# COMPARATIVE STUDY ON SHRINKAGE & CREEP BEHAVIOUR IN SELF COMPACTING CONCRETE & NORMAL VIBRATED CONCRETE

MOHD SAIFULLAH BIN ABD HAMIR

CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JANUARY 2009

**Comparative Study on Shrinkage & Creep Behaviour in Self Compacting Concrete & Normal Vibrated Concrete**

by

MOHD SAIFULLAH BIN ABD NASIR

6389

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

JANUARY 2009

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

# CERTIFICATION OF APPROVAL

**Comparative Study on Shrinkage & Creep Behaviour in Self Compacting Concrete & Normal Vibrated Concrete**

by

Mohd Saifullah Bin Abd Nasir
6389

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

______________________
(Mohamed Mubarak Bin Abdul Wahab)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2009

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD SAIFULLAH BIN ABD NASIR

# ABSTRACT

Many researches exist about self-compacting concrete (SCC) but there are not much on comparison of its behaviour, particularly creep and shrinkage, to its conventional counterpart, normal vibrated concrete. For that reason, this article outlines laboratory studies concerning durability aspects as shrinkage and creep of self-compacting concrete (SCC) mixture and to compare with normal vibrated concrete.

As SCC mixture is concerned, a higher volume of cement paste in used in the mix. Deformation of the hardened concrete has a potential to affects strains and deflections and often also stress distribution. In mass concrete, creep in itself may be a cause of cracking when a restrained concrete mass undergoes a cycle of temperature change due to the development of the heat of hydration and subsequent cooling.

This study however is limited to only one mix of SCC and one mix of normal vibrated concrete as a control. Effects of temperature and humidity are observed as well. Compressive strength development is determined at 3, 7 and 28 days. The study is carried out using Modulus of Elasticity equipment for shrinkage and specially fabricated steel equipment is used to measure creep. Load equivalent to the sample weight is induced to the sample. One sample is placed inside controlled humidity room and one sample is left exposed to room temperature. Tests on fresh SCC are carried out (Slump Flow Test, V-Funnel Test and L-Box Test) to proof it possess the desired characteristics.

Test results revealed in general higher shrinkage and creep deformations for the SCC mixtures compared with the normal vibrated concrete mix.

# ACKNOWLEDGEMENTS

The author would like to take this opportunity to first of all express his greatest gratitude to Allah for everything and thank everyone that has given him all the supports and guidance throughout the whole period of completing the final year project. Many thanks from the author to the university and the Final Year Project coordinators that have coordinated and made the necessary arrangements, especially in terms of logistics, for this study.

The author also acknowledges the endless help and support received from his supervisor, Mr. Mohamed Mubarak Abdul Wahab throughout the whole period of completing the final year project. His guidance and advices are very much appreciated.

The author would also like to thank the lab technicians in UTP, especially Mr. Johan and Mr. Hafiz for their endless support in terms of the preparation of logistics during the lab experiments for this study. Their continuous support and help throughout the whole period of experiments are very much appreciated.

Many thanks as well to my fellow colleagues for their help and ideas throughout the completion of this study. Thank you all.

# TABLE OF CONTENTS


| | | |
|---|---|---|
| **CERTIFICATIONS** | | i |
| **ABSTRACT** | | iii |
| **ACKNOWLEDGEMENT** | | iv |
| **CHAPTER 1 :** | **INTRODUCTION** | **1** |
| | 1.1 Background of Study | 1 |
| | 1.2 Problem Statement | 5 |
| | 1.3 Objectives and Scope of Study | 6 |
| **CHAPTER 2 :** | **LITERATURE REVIEW** | **7** |
| | 2.1 Concrete | 7 |
| | 2.2 Self Compacting Concrete | 9 |
| | 2.3 Shrinkage | 10 |
| | 2.4 Creep | 12 |
| **CHAPTER 3 :** | **METHODOLOGY** | **14** |
| | 3.1 Process Flow | 14 |
| | 3.2 Material Preparation | 15 |
| | 3.3 Mix Proportion | 16 |
| | 3.4 Concrete Mixing & Casting | 17 |
| | 3.5 Shrinkage Measurement | 18 |
| | 3.6 Creep Measurement | 19 |
| | 3.7 Curing | 21 |
| | 3.8 Compression Strength Test | 22 |
| | 3.9 Tests on Fresh SCC | 23 |
| | 3.10 Gantt Chart | 26 |
| **CHAPTER 4 :** | **RESULTS AND DISCUSSION** | **29** |
| | 4.1 Results | 29 |
| | 4.2 Discussion | 38 |
| **CHAPTER 5 :** | **CONCLUSION AND RECOMMENDATION** | **39** |
| **REFERENCES** | | **40** |

## LIST OF FIGURES


| | | |
|---|---|---|
| Figure 1.1 | Beam constructed using normal vibrated concrete | 2 |
| Figure 1.2 | Beam constructed using self compacting concrete | 2 |
| Figure 1.3 | Flow pattern of SCC and normal vibrated concrete | 3 |
| Figure 2.4.1 | Creep development graph | 13 |
| Figure 2.4.2 | Creep mechanism | 13 |
| Figure 3.4.1 | Concrete mixer | 17 |
| Figure 3.5.1 | Modulus of elasticity equipment | 18 |
| Figure 3.5.2 | Sharp points embedded into sample | 19 |
| Figure 3.6.1 | Setting up for creep measurement | 20 |
| Figure 3.7.1 | Plastic cover used for curing purpose | 21 |
| Figure 3.8.1 | Compression machine | 22 |
| Figure 3.9.1 | Slump Flow Test | 23 |
| Figure 3.9.2 | V-Funnel Equipment | 24 |
| Figure 3.9.3 | L-Box Test | 25 |
| Figure 3.10 | Gantt chart | 26 |
| Figure 4.1.1.1 | Dial gauge readings (shrinkage – NVC) | 30 |
| Figure 4.1.1.2 | Dial gauge readings (shrinkage – SCC) | 31 |
| Figure 4.1.1.3 | Dial gauge readings (shrinkage – overall) | 32 |
| Figure 4.1.2.1 | Dial gauge readings (creep – NVC) | 34 |
| Figure 4.1.2.2 | Dial gauge readings (creep – SCC) | 35 |
| Figure 4.1.2.3 | Dial gauge readings (creep – overall) | 36 |


## LIST OF TABLES


| | | |
|---|---|---|
| Table 3.3.1 | Mix proportion for normal vibrated concrete sample | 16 |
| Table 3.3.2 | Mix proportion for self compacting concrete sample | 16 |
| Table 4.1.1.1 | Dial gauge readings (shrinkage – NVC) | 29 |
| Table 4.1.1.2 | Dial gauge readings (shrinkage – SCC) | 29 |
| Table 4.1.2.1 | Dial gauge readings (creep – NVC) | 33 |
| Table 4.1.2.2 | Dial gauge readings (creep – SCC) | 33 |
| Table 4.1.3.1 | Compression strength development (NVC) | 37 |
| Table 4.1.3.2 | Compression strength development (SCC) | 37 |
| Table 4.1.4.1 | Fresh SCC Test Results | 37 |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background Study

Concrete durability has long been an issue in the early 80s. A durable concrete require proper and sufficient compaction, thus demand a higher expenditure on skill workers. Then, in 1988, self compacting concrete (SCC) was introduced in Japan. SCC consists of normal concrete elements with an addition of super plasticizer. Super plasticizer is added to enhance the workability of the mixture thus provide a free-flowing characteristic of SCC. The edge it possesses compared to normal concrete is that it is compacted only under the influence of gravity. This has led to the removal of compaction and eliminates noise when casting concrete at congested areas.

Another unique characteristic of SCC is that it provides sufficient compaction to every corner of formwork, be it congested reinforcement or narrow column. SCC is also resistance to segregation during placement and while flowing. The number of skill workers can be reduced and contractor can expect a better compaction of hardened concrete at the same time. Ouchi (1999) has reported that use of SCC in the construction of an LNG tank in Japan provides positive results; the number of lots decreases from 14 to 10, as the height of concrete casting was increased, the number of concrete workers reduced from 150 to 50 and the construction period was reduced from 22 months to 18 months only.

SCC application offer many benefits for the construction industry; the elimination of compaction work results in reduced cost of placement, a shortening of the construction period and therefore an improved productivity (Holschemacher & Klug, 2002). Persson (2001) says that adoption of SCC has also lowered down noise level at the construction site and thus improves both the condition for the labour at the site and the surroundings. Persson (1999) also reported that SCC has been used for 19 highway bridges and for slabs in dwelling houses in Sweden, resulted in a 60% increase in productivity. SCC also resulted in an increase in homogeneity of concrete and excellent surface quality without blowholes and other surface defects (Skarendahl & Petersson, 2000). Pictures in Figure 1.1 and Figure 1.2 provide a clearer view on how surface defects can be eliminate by incorporating SCC in construction.

*Figure 1.1* Beam constructed using normal vibrated concrete.
(National Ready Mix Concrete Association, 2009)

*Figure 1.2* Beam constructed using self compacting concrete.
(National Ready Mix Concrete Association, 2009)

SCC characteristics provide great values in the eyes of engineers. Improved constructability to produce homogeneous and uniform concrete allows for higher reliability in design assumptions. Engineering properties and their inter-relationships remain unchanged from those of conventional concrete and any differences are adequately addressed by conservatism in the design codes. The principles of concrete durability with respect to reduced permeability, resistance to freezing and thawing and sulphate attack, alkali-aggregate reactions, thermal stresses and corrosion protection of reinforcement also apply similarly to SCC.

SCC's superior rheology allows for the design and construction of complex shapes with congested reinforcement, and its non-segregating qualities are important for deep-section or long-span applications. The fluidity of SCC (see Figure 1.3) can be engineered in terms of its viscosity; both the rate and degree of flow; to allow for a wider variety of placement and construction means and methods.

