UNIVERSITI PUTRA MALAYSIA

DIRECT STRAIN AND STRESS MEASUREMENT FOR PRESTRESSED STEEL

SUHAILA BINTI ISAAK

DIRECT STRAIN AND STRESS MEASUREMENT FOR PRESTRESSED STEEL

BY

SUHAILA BINTI ISAAK

Thesis Submitted in Fulfilment of Requirement for the Degree of Master of Science in the Faculty of Engineering
Universiti Putra Malaysia

December 2000

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

DIRECT STRAIN AND STRESS MEASUREMENTS FOR PRESTRESSED STEEL

By

SUHAILA BINTI ISAAK

December 2000

Chairman : Samsul Bahari bin Mohd. Noor, Ph.D.

Faculty : Engineering

Bridge assessment requires knowledge of the design prestress and of any losses that may occur since stressing. The knowledge on state of stress in prestressing wires of prestressed beams is a very important criteria when assessment is conducted on an existing prestressed concrete structures. The high initial stress could slowly decrease due to creep, shrinkage and relaxation effects. The reduction in stress could also occur abruptly due to slippage and loss of concrete area.

The development of electronic instruments that test, measure, and control industrial processes has gone through a rather impressive growth pattern in recent years. In most industrial applications, the requirement of effective measurement method is very essential.

In general, the strain gauge only measures the change of strain and stress due to loading unless it has been fixed in the steel structure before the steel is stressed. Until now, there are no practical non-destructive methods for measuring residual stress. The hole drilling strain gauge method can be used but destructive in nature

To date, the non-destructive stress measurement of prestressed steel has not yet been established after the steel has been stressed. Therefore, the purpose of this project is to develop the non-destructive residual stress measurement technique for prestressed steel by using resistance measurement as a tool for determining the stress value.

Experimental tests were carried out to find a relationship between stress and resistance for three types of steel such as prestressing steel wire, prestressing steel strand and high tensile steel plate. The stress and resistance relationships obtained from the experiment have been analyzed by using statistical analysis. It was found that resistance in the prestressed steel is proportional to the applied stress.

Based on the stress and resistance relationships obtained from the three types of steel specimens, a software was develop by using Visual Basic to compute the stress value for the measured resistance in the prestressed steel. For the time being, the resistance value is keyed in but should later be able to be improved, so that it will read directly from the interfacing circuit.

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

PENGUKURAN TERUS TERIKAN DAN TEGASAN BAGI KELULI PRA-TEGASAN

Oleh

SUHAILA BINTI ISAAK

Disember 2000

Pengerusi : Samsul Bahari bin Mohd. Noor, Ph.D.

Fakulti : Kejuruteraan

Pengetahuan mengenai keadaan tegasan bagi keluli prategasan pada rasuk prategasan merupakan kriteria penting apabila penilaian dijalankan ke atas struktur konkrit prategasan. Nilai tegasan awal yang tinggi akan berkurangan secara perlahan-lahan akibat kesan rayapan, pengecutan dan santaian pada struktur tersebut.

Pengurangan dalam tegasan boleh juga berlaku akibat kegelinciran serta kehilangan pada konkrit.

Perkembangan dalam aspek pengujian, pengukuran dan pengawalan proses perindustrian dengan menggunakan peralatan elektronik telah melalui perubahan yang ketara sejak baru-baru ini. Dalam kebanyakan bidang perindustrian, keperluan kepada satu kaedah pengukuran yang berkesan adalah penting.

Secara umumnya, tolok terikan hanya mengukur perubahan terikan dan tegasan terhadap beban kecuali jika ianya dipasang pada keluli sebelum ia ditegaskan. Sehingga kini, masih tiada kaedah pengukuran tegasan baki yang tidak membinasakan. Kaedah "hole drilling" menggunakan tolok terikan boleh digunakan tetapi ia sebenarnya memusnahkan struktur keluli

Kini, pengukuran tegasan baki yang sebenar dan tidak membinasakan pada struktur keluli yang telah ditegaskan masih belum diselidiki sepenuhnya.. Oleh itu, objektif projek ini adalah untuk menghasilkan satu kaedah pengukuran tegasan yang tidak membinasakan terhadap keluli pra-tegasan dengan menggunakan kaedah pengukuran rintangan dalam mendapatkan nilai tegasan.

