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An Experiment on Durability Test (RCPT) of Concrete According to ASTM Standard Method using Low-Cost Equipments

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Abstract. Durability means the resistance to physical or chemical deterioration of concrete resulting from interaction with environment (physical deterioration) or interaction between constituents (chemical deterioration) of concrete. A durable concrete ensures corrosion resistance of embedded steel which in turn ensures a better longevity of the structure as a whole. Concrete in structures in the coastal areas are the most susceptible to chemical deterioration as sea water, with high concentration of chloride ions, has quite a detrimental effect on durability of concrete. In these cases, the lower the chloride permeability, the better the durability of concrete. As instruments for standard chloride permeability test is very expensive, an experiment has been conducted to carry out Rapid Chloride Permeability Test (RCPT) using improvised apparatus made of readily available low-cost materials. Several RCPT tests were performed using this simple method and results showed marked variation in chloride permeability for concrete with different quality.

Introduction

The durability of concrete structures is closely related to the nature and severity of the environment to which they are exposed as well as the nature of the concrete construction. Rapid Chloride Permeability test was developed in a FHWA research program [1]. The program was aimed at developing techniques to non-destructively measure the chloride permeability of in-place concrete. Prior to the development of the test, chloride permeability of concrete was measured by a ponding test, such as AASHTO T259-80 [1], “Resistance of Concrete to Chloride Ion Penetration.” Ponding tests typically take 90 days or longer and involve taking samples of the concrete at various depths to determine the chloride profile. The FHWA wanted a test that could be done in place and have a good correlation to data that was developed from chloride ponding tests. Chloride migration through concrete, even in high water/cement ratio concrete, is a very slow process. So researchers looked for a test method that would accelerate this migration [2]. They found that when an electrical current was applied to a concrete specimen it increased and accelerated the rate at which the chlorides migrated into concrete. The researchers also found that if one measured the coulombs (the integral of current vs. time plot) that were passed through the sample and then compared these numbers to results from a ponding test a good correlation exist. From these findings, researchers developed the test procedures that are currently specified in AASHTO T277 [1] and ASTM C1202. [1] This test, originally developed by Whiting [1981] [3], is commonly (though inaccurately) referred to as the “Rapid Chloride Permeability Test” (RCPT).There are instruments available in market for RCPT but they are quite expensive. This situation called for an attempt to build an experimental set-up with locally available materials and apparatus. Using this set-up, reliable test can be conducted with minimum possible costs.

Previous works based on Chloride Permeability Test

Several works has already done in different countries of the world on chloride permeability of concrete. The application of the near-infrared [NIR] spectrometry to the measurements of chloride concentrations in concrete was experimented by Vladimir S. Ban, Boris L. Volodin. [4]. Concentration of chloride ions was determined with a classical chemical titration method in three types of samples: a cracked concrete core and an undamaged concrete core, both taken from a bridge in Iowa, and also from concrete test samples prepared at Rutgers University [4]. A common method of determining diffusion coefficient through salt ponding test and its comparison with accelerated chloride mitigation test was performed in China Institute of Technology, Taipei, Taiwan [5]. The 90-day salt ponding test can be improved by using a depth of penetration approach rather than integral chloride content and by limiting the transport process to diffusion only was conducted in Canada [6]. Modification to the rapid chloride test by shortening the test time to 30 min did not improve the correlation to other test methods for the range of concretes was studied [6]. Based on research [7] that showed the RCPI correlated well with 90-day chloride pending tests, the American Association of State Highway and Transportation Officials (AASHTO) issued a test standard in 1983, "Rapid Determination of the Chloride Permeability of Concrete". The AASHTO Standard provides relative data on the number of coulombs passed in 6 hours for different concrete mixes [7]. A more common transport method is absorption. As a concrete surface is exposed to the environment, it will undergo wetting and drying cycles. When water (possibly containing chlorides) encounters a dry surface, it will be drawn into the pore structure though capillary suction. Absorption is driven by moisture gradients. Typically, the depth of drying is small, however, and this transport mechanism will not, by itself, bring chlorides to the level of the reinforcing steel unless the concrete is of extremely poor quality and the reinforcing steel is shallow. It does serve to quickly bring chlorides to some depth in the concrete and reduce the distance that they must diffuse to reach the rebar [Thomas, et al., 1995]. [3]

