

**BOND STRENGTH OF CORRODED HIGH
YIELD STEEL BARS EMBEDDED IN NORMAL
STRENGTH CONCRETE**

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**THIS IS SUBMITTED IN FULFILLMENT FOR
THE DEGREE OF MASTER OF ENGINEERING**



UNIVERSITI MALAYSIA SABAH

**FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH
2019**

UNIVERSITI MALAYSIA SABAH

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EMBEDDED IN NORMAL STRENGTH CONCRETE**

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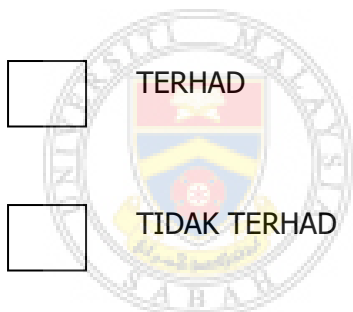
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DECLARATION

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ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my main supervisor Professor Ir. Dr. Abdul Karim bin Mirasa without his expertise and his guidance are provided, I would not have been able to complete this study. I would like to thanks to my co-supervisor Dr. Ahmad Nurfaidhi bin Rizalman for his insight, expertise, and valuable comments while reviewing this thesis.

I am so gratefully and would like to acknowledge the generous support I received from the University Malaysia Sabah and the Government of Public Works Department Sabah for their assistance in completed my study in their Laboratory, without such support I could not complete this thesis: Professor Ir. Dr. Abdul Karim bin Mirasa of University Malaysia Sabah, Faculty Engineering (Dean) and Datuk Ir Hj. Amrullah bin Hj. Kamal (Director) and Mr. Vyner Sikodol (Chief Assistant Director) of Public Works Department Sabah.

I would like to express my appreciations to Mr. Ismail bin Usop (Assistant Engineer) of Public Works Department Sabah, Material Testing Laboratory Kota Kinabalu and staffs of University Malaysia Sabah, for their advice and technical support throughout my experiments program. In addition, my deepest appreciations to Mr. Chia Min Kong (Contractor), Mr. Jamealy bin Abdullah (Contractor), Mr. Vun Soo Kong, Director of Pemborong Seri Jindo and Mr. Tan Kia Hong, Operation Manager of Kontraktor Fokus Niaga Sdn. Bhd. who helped throughout the completion of this works both physically and technically with my analytical works and emotions throughout the whole process.

Finally, I would like to give my deepest heartfelt thanks to Madam Angielina David, Miss Vivilen Langsi, Miss Stella Myfey John, Miss Danielle Myfey John, and my family for their constants support and encouragement.