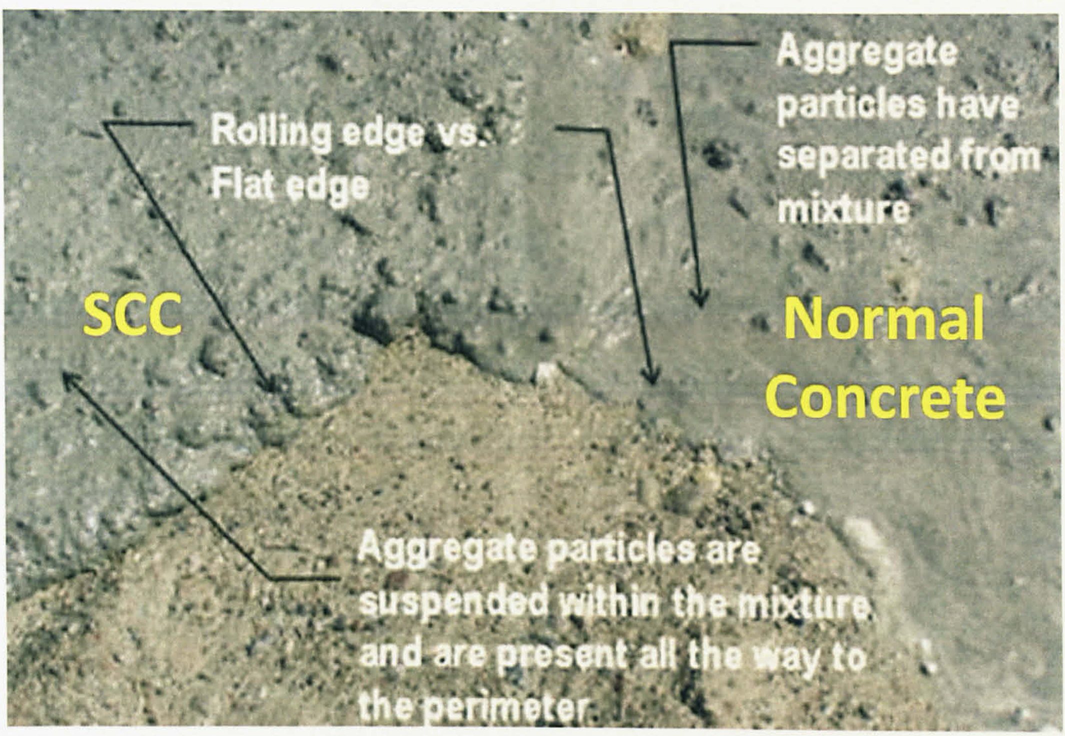


*Figure 1.3* Flow pattern of SCC and normal vibrated concrete.
(National Ready Mix Concrete Association, 2009)

SCC is also beneficial financially, especially when high strength is an existing prerequisite. Labour and time are driving up costs for concrete producers and contractors. SCC places quickly and easily with little or no vibration to give a smooth surface finish. Contractors are able to save money by reducing the wear and tear of equipment and improve the working environment for their employees. SCC also achieves very high early stripping strength that will yield a quicker turnaround. The smooth surface finish will minimize or eliminate the need for time-consuming cosmetic repairs.

All those inter-related activities provide a positive impact on maintaining projects on schedule. SCC's high cement content means that its economic benefits are amplified when high strength is a requirement. In addition to that, using SCC results in fewer safety and noise concerns as vibrator is totally eliminated.

## 1.2 Problem Statement

Despite all the positive remarks on SCC explained above, it does have its setback which is cost, associated with the addition of admixtures and high volume of cement paste. The potential problems associated with high cement paste volume are shrinkage and subsequently creep. Neville (2005) says that shrinkage and creeps affects strains and deflections and often also stress distribution. In mass concrete, creep in itself may be a cause of cracking when a restrained concrete mass undergoes a cycle of temperature change due to the development of the heat of hydration and subsequent cooling. A compressive stress is induced by the rapid rise in temperature in the interior of the concrete mass. Due to low strength of a young concrete and cooling the compressive stress disappears. On further cooling of concrete, tensile stresses develop. Rate of creep reduced with age (Neville, 2005) and may result in cracking. Neville (2005) also suggests that the rise in temperature must be controlled because of this.

Microstructure of the paste, the volume of the paste and the water cement ratio are important factors that influence the mechanism and the magnitude of creep and shrinkage (Poppe & De Schutter, 2001). From previous research on creep of SCC, it has been shown that shrinkage and creep of SCC do not differ much from that of NC provided aggregate is held constant (Persson, 2000, 2001). At early ages, however, the filler content of SCC caused early drying of the surface and substantial problems with plastic shrinkage if sealed curing is not performed (Persson, 2005). Plastic shrinkage mainly caused by evaporation of water from the surface and this is delayed in NC. Segregation is another cause for surface cracking in SCC especially when SCC is pumped into one place and moved a long distance before settling (Nishio, Tamura & Obashi, 1998).

Thus, the demand of this study arises, specifically to study the behavior of shrinkage and creep in SCC and finally to compare these elements with the normal vibrated concrete (NVC).

## 1.3 Objectives

The objective of the study is to investigate the creep and shrinkage behaviour of SCC and compare the results with creep and shrinkage in NVC. In line with that, several other sub-objectives are to be achieved; to determine the compressive strength of the design mix for SCC and NC, to provide proof on fresh SCC characteristics and to investigate the effect of temperature and humidity on creep and shrinkage of SCC.

## 1.4 Scope of Study

The scope of the study are the characteristics of fresh SCC, strength development of NVC and SCC versus time, shrinkage and creep behaviour in NVC and SCC, effects of temperature and humidity on creep and shrinkage in NC and SCC. Slump Flow Test, V-Funnel Test and L-Box Test are to be carried out to proof fresh SCC characteristics. Compressive Strength Test is to be carried out for each sample, NC and SCC.

Shrinkage and creep in NC and SCC are measured using specially fabricated steel equipment, using cylindrical shaped concrete samples. The samples will be placed under two conditions; controlled temperature and relative humidity and expose to weather to investigate effects of temperature and humidity on creep and shrinkage on all samples.

However, due to time constraint only one sample for SCC and one sample for NVC are studied. The idea of having more samples is not feasible as one steel equipment cost RM 350.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Concrete

Concrete is a construction material made up of cement (commonly Portland cement), aggregate, water and sometimes admixtures is also present. Concrete hardens and solidifies after being mixed with water due to hydration. The compositions of the said elements are determined during the mix design process. Many types of concrete have been introduced previously for various purposes to enhance certain criteria (workability, setting time, water consumption and etc.) under the influence of conditions (weather, humidity and etc.). The difference of various concrete is the proportion of its elements and the adoption of specially developed admixtures to produce a concrete mix fulfilling the desired characteristics.

### 2.1.1 Cement

Cement is a material possessing adhesive and cohesive properties, capable to form a bonding of mineral fragments into a compact whole (Neville, 2005). Cement used in concrete have the property of setting and hardening under water after chemical reaction of water and cement. Silicates and aluminates of lime are present in the fresh cement paste. Under the presence of water, silicates and aluminates form products of hydration which in time produce a firm and hard mass or the hydrated cement paste.

### 2.1.2 Aggregates

Aggregates consist of two elements; coarse and fine aggregates, which is commonly gravel and sand. Made up at least three-quarters of the volume of concrete, its quality is considerably important. Aggregates may limit the strength of the concrete, durability of the concrete and the structural performance of the concrete (Neville, 2005). Aggregates act as a filling material throughout concrete due to its cheaper price for economic reason. Aggregates also retained concrete in a desired shape and size due to its characteristic. Aggregates are cheaper than cement and thus it is economic to put more aggregates instead of more cement in the concrete. Besides that, aggregates possess a higher volume stability and durability compared to cement paste.

### 2.1.3 Water

The strength of concrete at a given age and cured in water is assumed to depend primarily on two factors only; water/cement ratio and degree of compaction. When concrete is fully compacted, its strength is taken to be inversely proportional to the water/cement ratio. Duff Abrams established the following rule in 1919 :

$$f_c = \frac{K_1}{K_2^{w/c}}$$

where,

w/c is the water/cement ratio of the mix

$K_1$ and $K_2$ are empirical constant

### 2.1.4 Admixture

Admixtures can be defined as chemical product which is added to the concrete mix in quantities no larger than 5 per cent by mass of cement during mixing or during an additional mixing operation prior to the placing of concrete, for the purpose of achieving a specific modification to the normal properties of concrete. The reason for the large growth in the use of admixtures is that they are capable of imparting considerable physical and economic benefits with respect to concrete. Sometimes, the use of admixtures is because they existed as natural deposits require no or little processing and they were a by-product or waste from industrial processes.

## 2.2 Self Compacting Concrete (SCC)

Self Compacting Concrete is described as a concrete compacted by means of its own weight. To achieve great flow ability, SCC is designed with greater paste volume than normal concrete. Because of its high paste volume, SCC is susceptible to have high shrinkage cracking risk, especially compared with normal concrete. To minimize this risk, one should optimize the composition of SCC mixtures (Roziere *et al.*, 2005). To achieve compact ability, a highly deformable paste and resistance to segregation must be made presence (Okamura & Ouchi, 2002). Limited aggregate content, low water cement ratio and the usage of super plasticizer are suggested by Okamura & Ozawa (2002) to produce self-compacting concrete. Okamura & Ouchi (2002) described the self-compactibility is influenced by influence of coarse aggregates depending on spacing size, role of mortar as fluid in flow ability of fresh concrete, role of mortars as solid particles and influence of coarse aggregates content, shape and grading. In SCC, the usage of plasticizers provides the flowability of the concrete. Superplasticizers are admixtures which are water reducing but significantly and distinctly more so than the water-reducing admixtures. Superplasticizers improve workability typically by raising the slump from 75 mm to 200 mm where the mix remains to be cohesive (Neville, 2005). The resulting concrete can be placed with little or no compaction and is not subject to excessive bleeding or segregation. Grube & Ricket (1998) reported that the characteristic properties of this concrete are:

- It flows "like honey" with no segregation, until almost completely level.
- Almost completed the de-aeration of the concrete while it is flowing.
- Every void within the formwork is filled, including all recesses, interstitial spaces in the reinforcement, etc., without any expensive compaction work with a vibrator.

According to French Association of Civil Engineering (AFGC) test standards 2000, for a mix to be accepted as SCC, it has to comply with the following:

- Slump flow between common values of 60 mm and 75 mm
- Segregation rate remained under 15% limit
- Filling rate, measured by L-Box, above recommended limit, which is 0.8

## 2.3 Shrinkage

When water moves out of concrete which is not fully rigid, contraction takes place. This happens in concrete, from its fresh state to later in life, such movement of water generally occurs. Hydration of cement paste resulted in changes in volume. Cement paste is plastic; it undergoes a volumetric contraction whose magnitude is of the order of one per cent of the absolute volume of dry cement (Swayze, 1942). Water can also be lost by evaporation from the surface of the concrete while it is still in the plastic state. This contraction is known as plastic shrinkage because the concrete is still in the plastic state. The magnitude of plastic shrinkage is affected by the amount of water lost from the surface of concrete, which is influenced by temperature, ambient relative humidity and wind velocity.

