

CONCRETE NEWS

ACI- Kuwait Chapter



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Who is the chapter president

Ms. Hayfaa Almudhaf is working as an associate research scientist in the Civil Engineering and Building Department, Kuwait institute for Scientific Research (KISR), where she conducts applied research with respect to building materials systems and structures.

Ms. Almudhaf is the author of over 30 publications including papers and technical reports. She is a senior member of the International Union of Testing and Research Laboratories for Materials and Structures (RILEM), the American Concrete Institute ACI, president of ACI Kuwait chapter, and a member of the Kuwait Society of Engineers. She served as the chairperson for the governmental committee on alternative building materials and technologies for cost effective structures in Kuwait which is part of the Supreme Committee for Kuwait Master Plan. Ms. Almudhaf is a member of the Board of Directors for the Environment Public Authority, EPA Kuwait.

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CONCREX'99

An Effective Start Towards Quality Concrete

Concrete is the most dominant building material in the whole world. Construction of simple houses to complex structures is increasingly done using concrete, to the extent that concrete is now considered the second consumed material in the whole globe with water being the first. So how are concrete practices and structures doing in Kuwait and the Gulf region? The answer normally comes readily and can be summed up as: the quality of concrete structures is not as anticipated leading to elaborate maintenance and repair requirements. In an effort to improve the quality of concrete structures, the American Concrete Institute ACI - Kuwait Chapter has organized CONCREX'99, an event aimed at creating a platform for the introduction of new technologies in all aspects related to concrete including raw materials, mixing, casting, curing, in addition to design, maintenance and rehabilitation. The exhibition hosted participants representing major design offices, contracting companies, cement and material suppliers, ready mix companies, specialty materials agents, blocks manufacturers, testing laboratories, research and development agencies. The seminars and life demonstrations further consolidated the event adding a perspective for exchange of information and exposure to state-of-the-art technologies which is vital for the ultimate upgrading of all involved in concrete.

We at the American Concrete Institute ACI - Kuwait Chapter would like to encourage all concerned with enhancing the quality of buildings and structures to join hands with us in making CONCREX'99 a prominent benchmark within the construction industry in Kuwait and the Gulf region. We highly recognize the support of Kuwait Foundation for the Advancement of Science for their valuable support and sponsorships.

Hayfaa Almudhaf
President
ACI - Kuwait Chapter

Glimpse on the Construction Business in Kuwait

Prepared by Eng. Moh'd Harb Sayed

Kharafi bids low for KNPC jetty repair work

The local **Mohamed Abdulmohsin Kharafi & Sons** has submitted the low bid at KD 11.8 million (\$ 38 million) for the contract to reconstruct the northern and southern oil jetties at the Mina Al-Ahmadi refinery. Kharafi undercut the price of its nearest competitor, Athens-based **Consolidated Contractors International Company (CCC)**, by just over 10 per cent. The project is the first of two major jetty schemes planned by **Kuwait National Petroleum Company (KNPC)**. The tender for the engineering, procurement and construction (EPC) of a new south pier is expected to be issued in the summer (MEED 29:1:99). The four bidders for the renovation contract are:

- * Kharafi - KD 11.8 million
- * CCC - KD 13 million (&41.9 million)
- * Saudi Archirodon Overseas - KD 13.9 million (\$44.8 million)
- * the UK's Christiani & Nielsen - KD 14.8 million (\$47.7 million)

Two other prequalifiers, Sweden's NCC and Germany's Ed Zueblin, declined to bid for the procurement and construction contract. Detailed designs have been completed by Frederic R Garriss of the Netherlands (MEED 17:10:97).

The contract calls for long-term repairs to be made to the north pier, as part of plans to keep it operational for another 15 years. The successful contractor will also undertake short-term repairs to the existing south pier, which will keep it in operation until the new south pier is built.

The new south pier is expected to be up to two kilometers long with four-six berths. It will handle a variety of products, including kerosene, gas-oil, naphtha, butane, propane and crude, and will be capable of handling vessels of 60,000-300,000 dwt. The UK's **Mouchel & Partners** is the front end engineering and design contractor and is in charge of preparing tender documents for the EPC package. Eight international contractors are expected to be invited to bid for the EPC contract.

A Call for a Stand

By : *Tariq Ahmad Y. El-Sayed*
Kuwait University

It is a fact that the concrete construction industry involves extensive human to human interaction. The parties involved are inevitably representing different and some times contradicting objectives and interests. With large amounts of capital involved and the persisting conflict of interests, it is very much foreseeable that some actions, which could be categorized as unethical.

Those actions may vary from criminal activities, which is dealt with by law enforcement agencies to a quick word of deceit, which is far from the hands of the law. It is definitely an issue not to be ignored. It is most unfortunate that there exists a common layman's belief that a "contractor" is a synonym for a "bandit".