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ABSTRACT

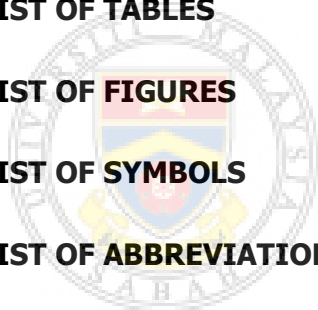
Strength and performance of reinforced-concrete depend on the good bond strength, between high yield steel bars and concrete, and the effects of corrosion on high yield steel bars in a range of 12 mm, 16 mm and 25 mm diameter reinforced the concrete for its bond strength and are debated endlessly on-site. To investigate the effects of corrosion on the bond strength between the high yield steel bars and concrete, 36 specimens of tensile test, 72 specimens of pullout test and 12 specimens of flexural test conducted. Descriptions of specimen data taken an average of three reading for tensile test and pullout test except for flexural test, uncorroded as control specimen and corroded as a final specimen. High yield steel bars ranges from 12 mm, 16 mm and 25 mm diameter 600 mm long used for tensile test, high yield steel bars ranges 12 mm, 16 mm and 25 mm diameter 800 mm long used as reinforcement bars and embedded vertically in a concrete mold 150 mm x 150 mm x 150 mm concrete grade 20 and concrete grade 30 for pullout test and 1500 mm x 150 mm x 200 mm beam concrete grade 20 for the flexural test. Results show, weight of high yield steel bars reduced by 0.13%, 0.07% and 0.02%, area reduced by 0.13%, 0.07% and 0.02% on 8 months and 12 months reduced by 0.13%, 0.04%, and 0.03%, the area reduced by 0.12%, 0.04% and 0.03% for high yield steel bars 12 mm, 16 mm and 25 mm diameter for the tensile test. The weight of high yield steel bars reduced by 0.14%, 0.05%, and 0.02%, area reduced by 0.13%, 0.06%, and 0.02% on 8 months and 12 months for high yield steel bars 12 mm, 16 mm and 25 mm diameter for pullout test concrete grade 20 and concrete 30. Weight of high yield steel bars reduced by 0.08%, 0.05% and 0.01%, area reduced by 0.08%, 0.04% and 0.01% for 8 months and 12 months for the high yield steel bars 12 mm, 16 mm and 25 mm diameter for flexural test concrete grade 20. Weight and area of high yield steel bar 12 mm, 16 mm and 25 mm diameter unchanged for the 4 months for pullout test concrete grade 20 and concrete grade 30, and flexural test concrete grade 20. In sum, the researcher discovered the uncleaned corrosion on high yield steel bars surface influences the bond strength on 4 months of corrosion and the cleaned corrosion on the high yield steel bars surface did not influence the bond strength on the 8 months and 12 months of corrosion for pullout test and flexural test conducted.

ABSTRAK
KEKUATAN IKATAN BESI WAJA BERKARAT DI TANAM
DALAM KEKUATAN KONKRIT BIASA

Kekuatan dan prestasi konkrit bertetulang bergantung kepada kekuatan ikatan yang sempurna antara besi waja dan konkrit. Kesan karat pada besi waja bersaiz 12 mm, 16 mm, 25 mm untuk tetulang pada konkrit selalu menjadi perbincangan ditapak bina. Penyiasatan terhadap kesan karat pada kekuatan besi waja dan konkrit bertetulang, sebanyak 36 spesimen untuk ujian regangan, 72 spesimen untuk ujian tarik keluar dan 12 spesimen untuk ujian lenturan telah dilaksanakan. Keterangan data daripada spesimen diambil berdasarkan purata daripada tiga bacaan untuk ujian regangan dan ujian tarik keluar kecuali ujian lenturan. Besi waja tidak berkarat digunakan sebagai spesimen rujukan ujian, manakala besi waja berkarat diuji untuk dapatan perbezaan kekuatan ikatan antara besi waja dan konkrit untuk diperbandingkan. Besi waja saiz 12 mm, 16 mm dan 25 mm 600 mm panjang digunakan untuk ujian regangan. Besi waja saiz 12 mm, 16 mm dan 25 mm 800 mm panjang digunakan sebagai tetulang konkrit dengan kaedah diletak menegak dalam acuan 150 mm x 150 mm x 150 mm berkonkritkan gred 20 dan 30 untuk ujian tarik keluar. Besi waja saiz 12 mm, 16 mm dan 25 mm 1400 mm panjang digunakan sebagai tetulang konkrit gelagar 1500 mm x 150 mm x 200 mm gred 20 di dalam ujian lenturan. Keputusan ujian menunjukkan, berat besi waja menurun 0.13%, 0.07% dan 0.02%, ukurlilit menurun 0.13%, 0.07% dan 0.02% pada 8 bulan dan pada 12 bulan berat besi waja menurun 0.13%, 0.04% dan 0.03%, ukurlilit menurun 0.12%, 0.04% dan 0.03% pada besi waja saiz 12 mm, 16 mm and 25 mm untuk ujian regangan. Pada 8 bulan dan 12 bulan berat besi waja menurun 0.14%, 0.05% dan 0.02%, ukurlilit menurun 0.13%, 0.06% dan 0.02% pada besi waja saiz 12 mm, 16 mm and 25 mm untuk ujian tarik keluar pada konkrit gred 20 dan konkrit gred 30. Pada 8 bulan dan 12 bulan berat besi waja menurun 0.08%, 0.05% dan 0.01%, ukurlilit menurun 0.08%, 0.04% dan 0.01% pada besi waja saiz 12 mm, 16 mm dan 25 mm untuk ujian lenturan konkrit gred 20. Pada 4 bulan, berat dan ukurlilit besi waja bersaiz 12 mm, 16 mm dan 25 mm tidak berubah, digunakan di dalam ujian tarik keluar konkrit gred 20 dan konkrit gred 30, dan ujian lenturan konkrit gred 20. Kajian menunjukkan karatan yang tidak dibersihkan pada permukaan besi waja mempengaruhi kekuatan di dalam ikatan antara besi waja dan konkrit pada 4 bulan tetapi tidak mempengaruhi kekuatan dalam ikatan antara besi waja dan konkrit pada 8 bulan dan 12 bulan pengkaratan setelah karatan dibersihkan pada permukaan besi waja.

