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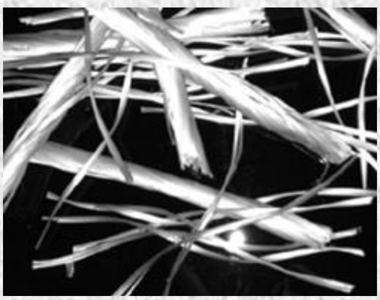
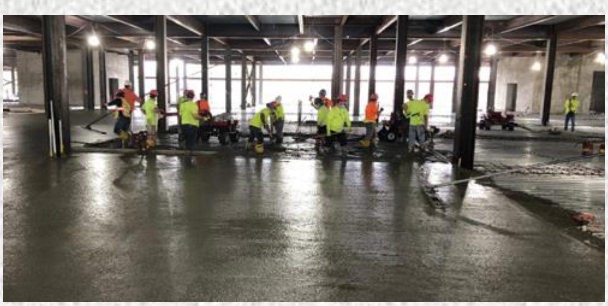
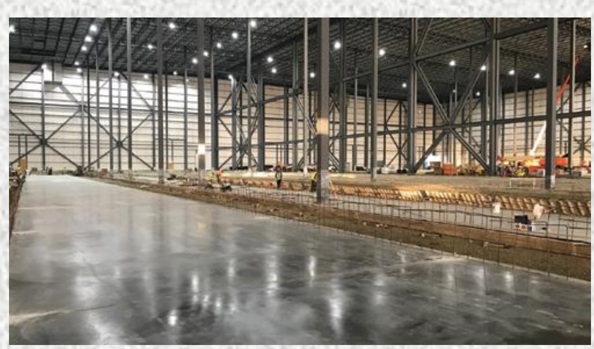
MYCONCRETE



# THE BULLETIN OF THE AMERICAN CONCRETE INSTITUTE – MALAYSIA CHAPTER (E-BULLETIN)





MyConcrete

# MyConcrete:
## The Bulletin of the American Concrete Institute – Malaysia Chapter

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# CONTENT

| Page | Contents of Bulletin |
|---|---|
| 4 | Introduction to ACI Malaysia Chapter |
| 5 | Past Presidents |
| 6 | Management for 2020-2022 |
| 7 | Notice |
| 9 | Upcoming Events |
| 12 | Preceding Events |
| 13 | Article |
| 18 | Technical Report |
| 24 | Case Study |
| 28 | Membership |
| 29 | Premium Sponsors |
| 30 | Loyal Sponsors |

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# INTRODUCTION TO ACI MALAYSIA CHAPTER

American Concrete Institute - Malaysia Chapter (ACI-Malaysia) is a non-profit technical and educational society representing ACI Global in Malaysia, which is one of the world's leading authorities on concrete technology. Our members are not confined to just engineers; in fact, our invitation is extended to educators, architects, consultants, corporate, contractors, suppliers, and leading experts in concrete related field. The purpose of this Chapter is to further the chartered objectives for which the ACI was organized; to further education and technical practice, scientific investigation, and research by organizing the efforts of its members for a non-profit, public service in gathering, correlating, and disseminating information for the improvement of the design, construction, manufacture, use and maintenance of concrete products and structures. This Chapter is accordingly organized and shall be operated exclusively for educational and scientific purposes.

Objectives of ACI-Malaysia are:

❖ ACI is a non-profitable technical and educational society formed with the primary intention of providing more in-depth knowledge and information pertaining to the best possible usage of concrete.

❖ To be a leader and to be recognized as one of Malaysia's top societies specializing in the field of concrete technology by maintaining a high standard of professional and technical ability supported by committee members comprising of educators, professionals and experts.

❖ Willingness of each individual member/organization to continually share, train and impart his or her experience and knowledge acquired to the benefit of the public at large.

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***Important Notes:***

*i) ACI Malaysia is only a platform for our members to advertise for interns.*

*ii) All application to be made direct to companies and would be subject to their terms and conditions.*

# UP COMING EVENTS

# UP COMING EVENTS


## Seminar on RC Flat Roof – Criteria for Concrete Design, Waterproofing Skin and Maintenance of Water Seepage related issues based on ACI-MY Technical Commentary No.1.

**25 February 2022, Friday | 9 am - 6 pm | Atlanta Ballroom, Armada Hotel, Petaling Jaya**

### Introduction

The problem of water intrusion leading to leakage in concrete roofs is of great concern and interest to many stakeholders and building owners in Malaysia This seminar will focus on the current practices in Malaysia pertaining to the design, construction and repair of waterproofing systems on concrete roofs of buildings. This is in line with the primary objective of ACI Malaysia to share, enhance and advance knowledge in concrete technology.

A RC flat roof can experience issues relating to water seepage if it is not designed and constructed properly. In fact, this is a common problem in many buildings in the country. These leakages, when they occur, will cause a lot of inconvenience to the occupants below, with unsightly stains and even damage to the ceiling and walls including the finishing, fittings and furniture. Long term leakage will also cause weakening and deterioration of the RC slab which can eventually affect its structural integrity if timely repairs are not carried out.

The requirements for proper and effective waterproofing systems are often not well understood or managed poorly, resulting in many problems related to unacceptable leakages of moisture through the concrete roof. At the end of this seminar, you will gain valuable insights on flat roof design, the functions of the waterproofing skin and how issues related to water seepages could be managed after the completion of the building construction.

### Registration Fee

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Closing Remarks
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Programme
8:30 am Registration
9:00 am Opening Speech by Mr Martin David
9:10 am Introduction to ACI-MY by Prof. Hamidah
9:25 am Preview of ACI Technical Commentary No.1
by Mr. Martin David
9:45 am Water Intrusion Issues at Concrete R
The Malaysian State of Affairs b
10:30 am Morning tea break
11:00 am A wholistic RC for concrete
roof from gineer's perspective
by Dr.
11:45 am Good pr ces in construction of reinforced
concrete roof by Dr. Zack Lim
12:30 am Lunch
2:00 pm Cement a ete technology by Mr. Steven Tan
2:45 pm elongation properties in
g membrane by Mr. Lee Chiew Fook
noon tea break
The Architectural perspective for a watertight RC Roof
by Ar. Alan Teh
4:45 pm Remedial methods for water intrusion at RC Roof
by Mr. James Lim
5:30 pm Q & A
5:55 pm Closing Remarks by Tan Sri Sufri Haji Mhd Zin
6:00 pm ACI-MBAM Fellowship Event
REGISTER NOW!
Postpone to 20th May 2022

# PRECEDING EVENTS

ARTICLE

Reprint from: CI Magazine
November 2021, Vol. 43, No11, Page 27-30

# Fiber-Reinforced Concrete

A brief review of advantages and opportunities

by Amir Bonakdar and Michael A. Mahoney

**A**s a construction technology, fiber reinforcement is almost as old as civilization itself. It has evolved many times over its long history, with some notable evolutions including: • In ancient Mesopotamia, straw fibers were used in clay and mud bricks1; • Near the beginning of the twentieth century, asbestos fibers were introduced to produce artificial stone plates from hydraulic cements; and • In the mid-1960s, steel fibers were investigated for their effects in concrete mixtures. Given the ongoing innovations in fiber reinforcement, ACI Committee 544, Fiber Reinforced Concrete, was formed in 1965. Since its formation, ACI Committee 544 and others have published several documents pertaining to the topic. This article summarizes key aspects of some of the documents.