Effects of chloride ions

Chloride ions induce reinforcement corrosion. Parts of structures which are in contact with seawater, splash, spray, salty-dust, or other chloride sources e.g. industrial process water, or irrigation water, are at risk from chloride penetration leading to reinforcement corrosion [8]. It is assumed that both alkali-silica reaction and the use of chloride-containing concreting materials, are avoided by proper specifications, and therefore are not relevant to a discussion on environmental exposure and transport mechanisms [8].

Interpretation of result from RCPT

Table 1: Chloride Permeability Based on Charge Passed [1]

Charge Passed (Coulombs)	Chloride Permeability	Typical of
>4,000	High	High W/C ratio (>0.60) conventional PCC
2,000–4,000	Moderate	Moderate W/C ratio (0.40–0.50) conventional PCC
1,000–2,000	Low	Low W/C ratio (<0.40) conventional PCC
100–1,000	Very Low	Latex-modified concrete or internally-sealed concrete
<100	Negligible	Polymer-impregnated concrete, Polymer concrete

This test method consists of monitoring the amount of electrical current passed through 2-in. (51-mm) thick slices of 4-in. (102-mm) nominal diameter cores or cylinders during a 6-h period. A potential difference of 60 V dc is maintained across the ends of the specimen. The total charge passed, in coulombs, has been found to be related to the resistance of the specimen to chloride ion penetration [9].The test results are compared to the values in the chart below. This chart was originally referenced in FHWA/RD-81/119 [9] and is also used in AASHTO T277-83 and ASTM C1202 specifications [9].

Methodology

Step 1: Sample casting: According to ASTM standard Test Method C 1202, samples can be concrete cores from test slabs or from large diameter cylinders or slices of 4-in. diameter cast cylinders, cut with water-cooled diamond saw or silicon carbide saw. [9]. For the purpose of this experiment, concrete cylinder (102 mm diameter & 204 mm height)was prepared in laboratory with mix proportion 1:2:3.5 (Cement: Fine Aggregate: Coarse Aggregate). Water cement ratio was kept at 0.4. Specimen was cured for 28 days. Then a 2 inch (51 mm) thick slices, which are the test specimens, were cut out from the ends of the cylinders. The curved surfaces were sealed with plastic paint according to ASTM C 1202. The specimens, upon drying of the paint, were ready to be taken to the vacuum chamber for conditioning.

Step 2: Preparation of de-aerated water: According to ASTM standard method, for de aeration, water is to be boiled vigorously in a large sealable container. Then the container is to be removed from heat, capped tightly, and the water is to be allowed to cool to ambient temperature [10]. For this experiment, potable water was boiled properly in a pressure cooker, which served as a perfect sealable container, about 30 minutes. After cooling for about 24 hours, this water was collected with such care that there is minimum disturbance to allow air to dissolve in.

Step 3: Vacuum suction: ASTM C 1202 requires the specimen to be applied suction for 3 hours in a vacuum dessicator with both ends of the specimens open [9]. The aim is to remove air particles from the pores inside the samples. For the current experiment, the specimens were directly placed in a vacuum desiccator. The specimens were placed in such a manner that both the ends of specimen were kept exposed. The desiccator was then sealed and the vacuum pump was started. Pressure decreased to less than 1 mm Hg (133 Pa) within a few minutes and this vacuum was maintained for 3 hours.

