STUDY ON WORKABILITY AND STRENGTH OF FRESH AND HARDENED CONCRETE CONTAINING VARIOUS PERCENTAGE OF CHIPBOARD WASTE

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ABSTRACT

Nowadays, natural raw materials such as aggregate become more limited. It can be outlined that, the need for other materials from the waste industrial product as an alternative material to replace the natural materials in the concrete. It is an opportunity to study the effectiveness of waste industrial products as aggregate replacement. The use of chipboard waste as the replacement in concrete is one of the alternatives and also environmental friendly. The objectives of this study are to determine the workability of fresh concrete, compressive strength and the splitting tensile strength of hardened concrete. In this study, the mixed of concrete used in this research is for grade 35 N/mm^2 and the water/cement ratio is 0.53. 36 numbers of cubes and 12 numbers of cylinder sample is prepared. Four different mix proportions of 0%, 5%, 15% and 25% by weight of chipboard was designated as Sample A, Sample B, Sample C and Sample D respectively. Concrete containing chipboard were classifies as medium workability. The compressive strength of concrete containing 0 %, 5 %, 15 % and 25 % of chipboard waste were 29.82 N/mm^2, 27.17 N/mm^2, 16.35 N/mm^2 and 6.51 N/mm^2 respectively and the tensile strength were 2.73 N/mm^2, 2.48 N/mm^2, 1.56 N/mm^2 and 0.94 N/mm^2 at age of 28 days.

ABSTRAK

Pada masa kini, bahan-bahan mentah semulajadi seperti batu baur semakin terhad. Ini boleh dikatakankan, keperluan bahan lain seperti produk daripada sisa industri boleh dijadikan sebagai bahan alternatif untuk menggantikan bahan semulajadi di dalam konkrit. Ia merupakan satu peluang untuk mengkaji keberkesanan bahan buangan industri sebagai pengganti batu baur. Penggunaan sisa 'chipboard' sebagai pengganti di dalam konkrit adalah salah satu alternatif dan juga mesra alam. Objektif kajian ini adalah untuk menentukan kebolehkerjaan konkrit, kekuatan mampatan dan kekuatan tegangan pecah konkrit. Dalam kajian ini, campuran konkrit yang digunakan dalam adalah gred 35 N/mm^2 dan nisbah air / simen adalah 0.53. 36 sampel kiub dan 12 sampel silinder disediakan. Empat campuran yang mengandungi kandungan berbeza 0%, 5%, 15% dan 25% dari berat 'chipboard' telah dilabelkan sebagai Sampel A, Sampel B, Sampel C dan Sampel D. Konkrit yang mengandungi 'chipboard' telah diklasifikasikan didalam konkrit kebolehkerjaan sederhana. Kekuatan mampatan konkrit yang mengandungi 0 %, 5 %, 15 % dan 25 % ‘chipboard’ adalah 29.82 N/mm^2, 27.17 N/mm^2, 16.35 N/mm^2 dan 6.51 N/mm^2 dan kekuatan tegangan adalah 2.73 N/mm^2, 2.48 N/mm^2, 1.56 N/mm^2 dan 0.94 N/mm^2 pada usia 28 hari.

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LIST OF ABBREVIATIONS

POFA	=	Palm Oil Fuel Ash
PWD	=	Public Work Department
IS	=	India Standard
BS	=	British Standard
MS	=	Malaysia Standard
OPC	=	Ordinary Portland Cement
WWA	=	Wood Waste Ash
f_{cm}	=	Compressive Strength
f_{ck}	=	Characteristic Strength
f_c	=	Non-Linear Stress
ε_c	=	Strain
E_c	=	Modulus of Elasticity
Al^2O^3	=	Aluminum Oxide
CaO	=	Calcium Oxide
Fe^2O^3	=	Ferric Oxide
MgO	=	Magnesium Oxide
Na_2O	=	Sodium Oxide
SiO_2	=	Silicon Dioxide
kN/m^3	=	Kilo-Newton per meter cube
kg	=	Kilogram
N/mm^2	=	Newton per millimeter square
mm	=	millimeter
µm	=	micrometer
m^3	=	meter cube
s	=	seconds

CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete is a material used in building construction, which consisting of an aggregate, which is bonded together by cement and water. Concrete has unlimited opportunities for innovative applications and construction techniques. Its great versatility and relative economy in filling a wide range of needs has made it is very competitive building material (Sashidar & Sudarsana Rao, 2010). The production of good concrete is reviewed regularly to ensure quality of the concrete is always in good condition. The uses of certain additives are seen could help to improve the quality of concrete than the conventional mixing methods. The concrete with high performance criteria can provide a big impact on the construction industry in Malaysia.

The Assyrians and Babylonians used clay as the bonding substance or cement. The Egyptians used lime and gypsum cement. In 1756, British engineer, John Smeaton made the first modern concrete (hydraulic cement) by adding pebbles as a coarse aggregate and mixing powered brick into the cement. In 1824, English inventor, Joseph Aspdin invented Portland cement, which has remained the dominant cement used in concrete production. Joseph Aspdin created the first true artificial cement by burning ground limestone and clay together. The burning process changed the chemical properties of the materials and Joseph Aspdin created stronger cement than what using plain crushed limestone would produce.

The usual primary requirement of good concrete is a satisfactory compressive strength in its hardened state. Besides that, good concrete having fluidity suitable to works is homogenous and unlikely to segregate. Concrete can be divided into normal concrete, lightweight concrete, first and second class concrete based on the aggregate used. Furthermore, concrete also can be classified into winter concreting, hot-weather concreting, lightweight concrete, pre-cast concrete, mass concrete, watertight concrete and underwater concrete based on materials used, construction condition and the required efficiency.

With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable for a situation. Added to this is the necessity to combat the increasing cost and scarcity of cement. Under these circumstances the use of admixtures is found to be an important alternative solution (Sashidar & Sudarsana Rao, 2010)

The use of materials that can be classified as waste materials can be used as a replacement to concrete raw materials. Some examples of waste material such as chipboard, rice husk, palm oil fuel ash (POFA) and fly ash. This research was to study on the properties of fresh and hardened concrete of concrete containing 0%, 5%, 15%, and 25% of chipboard waste.

1.2 Problem Statement

Generally, by products and waste materials are available in large quantity in industrial such as furniture in Malaysia. This industry has led to numerous production and disposal of industrial waste.

The statistic from Terang Bersih Sdn Bhd, a waste management disposal company in Kuantan, almost 10,000 tonnes of chipboard waste was produced in Kuantan and disposed at Jabor landfill, Kuantan. The chipboard waste is differing than paper or plastic waste. The paper and plastic waste has a way to recycle, but not the chipboard waste. In the other word, this chipboard waste should be managed properly or re-use the waste to produce another product.

It revealed that, natural raw materials that become more limited such as aggregate. It can be outlined that, the need for other alternative materials from the waste industrial product as an alternative material to replace natural materials. To face this problem, it is an opportunity to study the effectiveness of these waste industrial products as an aggregate replacement within the suitable percent chipboard waste.

With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable for a situation. Added to this is the necessity to reduce the increasing cost and scarcity of aggregate. Under these circumstances the use of replacement is found to be an important alternative solution. Hence an attempt has been made in the present investigation to study chipboard waste replacement in concrete.

The use of chipboard waste as the replacement in concrete also environmental friendly because it uses the waste material and can reduce the space at the landfill and it can increase the expected life of the landfill.

1.3 Objective

The objectives of this research are as follows;

i. To determine the workability of fresh concrete containing different percentages of chipboard waste.

ii. To determine the compressive strength of concrete containing 0 %, 5 %, 15 % and 25 % of chipboard waste.

iii. To determine the splitting tensile strength of concrete containing 0 %, 5 %, 15 % and 25 % of chipboard waste.