## Sources

Fibers are now well established in the concrete industry. ASTM C1116/C116M, for example, classifies fiber-reinforced concrete (FRC) by the material type of the incorporated fibers:steel, glass, synthetic, or natural, and *ACI Concrete Terminology* (ACI CT) includes fibers in its definition of reinforcement, along with bars, wires, strands, and "other slender elements that are embedded in a matrix such that they act together to resist forces."

ACI CT currently classifies fibers by equivalent diameter—the diameter of a circle with an equal aggregate sectional area as the fiber. Fibers with equivalent diameters less than 0.012 in. (0.3 mm) are classified as microfibers, and fibers with larger equivalent diameters are classified as macrofibers.

Examples are shown in Fig. 1. Microfibers are typically used for mitigating plastic shrinkage cracks. Macrofibers are typically used to limit the widths of cracks resulting from shrinkage and thermal stresses and provide post-cracking tensile reinforcement. They are commonly made from steel or synthetic (polymeric) materials, and they generally have a length of 1.0 to 2.5 in. (25 to 63 mm). This article is focused on macrofibers only.

Fibers provide three-dimensional (3-D) reinforcement and can enhance the ductile behavior of concrete. The level of tensile reinforcement provided by fibers depends on many factors, including fiber type, material, geometry, and bond strength. Today, fibers are used as reinforcement in slabs-onground, topping slabs, pile-supported slabs, crane track slabs, pavements, shotcrete, precast concrete pipes, precast tunnel segments, structural connections, and walls (ACI 544.4R-18).

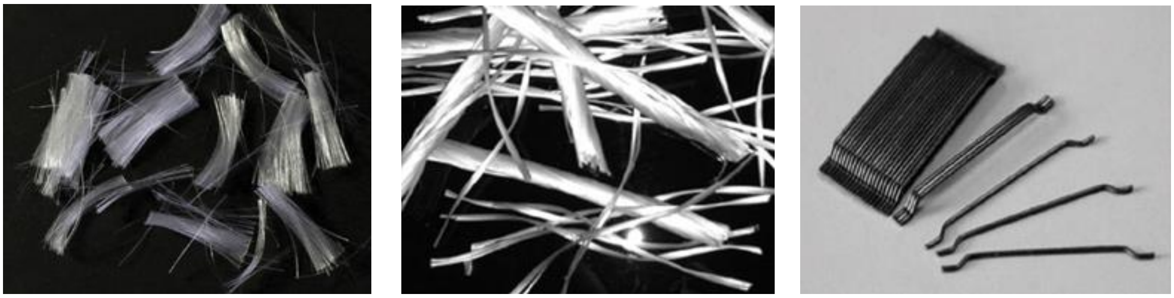

**Fig. 1: Examples of fiber types, including: (a) synthetic microfibers; (b) synthetic macrofibers; and (c) steel macrofibers**

## Benefits

### During construction

In contrast to conventional steel reinforcing wires or bars, fibers require no storage at the jobsite, labor for installation, supports or spacers, or personnel for inspection. So whether used in a slab, wall, or precast component, the appropriate use of fibers in place of wire or bar reinforcement can significantly reduce the time and cost associated with delivering, installing, and inspecting the reinforcement. Using fibers for slabs can also eliminate the potential tripping hazard created by wire fabric and reinforcing bars, and it makes it feasible to discharge concrete directly from the mixer truck and avoid the need for a pump or conveyor. Using fiber reinforcement may also result in reductions in greenhouse gas emissions due to using less steel in concrete.

Figure 2 shows a concrete slab on a metal deck under construction. The slab has been designed to incorporate fiber reinforcement in lieu of welded wire reinforcement. While no bars are included in this slab, some designers require conventional bars placed transversely over beams and girders to minimize cracking in the negative moment regions in the slab.

During service In contrast to the two-dimensional (2-D) reinforcement provided by steel wires and bars, fibers provide 3-D reinforcement throughout a member. Uniformly and randomly distributed fibers can arrest incipient cracking at any point in concrete, resulting in shorter and thinner cracks and enhancing long-term durability. The 3-D nature of reinforcement by fibers also reduces the potential for spalling or chipping caused by overloading, impact, or explosion.

For flatwork applications such as slabs-on-ground, elevated slabs, and pavements, traffic and vehicular loads create a fatigue-type loading; using fibers in concrete increases the toughness and fatigue resistance of concrete, resulting in a longer service life and reduced maintenance costs. Because fibers help to limit crack widths, FRC has been shown to improve the liquid tightness and service behavior of environmental concrete structures by reducing permeability and leakage.

Fibers have also been shown to significantly enhance the ductility and ability of concrete to absorb energy under earthquake, impact, or blast loadings.