Eksperimen bagi mendapatkan hubungan diantara tegasan dengan rintangan dilakukan terhadap tiga jenis keluli iaitu wayar keluli prategasan, lembar keluli prategasan dan kepingan keluli berkekuatan tinggi. Hubungan antara tegasan dan rintangan yang diperolehi daripada eksperimen telah dianalisa mengggunakan analisa secara statistik. Hasilnya mendapati bahawa hubungan diantara rintangan pada kesemua jenis keluli adalah berkadar terus dengan tegasan yang dikenakan.

Berdasarkan kepada hubungan tegasan dan rintangan bagi ketiga-tiga jenis keluli tersebut, suatu perisian telah dibina menggunakan "Visual Basic" bagi mengira nilai tegasan berdasarkan nilai rintangan yang diukur pada keluli prategasan. Buat masa ini, nilai rintangan perlu dimasukkan ke dalam perisian, namun ia perlu dipertingkatkan dengan membina litar antara muka agar ia boleh membaca nilai rintangan yang diukur secara terus.

ACKNOWLEDGEMENTS

In the name of Allah, The Most Merciful and Benevolent, who has made it possible for me to undertake this research work.

I would like to convey my deepest gratitude and most sincere thanks to my supervisor Dr. Samsul Bahari bin Mohd. Noor from the Electrical and Electronic Engineering Department, Universiti Putra Malaysia. His valuable guidance and advice in the pursuance of this project would continuously be referred to, in my future studies. I also wish a grateful appreciation to Dr. Mohd. Saleh bin Jaafar and Mr. Nasri Sulaiman for serving in my supervisory committee and providing suggestions and comments at different stages of this study.

I would like to thank Mr. Halim, Tuan Haji Razali and Mr. Nayan from Faculty of Engineering Universiti Putra Malaysia, for their kindness in assisting in my project. My special thanks go to Mr. Nordin bin Abu and Dr. Mohd. Hanim Osman from Universiti Teknologi Malaysia for their constant assistance, advice and encouragement as well as using facilities in the laboratory.

My appreciation goes out to my dearest parents for their understanding and encouragement. I also would like to express my heartfelt expression to my family member. This thesis is specially dedicated to my husband, Roslli who had shared the difficulties that I went through in completing this thesis and M.Sc course.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

L	Length
V	Voltage
R	Resistance
A	Area
E	Modulus of Elasticity
I	Current
G	Gauge Factor
D	Distance
t	Thickness
w	Width
r	Internal resistance
ρ	resistivity
ε	strain
σ	stress
g	acceleration
R_s	Steel plate resistance
R_g	Gauge resistance
R_m	Measured resistance
R_{fixed}, R_1, R_2	Fixed resistor
R_3	Variable resistor
R_k	Measured resistance
R_c	Variable resistor
R_p	Potential Resistance

R_A	Balancing resistor
Δl	The change of length
ΔR	The change of resistance
AC	Alternating Current
DC	Direct Current
DAC	Digital to Analog Converter
ADC	Analog to Digital Converter
UART	Universal Asynchronous Receiver Transmitter
TTL	Transistor-Transistor Logic
CMOS	Complementary Metal-Oxide Semiconductor
εmf	Electromagnetic Field

CHAPTER 1

INTRODUCTION

Introduction

Bridge assessment requires knowledge of the design prestressed and any losses that may have occurred since stressing. The engineer often faced with a problem of determining the stress and strain value during the long life of the bridge. In this case, in-situ determination of residual stress in the assessment of existing bridges. In this project, the use of resistance principle and measurement technique has been used for direct measurement of stress in the prestressed steel after it has been stressed.

Background Problem

During the life of the structure differential foundation, corrosion of steel, deterioration of the concrete and the effect of abnormal loading can cause the state of stress to change. Experimental techniques for the determination of stress in existing bridges structure are very important in providing data to support structural assessment.

In mechanical as well as in civil engineering, a fundamental concern is the soundness of loaded structures. In cases of simple geometry, the load per unit area (stress) can be computed. When it is compared with known values of safe stress for specific materials and particular types of loading, it should give adequate information on safety. However, the situation is usually more complex and thus requires the measurement of distortions which can be assumed to be proportional to the applied stresses.

