A study on reinforcement corrosion of concrete structures near coastal areas of Oman

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A lot of buildings and structures in coastline areas facing many issues such as huge number of cracks shown on the wall structures. Moreover, this issue is affecting the aesthetic and the beauty of the buildings. Research discover that reasons behind this problem is concrete corrosion or especially corrosion of steel that causes enormous damage to the structure. This issue starts when the chloride is containing in concrete and due to formation of the oxide film. Rapid chloride permeability test according to ASTM C1202 is performed to study the behavior of different concrete mixes such as normal concrete, concrete with fly ash and concrete with Ground Granulated Blast-furnace slag(GGBFS). In this experiment when the concrete blocks are dipped into the solution, the electric current passes through it in order to determine the permeability of the material. In addition, corrosion acceleration test is performed to observe the electric current flow through the different mixes with different time intervals and days when it is merged to sodium chloride (NaCl). From the rapped chloride permeability test results, it is found that the permeability of chloride of all mixes is categorized as a moderate. From the corrosion acceleration test, it is found that all specimen of concrete containing fly ash had an attack at the first days of the test. A little rust appears on the normal concrete mix in the second week as the magnitude of electric current passing through it was not stable.

Introduction

The coastline distance in Oman were measured to be 3165Km from Musandam in the north to Dhofar in the south. A lot of buildings and structures in these areas facing many issues such as a huge number of cracks shown on the whole structure. Moreover, this issue is affecting the aesthetic and the beauty sides of buildings. To study this problem many of the experts doing researches to find the main reasons of this phenomena. Research discovered that reasons behind this problem is concrete corrosion or especially corrosion of steel that causes enormous damage to the structure. This will be studied also in Alseeb coasts. This issue starts when the chloride is contained in concrete and due to formation of the oxide film. This occurs due to the chemically action of carbon dioxide. This influences the safety and the strength of the buildings and reduces the cross-sectional areas. There will be decreases ductility properties, strength and the bonds surrounding the concrete. Therefore, corrosion of steel is result from chloride and it is the main source of damage in reinforcement designs. The selection of material in the construction phase is affecting on the durability of concrete. In addition, there are many other factors which contributing in the process of corrosion and its appearance over the time.

Deterioration of concrete:

Concrete is a combination of mixed material which is composite and a suitable mixed properties are used from fine aggregate, coarse aggregate, cement and water as well as adding with steel reinforcement which consider an excellent construction material. Concrete is good in compression and weak in tension and steel is strong in tension and weak in compression so steel is provided in concrete to fulfil the weakness in concert. In addition, it is important to design the concrete

properly to ensure durability and strength. Concrete has alkaline environment because the pH of concrete is high about13 and this will provide a durable non-corrosive environment in the reinforcement, however, with the time due to many factors the pH of concrete will decrease causing corrosion phenomena in the concrete. The deterioration of concrete is caused due to many factors like environmental factors for example carbon dioxide, moisture content and salty environment. In addition, the procedures of casting like using saline water while mixing, not implementing proper vibration, using unappropriated reinforcement cover and using porous and soft aggregate. Moreover. The defects of structural design, for example, wrong design and the structure settlement. Also another factor which is temperature such as subjecting concrete to high temperature and freezing and thawing as well. There are many signs in concrete which indicate the deterioration like deflection, corrosion, cracking, abrasion, spalling and erosion. In addition, environmental factors are the most factor which causing deterioration leading to reinforcement corrosion **(Panaji 2014).**

The influence of carbonation on concrete with Ground granulated blast-furnace slag (GGBS):

