FIELD RESEARCH STATION FOR CONCRETE DURABILITY

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ABSTRACT

In the severe environmental exposure conditions that prevail in the Arabian Gulf region, durability is still the most important factor for the service life of most concrete structures, both in terms of economy and safety. Of the various types of deterioration mechanisms, reinforcement corrosion is at present considered to be the main cause of premature failure of reinforced concrete structures in most countries. Field exposure station has been established at Khaleej Mardomah in Jubail Industrial City to gain practical knowledge on how to produce and protect concrete structures under natural and long term exposure conditions. This field station is the first of its kind in the region. Exposure conditions include aggressive ground-water, marine environment (submerged, splash zone and zone above sea water), and outdoor exposure in air. The study involves casting different concrete specimens using different design and protection parameters, including cement type, water/cement ratio, pozzolanic additives, reinforcement type, water type, curing condition, corrosion inhibitors, and concrete coatings. The prepared specimens are subjected to continuous monitoring for corrosion at predetermined intervals over long term exposure. In addition, samples are retrieved to determine the chloride, sulfate, and alkalinity profiles, compressive strength, chloride permeability, water permeability, electrical resistivity, sulfate resistance, and carbonation of concrete.

The paper will highlight the scope and objectives of establishing the field station. Such field exposure station will be a very important tool both for practical recommendations concerning durability of concrete structures under various exposure conditions, and for the benefit of future research.

Keywords*: Above ground, Beams, Below ground, Columns, Concrete Durability, Concrete properties, Concrete variables, Cubes, Cylinders, Field station, Partially buried, Splash zone, Tidal zone.*

الملخص

في الظروف البيئية القاسية المعروفة عن منطقة الخليج العربي ، تعد خاصية المتانة العامل الأساس في عمر وأداء المنشآت الخرسانية من الناحية الاقتصادية وكذلك سلامة هذه المنشآت . ومن بين العوامل المسببة لتدهور المنشآت الخرسانية ، فإن التآكل يعد العامل الأساس للتدهور السريع في أغلب الدول . لذلك تم إنشاء محطة أبحاث في خليج مردومة بمدينة الجبيل الصناعية لاكتساب المعرفة العملية في كيفية إنتاج وحماية منشآت خرسانية تحت ظروف بيئية طبيعية ولفترات تعرض طويلة . وتعد هذه المحطة الأولى من نوعها في المنطقة .

تضم المحطة البيئات المطلوبة والمتمثلة بمياه البحر والتربة والمياه الجوفية . حيث تم تصميم عدد العينات لإجراء اختبارات طويلة الأجل لمدة تصل إلى عشرين سنة . تتضمن الدراسة إعداد عينات خرسانية ذات جودة عالية تشمل عدد من المتغيرات مثل مانع الصدأ ونوع قضبان التسليح وإضافات بوزولانية ونسبة الماء إلى الإسمنت ونوع الماء المستخدم في المعالجة والخلط وطريقة المعالجة وطلاء الخرسانة . الخلطة الأساسية في هذه الدراسة مطابقة لمواصفات الهيئة الملكية . العينات الخرسانية تم إعدادها في الحقل . وبعد الانتهاء من المعالجة المطلوبة ، تم توزيع العينات على أربع مناطق في محطة الأبحاث ، شملت منطقة المد والجزر ومنطقة تلاطم الأمواج ومنطقة تحت الأرض ومنطقة فوق الأرض . حيث يتم مراقبة التآكل لجميع العينات الموجودة في المحطة وذلك كل ثلاث أشهر منذ بدء تعريضها في الموقع . وسوف يتم الحصول على عينات خرسانية بعد فترات محددة لإجراء عدد من الاختبارات المعملية .

هذه الورقة العلمية تصف خطوات إنشاء المحطة وأهدافها ونوعية العينات والاختبارات التي تنفذ على المدى البعيد . إن النتائج التي سيتم الحصول عليها ستكون هامة جداً في إعداد توصيات لتحسين المواصفات المعمول بها حالياً بهدف الرفع من مستوى أداء ومتانة المنشآت الخرسانية تحت ظروف بيئية مختلفة .