Rate of loss of water is not the absolute prediction of plastic shrinkage, dependent on the rigidity of the mix. Shrinkage can lead to cracking. Plastic shrinkage cracking can occur when the amount of water lost per unit area exceeds the amount of water brought to the surface by bleeding (Neville, 2005). Complete prevention of evaporation immediately after casting eliminates cracking (Ravina & Shalon, 1968). It is recommended by ACI Manual of Concrete Practice Part 2 (1994) that the rate of evaporation of 1 $kg/m^2$ per hour should not be exceeded. Evaporation is increased when the temperature of the concrete is much higher than the ambient temperature meaning that even under relatively humid condition, plastic shrinkage can occur. Plastic shrinkage is greater the greater the cement content of the mix and the lower the water/cement ratio (L'Hermite, 1960).

Volume changes occur also after setting has taken place due to continued hydration when no moisture movement to or from the cement paste is permitted, shrinkage occur. This shrinkage is the consequence of withdrawal of water from the capillary pores by the hydration of the hitherto unhydrated cement, a process known as self-desiccation. Shrinkage of such conservative system is known as autogenous shrinkage and occurs in the interior of concrete mass. The contradiction of cement paste is restrained by the rigid skeleton of the already hydrated cement paste and the aggregates particles. Typical values of autogenous shrinkage are about $40 \times 10^{-6}$ at the age of one month and $100 \times 10^{-6}$ after five years (Davis, 1940). Autogenous shrinkage is relatively small and for practical purpose need not be distinguished from shrinkage caused by drying out of concrete.

Withdrawal of water from concrete stored in unsaturated air causes drying shrinkage. A part of this movement is irreversible and should be distinguished from the reversible moisture movement caused by alternating storage under wet and dry conditions. The change in the volume of drying concrete is not equal to the volume of water removed (Neville, 2005). The loss of free water, which takes place first, causes little or no shrinkage. In concrete, the loss of water with time depends on the size of sample. As far as shrinkage of the hydrated cement paste is concerned, shrinkage is larger the higher the w/c ratio because w/c determines the amount of evaporable water in the cement paste and the rate at which water can move towards the surface of the specimen. Brooks (1989) demonstrated that shrinkage of hydrated cement paste is directly proportional to the water/cement ratio between the values about 0.2 and 0.6. At higher water/cement ratios, the additional water is removed upon drying without resulting in shrinkage.

Shrinkage takes place over long periods; some movement has been observed even after 28 years (Troxell, Raphael & Davis, 1958). Prolonged moist curing delays the advent of shrinkage, but the effect of curing on the magnitude of shrinkage is small. As far as neat cement paste is concerned, the greater the quantity of hydrated cement the smaller is the volume of unhydrated cement particles which restrain the shrinkage, thus prolonged curing could expect to lead to greater shrinkage (Powers, 1959). However, the hydrated cement paste contains less water and becomes stronger with age and is able to attain a larger fraction of its shrinkage tendency without cracking.

## 2.4 Creep

Stress and strain relation in concrete is a function of time; the gradual increase in strain with time under load is due to creep. Creep is defined as the increase in strain under a sustained stress (Neville, 2005). Creep may also be viewed from another standpoint: if the restraint is such that a stressed concrete specimen is subjected to a constant strain, creep will manifest itself as a progressive decrease in stress with time (Ross, March 1958). If a specimen is drying while under load, it is usually assumed that creep and shrinkage are additive; creep is thus calculated as the difference between the total time-deformation of the loaded specimen and the shrinkage of a similar unloaded specimen stored under the same conditions through the same period. Shrinkage and creep are not independent and the effect of shrinkage on creep is to increase the magnitude of creep.

Creep is a function of the volumetric content of cement paste in concrete, but the relation is not linear. The grading, maximum size and shape of the aggregate have been suggested as factors in creep. Neville (2005) reported that an increase in the aggregate content by volume from 65 to 75 per cent can decrease creep by 10 per cent. There are certain physical properties of aggregate which influence the creep of concrete. The modulus of elasticity of aggregate is probably the most important factor. The higher the modulus the greater the restraint offered by the aggregate to the potential creep of the hydrated cement paste.

The type of cement affects creep as it influences the strength of the concrete at the application of the load. Fineness of cement affects the strength development at early ages and thus influences creep. It does not seem that fineness per se is a factor in creep: contradictory results may be due to the indirect influence of gypsum. The finer the cement the higher its gypsum requirement, so that re-grinding a cement in the laboratory without the addition of gypsum produces an improperly retarded cement, which exhibits high shrinkage and high creep (Lerch, 1946). Most important external factors influencing creep are temperature and the relative humidity of the air surrounding the concrete. Creep is studied to be higher the lower the relative humidity.

Summary of creep phenomenon is showed in Figure 2.4.1. When load is induced, creep developed. If the load is sustained for a certain period and then removed, there will be creep recovery. However, the recovery is not 100% and permanent deformation is observed. The significance difference between creep and shrinkage is creep developed by the load sustained on the sample where shrinkage occurs automatically due to heat of hydration.

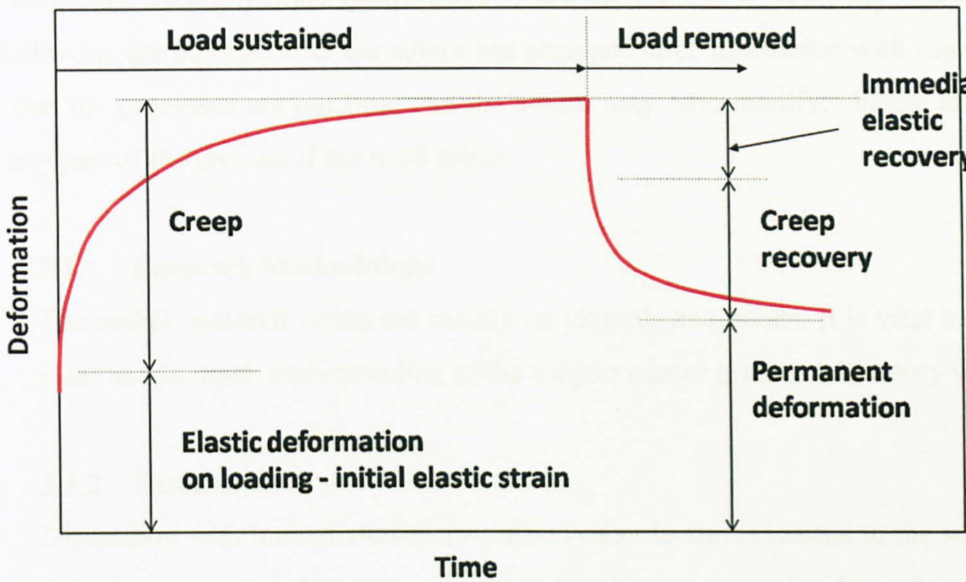


*Figure 2.4.1* Creep development graph.

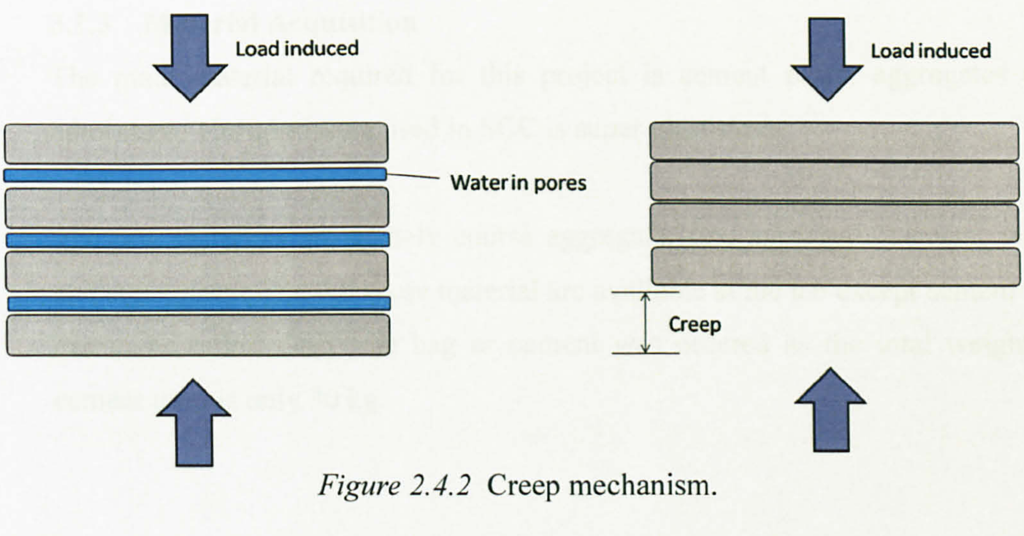


*Figure 2.4.2* Creep mechanism.

# CHAPTER 3

# METHODOLOGY

## 3.1 Process Flow

Research, discussion and pre-requisite works (material acquisition, mix design proportion and testing method determination) are carried out to complete this project. The following are planned after the author has arranged upon discussion with supervisor. Note that the processes are not final and the author may edit, modify, change and even omit any part of the process if the need arises.

### 3.1.1 Research Methodology

The author research works are mainly on journals and books. It is vital to have a clear and in depth understanding of the subject matter prior to laboratory work.

### 3.1.2 Discussion

Discussion with immediate supervisor and other lecturers related to the subject is done every week and upon requirement. Clarifications, feedbacks and comments are gained in the discussion from exchanging ideas.

### 3.1.3 Material Acquisition

The main material required for this project is cement paste, aggregates and admixture. The admixture used in SCC is super plasticizer.

The raw materials are namely course aggregate, fine aggregate, cement, water and superplasticizer. All those material are available at the lab except cement that has to be order. Only one bag or cement was ordered as the total weight of cement used is only 30 kg.

### 3.1.4 Testing Methods

Upon discussion and references, the author has come out with the following testing methods for the project:

- Compressive Strength Test for NC and SCC to determine the strength development at 3, 7 and 28 days
- V-Funnel Test to proof the deformability of the SCC mix
- Slump Flow Test to proof the workability of SCC mix
- L-Box Test to proof the passing ability of SCC mix
- Shrinkage and creep measurement using specially fabricated steel equipment under controlled temperature and relative humidity
- Shrinkage and creep measurement using specially fabricated steel equipment exposed to weather

### 3.1.5 Results Analysis

The expected results are cube test results for NC mixes and shrinkage and creep measurement for normal concrete. As for SCC, the laboratory will start on 17th April 2009. Comparison of both results from NC and SCC will be provided as well in the later part of this project.

