President's memo

Concrete — The Need to Tell Our Story

I believe that most will agree that the post-World War II years have seen a more rapid pace of technological development in all fields of science and engineering than experienced in any prior period of history. Some of these advancements are well-known to the average man on the street and are described frequently on the pages of our daily newspapers. Notable recent examples are progress in electronics, space travel, and new surgical procedures, all relatively unknown only a few years ago. However, the average citizen too often knows little about significant advancements that have been made by the construction industry during this same period of time.

Recent advancements in construction have been as dramatic in their own way as events that have captured front-page headlines for other industries. Yet, progress in construction is little known or seen beyond the pages of *Engineering News-Record* or other journals whose readership is largely those already close to construction. Even worse, perhaps, is the fact that all too often when the construction industry does capture front-page headlines it is because of malperformance or failure of a structure to meet requirements expected of it by the designer, owner, or general public. Because of problems of this kind, the American Society of Civil Engineers currently is offering to provide the leadership necessary to properly establish responsibility among all who participate in developing a new project to serve the public. Too often the negative side of construction gains more attention than the positive.

This leads me to the growing conviction that we in the construction industry are at times our own worst enemy because we fail to tell others adequately of advancements we have made that not only benefit our industry but, more importantly, benefit the general public whom we serve.

We in the concrete industry have shared in spectacular progress since World War II. In that period of time, the height of concrete high-rise buildings has doubled due to developments such as high strength concretes, lightweight concrete, and high strength reinforcing steels. The long-span bridge, once the sole domain of structural steel, is increasingly a concrete structure. Some of the tallest structures in the world, those involved in offshore oil recovery, are marvels of technology in concrete. Today, we are hearing of cement-based materials having characteristics approaching those of structural aluminum and we are seriously discussing ways in which concrete can be involved in construction on the moon, a new challenge that is certain to become a reality in future years. These are only a few examples of spectacular progress that has been made or will be made with concrete. Others could be cited. But the point is that we, the researchers, educators, designers, materials producers, and constructors, have much of which we can be justly proud as we work together to solve problems that once seemed insurmountable. We should be doing more to tell the world around us about these accomplishments.

I plan to devote several future "Memos" to brief descriptions of some outstanding successes achieved by concrete in recent years. These should be thoroughly understood and appreciated by us who work closely with concrete and, through our efforts, they should be communicated to the general public. Among topics addressed will be high strength concretes, ships and offshore structures, long-span bridges, high-rise buildings, and improvements in the durability of concrete.

Any field of technology experiences some failures as it reaches out for progress and, we in the concrete industry, have not yet solved all of our problems. Perhaps we never will, if for no reason other than the difficulty we experience in passing our knowledge already gained to less experienced persons who are steadily joining our ranks. But the opportunities for finding a challenging, satisfying, and rewarding career are as great in the concrete industry today as in any other field of endeavor. How we meet these challenges depends upon our imaginations, our creativity, and our willingness to work. But, as we meet them, we should never stop telling other people about our valid accomplishments.

W E Kunze

President's memo

The Dramatic Climb of Concrete High Rise Buildings

In my first memo, I indicated my intention to identify a number of recent, significant accomplishments of the concrete industry that are worthy of special recognition, not only by those of us who regularly work with concrete, but also by the general public. Certainly the dramatic growth in the height of concrete buildings deserves this kind of attention. Earlier this year at an international conference entitled "Second Century of the Skyscraper," several speakers addressed the topic of super tall buildings with heights as high as 8,000 ft (2438 m). This is quite remarkable considering that it has been only 100 years since construction of the Home Insurance Building in Chicago — considered to be the first skyscraper because of its independent iron frame. Included in the presentations at the conference was a concept for a mile high concrete building. We should be extremely proud that we now can think in terms of the feasibility of such tall structures.

Construction of the twin towers of Marina City in Chicago in 1962 was heralded as a major step forward. Not only did these buildings hold the height record for concrete structures at that time, but the architectural features of the buildings also were unique. The widespread publicity that resulted from the twin towers increased awareness of the capabilities of concrete for tall buildings. Of interest, a photograph of the Marina towers was recently used again on the cover of the January-February 1986 ACI JOURNAL. We also can be proud of Chicago's Lake Point Tower constructed in 1968 with a record height at that time of 645 ft (196 m). This 70-story apartment building utilized concrete with a compressive strength of 7500 psi (52 MPa) and Grade 75 reinforcement. We can also praise ourselves for Water Tower Place, also in Chicago, completed in 1975 at a height of 859 ft (261 m). This structure is special not only because of its record height for an all-concrete building (and this record has endured for more than 10 years) but also for the fact that it would have been a steel framed structure if it had not been for the recent developments which make concrete an excellent material for tall buildings. It is to our credit that such a building of this height could compete economically against steel frame proposals.

In case you are thinking that my remarks are oriented too much toward the Chicago skyline, I want to mention other structures in different parts of the United States. An example is the 72-story Interfirst Plaza building in Dallas, Tex., with 10,000 psi (69 MPa) concrete in its columns. This structure is again different in that it was designed utilizing composite construction. High strength concrete was specified to give the slender building a more cost effective stiffness than could be achieved by utilizing a steel frame bracing system. In Seattle, Wash., we have the 76-story, 955 ft (291 m) tall Columbia Sea-First Center. Again, this is a composite structure in which high strength concrete is utilized to carry vertical loads in the building and to reduce sway. In Houston, Tex. the 1,002 ft (305 m) tall Texas Commerce Tower, completed in 1983, is the world's tallest composite building.

