UNIVERSITI TEKNOLOGI MALAYSIA

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **DEVELOPMENT OF CREEP AND SHRINKAGE PREDICTION MODEL FOR MALAYSIAN NORMAL STRENGTH CONCRETE**

SESI PENGAJIAN: 2005 / 2006

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DEVELOPMENT OF CREEP AND SHRINKAGE PREDICTION MODEL FOR MALAYSIAN NORMAL STRENGTH CONCRETE

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A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

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MAY 2006

I declared that this project report entitled "DEVELOPMENT OF CREEP AND SHRINKAGE PREDICTION MODEL FOR MALAYSIAN NORMAL STRENGTH CONCRETE" is the result of my own research except as cited in references. This project has not been accept for any degree and is not concurrently submitted in candidature of any degree.

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ACKNOWLEDGEMENT

I wish to express my most sincere gratitude and appreciation to my supervisor, Assoc. Prof. Ir. Dr. Wahid Omar for his constant advice, patient guidance and supervision in the completion of this thesis. I would like to thank Ms.Tan Pui Lai, Ms. Roslina and Mr.Ng Ming Kwong for their invaluable assistance in ensuring the successful completion of this report. Last but not least, i am greatly indebted to my family for their encouragement throughout this course of study.

ABSTRACT

A study was conducted to investigate the degree of accuracy of creep and shrinkage prediction models developed in other countries applied to Malaysian concrete. Currently, creep and shrinkage strains for Malaysian concrete are predicted using foreign standard codes and prediction models developed in temperate countries. As creep and shrinkage are influenced by many factors including the constituent materials, temperature and relative humidity of the environment, it is therefore essential to study the appropriateness of using these models for Malaysian concrete. In this study, the test results obtained from concrete specimens having characteristic compressive strength of 20, 30 and 40N/mm^2, respectively and loaded at 7 days and 28 days were compared with Eurocode 2 (EC2), ACI 209 model (developed by American Concrete Institute), CEB-FIP 90 model (developed by Euro-International Concrete Committee and International Federation for Prestressing), B3 model (developed by Z. P. Bazant and S. Baweja), GL2000 model (developed by N. J. Gardner and M. J. Lockman) and Australian Standard code model (AS3600). From the study, AS3600 code model and B3 model were found giving the best prediction for creep and shrinkage, respectively. However, CEB-FIP 90 model was preferred than AS3600 code model as AS3600 code model predicts creep by interpreting graph, thus the accuracy of the predicted values are questionable. Modification factors were proposed to CEB-FIP 90 model and B3 model for predicting creep and shrinkage strains of Malaysian normal strength concrete.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete is a commonly used construction material for Malaysia construction industry since centuries ago. One of the important behaviour of concrete is it undergoes volumetric changes throughout its service life. These changes are a result of creep and shrinkage, which are time-dependent deformation of concrete.

According toVincent, Townsend and Weyers (2004), creep is defined as the time-dependent deformation resulting from a sustained load. Creep without moisture loss is referred as basic creep whereas with moisture loss is referred as drying creep. Therefore, total creep strain comprises of basic creep and drying creep. Shrinkage deformation on the other hand is the time-dependent deformation that occurs in the absence of an applied load. It is caused by loss of water due to evaporation, hydration of cement and carbonation. There are four types of shrinkage in a hardened concrete, which are plastic, autogeneous, drying and carbonation shrinkage. Plastic shrinkage occurs due to moisture loss before the concrete has set. Autogeneous shrinkage is a result of the hydration process. Drying shrinkage occurs as surface water evaporates and internal water moves out in an attempt for hygral equilibrium. Carbonation shrinkage occurs with the carbonation of the hydrated cement products with carbon dioxide in the atmosphere.

Creep and shrinkage of concrete had been researched since the early decades of the last century to provide a good understanding of the effect of creep and shrinkage on concrete and the processes through their evolve. Hatt of Purdue University, USA had published the first data on creep of reinforced concrete in the 1907 Proceedings of the American Society for Testing Materials. He tested 200mm wide beams with an effective depth of 250mm, made of 1:2:4 concrete, loaded at third-points over a span of 2.4 to 3.6m. The percentage of longitudinal reinforcement varied between 0.75 and 1.50. The beams were loaded at the age of two months in an outdoor location. Hatt found that the deflection of beams increased under sustained load as shown in Table 1.1. The importance of Hatt's results lies in the fact that concrete demonstrates a large non-elastic deformation under sustained load. He also found that the instantaneous deflection approximately double after two months (Neville, 1983).

Table 1.1 Deflection of beams (Neville, 1983)

Initial stress in steel (MPa)	Centre deflection immediately after loading (mm)	Deflection after 47 days of sustained loading (mm)
20.7	1.0	2.5
55.2	2.5	4.3
110.3	3.8	7.4
204.8	5.1	9.4

The structural significance induced by shrinkage was observed by White in 1911. He had published his paper to American Society for Testing Materials regarding the stresses developing due to shrinkage. McMillan was another scientist who had carried out earliest studies in 1915 on time-dependent deformation of both loaded and non-loaded concrete. The phenomenon of creep recovery was first discovered by Smith in 1917. He pointed out that creep undergoes recovery when the load was removed from the concrete structure. The research of creep and shrinkage of concrete continues to be active and the literature on concrete creep and shrinkage has been growing at a rapid pace. In 1967, the American Concrete Institute published an Annotated Bibliography on Shrinkage and Creep in concrete. this contains 487 items. In 1972, a second volume of Annotated Bibliography containing 271 references was published.

From past research, it was found that creep and shrinkage have important effects on the behaviour of concrete structures. They contribute to the increase in deflection and curvature of beams, cracking, loss of prestress in prestressing elements and redistribution of stresses in the structures. It was reported by Petersen and Watstein (1968) that, the losses in prestressing members due to creep and shrinkage may reach up to about 45% for concrete which is prestressesed at 60% of its compressive strength and cured in relative humidity of 50%. The reduction in compressive stress induced by the prestressing force may lead to the formation of cracking in prestressing elements (Neville, 1970). On the other hand, the shortening of vertical members due to creep and shrinkage in high rise building will induce redistribution of stress in structure. It is estimated by Park (2003) that, the maximum vertical shortening due to elastic, creep and shrinkage deformations is approximately 3.6 inches for a seventy storeys building. In addition, the maximum differential shortening between the exterior and the interior wall is approximately 1 inch. Hence, it is critical for creep and shrinkage sensitive structures, such as prestressed members, high rise buildings and long span bridges to use a realistic creep and shrinkage prediction model for the analysis of its time dependent behaviour. Inaccurate prediction of creep and shrinkage can result in serviceability and durability problems through its service life.

1.2 Problem Statement

In practice, local engineers predict the creep and shrinkage strains by using standard codes or other available prediction models which were developed in temperate country. These prediction models consist of Eurocode 2 (EC2), ACI 209 model (developed by American Concrete Institute), CEB-FIP 90 model (developed by Euro-International Concrete Committee and International Federation for Prestressing), B3 model (developed by Z. P. Bazant and S. Baweja), GL2000 model (developed by N. J. Gardner and M. J. Lockman) and Australian Standard code model (AS3600). These prediction models were derived by empirical approach, in which time functions were determined by curve fitting of test results. It is well documented that creep and shrinkage are influenced by various factors such as constituent materials, temperature and relative humidity of environment. Therefore, creep and shrinkage for Malaysian concrete is deemed to have different magnitude from the predicted values by those prediction models. However, local experimental works are scarcely available to study the effects of the influencing factors for Malaysian concrete. In addition, the degree of difference in creep and shrinkage values by implementation of these models in tropical country and how critical is the problem is never significantly verified. Hence, it is difficult for local design engineer to predict creep and shrinkage related behaviour such as deflection and prestress loss with confidence.

1.3 Objectives of Study

Based on the data obtained from experimental works carried out in Universiti Teknologi Malaysia for concrete grade 20, 30 and 40, a study was conducted to analyse the degree of accuracy of creep and shrinkage prediction models developed in other countries applied to Malaysian concrete. The aim of this study is to provide Malaysian engineers with an accurate design value of creep and shrinkage to predict the magnitude of long-term deformation with confidence. The objectives of this study are:

1. To compare the predicted creep and shrinkage to the values obtained by experimental works based on local environment and material.

2. To verify the best creep and shrinkage prediction model for Malaysian concrete.
3. To propose modification factor to the best prediction model to achieve a better accuracy of creep and shrinkage strains.