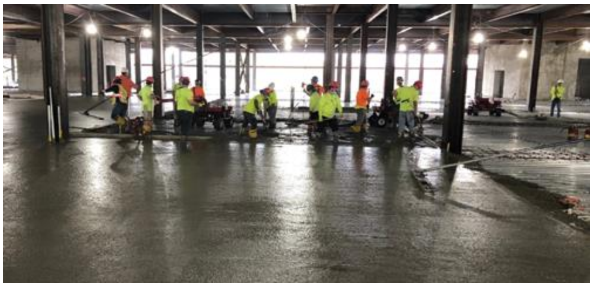

**Fig. 2: A concrete placement on an elevated floor in a hospital in Ridgewood, NJ, USA. The concrete slab on a metal deck was reinforced using only synthetic macro fiber reinforcement**

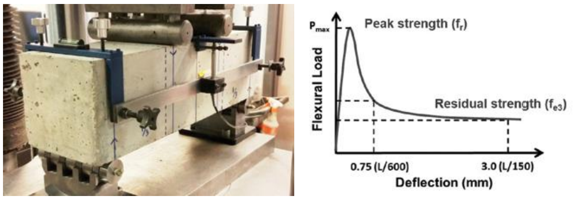


**Fig. 3: FRC can be characterized using beam tests per ASTM C1609/C1609M: (a) a typical test assembly; and (b) a schematic representation of a flexural test result with post-crack residual strength (after Reference 6)**

## Execution

### Design

Like reinforcing bars, fiber reinforcement bridges cracks and transfers tensile loads through anchorage and bond action. However, fiber reinforcement works at a different scale, acting as hundreds of mini bars providing tensile strength to concrete. Fiber reinforcement can change the post-crack response of concrete from brittle to ductile under compression, tension, flexure, and impact loads.9 For design, the tensile properties of FRC can be back-calculated from the results of flexural tests perASTM C1609/C1609M or BS EN 14651.10,11 Both test methods use beams loaded under four-point or three-point bending configurations until reaching a specific deflection or crack opening. The results include full load-deflection or load-crack opening curves and parameters regarding the post-crack flexural residual strength. Figure 3 shows a test of an FRC beam and schematics of a typical flexural test result with post-crack residual strength measured perASTM C1609/C1609M.

Fibers can do more than control cracking due to temperature changes and shrinkage. An FRC section can be designed to have a specific tensile and moment capacity. Similarly to a conventionally reinforced concrete section, reduction factors may be used to account for uncertainties with the material properties and the construction processes. Reference 6 provides guidance and summarizes the derivation of formulas for post-crack tensile and moment capacities using residual strength parameters obtained from beam tests. For example, that document recommends that the residual tensile strength of FRC, $F_{ut\text{-}FRC}$, can be estimated as

$$F_{ut\text{-}FRC} = 0.37 f_{150}^{D}$$

where $f_{150}^{D}$ is the flexural residual strength at a deflection of $L$/150 for beams with span $L$ tested per ASTM C1609/C1609M. Similarly, Reference 6 recommends that the nominal moment capacity, $M_{n\text{-}FRC}$, of an FRC section of width $b$ and height $h$ can be estimated as

$$M_{n\text{-}FRC} = f_{150}^{D} bh^2/6$$

The selection of design parameters and their limits will depend on the specific application and design limit states. For example, where small crack widths are required under the serviceability limit state, the residual flexural strength at a deflection of $L/600$, $f_{600}^{D}$, may be used in calculations.

Under the ultimate limit state, however, $f_{150}^{D}$ may be more appropriate than $f_{600}^{D}$. In applications such as slabs-on-ground, the equivalent flexural residual strength $f_{e,150}^{D}$ (also known as $f_{e,3}$), which accounts for the flexural toughness (energy absorption) of FRC, is often used for design. Schematic stress distributions and the corresponding design parameters for an FRC section are provided in Fig. 4. Other design aspects, including determining shear strength, controlling crack width, and designing using hybrid reinforcement comprising reinforcing bars plus fibers are also discussed in Reference 6. A detailed discussion of the stressstrain analysis of FRC, including softening and hardening behaviors, can be found in Reference 12, and information on the design for specific applications for FRC, such as precast tunnel segments,13 shotcrete,14 and slabs-on-ground.15 Lastly, proposals for parametric models for determining the tensile stress-strain response of FRC for use in finite element models can be found in References 16 to 18.

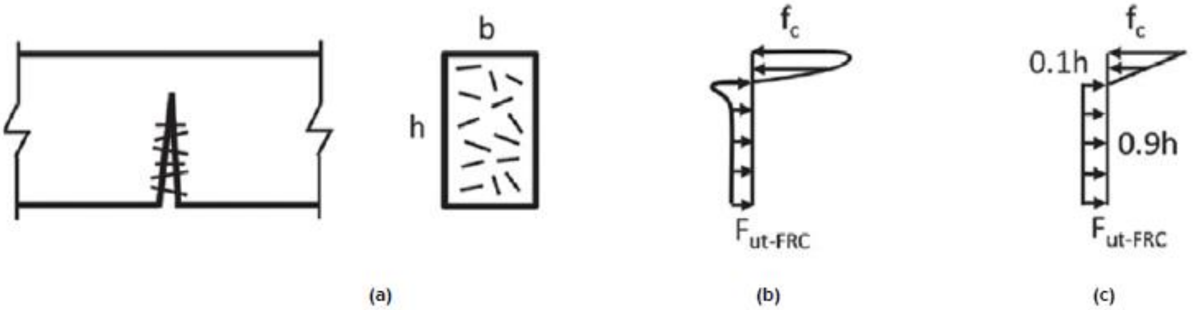


**Fig. 4: Schematics of stresses in a cracked FRC section loaded in flexure: (a) FRC beam and section; (b) idealized distribution of normal stresses; and (c) simplified distribution of normal stresses (after Reference 6)**

## Specification

Because residual strength values vary with fiber type, using a performance-based specification can ensure proper performance . The specification can dictate parameters per ASTM C1609/C1609M or per BS EN 14651. For example, 150 f D or e,3 f values can be specified for FRC, along with some main physical parameters such as fiber length or aspect ratio. Additionally, it is important to include fiber dosage and properties in the general structural notes and specification as well as to indicate locations on the plans that require FRC. To ensure proper mixing, placing, and finishing of FRC, we recommend that the specification requires that a representative of the fiber manufacturer attend relevant preconstruction meetings.

Applications

Over the last four decades, fibers have been used to replace conventional reinforcement, fully or partially, in hundreds of successful projects, including:

- Slabs-on-ground with conventional or extended joint spacing;
- Pavements;
- Overlays and topping courses;
- Shotcrete for tunnel linings, slope stabilization, or swimming pools;
- Precast concrete for tunnel segments, septic tanks, sound walls, or decorative panels; and
- Structural elements with hybrid reinforcement.

While fibers cannot fully replace reinforcing bars where continuous reinforcement is needed for structural integrity, systems with hybrid reinforcement may provide viable alternatives that allow for accelerated construction. Recent examples include slabs-on-piles, coupling beams, shear walls, footings, foundation walls, precast walls, and tilt-up concrete panels in which the designer has used fibers to replace a portion of the reinforcing bars that would normally be used. Figure 5 shows two exemplary projects.