In the period from 1962 until 1973, the height of the tallest all concrete buildings went from under 600 ft to over 850 ft (182 to 259 m) representing an increase in height of over 40 percent. As already mentioned, we are seeing even taller composite buildings being utilized with concrete playing a major role.

What developments then have led to taller concrete buildings? Developments have included both the utilization of higher strength and lighter materials and improvement in design concepts. Introduction of Grade 60 reinforcement resulted in less steel being needed in many applications. In particular, column steel could carry a greater portion of the vertical load and reinforcement percentages became less. By utilizing lightweight instead of normal weight concrete in floor slabs, weight of floors is reduced by up to one third. Because the weight of floors represents a large part of the load carried by the columns, significant savings are made in the weights of our tall buildings. Just as high strength reinforcement can result in smaller column sizes, so too can the use of high strength concretes. A few years ago, concrete with a strength of 6000 psi (41 MPa) was considered high strength. Now we think in terms of 14,000 psi (96 MPa) concrete being available for high rise construction. In fact, were it not for the availability of these

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high strength concretes, we would not see the utilization of as much concrete in very tall buildings.

There have been other developments which aided in the increased use of concrete in high rise buildings. New admixtures have made concrete a material that is easier to place in congested areas. Contractors have developed innovative, economical forming systems and have achieved the organization of work on the job that has made it possible to erect two floors per week. The ready-mixed concrete industry has established quality control procedures making it possible to deliver high strength concretes in a consistent and predictable manner.

The final item contributing to the growth of tall concrete buildings is the development of new design concepts. This includes the introduction of the strength design method which utilizes a more rational approach to design. Along with new design concepts has come the widespread application of computerized design for very tall buildings. These days it is economically possible to carry out a number of alternate computerized calculations before the final design of a building is completed. In this way, material and labor costs can be optimized to produce the most efficient and economical structure.

We as an industry have made an outstanding contribution to our society in the high rise concrete building. This achievement is one of which we can be justifiably proud and one that is very visible to the public scanning the skylines of our cities.

A Magnificent Leap Forward

In June 1973, the first major offshore concrete structure was towed 300 miles from a sheltered construction site in Norway to its final location in the Ekofisk oil field of the North Sea. Thirteen years and 18 concrete platforms later, designs are ready for the "Troll" platform shown on the cover of this issue. The total height of this structure from seabed to drilling tower will be 1,540 ft (470 m) which exceeds the 1,425 ft (435 m) height of the Sears Building in Chicago, currently the world's tallest.

These offshore structures have produced substantial advancements in concrete engineering pertinent to a variety of applications ranging from bridges and buildings to industrial facilities. Naturally, they are also impressive accomplishments in maritime, foundation, and petroleum engineering.

The size and complexity of these structures have increased as illustrated by comparing Ekofisk to Gullfaks C, construction of which began in 1985. Ocean depth increased from 230 to 710 ft (70 to 216 m), area of the gravity base from 2 to 4 acres (0.8 to 1.6 ha), and tow-out weight from 500,000 to 1,650,000 short tons (453,000 to 1,496,000 Mg). Consumption of materials increased from 95,000 to 285,000 cu yd (73,000 to 218,000 m^3) of concrete and from 13,000 to 77,000 short tons (11,800 to 70,000 Mg) of reinforcing steel, enough steel to build ten Eiffel Towers. The work required to build the concrete structure is estimated at 4.4 million man-hours or about 2,500 man-years. The installed cost with petrochemical and service facilities will exceed $1 billion (U.S.).

Structural design of offshore structures has always been on the cutting edge of concrete technology. Because they must float as they are towed great distances from the construction site to final location, they must not be overdesigned. On the other hand, the cost of on-board equipment and facilities is three to five times the cost of the structure itself, so that the risk of structural inadequacy must be minimized. Superb structural design, therefore, is a necessity.

Criteria for the Ekofisk offshore structure based on ultimate strength were pioneered in 1971 during a meeting between owners, government, designers, contractors, and insurance writers. Known as the Oslo Criteria of September 1, 1971, these principles became the origin of various international criteria, including the "Guide for the Design and Construction of Fixed Offshore Structures," reported by ACI Committee 357 in 1978 with a 2nd edition in 1984. Structural analysis involved rather simple calculations in 1971, which evolved gradually into the sophisticated finite element analyses used for recent platforms, including the Gullfaks C and Troll structures.

Known principles of concrete technology were vigorously applied under strict quality control during construction of the Ekofisk structure in the early 1970's. The aggregates selected, quartz sand and granitic coarse aggregate, had an excellent service record in excess of 50 years in spite of the use of high-alkali cements. Examination at two prominent laboratories confirmed that these aggregates are not reactive to alkalies. A ligno sulphonate retarder was used to facilitate slipforming, together with a vinsol resin air entraining agent. An average cylinder strength of 6,000 psi (41 MPa) was achieved at 28 days with a coefficient of variation of 7 percent for the entire project.

Performance and durability of such structures are a matter of constant vigilance. In 1982, evaluation engineers conducted an extensive inspection of 11 existing offshore structures and classified them all as "excellent" in terms of performance and durability. Since the installation of the first structures, a number of new materials and concepts have been introduced in order to improve performance. One such development was high range water reducers, in some cases combined with silica fume. Strengths of 10,000 psi (69 MPa) at 28 days and 15,000 psi (103 MPa) at 6 months are now a practical reality.