It is the responsibility of the engineering body of the concrete construction industry to take up a stand against all that undermines its importance and contribution to the civilization of the human being. The ACI Kuwait Chapter is an excellent starting point for such a much-needed effort. It is the role of the chapter to enhance the standards of the concrete construction industry in Kuwait. With our member list of many distinguished and leading professionals it would be such a waste to only emphasize the technical aspects of the industry and bypass the ethical ones.

This is a call to establish an Ethics Committee in the ACI Kuwait chapter. This committee should work to:

1. Attempt to set ethical standards for the concrete industry in Kuwait.
2. Identify unethical practices by all parties involved in the concrete construction industry.
3. Enhancing the level of awareness of the professionals and the public of ethical issues related to the concrete construction industry.

The committee, by all means, should not at all be thought of as a court. It should not be at all involved in any particular cases or claims. Rather, the committee should revise procedures undertaken by owners, private and governmental, designers, contractors, consultants and supervision in order to produce proper recommendations if any ethical imbalances are to be found. Furthermore, this committee needs not be seen as a watchdog for the concrete construction industry, but rather as a keen observer whose primary role is to aid the industry in the identification of its weaker points and provide suggested remedies to insure our profession the reputation and esteem it deserves.

CALENDAR OF EVENTS 1999

April 1999	Field visit - Marine Base Project
April 1999	Social Event - Open Day - Bayan Garden
10 - 13 May 1999	CONCREX'99
11 - 13 1999	Technical Seminars & Demonstrations CONCREX'99
June 1999	Social Event Gathering at Hunting and Equestrian Club
June 1999	Field visit - Salmiya Slaughter House
19 October 1999	Technical Seminar
November 1999	Field visit - KFAS Science Center
23 November	Technical Seminar
14 December 1999	Election Day - Dinner at KSE

The

PHILOSOPHY of concrete testing

Every year the Concrete Advisory Service receives many enquiries on testing concrete, most about testing for compressive strength. From these it would appear that many in the construction industry do not fully understand the importance of testing, the significance of test procedures and test results.

The following areas are those which seem to give the most problems.

The cube test

The industry generally seems to place too much emphasis on the humble cube test and overestimates its significance. The fact is that the cube strength in itself has no absolute meaning: it is simply a standardised way of comparing concretes. Differences in the size and shape of the test piece or in test procedures will give different compressive strengths for the same concrete: the difference between the strength of a standard cylinder and cube is a good example.

There is in the industry a lack of appreciation of the vital importance of the correct sampling, making, and storage procedures for cubes. Time and again, Advisory Engineers find that suspect cubes are the result of poor cube-making procedures rather than suspect concrete. For BS 5328 compliance, cubes should be made strictly in accordance with the procedures given in BS 1881: if they are not, they are worthless. Indeed, it has been suggested that a true BS 1881 site cube is 'as common as rocking-horse dropping'! Too often, contractors do not allocate adequate financial and management resources to making cubes. The message needs to be driven home to both contractors and specifiers that unsatisfactory cube-making will often lead to expensive, time-consuming and unnecessary disputes over suspect cubes.

Cores

As most cores are taken in the wake of suspect cube results, it follows from the above that they are often taken unnecessarily. Typically, cores are taken unilaterally after suspect cube results are received. Such unilateral testing is not good practice as it tends to aggravate disputes, not solve them. If cube results are suspect, further investigation should be agreed between all those involved. Most importantly, before testing is started, the parties should agree on the 'compliance' values for the further tests. The Concrete Advisory Service strongly recommends that cores are taken from non-suspect concrete in similar elements and locations. The cores from the non-suspect concrete should then enable realistic relationships between the cube strength and the in-situ strength to be determined.

Relationship between cores and cube

Another fact still often misunderstood is that there is no unique relationship between the in-situ strength and the standard cube strength because the in-situ strength will depend on many factors,

including the location of the test sample, its curing and temperature history, and the degree of compaction. Usually, the in-situ strength as measured by a core will be lower than the standard cube strength of the same concrete. Theoretically, the material safety factors should accommodate the difference between in-situ and cube strengths for structural design purposes.

Accuracy of test results

The fact that no test result is totally accurate and needs to have confidence limits applied to it, is frequently forgotten. The degree of accuracy - and hence the width of the confidence limit band - will depend on many factors, principally the type of test, the number of samples, and how representative the samples are of the material. For example, cement content determination by hardened analysis will typically have confidence limits in the range $\pm 40-80$ kg/m³ and in-situ strengths from core tests will have a confidence limit of $\pm 12\%$ n, where n is the number of cores from one batch of concrete.

In addition to considering the relevant confidence limits, those commissioning tests need to be aware that most tests have inherent limitations.

For example, in-situ permeability measurement is markedly affected by the concrete moisture content, ultrasonic pulse velocity determination depends on an accurate path length, and core strengths are influenced by the location of the sample. All these factors must be taken into account in any analysis of test results.