In the stress and strain analysis of prestressed concrete, the stress and strain in a section due to prestressing are calculated by considering the effect of a compressive force on a plain concrete section. Meanwhile, the loss in tension in the prestressed steel due to creep, shrinkage and relaxation is estimated. Equations which give the loss in tension in a prestressing tendon can be found in many codes and design recommendation (Ghali, 1989).

The constant demand for improvement in the design of machine and structural parts has led to the development of various experimental techniques for determining stress distributions. These experimental methods are employed for checking of theoretical predictions and evaluating the stresses in certain situations where mathematical approaches are unavailable.

Nowadays, the demand for an in-situ stress measurement technique for the bridge construction industry is become useful. Therefore, the knowledge on state of stress in prestressed steel is an important criteria when assessment is conducted on an existing prestressed concrete structures. This is due to high initial stress that may slowly decreased due to creep, shrinkage and relaxation effects. Moreover, the reduction in stress could also occur due to slippage and loss of concrete area.

To date, the non-destructive stress measurement has not yet been establish after the steel has been stressed although the development of electronic instruments that test, measure and control industrial processes have gone through a rather impressive growth pattern in recent years. Strain gauge only measures the change of strain and stress due to loading unless it has been fixed before the steel is first stressed. The hole drilling strain gauge method, which have established can be used but destructive in nature.

Objectives

Recognising the fact that the demand for direct stress measurement is an important criteria in bridge assessment, a study of in-situ stress in prestressed steel is considered necessary. Therefore, the objective of this project is to establish the relationship between stress and resistance for measuring residual stress in prestressed steel. By using the relationship that obtained from the experiment, a software would be develop to compute the stress value based on the measured resistance value.

Scope of the study

The project performed can be divided into three main parts. The tensile test has been carried out as the first part in order to verify the ultimate strength and the elastic modulus for each specimen. There are two types of prestressed steel and one type of high tensile steel that have been used in this project, i.e. prestressing steel wire (7 mm diameter), prestressing steel strand (12.7 mm diameter) and high tensile steel plate (2 mm thickness).

The second part involves the non-destructive resistance measurement for each specimen. The resistance measurement has been employed as a tool to determine stress value due to loading increment in elastic region of all specimens. The strain-resistance and stress-resistance relationship gained from the experiment would be used to measure the value of residual stress.

The final part deals with the developing software based on the established relationship to compute the stress value for a given measured resistance value.

CHAPTER II

LITERATURE REVIEW

Introduction

Nowadays, most of bridge constructions used the prestressed concrete beams or steel structures as their main elements. Prestressed concrete beams usually used prestressing steel material to induce prestressed forces to the beams. Reinforced concrete structures without prestressing generally crack and in some cases have excessive deflection. If the reinforcement is replaced by prestressed steel, cracking and deflection could be controlled. The amount of prestressing may be sufficient to avoid cracking. This condition is referred as full prestressing , as opposed to partial prestressing where controlled cracking is allowed.

Meanwhile, prestressed steel structure is able to save construction material required compared to unstressed steel structure. For structure supporting most of its self-weight, for example long span root truss, prestressing steel would be able to reduce dead load. This would save material for other members of the construction. That is why many of the bridge structure using the prestressed steel (FHWA, 1998).

Residual Stresses by Hole-Drilling Strain Gauge Method

The hole drilling strain gauge method measures residual stresses near the surface of a material. The method involves attaching strain gauges to the surface, drilling a hole in the vicinity of the gauges, and measuring the relieved strains. The measured strains are then related to relieved principal stresses through a series of equations (Rendler, 1966).

The test method is often described as semi-destructive because the damage that it causes is very localized and in many cases does not significantly affect the usefulness of the specimen. In contrast, most other mechanical methods for measuring residual stress destroy the specimen. Since the test method does cause some damage, it should be applied in those cases where the specimen is expendable.

Prestressing Steels

Prestressing steels, or tendons, are embodied in zones of prestressed concrete members that are subjected to tensile stresses resulting from dead loads and live loads.

As a result of the initial prestressing, these zones of the concrete are subjected to such high compressive prestressed that even under a combination of no tensile stresses (full prestressing) or only limited tensile stresses (limited prestressing) can occured in the concrete.