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Benefits of high strength concrete are substantial during the towing phase in the ocean. Similar benefits can be realized through the use of high strength lightweight aggregate concrete as developed in Japan, Norway, and the United States. The CIDS structure was towed over 6,000 miles (9700 km) from Japan to the North Coast of Alaska in 1984. Strengths of 7,000 to 8,000 psi (48 to 56 MPa) were realized at 28 days with a specific gravity of 1.8.

Slipforming was extensively used in construction of all North Sea concrete structures. Initially, experience from construction of silos was utilized. Refinements were developed when conical towers emerged from improved conceptual design, so that both variable cross section and variable wall thickness became required. A further refinement was tested in 1984 by construction of a 160 ft tower (49 m) leaning 16 degrees with variations in diameter and wall thickness. Thus, all refinements required to build the Troll platform are firmly in hand.

Construction management has always been a cardinal branch of concrete engineering. There is very limited room for mistakes in construction of structures containing massive amounts of petrochemical equipment and a variety of facilities. Towing can only take place safely in the fair weather of early summer. If that opportunity is missed, an entire year of production will be lost to the owner. "On site, on time, within budget" is a meaningful motto characteristic of offshore structures.

W E Kunze

President's memo

ACI's Expanding Horizons

One of the privileges of the President of ACI is being able to report to you, the member, the innovations being undertaken by the Institute in response to your needs. I am sure that you are aware of the Board of Direction decision in San Francisco to create two new technical journals. I want to take this opportunity to provide you with the reasoning behind this decision and the value to you as a member.

A primary mission of the Institute is to publish timely, authoritative information about concrete and concrete technology. The need to expand the present ACI JOURNAL is in response to the increase in the number of excellent manuscripts and the need to get these papers into print. There was an obligation to expand the Institute's publishing capabilities. A stopgap measure was implemented to decrease the backlong of papers awaiting publication. This "quick fix" solution to the problem in 1985 and 1986 was to simply double the number of pages printed in each issue of the JOURNAL and subsidize it from Institute general funds. But a more permanent and self-supporting solution was needed, and a study was initiated by the Board's Publications Committee to determine the most effective method of achieving this goal. The recommendation for the publication of two new journals was the result of this study.

The publication of these new bimonthly journals — to be known as the *ACI Structural Journal* and the *ACI Materials Journal* — will expand the publishing power of the Institute. Beginning in January of 1987 each journal will be published bimonthly, on alternate months. The existing JOURNAL will be retired at the end of 1986. It was the consensus of the Board that this alternative would allow ACI to publish even more papers than previously, on a timely basis.

Separating the papers into a structural journal and a materials journal, will allow you as a member to choose, as part of your dues, whichever publication best satisfies your needs. The second journal is also available to you for a modest subscription fee. Abstracts from each journal will appear in the other, with copies of individual papers available upon request for a nominal charge.

Realizing that you have not seen the new journals, a special introductory offer will be presented to you in September along with your 1987 dues invoice. For this year only, you can choose to receive both journals at no additional cost. All you need to do is return your 1987 dues payment postmarked no later than October 15, 1986 (dues invoices will be mailed September 1, 1986).

I cannot overemphasize that, by creating these two new journals, ACI will be providing you — the member — with the most timely and authoritative information possible about concrete and concrete technology.

President's memo

Research for a Better Tomorrow

At a recent American Society of Civil Engineers meeting, the man who heads the U. S. Army Corps of Engineers mildly chided those in the profession of which he himself is a member. Civil engineers, said Lt. Gen. E. R. Heiberg III, tend to be too conservative, too willing to shy away from new concepts and innovative technology. They avoid, he said, looking at new challenges such as those that will be required for extraterrestrial engineering.

"I fear that civil engineers might be a bit conservative because of their training and experience. They cannot afford to have buildings fall down, walls cave in, nor dams fail," said Heiberg. Incidentally, the American Concrete Institute will be honored to have General Heiberg as our keynote speaker at the Baltimore, Md., convention in November.

I think there is a degree of truth in Heiberg's statement. Certainly, he, as the chief engineer of the Department of the Army, is in a position to understand the basic traits, good and bad, of the profession.

All of this brings to mind a most important challenge that was presented to ACI only a few years ago. It is the challenge of research which is an absolute necessity if we are to move ahead boldly, and with confidence, into new areas of materials and design for futuristic construction such as extraterrestrial engineering. There is no question that research in concrete and cement technology has been on a decline in recent years. A National Research Council report, now more than six years old, decried the state of research and development which, even then, was termed "inadequate in the light of the needs and opportunities."

It has been nearly two years since ACI formed the Concrete Materials Research Council. Nothing would please me more than to be able to report to you that CMRC achievements have been spectacular, that its pleas for funding of proposals have had an overwhelming response. This, however, is not the case but, again, I doubt that anyone expected it to be otherwise.

The Council has received and evaluated numerous research proposals. Of the many worthy proposals, four were approved by the Council at its March 1986 meeting in San Francisco:

1. Improvement of the contribution of fly ash to the strength of concrete
2. Effect of curing regimens on concrete performance
3. Effects of fly ash composition and type on cement paste mortar pore solution composition and its role in alkali-silica reactivity
4. The effects of microcracking on the permeability of concrete.