Those commissioning tests should explore the test method, and make themselves aware of its limitations and the confidence limits to be applied. The inherent inaccuracies in tests may mean that it may be prudent to undertake more than one type of test to improve confidence in the analysis.

The above comments could be regarded as rather negative. However, they do realistically reflect the misunderstanding of testing and its role found by the Advisory Engineers. As is often the case in the construction industry, the key to improvement is better education and training at all levels.

Source, Concrete for the Construction Industry Magazine.

A NEED FOR STRUCTURAL LIGHTWEIGHT CONCRETE IN KUWAIT AND THE GULF AS THE NEW MILLENNIUM DAWNS

By M.N. Haque, H. Al-Khaiat, J. Alduaij & K. Alshaleh
Civil Engineering Department, Kuwait University

A Case for Structural Lightweight Concrete

The use of structural lightweight concrete (SLWC) has steadily grown both in Europe and North America since the early 1960's. SLWC has several potential advantages over normal weight concrete (NWC), including: (i) reduced dead load of the structure, which can lead to a reduction in foundation size, (ii) smaller lifting equipment for placing precast panels, (iii) floor slabs requiring smaller supporting columns, (iv) low density, making it particularly suitable with cantilever structures, (v) high thermal insulation for building, (vi) inherent fire resistance. However, the actual aggregate tends to be more costly and SLWC usually requires a higher cement content than NWC of comparable strength, thus making it more expensive. This increase in unit material costs can often be compensated for by savings mentioned above. Artificial aggregates also have the advantage that their production is less environmentally damaging, often involving the recycling of byproducts, than that of natural aggregates which are quarried.

Lightweight concrete (LWC) is an ideal material of construction in hot coastal environmental conditions that prevails in the Arabian Gulf because of its thermal insulation characteristics. Unfortunately, in the Gulf, there is a scarcity of both naturally occurring materials like clays and shales, and suitable industrial byproducts like fly ash and granulated blast furnace slag which are normally used in the manufacture of lightweight aggregate (LWA). Severe weather conditions associated with the coastal desert, abundance of chloride and sulphates in the environment, in ground and water and the limited supply of good quality aggregates all pose yet additional challenges to the durability of concrete and concrete structures. There are of course worldwide environmental, economic and technical impetuses to encourage the structural use of LWC. Low density products reduce the selfweight, foundation size and construction costs.

Past and Present Research in Kuwait University

Having convinced with the role, importance and a place of SLWC in Kuwait, the first two authors undertook a research project starting in 1995 to investigate the physical, mechanical and durability characteristics of both total lightweight and sand-lightweight concrete of 30 to 50 MPa compressive strength. For this research lightweight aggregate (LWA), LYTAG, a sintered fly ash, was imported from overseas to make the SLWC. The differing mechanical and durability parameters for the SLWC's have been determined by exposing them to the hot marine ambient conditions prevalent in Kuwait. The results are encouraging and are in a process of publication in the various international technical journals. The first two authors are to present some of the research findings in a International Conference to be held in England in June/July 1999.

The last two authors have undertaken a very interesting research project of producing and characterizing lightweight concrete using crushed lightweight bricks (CLWB), a byproduct available in Kuwait. Certainly, this project is important from the environmental enhancement and preservation point of view. Again, the results are being submitted for publications.

The Future of SLWC Research in Kuwait

As has been highlighted earlier, the use of lightweight concrete in construction has many and varied advantages, more so in the Gulf and the Middle East as a whole. The good quality concrete making aggregates are rapidly depleting everywhere. To achieve sustainable development in the construction industry, there are more pressures on the utilization of industry byproducts and recycling of resource material.

The authors of this article are soliciting more information and input, examples of use if any of SLWC locally from the membership of the ACI Kuwait Chapter to broaden the scope of the present research being undertaken at the Kuwait University.

How to stitch cracks

Use stitching dogs, interlocking plates, or dowel bars to restore concrete tensile strength

By Bruce A. Suprenant
(Seminar - world of 95 concrete USA)

Stitching is a simple, cost-effective technique for restoring the tensile strength to a cracked concrete section. It also can increase the shear capacity of flexural members. Most repair contractors already have the necessary equipment and tools to stitch cracks. Follow these tips to add stitching to your services.

The most common stitching methods use either stitching dogs (U-shaped metal units), thin metal interlocking plates (Figure 1), or dowel bars for reinforcement. In each method, the reinforcement is installed across the crack and is bonded to each side of the crack with epoxy or cementitious materials. The amount of reinforcement can be varied to achieve the desired strength restoration.

Stitching dogs

Unlike interlocking plates and dowel bars, which are embedded in the concrete, stitching dogs are surface-mounted. Concrete in axial tension, therefore, requires stitching dogs on both faces. Stitching dogs are most effective when restoring tension in bending members since they are placed at the critical location - the tension face. To install stitching dogs, drill holes on both sides of the crack, clean the holes, then anchor the legs of the dog in the holes with nonshrink grout or epoxy (Figure 1). Vary the length, orientation, and location of the stitching dogs so that the tension is transmitted across an area, not across a single plane within the section.