1. INTRODUCTION

In the severe environmental exposure conditions that prevail in the Arabian Gulf region, durability is still the most important factor for the service life of most concrete structures, both in terms of economy and safety. Of the various types of deteriorating mechanisms, chloride induced reinforcement corrosion is at present considered the main cause of premature deterioration in most countries. Other common deteriorating mechanisms are chemical attack and carbonation.

The production and placement of high-quality durable concrete has always been a major concern for Madinat Al-Jubail Al-Sinayah (MAJAS). The primary reasons for this concern are related to the extensive use of concrete as a major construction material in MAJAS and the severity of the environment, which causes concrete deterioration to occur in a relatively short period of time unless proper corrosion protection is provided.

The Royal Commission has, in the past, researched ways of improving the durability performance of concrete. Although these tasks were carried out under laboratory and natural exposure conditions and covered extensive testing of concrete properties, none of these tasks lasted more than two years [Saricimen, 1999]. Laboratory or short-term research is useful in

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obtaining information for comparing the performance of different types of concrete; however, it is through long- term monitoring that durability performance is evaluated with a high degree of reliability. Therefore, there is a need to evaluate the long-term performance of high-quality concrete that is presently specified by the Royal Commission.

The most reliable way of assessing the durability of a concrete structure is to study the performance under natural conditions. By varying the main parameters affecting durability against reinforcement corrosion, such as production, material quality, reinforcement type and environment, more valuable information can be obtained within the order of a decade than in accelerated laboratory tests. In addition, accelerated tests on specimens of the same material can be used to give a correlation between real exposure and accelerated laboratory tests.

2. OBJECTIVES AND SCOPE

The purpose of establishing a field research station is to gain practical knowledge on how to develop durable concrete and protect concrete structures against deterioration under various natural conditions. Exposure conditions may include aggressive ground water, marine environment (submerged, splash zone and zone above sea water), and outdoor exposure in air.

The general objective of the proposed research is to conduct long-term research on high quality concrete in the Arabian Gulf. Specifically the objectives consist of the following:

1. Documenting the long term performance of properly produced and placed concrete in the local environment of Madinat Al-Jubail Al-Sinaiyah.

2. Identifying variables that are important to control early deterioration in concrete.

3. Establishing the degree of deterioration that may be expected from good quality concrete.

4. Making recommendations to the Royal Commission towards improving the Guidelines Specifications based on the results obtained from this study.

The above objectives will be met whenever possible based on the collected results over the monitoring period.

3. SCOPE OF WORK

The field exposure station has been established at Khaleej Mardomah in Jubail Industrial City to gain practical knowledge on how to develop and protect concrete structures under natural and long-term exposure. This field station is the first of its kind in the region. Exposure conditions include aggressive ground water, marine environment (submerged, splash zone and zone above sea water), and outdoor exposure in air. The study involves casting of different concrete specimens using different design and protection parameters including cement type,

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water/cement ratio, pozzolanic additives, reinforcement type, water type, curing condition, corrosion inhibitors, and concrete coatings. The prepared specimens are subjected to continuous monitoring for corrosion at predetermined intervals over long-term exposure. In addition, samples are retrieved to determine the chloride, sulfate, and alkalinity profiles, compressive strength, chloride permeability, water permeability, electrical resistivity, sulfate resistance, and carbonation of concrete.

The research study involves long term monitoring of high-quality concrete specimens subjected to seawater, soil, and groundwater conditions at a fenced field-test station. Concrete specimens were cast and cured according to procedures recommended in the Royal Commission's Guideline Specifications [RCJY, 2000]. The setup and number of specimens have been designed for monitoring and testing over 20 years.

The principal work under this project involved field and laboratory work. The reinforced concrete specimens were prepared using high quality concrete and considering different variables, including corrosion inhibitors, type of reinforcement, pozzolanic additives, water/cement ratio, water type, cover thickness, curing conditions, and concrete coatings.