Although estimated costs of these individual research proposals ranged as high as $183,000, CMRC's authorization is limited to $10,000 for each. The researchers, of course, have other avenues to pursue with respect to additional finances for their undertakings.

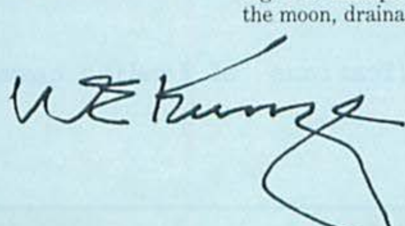
In addition to the proposals discussed above, several private firms have indicated an interest in sponsorship of a CMRC program on influence of admixed chloride on the corrosion behavior of steel in conventionally reinforced concrete. This has been a most controversial issue, largely because of debatable chloride limits; and it is felt that research would lead to realistic and reliable information for use in building construction. Such research data are expected to be considered in future revisions of the ACI 318 Building Code.

A CMRC Task Group prepared a request for proposals for both laboratory and field studies for this program, and has completed its evaluation of proposals and selection of research organizations.

The Council is now in need of industry support for such research. An announcement of these programs, a discussion of the need for research, planned research approaches, and anticipated impact of the studies appear on page 6 of this issue of *Concrete International*.

Let's move ahead on this and, hopefully two years from now, the president of ACI will be able to write more glowingly about CMRC achievements.

P.S. I neglected to point out that General Heiberg observed that there are certain benefits in things like extraterrestrial engineering. For example, he noted that for the construction of a hotel on the moon, drainage problems would be minuscule!



President's memo

High-Strength Concrete

In my second memo, I addressed the dramatic increase in height that has occurred in recent years with concrete high-rise buildings. One factor contributing to our ability to build taller structures and do so economically, has been the availability and acceptability of high-strength concrete. The designer of a high-rise building is concerned both with the ability of the structure to resist lateral loads and also to transfer vertical loads down to the foundation. Numerous studies have indicated that the most economical way to carry these loads is with high-strength concrete and small concrete column sizes. Smaller column sizes mean less interference with the internal, rentable floor space of a building.

High-strength concrete has been a major development of our industry, starting with concrete compressive strengths of 6000 psi (41 MPa) in the 1960s and continuing to current strengths of over 14,000 psi (97 MPa) for columns in buildings. This success story is one of cooperation among owner, architect, engineer, contractor, concrete supplier, and suppliers of the concrete constituents. Cooperation of this kind is essential for successful use of high-strength concrete. The engineer is not going to specify this material without knowing that the concrete supplier can provide the desired strengths. The concrete supplier in turn must be assured that the constituent materials are available on a consistent basis. In turn, all parties must rely on testing laboratories to provide a consistent level of quality control in performing acceptance tests. And, finally, the contractor must be willing to handle the material because in some situations, he may well be placing concretes of two different strengths on the same day at the same floor level. Utilization of fly ash, silica fume, and superplasticizers combined with improvements in cements have led to a product of which the concrete community can be proud.

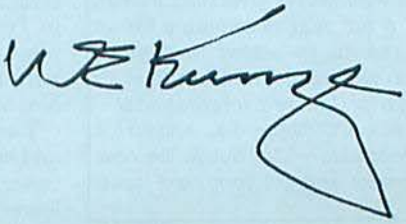
In recent years, we have seen a rapid growth in interest and in information available on high-strength concrete. The ACI committee report entitled "State-of-the-Art Report on High-Strength Concrete" published in 1984 lists over 200 references on high-strength concrete. We have seen numerous convention technical sessions with related publications on high-strength concrete, an ACI educational series on this subject, as well as the formation of a high-strength concrete committee by the Prestressed Concrete Institute. The goal of this latter committee is to look at high-strength concretes at early ages whereas the thrust of ACI activities to date has been with later ages.

With this proliferation of information, we have seen a significant growth in utilization of high-strength concretes in many geographic locations. At one time, Chicago was considered to be the home of this material. More recently there have been applications in Dallas, Denver, Houston, Miami, Minneapolis, New York, Seattle, and Toronto, to name a few locations. High-strength concrete is used not only for its strength, but also for its ability to provide a stiffer structure.

Although the most frequent use of high-strength concrete has been in building columns, there have been many applications in precast prestressed girders. We have also been slow to acknowledge these achievements. Consequently, published information on applications of high-strength concrete in bridges is somewhat limited and reported design strengths in general have not exceeded 6000 psi (41 MPa). However, there have been incidents of higher strength bridge applications including 8000 psi (55 MPa) in the Huntington, W. Va., to Proctorville, Ohio, cable-stayed structure and 7000 psi (48 MPa) in the Coweman River bridges in Washington. On the other hand, the Japanese have been more aggressive in utilizing high-strength concrete, including design concrete strengths as high as 11,400 psi (76 MPa) for applications in railway bridges.

In general, we tend to associate high-strength concrete with normal weight aggregates. We should not, however, overlook the use of high-strength lightweight concrete. Strengths as high as 12,000 psi (83 MPa) can be achieved with semi-lightweight concretes having densities of about 125 lb/ft^3 (2.0 Mg/m^3). Of significance is the development of lightweight concrete for use in floating structures in the arctic. Here, concrete with compressive strengths of 9000 psi (62 MPa) and densities of 130 lb/ft^3 (2.1 Mg/m^3) have been utilized successfully.

