CONCRETE NEWS

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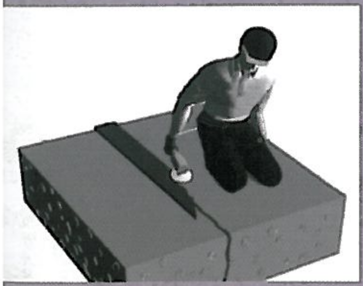
From The President

aci KUWAIT CHAPTER

Contents



The world around us is changing continuously with many advances in every aspect of our lives. At ACI-KC, we put our utmost into providing our members with all the relevant information we can on our part.

In 2005, we arranged five technical seminars on "Corrosion Inhibitors – the Way Forward", "Seismic Dumping in Structures and Bridges", "High Performance Concrete", "Post Tension Slabs – Way of Construction", and "High Performance Plastering and Substrate Preparation". We conducted an Open-Forum Discussion (Concrete Diwaniya) on the "Quality of Cement in Kuwait and its Impact on Concrete Quality".

To increase the number of professional users in Kuwait, we were successful in translating our four technical guides (ACI-KC 01-98, 02-98, 03-2001, 04-2001) into Arabic with the support of the Kuwait Foundation for the Advancement of Sciences. Each document is printed in Arabic and English to be distributed to professionals working in private and public organizations in Kuwait.

Our social committee was very active this year, increasing activities for our members to gather and have a good time or to visit sites of professional interest. We had our 1st ACI-KC spring camp which was a new and different experience for our members in addition to the unique dinner at Zorba Greek Restaurant with the climax at our Annual Award Banquet 2005 at the Kuwait Chamber of Commerce and Industry. With regard to field visits, there were three interesting visits to Dar Al-Awadhi Complex, the Golf Course project and the Sulaibiya Wastewater Treatment and Reclamation Plant which is the first BOT project in Kuwait.

Dr. Naji Al Mutairi

To top the year's activity, we had our 5th Annual Award Banquet, which took place at the Kuwait Chamber of Commerce and Industry. Dr. Ibraheem Al-Shaheen and the KPC complex were honored with the Chapter's Award of Achievement and Award of Excellence respectively. It was an excellent event that showed the professionalism of ACI-KC and its appreciation of excellent work. The Awards Night left a very good impression on the attendees and added to ACI-KC's credit.

That is not all we have planned and implemented - we have many other activities that you will see shortly, such as the ACI-KC 2nd International Conference which is planned for 2007 with the theme "Design and Sustainability of Structural Concrete in the Middle East"; the certification training programs for engineers and professionals; a new technical document regarding concrete practice in Kuwait; and much more.

On a final note, we hope the year's activities met your expectations. We look forward to our members' participation by way of ideas, suggestions, or articles. The Board of Directors welcomes your comments on any matter related to ACI-KC affairs to enhance our organization. Please be generous with your ideas, suggestions and prayers.

Seismic Damping in Structures & Bridges Seminar:

The event was sponsored by Degussa MBT Construction Chemicals, and the seminar was offered by Mohammad Hamam, Technical Marketing Manager of Degussa MBT Construction Chemicals, on 28th March, 2005. Mr. Hamam presented the latest innovation in Seismic device technology and seismic damping, utilizing viscous dampers and lock up devices.

High Performance Concrete Seminar:

The event was sponsored by Boodai/Al-Gurg Fosroc, and the seminar was offered by Eng. M. Ghassan El-Nahhas, General Sales Manager of Al-Gurg Fosroc on 11th April 2005, focusing on high performance, high strength concrete. The definition, materials used, design mixes and the production QA.

Site Visit to Dar Al Awadi Complex:

The Social Committee cooperating with Projacs Analysis & Control System organized a technical visit to Dar Al-Awadi Complex on 26th April, 2005. The project manager Eng. Jamal Al-Sayyed explained and discussed the Construction problems during the executing of the project.

Site Visit to Golf Course:

The Social Committee cooperating with Gulf Consult organized a technical visit to the Golf Course on 26th May, 2005. The project Engineer Khalid Einad explained and discussed the construction problems during the executing of the project.

Post Tension Slabs-Way of Construction Seminar:

The event was sponsored by Hayat Group Co., and the seminar was offered by Dr. Amr Abu Hashish, Assistant Professor at Helwn University, Cairo, Egypt. on 28th May, 2005. He explained the way of construction using prestressing concrete systems focusing on the procedure of construction from installation, stressing and grouting of prestressing cables. and also, introduced the precautions needed throughout these various operations

High Performance Plastering and Substrate Preparation Seminar:

The event was sponsored by Al-Taneeb Trading Co., and seminar was offered by Alberto Casali and Corrado Scollo from Technokolla, Italy, on 13th June, 2005 The seminar addressed in detail the techniques and characteristics of materials that may be used to achieve high performance substrate.