The study includes durability testing and monitoring of reinforced concrete specimens under aggressive field exposures to evaluate the actual long-term performance and determine the causes of deterioration for different concrete mixes. Reinforcement corrosion is being monitored by the periodic measurement of the corrosion potentials. Chloride, sulfate and alkalinity profiles in the specimens are to be established. In addition, concrete properties, such as water and chloride permeability, compressive strength, weight loss due to sulfate attack, and carbonation are also determined at 28 days after casting, and at specific periods of long term exposure for the main concrete mixes.

4. SITE PREPARATION

A detailed layout drawing of the research field site was prepared showing the dimensions and locations of the access roads and the different zones considered for exposing the specimens. In coordination with RCJY a research field site was selected in Khaleej Mardomah at MAJAS. The preparation of the field site included several activities, such as site grading, access road paving, and setting up of two portable offices. The research field site was prepared as a long-term exposure station.

Complete engineering drawings detailing the specimens and their layout in the field station were prepared. These drawings included details of the specimens, materials and specimens placement layout in the field station at four zones: namely, the tidal zone, splash zone, partially buried and below ground zone and above ground zone.

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5. FIELD EXPOSURE ZONES

The research field station as shown in Figure 1, is divided into four zones representing the most aggressive and harsh conditions that prevail in the Arabian Gulf region and attack concrete structures. The following sections describe the field exposure zones.

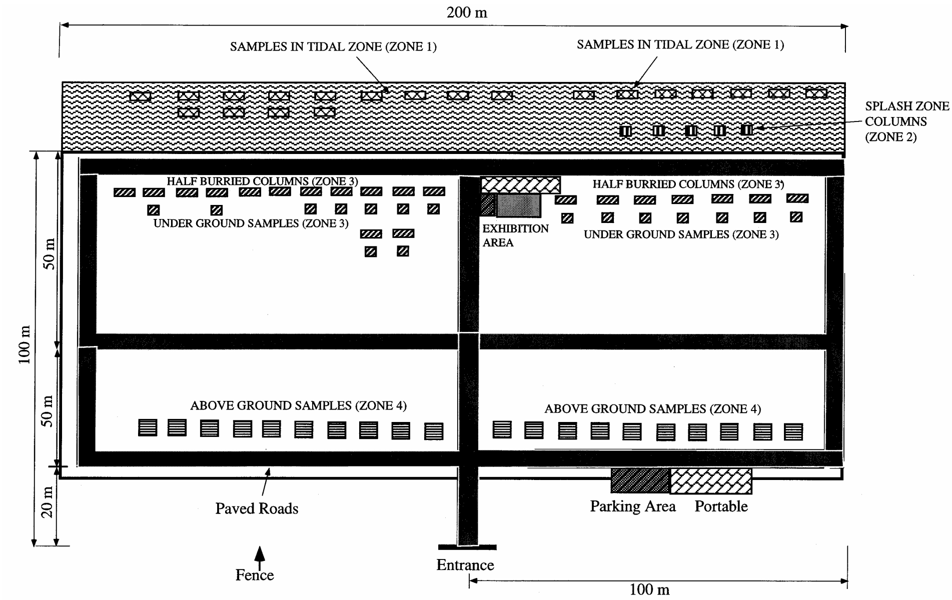

Figure 1. Sketch of the four exposure zones in the field station.

5.1 Tidal zone (zone 1)

The tidal zone represents one of the most aggressive conditions on the durability of concrete structures in the Arabian Gulf region. In this zone the prepared concrete specimens are subjected to two cycles of wetting/drying per day due high and low tides.

5.2 Splash zone (zone 2)

The splash zone is considered to be the most critical marine exposure. In this zone part of the surfaces of the prepared concrete specimens is located above seawater.

5.3 Partially buried and below ground zone (zone 3)

This zone represents the actual exposure condition where most concrete structures such as foundations and buried structures are located and subjected to salt and sulfate contaminated ground water. This exposure causes the most widespread deterioration problems in concrete structures located along the coastal areas and in areas of high ground water.

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5.4 Above Ground zone (zone 4)

This zone represents the atmospheric exposure zone along the coastal areas of the Arabian Gulf region. Reinforced concrete superstructures, which do not come in direct contact with the ground, are usually subjected to the atmosphere with high daily and seasonal variations in temperatures and humidity.

6. SPECIMEN PREPARATION

High-quality concrete specimens were cast as per RCJY specification [03347, 2000]. For reference purposes, unreinforced concrete specimens were cast representing the main concrete mixes and cured in water under laboratory condition for up to 90 days.

6.1 Variables and Materials

The prepared concrete mixes consist of twenty different mixes covering a wide range of materials and variables as summarized in Table 1. The control concrete mix (M1) used is represented by mix J 25 b according to RCJY specifications 033347 as described in Table 1. All the variables listed below were used with the control mix J 25 b unless mentioned otherwise. Detailed description of the materials and variables used in this study is listed below:

Cement type

Cement types I and V as per ASTM C 150 was used.

Cement content

Two cement contents were considered in the plain cement concrete mixes, namely 370 kg/m^3 and 450kg/m^3.

Mixing water type

Two types of water were used namely potable water and reclaimed water.

W/C ratio

Two effective water to cementitious materials ratios were used namely 0.40 and 0.30.

Aggregates

One type of both the fine aggregate (sand) and coarse aggregate were used in preparing all the concrete mixes. The fine aggregate was dune sand with 2.61 saturated surface dry specific gravity and 0.96 % water absorption. The coarse aggregate was crushed limestone with 2.55 saturated surface dry specific gravity and 1.87 % water absorption.

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Table 1. Summary of the concrete variables*.

Mix No.	Cement Content kg	Water Type	Reinforcement	Additives	Curing	Coating	Corrosion Inhibitors	Exposure zone No.
Control M1	370	Potable	Uncoated Steel	-	Normal	-	-	1, 2, 3, 4
M2	370	Potable	Uncoated Steel	-	-	-	-	1, 3, 4
M3	450	Potable	Uncoated Steel	-	-	-	-	1, 3, 4
M4	370	Potable	Uncoated Steel	-	-	-	-	1, 3, 4
M5	370	Reclaimed	Uncoated Steel	-	-	-	-	1, 3, 4
M6	370	Potable	Uncoated Steel	0.2 % PP Fibers	Normal	-	-	1, 3, 4
M7	355	Potable	Uncoated Steel	30 kg SF	Normal	-	-	1, 2, 3, 4
M8	300	Potable	Uncoated Steel	70 kg FA	Normal	-	-	1, 2, 3, 4
M9	370	Potable	Uncoated Steel	-	Curing Compound	-	-	1, 3, 4
M10	370	Potable	Uncoated Steel	-	Normal	Coal tar epoxy	-	1, 3, 4
M11	370	Potable	Uncoated Steel	-	Normal	-	SIKA 901	1, 3, 4
M12	370	Potable	Uncoated Steel	-	Normal	-	SIKA 903	1, 3, 4
M13	370	Potable	FBEC	-	Normal	-	-	1, 3
M14	370	Potable	GFRP C-Bar	-	Normal	-	-	1, 3
M15	300	Potable	Uncoated Steel	37 kg Super-Pozz	Normal	-	-	1, 3, 4
M16	370	Potable	Rusted Bars	-	Normal	-	-	1, 3
M17	260	Potable	Uncoated Steel	110 kg FA	Normal	-	-	1, 3, 4
M18	370	Potable	GFRP (Aslan)	-	Normal	-	-	1, 3
M19	370	Potable	Uncoated Steel	-	Reclaimed Water	-	-	1, 3, 4
M20	111	Potable	Uncoated Steel	159 kg GGBS	Normal	-	-	1, 2, 3, 4
M21	370	Potable	Stainless steel	-	Normal	-	-	2

* Cement type I for all mixes except M2 where type V was used.
W/C ratio of 0.4 was used for all mixes except M4 where 0.30 was used.

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Reinforcement type

Six types of bars where used to reinforce concrete columns and beams. The types of reinforcement are listed below:

1. Regular deformed steel reinforcement conforming to ASTM A 515M.

2. Rusted deformed steel reinforcement.

3. Fusion bonded epoxy coated (FBEC) reinforcement conforming to ASTM A 775.

4. Hot rolled stainless steel (SS) reinforcement from the austenitic group with 18 % chromium, 10 % nickel and 2 % molybdenum (grade 1.4401/AISI 316) was used to reinforce concrete columns exposed to the splash zone.

5. Glass Fiber Reinforced Plastic (GFRP) reinforcement bars known as C-Bar.

6. GFRP reinforcement bars known as Aslan 100.

Pozzolanic admixtures

The following pozzolanic admixtures were used in preparing some of the concrete mixes:

1. Silica fume (SF): Densified silica fume material, was used with 8% replacement of the total cementitious materials in preparing some of the concrete mixes as per the RCJY specifications.

2. Fly ash (FA): Class F fly ash material known as Lethabo fly ash was used in preparing some of the concrete mixes. The two dosage rates used were 20 % and 30% replacement of cementitious materials.

3. Super-Pozz: Highly fine and reactive alumino-silicate fly ash, was used in preparing some of the concrete mixes. The dosage rate used was 10 % replacement of the total cementitious materials.

4. Ground Granulated Blast-furnace Slag (GGBS): The dosage rate used was 70 % replacement of the total cementitious materials.

Additive

Polypropylene (PP) fibrillated fibers. The polypropylene fibers used in this study are available locally under the brand name Fibermesh. The length of theses fibers was 19 mm, and they were added to the concrete mix at a dosage of 0.2% by volume of concrete.

Curing

The following methods of curing were used during the preparation of the concrete specimens:

1. Wet burlap using potable water: The concrete specimens were cured in accordance with the RCJY specifications. The curing was carried out for seven days for plain Portland Cement concrete, and twenty-one days for concrete containing pozzolanic admixtures.
2. Wet burlap using reclaimed water: Wet burlap using reclaimed water supplied by RCJY was used in curing concrete specimens without pozzolanic admixtures. The curing was carried out for seven days since no pozzolanic admixtures were used.
3. Membrane curing compound: A resin based curing compound was supplied in clear grade but with a green fugitive dye and applied immediately the concrete was free from surface water. After removal of formwork, new surfaces were saturated with water and then the curing compound was applied.

Concrete coating

Coal tar epoxy coating was applied on clean and dry concrete surfaces after proper curing. This 100% solids coal tar epoxy protective coating was applied in accordance with both RCJY specification and the supplier procedure. Two coats were applied with total dry film thickness of 400 microns.

Corrosion inhibitors

The following two corrosion inhibitors were used:

1. Corrosion inhibiting admixture: A green liquid concrete admixture (Sika-901) consists mainly of nitrogen containing organic and inorganic substances. The dosage rate used was 4 % by weight of cement, and it was mixed with water and added to the concrete mixer.
2. Corrosion inhibiting impregnation: A transparent emulsion type impregnation liquid for concrete (Sika-903). After proper curing, the concrete specimens' surfaces were wetted with clean water prior to the application. Then three coats of the material were applied using a brush.

6.2 Types of Specimens

To meet the objectives of this study reinforced and unreinforced concrete specimens were prepared. Details of the specimens are described below.

Reinforced concrete specimens

Total of seventy columns and sixty beams reinforced with uncoated steel bars, Fusion Bonded Epoxy Coated (FBEC) steel bars, rusted steel bars, Glass Fiber Reinforced Plastic bars, and

Stainless Steel were prepared and placed at the exposure site for field monitoring as described below:

1. Columns with 35x35x300 cm dimensions were installed in the partially buried zone (zone 3), and splash zone (zone 2). The reinforced columns are utilized for visual observation and corrosion monitoring since the commencement of field exposure. Electrical lead wires were tied to the reinforcing steel of each column to facilitate the measurement of corrosion potential.

2. Beams with 25x30x75 cm dimensions were installed under the tidal zone condition (zone 1). The reinforced beams are used for visual observation and corrosion monitoring since the commencement of field exposure. Electrical lead wires were tied to the reinforcing steel of each column to facilitate the measurement of corrosion potential.

Unreinforced concrete specimens

1. A total of more than 1150 cubes with 15x15x15 cm dimensions were placed at the tidal zone (zone 1), below ground zone (zone 3), and above ground zone (zone 4), and for laboratory conditioning. The cubic specimens are used for conducting the water permeability test.

2. A total of more than 2600 cylinders measuring 7.5 cm in diameter and 15 cm in height were placed at the tidal zone (zone 1), below ground zone (zone 3), and above ground zone (zone 4), and for laboratory conditioning. The cylindrical specimens are used to conduct chloride permeability, electrical resistivity, water absorption, compressive strength, and sulfate resistance tests.

6.3 Casting of specimens

Reinforced and unreinforced concrete specimens of all the mixes were prepared using the materials described above in accordance with the RCJY specifications and under close supervision by the project team researchers and engineers.

The concrete mixes consist mainly of cementitious materials, water, crushed limestone and dune sand. Superplasticizer was added to all concrete mixes to maintain the slump in the range from 75 to 125 mm.

Plywood forms were fabricated to cast the columns, beams and cubes according to the specified dimensions. For the cylindrical specimens, PVC moulds were prepared. The inside surfaces of the forms and mould were smooth and free of defects to produce the required finish. For the reinforced concrete columns and beams, the reinforcement cages were fabricated to the dimensions required to maintain a concrete cover at 75 mm, except for the GFRP reinforcement where the concrete cover reduced to 25 mm.

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The steel cages of the reinforced columns and beams were instrumented with electrical wires to facilitate the potential measurements. For each specimen, electrical lead wire was tied to the steel reinforcement and coated with cement slurry overlaid by an epoxy resin.

Prior to each casting, the concrete slump was checked (according to ASTM C 143) as well as the temperature. The concrete mix was placed horizontally inside the columns and beams' forms by pumping. Using internal vibrators, the concrete was consolidated in horizontal layers. The unreinforced cubic and cylindrical moulds were cast in three layers using trowels, then properly consolidated using external vibrators.

The surfaces of the cast specimens were properly finished. Immediately after finishing, the specimens were carefully covered with polyethylene sheets to prevent drying. After 24 hours, the forms were removed and specimens were demolded, and the required curing process started.

6.4 Curing of the specimens

The prepared specimens were divided into two groups, one group was cured in the field and the other group transported to the laboratory at KFUPM for curing and testing. The curing schemes used for both groups are described below:

Field curing

All the specimens intended for field exposure were cured for at least 7 days for the Portland cement concrete mixes without pozzolanic admixtures, and 21 days for the concrete mixes containing admixtures such as silica fume and fly ash, Super-Pozz and GGBS. The only exceptions to that was the application of curing compound.

Laboratory curing

In addition to the specimens subjected to the field exposure, unreinforced cylindrical and cubic concrete specimens of the main concrete mixes listed in Table 1 were cast in the field, then after 24 hours transported to KFUPM and stored in water under laboratory condition for 28 and 90 days periods. These specimens designed to be the reference or control for the field cured and exposed specimens.

6.5. Placement of the specimens in the field exposure

After proper curing, the specimens were kept in the casing ground to reach a minimum age of 28 days prior transportation and placement in the field exposure zones. Figure 2 shows the erection of a reinforced concrete column in splash zone (zone 2). By May 2001 all specimens were placed in their particular zones of the field station. The following describe the distribution and placement of the specimens for each zone.

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Figure 2. Erection of a reinforced concrete column in zone 2.

Tidal zone (zone 1)

The specimens in this zone consist of unreinforced cylindrical and cubic concrete specimens and reinforced concrete beams. The cylindrical specimens and cubic specimens of each mix were placed inside two PVC coated cages assembled on two concrete pedestals, respectively. The reinforced concrete beams of each mix were placed on the concrete.

Splash zone (zone 2)

The specimens in this zone consist of reinforced concrete columns. The reinforced concrete columns were erected on precast buried foundations with recesses in the center.

Partially buried and below ground zone (zone 3)

The specimens in this zone consist of unreinforced cylindrical and cubic concrete specimens and reinforced concrete columns. The cylindrical specimens and cubic specimens of each mix were buried as a group in plastic crates at 1.30 m below ground. The reinforced concrete columns of each mix were partially buried at 1.5 m below and 1.5 m above ground level. The columns were placed at about 1.5 to 2.0 m apart.

Above ground zone (zone 4)

The specimens in this zone consist of unreinforced cylindrical and cubic concrete specimens. The cylindrical specimens and cubic specimens of each mix were placed inside two PVC coated cages assembled on two concrete pedestals, respectively.

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7. MONITORING AND TESTING

Over the course of this study several tests will be conducted on the concrete specimens. Some tests will be conducted on the field specimens and others will be conducted on laboratory specimens. This section describes the monitoring and testing methodology that will be followed.

The field specimens will be visually observed for signs of deterioration and monitored for corrosion at predetermined intervals over the duration of the study. The intervals are described under their respective items. At each interval, specimens and core samples from the columns and beams will be retrieved for testing and analysis in the laboratory.

7.1. Field monitoring

Visual observation in field

All the exposed specimens will be monitored and observed for any noticeable signs of deterioration every two months throughout the duration of the study.

Corrosion monitoring in field

The corrosion potential of the steel reinforced columns and beams in zones 1, 2 and 3 is monitored according to [ASTM C 876, 1996], and readings will be taken every three months for the period of the study.

The locations of the corrosion potential readings were determined using an iron depth meter. Thirty two points were identified for corrosion potentials on two faces of each beam specimen in zone 1. Forty eight and forty points were identified for corrosion potentials on two faces of each column specimen in zones 2 and 3, respectively.

7.2. Testing of Field Specimens in Laboratory

Cylindrical and cubic concrete specimens were retrieved from the field-cured specimens after 28 days of casting and before they were placed in their respective exposure zones. The tests listed below were conducted on these specimens to establish a baseline for the field concrete specimens.

Similarly, concrete core samples and cylindrical and cubic concrete specimens will be retrieved from the field exposed specimens after 12 and 24-month periods to monitor changes in the physical and mechanical properties of the concrete mixes.

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The following tests are being conducted in the laboratory on these specimens:

- Chloride, sulfate, and alkalinity (OH^-) profiles by analyzing core samples collected at several depths from the columns and beams [Vogel, 1985].
- Water permeability according to the standard test, [DIN 1048, 1990].
- Chloride permeability according to [AASHTO T277, 1999].
- Electrical resistivity using an SGABEM Terrameter SAS 330 C precision digital electrical resistance meter.
- Water absorption according to [ASTM C 642, 1996].
- Compressive strength according to [ASTM C 39, 1997].
- Sulfate resistance through visual examination and reduction in compressive strength using concrete cylinders.
- Carbonation depth by spraying phenolphthalein indicator on the freshly cored samples from the columns and beams.

7.3. Testing of laboratory conditioned specimens

In addition to the specimens subjected to the field exposure, plain concrete specimens of the selected main concrete mixes were cured in water under laboratory conditions, to be used as reference specimens for the field exposed specimens. These specimens were tested after 28 and 90 days to determine the following concrete properties:

1. Electrical resistivity.
2. Water absorption.
3. Compressive strength.

8. CONCLUDING REMARKS

This paper gives an account of the exposure site preparation at Khaleej Mardumah, materials used for specimen preparation, procedure and practice of specimen preparation, and field and laboratory tests. The field exposure of all specimens commenced on May 2001, therefore, no results and discussion included at this premature stage.

The results that will be obtained from investigation in such a field research station will be very important both for practical recommendations concerning durability under various exposure conditions, and for the benefit of future research. Continuing the research on an existing exposure station is an efficient way to gain reliable documentation of long time durability of reinforced concrete structures under our local environment.

The results that will be generated can also be shared with similar field stations, and professional institutions and agencies on the regional as well as international levels.

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