Although the columns of high-rise buildings are often hidden behind the architectural features of these buildings and the superstructures of bridges usually are not visible as we drive over our long-span structures, high-strength concrete is playing a significant role in enabling us to construct taller buildings and longer span bridges economically. All parts of the concrete community should be proud of these achievements.



President's memo

Service Life Design: Is It Attainable?

Walter E. Kunze

We talk a great deal about achieving durable concrete. However, are we not really interested in the service life of a concrete structure? A life dictated by the intended use of the structure in its particular environment? Presumably, we want to design a structure for a specific service life, recognizing its function and exposure, and be assured that this service life is at least attained, if not exceeded. And, of course, the cost related to achieving this result must be considered if concrete is to remain a competitive alternative to other construction materials.

ACI has played a major role in developing and disseminating a vast amount of knowledge directed toward the performance of concrete and the effect of concrete's varied components on its performance. Significant progress has been made in recent years with respect to durable bridge decks, control of the alkali-silica reaction, and a better understanding of factors affecting the corrosion of reinforcing steel. Our technical committees are working diligently to bring together the latest developments in concrete technology and make them available for proper use in the scheme of things. ACI Committee 225 recently issued a "Guide to the Selection and Use of Hydraulic Cements," a much needed synthesis of current knowledge. ACI Committee 226 is on the verge of publishing separate state-of-the-art reports on fly ash, ground granulated blast-furnace slag, and silica fume. Proper utilization of all of these materials, along with the other components of concrete, will enhance the performance and durability of this versatile construction material.

We need, however, to direct our efforts to a broader objective, one which has probably always been in the back of our minds, namely to ensure that a structure performs in an acceptable manner over its intended service life. The capability to predict the service life of concrete structures should be developed as rapidly as possible. Dr. Eivind Hognestad of the Portland Cement Association in his recent Raymond E. Davis Lecture (*Concrete International*, June, 1986) highlighted this need in the following statement:

> "The primary aim in future design for service life is to incorporate all aspects of durability into the analytical design process with an emphasis equal to that now given to structural strength."

Dr. George Somerville of the Cement and Concrete Association in Great Britain, in a recent paper, "The Design Life of Concrete Structures" (February 1986 issue of the *Structural Engineer*) stated:

> "Clearly, nothing lasts for ever; equally clearly, the performance requirements, in time terms, are quite different for a nuclear reactor, a cathedral, a bridge, or a barn. The definition of precise design lives for different types of structure is fraught with all sorts of difficulties — conceptual, social, economical, and practical. However, at the present stage of development, to have even a nominal design life in mind would be an enormous step forward, since it is no credit to the profession, or service to society, to produce either low quality cathedrals or gold-plated barns.
>
> "This leads to a possible definition of nominal design life as 'the minimum period for which the structure can be expected to perform its designated function, without significant loss of utility, and not requiring too much maintenance.' Words such as 'expected,' 'designated,' 'significant' would require definition in turn."

G. Fagerlund of the Swedish Cement and Concrete Research Institute, voiced similar thoughts in a paper, "Service Life of Concrete Structures," which appears in the proceedings of a 1982 Stockholm conference on Contemporary European Concrete Research. The need for techniques to aid in making reliable predictions of service life is further emphasized in a paper "Prediction of Concrete Service-Life," by J. Pommersheim (Bucknell University) and J. Clifton (National Bureau of Standards) which appeared in RILEM's *Materials and Structures* (Vol. 18, No. 103, January-February, 1985).

These papers highlight the growing interest in the functioning of the structure as a whole, rather than merely in the capabilities of the material alone, an interest that is somewhat more apparent in Europe at this time than in the United States or Canada. ASTM Committee E-6 on Performance of Building Construction did, however, develop in 1978 ASTM E632, "Standard Practice for Developing Accelerated Tests to Aid Prediction of the Service Life of Building Components and Materials," a necessary preliminary to predicting the service life of a structure. One wonders how many of us are aware of the availability of this standard practice.

It is obvious that much more is needed than merely proper knowledge on the durability of the material concrete. One must consider as equally important such aspects as structural design, detailing, construction techniques, environmental exposure, the use to which the structure is put, the level of maintenance to be provided, and the intended life span of the structure. All of these interact to determine performance. While there are ACI technical committees which address some of these issues, I feel that there is an urgent need for an overview technical committee to draw these efforts together, promote the development of information needed to fill the gaps, and establish a means for utilizing this knowledge in developing reliable service life prediction practices. Progress of this kind will do much toward enhancing concrete's role in the construction marketplace.

President's memo

Bridges for the Future

Over the past 35 years, achievements in the field of concrete bridges have been truly remarkable. Yet, to the general public, engineers are probably better recognized for bridges that have failed to meet the public's expectations than for the achievements. The public sees traffic delays caused by the large number of bridge decks currently being removed and replaced. They hear, through the national media, about the collapse of the Mianus River Bridge in Connecticut or failures during construction such as the Zilwaukee Bridge in Michigan or the Cline Avenue Ramp in Indiana. The public deserves and needs to hear more about our successes.

In 1978, the Prestressed Concrete Institute celebrated its 25th anniversary with a series of articles about the beginnings of prestressed concrete in America. In the first of these articles, Charles Zollman reported on the Walnut Lane Bridge in Philadelphia. Zollman quoted a statement by the Belgian contractor Emile Blaton: "Ah! Those Americans. They have guts. When we started prestressed concrete, we built first a beam having a 20 ft (6 m) span; then, when we had learned how to do that well, we made a 40 ft (12 m) beam, and then a 50 ft (15 m) beam; we progressed step by step. But the Americans! No, they have to start their first prestressed concrete bridge with 160 and 74 ft (49 and 23 m) spans." Not too many prestressed bridges with spans approaching those of the Walnut Lane Bridge were built in the 1950s and 1960s. However, the introduction of prestressed concrete into the United States and Canada was a significant step forward in establishing concrete as a viable material for long span bridges. According to 1985 statistics by the U.S. Federal Highway Administration, approximately 68 percent of all bridges built in the United States with federal funds are made with concrete. Of the 68 percent, just over one-half are built with prestressed concrete.

Concrete bridge construction has evolved over the years such that the designer has available a wide variety of design possibilities depending upon span length. Construction may be either reinforced or prestressed concrete. Prestressed concrete may be pretensioned or post-tensioned. A variety of girder cross sections are available such as the AASHTO girders for shorter spans. Hollow box sections of constant or variable depth are used for longer spans. The superstructure may consist of simple spans, continuous spans, or a combination of these. For longer spans, cable stayed structures are now built with concrete. In addition, a variety of construction methods are available. For example, the structure may be built on falsework, it may be built by the balanced cantilever method of construction, it may be incrementally launched, or constructed by the progressive placement method. All of these choices offer the bridge engineer a variety of concepts for different applications. As a result, we now see concrete construction competitive with steel bridges for spans beyond 1,000 ft (300 m).

It is of interest today that we have the new Sunshine Skyway Bridge across Tampa Bay in Florida with a main span of 1200 ft (366 m). (See front cover photo.) The new bridge replaces an older, existing crossing. The approach spans for the old crossing were built in 1951, shortly after the Walnut Lane Bridge. At that time, the approach represented the largest application of prestressed concrete girders in North America. The acceptance of prestressed concrete in the original Tampa Bay Bridge served as a major stepping stone for the expansion of prestressed concrete in Florida and the United States. Bridges such as the new Sunshine Skyway, the East Huntington Bridge across the Ohio River between Ohio and West Virginia, the Linn Cove Viaduct in North Carolina, and the Houston Ship Channel Bridge in that Texas city, all represent achievements of which we can be proud.

What then of the future? From a technical standpoint, we have seen many advances in concrete bridge design. However, there are two areas that could use further development. These relate to new applications of existing materials. In bridges we have not seen the same growth in utilization of high-strength concrete that we have seen in buildings. As bridge spans become longer, dead weight becomes greater and use of high-strength concrete to carry compressive forces offers the opportunity to minimize cross-sectional dimensions. Another material that we have not seen widely used is lightweight concrete. Again, the objective is to reduce the self-weight of long span structures. Obviously, research is necessary before the bridge designer has full confidence in these materials. The Walnut Lane Bridge design was not accepted until extensive testing had demonstrated the viability of this new form of concrete construction.

Long-span bridges offer us a technical challenge. They also expose our work to the general public because they are esthetically pleasing as well as functional. In this regard, we can and should be proud of these achievements and we should publicize their contribution to the growth of the country's highway systems.

W E Kunze

President's Memo

Concrete Ties — The Economic Choice

Although the growing acceptance of concrete for railroad cross ties in North America is not highly visible, definite gains are being made by this application of concrete as the complexities of design and fabrication become better understood. This progress is worthy of special note.

It has been more than a century since concrete first was considered as a material for railroad cross ties. The first designs of these ties were introduced in France in 1884. Nine years later, in 1893, concrete ties were installed for the first time in the United States by the Reading Company in Germantown, Pa. Between 1893 and 1930, over 150 types of conventionally reinforced concrete cross ties were patented in the U.S. and more than 60 experimental installations were made by about as many railroads.

A severe shortage of timber provided impetus for an extensive examination of concrete ties in Europe in the early 1940s. However, serious work on the development of concrete cross ties did not begin in the United States until 1957 when staff of the Association of American Railroads developed several designs for prestressed concrete ties. The first installation of these was in 1960 on the Atlantic Coast Line and Seaboard Airline Railroads. The first major use of prestressed concrete ties in the United States (and also in North America) occurred in 1966 when 74,000 were installed by the Florida East Coast Railway.

Today, there are more than 425 million concrete ties in use worldwide and about 20 million are produced annually. More than 12 million concrete ties have been installed in North America. In Canada, concrete ties are used almost exclusively on curves in heavy tonnage territory. In the United States, concrete ties are used on high speed passenger lines and on freight lines. In Mexico, concrete ties are used on mainlines in tangent and curved tracks. In addition, each railroad in these countries has utilized a different fastening system to secure rails to the ties and to hold gauge and alignment. This remarkable diversity in tie designs, fastening systems, and applications in track reflects the changing technology and versatility of concrete tie and fastener design to satisfy today's requirements.

Concrete ties also are playing an important role in developing modern urban transit systems in North America. Transit systems in San Francisco, Atlanta, Boston, Baltimore, Miami, Chicago, Toronto, Calgary, and Vancouver have utilized concrete ties. In addition, concrete ties are being used to replace timber ties on open deck bridges. Concrete turnout ties have been installed in the U.S. and Canada. Concrete crossing ties designed to serve with precast concrete slabs have been installed in the U.S. and are gaining acceptance by highway departments.