Because dogs are thin and long and aren't supported laterally, they can't take much compressive force. If the crack closes as well as opens, stiffen and strengthen the dogs to prevent buckling. One method to prevent buckling is to embed the dogs in an overlay. If an overlay is undesirable, stitching dogs can be placed in slots saw cut into the concrete. After the dogs are anchored in

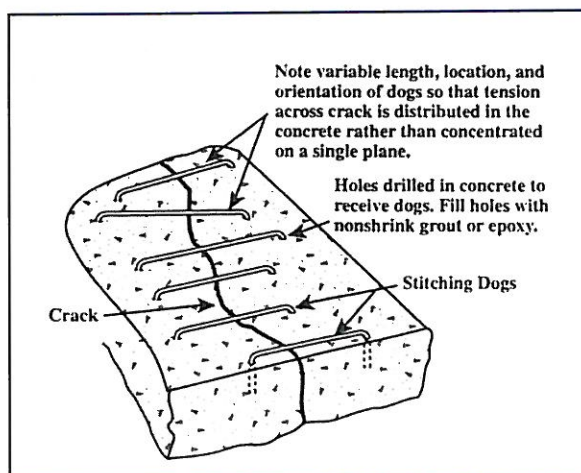


Figure 1. Unlike interlocking plates and dowel bars, stitching dogs are surface-mounted. Stitching dogs are most effective when restoring tension in bending members because they are placed at the critical location - the tension face.

place, use epoxy or cementitious materials to fill the slot.

Interlocking plates

To install interlocking plates, make two sawcuts parallel to, and one saw cut perpendicular to, the crack. Fill the saw cuts with cementitious grout, then lightly hammer three interlocking plates into the saw cuts. The interlocking plates form an H-shape, the flanges act as an anchor to transmit tension through the web.

The plates can be embedded to any depth within the concrete section but typically are within 1/2 inch of the top surface. Unlike surface-mounted stitching dogs, the embedded plates won't buckle if the crack closes.

Dowel bars

To install dowel bars, drill two diagonal holes through the crack, one from each side (Figure 2). Fill the holes with nonshrink cementitious or epoxy materials, then drive a dowel bar into each hole. The bonded dowel bars transmit force across the crack face.

The angled dowel bars restore shear transfer and transmit axial tension, but aren't very effective for restoring tension in flexural members.

Regardless of the stitching method used, reduce the spacing of the reinforcing near the ends of the crack. If possible, drill a small hole (less than 1 inch

diameter) at each end of the crack to stop the crack from propagating and to relieve the stress concentration.

Stitching a crack stiffens the local area, increasing the restraint such that a crack may form elsewhere. If necessary, strengthen the adjacent area using external reinforcement such as bonded plates or a reinforced overlay.

Stitching doesn't close a crack, it only prevents it from opening wider. If the crack seeps water, rout and seal the crack before stitching to protect the reinforcement from corrosion. The crack is easier to rout and seal before the reinforcement is in place. For severely corrosive environments, consider using epoxy-coated or stainless steel reinforcement.

Most cracks can be stitched, but a few can't. Avoid stitching cracks near control or expansion joints. If the crack is too close to a joint (within 1 foot), there's not enough concrete on one side to anchor the reinforcement and the crack will continue to widen. Also, don't stitch a crack by embedding the reinforcement across a control or expansion joint. This prevents the joint from working as originally intended.

Reference

1. ACI 224, "Causes, Evaluation and Repair of Cracks in Concrete Structures (ACI 224.1R-90), American Concrete Institute, P.O. Box 1910, Redford Station, Detroit, Michigan 48219.

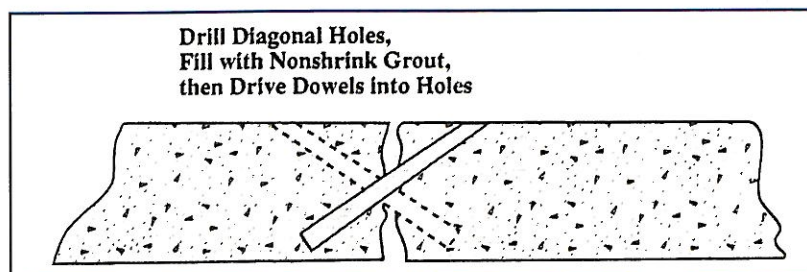


Figure 2. Angled dowel bars restore shear transfer or transmit axial tension, but aren't very effective for restoring tension in flexural members.

Repairing joints in industrial floors

some joint defects appear early, but can be repaired before the owner moves in

By Steven N. Metzger

President Metzger/McGuire Concord, New Hampshire
(Seminar - world of 95 concrete USA)

What's the most troublesome repair problem for plant engineers at warehouses and distribution centers? In a survey my company conducted, deteriorated joints were cited most often. I described four common joint problems in a previous article (Concrete Construction, August 1988, page 749).

