UNIVERSITI PUTRA MALAYSIA

DURABILITY STUDY OF PRECAST CONCRETE SANDWICH PANEL UNDER EXPOSURE TO SEA WATER

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DURABILITY STUDY OF PRECAST CONCRETE SANDWICH PANEL UNDER EXPOSURE TO SEA WATER

By

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DURABILITY STUDY OF PRECAST CONCRETE SANDWICH PANEL UNDER EXPOSURE TO SEA WATER

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August 2002

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An experimental investigation was conducted to observe and study the behavior of precast concrete sandwich panels in corrosive environment of chloride ion in marine environment. Three different strengths of marine waters were prepared namely one time, three time and six times of the concentration of actual ocean water. Twenty-seven numbers of sandwich panels were casted and nine numbers were placed in each types of solution. Along with that one number of Panel was casted to use as control specimen and left in air for eight months .Two more sandwich panel were used for permeability tests. The study deals with the experimental investigation of panels for their ability to stand in corrosive environment and probability of corrosion in panel reinforcement.

The results obtained were analyzed and observation was made to identify the corrosion probability, location of maximum corrosion and corrosion rate of the sandwich panel reinforcement. Comparative behaviors of the concrete strength variation in different chloride environment were observed. From the observation of the experimental results it was found that at higher chloride concentration in the environment causes higher corrosion and in the same environment highest corrosion was found along the edges of the precast concrete sandwich panel. There was no critical loss of concrete strength in sandwich panel due to submersion test.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KAJIAN KETAHANAN 'PRECAST CONCRETE SANDWICH PANEL' DI BAWAH PENDEDAHAN AIR LAUT

Oleh

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Satu kajian telah dijalankan untuk memerhati dan mengkaji mengenai kelakuan precast concrete sandwich panels di dalam persekitaran ion kloride yang menghakis di dalam persekitaran air laut

Tiga contoh air laut yag berlainan kepekatan telah disediakan iaitu satu kali, tiga kali dan enam kali ganda kepekatan sebenar air laut 27 sandwich panel telah dibuat dan 9 telah direndam di dalam setiap satu jenis cecair yang disediakan Di samping itu juga 1 panel telah dibuat untuk digunakan sebagai ujikaji kawalan dan dibiarkan terdedah kepada udara selama lapan bulan 2 lagi sandwich panel telah digunakan untuk ujian permeability

Penyelidikan ini adalah mengenai kajian dan analisa ke atas panel untuk mengetahui kebolehannya untuk bertahan di dalam persekitaran yang menghakis dan kebarangkalian hakisan pada besi sandwich panel

Keputusan yang diperolehi dianalisa dan pemerhatian dibuat untuk mengenalpasti kebarangkalian hakisan, lokasi hakisan yang paling tinggi dan kadar hakisan pada besi sandwich panel. Perbandingan kelakuan konkrit yang berlainan kekuatan di dalam persekitaran kloride yang berlainan telah diterap. Daripada pemerhatian yag telah dibuat daripada keputusan kajian ini, didapati pada kepekatan kloride yang tinggi di dalam persekitaran menyebabkan hakisan yang tinggi dan di dalam persekitaran yang sama, hakisan yang paling tinggi didapati di sepanjang tepi precast konkrit sandwich panel. Tidak ada kehilangan yang kritikal pada kekuatan konkrit di dalam sandwich panel disebabkan oleh ujian perendaman ini.

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I certify that an Examination Committee met on 10th August 2002 to conduct the final examination of Aftab Ahmad on his Master of Science thesis entitled "Durability Study of Precast Concrete Sandwich Panel Under Exposure to Sea Water" in accordance with the Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981.The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously of concurrently submitted for any other degree at UPM or other institutions.

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CHAPTER 1

INTRODUCTION

1.1 General

Concrete is an ubiquitous material. Concrete is the combination of cement acting as a binder and non-reactive or partially reactive aggregate fillers. It is normally considered protective to the reinforced steel embedded in it because of the alkalinity produced during the hydration reactions that contained in the pore solution. Nevertheless, corrosion of reinforcing steel in concrete occurs as a result of many factors, including chloride ion contamination, carbonation of the concrete, etc. These result in a build-up of corrosion products, which being more voluminous than the embedded metal. It introduces significant tensile and compressive loads on the concrete, which leads to cracking, disbandment and ultimately, spalling of the concrete cover. Cracking and disbandment lead to further corrosion, which can compromise the life of the entire structure. The problem involves reinforced concrete structures, such as costal concrete structures, bridges, etc.

1.2 Corrosion Problem

The corrosion of reinforcing steel bars (rebars) in concrete is a growing problem affecting the integrity of a vast number of structures. The reinforcing steel is embedded in the concrete, which initially provides an alkaline environment conducive to surface passivation. Under these conditions, metal dissolution takes place at an extremely low rate.

However, depassivation of the steel surface can take place if chlorides from seawater penetrate through the concrete cover and reach the rebar.

Depassivation can also result from penetration of a carbonation front through the concrete as a result of exposure to atmospheric carbon dioxide. The locally active steel surface behaves predominantly as an anode while the entire bar may serve as a cathode. The main cathodic reaction is thought to be the reduction of oxygen, which is transported to the metal surface through the concrete cover. Metal ions dissolved at the anodic reaction form the corrosion products, which are expected to occupy a significant amount of volume larger than the initial metal. Cracking and spilling of the concrete cover eventually follow and require expensive repairs or replacement of the structure.

Substructure members and pilings supporting marine bridges are frequently constructed using steel reinforced concrete. In typical installations, the columns are partially submerged in seawater, so that a region of high chloride ion concentration builds up in the splash zone just above the high water line. Passivity breakdown at the surface of the steel embedded in this region and below water; results in a subsequent active corrosion of the steel and shortening the useful life of the element.

1.3 Corrosion Prediction

There are few quantitative studies aimed to predict the distribution of potential in re-bars. Moreover, these predictions cannot be confirmed easily by experimental measurements.

This is because the polarization conditions at the steel surface are complicated by slow transport of oxygen and corrosion products. There is a need to predict the steel's potential in concrete.

Steel in concrete is a clear example of a half-cell. It is a metal surrounded by an electrolyte. The potential of such a half-cell can only be measured relative to another half-cell, which is known as a reference half-cell or a reference electrode. In 1980, ASTM issued its standard C876-77, which describes the test procedure for measuring the potentials of reinforcing steel in concrete. The placement of a reference electrode on the concrete surface and the measurement of the potential difference from the reference electrode and the embedded steel. It allows to measure the potential difference, which indicates the state of corrosion of steel.

The potential of steel reinforcement can be used to assess the probability of corrosion at the time of measurement.

.

1.4 Non-destructive Testing

In a short span of time, nondestructive testing, especially, Ultrasonic Pulse Velocity (UPV) testing has achieved its importance in quality assessment of harden the concrete's strength and durability evaluation of existing concrete structure. For instance, when investigating width and depth of the crack in concrete, nondestructive (UPV) test method is the only one that can provide reasonable answers. The primary cause of failure in concrete structure in