Two types of concrete ties are used worldwide. One is the familiar monoblock consisting of a single prestressed structural member. The other is the two-block or duoblock tie utilizing two reinforced concrete blocks connected by a steel member. The monoblock is the tie most widely used in North America. Pretensioning is used in the U.S. and Canada, while post-tensioning is used in Mexico. However, interest in use of reinforced two-block ties has been shown by several U.S. railroads in recent years. Pretensioned ties are commonly manufactured using the long line method, although one plant in the U.S. utilizes the individual form method. Post-tensioned and two-block concrete ties generally are manufactured in individual forms.

A concrete tie is subjected to tens or even hundreds of millions of load repetitions during its service life of about 50 years, including severe dynamic effects caused by imperfections in rail surface and wheel tread. Therefore, special provisions are required to improve fatigue strength and durability. A minimum compressive strength of 7000 psi (48.3 MPa) at 28 days is required to reduce prestress losses and increase resistance to cracking under service loads. Also, 4000 psi (27.6 MPa) at release (about 16 hours) is desirable to improve form utilization. Prestressing ten-

(Cont. on page 6)

dons having a tensile strength of up to 270 ksi (1862 MPa) and low relaxation properties also are used to reduce long-term prestress losses and ensure adequate strength during service life.

Although the production process of concrete ties is straightforward, stringent quality control programs must be maintained during each stage of manufacture to assure uniformity in quality and performance, long-term durability, and acceptable strength. These programs should address all aspects of material properties, production operations, and tolerances. To verify tie dimensions and strength, testing of randomly selected samples of produced ties should be part of a quality assurance program.

Numerous comparative life-cycle costing studies have demonstrated concrete's distinct competitive edge in certain areas. Among benefits contributing to overall cost-effectiveness are longer service life, reduced maintenance requirements, increased tie spacing, and reduced fuel consumption.

Acceptance of concrete tie systems is growing rapidly. Many railroads and transit properties in North America are regular users. Some choose concrete because wood supplies are short. Others seek greater gauge-holding ability and increased rail life. Many want improved riding quality, better track stability, and longer service. However, most are encouraged by the economy of low maintenance and fuel efficiency.

Experience to date indicates that concrete ties not only are technically and economically feasible, but also provide a superior track system that assures good performance and improved safety. There is no doubt that in years to come, concrete tie systems will offer even broader applications and benefits aided by such things as the utilization of improved electronic measuring equipment that will permit a better understanding of the static and dynamic forces developed in track.

The concrete cross tie is one more example of progress of which we may be rightfully proud. It is another story that needs to be told and understood by the public that our industry serves.

President's Memo

Achieving Solutions to Elusive Problems

Just as medical researchers sometimes make seemingly slow progress toward unraveling the secrets of diseases that plague mankind, so also concrete technologists sometimes pursue problems associated with concrete only to find their progress slow and final solutions elusive. The alkali-silica reaction is such a problem. Although much progress had been made toward finding acceptable solutions, more remains to be done.

Since its initial recognition in the United States in the late 1930s, alkali-silica reactivity has been identified as a major cause of deterioration of concrete structures throughout the world. From research during the 1940s and early 1950s, a solid understanding of the reaction has evolved, and specifications to minimize the problem have been developed. Subsequent investigations, particularly in the 1970s and 1980s, have refined our understanding to the point where deleterious reactivity can be avoided with a high degree of assurance. It is informative to review important aspects of our present state of knowledge of reactivity with this objective in mind.

By the early 1940s, a variety of rock types had been identified as being deleteriously reactive. These included the generally pure forms of silica such as opal, chalcedony, tridymite, and cristobalite, together with feldspathic materials such as glassy to cryptocrystalline volcanics of andesitic to rhyolitic composition, and metamorphic rocks such as phyllite, schist, and graywacke. The reactive silica minerals are found in such rock types as carbonates, sandstones, shales, and, occasionally in volcanic materials. Within the past 20 years or so, additional rock types have been found to be associated with deleterious reactivity. These are quartzites and granitic gneisses in which quartz with a highly strained crystal structure is postulated to be the reactive component. Artificial glasses of certain composition also have long been known to be deleteriously reactive with alkaline solutions in concrete. Thus, our knowledge of potentially reactive rock types has, for the most part, been fairly complete ever since reactivity was first identified as a possible problem.

Initial work in the 1940s established that deleterious reactivity in structures was associated with relatively high alkali contents in portland cement. Based on tests at that time, a limit of 0.6 percent alkali as equivalent sodium oxide was placed on cement for construction where potentially reactive aggregates were to be utilized. Such cements became known as low-alkali cements. This limit was quite successful in minimizing or eliminating otherwise harmful reactivity. During the 1960s and 1970s, however, it became painfully obvious that the 0.6 percent alkali limit often only reduced the rate of expansive reactivity, thereby misleading specifiers into believing that they were safe in specifying low-alkali cement. About the same time, additional research revealed that cement may not be the only source of alkali contributing to expansive reactivity. Alkali originally present in feldspathic aggregates was found to be readily leachable in alkaline solutions, thereby possibly further aggravating the problem. Also, some evidence was developed that extraneous sources of alkali such as sodium chloride deicer salts and seawater might contribute to alkali-silica reactivity. In the case of seawater, evidence of alkali-silica reactivity was found in a structure in the field where the alkali content of the cement was less than 0.20 percent equivalent sodium oxide. Thus, it appears that our initial concept of classifying cements as high and low alkali with respect to reactivity must be revised to accept the fact there is no single permissible maximum cement alkali limit below which expansive reactivity cannot occur.