## 3.2 Material Preparation

OPC

Ordinary Portland cement that is going to be used is the standard grey cement. One bag of cement are ordered kept in concrete lab. Cement are weighted and placed in tray before pouring into mixing machines.

Aggregate

Aggregates (sand and gravel) are available at the concrete lab. Aggregates with suitable shape, size and homogeneity are to be selected, soaked and dried. Sieve analysis might be done as well to have well graded aggregates. For course aggregate, there are two size ranges namely 20 mm and 8 mm. Fine aggregate size is less than 4 mm. Aggregates are also weighted and placed in trays for mixing purpose.

Superplasticizer

Superplasticizer is in the form of liquid. A very small weight of superplastizicer is used, only 0.44 kg.

### 3.3 Mix Proportion

The mix proportion is developed by the assistance from a postgraduate student, Mr. Agus. Mix for normal vibrated concrete is presented in Table 3.3.1 and mix for SCC is presented in Table 3.3.2. All units are in kg.

Mix for VC

| OPC | CA (20-8) | CA (8-4) | FA | WATER |
|---|---|---|---|---|
| 14.52 | 7.70 | 16.70 | 23.53 | 7.26 |

*Table 3.3.1* Mix proportion for normal vibrated concrete sample.

Mix for SCC

| OPC | CA (20-8) | CA (8-4) | FA | WATER | SP |
|---|---|---|---|---|---|
| 14.52 | 9.44 | 17.72 | 23.67 | 4.36 | 0.44 |

*Table 3.3.2* Mix proportion for self compacting concrete sample.

### 3.4 Concrete Mixing & Casting

All concrete component are prepared a day before the day to mix it. Safety is observed at all times as goggle, glove and ear muff are wore. Lab technicians, Mr. Johan provide the required safety briefing in the lab before any work proceed.

The mixer (see Figure 3.4.1) is wetted to ensure it will not use up the water from the mix. Coarse and fine aggregates are mixed for 25 seconds for uniform distribution to take place. Half of the water then poured into the mixer for a minute. The mix is left for 8 minutes for the coarse and fine aggregate to absorb the water. Later, OPC is poured into the mixture and mixed for a minute. The remaining half of the water is poured into the mixture and mixed for 3 minutes. Mixture must be ensured uniformly mixed. Hand mixing is done if required.

The cubes and cylindrical moulds are before hand cleaned, tighten and oiled. The fresh NC and SCC mixture are then cast into three 100 mm × 100 mm cubes and into four 150 mm diameter × 300 mm cylindrical mould respectively. For both cubes and cylinders, fresh concrete are poured in three layers and vibrated sufficiently for NVC. The top surface is ensured its flatness by using scrapper. The specimens are left to cool for 24 hours and the moulds are to be dismantled the next day.

*Figure 3.4.1* Concrete mixer.

## 3.5 Shrinkage Measurement

Two of the cylindrical moulds are placed into the Modulus of Elasticity equipment (see Figure 3.5.1) to measure its deformation due to shrinkage. Shrinkage is the deformation of the sample without the influence of load. It is mainly caused by heat of hydration of concrete during its early age. The cylinder samples are put under two different conditions in order to study the effect of weather on shrinkage and creep. One sample is to be placed inside a controlled temperature and relative humidity room and the other exposed to room temperature. The sharp points in the equipment are embedded into the samples (see Figure 3.5.2) and the changes in size will be read from the dial gauge. Water is splashed onto the samples on daily basis to assist the curing of the sample.

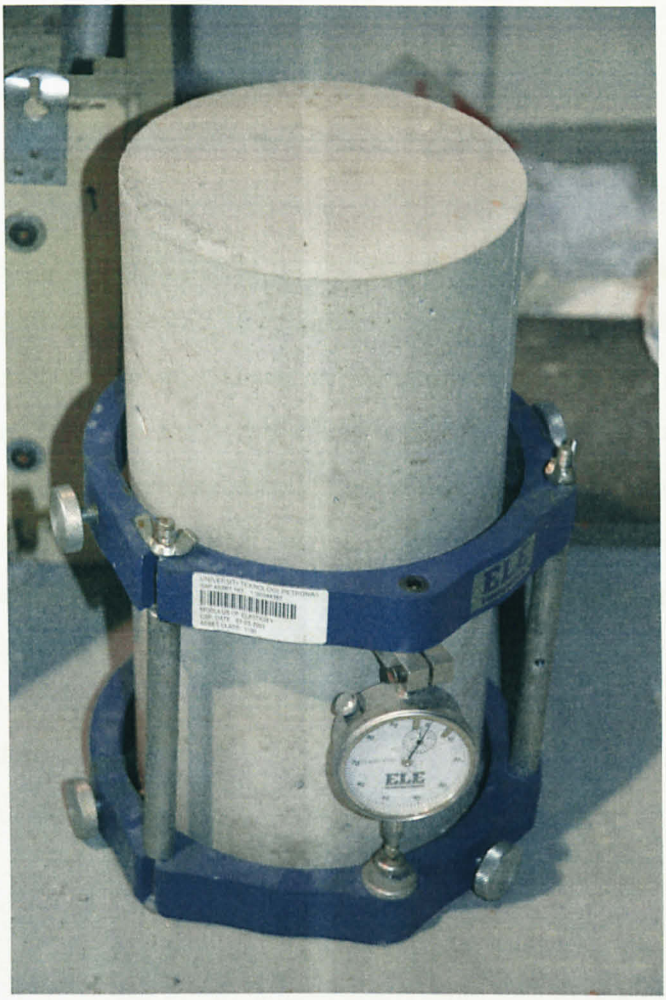


*Figure 3.5.1* Modulus of elasticity equipment.

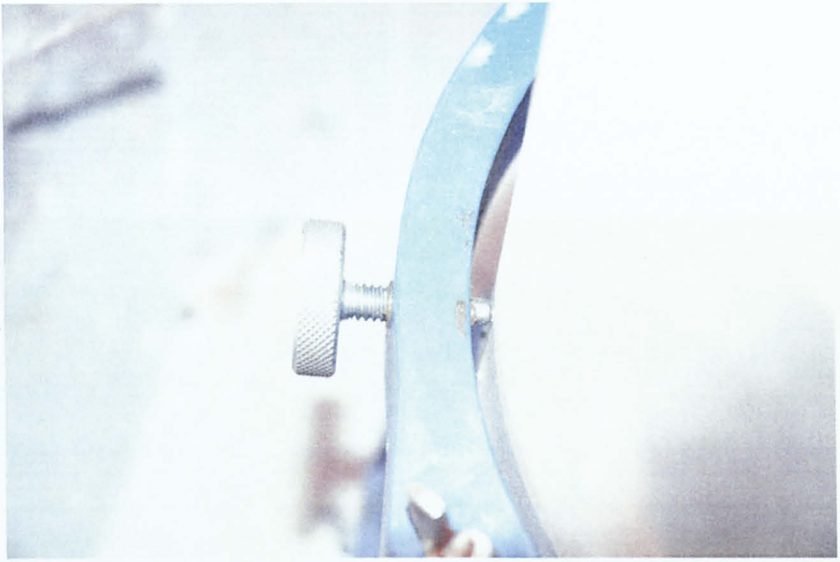

*Figure 3.5.2* Sharp points embedded into sample.

### 3.6 Creep Measurement

Creep is also deformation experienced by the sample but it is because of load induced onto it. The setting up of the testing is by using specially fabricated steel equipment. The equipment consists of 2 NOS of 300 mm × 300 mm steel plates with a thickness of 12 mm and 4 NOS of R20 steel rods with a length of 400 mm. Holes are provided at all sharp edges to that the rods can pass through the plates. Sample will be place in between the steel plates and load equivalent to the sample weight applied on top of the equipment. Grease is applied to provide a smooth movement of the steel plates. Two dial gauges are installed below the top steel plate so that movement of the plate can be recorded in order to determine the deformation that occurred. Wet gunny is used to ensure curing on the sample is done.

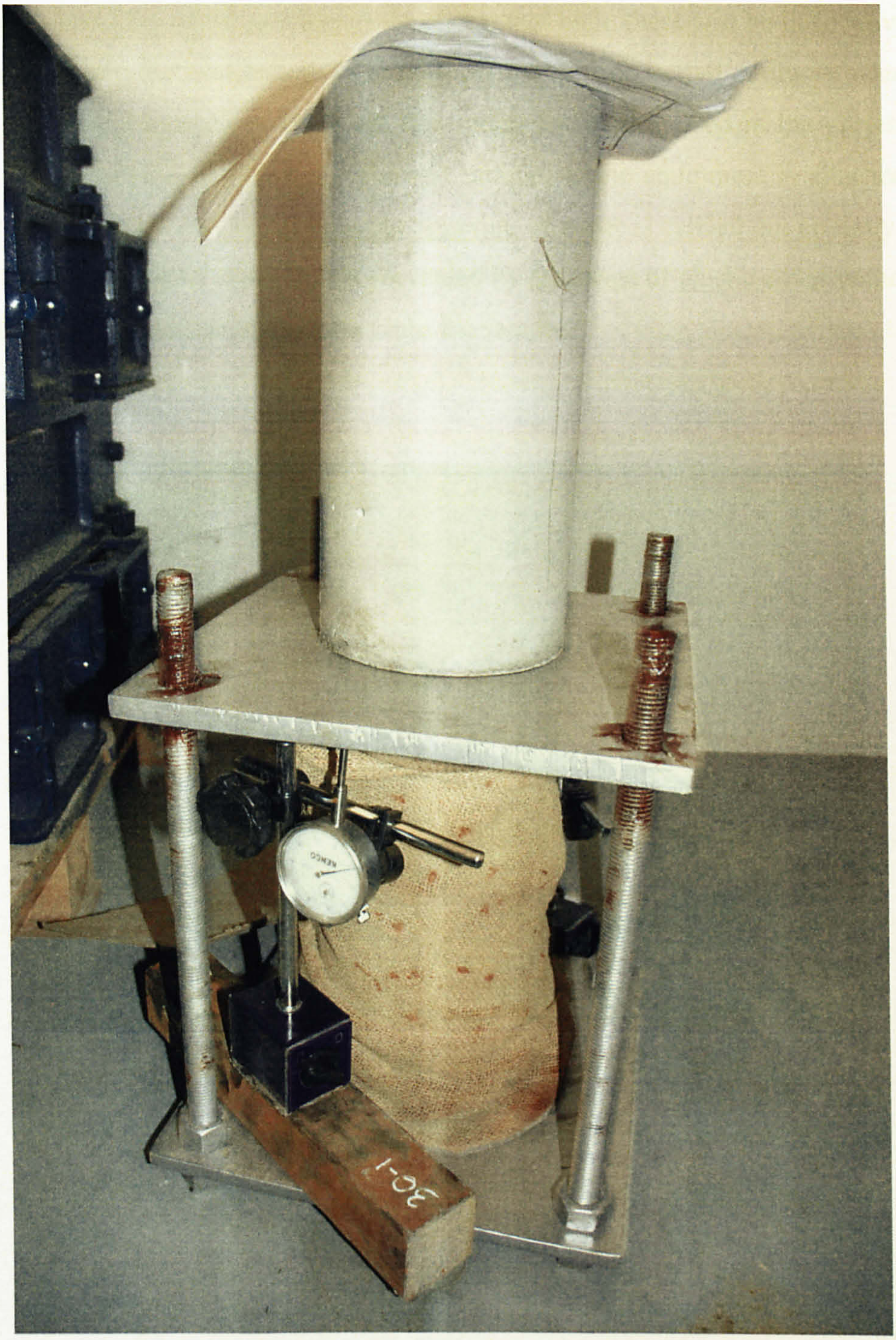


*Figure 3.6.1* Setting up for creep measurement.