This article shows how to solve those problems before owner occupancy. Repairing a 4- to 6-month-old industrial floor requires special care. For successful repairs, keep the following four principles in mind:

1. Re-establish a smooth surface.

The ideal industrial floor is smooth. If a hard wheel from a material handling vehicle crosses a bump or void, the resulting impact will damage the concrete.

2. Don't weld slab units together.

A floor-on-grade is really a group of semi-independent concrete segments. If joints are spaced closely enough, stress doesn't get high enough to cause cracking. Also, stress buildup in one segment doesn't affect the adjacent panel. But gluing concrete together at the joints can cause a chain reaction of shrinkage-related stress. Either the other joints will open wider or cracks will occur between joints. Because new floors often shrink for up to a year, a floor that's 4 to 6 months old still has enough shrinkage potential to cause cracking if joint faces are glued together. Even an older facility that has significant winter-to-summer temperature fluctuations must be kept segmented or thermal shrinkage and expansion can create stress cracking.

Problem: Metal keys in joints create a cantilevered concrete nose that may break off after the joint opens.

As wheels cross the joint, the metal key continues to batter the concrete.

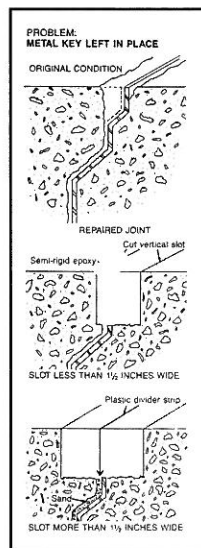
Repair: Remove key to a depth of about 1 inch. You can do this with a torch or saw after saw cutting two parallel cuts at the outer edge of the spalling. With vertical cuts, repair material doesn't have to be feathered. A concrete router also can create the slot.

For slots up to 1 1/2 inches wide, use a semi-rigid epoxy, field-modified with silica sand to increase its hardness. If the slab shrinks and the joint widens, the epoxy will separate from the concrete on one side or the other, usually in an alternating pattern.

For slots greater than 1 1/2 inches, use a high-strength epoxy. A plane of weakness is created by a plastic divider strip. Should movement occur, the repair will split down the middle without tearing the concrete. Use sand to fill the crack below. Epoxy would restrain the slab.

3. Keep repairs as narrow as possible

Wider repairs are subjected to greater



wheel exposure. If you keep repairs narrow, you'll keep more of the wheel load on the slab, where it belongs. For example, don't use a 3/4 inch-diameter router bit to cut out a slightly spalled 3/16-inch saw cut.

4. Don't featheredge repairs.

Many epoxy manufacturers say their products can be feathered. To feather means to taper to zero thickness. Common sense tells you that the point of zero thickness must be the most vulnerable point of the repair with a saw cut to create a vertical edge.

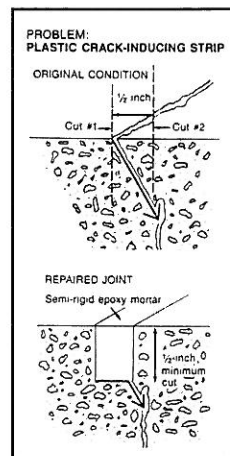
The correction procedures shown in these drawings are project-proven, but may have to be customized for your jobs. Consult with your epoxy supplier to verify that the epoxy is suitable for the application.

For example, some semi-rigid epoxies have a tensile and adhesive strength that's too high for a stress-relieving joint design. It's also important to confirm that the material is specifically formulated for industrial floors, meaning it can tolerate repeated impact and abrasion. Using just any epoxy is no assurance you're using the right material.

Problem: Plastic crack-including strips may be out-of-plumb during finishing. This creates a cantilevered concrete nose that breaks off under traffic.

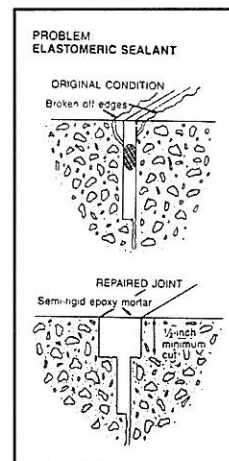
Repair: Determine the position of the strip. The more severe damage is usually on the cantilevered nose. Make a saw cut just beyond the spalling, then another about 1/2 inch onto the nose. Cut a minimum of 1/2 inch deep - 3/4 to 1 inch is preferred. Remove the concrete between the cuts.

Fill the slot with a semi-rigid epoxy mortar. Be sure to fill the joint flush to the surface or slightly high.