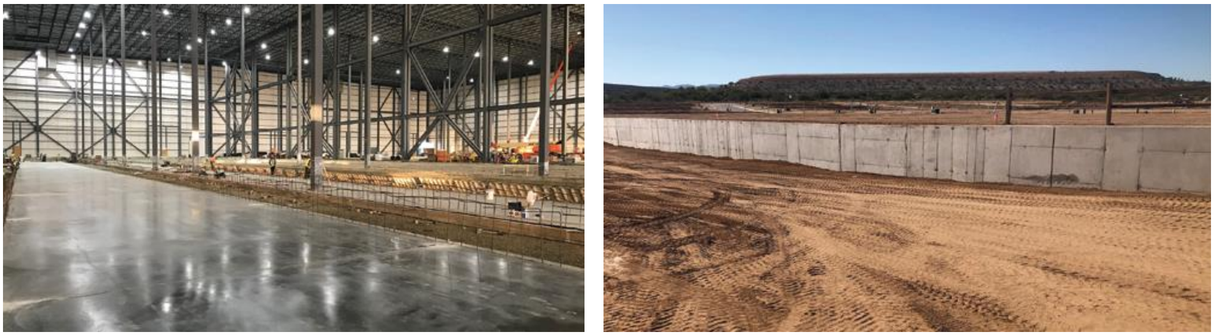

**Fig. 5: Examples of projects constructed using FRC: (a) the slab-onground floors in this food processing facility in Troy, OH, USA, were designed and constructed using FRC reinforced with steel fibers only; and (b) the retaining walls for a flood control project in Tucson, AZ, USA, were constructed with synthetic macrofibers designed to replace 40% of the steel bar reinforcement determined during preliminary design.**

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ACI member **Amir Bonakdar** is the Business Development Manager for The Euclid Chemical Company, Los Angeles, CA, USA. He is Chair of ACI Subcommittee 544-C, FRC-Testing, and is a member of ACI Committees 201, Durability of Concrete; 360, Design of Slabs on Ground; and 544, Fiber Reinforced Concrete. He received the 2018 ACI Young Member Award for Professional Achievement. He received his master's degree in structural engineering from the University of Tehran, Tehran, Iran, in 2006, and his PhD from Arizona State University, Tempe, AZ, USA, in 2010. A licensed professional engineer, Bonakdar has coauthored several papers on mechanical characterization of concrete and is focused on educating and promoting the use of novel and sustainable materials in concrete construction.

**Michael A. Mahoney**, FACI, is the Director of Marketing and Technology, Fiber-Reinforced Concrete, for The Euclid Chemical Company, Cleveland, OH, USA. He is a Past Chair of ACI Subcommittee 544-A, FRC-Production and Applications, and is a Past President of the Fiber Reinforced Concrete Association (FRCA). In 1997, he received his master's degree in civil engineering from the Technical University of Nova Scotia, Halifax, NS, Canada, where he helped to develop and patent an innovative synthetic fiber for concrete reinforcement. Mahoney has coauthored several papers on FRC and currently directs research and marketing projects while educating engineers and contractors on the use of FRC.

TECHNICAL REPORT

Reprint from: CI Magazine
January 2022, Vol. 44, No1,
Page 34-39

# Durability of Portland Limestone Cement Concrete

## Testing mixtures for an infrastructure project

*by Neal S. Berke, Ali N. Inceefe, Allan Kramer, and Oscar R. Antommattei*

The cement industry in North America is making positive commitments to lower the environmental impacts of cement in several ways: by increased use of alternative fuels, increased use of upplementary cementitious materials (SCMs), the addition of limestone for blended cement production, the initiation of carbon capture technologies, and the practice of hardened concrete recarbonation accounting. All of these sustainable technologies and practices will reduce the carbon footprint of concrete. Even greater, long-term reductions in the carbon footprint of concrete are obtainable by increasing its durability so that concrete structures will not need to be repaired or replaced as frequently. Portland limestone cement (PLC) is fast becoming the main cement used in North America. PLC is included in the ASTM C595/C595M1 blended cement standard as Type IL, which allows replacement of 5 to 15% of the portland cement clinker with natural limestone that is interground with the clinker. This results in a reduction of the carbon footprint of the cement while not impacting the performance of concrete using PLC.

Previously conducted research has shown that concrete made with PLC has good sulfate and alkali-aggregate resistance. In this article, we show more data from an infrastructure project on PLC concrete durability properties, such as resistance to freezing and thawing and chloride ion ingress, for a longer service life. Concrete for a large light-rail infrastructure project in the Northwest region of the United States was proposed to be switched from using ordinary portland cement (OPC) to PLC. This project had a design target requirement of a 100 year concrete service life. Therefore, it became very important to be able to document that the project's 100-year concrete service life specification requirement could be successfully obtained using PLC.

The work described herein shows that good concrete durability meeting a 100-year service life is obtainable with PLC concretes containing Class F fly ash as an SCM. A few experiments with PLC and ground-granulated blast-furnace slag (slag cement) also gave good concrete durability results (not included). However, because slag cement was not readily available for the project, this study concentrated on the use of Class F fly ash as an SCM.

### Experimental Work

#### Materials

PLC used in this study met the requirements for a Type IL blended cement according to ASTM C595/C595M. Fly ash used for this study met the requirements of ASTM C6183 Class F fly ash. OPC used in this study met the requirements of ASTM C150/C150M4 for Type I/II cement. Concrete aggregates and admixtures used in this study met the requirements of ASTM C33/C33M5 and ASTM C494/C494M,6 respectively. Concrete for testing was produced using a large laboratory concrete mixer at the Corliss Resources, Inc., concrete laboratory located in Sumner, WA, USA. Concrete cylinder samples for durability testing were shipped moist in insulated crates to the Tourney Consulting Group's laboratory in Kalamazoo, MI, USA. Concrete mixture proportions, plastic properties, and compressive strengths are listed in Tables 1(a) and (b) for mixtures with PLC, and Table 2 for mixtures with Type I/II cement.

## Durability testing

The PLC concrete was to be used in various elements of the light-rail project. The concrete mixture designs were based on exposure to chloride, concrete cover over the reinforcing steel, and freezing-and-thawing conditions for the specific elements. The aggregates used were not susceptible to alkali-silica reaction (ASR) attack, and sulfate exposure was low, so testing for resistance to these degradation mechanisms was not conducted. The PLC used had good sulfate resistance according to ASTM C1012/C1012M7 in tests conducted by the cement producer.