Ground granulated blast-furnace slag (GGBS) is used and to be added to the concrete in order to increase the durability and strength of concrete especially for marine structures as well as for pavement slabs. In addition, structures which are located in severe environments are exposing to loads which are repeated continuously. Also the repeated load will lead to failure of structure as well as fatigue failure. Research were conducted in order to determine the concrete performance when subjected to fatigue load. Thera are many factors which lead to fatigue of the structure for example, sulfate, carbon dioxide, temperature, acid and free thaw. This research is study the effect of carbonation on concrete. one of the essential factor which can recognize the service life of structure is carbonation. The carbonation is occurring due to the formation of CaCO3 and it has impact on concrete mechanical properties. When the carbonation degree increase, the elastic modulus and strength of concrete increase too while flexural strength decrease. Moreover, in windy sheltered environment concrete with ground granulated blast-furnace slag has more chance to carbonated than ordinary Portland cement concrete. In normal structure with service life span 50 years the carbonation depth is acceptable and it is important to mention that humidity is one of the important factor which can impact on the accelerating of carbonation. The degree of carbonations increases in severe environments (**Lushen et al 2015).**

Chloride attack:

In this research theb effect of chloride iton is studied on portland cement concrete and steel reinforcemnt as well. The effect of chloride in low consertation is very small on physical properteis of concrete but it can cause corrosion of reinforcmnt steel in concret, however, the effect is increased when the consentrationm of chloride is high. In addition, high consentration of concrete in low temprature causes cracking and expansion in concrete. the devolusion is comprises through the formation of calcium oxychloride salts. Morover, the desroying mechanisim is occue becaause of the calcim oxychloride salts **(Birnin and Saidu 2006).**

Figure 1. *The effect of corrosion on concrete*

Rapid chloride permeability test:

Rapid chloride permeability test is performed to test a sample of 100mm diameter*50mm thickness using concrete specimen. In this test it can be four number of sample can be tested at time according to ASTM C1202. The test is providing an electrical indicator of how concrete is resisting chloride ion to penetrate or it is a check for concrete ability to resist chloride ion penetration concrete **(Prakash and Cesar 2002).**

Rating	Typical concrete type permeability coulombs
High	> 4000 High w-c ratio (> 0.6) conventional PC concrete
Moderate	2000 to 4000 Moderate w-c ratio (0.40 to 0.50) conventional PC concrete
Low	1000 to 2000 Low w-c ratio (< 0.40) conventional PC concrete
Very low	100 to 1000 Latex-modified concrete, internally sealed concrete
Negligible	< 100 Polymer-impregnated concrete, polymer concrete

Figure 2. *Chloride permeability rating of concrete:*

Figure 3. *Preparation of the cells*

Corrosion accelerated test:

When chloride ions penetrate to the concrete cover there will be chloride induced corrosion. In addition, it is reacting as an electrochemical process and the reaction take place when the chloride reacts with the passive film which is protective on the reinforcement steel causing in depassivation. Moreover, the depassivation process will leads to the production of compounds known as complex iron and it is soluble in solution of pore concrete. Corrosion acceleration test is a test performed to observe the corrosion of reinforcement concrete and the effect of chloride penetration on the different concrete structure through the time. In addition, corrosion acceleration test is a method which can help to indicate the concrete ability to resist the penetration of chloride ion when there is an electric field is provide when time pass and the cracks take place **(Wayne et al 2017)**.

Methodology:

The collection of data has been gathered by using primary and secondary data. The process of gathering the data is performed in order to find solution in order to find solution for the proposed problem. In addition, it is away to determine the test hypothesis and estimate the outcomes as well. In this research study and the collection of data will be performed by using primary and secondary data. In order to meet the objectives of the case study there should be a proper methodology to be followed to meet the objectives. In addition, primary data where used in this project was conducting an interview and experiments.

Searching from secondary data where done by searching from internet website, books, magazines and newspaper as well. The process of searching data was depended on searching properly.

Experiments based on previous literature review are used in order to follow the procedure and find out important data and information based on standard and cods.

First the mix has been prepared for three different mixes and the calculation of their quantities were done also according to the volume of cubes and cylinders. In this experiment the mix has been performed for both corrosions accelerated test and rapid chloride permeability test. Total of 18 cubes and 9 cylinders has been casted. In addition, three cylinder of 100mm*50mm has been casted for Rapid chloride permeability test. Cylinders of 100mm*300mm has been used for corrosion accelerated test and cubes are used to perform compressive strength test at 14 days' test and 28 days' test as well.