ACI-KC Members Dinner Party:

The Social Committee organized an annual dinner party for Chapter members at Zorba Greece Restaurant on 27th Sept., 2005.

Site Visit to Sulaibiya Wastewater treatment annd Reclamation plant:

The Social Committee cooperating with Utilities Development Company organized a technical visit to Sulaibiya Wastewater Treatment and Reclamation Plant on 29th Sept., 2005. The Project was explained and discussed by Eng. Ehab

Oil Sector Headquarter Complex Buildings

Modern Landmark Buildings with Creative Use of Concrete

ACI – Kuwait Chapter presents the Award of Excellence to a Project in recognition of outstanding work in Concrete Construction and Practices within Kuwait.

The Kuwait Petroleum Corporation (KPC) received the Award of Excellence for this year for the Oil Complex Headquarter Buildings.

The building uses concrete in a very creative way to create an exciting three-dimensional visual landmark.

The Complex will house the Ministry of Energy (Oil) and KPC employees; each organization has its own tower which consists of a taller curved lens shaped building and a lower triangular mass. The concave facades of the lens shaped building are fully glazed from floor to ceiling and provide extensive views out over Kuwait Bay.

By contrast, the triangular masses, which generally face south, are clad in limestone with deeply recessed shaded window openings configured as bands of vertical slits.

A special feature of the design is the three storey high entrance lobby with full height glazing which looks out over a large "infinity" reflective pool towards Kuwait Bay. This pool brings the waters of Kuwait Bay right up to the entrance lobby and symbolically reinforces the important link between the trade of oil and the sea.

The Award co-recipients are:

- Architect & Engineer: Salem AlMarzouk & Sabah AbiHanna WLL (SSH International) in Association with Arthur Erickson Architectural Corp.
- General Contractor: Al-Ghanim International General Trading & Contracting Company WLL
- Concrete Supplier: Kuwait British Readymix Concrete

مؤسسة البترول الكويتية
Kuwait Petroleum Corporation
and Subsidiaries

Dr. Ibrahim Majid Al-Shaheen

Over 30 Years of Contribution and Leadership

ACI – Kuwait Chapter presents the Award of Achievement to an individual in recognition of outstanding contribution in the field of concrete and engineering in the State of Kuwait.

The Award's recipient this year is Dr. Ibrahim M. Al-Shaheen, in recognition of his valuable contributions to the engineering community and Kuwait's society.

Dr. Al-Shaheen earned his Bachelor of Architecture, Washington State University, U.S., 1971; Master of Architecture, University of Pennsylvania, Philadelphia, U.S. 1973 as a Student of Professor Louis Kahn; Ph.D. in Architecture and Planning, Technical University of Prague, Czechoslovakia, 1985

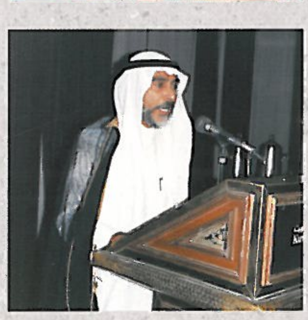
Dr. Al-Shaheen assumed several leadership positions in the public sector. He was the Director General of National Housing Authority for over 13 years from 1977 to 1991 where he supervised over 2.5 billion KD worth of construction and more than 3000 staff delivering integrated new towns.

After the liberation of Kuwait from the Iraqi invasion, he was the director of the Emergency and Recovery Program for the rebuilding of Kuwait. He also served as Minister of State for Municipal Affairs and as Deputy Chairman for Kuwait's Committee for Prisoners of War.

Private Sector involvement

In 1992, he established Al-Shaheen Consultant Office. He also served on the board of several large private institutions such as Kuwait Real Estate Company, Kuwait Real Estate Bank, First Investment Co, Engineering Systems Group, and Kuwait Computer Company.

He is a Board Member of Al Najat Charitable Organization and the Africa Muslim Agency.



Perspective on Prescriptions

Can America learn form the Australian experience?

BY KEN W. DAY

It has been well established that strength and many other desirable characteristics are inversely proportional to the water-cementitious material ratio (w/cm). Further, it is clear that if an increase in w/cm is permitted, more water is more deleterious than less cement (for example, less paste results in less shrinkage).

Of course, concrete producers must provide a degree of workability that is acceptable to their clients. Apart from this, they are also strongly motivated by economic considerations to minimize cement content and therefore minimize water content. Unfortunately, it is still common practice for American designers to specify a minimum cement content, thus removing all incentive. It is also still common for specifiers to provide aggregate grading limits - further hindering the ability of the producers to achieve the desired concrete properties. These limits are almost certain to increase costs and, in some situations, may also increase cement requirements.

Fortunately, the Prescription to Performance (P2P) Initiative appears to be gaining popular support, and many producers are now investing in advanced technology so they can benefit from the changes.1 I applaud that initiative, and (because I have considerable experience with a similar transformation in Australia) I think it would be useful to share my perspective.

PRESCRIPTION FOR WHAT?

Prescriptive specifications for ready mixed concrete have a number of negative consequences:

1. Because adjustment of mixture proportions is often prohibited, changes in material characteristics of production conditions (such as temperature) must necessarily result in more variable concrete.
2. Because mixture proportioning is highly dependent on the local material qualities, the specifier must employ an expert (or must be an expert) to ensure that inferior materials are not specified and used.
3. Because specification of a mixture with a low-water requirement will risk having unsatisfactory fresh properties, it is difficult for the specifier to prescribe such a mixture.
4. Because each specifier can (and often does) generate a unique specification, each producer must maintain a confusing plethora of similar (but not necessarily satisfactory) mixture proportions.
5. Because the properties of the concrete resulting from a prescriptive specification can't be within the producer's control, the responsibility for unacceptable results should be assigned to the specifier. Although this is logical, it is regrettably not always the case.
6. Because prescriptive specifications eliminate any advantage for concrete producers that improve their mixture proportioning and quality control through the acquisition of knowledge, equipment, or skilled staff, such specifications actually lead to reduced quality and increased costs.

Unfortunately, use of prescriptive specifications continues to be common practice in the U.S. It is therefore not surprising that quality control and mixture proportioning technology have lagged behind in most other countries.

Australia was a world leader in the adoption of specification techniques favoring competent producers. As a consequence, Australian producers provide concrete with lower variability than producers in much of the world, and Australian companies are exporting quality control technologies worldwide. It may therefore be useful to consider that country's experiences. The following is a brief summary.

AUSTRALIAN STANDARDS

Australian Standards are formulated by Standards Australia International. This body is funded partly by sales of its standards and through government allocations, but the association is not government controlled. The relevant committee for concrete production, BD/49, Manufacture of Concrete, is responsible for Australian Standard (AS) 1379.2 This document was previously part of AS 1480 3 and then AS 3600,4 which are the overall standards for concrete structures. While committees initially tended to be dominated by government personnel and consulting engineers, there is now a substantial concrete producer representation on BD/49. Two other organizations bear on the Australian scene, the National Association of Testing Authorities (NATA) - the first such in the world - dating from the 1940s, and the International Organization for Standardization (ISO).

A TEST OF THE TESTERS

There has never been a strong tendency toward full prescriptive specifications in Australia, Specifications dictating minimum cement content, however, were common into the 1960s, and strength was evaluated using a minimum value for a single test and a minimum average for a group of six. In those days, specifications required testing to be conducted by a NATA- registered independent laboratory, and the contractor (not the concrete producer) was permitted to accept the lowest bid from any qualified laboratory.

The NATA organization, through its voluntary assessors, checked on quality and calibration of equipment, experience and qualifications of the person in charge, and reliability of the recording and reporting system. They were not required to check on other personnel, check comparative results, or check within sample standard deviation. Within this context, producers complained about the quality of testing by some independent labs.

In the late 1960s, I became a consultant with the useful background of having previously been an owner and operator of an independent lab. As a consultant, much of my work was for a structural consulting partnership in Melbourne, John Connell & Associates (JCA). Each of JCA's project specifications required that I be engaged by the contractor as the "Concrete Quality Controller." In this position, I received all test results, analyzed them, and reported monthly to JCA. I also received details of proposed mixtures and made acceptance recommendations after negotiation with the proposed concrete producer.5

Test results were analyzed using a computer program that evaluated average pair difference (which equates to a within-sample standard deviation and is the best measure of testing quality). Data included 7-to-28-day strength gain, strength, slump, and specimen density. If possible, comparisons were made with results submitted by the concrete producer on the same truck-load of concrete. Using these analyses, it almost invariably became quite clear whether results indicating defective concrete were indeed correct or were the result of improper testing.

Our client's project list was extensive. We were therefore able to obtain data from all of the major producers and independent labs and to produce a monthly "league table" showing relative testing quality for the various labs. With this broad view, it soon became apparent that the concrete producer's labs were, in general, doing a better job than most of the independent labs.

CORRECTING FOR THE DATA

JCA therefore modified its specification. Rather than requiring frequent testing by an independent lab and check testing by the producer's lab, the responsibilities were reversed, allowing the producer to conduct the main testing and the independent labs to conduct a few check tests. Of course, the independent labs reacted by greatly increasing their unit pricing. We therefore countered by defining an independent lab as a lab not attached to a particular producer. As a result, we had one producer testing another producer's concrete.

Where check tests were performed and a lower result was obtained, the producer often complained that the sample had not been properly taken. Both this and the higher cost of duplicate sampling were countered by requiring the producer to make a double set of cylinders and deliver half to an independent lab. This was effective in ending excuses and revealed some interesting, small but persistent, differences between testing machines that had both been recently calibrated.6,7

Perhaps the most significant development came about when one major producer observed that we knew more about what was happening to their concrete than their own technical manager. As a result, they purchased our control system.

ONGOING EVENTS

In the early 1990s, ISO 9000 Quality Assurance became popular and was widely adopted. This reinforced the concept that the producers were fully responsible for the quality of their product. To qualify for registration, producers had to demonstrate that they had a quality system covering all aspects of production and material acquisition. Unfortunately, such systems are often neither designed nor assessed by competent concrete technologists (in other words, quality systems should be implemented by persons experienced in concrete quality control rather than in theoretical quality assurance).

AS 1379 now requires that concrete shall be designated as "normal class" or "special class." The latter class is further subdivided into "performance" or "prescription" requirements. The producer can choose to accept special class requirements as performance or prescription. If the latter case is selected, the producer is not responsible for performance. The great majority of concrete is of normal class, and very little of special class is designated prescription.

For normal class concrete, and often also for special class concrete, the producer is required to designate a "control grade" and a production interval (which can vary from 2 weeks to 3 months, but is normally 1 month) on which the producer's control is based. The producer must assess, report on, and adjust mixtures at the production interval. If any low results are encountered, the producer must report these results to all purchasers.

AS 1379 continues to allow a specifier to elect that "project assessment" shall apply, setting sampling rates and acceptance criteria for concrete delivered to a particular project or element. It also makes clear, however that for normal class concrete, the producer's results are generally more reliable. Because of this and the associated extra expense, project assessment is now rarely used.

HOW TO PROCEED?

Assuming that American producers would like to bring about a similar situation, I recommend they proceed as follows. First, they must establish that they merit the confidence of their clients. Each major producer must, therefore, have its own laboratory (a lab, I should add, that is unquestionably the equal of any independent lab), and each smaller producer must contract with a selected laboratory.

In both cases, a control system must be operated either by, or on behalf of, each producer. Using the control system, a wide range of reports should be produced and distributed to clients. The laboratory and its control system should be open to inspection by clients at any time.

The control system should provide two estimates of standard deviation, one by a standard analysis of all the results in a grade of concrete, the other (for all grades) from the average difference between successive results in the same grade. The latter will be lower than the former because it will be substantially unaffected by changes in mean strength (the detection and rectification of these "change points" should be the objective of the control system). The producer will then be able to show any clients who have not permitted adjustments when and what adjustments should have been made and by how much it would have reduced variability.

The producer should make an effort to establish the within-sample standard deviation of every laboratory and every individual technician testing the producer's concrete. Of course, such information would be proprietary and would therefore have to be used with discretion.

It must be made clear to all clients and regulating authorities that the producer has a complete knowledge of the performance of its product and all the factors affecting it.

It would help if some clearly independent and preferably well-known person could be engaged to fulfill the role I played in Australia (and in Singapore) in the 1970s and '80s. If not a person, then perhaps an independent and well-known organization could serve the same purpose.

The preceding represents a substantial expenditure. Although the cost cannot be offset under prescription specifications, it is necessary to bring about change. At the outset, it would be prudent to select one or more regions for initial implementation (in Australia, much of the initial action took place only in Melbourne).

P2P = WIN

The current situation in Australia represents a win-win situation for most of those concerned. When compared with the prescriptive alternative:

* The purchaser of the concrete receives a more economical, uniform, and reliable product (with no effort or difficult decisions);

* The producer will be in a position to provide the purchaser with a wider range of test data on shrinkage, pumpability, bleeding, heat generation, and other properties (owing to the standardization of mixtures);

* The purchaser often finds that more expert advice is available (at no cost); and

* The expert producer gets the opportunity to use a wider range of materials, more economical mixture proportions, and a smaller control margin (between specified strength and necessary mean strength).

FURTHER ADJUSTMENTS

Of course, some adjustments will be painful. Those producers that are not technically advanced will have their challenges. They will still have, however, the opportunity to use independent expertise.

Independent laboratories will also experience challenges. They will still have, however, the opportunity to serve the less technically advanced producers.

References

1. "The P2P Initiative, "National Ready Mixed Concrete Association, Silver Spring. MD. available at: www.nrmca.org/P2P/.6pp.

M.N. Haque

Muhammad Naseerul Haque comes from a very humble background and both his father and grandfather were school teachers. So you can say I was born with a chalk in my hand. After graduating in Civil Engineering from Lahore, Pakistan, I managed to obtain Master's in Structural Engineering from Asian Institute of Technology, Bangkok, Thailand. Back in 1965, only those parents would send their sons to Bangkok who wanted to spoil them. Bangkok was then R & R place for the American soldiers fighting in Vietnam. Al-Hamdo lillah, I managed to come back to Lahore unblemished! It is then that I returned to the profession of my ancestors – teaching. All of a sudden I became a powerful lecturer teaching both Structural Analysis and Structural Design to the graduating class. I became so popular that a Jordanian student came to visit me twice at my home and he was told by my mother that Naseer had gone for his prayers to the mosque. Third time when he came to visit me he brought a 'Praying mat' with him and gave it to me saying : "You are the only person who deserves this gift".