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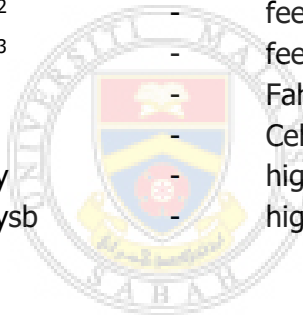
°	-	Degree
∅	-	Diameter
ℓ	-	litres
%	-	Percentage
±	-	Plus or Minus
ε	-	Strain
σ	-	Stress
μm	-	micrometer or micron



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LIST OF ABBREVIATIONS

ACI	-	American Concrete Institute
ASTM	-	American Society for Testing and Materials
BS	-	British Standard
MS	-	Malaysian Standard
N/mm ²	-	Newton millimetre square
N	-	Newton
mN	-	milliNewton
kN	-	KiloNewton
MN	-	MegaNewton
Mm	-	millimetre
mm ²	-	millimetre square
mm ³	-	millimetre cubic
mm/s	-	millimetre per second
m ²	-	meter square
m ³	-	meter cubic
kg	-	Kilogram
ft ²	-	feet square
ft ³	-	feet cubic
F	-	Fahrenheit
C	-	Celsius
hy	-	high yield
hysb	-	high yield steel bar



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CHAPTER 1

INTRODUCTION

1.1 Introduction

One of the most significant currents of discussions is regarding the corrosion of the high yield steel bars. Corrosion of high yield steel bars are commons problem faced by contractors and constructors, and becoming increasingly difficult and sometimes been ignored in practices of keeping the material in the construction site. High yield steel bars are common material characterized by iron and an important component that reinforces the concrete for better and stronger bond strength. The corrosion of the high yield steel bars becomes an issue in a structural buildings industry for past developments. Corrosion of high yield steel bars has been thoughts of the factors in giving bad bond strength to reinforces the concrete, and which is most widely used in a constructions development industry. Corrosion of high yield steel bars occurs because it is placed on the ground and expose to weathers for the long periods of time, presented in Figure 1.1 and Figure 1.2 respectively.



Figure 1.1: Corroded High Yield Steel Bars laid on the Ground



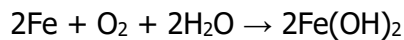
Figure 1.2: Corroded Reinforcement

High yield steel bars, one of the most common and useful materials used to reinforces the concrete in the structural constructions, and it has one major flaw, it corrodes when exposed to oxygen and water. High yield steel bars are most highly manufactured by man-made materials and its subject to corrosion as it is was made almost entirely of iron in its production respectively.