The primary concern was ingress of chloride into the concrete that could result in corrosion of steel reinforcement and subsequent cracking and spalling of the concrete.

To determine the susceptibility to chloride ingress, bulk diffusion tests per ASTM C15568 were performed. For quality control purposes, a rapid chloride permeability test (RCPT) per ASTM C12029 was performed due to the shorter test duration.

The diffusion coefficient tests were performed on 28-day moist-cured concrete samples. In these tests, the ages of the concrete samples at the start of exposure differed from each other by a few days; thus, the apparent diffusion coefficient (D*a*) values needed to be converted to diffusion

**Table 1(a):**
**First group of concrete mixtures with PLC and Class F fly ash (FA)**

| Materials or properties | Mixtures | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1A with 30% FA | 1B with 25% FA | 1C with 25% FA | 4A with 30% FA | 4D with 30% FA | 4E with 25% FA | 4F with 25% FA |
| *w/cm* | 0.38 | 0.40 | 0.40 | 0.38 | 0.38 | 0.40 | 0.40 |
| Type IL cement,* lb/yd$^3$ | 420 | 469 | 469 | 559 | 507 | 551 | 551 |
| Class F fly ash, lb/yd$^3$ | 180 | 156 | 156 | 240 | 218 | 184 | 184 |
| Total cementitious, lb/yd$^3$ | 600 | 625 | 625 | 799 | 725 | 735 | 735 |
| 3/4 in. coarse aggregate, lb/yd$^3$ | 1399 | 1368 | 1368 | 1337 | 1349 | 1352 | 1352 |
| 3/8 in. coarse aggregate, lb/yd$^3$ | 463 | 453 | 453 | 352 | 370 | 391 | 391 |
| Fine aggregate, lb/yd$^3$ | 1216 | 1189 | 1216 | 1014 | 1123 | 1047 | 1047 |
| Total water, lb/yd$^3$ | 230 | 250 | 250 | 302 | 275 | 295 | 295 |
| Air-entraining admixture | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| High-range water-reducing admixture | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Shrinkage-reducing admixture | — | — | ✓ | — | — | — | ✓ |
| Entrained-air content, % | 6.2 | 6.0 | 7.0 | 5.0 | 7.5 | 5.4 | 6.2 |
| Slump, in. | 6.25 | 5.00 | 5.25 | 6.25 | 6.00 | 7.00 | 6.00 |
| Unit weight, lb/ft$^3$ | 144.64 | 144.48 | 142.64 | 145.28 | 140.80 | 144.64 | 143.60 |
| 28-day compressive strength, psi | 7228 | 7189 | 6439 | 7552 | 7361 | 7205 | 6574 |
| 56-day compressive strength, psi | 8294 | 7747 | 7206 | 8508 | 8075 | 7985 | 7473 |

*Lehigh NW Cement Company

Note: 1 lb/yd$^3$ = 0.6 kg/m$^3$; 1 in. = 25 mm; 1 lb/ft$^3$ = 16 kg/m$^3$; 1 psi = 0.007 MPa

**Table 1(b):**
**Second group of concrete mixtures with PLC and Class F fly ash (FA)**

| Materials or properties | Mixtures | | | | | |
|---|---|---|---|---|---|---|
| | 9A with 30% FA | 9B with 25% FA | 9C with 25% FA | 10A with 30% FA | 10B with 25% FA | 10C with 25% FA |
| *w/cm* | 0.38 | 0.40 | 0.40 | 0.38 | 0.40 | 0.40 |
| Type IL cement,* lb/yd$^3$ | 455 | 529 | 529 | 420 | 469 | 469 |
| Class F fly ash, lb/yd$^3$ | 195 | 176 | 176 | 180 | 156 | 156 |
| Total cementitious, lb/yd$^3$ | 650 | 705 | 705 | 600 | 625 | 625 |
| 3/4 in. coarse aggregate, lb/yd$^3$ | 1359 | 1327 | 1327 | 0 | 0 | 0 |
| 3/8 in. coarse aggregate, lb/yd$^3$ | 450 | 401 | 401 | 1670 | 1660 | 1660 |
| Fine aggregate, lb/yd$^3$ | 1181 | 1129 | 1129 | 1401 | 1338 | 1338 |
| Total water, lb/yd$^3$ | 246 | 280 | 280 | 228 | 250 | 250 |
| Air-entraining admixture | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| High-range water-reducing admixture | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Shrinkage-reducing admixture | — | — | ✓ | — | — | ✓ |
| Entrained-air content, % | 6.0 | 5.5 | 6.0 | 7.5 | 7.4 | 5.8 |
| Slump, in. | 6.00 | 6.75 | 6.50 | 4.00 | 3.50 | 3.50 |
| Unit weight, lb/ft$^3$ | 144.88 | 143.52 | 143.36 | 142.00 | 142.08 | 144.80 |
| 28-day compressive strength, psi | 7238 | 6992 | 6529 | 6993 | 7995 | 8091 |
| 56-day compressive strength, psi | 7668 | 7686 | 7236 | 8005 | 8836 | 8995 |

*Lehigh NW Cement Company

Note: 1 lb/yd$^3$ = 0.6 kg/m$^3$; 1 in. = 25 mm; 1 lb/ft$^3$ = 16 kg/m$^3$; 1 psi = 0.007 MPa

**Table 2:**
**Concrete mixtures with Type I/II cement and Class F fly ash (FA)**

| Materials or properties | Mixtures | |
|---|---|---|
| | 4G with 30% FA | 4I with 25% FA |
| *w/cm* | 0.38 | 0.40 |
| Type I/II cement, lb/yd³ | 507 | 551 |
| Class F fly ash, lb/yd³ | 218 | 184 |
| Total cementitious, lb/yd³ | 725 | 735 |
| 3/4 in. coarse aggregate, lb/yd³ | 1349 | 1352 |
| 3/8 in. coarse aggregate, lb/yd³ | 370 | 391 |
| Fine aggregate, lb/yd³ | 1123 | 1047 |
| Total water, lb/yd³ | 275 | 295 |
| Air-entraining admixture | ✓ | ✓ |
| High-range water-reducing admixture | ✓ | ✓ |
| Shrinkage-reducing admixture | — | ✓ |
| Entrained air content, % | 6.6 | 5.6 |
| Slump, in. | 6.00 | 6.50 |
| Unit weight, lb/ft³ | 142.32 | 142.88 |
| 28-day compressive strength, psi | 7087 | 6548 |
| 56-day compressive strength, psi | 7872 | 7515 |