My parents decided to marry me in a hurry in October 1970 when they found out that I was migrating to Australia to pursue Ph.D in the University of New South Wales (UNSW) in Sydney.

Overnight, in Sydney, I became a leader ! In March 1971 (the month I landed in Australia), I was elected President of the Muslim Students Association of the UNSW. In April 1972, I was elected President of the Pakistan Students Association of the UNSW. I started growing in my stature by leaps and bounds. It is in 1988 that I became the President of Australian Federation of Islamic Councils (AFIC) for two years. During this leadership boom I had fathered 4 children as a byproduct. It was in 1990 that I was made to realize, that I had to play a moderate, if not a serious role, to bring up and educate my children! In 1995, UNSW promoted me to the rank of an Associate professor for my extracurricular activities. Unlike the American system, where every Tom, Dick and Harry can become a Professor, in Australia often an Assoc. Prof. has to go through an 'induced coma' and those who relive afterwards can struggle to become a Full Professor.

Since joining Kuwait University in September 1998, I am a member of ACI Kuwait Chapter. Fortunately, I have been a Director in the board of the Chapter for two years and Chair of its Technical Committee for one year.

My wish was to learn more Arabic while in Kuwait. I was told the easier way to do this was "to marry an Arabic speaking lady". Alas ! At this late stage and age, I just cannot afford that ! Thanks to Allah Almighty : I am still a happy man.

Structural Crack Repair by Epoxy Injection

by Brian F. Keane

(an abridged version of original article)

Introduction

Some of the more typical causes for concrete cracking include drying shrinkage, thermal contraction or expansion, settlement, lack of appropriate control joints, overload conditions that produce flexural, tensile, or shear cracks in concrete, and restraint of movement. One of the potentially effective repair procedures is to inject epoxy under pressure into the cracks. The injection procedure will vary, subject to the application and location of the crack(s), with horizontal, vertical, and overhead cracks requiring somewhat different approaches. The approach used must also consider accessibility to the cracked surface and the size of the crack. Cracks can be injected from one or both sides of a concrete member. If access is limited to only one side, installation procedures may include variations in epoxy viscosities, injection equipment, injection pressure, and port spacing to ensure full penetration of epoxy into the crack. Depending on the specific requirements of the job, crack repair by epoxy injection can restore structural integrity and reduce moisture penetration through concrete cracks 0.002 in. (0.05 mm) in width and greater. However, before any concrete repair is carried out, the cause of the damage must be assessed and corrected and the objective of the repair understood. If the crack is subject to subsequent movement, an epoxy repair may not be applicable.

How do I prepare the surface?

Clean the surface area about 1/2 in. (13 mm) wide on each side of the crack. This is done to ensure that materials used to seal the top of the crack (the cap seal) will bond properly to the concrete. Where concrete surfaces adjacent to the crack are deteriorated, "V"-groove the crack until sound concrete is reached. "V" grooves can also be used when high injection pressures require a stronger cap seal.

How do I select the right material?

The appropriate viscosity of the epoxy will depend on the crack size, thickness of the concrete section, and injection access. For crack widths 0.010 in. (0.3 mm) or smaller, use a low-viscosity epoxy (500 cps or less). For wider cracks, or where injection access is limited to one side, a medium to gel viscosity material may be more suitable. ASTM C 881, "Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete," identifies the basic criteria for selecting the grade and class of epoxies (see Table 1). For concrete sections greater than 12 in. (305 mm), the working time may need to be increased, and the viscosity decreased, as the crack gets smaller. The following product characteristics may also have to be considered: modulus of elasticity (rigidity), working life, moisture tolerance, color, and compressive, flexural, and tensile strengths.

What equipment do I need?

Equipment for epoxy injection by high-pressure or low pressure systems includes air guns, hand-actuated delivery systems, spring-actuated capsules, and balloon-actuated capsules. Determine the delivery method that will best suit the repair requirements by considering the size and complexity of the injection repair and the economic limitations of the project.

Fig. 1—Installation of cap seal.

Repair procedure

1. Port installation.

Install the entry ports only after proper surface preparation. Two types of entry ports are available for the injection process: surface-mounted; or socket-mounted. Entry ports (also called port adapters) can be any tube-like device that provides for the successful transfer of the epoxy resin under pressure into the crack. Proprietary injection guns with special gasketed nozzles are also available for use without port adaptors. Port spacing is typically 8 in.(200 mm) on center, with increased spacing at wider cracks. Port spacing may also be a function of the thickness of the concrete element. Surface-mounted entry ports are normally adequate for most cracks, but socket-mounted ports are used when cracks are blocked, such as when calcified concrete is encountered. Entry ports can also be connected by a manifold system when simultaneous injection of multiple port locations is advantageous.

2. Install the cap seal (see Fig. 1).

Properly installed, the cap seal contains the epoxy as it is injected under pressure into the crack. When cracks penetrate completely through a section, cap seals perform best when installed on both sides of the cracked element, ensuring containment of the epoxy. Cap seals have been successfully installed using epoxies, polyesters, paraffin wax, and silicone caulk. The selection of the cap seal material should consider the following criteria, subject to the type of crack to be repaired: non-sag consistency (for vertical or overhead), moisture-tolerance, working life; and rigidity (modulus of elasticity).

Concrete temperature changes after installation of the cap seal but prior to injection may cause the cap seal to crack. If this occurs, the cap seal must be repaired prior to resin injection. Prior to proceeding with installation of the cap seal, mark the location of the widest portion of the crack and pay close attention to the following: Use only materials that haven't exceeded their shelf life; Accurate batching of components; Small batches to keep material fresh, and dissipate heat; Port spacing; and Consistent application of the material (1 in. wide x 3/16 in. thick [25 x 5 mm]) over the length of the crack.

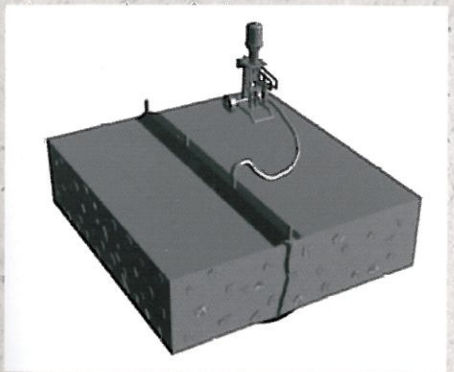


Fig. 2—Start injection at widest segment of the crack.

3. Inject the epoxy (see Fig. 2).

For a successful epoxy injection, start with the proper batching and mixing of the epoxy components in strict accordance with the manufacturer's requirements. Prior to starting the actual injection, be sure that the cap seal and port adapter adhesive have properly cured so they can sustain the injection pressures. Start the injection at the widest section of a horizontal crack. (Be sure to locate and mark these areas before installing the cap seal.) Vertical cracks are typically injected from the bottom up. Continue the injection until refusal. If an adjacent port starts bleeding, cap the port being injected and continue injection at the furthest bleeding port. Hairline cracks are sometimes not well suited to "pumping to refusal." In those cases, try injecting the epoxy at increased pressure (approximately 200 psi [1.3 MPa]) for 5 min. Closer port spacing can also be considered. When injection into a port is complete, cap it immediately.

Higher pressure can be used for injecting very narrow cracks or increasing the rate of injection. However, the use of higher pressure should be managed with care to prevent a blowout of the cap seal or ports.

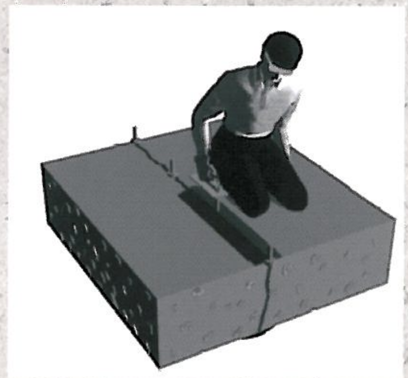


Fig. 3—Remove cap seal.

4. Remove ports and cap seal (see Fig.3).

Upon completion of the injection process, remove the ports and cap seal by heat, chipping, or grinding. If the appearance is not objectionable to the client, the cap seal can be left in place. If complete removal is required for a subsequent application of a cosmetic coating, prepare the concrete surface by grinding.

How do I check the repair?

To ensure that the injection has been successful, quality assurance measures may include test cores (normally 2 in. [50 mm] diameter) or nondestructive evaluation (NDE): Impact echo (IE); Ultrasonic pulse velocity (UPV); and Spectral analysis of surface waves (SASW). The location for the test cores should be carefully chosen to avoid cutting reinforcing steel, drilling cores in areas of high stress, or creating core holes below the waterline. The engineer should also make sure the epoxy has set before extracting the cores.

Table 1—ASTM C 881 requirements for epoxy resins that are used to bond hardened concrete to hardened concrete

	Type I*	Type IV†
Viscosity, centipoise		
Grade 1 (low-viscosity), maximum	2000	2000
Grade 2 (medium-viscosity), minimum	2000	2000
Maximum	10,000	10,000
Consistency, in.		
Grade 3 (non-sagging), maximum	1/4	1/4
Gel time, min.	30	30
Bond strength, minimum, psi		
2 days, moist cure‡	1000	1000
14 days, moist cure	1500	1500
Absorption, 24 h maximum, %	1	1
Heat deflection temperature		
7 days minimum, °F	—	120
Linear coefficient of shrinkage		
On cure, maximum	0.005	0.005
Compressive yield strength		
7 days minimum, psi	8000	10,000
Compression modulus, minimum, psi	150,000	200,000
Tensile strength, 7 days minimum, psi	5000	7000
Elongation at break, minimum, %	1	1

*Type I: for use in nonload-bearing applications.
†Type IV: for use in load-bearing applications.
Source: ASTM C 881, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.
‡Moist-cured systems should be tested by assembling the sections to be bonded before immersing in water.

Structural Crack Repair by Epoxy Injection

by Richard Montani
(an abridged version of original article)

Introduction

This type of crack repair uses a polymer resin to fill the crack. Penetrating by gravity alone, the resin fills the crack and forms a plug that seals out water, salts, and other aggressive elements.

Before any concrete is repaired, the cause of the damage must be assessed and the objective of the repair must be understood.

Typical causes of concrete cracking include steel corrosion, freezing and thawing, sulfate attack, alkali-aggregate reaction (AAR), poor practices during the original construction, and improper joint spacing and load imbalances .

What is the purpose of this repair?

This repair is to seal cracks that are not moving—e.g. shrinkage cracks, and settlement cracks that have stabilized. By penetrating and filling the cracks, the resin is able to form a plug that bonds the concrete on both sides of the crack and seals the crack, keeping out potentially aggressive liquids and gases. Thus, this repair method can be a way to reduce possible future deterioration caused by steel corrosion and chemical attack of the concrete.

It is occasionally an objective to achieve a structural repair of the cracks using this method. Consult a qualified structural engineer if it is determined that a structural repair is needed. If a structural repair of the crack is critical, pressure injection may be a preferred option.

When do I use this method?

This repair can only be applied to horizontal concrete elements and surfaces. Gravity feed of resin is not effective for repairing moving cracks as the materials are unable to act as a flexible joint material. In these cases it is most often necessary to rout and seal the crack to create a joint capable of movement.

Gravity feed of resin should not be viewed as a long-term solution to cracking caused by corrosion, sulfate attack, or AAR. At best, this repair will keep out water, chlorides, and sulfates, which may slow the progress of future damage around the crack, but it certainly will not stop it indefinitely. In these situations, a complete repair and protection approach is required to address the entire area affected.

How do I prepare the surface?

Proper preparation of the cracks for gravity feed of resin is essential. All potential barriers to penetration must be removed. Clean away all coatings and contaminants.

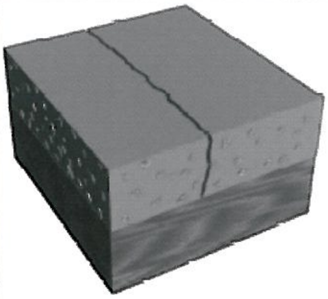


Fig. 1—Cracks must be clean and free of debris.

Fig. 1-Cracks must be clean and free of debris

To prepare large areas, consider sand- or shotblasting. For cleaning individual cracks, begin with wire brushes and wheels, followed by high pressure, oil-free compressed air to remove dust from the surface of the crack. If the crack is packed solid with dirt or debris, remove it prior to applying the resin. Vacuum cleaning of cracks can prevent dust from getting packed into the crack, which can hamper resin penetration. Allow the repair area to dry for at least 24 hours before applying the resin. Moisture within the cracks and the concrete pores can prevent penetration because the resin materials are very thin and are not able to easily displace water.

How do I select the right material?

The two most common polymer materials used for gravity feed crack repairs are epoxies and high molecular weight methacrylates (HMWM). Both must be formulated to have a very thin consistency (low viscosity) and low surface tension. Viscosities below 200 centipoise (cps) should be a minimum requirement. Many epoxies are available with viscosities below 100 cps while most HMWMs have viscosities below 50 cps.

While both resin types are able to form the desirable plug within the crack, they do have their differences. The epoxies tend to bond better when moisture is present within the concrete pores and they are easier and can be safer to mix and apply. HMWMs are generally lower in viscosity and surface tension and have less critical mixture ratios than epoxies. They can also be formulated to set faster.

What equipment do I need?

For small to midsize projects (up to 930 m2):

- Mixing buckets, drills, mixing paddles;
- Flat rubber squeegees, brooms, or rollers;
- Small cans or squeeze bottles for pouring into individual cracks; and
- Grinder and air compressor.

For large projects (930 m2):

- Mixing buckets, drills, mixing paddles;
- Mixing tanks with spray bar (low pressure pumps, no atomization);
- Flat rubber squeegees, brooms, or rollers;
- Sand spreaders or blowers; and
- Grinder and air compressor.

What are the safety considerations?

Epoxies and HMWMs are hazardous materials and should be treated as such. Job-site safety practices should always follow best practice and any special recommendations from the manufacturer. ACI does not make any representations with regard to health and safety issues and the use of this document. Special note regarding HMWM mixing: These polymers utilize a two-part catalyst usually consisting of an initiator (such as a peroxide) and a promoter (such as cobalt napthanate). These two materials must never come into direct contact with one another or a violent reaction may occur. It is important that the promoter first be added to the HMWM monomer and mixed uniformly throughout before adding the initiator. Some formulations are available as a two-component system (pre-promoted) to avoid this potentially dangerous situation. Always refer to the material manufacturer's instructions.

Repair procedure

1. Mix the resin.

After preparing the surface, mix the resin according to the manufacturer's instructions. If cracks run all the way through and the underside of the deck or slab is accessible, seal the underside of cracks at least temporarily to prevent resin loss.

2. Pour the resin.

Pour the mixed material over the top of the cracks and allow it to penetrate. Keep filling the cracks until they will no longer accept resin. For flood coat applications, distribute the resin evenly over the deck initially and then puddle the resin over the cracks. On smooth surfaces, use flat rubber squeegees; on tined or irregular surfaces, use brooms or rollers.

3. Inspect the filling.

Look for signs of penetration such as air bubbles escaping from the cracks as the resin displaces the air.

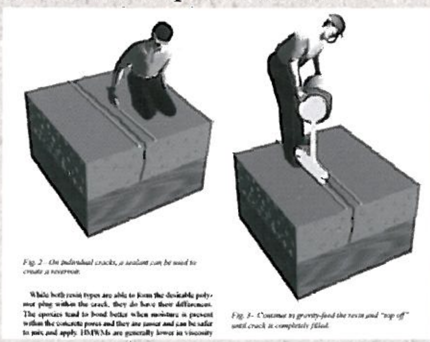


Fig. 2—On individual cracks, a sealant can be used to create a reservoir.

Fig. 3—Continue to gravity-feed the resin and "top off" until crack is completely filled

ALLOW TIME FOR PENETRATION.

Twenty to 30 minutes should be a minimum. Also, be aware that several minutes may pass before the resin has fully penetrated tight cracks and more resin may still be required.

4. Remove excess resin.

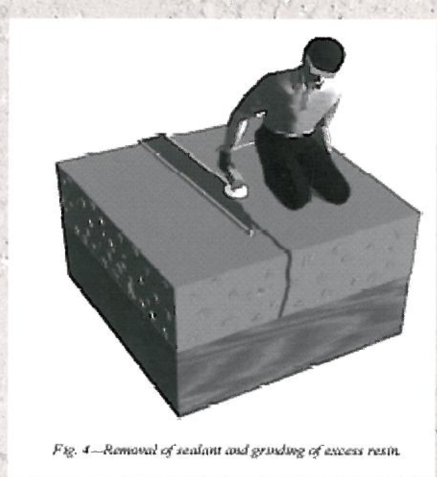


Fig. 4-Removal of sealant and grinding of excess resin

Once all cracks have been filled to refusal, remove the excess surface resin with a flat rubber squeegee.

5. Apply sand.

For safety purposes, lightly broadcast sand into the remaining resin to produce a skid-resistant surface. Apply about 0.5 to 1.0 kg/m2 of an ordinary 8/20 blasting sand (or similar) within 20 to 30 minutes after the last application.

6. Finish smooth (if desirable).

After the polymer has fully cured, remove sealant and grind smooth. Be careful not to inhale vapors during the grinding of the polymers.

How do I check the repair?

Quality control tests should be taken on site to verify:

• Resin properties

- Penetration depths—verified by cores
- For structural repair checks, take cores and follow ASTM C 496, "Splitting Tensile Test."

ACI INTERNATIONAL

The ACI Kuwait Chapter is approved and authorized by the Board of Directors of ACI International to advance the objectives of the Institute in the State of Kuwait. The Chapter is managed by a local Board of Directors whose members constitute the Chapter officers. Chapter membership is open to all individuals and organizations with an interest in any aspect of concrete technology. The Chapter operates through its committees, which are made up of volunteers to meet the needs of the Chapter members. The Chapter may hold several meetings each year and engage in activities that include:

- Sponsoring educational seminars, short courses or work-shops.
- Holding or sponsoring certification training courses and examination.
- Publishing technical information and newsletters.
- Conducting awards programs to recognize quality, innovation and achievement.

Concrete News is published periodically by ACI-Kuwait Chapter to share information between members, exchange technical knowledge and enhance the Chapter's position within the engineering community.

ACI KUWAIT CHAPTER

The American Concrete Institute (ACI), is a nonprofit international organization that promotes improved technology, technical competence, design, and construction related to concrete for the benefit of society.

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The purpose of the Chapter is to further the charter objective for which the American Concrete Institute was organized, i.e. to further education and technical practices, scientific investigation and research by organizing the efforts of its members for a nonprofit, public service in gathering, correlating, and disseminating information for the improvement of the design, construction, manufacture, use and maintenance of concrete products and structures.

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