits increased.

Owners and purveyors can reduce the time and cost of litigation by developing contracts on how disputes would be resolved, such as by mediation. Construction participants should take care in selecting insurance agents who know the construction business and the insuree's part in the process.

7. THE REGULATORY PROCESS

7.1 Introduction

Under the Constitution of the United States, the responsibility for regulation of building construction is retained by the States. The States, in turn, have in many cases relegated this responsibility to local municipalities or other within-state jurisdictions. This has contributed to the growth of many different approaches to building regulation both in content of regulations and their enforcement. Today, however, there is much consistency in the regulations themselves, with most regulations being patterned after one of the three model building codes, which are very similar in technical content. The conference identified only very limited criticism of the technical requirements of the codes themselves. However, some related issues were discussed, particularly related to safety factors and special consideration being given to innovative construction and lack of redundancy.

It was recognized that there is increased pressure for swift regulatory turnarounds. At the same time, due to the pressures of governmental budgets, there has been a general reduction in financial support for building departments. In many cases, this has forced building departments to be less thorough in their evaluation of the design documents for compliance with the codes and in inspection during construction to ensure compliance with the codes and the design documents.

Third party support, if performed by competent professionals, is considered by some to offer ways for improving the safety of buildings and their construction. The regulator, too, is depending increasingly upon computers and automation to check for compliance, to schedule the regulatory review and inspections, as well as to develop and maintain a regulatory data base.

The administration of building codes includes the code compliance process which is normally made up of two major steps. The first is plan review or a review of the contract documents to assure compliance with the building regulations, and the second includes onsite inspection to assure compliance with the contract documents and the general requirements of the building code where the contract documents are not specific.

7.2 Plan Review

In most jurisdictions, building officials provide a plan review which varies from superficial spot checking to indepth review, particularly of life safety considerations including structural and fire-related requirements. Recently, due to reduced budgets and the complexity of building design, plan review has become an ever-increasing burden for building departments. In lieu of indepth plan reviews, some jurisdictions now rely on third parties who review the plans, specifications, and calculations for a fee; some other jurisdictions, such as Boston, require peer review of the structural design. The peer review structural engineer may be selected by the building department, or selected by the design engineer with the approval of the building department. Agreement was not reached as to which approach is preferred. It was agreed that there is need for a fee sufficient to conduct the review, and that the reviewer should be held harmless from lawsuits and compliance of the design with the code requirements. One of the most thorough reviews by a major city building department is conducted by the Los Angeles Building Department itself. Another approach, due to budget and staff limitations, has been implemented in New York City, where reviews are no longer undertaken, but the design professional is required to certify that the building code requirements have been met. In this case, the professional engineer who seals the design is totally responsible for structural design compliance with the code.

7.3 Onsite Inspection

Onsite inspection is intended to assure that the construction is completed in compliance with the approved contract documents as far as building regulations are concerned. It was suggested that frequently this is not the case, that buildings are not built in compliance with the contract documents for various reasons. In some cases, such as New York City, the design engineer is responsible for onsite inspection. In this case, when inspection is not provided by the structural engineer, he is responsible for approving other licensed professionals to inspect in his place. Other jurisdictions, such as the State of New Jersey, require that all building inspectors be certified to have knowledge of code requirements and their enforcement. Another approach is the use of third parties which report to and are paid by the building department to conduct onsite inspection. In carrying out quality control at the building site, testing agencies are frequently called upon. In most cases, these need to be approved by the building department. Some building departments maintain a list of recognized testing agencies.

7.4 Designer's Responsibility for Code Compliance

In spite of the various programs to assure compliance with building codes, in most jurisdictions the responsibility for design documents complying with the building code rests with the designing professionals. However, responsibility for delivering a building that has complied with the building code is another area where there is a lack of clarity. The nature of spot inspections during construction does not assure either that the code has been complied with or that the building has been built consistent with the contract documents. Seldom, except in very major projects, are there full-time inspectors reporting to the designers or to the building department. It was suggested by some that design professionals should be responsible for certifying that the building has been built to comply with the building code. Design professionals, of course, should be compensated accordingly.

8. CONCLUSIONS

Building design and construction has rapidly changed in recent years and is in a state of flux. The product, the building itself, is different than those of the past. There is increased evidence of innovation in design and construction. But it is the process of design and construction that has changed the most. New methods such as fast tracking, turn-key, the use of the construction manager, design/build approaches, and the lack of dependence on a single design and construction team have greatly complicated the construction of a building.

These changes have developed problems in four major areas. A very difficult issue is the problem of inadequate communication. Communication problems are particularly acute because of rapidly developing changes in the building process and the roles of the participants. There are some technical problems in respect to building design due to changes in materials and methods and lack of effective ways and means to assure quality of the delivered building. Another process problem relates to the increase in litigation to resolve disputes and the high costs of insurance to protect the parties involved in planning, regulating, and constructing buildings. However, the single largest problem, which directly relates to each of the other problems, is the lack of clear understanding and agreement on responsibility. Throughout the conference, the question came up over and over again, "Who is responsible for what, when?"

The specific and virtually unanimous conclusions of the conference regarding necessary actions are summarized in Chapter 2 RECOMMENDATIONS of this article.