COMPRESSIVE STRENGTH OF HIGH STRENGTH CONCRETE USING BRITISH STANDARD, EURO CODE AND NON- DESTRUCTIVE TEST APPROACHES

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ABSTRACT

High strength concrete has been widely used in civil engineering in recent years. High strength concrete provides high compressive strength but lower the ductility than normal strength concrete. In this study, the compressive strength of cube and cylinder specimens was compared. Cube test is the common measurement of concrete compressive strength. According to British Standard 8110, the design of concrete structures is depend on the cube strength. In industries, the cube strength test is conducted to obtain the grade of concrete before it is applied to the work. In future, Eurocode 2 (EC2) will replace the existing British code BS8110 for the design of concrete structure. EC2 have some benefits compared to British Standard. Concrete strengths are referred to by cylinder strength, which are typically 10-20% less than the corresponding cube strengths. In this investigation, the concrete cube and cylinder were tested on 7 and 28 days of water curing. The result show that the value of cylinder strength is about 18-21% less than the cube strength. Nondestructive test which are Rebound Hammer test and Ultrasonic Pulse Velocity test was also used to test the concrete strength.

ABSTRAK

Konkrit kekuatan tinggi digunakan secara meluas dalam bidang kejuruteraan awam pada kebelakangan ini. Konkrit kekuatan tinggi mempunyai daya mampatan yang tinggi tetapi kerapuhan yang rendah berbanding konkrit biasa. Dalam kajian ini, daya mampatan antara konkrit kiub dan konkrit silinder dibandingkan. Ujian kiub adalah ujian biasa digunakan untuk mengukur daya manpatan konkrit. Berdasarkan kepada British Standard BS8110 (BS8110), reka bentuk struktur bergantung kepada kekuatan kiub. Dalam industri, ujian kekuatan kiub dijalankan untuk mendapatkan gred konkrit sebelum diaplikasikan dalam kerja pembinaan. Walaubagaimanapun, Eurocode (EC2) akan menggantikan Bs8110 dalam merekabentuk struktur pada masa yang akan datang. Eurocode mempunyai kelebihan berbanding dengan British Standard. Kekuatan konkrit silinder adalah antara 10 – 20% kurang daripada kekuatan kiub. Dalam kajian ini, kekuatan konkrit kiub dan silider diukur pada hari ke 7 dan hari ke 28 selepas rendaman air dijalankan. Hasil ujikaji menunjukkan kekuatan silinder adalah 18-21% kurang daripada kekuatan kiub. Ujian nondestructive iaitu ujian Rebound Hammer dan ujian Ultrasonic Pulse Velocity juga digunakan untuk menguji kekuatan konkrit kiub.

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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 Background of Study

High strength concrete has been widely used in civil engineering in recent years. This is because most of the rheological, mechanical and durability properties of these materials are better than those of conventional concretes.

High strength is made possible by reducing porosity, inhomogeneity and microcracks in concrete and the transition zone (Nawy, 1996). A definition of high strength concrete in quantitative term which is acceptable to everyone is not possible. In North American practice, high strength concrete is usually considered to be a concrete with a 28-day compressive strength of at least 42 MPa. In a recent CEB-FIP state-of-the-art report on high strength concrete, it is defined as concrete having a minimum 28-day compressive strength of 60 MPa. In many developed countries, the concrete producers arbitrarily defined the high strength concrete as the concrete having the 28-day cube strength of above 45 MPa when the normal weight aggregate is used. Clearly then, the definition of high strength concreteis relative; it depends upon both the period of time in question, and the location (Neville, 1997).

The use of high strength concrete results in many advantages, such as reduction in beam and column sizes and increase in the building height with many stories. In pre-stressed concrete construction, a greater span–depth ratio for beams may be achieved with the use of high strength concrete. In marine structures, the low permeability characteristics of high strength concrete reduce the risk of corrosion of steel reinforcement and improve the durability of concrete structures. In addition, high strength concrete can perform much better in extreme and adverse climatic conditions, and can reduce maintenance and repair costs (Mehta and Monteiro,1993).

The progress in the manufacturing of increasingly high strength concrete and their successful use in high rise structures over the last 20 years is well known. Most recently, concretes having the strength of around 138 MPa are being used in columns of high rise buildings and in a few European bridges. Concretes having the strength up to 800 MPa have been produced in France for special purposes (Gjorv, 1992).

By far, the most common test carried out on concrete is the compressive strength test. The main reason to understand this fact is that this kind of test is easy and relatively inexpensive to carry out (Mindess et al, 2003). Testing standard requirements use different geometries of specimens to determine the compressive concrete strength, f_c. The most used geometries are cylinders with a slenderness equal to two and cubes. Shape effect on compression strength has been widely studied and different relationships between the compressive strength obtained for these geometries have been proposed, mainly from a technological standpoint. Such approach eludes the fact that there is a direct relation between the nucleation and propagation of fracture processes and the failure of the specimen. Indeed, experimental observations confirm that a localized micro-cracked area develops at peak stress (Mier, 1984) or just prior to the peak stress (Torreti et al, 1993). For this reason compressive failure is suitable to be analyzed by means of Fracture Mechanics.

1.2 Problem Statement

Eurocode 2 (EC2) gives many benefits such as less restrictive than British Standards, 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 public works must allow the Eurocodes to be used for structural design. 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. Other than that, EC2 also give the economic benefit. It is expected that there will be material cost saving of between 0 and 5% compared to using BS 8110 (Moss et. al,2004). In future the Malaysia will use Eurcode as a standard in construction and British Standard will eliminate. The testing result in this study can be made as a reference in our future study ofEurocode in Malaysia.

According to the grade of concrete, EC2 allows benefits to be derived from using high strength concretes, which BS8110 does not. Concrete strengths are referred to by cylinder strengths, which are typically 10-20% less than the corresponding cube strengths. The maximum characteristic cylinder strength, f_{ck} permitted is 90N/mm^2, which corresponds to characteristic cube strength of 150N/mm^2 (Moss et.al, 2002). However, the data are obtained from Europe and the strength of cylinder test less than the corresponding cube test for material from Malaysia is unknown? This study will conducted to make a comparison of cylinder strength with cube strength using material from Malaysia.

The non-destructive tests used are mainly focus on rebound hammer test and Ultrasonic Pulse Velocity test in order to check the accuracy of these testing compared to the actual concrete grade by compressive strength test.

1.3 Objectives of Study

The objectives of this study are:

i. To determine the compressive strength of high strength concrete using British Standard and Eurocode approaches.
ii. To check the strength of concrete using non-destructive test.
iii. To compare the compressive strength of concrete using difference method of test.

1.4 Scope of Study

The scope is related to the materials and equipments that involved in this study and fulfill the requirement according to standards below:

i. The concrete grades covered are G40 and G50.
ii. The non-destructive test is mainly focus on rebound hammer test and Ultrasonic Pulse Velocity test.
iii. Method to cure the concrete is water curing.
iv. Testing will be carried out on 7 and 28 day age of concrete.
v. The testing will be carried out according to:

- C 192/C 192M – 05 Standard Practice for Making and Curing Concrete Test Specimen in the Laboratory.
- C 136 – 05 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
- C 19/C 39 M – 04a Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
- BS 1881: Part116: 1983 Concrete Compressive Test.
- BS 1881:Part202: 1986 Rebound Hammer Test.
- BS 1881:Part203:1986 Ultrasonic Pulse Velocity Test.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Construction achievement always associated with the availability of suitable material and its design. The recent tendency has been develop more accurate and elaborate method of design which effect saving material. Due to industrial demand and the development of high strength concrete have improved rapidly because the industrial demand of new features in concrete have improved rapidly because the industrial demand of new features in concrete member stiffness. The benefit of increased in compressive strength is lower volumes and produce smaller design in term of design perspectives (Jeffry, 2008)

In recent year, high strength concrete has rapidly used on the construction industry especially for buildings and infrastructures. The utilization of high strength concrete has been spurred on by the superior mechanical properties of the material and it cost-effectiveness. However, high strength concrete tends to be more brittle or less tough than normal strength concrete under compression load (Neville, 2002).

High strength concrete provides high compressive strength but lower the ductility than normal strength concrete. The low ductility and compressive strength can be increased by applied the confining reinforcement to the concrete under compression. However, these confining effects are most determined by experimental test. When the general view of studies is observed, many cases are found in which experimental results were investigated analytically and give a feedback between experiments and analyses.

In future, Eurocode 2 (EC2) will replace the existing British code BS8110 for the design of concrete structure. For example, EC2 allows benefits to derived from using high strength concretes, which BS8110 does not. Concrete strengths are referred to by cylinder strength, which are typically 10-20% less than the corresponding cube strengths (Moss et.al 2002).

2.2 History of Concrete

The word concrete comes from the Latin word "concretus" which mean "to harden". In Serbia, remains of a hut dating from 5600 BC have been found, with a floor made of red lime, sand, and gravel. The pyramids of Shaanxi in China, built thousands of years ago, contain a mixture of lime and volcanic ash or clay. The Assyrians and Babylonians used clay as cement in their concrete. The Egyptians used lime and gypsum cement.

According to-Rubin (2008), during the Roman Empire, Roman concrete made from quicklime, pozzolanic ash/pozzolana and an aggregate made from pumice was very similar to modern Portland cement concrete. The secret of concrete was lost for 13 centuries until in 1756, the British engineer John Smeaton pioneered the use of hydraulic lime in concrete, using pebbles and powdered brick as aggregate. Portland cement was first used in concrete in early 1840s.

In modern times, the use of recycled materials as concrete ingredients is gaining popularity because of increasingly stringent environment legislation. The most conspicuous of these is fly ash, a byproduct of coal fired power plants. This has a significant impact by reducing the amount of quarrying and landfill space required, and, as it acts as a cement replacement, reduces the amount of quarrying and landfill space required, and, as it acts as a cement replacement, reduces the amount of cement required to produce a solid concrete. As cement production creates massive quantities of carbon dioxide, cement replacement technology such as this will play a huge role in future attempts to cut CO_2.

The lightweight foam concrete has been discovered for a very long time ago. Two thousand years ago the Romans were making a primitive concrete mix consisting of small gravel and coarse sand mixed together with hot lime and water. They soon discovered that by adding anima blood into the mix and agitating it, small air bubbles were created making the mix more workable and durable (Aldridge, 2005).

2.2.1 Background of High-Strength Concrete

Although high-strength concrete is often considered a relatively new material, its development has been gradual over many years. As the development has continued, the definition of high strength concrete has changed. In the 1950s, concrete with a compressive strength of 34 MPa was considered high strength. In the 1960s, concrete with 41 and 52 MPa compressive strength were used commercially. In the early 1970s, 62 MPa concrete was being produced.

More recently, compressive strength approaching 138 MPa have been used in cast-in-place buildings. For many years, concrete with compressive strength in excess of 41 MPa was available at only a few location. However, in recent years, the applications of high-strength concrete have increased, and high-strength concrete has now been used in many parts of world. The growth has been possible as a result of recent developments in material technology and a demand for higher-strength concrete.

2.2.2 Advantages and Disadvantages of High-Strength Concrete

High strength concrete gives a lot of advantages in construction industry. It's provides an economical benefits as it used in a primary member such as structural members. Designer can design small size of structural member and ease the construction method. With an increase in concrete strength, the engineers can design a smaller member that carries the same amount of load. Hence, it's become more economical advantage and gives a lot of aesthetical values.

However, high strength concrete is brittle and will crack when it is under tension. Thus, it has lower ductility compare to normal strength concrete. Besides, careful materials selection is necessary these materials may need more materials in lower quality. Furthermore, allowable stress design stress design stress design discourages the use of high strength concrete and load factor and resistance design will be used. The used of load factor and resistance will increase the size of the high strength concrete member. High strength concrete-has more issue relating to the lack of performances standard because lack of control to maintained special properties required.

2.3 Material

The material that produced high strength concrete is fine aggregate, water, Portland cement and course aggregate. The proportion of mix design should be accurate to get the actual grade of high strength concrete designed.

2.3.1 Fine Aggregate

Natural materials such as river sand and crushed fine stone are generally used in concrete as fine aggregates. Most of the aggregates used in our country are river and sand as fine aggregates. Fine aggregate s used for concrete should conform to the requirements for the prescribed grading zone as per IS: 383 – 1970. The stone particles comprising the sand should be hard and sound. The sand particles should be near cubical or spherical in shape. They should not be covered with deleterious materials like clay slumps and should be clean. They should not contain organic or chemically reactive impurities.

Natural or river sand may not conform to all the above requirements and may have to be improved in quality. Improvements by washing, grading and blending may have to be done before use at consumer end. But, in the case of crushed stone sand / manufactured sand all these processes can be done in the plant itself and quality sand can be made available to the consumer directly by supplier.

2.3.2 Water

Water is the important factor to determine the strength of concrete. In construction work, extra in utilizing water is not efficient. Pouring and mixing concrete process will be and uncomplicated but the strength of concrete will become low. This situation affects the durability of concrete in future. Sea sand is totally cannot used because sea sand contain high value of salt. The kind of sand is not suitable for masonry construction because affect reinforcement bar of structure. The usage of sea sand also can expose a concrete structure to sulphate attack which can cause expansion, corrosion and cracking in concrete.

2.3.3 Portland Cement

The properties of concrete depend on the quantities and qualities of Portland cement. Because cement is the most active component of concrete and usually has the greatest unit cost, its selection and proper use are important in obtaining most economically the balance of properties desired for any particular concrete mixture.

Type I/II portland cements, which can provide adequate levels of strength and durability, are the most popular cements used by concrete producers. However, some applications require the use of other cements to provide higher levels of properties. The need for high-early strength cements in pavement repairs and the use of blended cements with aggregates susceptible to alkali-aggregate reactions are examples of such applications.

It is essential that highway engineers select the type of cement that will obtain the best performance from the concrete. This choice involves the correct knowledge of the relationship between cement and performance and, in particular, between type of cement and durability of concrete.

2.3.4 Coarse Aggregate

The grading and shape of coarse aggregates and maximum size of coarse aggregates have important effects on workability. The maximum size of coarse aggregate must be selected for each specific concrete condition. The choice will usually involve consideration of such factors as spacing of reinforcing bars, minimum width of form, and methods of placing and compacting the concrete mass.

2.4 European Standard

European Standard is containing common structural rules for the design of building and civil engineering structures.

2.4.1 History of European Standards

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonization of technical specifications. Within this action programme, the Commision took the initiative to establish a set of harmonized technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member State and ultimately, would replace them (European Committee for Standardization, 2002).

European programme, led the first generation of European codes in the 1980s. The Structural European programme comprises the following standard generally consisting of a number of Parts (European Committee for Standardization, 2002):

EN 1990 Eurocode 0: Basis of Structural Design
EN 1991 Eurocode 1: Actions on structures
EN 1992 Eurocode 2: Design of concrete structures
EN 1993 Eurocode 3: Design of steel structures
EN 1994 Eurocode 4: Design of composite steel and concrete structures
EN 1995 Eurocode 5: Design of timber structures
EN 1996 Eurocode 6: Design of mansory structures
EN 1997 Eurocode 7: Geotechnical design

2.4.2 Eurocode 2

Eurocode 2 (EC2) is a set of ten Eurocode programme in European Standards that contain the design standard for concrete structures.

EC2 gives many benefits such as less restrictive than British Standards, 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 public works must allow the Eurocodes to be used for structural design. 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. Other than that EC2 also give the economic benefit. It is expected that there will be material cost saving of between 0 and 5% compared to using BS 8110 (Moss et. al,2004).

2.4.3 Comparison between EC2 and BS8110

According to the grade of concrete, EC2 allows benefits to be derived from using high strength concretes, which BS8110 does not. Concrete strengths are referred to by cylinder strengths, which are typically 10-20% less than the corresponding cube strengths. The maximum characteristic cylinder strength, f_{ck} permitted is 90N/mm^2, which corresponds to characteristic cube strength of 150N/mm^2 (Moss et.al, 2002).

As with BS8110, EC2 uses a basic material partial safety factor, y_m for concrete of 1.5. Several years ago the material partial safety factor for reinforcing steel in BS8110 was reduced from 1.15 to 1.05. EC2 uses a value of 1.15 although this is subject to a National Annex. 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, fy_d will be virtually identical (Moss et.al, 2002).

In designing for fire and cover, EC2 does not considered this topic and in making comparisons between BS8110 and EC2 assumes that covers and dimensions of members are largely unaffected by the changed design process.