Mechanism of the corrosion occurs when iron (Fe) surface undergoes simple changes as following:

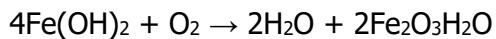
- a. First, ($\text{Fe} \rightarrow \text{Fe}^{n+} + n \text{ electrons}$) iron atoms lose some of the electrons and become a positively charged ion, and allow it to bond with another group of the negatively charged atom. The negatively charged atoms combined with electrons and the specimens (high yield steel bars) produce the first rusting reaction (Malaysia Steel Industry).

- b. Second, the reaction involves oxygen (O_2) and water (H_2O) or ($\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$) to give a variant of iron oxide to rusted the wet iron (Malaysian Steel Industry).



Iron (High Yield Steel Bars) + Oxygen + Water \rightarrow Iron Hydroxide dissolved in it.

Oxygen dissolves in water and reacts with Iron Hydroxide caused Corrode.



Iron Hydroxide + Oxygen \rightarrow Water + Hydrated Iron Oxide (Brown color corrode).
(Malaysian Steel Industry).

In this study, high yield steel bars reinforced concrete cubes 150 mm X 150 mm X 150 mm dependent on bar's sizes, concrete covers, and position of high yield steel bars. Its mechanism allowed the anchorage positions and composites actioned which reacts when concrete cube pulled out from high yield steel bar, which causes slips and cracks during the process to separates both of the specimens. High yield steel bars reinforce the concrete beams 1500 mm X 150 mm X 200 mm dependent on bar's sizes, concrete covers, spacing and positions between high yield steel bars and stirrups. Its mechanism allowed the anchorages of the horizontal, parallel and vertical positions of high yield steel bars reinforced concrete for its bond strength, and it also allowed composites action reacts when the loads applied to the concrete beam during flexing respectively.

1.2 Problem Statement

It has been discussed regarding corrosion of the high yield steel bars by contractors and constructors that confused and uncertainty, how corrosion can affects the bond strength between corroded high yield steel bars and concrete. However, there are little attentions has been paid to prevents corrosion for the unstable practicals ways of keeping high yield steel bars. In Sandakan, most of high yield steel bars that are used in the construction abandoned for months and hence, the high yield steel bars exposures to weathers pore to the corrosion and moreover, contractors also tend to purchases corroded steel bars without knowing the actuals strength and therefore, the researcher focuses on the tensile strength and the bond strength respectively.

The critical of the study is to investigate and reveal the finding on high yield steel bars strength on its tensile strength and bond strength between the high yield steel bars and concrete for pullout strength and flexural strength of uncorroded and corroded high yield steel bars which corrosion is uncleaned and cleaned on surfaces of high yield steel bars might be. The limitation of this production for the specimens are all high yield steel bars are new and come in a bundle of each size ranges from 8 mm \varnothing , 12 mm \varnothing , 16 mm \varnothing and 25 mm \varnothing . The brand new high yield steel bars cut 600 mm length of 12 mm \varnothing , 16 mm \varnothing and 25 mm \varnothing , 800 mm length of 12 mm \varnothing , 16 mm \varnothing and 25 mm \varnothing , 1400 mm length of 12 mm \varnothing , 16 mm \varnothing and 25 mm \varnothing and 500 mm length of 8 mm \varnothing mild steel for stirrups of 100 mm X 150 mm X 100 mm X 150 mm which tie with the 1400 mm long high yield steel bars then kept above the ground level of 76 cm under the shed for corrosion process respectively.

1.3 Objectives

The aimed of this study is to investigate the tensile strength and the bond strength of the high yield steel bars that subjected to different periods of corrosion. In order to achieve the aims the following objectives are set:

Objective 1: To investigates high yield steel bars that exposed to weathers for 4 months, 8 months and 12 months of corrosion for the tensile strength.

Objective 2: To investigates high yield steel bars that exposed to weathers for 4 months, 8 months and 12 months corrosion, high yield steel bars embedded vertically in concrete cubes 150 mm X 150 mm X 150 mm for the pullout test.