Note: 1 lb/yd³ = 0.6 kg/m³; 1 in. = 25 mm; 1 lb/ft³ = 16 kg/m³; 1 psi = 0.007 MPa

coefficient values at a reference time for comparison purposes. The Da calculated by fitting the ASTM C1556 results to the well known solution of Fick's Second Law is the average of the changing diffusion coefficient over the test period. To make this conversion, one first needs to determine the time at which Da occurs, which can be done using Eq. (1).10 Then, Eq. (2) is used to calculate the diffusion coefficients at the reference time. In this study, a reference time of 28 days was used, as in the most common service-life prediction models.

$$t_{eff} = \left[\frac{(1-m)(t_2 - t_1)}{t_2^{1-m} - t_1^{1-m}}\right]^{1/m} \quad m \neq 0.1 \qquad (1)$$

$$D_{28} = \frac{D_a}{\left(\frac{28}{t_{eff}}\right)^m} \qquad (2)$$

where $t_{eff}$ is the effective time in days at which the Da occurs; m is the aging factor; t1 is the age of the concrete at the start of the exposure; t2 is the age of the concrete at the end of the exposure; and D28 is the 28-day diffusion coefficient.

Aging factors were determined by plotting bulk conductivity results at various ages obtained from ASTM C176011 on a log-log scale and fitting a power function. Figure 1 shows the test results for various concrete mixtures;

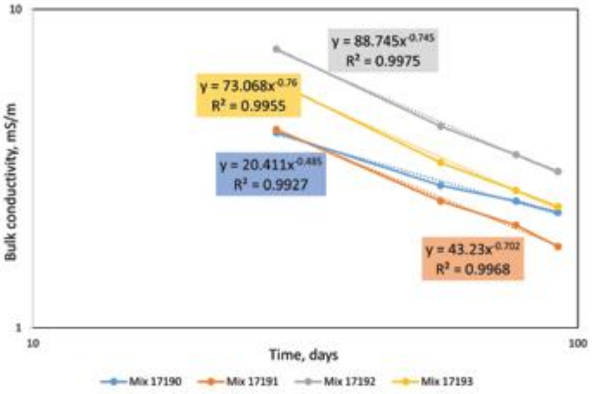


**Fig. 1: Example bulk conductivity results versus time, plotted on a log-log scale. Aging factors are defined by the slopes (the power terms) for the fitted functions.**

the negative slopes correspond to aging factors. The following sections provide the conductivity and calculated m values for the tested concrete mixtures. ASTM C457/C457M12 hardened concrete air void analysis was performed to estimate freezing-and-thawing resistance. If spacing factors were above 0.008 in. (0.2 mm), then ASTM C666/C666M, Procedure A,13 was performed.

## Concrete Permeability and Bulk Diffusion Results

### PLC and Class F fly ash mixtures

The RCPT results are shown in Fig. 2. They are for normal-temperature curing and accelerated curing (7 days at normal curing followed by 21 days moist curing at 100°F [38°C]), which is used for concrete mixtures containing SCMs.

The RCPT results for accelerated-curing PLC concrete mixtures were near or below 1500 coulombs in most cases, with the best performers in general being at a water cementitious materials ratio (w/cm) of 0.38 with 30% Class F fly ash replacement. The bulk conductivity results are shown in Fig. 3. As this is a nondestructive test, the same concrete cylinders can be tested multiple times, reducing variability. In all cases, there was a significant decrease in conductivity between 28 and 56 days. The 28-day conductivity values show less variation than the rapid chloride permeability values as the concrete does not heat up in the ASTM C1760 test method, which causes the current to rise in time in the RCPT.15

The data shown in Fig. 3 were used to calculate the m value, which relates to the reduction in concrete permeability with time. These values were used, as noted earlier, to convert the ASTM C1556 bulk diffusion coefficients from an average value determined over the course of the test to the value at 28 days. D28 and m values were then used to predict chloride ingress into concrete in conjunction with the exposure conditions. Figure 4 shows D28 and m values for the tested PLC and fly ash concretes.

The 28-day diffusion coefficients for concrete mixtures with PLC and fly ash in Fig. 4 were lower than those predicted in Life-365™ for concrete mixtures with portland cement and fly ash.15

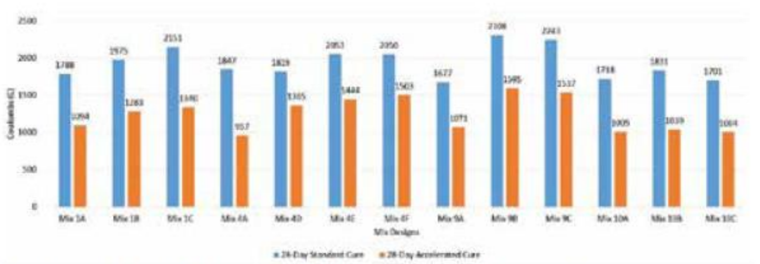

Fig. 2: ASTM C1202 RCPT results for PLC concretes containing Class F fly ash

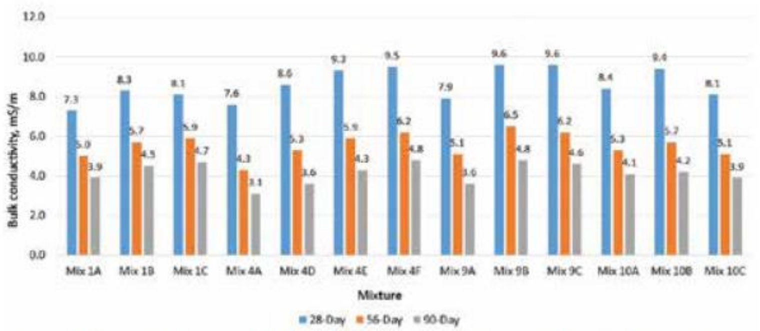


Fig. 3: ASTM C1760 bulk conductivity results over time for PLC concrete mixtures containing Class F fly ash

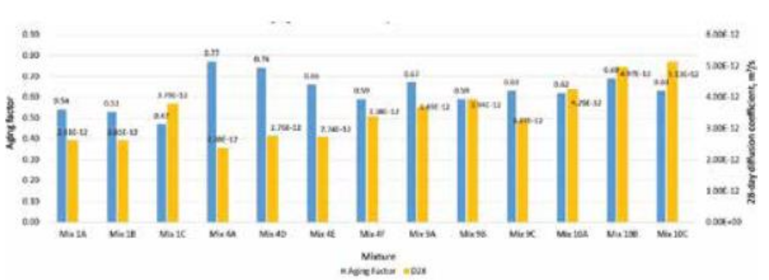

Fig. 4: Aging factors and 28-day diffusion coefficients for concrete mixtures containing PLC and Class F fly ash

## Comparison of PLC and Type I/II Cement Mixtures

Two of the mixtures with PLC and Class F fly ash were compared to two mixtures with Type I/II portland cement and Class F fly ash. Figure 5 shows the RCPT for these mixtures; Fig. 6 shows the bulk conductivities; and Fig. 7 shows the diffusion coefficients and aging factors.

The RCP (normal cure), bulk conductivity, and diffusion coefficient values for the PLC concrete specimens were all lower than those of the Type I/II concrete specimens, indicating that PLC improves resistance to chloride penetration. The RCP (accelerated cure) appeared to have been more effective with the Type I/II concrete specimens as those specimens had a lower RCP value.

## Air Entrainment and Freezing and Thawing Results

### PLC and fly ash mixtures

Figure 8 shows the plastic air, hardened air, and spacing factor data for the PLC concrete specimens containing Class F fly ash. All concretes had good air systems, as can be seen in Fig. 8. Specimens from Mixture 10C were tested for ASTM C666/C666M, Procedure A, because the spacing factor was at the upper specified limit. The relative dynamic modulus of elasticity (RDME) factor at 300 cycles was 96.5%, indicating good concrete durability against freezing and thawing.

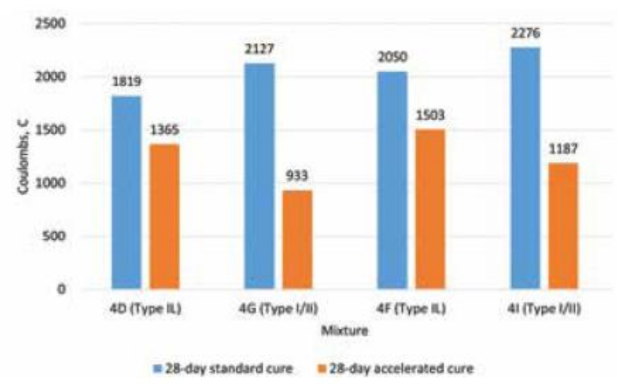


**Fig. 5: Comparison of RCP results for PLC (Type IL) and Type I/II concretes containing Class F fly ash**

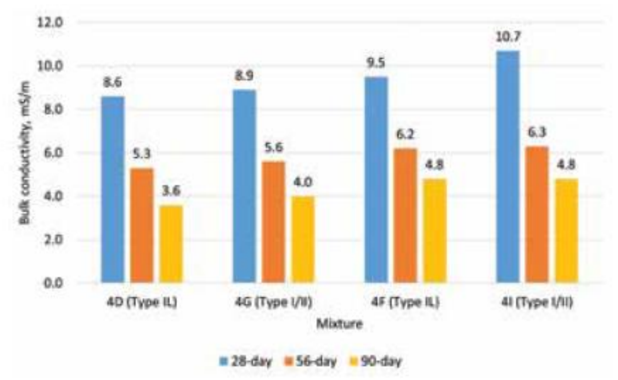


**Fig. 6: Comparison of bulk conductivity results for PLC (Type IL) and Type I/II concretes containing Class F fly ash**

## Comparison of PLC and Type I/II concretes with fly ash

The air-void data comparisons between the PLC with Class F fly ash concretes and Type I/II portland cement with Class F fly ash concretes are shown in Fig. 9. The spacing factors were identical, and the air contents were similar.

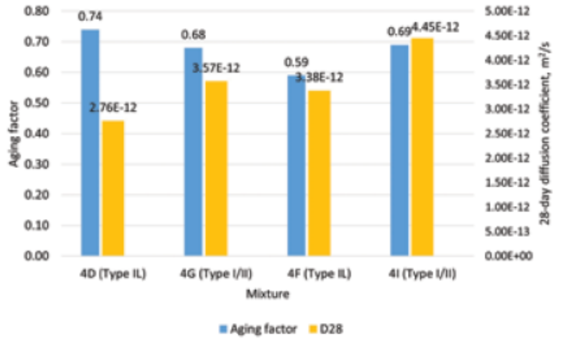


**Fig. 7: Comparison of aging factor and 28-day diffusion coefficient values for PLC (Type IL) and Type I/II concretes containing Class F fly ash**

## Conclusions

Concrete mixtures containing ASTM Type IL PLC and ASTM Class F fly ash were proposed for a large light-rail infrastructure project in the Pacific Northwest. The test program described in this article showed that the PLC concrete mixtures met the project's concrete durability plan's specific 100-year service-life parameters. Limited tests of concrete containing PLC and slag cement (not presented in this article) indicated that this mixture also would have met the project's durability plan and 100-year service-life parameters. Additional tests showed that the PLC concretes had lower permeability to chloride ingress than concretes produced with Type I/II OPC and that air entrainment was comparable between the two. Based on the concrete testing performed, PLC concrete with Class F fly ash can provide better performance related to chloride ingress than Type I/II OPC concrete with Class F fly ash.