## 3.7 Curing

Curing is the procedure used for promoting the hydration of cement. Hydration is greatly reduced when the relative humidity within the capillary pores drops below 80 percent. If the relative humidity of the ambient air is at least that high, there will be little movement of water between the concrete and the ambient air, and no active curing is needed to ensure continuing hydration. There are two method of curing used in the project; wet curing and membrane curing. For shrinkage sample, as the equipment is attached very closely to the sample surface, continuous spraying of water is carried out on daily basis. As for the creep sample, water loss is prevented by the usage of plastic cover without the possibility of external water ingressing into the sample.

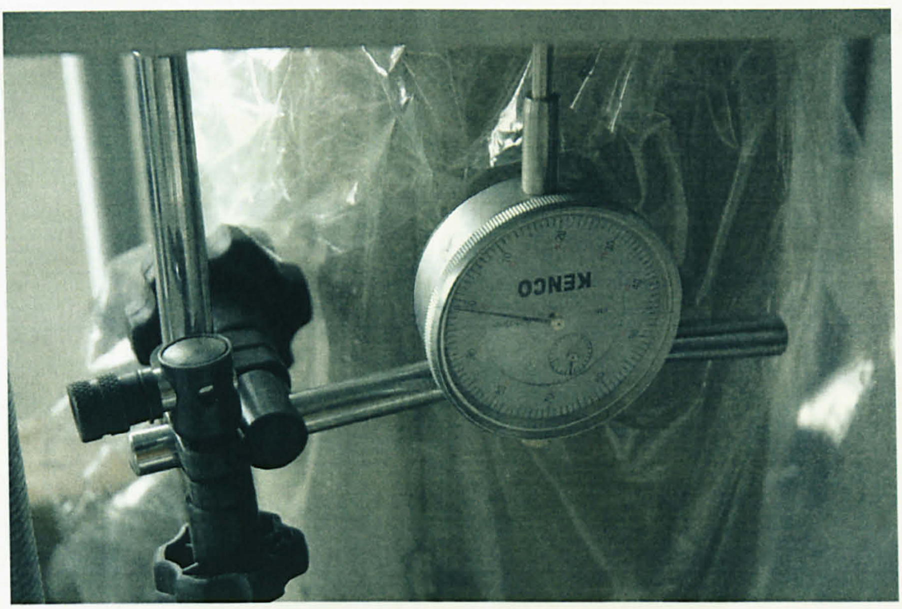

*Figure 3.7.1* Plastic cover used for curing purpose.

## 3.8 Compression Strength Test

Strength development of the concrete cubes is to be tested at the age of 3, 7 and 14 days. This test is to be carried out in order to justify the grade of NC and SCC mixes used. The cubes size is 100 mm. The mould and its base must be clamped together during casting in order to prevent leakage of mortar. Before assembling he mould, its mating surfaces should be covered with mineral oil, and a thin layer of similar oil must be applied to the inside surfaces of the mould in order to prevent the development of bond between the mould and the concrete.

According to BS 1881 : Part 116 : 1983, the load on the cube should be applied at a constant rate of stress equal to 0.2 to 0.4 MPa/second. Because the non-linearity of the stress-strain relation of concrete at high stresses, the rate of increase in strain must be increased progressively as failure is approached. The compressive strength, known also as the crushing strength, is reported to the nearest 0.5 MPa.

*Figure 3.8.1* Compression machine.

## 3.9 Tests on Fresh SCC

### 3.9.1 Slump Flow Test

The purpose of this test is to measure workability and deformability of a concrete mix. It is also meant to study the capability of mix to deform under its own weight against the friction of the surface with no external restraint present. Compaction must not be applied during the test. According to EN12350-2 Code, this test results indicate the filling ability of SCC.

The test begins with pouring fresh concrete into a standard slump cone. The cone is raised upward without disturbing the concrete flow. The largest diameter of the flow spread of concrete mix is measure to the nearest 10 mm. Diameters of the spread at right angles are also to be measured and the mean reading is the slump value. Segregation is checked by T-50 test. The time for the flow to reach 500 mm for SCC should be 2 to 5 seconds.

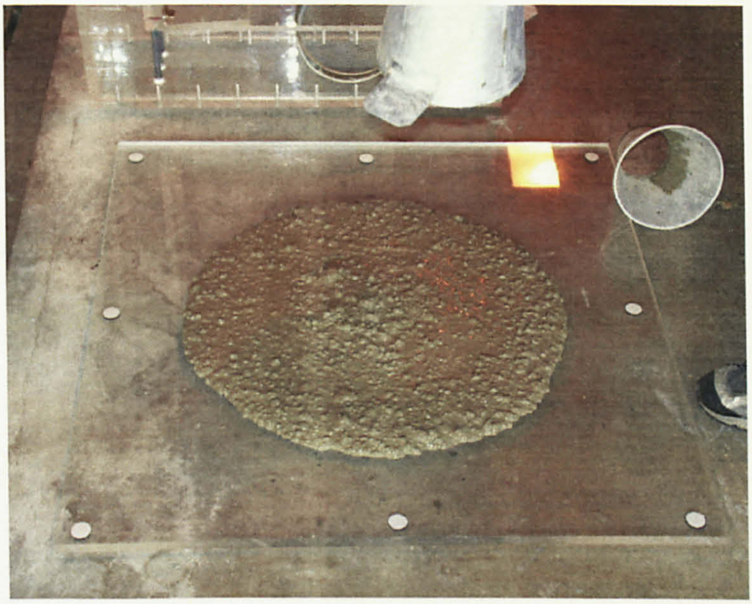

*Figure 3.9.1* Slump flow test.

### 3.9.2 V-Funnel Test

Fresh property of high fluidity mix cannot be described completely without considering its viscosity. One method used to assess the different viscous condition of mix is the V-funnel test. V-Funnel test is used to determine the segregation potential. The behaviour of V-funnel time against flow ability of mixes having different viscosity was investigated. This study showed that the measurement of V-funnel time became steady when mix reached optimum flow ability. There was close relationship between V-funnel time and W/C. It was also concluded that the use of V-funnel time are not recommendable for high viscosity and less flowable mix. Finally, the V-funnel time was shown to be a good tool to indicate the segregation tendency of a mix. A V-funnel time greater than 10-secs has strong resistance against segregation. A longer funnel flow time represents higher viscosity of the SCC mixture, which translates into better resistance to segregation.

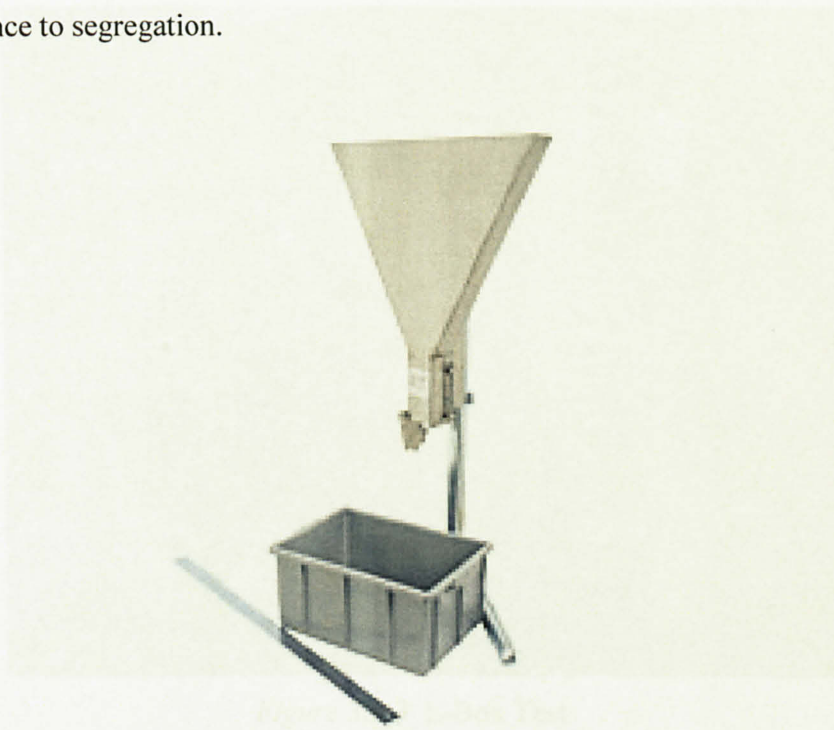

*Figure 3.9.2* V-Funnel Equipment

### 3.9.3 L-Box Test

This is a method used to determine flow rates and passing ability of SCC in confined spaces. Test box is comprised of concrete reservoir, slide gate, three obstacles, test basin including metal strikeoff bar. This test is also beneficial to observe higher possibility of segregation between coarse aggregate and cement matrix. Filling ability, passing ability and easiness to place SCC mixture are as well determined. In this method a closed vertical chamber is filled with the concrete to be tested so that a hydrostatic pressure head is produced. After the slide is opened the concrete has to level out through horizontal (L-box) flow obstacles. Passing ability is indicated by visual inspection of the area around the rebar – with an even distribution of aggregate indicating good passing ability.

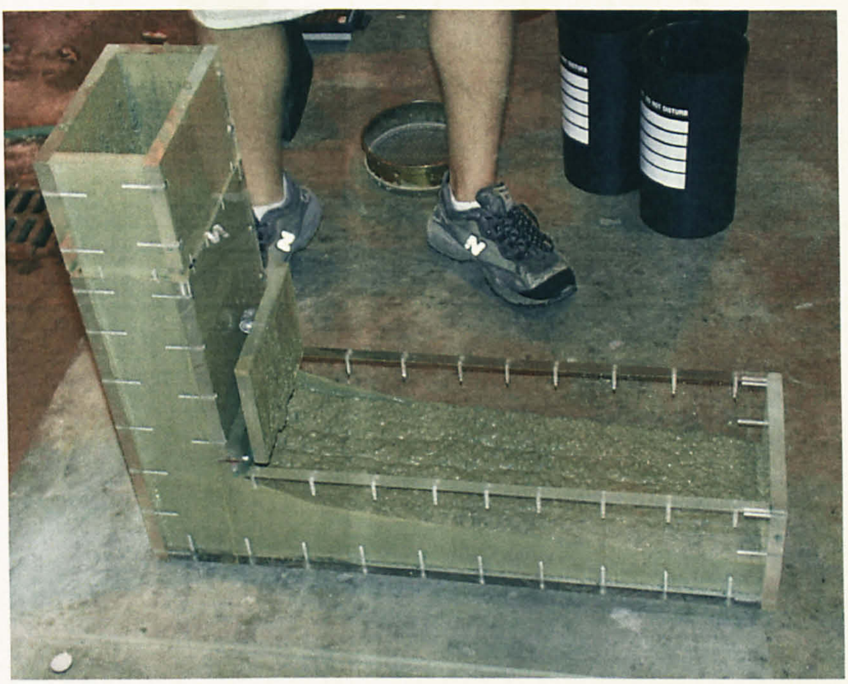

*Figure 3.9.3* L-Box Test

## 3.10 Gantt Chart

*Table 3.10* Gantt Chart

| Detail/Day | i | ii | iii | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Preparation | ■ | | | | | | | | | | |
| Mixing | | ■ | | | | | | | | | |
| Casting of Samples | | ■ | | | | | | | | | |
| V-Funnel Test | | ■ | | | | | | | | | |
| L-Box Test | | ■ | | | | | | | | | |
| Slump Flow Test | | ■ | | | | | | | | | |
| Opening mould | | | ■ | | | | | | | | |
| Strain Measurement | | | | ■ | | ■ | | | | ■ | ■ |
| Compressive Strength Test | | | | | | ■ | | | | ■ | ■ |

# CHAPTER 4
# RESULTS & DISCUSSION

## 4.1 Results

### 4.1.1 Shrinkage Measurement

Shrinkage measurement started immediately after the mould is dismantled (± 24 hours). Results of the shrinkage measurements are presented in Table 4.1.1.1 and Table 4.1.1.2 and graphs plotted for both sets of result.

*Table 4.1.1.1* Dial gauge readings (shrinkage – NVC)

| Days | Room Temperature | Controlled Humidity |
|---|---|---|
| | Reading on Gauge ($10^{-2}$ mm) | |
| 1 | -2.0 | -1.5 |
| 3 | -3.0 | -2.5 |
| 7 | -4.0 | -3.0 |
| 14 | -5.0 | -3.5 |

*Table 4.1.1.2* Dial gauge readings (shrinkage – SCC)

| Days | Room Temperature | Controlled Humidity |
|---|---|---|
| | Reading on Gauge ($10^{-2}$ mm) | |
| 1 | -2.5 | -2.0 |
| 3 | -4.0 | -3.0 |
| 7 | -6.0 | -5.0 |
| 14 | -8.0 | -7.0 |

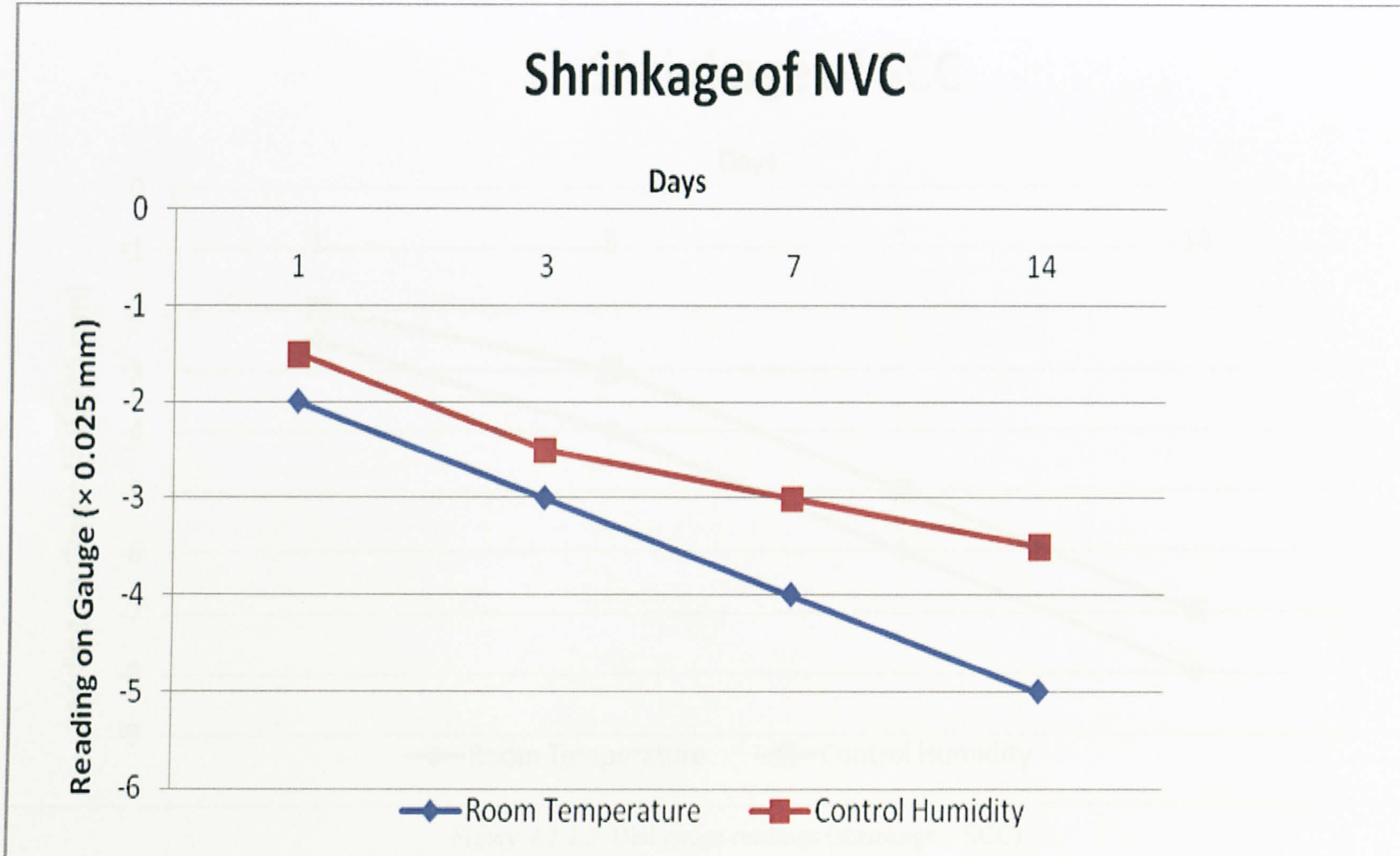


*Figure 4.1.1.1* Dial gauge readings (shrinkage – NVC)

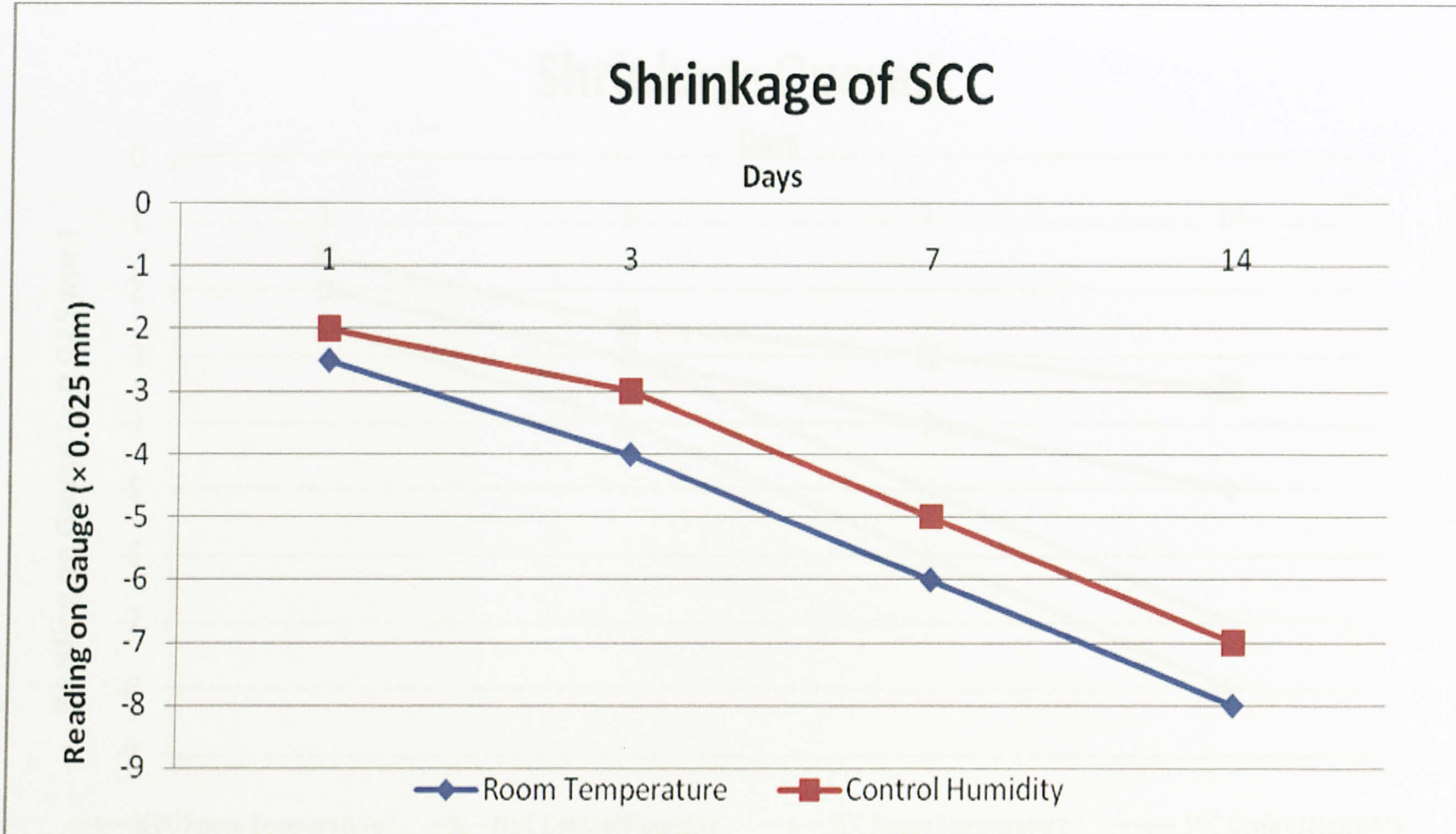


*Figure 4.1.1.2* Dial gauge readings (shrinkage – SCC)