Results and Discussion:

Rapid Chloride permeability test:

Table1 shows the total charge pass through when the six hours' finish and they related to the amount of resistance of all the specimens against chloride ion penetration. According to Chloride permeability rating of concrete. table based on RCPT test it is concluded that normal concrete has the highest amount of charge pass through which is 2453coloumbs which considers as moderate rating for chloride permeability. In addition, the second specimen rated as moderate too with amount of current pass through was 2236 coulombs and it consider as a moderate to resist chloride penetration. In the third place comes fly ash specimen with amount of charge pass through 2066coloumbs and it is rated as a moderate to resist chloride penetration. Figure 3.46 indicates the amount of charge pass through all the specimen after completing six hours and the highest charge was for normal concrete therefore it has more ability to resist the chloride attack to concrete as it considers as moderate rate. In addition, specimen with GGBFS has 2236 coulombs and specimen with fly ash has 2066 coulombs.

Type of concrete	The amount of charge pass through(Coulombs)
N/C	2453C
GGBFS	2236C
Fly ash	2066C

Table 1. *The amount of charge passes through the specimens:*

Corrosion acceleration test:

The data below are taken for the sample mixes for normal concrete, fly ash and GGBSF. Nine cylindrical samples of 100mm*300mm has been tested in order to perform corrosion acceleration test. The data are representing the amount of current that are pass through the samples taken in 2 weeks in order to represent the amount of sodium chloride that penetrate into the samples when the time run.