Vacuum suction without water

Vacuum suction with water

Fig 1: Vacuum process

Then the de-aerated water was poured into the dessicator, with vacuum pump still running, using a separatory funnel so that the water enters the vacuum chamber with minimum contact with air. Sufficient amount of water was poured to submerge the specimen completely. Air was not allowed to enter desiccator through the stopcock by turning it off. The vacuum pump was allowed to run for one additional hour. Then the pump was turned off but the specimens were kept under water for 18 hours to fill up the voids with water. The total process was in accordance with ASTM C 1202 Test Method.

Step 4: Experimental setup. Test set-up for ASTM C 1202 is shown in figure 2 so that a comparison can be made with this present setup.

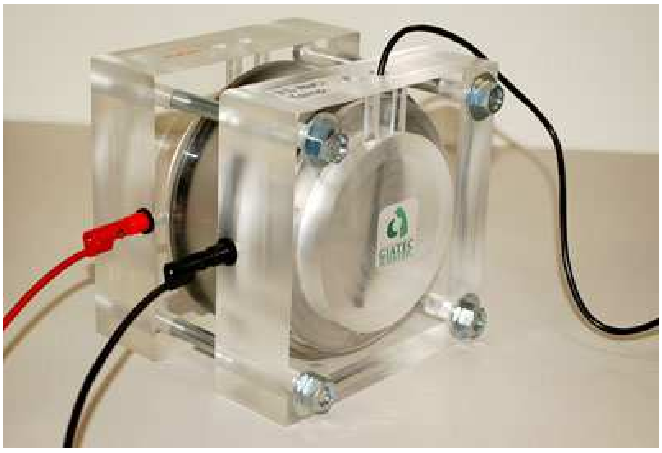

Fig 2: Rapid Chloride Permeability Test setup (As per Code)

For the experiment, glass chambers were prepared as shown in figure 3. Two separate glass boxes with 200mm x 200 mm x 250 mm (8inch x 8inch x 10inch) dimension were made with 5 mm glass Each of the boxes contained 113 mm (4.5 inch) diameter hole in one side for the placement of the concrete sample. Wire meshes of pure stainless steel were prepared and placed at each end of the sample. Samples were placed in the hole and then properly sealed with silicone sealant. One of the chambers was filled up with 3% NaCl solution and the other one with 0.3N NaOH solution. Then 60 volt DC source was connected to the wire meshes at the ends so that the negative end was connected with the side in NaCl solution and the positive end was with the side in NaOH solution. Electricity was allowed to pass for 6 hours during which reading was taken every 30 min. Total charge passed was computed from the readings taken.