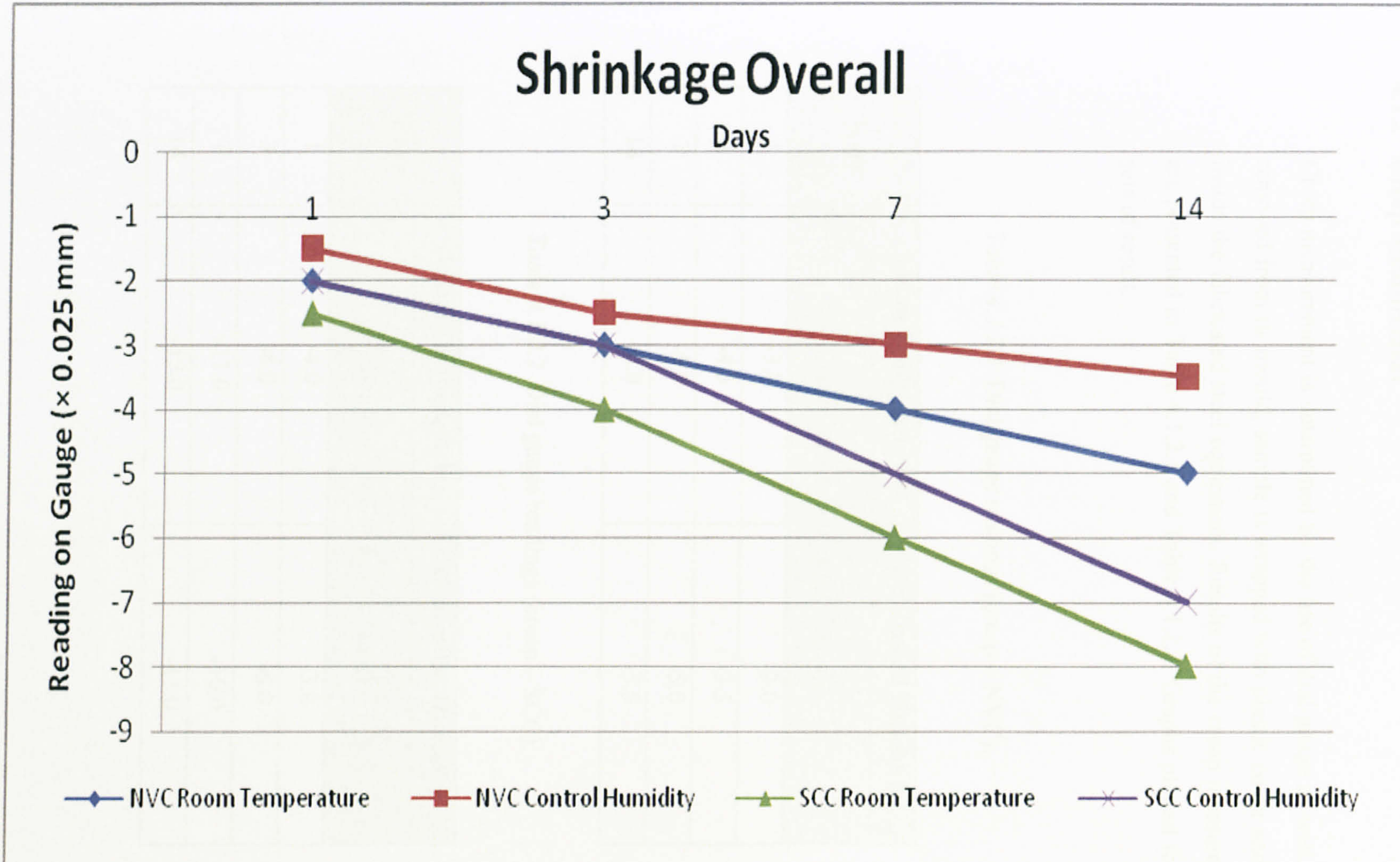


*Figure 4.1.1.3* Dial gauge readings (shrinkage – overall)

### 4.1.2 Creep Measurement

Creep measurement is determined by the use of dial gauge as well. Once removed from its mould, sample is wrapped with plastic cover and place inside the fabricated steel equipment. Results of the creep measurements are presented in Table 4.1.2.1 and Table 4.1.2.2. Graphs plotted for both sets of result.

*Table 4.1.2.1* Dial gauge readings (creep – NVC).

| **Days** | **Room Temperature** | **Controlled Humidity** |
|---|---|---|
| | **Reading on Gauge ($10^{-2}$ mm)** | |
| 1 | -3.0 | -2.0 |
| 3 | -4.5 | -3.5 |
| 7 | -5.5 | -5.0 |
| 14 | -6.0 | -5.5 |

*Table 4.1.2.2* Dial gauge readings (creep – SCC).

| **Days** | **Room Temperature** | **Controlled Humidity** |
|---|---|---|
| | **Reading on Gauge ($10^{-2}$ mm)** | |
| 1 | -4.0 | -3.0 |
| 3 | -8.0 | -6.0 |
| 7 | -11.0 | -10.0 |
| 14 | -12.0 | -11.0 |

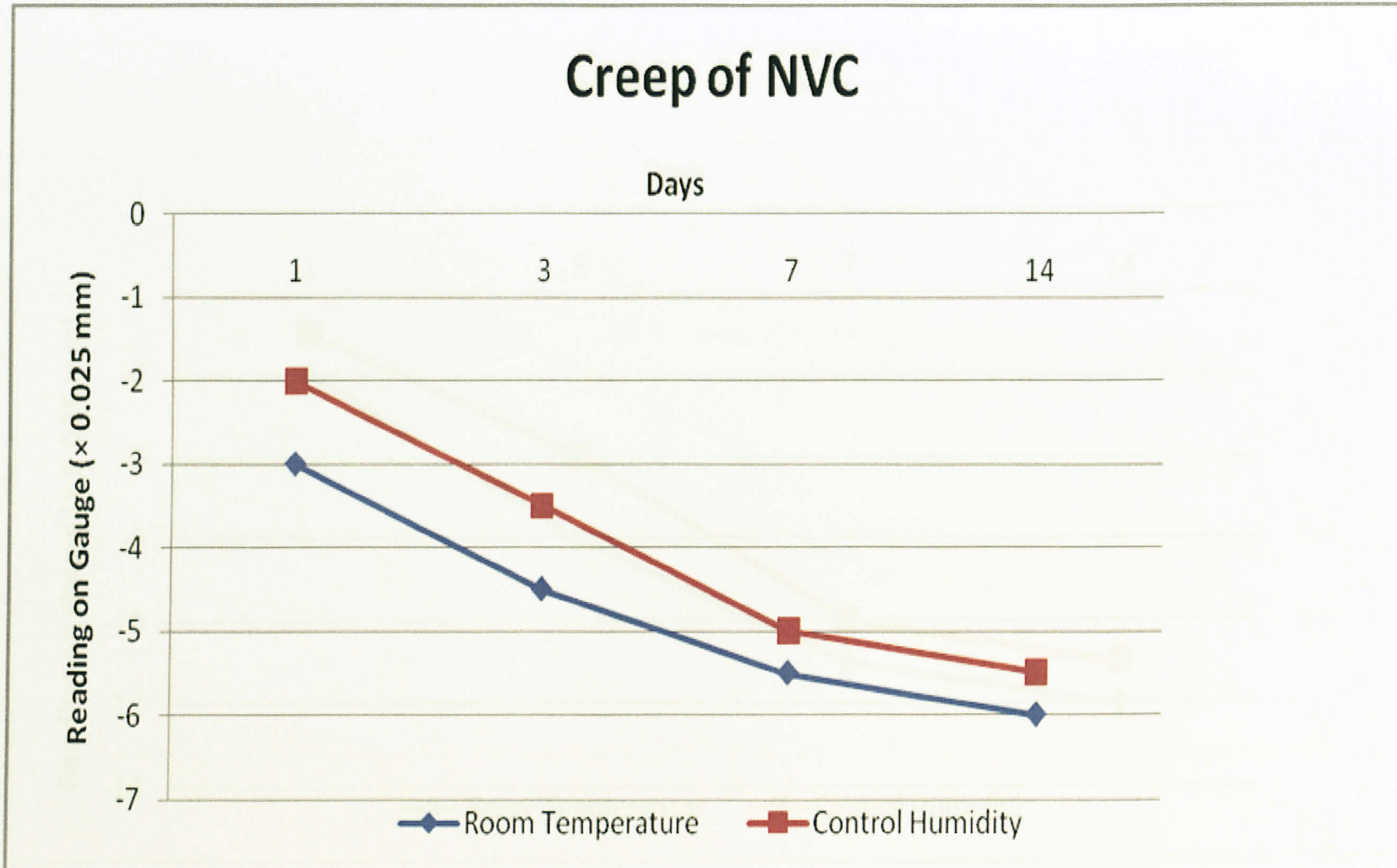


*Figure 4.1.2.1* Dial gauge readings (creep – NVC)

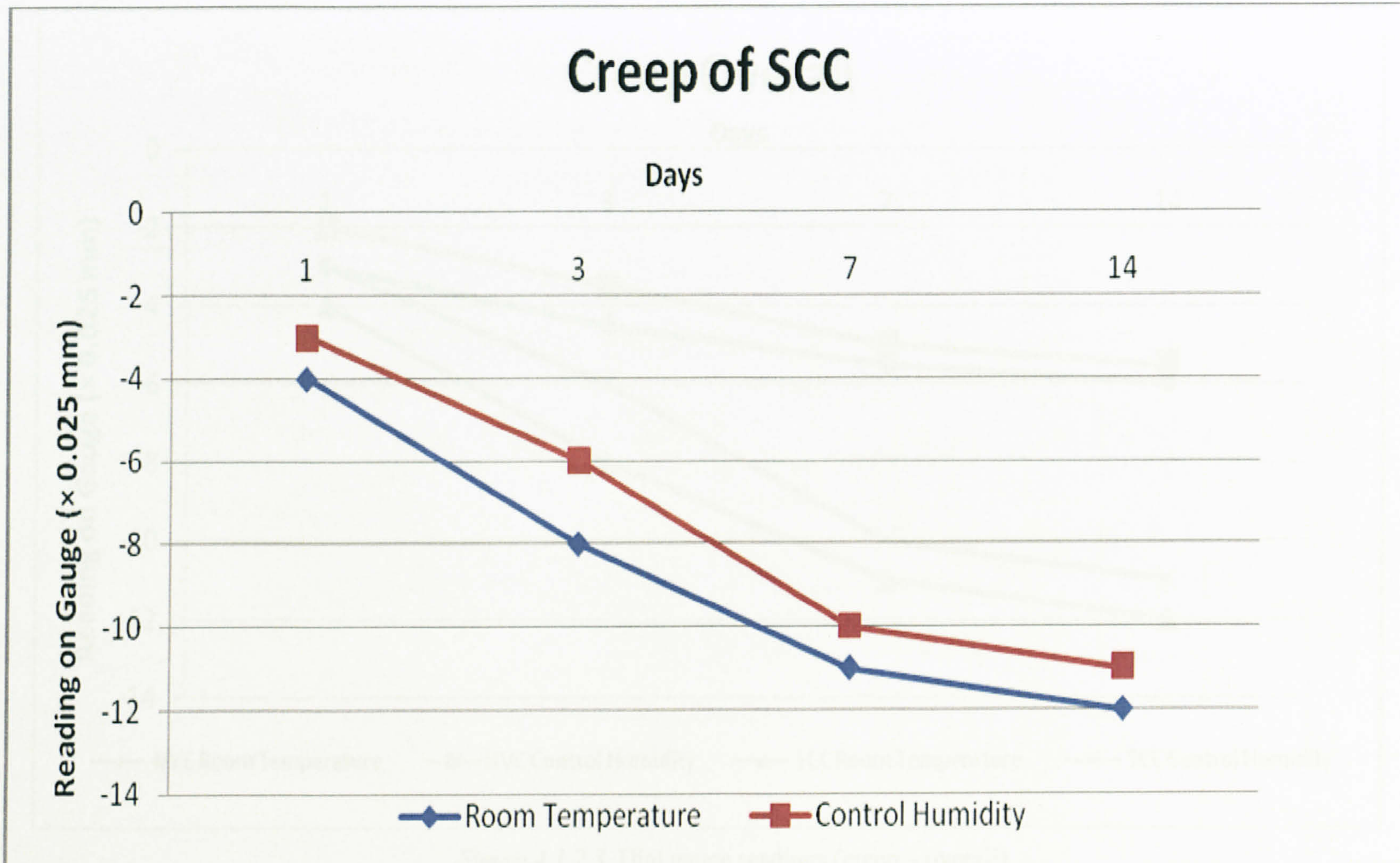


*Figure 4.1.2.2* Dial gauge readings (creep – SCC)

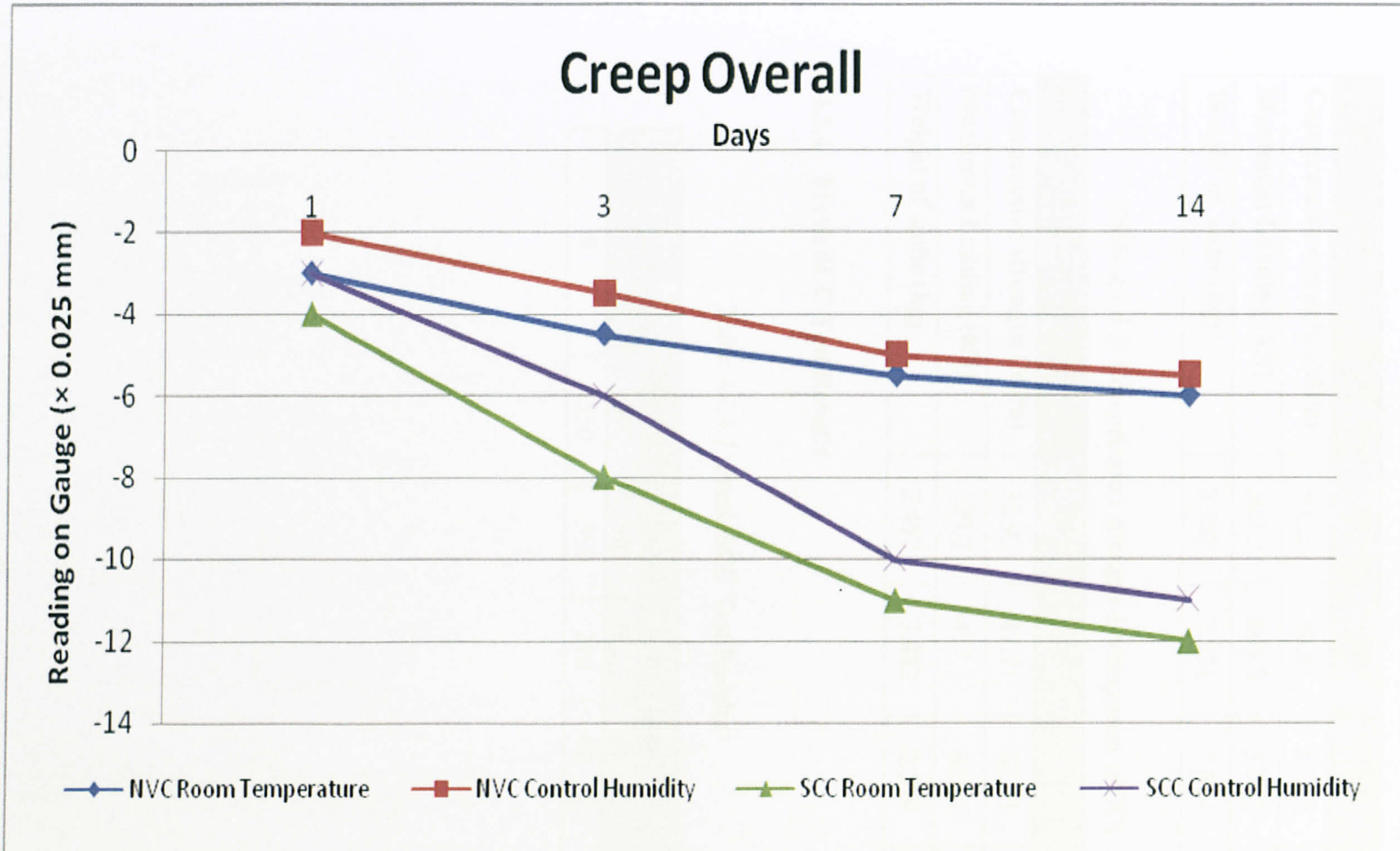


*Figure 4.1.2.3* Dial gauge readings (creep – overall)

### 4.1.3 Compression Strength Test Results

*Table 4.1.3.1* Compression strength development (NVC)

| Item/Days | 1d | 3d | 7d | 14d |
|---|---|---|---|---|
| **Compressive strength (MPa)** | 50.22 | 50.83 | 52.17 | 55.91 |
| **Maximum Loading (kN)** | 502.2 | 508.3 | 521.7 | 559.1 |
| **Weight of cube (kg)** | 2.587 | 2.551 | 2.614 | 2.523 |

*Table 4.1.3.2* Compression strength development (SCC)

| Item/Days | 1d | 3d | 7d | 14d |
|---|---|---|---|---|
| **Compressive strength (MPa)** | 32.92 | 47.71 | 62.51 | 64.90 |
| **Maximum Loading (kN)** | 329.2 | 477.1 | 625.1 | 649.0 |
| **Weight of cube (kg)** | 2.457 | 2.482 | 2.579 | 2.506 |

### 4.1.4 Fresh SCC Test Results

*Table 4.1.4.1* Fresh SCC Test Results

| V- Funnel (sec) | Slump Flow (mm) | | L-Box (mm) | | $T_{50}$ (sec) |
|---|---|---|---|---|---|
| | 0° | 90° | $H_{max}$ | H | |
| 9 | 550 | 590 | 210 | 90 | 5 |

## 4.2 Discussion

The analysis if the test results revealed that :

- Higher shrinkage observed in SCC than in NVC
- Higher creep observed in SCC than in NVC
- Deformations (creep and shrinkage) are higher at room temperature than control humidity room
- NVC samples yielded higher early strength but lower long term strength
- SCC samples yielded higher long term strength than NVC samples
- Fresh SCC mix proved to possess SCC characteristic (Slump flow range from 560 mm to 760 mm)

# CHAPTER 5
# CONCLUSION & RECOMMENDATION

With reference to the test results, the author could conclude that a general higher shrinkage and creep deformations for SCC mixture compared to NVC mixture.

The author has limited time and resource to carry out the study for a longer period with a more precise measuring mechanism. A recommendation for further study on this topic would be to carry our observation on how creep and shrinkage behave in longer time period.

# CHAPTER 6

# REFERENCES


1. Daye M. A & Fu C. C. (1992). Creep and Shrinkage of Concrete: Effect of Materials and Environment. *American Concrete Institute*

2. Holschemacher K. & Klug Y. (2003). Comparison of the Hardened Properties of Self-Compacting and Normal Vibrated Concrete. *Conf. Proc. 3rd Int. RILEM Symp. On SCC*

3. Mazzotti C., Savoia M. & Ceccoli C. (2005). A Comparison between Long Term Properties of SCC and Normal Vibrated Concrete with Same Strength.

4. Neville A. M. (2005). Properties of Concrete. 4th Edition, Prentice Hall

5. Nishio A., Tamura H. & Obashi M. (1998). SCC with High Volume Crushed Fines. *ACI Symposium. Advances in Concrete Technology, Tokushima*

6. Okamura H. & Ouchi M. (2003). Self-Compacting Concrete. *Journal of Advanced Concrete Technology, Volume 1.*

7. Ouchi M. (1999). Self-Compacting Concrete: Development, Applications and Investigations.

8. Persson B. (2005). Creep of Self-Compacting Concrete. *CONCREEP 7*

9. Persson B. (2000). Strength and Shrinkage of SCC. *RILEM Workshop on Shrinkage in Concrete.* Paris

10. Phillippe Turcry *et. al.* (2006). Cracking Tendency of SCC Subjected to Restrained Shrinkage : Experimental Study and Modelling.