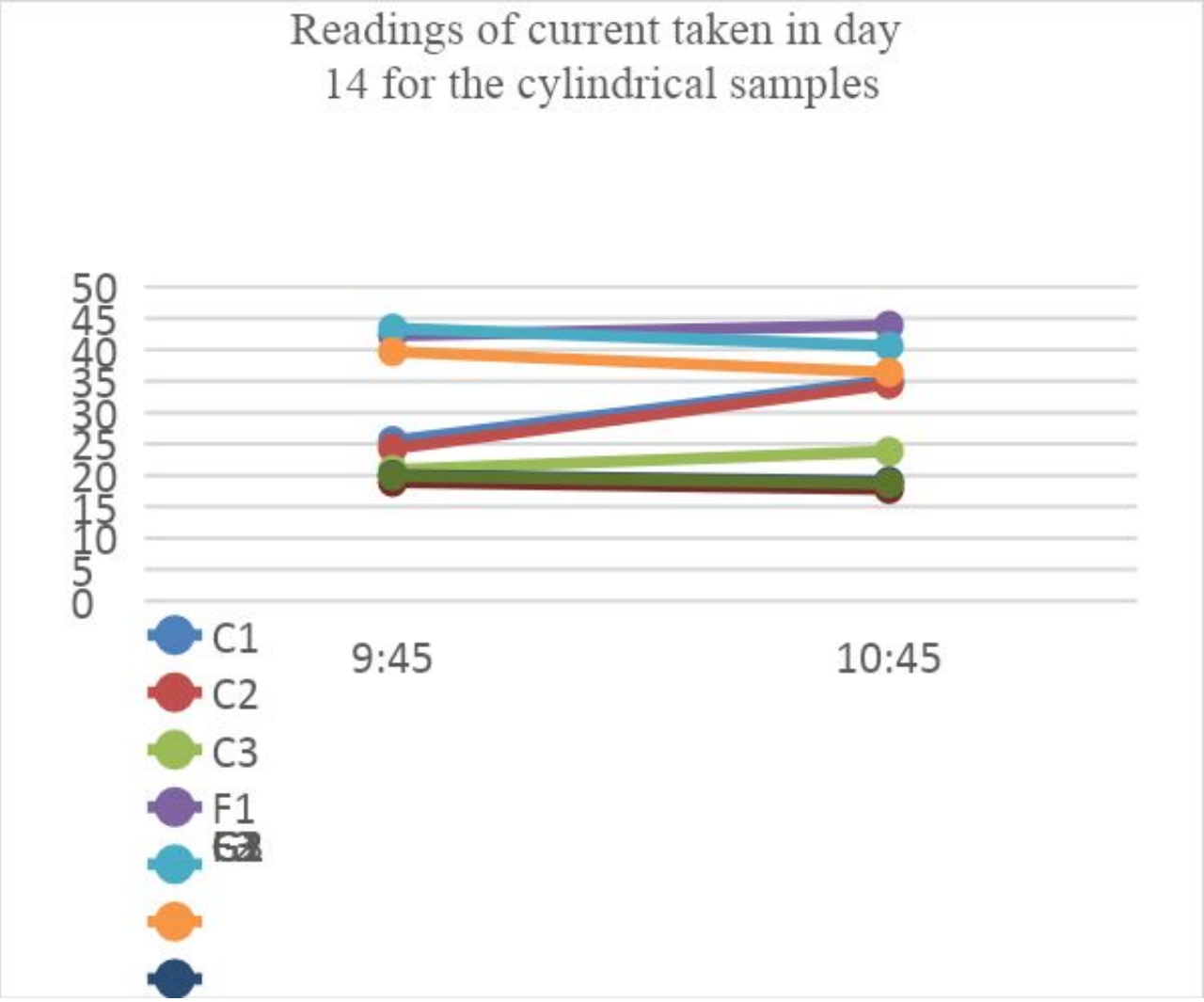

Figure 4. *Readings of current taken in day 14 for the cylindrical samples*

The above graph shows the reading of the current pass through the the three differenty mix of normal concrete, fly ash and GGBFS which represinting clyndrical specemens of 100mm*300mm. After completing two weeks excately. The currrent passing through Normal concret sampel was 25.5 mA in the first hour and it incresee in the second hour and also the same with other two sampels and little rust is appeared on the sample specimens.. Fly ash show a considrable increse and has the highest current values amoung all the samples as the corrosion took a huge amount on the speciemns due to the chemical rection of the material and sodium chloride as well. GGBFS reading shows a small amount of decrese as there was no sign of corrosion in the samples.

Figure 5. *Corrosion accelerated test*

Conclusion:

Absorption in concrete include water and different kind of salts, for example the walls of concrete in the areas that near to sea absorbs water through capillary action that also contain salts such as Chloride salts and Sulfate. In addition, when the moisture reduces and heat increases, the water evaporates leaving the salts on the walls that reacts chemically with the concrete(rusting) causes the weakness of reinforcing steel which swell or increases their sizes subsequently pressure

increases on the walls and spooling of concrete. This process occurs continuously until the concrete is completely damaged. Corrosion of steel reinforcement in concrete is a constant problem and there is special knowledge in the rehabilitation of buildings exposed to rust, and there must be special specifications must be imposed on projects located on the sea, especially in Oman, there are many coasts where buildings suffer from heat and humidity and must be dealt with. There are many factors that causing corrosion of steel reinforcement in, for example, Grade of concrete, concrete thickness, Exposure condition and Water cement ratio. In addition, type of cement, Environment (Agriculture, Acids and Chemicals, Fertilizers Stores, water). The selection of material in the construction phase is affecting on the durability of concrete. In addition, there are many other factors which contributing in the process of corrosion and its appearance over the time. Rapid chloride permeability test is performed to study the behavior of different mixes containing Normal concrete, fly ash and GGBFS when it is applied with solution and calculate the current pass through it in order to determine how the material is permeable according to ASTM C1202. From the result obtained it is found that the permeability of chloride of all mixes is categorized as a moderate. In addition, corrosion acceleration test is performed to observe the current pass through the different mixes through different time interval and days when it subjected to sodium chloride (NaCl). From the obtained results it is found the amount all the samples fly ash specimens had an attack at the first days of the test than other specimens. Whereas, a little rust appears on the normal concrete mix in the second week as the amount of current pass through it was not stable.

Figure 6. *Increasing the amount of corrosion at fly ash samples in week two*

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