Initial work with reactive aggregates in concrete indicated that damp environments were favorable to expansive reactivity. However, it was not known how dry concrete had to be to preclude expansion. Furthermore, the moisture condition of concrete in the field was not sufficiently known to predict when and where expansive reactivity was liable to occur. This state of knowledge continued until the late 1970s and early 1980s when studies indicated that relative humidities exceeding about 80 percent, referenced to 70 to 75 F, were required for expansive reactivity to occur. In addition, techniques developed to measure the moisture condition of field concrete revealed that internal relative humidities of mass concrete and slabs-on-grade were normally greater than 95 percent, even in desert regions. Atmospheric wetting and drying were found to affect only relatively thin surface layers of concrete in large structures. Similarly high relative humidities were found in massive concrete members in interiors of

(Cont. on page 6)

structures, even after more than 40 years under controlled environments of less than 60 percent relative humidity. One implication from this work is that residual concrete mix water may be the only moisture required for long-term expansive reactivity to occur.

Several test procedures conceived in the 1940s to identify the potential for deleterious reactivity are in use today as ASTM test methods. These include the ASTM C 227 mortar bar test and the ASTM C 289 quick chemical test for evaluating cement-aggregate combinations and unused aggregate, respectively. Limitations of these tests, such as chemical interference or extended time periods required to achieve results suggest the need for refinements and improvements, including a better understanding of acceptable cement alkali levels to permit more appropriate specifications for structures. Several possibilities are currently under development. These include rapid methods for identifying potentially reactive aggregate, the testing of concrete prisms instead of mortar bars, and utilizing the concept of total alkalinity of the concrete.

Several long standing methods that have been used to prevent expansive alkali-silica reactivity are still very effective today. Besides avoiding the use of potentially reactive aggregates, these include the use of natural and artificial pozzolans as cement additions or replacements, and the use of low-alkali cement. As noted earlier, the latter approach has not always been successful. A much better understanding of the mechanism by which pozzolans prevent expansive reactivity has been obtained in recent years from research carried out in different parts of the world.

Several aspects of alkali-silica reactivity are currently in need of further study. These include better characterization of rock types such as quartzite, which may produce slow, long-term expansion, better understanding of the effects of alkalies from sources other than portland cement, evaluation of the remaining potential for expansive reactivity in existing structures and development of cost effective means of preserving structures already affected by alkali-silica reactivity.

President's Memo

An Opportunity for You to Help

In this, my final memo to ACI's membership, I am motivated to comment on several strong impressions I have as a result of this year's opportunities to visit and work with ACI's members from coast to coast, border to border and beyond. I have been privileged to participate in fifteen ACI chapter meetings, two roundtable meetings, and two special conferences involving, in total, about 1400 persons or approximately 8 percent of ACI's membership. This number may or may not represent an acceptable statistical sampling of the membership, but the uniformity of my observations with respect to the characteristics of these people makes me believe that ACI members are indeed a very special group.

Again and again, the discussions and questions at these meetings made evident the fact that the membership is sincerely and enthusiastically dedicated to its chosen field, whether this be design, construction, teaching, supplying of materials or testing services, or any of the other important activities needed to sustain concrete construction. However, I continue to believe that one of the shortcomings of this enthusiastic, sincere, and dedicated group of people is its lack of success in conveying the story of what it is doing to others who are not a part of the concrete community.

As noted in my first memo, my belief about the advances in concrete uses and technology remains unchanged. Many significant accomplishments have been recorded in concrete design and construction in recent years, some rivaling the advancements in any other scientific or technical field. ACI members have made substantial contributions to these developments, and ACI itself has provided the forum of communication that has made possible the interchange of ideas so necessary in the development of new design or construction concepts. However, my principal premise in these memos has been that too few people in our society, outside of the concrete construction community itself, are aware of our accomplishments and of how these are contributing to a better life for all. The use of concrete affects everyone's life, whether its use be in the form of homes, hospitals, churches, schools, office buildings, highways, bridges, airports, dams, pipelines, and an almost countless number of other applications. To tell our story, each of us must take advantage of our own opportunities to tell others of the accomplishments of those involved with concrete. A failure to do so is a disservice to ourselves and to those we serve.

We have a strong Institute that enjoys a position of prominence in the construction industry and we have many individual members who are highly qualified and respected by their peers and in their local communities. These are the tools needed to provide effective communication. The remaining need is for action by ourselves. Special attention should be given to disseminating information to the general public by way of the nontechnical media. ACI itself can contribute to such an effort. An example is the need to give wider exposure in the news media to our conventions. As Emery Farkas has correctly said, "ACI's conventions are its windows to the world." These conventions often receive recognition by the local technical press in cities where they are held, but too often the general press in these areas remains silent.

We have every reason to be proud of our Institute and of the industry in which we work. But, along with the privilege we have to work in one of the top fields of endeavor goes a responsibility to tell others of what we are doing. We and the society in which we live will be better served as a result. Your help is needed.