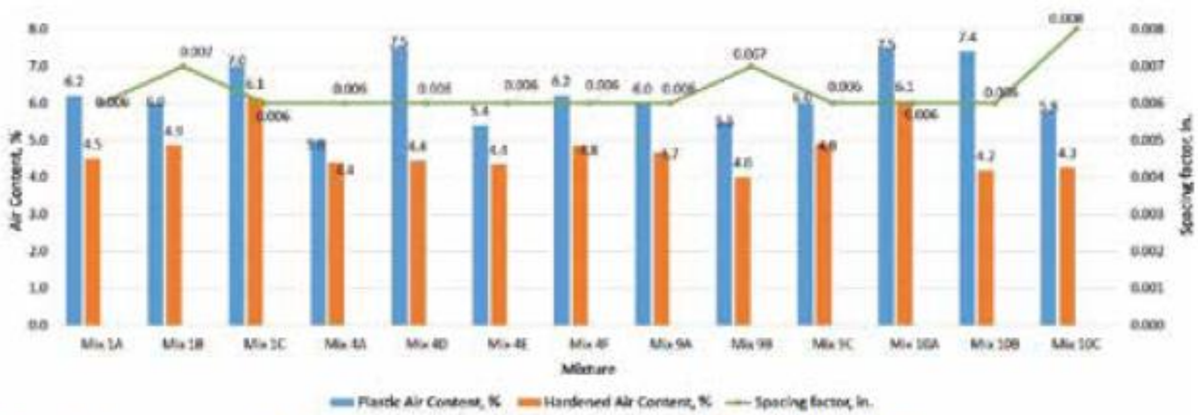


**Fig. 8: Air-entrainment parameters for PLC concretes containing Class F fly ash**

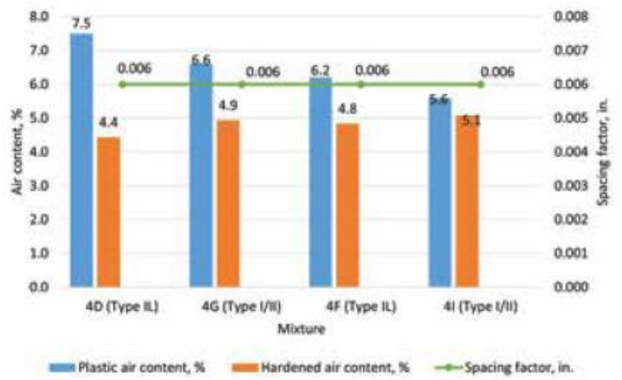


**Fig. 9: Air-void system comparison of PLC (Type IL) and Type I/II concretes with Class F fly ash**

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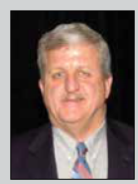

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CASE STUDY

**Reprint from: CI Magazine**
**November 2021, Vol. 43, No11, Page 37**

# Soundly Sustainable

## Hydrodemolition maximizes the life expectancy of repairs while minimizing damage and waste

by Keith Armishaw

Hydrodemolition machines use high-pressure water jets to precisely remove unsound concrete, resulting in a rough, dampened surface that is ideal for bonding new material. Unlike processes based on impact, hydrodemolition precludes the formation of microfractures that jeopardize the integrity of a structure while also cleaning and descaling reinforcing bars. Independent pulloff tests show that the bonding strength achieved through hydrodemolition is much higher than that of chipping hammers or other mechanical methods. According to the Swedish Cement and Concrete Research Institute, using hydrodemolition for concrete repair results in a life expectancy of 21 to 35 years versus 7 to 12 years with mechanical chiseling.

Hydrodemolition technology also enables a very selective removal process, eliminating unnecessary waste. By using a lower water pressure, a hydrodemolition robot will remove only the defective, damaged, or deteriorated concrete, leaving sound concrete intact and ready for new material to be applied. Exciting new technology in concrete recycling is even making it possible to reuse the slurry produced from hydrodemolition. A specialty chemical company has developed a new process that incorporates old concrete into new concrete mixtures, providing similar performance to traditional material.

Minimal removal coupled with the ability to effectively recycle what is removed is a big step toward sustainability.

Further, the water used in the hydrodemolition process can be treated and reused. The blast water is captured and treated in a fully automated, high-capacity system that neutralizes the pH and reduces suspended solids from 15,000 to 20 to 40 mg/L. While some of the blast water is lost through evaporation, 80 to 90% can be captured and treated. The treated water can be safely discharged into the environment or reused for the hydrodemolition process. Not only does this reduce water consumption but it also reduces the need to haul water in and out of jobsites.

Hydrodemolition robots can be programmed to remove only unsound concrete, leaving the remaining concrete and reinforcing bars in ideal condition for application repair materials *(photo courtesy of Duron Atlantic)*

In summary, hydrodemolition can contribute significantly to sustainability efforts by:

- Extending the life expectancies of concrete structures;
- Ensuring that sound concrete and reinforcing bars remain intact; and
- Enabling the recycling and reuse of valuable resources.

Those of us involved in the construction industry must reduce our industry's ecological footprint. While that is not an easy task, hydrodemolition is clearly a tool that can make major contributions to those efforts.

—Aquajet, www.aquajet.se

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| ❒ Organizational Member: | A Firm, Corporation, Society, Government Agency or other organizations. **RM800.00** | (RM500.00 + | RM300.00) |
| ❒ Associate Member: | An individual who is not a member of **ACI International** but American Concrete Institute – Malaysia Chapter only. **RM200.00** | (RM100.00 + | RM100.00) |
| ❒ Student Member: | **RM30.00** | (RM30.00 + | RM0.00) |

To be admitted as a **Chapter Member**(*), return this form together with **Crossed-cheque** (any outstation cheque to include Bank Commission)/ **Online Bank Transfer/ Cash Deposit** made payable to:

Account Holder Name: **American Concrete Institute – Malaysia Chapter**
Bank: **Hong Leong Bank Berhad (HLB)**
Account Number: **291.0002.0936**

*Once payment has been made, it is important to send **Remittance Slip/ Deposit Advice/ Bank Transfer Receipt** to our Administrative Office for confirmation, via these channels:*

WhatsApp: **+60 (14) 2207.138** (*ACI.my Administrative-2*); or
eMail: **admin@acimalaysia.org**

**(*) Benefits** provided by **ACI International** for Chapter Members:

1. Digital subscription to Concrete International magazine;
2. Access to the ACI Membership Directory; and
3. 3-Tokens to ACI University Courses;
4. Printable ACI Membership Certificate

**Important Notes**:

- Benefits will be accessible via Temporary Password sent to your email account either in the month of **June** or **December**, depend on time slot of **Chapter Member List** update to **ACI International**;
- All benefits are subject to change without prior notice.

## Personal Particulars:

Are you a Member of **American Concrete Institute International** (ACI International)?
❒ No.
❒ Yes. (Please provide your ACI Int'l Membership Number: ________ Since (Year): ________)

Name: ________ (First) ________ (Last)
Salutation / Title: ________ (Mr./ Ms./ Mdm./ Ir./ Ar./ Dr./ Prof./ ) Other: ________
NRIC/ Passport No: ________ Nationality: ________
Mobile Number: +60 (1 ) - ________ Email: ________
Company / Organization: ________ Designation: ________
Postal Address: ________
________
Postal code: ________ State: ________
Tel.: ________ Fax: ________ Email: ________
I am introduced to ACI-Malaysia Chapter by: ________

Applicant Signature ........ Date ........

***For Office Use Only***

Membership No: [ | - | | | | ] Receipt No.: ________ Date: ________
Verified by: ________ (Name: ________ ) Date: ________

❒ NF/ RF ❒ PoP ❒ DB ❒ MRR ❒ GgIC ❒ RvnT ❒ InvT ❒ I&R ❒ MF/PoP/I&R-F

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