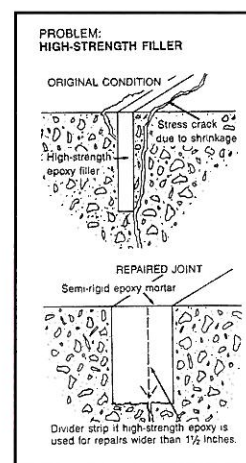
Problem: Joint edges spall under hard-wheel traffic because soft elastomeric sealants provide no support. These sealants only keep dirt and moisture out. They do nothing to protect joints from impact.

Repair: Create a vertical slot by saw cutting or routing. Make it at least 1/2 inch deep - 3/4 to 1 inch deep is preferred. Fill the joint with semi-rigid epoxy mortar. The epoxy will separate from the concrete if the slab moves.



Problem: When the joint filler is stronger than the concrete on each side, a stress crack due to shrinkage can occur.

Repair: Saw cut (or cut) a slot that's as deep or deeper than the original cut. In most cases, a semi-rigid epoxy mortar is the best repair material, especially if the slot is less than 1 1/2 inches wide. A high-strength epoxy mortar can be used for wider repairs, but a plastic divider strip (or a new saw cut control joint through the repair) must be provided to prevent shrinkage stress buildup.



Influence of carbonation and chlorides on concrete durability

(Concrete Repaire Publication)

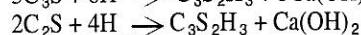
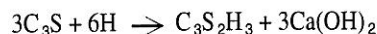
While it has long been recognised that concrete quality and concrete cover are important factors in ensuring durability and protection against reinforcement corrosion, the practising engineer has perhaps only recently become seriously aware of the physico-chemical processes which relate to quantitative assessments of the effectiveness of these factors.

One such process which influences the durability of reinforced concrete is carbonation. The effect of carbonation on the alkalinity of concrete has been known for well over 50 years¹ through is only recently that its significance has received general recognition. The March 1982 draft BS 000: The Structural Use of Concrete (formerly CP110: 1972), Part 2² devotes a complete section to concrete properties and durability and a sub-section dealing with deterioration resulting from physico-chemical effects refers to both carbonation and chlorides.

Aspects of carbonation

There are a number of aspects of carbonation which influence the properties of concrete, the most important of which are shrinkage and the neutralisation of the alkaline conditions of the hydrated cement paste. It is the latter which has the greater significance in relation to the protection of reinforcement from corrosion and a simplified explanation of the physico-chemical processes which take place, hydration, carbonation, corrosion is given below:

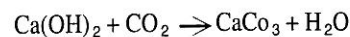
A typical composition of the compounds in Ordinary Portland Cement is shown in Table 1. C_3S & C_2S are the main cementitious compounds and react with water (hydration) to form calcium hydroxide $Ca(OH)_2$. The reactions may be expressed approximately as:



where $H = H_2O$, water

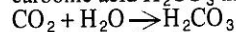
The hydration product calcium hydroxide $Ca(OH)_2$ is strongly alkaline with a pH value of about 13. In the presence of an alkaline environment corrosion of reinforcement is inhibited by the rapid formation of a thin protective film of iron oxide on the metal surface which renders it passive. If the alkaline environment is destroyed and air and moisture permeate to the reinforcement, the conditions are right for corrosion to take place.

Carbon dioxide CO_2 forms about 0.03 per cent of the atmosphere and reacts with the strongly alkaline calcium hydroxide to form calcium carbonate $CaCO_3$ as below:



Thus the alkaline environment is neutralised by carbonation. Under normal conditions the rate of carbonation is low and an indication of the number of years required for the carbonation zone to penetrate a specified cover for a range of water/cement ratios is given in Table 2. Thus with OPC, water/cement ratio 0.55, cover 10mm, the carbonated zone will penetrate the cover in about 12 years. These tables are based on work carried out in Japan¹ and should be considered as indicative only, as the environmental conditions were not defined. However, they do emphasise the importance of the cover to the reinforcement and the water/cement ratio.

If the concrete is carbonated to the full depth of the cover the steel is no longer protected by an alkaline environment. The carbon dioxide dissolves in any moisture present to form carbonic acid H_2CO_3 that is:



Carbonic acid is a weak electrolyte which allows the steel to be oxidised by the atmospheric oxygen and then react with the water to form the corrosion product Fe_2O_3 (H_2O) known as hydrated iron oxide (rust). The corrosion product occupies a much greater volume than the metal from which it was formed and thus sets up bursting forces in the surrounding concrete. Rust stains are not generally visible on the surface of concrete with corroded reinforcement, but cracks running in the direction of the reinforcement (Figure 1) are indicative of the presence of corrosion. The development of corrosion cracks is followed by spalling of the corners of columns or the cover to the main reinforcement of beams.

The depth of carbonation is determined by treating a freshly broken surface with a phenolphthalein indicator solution. Where the concrete is still highly alkaline a purple-red colouration is obtained. If no colouration occurs, carbonation has taken place and thus the depth of the carbonated surface layer can be measured.