Concrete Sample

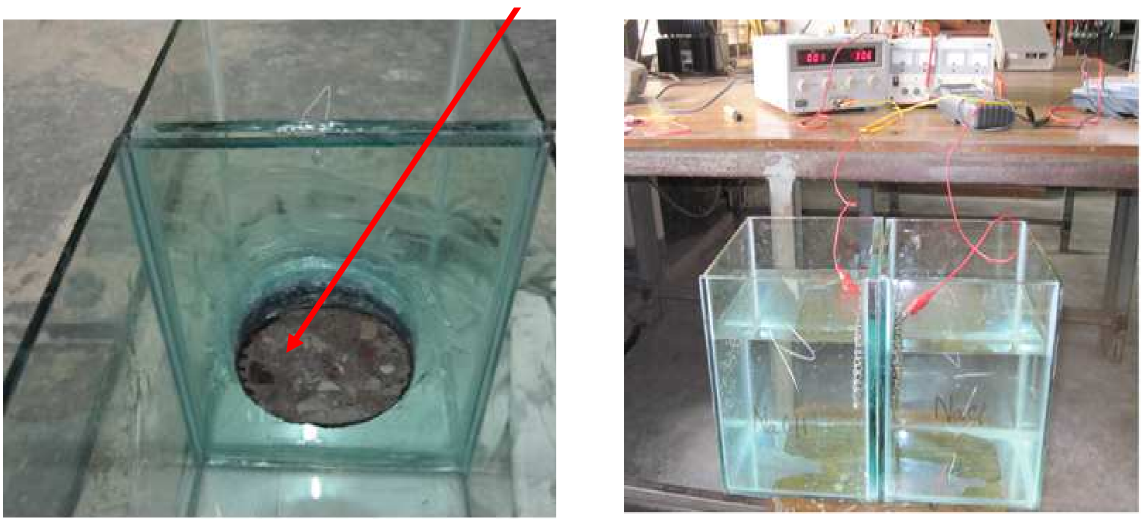

Fig 3: Rapid Chloride Permeability Test setup

Results

The average total charge passed through the concrete specimens (3 specimens) was 4719.5 Coulomb. This amount of charge is in the range of >4000 Coulomb. Thus the test indicates that the concrete is highly penetrated by accelerated chloride ions. So, it can be deduced from the results that the concrete may not be durable if exposed to marine conditions. The successful completion of this test also shows that this simple economic method of testing is effective if performed well. A comparison shall be done performing the same test on similar samples with both this test set-up and commercially available instruments.

Cost comparison

The total cost for the experiment was around 30,000 BDT which is equivalent to almost 375 USD. The cost for further tests would accrue only for the chemical costs. Whereas, the instrument from Humboldt Manufacturing Company of USA for RCPT would cost 6075 USD. Also there are some ready apparatus available in the market those give direct measurement of chloride ions in hard concrete. It requires 4000 USD. This comparison shows how economic this method is when cost is taken into consideration.

Conclusion

The experimental set-up requires less than 10 percent of the cost required for chloride permeability test with other available apparatus or equipments. Materials used to make the apparatus should also be readily available everywhere. And the most important aspect of this method is that there is no compromising of the reliability and accuracy. The procedure with these improvised techniques should yield reasonably good test results if conducted properly. Comparison of results from tests following this method with those using sophisticated instruments are yet to be seen, but there are enough reasons to believe that this method would successfully emulate the precision of those expensive apparatus. In order to ensure adequate durability and long-term performance of reinforced concrete structures exposed to aggressive environments, relevant quality control measures/methods are needed, which can provide a better basis both for job specifications and control of in situ quality. So this method can be easily followed by any developing country like Bangladesh.

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References

[1] Technical Bulletin TB 0100 (Concrete), "Understanding AASHTO T277 and ASTM C1202 Rapid Chloride Permeability Test".

[2] Donald W. Ptefier S.E., "The Rapid Chloride Permeability Test and its Correlation to the 90 day Chloride Ponding Test" (1994).

[3] K.D. Stanish, R.D. Hooton and M.D.A. Thomas, "Testing the Chloride Penetration Resistance of Concrete: A Literature Review", University of Toronto Toronto, Ontario, Canada (1991).

[4] Vladimir S. Ban, Boris L. Volodin, Sergei Dolgi, "Determination of chloride ion concentrations in concrete by means of near-infrared spectrometry" PD-LD, Pennington, NJ 08634

[5] CC Yang, SS Lin & SW Chow, "Relation between Migration Coefficient from Accelerated Chloride Migration Test and Diffusion Coefficient from Ponding Test", China Institute of Technology, Taipei, Taiwan (2005).

[6] Patrick F. McGrath, R. Doug Hooton, "Re-evaluation of the AASHTO T259 90-day salt ponding test", North Vancouver, British Columbia V7J 3L7, Canada & Department of Civil Engineering, University of Toronto, Canada (1999).

[7] Bruce Suprenant, "Testing for Chloride Permeability of Concrete- The rapid chloride permeability test (RCPT) is an alternative to ponding tests".

[8] Adil K. Al-Tamimi, Mufid Al-Samarai, Ali Elian, Nigel Harries, and David Pocock, "GUIDELINES FOR CONCRETE DURABILITY TESTING IN THE U.A.E"

[9] ASTM: C 1202 – 97, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration"