INTRODUCTION

1.1 Background

Concrete is a composite building material made from the combination of aggregate and cement binder. The most common form of concrete consists of Portland cement, mineral aggregates (generally gravel and sand) and water. Contrary to common belief, concrete does not solidify from drying after mixing and placement. Instead, the cement hydrates, gluing the other components together and eventually creating a stone-like material. When used in the generic sense, this is the material referred to by the term concrete.

The quality of concrete can be assessed from several characteristics, namely its strength, durability, creep and shrinkage. These are the most important and common criteria used to grade a concrete into its quality level. A concrete of good quality should be able to work up to the structural ability for which it is designed for, and also to last for at least the design lifetime for which it is designed for.

The behavior of hardened concrete can be characterized in terms of its short-term (essentially instantaneous) and long-term properties. Short-term properties include strength in compression, tension, bond, and modulus of elasticity [17]. The long-term properties include creep, shrinkage, behavior under fatigue, and durability characteristics such as porosity, permeability, freeze-thaw resistance, and abrasion resistance [17].

Concrete is one of the most durable construction materials. However, cracking adversely affects its durability, functionality, and appearance. A major cause of cracking is related to shrinkage-induced strains, creating stresses when concrete is restrained [4]. The shrinkage of concrete is often attributed to drying of the concrete over a long period of time, and recent observations have also focused on early age shrinkage and creep problems. Cracked concrete typically needs to be repaired to prevent further deterioration due to freezing and thawing, and corrosion of steel reinforcement resulting from infiltration of water with or without chloride ions from de-icing salts. The cracking leads to additional costs for repair to prevent premature deterioration of the concrete and the corrosion of reinforcement steel.

The early age of concrete is known to have a significant control on the overall performance of concrete structures. During this stage, concrete may be subjected to severe internal actions due to thermal and hydric gradients within concrete itself and at the same time it may be affected by the external conditions of environment and loading [18]. All these actions may lead to different deformations within the concrete that is just building its resistance and stiffness. Creep and shrinkage of concrete are known to have significant effect at early age of concrete. Thus, discussing the performance of this young age concrete with special attention to the shrinkage and creep and time dependent deformations is of interest by many researchers.

In predicting the strength and serviceability of reinforced and pre-stressed concrete structures, appropriate descriptions of the mechanical properties of the materials are required including the prediction of the long term behavior of the concrete. The prediction of short-term shrinkage and creep is also important to assess the risk of concrete cracking and stripping and unshoring times [17]. The mechanical properties of concrete are significantly affected by the temperature and availability of water during curing, the environmental humidity and temperature after curing, and the composition of the concrete, including the mechanical properties of the aggregates.

When concrete is subjected to sustained compressive stress, deformations continue to increase with time due to creep and shrinkage. Creep strain is produced by sustained stress. Shrinkage strains are independent of stress and are caused by chemical reactions in the hydrating cement paste and by the loss of water during the drying process. The creep and shrinkage deformations in a concrete structure are frequently larger, and in some cases much larger than the initial deformations produced when the external loads are first applied [7]. They thus have a significant effect on service-load behavior.

The resistance to deformation that makes concrete a useful material means also that volume changes of the concrete itself can have important implications in use. Any potential growth or shrinkage may lead to complications, externally because of structural interaction with other components or internally when the concrete is reinforced. There may even be distress if either the cement paste or the aggregate changes dimension, with tensile stresses set up in one component and compressive stresses in the other. Cracks may be produced when the relatively low tensile strength of the concrete or its constituent materials is exceeded.

Cracking not only impairs the ability of a structure to carry its design load but also affect its durability and damage its appearance. In addition, shrinkage and creep may increase deflections in one member of a structure, adversely affecting the stability of the whole. Volume change of concrete is not usually associated with changes that occur before the hardened state is attained. Quality and durability, on the other hand, are dependent on what occurs from the time the concrete mix has been placed in the mold.

Control of cracking may also be done by providing appropriate reinforcement. The reinforcement, however, does not reduce shrinkage but helps to keep cracks from widening. The use of expansive cements, coal-combustion products containing calcium sulfite or sulfate, and fibers is one way of counteracting shrinkage. Usually, expansive cements and clean-coal ash produce expansion by formation of ettringite. When the expansion is restrained by reinforcement, a compressive pre-stress is induced in concrete, compensating shrinkage.

Figure 1.1 illustrates the relationship between various measured and derived strain values. The figure shows that the concrete undergoes autogenous shrinkage before drying. Once drying commences at time t_0, drying shrinkage occurs. Upon loading, both drying and basic creep occurs in the drying specimen.

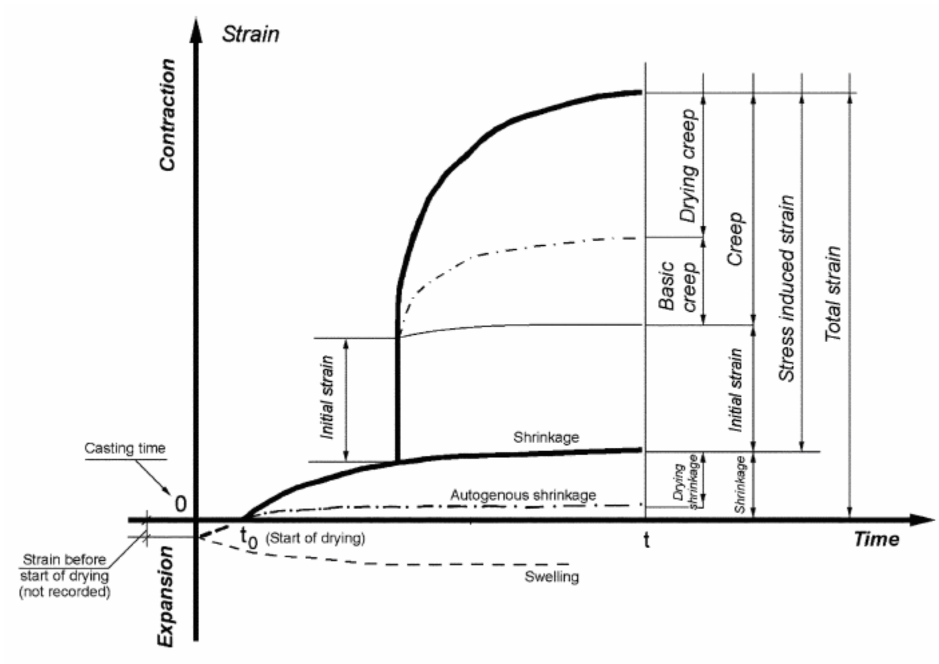

Figure 1.1: Relationship between concrete strain and time [8]

1.2 Serviceability of Concrete Structures

For a concrete structure to be serviceable, cracking must be controlled and deflections must not be excessive. The design for serviceability is possibility the most difficult and least well understood aspect of the design of concrete structures. Service load behavior depends primarily on the properties of the concrete and these are often not known reliably at the design stage. Concrete behaves in a non-linear and inelastic manner at service loads and the non-linear behavior that complicates serviceability calculations is due to cracking, tension stiffening, creep, and shrinkage.

The control of cracking in a reinforced or pre-stressed concrete structure is usually achieved by limiting the stress increment in the bonded reinforcement to some appropriately low value and ensuring the bonded reinforcement is suitably distributed. For deflection control, engineer should select maximum deflection limits that are appropriate to the structure and its intended use. The calculated deflection must not exceed these limits.

The quest for serviceable concrete structures must involve the development of more reliable design procedures. It must also involve designers giving more attention to the specification of an appropriate concrete mix, particularly with regard to the creep and shrinkage characteristics of the mix, and sound engineering input is required in the construction procedures.

When designing for serviceability, engineer must ensure that the structure can perform its intended function under the day to day service loads. Deflection must not be excessive, cracks must be adequately controlled and no portion of the structure should suffer excessive vibration. Shrinkage cause time-dependent cracking, thereby reducing the stiffness of a concrete structure, and is therefore a detrimental factor in all aspects of the design for serviceability.

Excessive wide cracks can be unsightly and spoilt the appearance of an exposed concrete surface. They allow the ingress of moisture accelerating corrosion of the reinforcement and durability failure. In exceptional cases, they reduce the contribution of the concrete to the shear strength of a member. Excessively wide cracks in floor systems and walls may often be avoided by the inclusion of strategically placed contraction joints, thereby removing some of the restraint to shrinkage and reducing the internal tension. When cracking occurs, in order to ensure that crack widths remain acceptably small, adequate quantities of well distributed and well-anchored reinforcement must be included at every location where significant tension will exist.

Deflection problems that may affect the serviceability of concrete structures can be classified into three main types:

a. Where excessive deflection causes either aesthetic or functional problems.

b. Where excessive deflection results in damage to either structural or non-structural element attached to the member.

c. Where dynamics effects due to insufficient stiffness cause discomfort to occupants.

1.3 Problem Statement

Creep and shrinkage are very important time-dependent properties of concrete. They are in direct relation to the performance of concrete. The prediction of time-dependent behaviour is the most uncertain part of the design of concrete structures. Moreover, the prediction of the time-dependent behaviour is important not only for the structural maintenance after its completion, but also for the stress and deformation control during the erection stages of the structure.

Most of the engineers today do not consider the concrete behaviour of creep and shrinkage in their design work because of lacking experience and understanding on the phenomenon and the effect on concrete specimen. Most of them consider creep and shrinkage cracks as non-structural cracks which is not important and will not cause any serious effect on concrete specimen. This assumption and consideration is not true because cracking deteriorate concrete's durability and integrity. A number of analytical techniques are available for the prediction of creep and shrinkage on concrete members. However, each has its own simplifying assumptions, advantages and disadvantages. Some of those codes are more suited to particular conditions than others such as parameters used in BS are based on the conditions in Europe which may not be accurately applicable in Malaysia.

Therefore, the study is mainly concentrates on the understanding of concrete behaviour due to creep and shrinkage and to study the prediction of creep and shrinkage strain using different code of practice.

1.4 Objectives of Project

Based on the scope of work, the objectives of the project are defined below:

(i) Study the properties and deformation of concrete due to creep and shrinkage.

(ii) Evaluate and identify the parameters and method used in determining the coefficient of creep and shrinkage for British Standard, Eurocode and Australia Standard.

(iii) Develop spreadsheets that calculating the creep and shrinkage of concrete for British Standard, Eurocode and Australia Standard.

(iv) Compare the creep and shrinkage strain using BS8110, EC2 and AS3600 under controlled parameters.

1.5 Scope of Work

Time-dependent concrete deformation is nowadays one of the concerns in engineering field as it affects the serviceability and aesthetic of the concrete structures. The main factors that cause concrete deforms due to environment and applied stress are shrinkage and creep. Therefore, the research on this topic has been proposed in the Final Year Project of Master Studies (Civil-Structural) in Universiti Technologi Malaysia.

In Masters Pre Project, the scope of work was mainly focused on the literature review of related studies. Substantial information on concrete properties such as modulus of elasticity, creep and shrinkage will be gathered through latest journals and publications in libraries and also articles from internet. The history of concrete, effect of admixtures on concrete properties and factors affecting deterioration on concrete and the effects are studied in this study.

In Masters Project, detail studies on the concrete deformation due to time-dependent factors (creep and shrinkage) will be made. The formulas, and method used in predicting concrete deformation due to creep and shrinkage will be identified using British Standard, EURO Code and Australia Standard. Spread sheet to determine concrete creep and shrinkage will be produced by inputting the controlling parameters such as strength of concrete (f_{cu}), relative humidity, type of cement, effective thickness, provided steel reinforcement, etc.

1.6 Expected Outcome

There are some outcomes to be expected through this master research studies such as:

(i) To understand the concrete properties due to creep and shrinkage.

(ii) To be familiar with the codes in creep and shrinkage of concrete specification.

(iii) To understand the parameter and method used in calculating concrete creep and shrinkage for British Standard, Eurocode & Australia Standard.