The potential for corrosion of reinforcement is enhanced if chloride ions are present in the concrete. The risk of using chloride containing admixtures to accelerate the hardening of concrete is universally recognised. The proposed revision of CP110 (1982): Part 1³ recommends that calcium chloride and chloride based admixtures should never be added in prestressed or reinforced concrete or concrete containing embedded metal. It limits the total percentage chloride ion by weight of cement to 0.1% for prestressed or heat cured concrete containing embedded metal and 0.4% for concrete made with cement complying with BS12, BS146, BS1370, BS4246 or combinations with slag or pfa.

Sources of chlorides other than admixtures are their presence in water and aggregates in marine environments and penetration of the hardened concrete by exposure to de-icing salts. Calcium chloride breaks down in water to form a strong electrolyte



The consequent effects are to reduce the alkalinity of the concrete, increase the flow of corrosion currents and penetrate the passivating iron oxide film on the steel surface.

Table 3 is based on a recent Building Research Establishment assessment of the durability of steel in concrete and the risk of corrosion in relation to carbonation and chloride ion content 456. The chloride content is frequently expressed as a percentage anhydrous calcium chloride by weight of cement and this is obtained by multiplying the chloride ion value by 1.565.

The rapid deterioration of an external reinforced concrete member in which the chloride ion content is in the medium to high category (see Table 3) and carbonation has penetrated the full depth of cover is illustrated in Figures 2 and 3. The member is less than ten years old.

The draft revision of CP110 (1982) Part 2 states that... the 'life' of structural concrete is often

Table 1 : Composition of Ordinary Portland Cement

	Mineral shorthand	Average % by weight cement
Tricalcium silicate	C_3S	55
Dicalcium silicate	C_2S	18
Tricalcium aluminate	C_3A	9.7
Tetracalcium aluminoferrite	C_4AF	9
Free lime	C	1.7
Alkalis	-	0.61
Minor compounds	-	5

Table 2 : Carbonation time (years) for various depths of cover and W/C ratios

(a) Ordinary portland cement (no additives), aggregate type, sand and gravel						
W/C Ratio	Cover mm					
	5	10	15	20	25	30
0.45	19	75	100+	100+	100+	100+
0.50	6	25	56	99	100+	100+
0.55	3	12	27	49	76	100+
0.60	1.8	7	16	29	45	65
0.65	1.5	6	13	23	36	52
0.70	1.2	5	11	19	30	43
(b) Rapid hardening portland cement (no additives) aggregate type, sand and gravel						
W/C Ratio	Cover mm					
	5	10	15	20	25	30
0.45	52	100+	100+	100+	100+	100+
0.50	17	69	100+	100+	100+	100+
0.55	8	34	76	100+	100+	100+
0.60	5	20	45	80	100+	100+
0.65	4	16	36	65	100+	100+
0.70	3	13	30	53	84	100+

not defined but most building and civil engineering structures should be expected to remain fully serviceable for at least thirty to fifty years.

Twenty five years ago the explanatory handbook to CP114: 1957⁷ emphasised the great importance of ensuring that all reinforcement, particularly in members exposed to the weather, is protected by an adequate cover of well compacted concrete, since experience has shown that corrosion of the reinforcement and consequent spalling of the concrete have frequently resulted from inadequate cover.

The effects of ignoring this recommendation have now materialised and in order for new

Figure 1 : Crack Running in the direction of reinforcement induced by corrosion, note absence of rust stains



structures to remain serviceable for thirty to fifty years, greater attention must be paid to cover, water/cement ratio, permeability, compaction, curing and cement content.

Assessment of the risk of premature lack of durability in existing structures necessitates the determination of chloride and cement content and the depth of carbonation.

carbonation tests are readily carried out using the phenolphthalein indicator solution.

Recommendations for the locations and frequency of sampling, and the method of taking samples for chemical analysis to determine chloride and cement contents are given in the BRE information sheet IS 13/77⁸. It is common practice to obtain samples by

drilling the concrete using a 10mm bit discarding material from the first 5mm. Drilling several adjacent holes to a depth of about 25mm is recommended to obtain a sample of at least 25g. it is my experience that chloride ion percentages obtained may be significantly influenced by the depth of drilling, particularly if the penetration of carbonation is high. With a concrete of high permeability, the depth of carbonation can extend to over 20mm in ten years.

The presence of chloride ion concentration in the medium to high risk category (see Table 3) will normally manifest itself within a few years, particularly if associated with concrete of low cement content and high permeability in a moist environment.

Currently, there is inadequate long-term evidence to be able to recommend a permanent repair technique in this situation.

Protective coatings

If the chloride ion concentration is low and carbonation does not extend to the level of the reinforcement then the use of a protective surface coating to arrest further carbonation merits consideration. Further, the coating can be used to improve the appearance of the concrete. The requirements of a surface coating are high UV resistance, prevention of water ingress and high resistance to carbon dioxide and chloride ion diffusion. The coating should permit two-way vapour diffusion. If carbonation has reached the level of the reinforcement and corrosion cracks and spalling initiated, then it will be necessary to hammer test to expose all defective concrete.

