COMPRESSIVE STRENGTH OF NORMAL STRENGTH CONCRETE (NSC) USING BRITISH STANDARD, EURO CODE AND NON- DESTRUCTIVE TEST APPROACHES

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ABSTRACT

Concrete is a very important material and widely used in construction industry. It offers stability and design flexibility for the residential marketplace and environmental advantages through every stage of manufacturing and use. Locally, the characteristic compressive strength is usually measured based on 150 mm cubes according to BS approach. But in future, the design compressive strength is usually based on the standard 150 x 300 mm cylinders as recommendation by Eurocode. Compression Test, Rebound Hammer Test and Ultrasonic Pulse Velocity Test method are used to determine the compressive strength. Each of the method gives the different method to measure compressive strength value. Experimental results indicate that the ratio of cylinder to cube samples was ranging between 0.70 and 0.83. It was found, that on average, the ratio of the compressive strength of 150 x 300 mm cylinders to 150 mm cubes was 0.79. Rebound Hammer method was preferable to be used for Non Destructive Test due to the slightly differences of compressive strength value compared to Ultrasonic Pulse Velocity method. A comparison of the compressive strength between Compression Test method on cube, Rebound Hammer method and Ultrasonic Pulse Velocity method on prism was performed. These types of methods were chosen because it represented Destructive and Non Destructive test that are most commonly used locally in the construction industry and research.

ABSTRAK

Konkrit merupakan bahan yang sangat penting dan digunakan secara meluas dalam industri pembinaan. Konkrit memberi kestabilan dan rekabentuk yang fleksibel untuk pasaran perumahan tempatan dan kebaikan alam sekitar melalui setiap fasa a pembuatan dan kegunaannya. Ciri- ciri kekuatan mampatan di tempatan biasanya disukat berdasalkan kiub bersaiz 150mm yang mana mengunakan piawaian British. Tetapi, dalam era mendatang, kekuatan mampatan rekabentuk selalunya berdasalkan piawaian silinder yang bersaiz 150 x 300 mm seperti yang dicadangkan oleh Eurocode. Kaedah ujian Mampatan,ujian Rebound Hammer dan ujian Ultrasonic Pulse Velocity digunakan untuk menentukan kekuatan mampatan.konkrit Setiap kaedah memberi kaedah yang berlainan untuk mengukur nilai kekuatan mampatan. Keputusan kajian menunjukan nisbah silinder kepada kiub adalah antara 0.70 dan 0.83. Keputusan kajian didapati bahawa purata nisbah bagi kekuatan mampatan untuk 150 x 300 mm silinder kepada 150mm kiub adalah 0.79. Kaedah Rebound Hammer lebih sesuai digunakan sebagai Ujian Tanpa Musnah disebabkan perbezaan kekuatan mampatan yang sedikit berbanding dengan Kaedah Ultrasonic Pulse Velocity. Perbandingan daya mampatan antara kaedah ujian mampatan, kaedah ujian Rebound Hammer dan kaedah ujian Ultrasonic Pulse Velocity pada prisma dilakukan. Jenis kaedah ujian ini dipilih kerana ujian Musnah dan Tanpa Musnah yang paling sering digunakan secara tempatan dalam industri pembinaan dan kajian penyelidikan.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

f_{ck}	-	Characteristic cylinder strength
$f\gamma_d$	-	Design yield strength
fc	-	Concrete strength
γ_m	-	Partial safety factor
T	-	Time in second
V	-	Velocity
cm	-	Centimeter
mm	-	Millimeter
km	-	Kilometer
UPV	-	Ultrasonic Pulse Velocity
NSC	-	Normal Strength Concrete
NDT	-	Non Destructive Test
ASTM	-	American Society of Testing Material

CHAPTER 1

INTRODUCTION

1.1 General

Concrete is a construction material composed of cement (commonly Portland cement) as well as other cementations' materials such as fly ash and slag cement, aggregate (generally a coarse aggregate such as gravel, limestone, or granite, plus a fine aggregate such as sand), water, and chemical admixtures. Concrete is a very important material and widely used in construction industry. It offers stability and design flexibility for the residential marketplace and environmental advantages through every stage of manufacturing and use. There are many advantages of concrete such as built-in-fire resistance, high compressive strength and low maintenance.

Various methods of concrete testing are carried out to ensure that it remains of adequate strength and durability. Testing method such as Non-destructive method, British Standard and Euro code are used to determine the compressive strength. Each of the method gives the different type of compressive strength value. In most structures, concrete is often subjected to biaxial states of stress, and the behavior of the material under these types of loadings must be well understood.

It is therefore not surprising that numerous investigations into the behavior and strength of Normal Strength Concrete (NSC) under biaxial stresses have been done in the past 40 years. On the other hand, High Performance Concrete difference from Normal Strength Concrete in several.

In normal strength concrete, the micro cracks form when the compressive stress reaches until 40% of the strength. The cracks interconnect when the stress reaches 80-90% of the strength. The fracture surface in NSC is rough. The fracture develops along the transition zone between the matrix and aggregates. Fewer aggregate particles are broken. Marcio (2002)

1.2 Problem Statements

Eurocode 2 (EC2) defined as a set of ten Eurocode programme in European Standard that contains the design standard for concrete structures. EC2 gives many benefits such as less restrictive than British Standard, extensive and comprehensive, logic and organized to avoid repetition and the new EC2 are claimed to be the most technically advanced codes in the world. In Europe, all the public works must allow the Eurocodes to be used for structural design. (Moss et.al 2004)

According to the grade of concrete, EC2 allows benefits to be derived from using which BS8110 does not. Concrete strengths are referred to by cylinder strength, which are typically 10-20% less than the corresponding cube strengths. The maximum characteristic cylinder strength, f_{ck} permitted is 90 N/mm^2 which corresponds to characteristic cube strength of 105 N/mm^2.

A basic material partial safety factor, γ_m of EC2 for concrete is 1.5 compared to reinforcing steel in BS8110 which the material partial safety factor was reduced from 1.15 to 1.05 several year ago.

This is unlikely to have any practical impact however as steel intended to meet the existing yield strength of 460N/mm^2 assumed by BS8110 is likely to be able to meet the 500N/mm^2 assumption made by EC2, so that the design yield strength, $f\gamma_d$ will be virtually identical (Moss et.al 2002).

Use of the EC2 will provide more opportunity for United Kingdom (UK) designers to work throughout Europe and for Europeans to work in the UK (Moss et.al 2004).

Similarly to the Malaysian designer whose are going to work in Europe gives advantages when design compressive strength of the building. Most importantly, Eurocode going to introduced all over the world included Malaysia.

So the compressive strength of Eurocode when applying concrete design in Malaysia building due to the different climate and material used compare to the Eurocode in European is questionable.

1.3 Objective of Study

This project has three main objectives which are:-

i. To determine compressive strength of Normal Strength Concrete (NSC) using British Standard and Euro Code method.
ii. To check the strength using Non Destructive Test (NDT).
iii. To compare compressive strength using different method of testing.

1.4 Scope of Study

The scopes of this study are:

i. Normal strength concrete covered are 20 N/mm^2 and 30 N/mm^2
ii. Non Destructive Test used are Rebound Hammer and Ultrasonic Pulse Velocity.
iii. Sample will be cured in water for duration of 7 and 28 days.
iv. All the testing will be carried out at the 7 and 28 days of concrete.
v. Compressive strength test will be conducted to BS1881:PART 116:1983 and ASTM:C 39/C 39m-04

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Based on the Balaguru et.al (1992) research, with the rapid development in concrete technology, concrete of strength over 100 MPa can be easily produced with ordinary materials and conventional mix methods. Clarke (1994) stated that high strength normal or high strength lightweight concrete offers more options for the design of tall buildings and long-span bridges .

According to the Zhou et.al. (1994) in Fracture mechanical properties of high strength concrete with varying silica fume contents and aggregates , the main concern with high strength concrete is the increasing brittleness with the increasing strength. Therefore, it becomes a more acute problem to improve the ductility of high strength concrete.

Most accumulated experience in normal strength "bre-reinforced" concrete may well be applicable to high strength concrete but the effectiveness of "bre reinforcement" in high strength concrete may be different and thus needs to be investigated.

2.2 Compressive Strength of Concrete

According to Seong et.al. (2005), the compressive strength of concrete is used as the most basic and important material property when reinforced concrete structures are designed. It has become a problem to use this value, however, because the control specimen sizes and shapes may be different from country to country.

The ultimate strength of concrete is influenced by the water-cementitious ratio *(w/cm)*, the design constituents, and the mixing, placement and curing methods employed. All things being equal, concrete with a lower water-cement (cementitious) ratio makes a stronger concrete than that with a higher ratio.

In this study, the effect of specimen sizes, specimen shapes, and placement directions on compressive strength of concrete specimens was experimentally investigated based on fracture mechanic. The analysis results show that the effect of specimen sizes, specimen shapes, and placement directions on ultimate strength is present. In addition, correlations between compressive strengths with size, shape, and placement direction of the specimen are investigated.