On renewal of the defective concrete the exposed reinforcement should be thoroughly cleaned, preferable by blast cleaning. the requirements of the patch repair material are good adhesion in dry, damp or wet conditions, mechanical properties similar to the base material, low shrinkage, high inherent alkalinity and high impermeability.

To summarise, we have inherited the problems of the addition of chlorides to existing concrete structures and as yet there does not appear to be a satisfactory long-term repair solution. With new structures, the problem can obviously be avoided.

The presence of carbon dioxide in the atmosphere can be combated by closer attention to mix design, compaction and curing. This can be supplemented by the use of an appropriate surface treatment. The most onerous conditions for carbonation are at a relative humidity of between 50 to 70 per cent in an exposed alternatively wet and dry environment. Carbonation is minimal at a relative humidity of 100 per cent or at less than 30 cent 9.

Table 3 : Potential for corrosion based on the BRE Digest 264

Chloride ion Content as a percentage of cement content	Carbonation	
	less than cover depth	greater than cover depth
low (up to 0.4)	Low risk in all environmental conditions	Moderate risk in damp conditions
medium (0.4 to 1.0)	Moderate risk in damp conditions	High risk enhanced by damp conditions and poor concrete quality
high (above 1.0)	High risk enhanced by damp conditions and poor concrete quality	High risk enhanced by damp conditions and poor concrete quality

Figure 2 : Concrete spalled from the corner of a reinforced concrete column

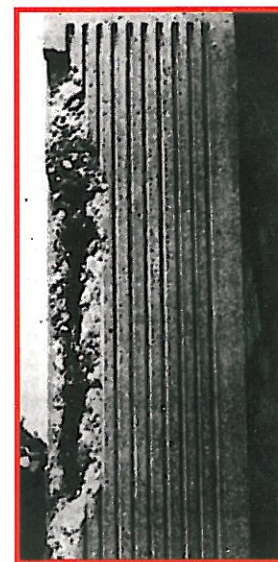
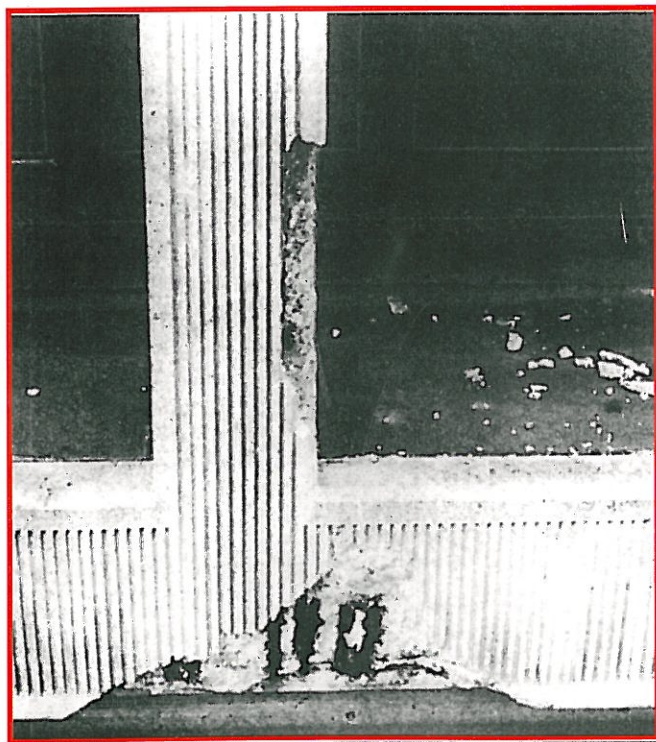


Figure 3 : Concrete spalled from a column and beam



Architect and Engineer Jokes

Real Engineers...

Real Engineers consider themselves well dressed if their socks match

Real Engineers buy their spouses a set of matched screw-drivers for their birthday.

Real Engineers wear moustaches or beards for "efficiency". Not because they're lazy.

Real Engineers know the second law of thermodynamics - but not their own shirt size.

Real Engineers repair their own cameras, telephones, tel-visions, watches, and automatic transmissions.

Real Engineers say "it's 70 degrees Fahrenheit, 25 degrees Celsius, and 298 degrees Kellvin" and all you say is :Isn't it a nice day"

Real Engineers give you the feeling you're having a conversation with a dial tone or busy signal.

Real Engineers wear badges so they don't forget who they are. sometimes a note is attached saying "Don't offer me a ride today. I drive my own car".

Real Engineers politics run towards acquiring a parking space with their name on it and an office with a window.

Real Engineers know the "ABC's of Infrared" from A to B.

Real Engineers will make four sets of drawings (with seven revisions) before making a bird bath.

Real Engineers' briefcases contain a Philips screwdriver, a coy of "Quantum Physic", and a half of a peanut butter sandwich.