2.3 Relationship between Cube Concrete and Cylinder Concrete

According to Seong et.al (2005), relationship between specimen shapes shows the cube strength against the cylinder compressive strength for representative specimen sizes.

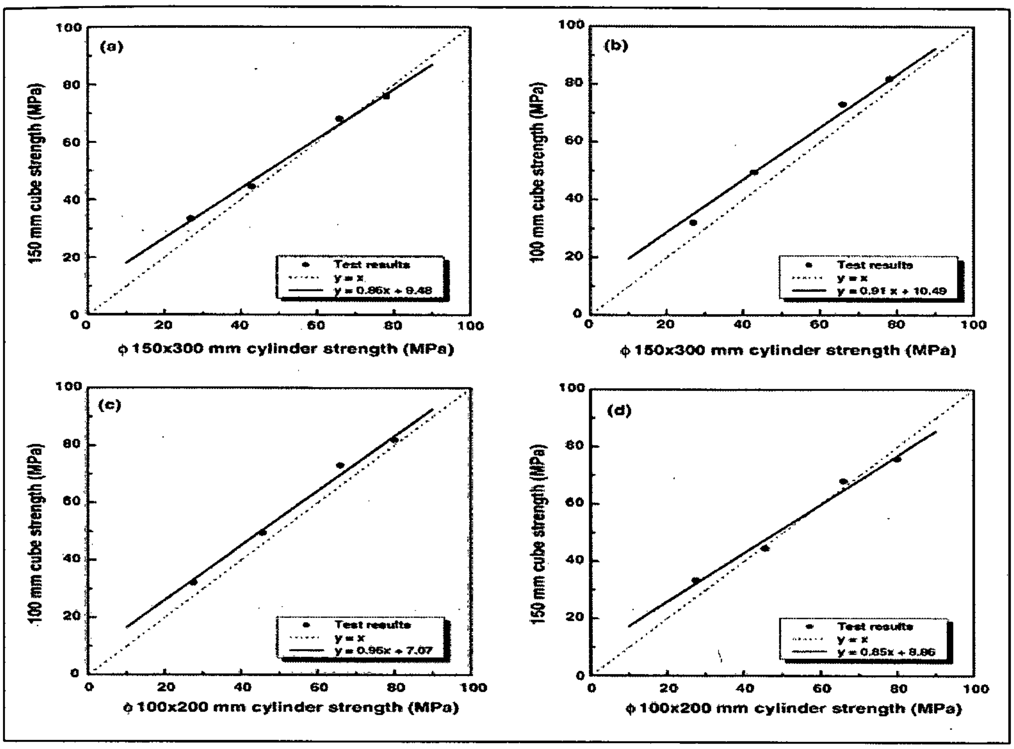

Figure 2.1: Cube strength against the cylinder compressive strength for representative specimen sizes. (Seong et.al. ,2005)

In these figures, solid lines and dashed lines indicate the best-fit lines obtained from the linear regression analyses and the lines of equality $y = x$, respectively. In addition, the equations shown are obtained from the linear regression analyses with test data points.

Figure 2.1 divided into 4 types of specimens size that is (a) Relationship between compressive strengths of 150 mm cube and Ø150 mm × 300 mm cylinder; (b) relationship between compressive strengths of 100 mm cube and Ø150 mm × 300 mm cylinder; (c) relationship between compressive strengths of 100 mm cube and Ø100 mm × 200 mm cylinder; (d) relationship between compressive strengths of 150 mm cube and Ø100 mm × 200 mm cylinder.

The 150 mm cube strength, when plotted against the corresponding Ø150 mm × 300 mm cylinder strength as shown in Figure 2.1a), shows that cube strength is higher for lower grades of concrete.

At approximately 65 MPa, however, the two strengths become identical. After that point, standard cylinders indicate a slightly higher strength than that of the corresponding cubes.

Meanwhile, the relationship between prisms and cylinders can be analogized from some literatures. Namely, Markeset and Hillerborg (1995) experimentally showed that the post-peak energy per unit area is independent of the specimen length when the slenderness is greater than approximately 2.50 for concrete cylinders.

Jansen and Shah (1997) also experimentally showed that pre-peak energy per unit cross-sectional area increases proportionally with specimen length and post-peak energy per unit cross-sectional area does not change with specimen length for lengths greater than 20.0 cm in concrete cylinders.

Kim et al. (2001) concluded that flexural compressive strength does not change for specimens having a length greater than 30.0 cm for C-shaped concrete specimens having a rectangular cross-section. From these contents, it can be concluded that the relationship between prisms and cylinders will be similar with the relationship between cubes and cylinders.

2.4 Effect of Placement Direction on Compressive Strength for Normal Strength Concrete and High Strength Concrete

According to the Seong.et.al (2005), Figure 2.2 a) and b) show cube placement direction is parallel to the loading direction; the compressive strength is higher than the normal case. For Normal Strength Concrete, the size effect difference with displacement direction is not distinct compared to HSC. The reason is that, for NSC, the general fracture mechanism based on the movement of water is changed by the end restraint effect occurred due to the machine platen as well as the failure pattern (in this study, it is a crushing failure).

Accordingly, the strengths of both specimens become a similar value. And, when the compressive test for cubes is performed, since the loading direction is normal to the placement direction, no homogeneous characteristics occurred due to the settlement difference of materials is additionally reflected on the reduction of the strength. Namely, the size effect of cubes is more apparent compared to cylinders regardless of strength level.

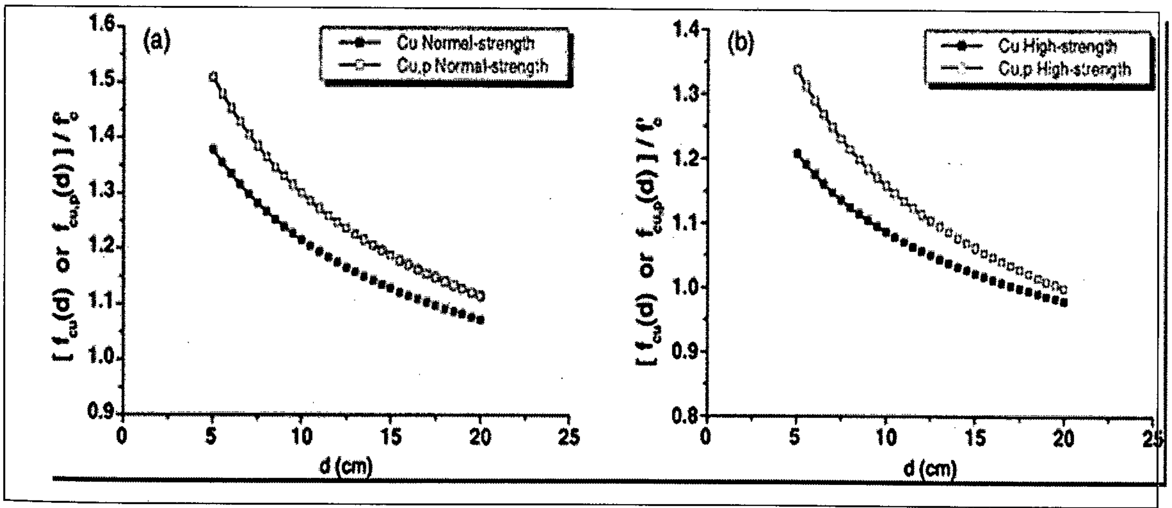

Figure 2.2: a) Relationship between compressive strengths against diameter cube of Normal Strength Concrete. b) Relationship between compressive strengths against diameter cube of High Strength Concrete (Seong.et.al, 2005)

2.5 Non Destructive Test: Rebound Hammer

According to the British Standard Institution, the use of rebound hammers is for testing the hardness of concrete. It describes the areas of application of rebound hammers, their accuracy, the calibration procedure, the procedure for obtaining a correlation between hardness and strength, the conditions of the concrete.

According to Hisham (2000), the term ``nondestructive" is given to any test that does not damage or affect the structural behavior of the elements and also leaves the structure in an acceptable condition for the client. According to Malhotra (1976), Non destructive methods normally used for concrete testing and evaluation. However, a successful nondestructive test is the one that can be applied to concrete structures in the field and be portable and easily operated with the least amount of cost.

Hardness measurements can be used in the production of concrete where it may be desirable to establish the uniformity of products or similar elements in a structure in situ at a constant age, temperature, maturity and moisture condition. Measurements can also be used to define areas of different quality prior to testing by other methods, possibly using destructive tests. Hardness measurements provide information on the quality of the surface layer (about 30 mm deep) of the concrete only. Rebound hammers are unsuitable for detecting strength variations caused by different degrees of compaction. If the concrete is not fully compacted strength cannot be reliably estimated. A wet surface gives lower rebound hammer readings than a dry surface. This effect can be considerable and a reduction in rebound number of 20 % is typical for structural concrete, although some types of concrete can give greater differences.

Tests on molded surfaces are generally to be preferred. Lack of quantitative evidence on how different surfaces behave under a hardness test can lead to considerable errors if results are compared. In such cases separate calibrations are necessary.

2.6 Non Destructive Test: Ultrasonic Pulse Velocity

Ultrasonic pulse velocity equipment measures the transit time of a pulse between transducers placed on the surface of a body of concrete. The pulse velocity can then be calculated using the measured path length through the concrete. The pulse velocity depends upon the dynamic Young's modulus, dynamic Poisson's ratio and density of the medium.

According to the BS 1881-201 (1986), the principal advantages of ultrasonic pulse velocity measurement are that it is totally non-destructive, quick to use and reflects the properties of the interior of a body of concrete. It is particularly valuable in circumstances where a considerable number of readings is required for the assessment of uniformity of hardened concrete.

According to Manish and Gupta (2005), numerous attempts to use Ultrasonic Pulse Velocity (UPV) as a measure of compressive strength of concrete have been made due to obvious advantages of non-destructive testing methods.

2.7 Cement

Generally, cement can be described as a material with bonding agent and cohesive properties, which it make it proficient of bonding mineral fragments into a solid hole. Portland cement is hydraulic cement that hardens by interacting with water and forms a water resisting compound when it receives its final set. Portland cements are highly durable and produce high compressive strengths in mortars and concrete. Portland cement is made of finely powdered crystalline minerals composed primarily of calcium and aluminum silicates

The strength of cement paste is the result of a process of hydration. The early strength of Portland cement is higher with higher percentages of C_3S. If moist curing is continuous, later strength level becomes greater with higher percentages of C_2S. C_3S contributes to the strength developed during first day after placing the concrete because it is the earliest to hydrate.

The size of the cement particles has a strong influence on the rate of reaction of cement with water. For a given weight of finely ground cement, the surface area of the particles is greater than that of the coarsely ground cement. Finely ground cement is desirable in that they increase strength, especially at the early age, by the way increase workability.

These result in a greater rate of reaction with water and a more rapid hardening process for larger surfaces areas. This is one of the reasons for the use of high early strength type III cement. It gives in 3 days the strength that type I gives 7days, primarily because of the finer size of its particles. Figure 2.3 show that specific surface in square centimeters per gram of cement, on the compressive strength of concrete at four different ages.

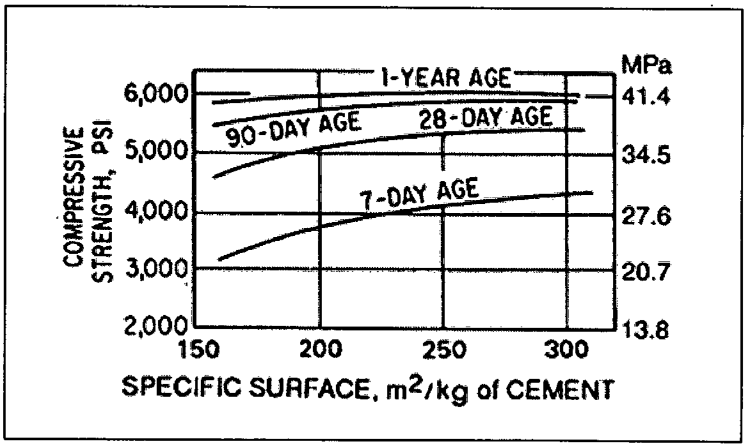

Figure 2.3: Compressive strength against the specific surface of cement (Charles,2007)

2.8 Water

According to the Charles (2007), water used for mixing concrete should be free from impurities that could adversely affect the process of hydration and, consequently, the properties of concrete. BS EN 1008 specifies requirements for the water and gives procedures for checking its suitability for use in concrete.

Drinking water is suitable, and it's usually simply to obtain from local water utility. Some recycled water is being increasing by used in the interest of reducing the environment impact of the concrete production. Some organic matter can cause retardation, whilst chloride may not only accelerate the stiffening process but also cause embedded steel.

According to Nawy (2000), gradual evaporation of excess water from mix, pores are produced in the hardened concrete. If the pores are evenly distributed, they could give improved characteristic to the product. Very even distribution of pores by artificial introduction of finely divided uniformly distributed air bubbles throughout the product is possible by adding air-entraining agents. Air entrainment increases workability, decreases density, increases durability and frost resistances, reduces bleeding and segregation, and reduces the required sand content in the mixture. Optimum air content is 9% of mortar fraction of the concrete. Air entraining in excess of 5-6% of the total mix proportionally reduced concrete strength proportionally.

2.9 Aggregate

Aggregate are those parts of the concrete that constitute the bulk of the finished product. They comprises 60-80% of the volume of the concrete and have to be so graded that the entire mass of concrete acts as a relatively solid, homogeneous, dense