1.4 Scope of Study

The research was done to determine the suitability percentage of chipboard waste to replace in concrete mix. The chipboard waste used in this study was taken from Jabor Landfill in Kuantan, Pahang.

The main focus in this research is to review the workability of fresh concrete and the compressive strength and splitting tensile strength of hardened concrete. For the fresh concrete, the tests that were involved are slump test, compaction factor test and VEBE test. Meanwhile for hardened concrete, the experiments that were involved are concrete compression test and splitting tensile test. Strength is one of the most important properties of concrete, since the first consideration in structural design is that the structural element must be capable of carrying the imposed loads. Furthermore, strength characteristic is also vital because it is related to several other important properties which are more difficult to measure directly.

According to this matter, the workability of fresh concrete and strength characteristic of hardened concrete is studied. The mixed of concrete used in this research is for grade 35 N/mm^2. The Concrete grade 35 N/mm^2 is most commonly used grade in the Public Work Department (PWD) projects. The Concrete mixing ratio for 35 N/mm^2 grade concrete as per IS (India Standard) Mix design is 1:1.6:2.9 (cement : fine aggregate : coarse aggregate). The ratio obtained is as per design calculations by considering the grade of aggregates and the type of cement used. The Water/cement ration is 0.53. For the sample collection, 36 numbers of cube samples with dimension 150 mm x 150 mm x 150 mm and 12 numbers of cylinder sample with dimension of 150 mm x 500 mm was prepared. Four different mix proportions of 0 %, 5 %, 15 % and 25 % of chipboard was designated as Sample A, Sample B, Sample C and Sample D respectively. Mix proportion of 1 m^3 sample as illustrated in Table 1.1

Table 1.1: Mix Proportion of 1 m^3 Sample

Material	Sample A	Sample B	Sample C	Sample D
Cement (kg)	350	350	350	350
Coarse Aggregate (kg)	1185	1125.75	1007.25	888.75
Chipboard Waste (kg)	-	59.25	177.75	296.25
Fine Aggregate (kg)	725	725	725	725
Water (kg)	127.27	127.27	127.27	127.27

All the concrete specimens are cured by immersion in water at room temperature. Concrete tests are conducted on the concrete specimen at the specific ages. All the strength tests are limited to the ages of 7, 14 and 28 days after production of the specimens.

The standards that were used as reference in this research are:

i. BS 1881: Part 102:1983 for Slump Test
ii. BS 1881: Part 104:1983 for Vebe Time Test
iii. BS 1881: Part 103:1983 for Compacting Factor Test
iv. BS 1881: Part 116:1983 for Concrete Compression Test
v. BS 1881: Part 117:1983 for Split Cylinder Test

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many studies already carried out on the use of wastes as innovative construction materials have been very encouraging: Ash from sludge, oil-palm, and municipal solid wastes have been used as concrete materials (Berg & Neal, 1998; Tay et al., 2000), coal fly ash and rice husk ash have also been used as a pozzolan to improve the properties of Ordinary Portland Cement (OPC) concrete (Jauberthie et al., 2000), and recent studies on the use of sawdust ash in concrete have shown that inclusion of the material in the matrix may not only lower the cost of concrete but also offer a large potential market for the utilization of wood waste ash (WWA) concrete as a cost-effective alternative to current disposal methods of the waste (Udoeyo & Dashibil, 2002).

Some industrial by products such as furniture industry have led to numerous production and disposal of chipboard waste. In the other word, this industrial waste should be managed properly or re-use the waste to produce another product. The enormous amount of wastes produced during furniture processing operations provides opportunities for the use of chipboard waste as a construction material. In this research, the chipboard waste of 0 %, 5 %, 15 % and 25 % by weight of concrete was added as a replacement to a concrete and the workability and physical strengths of fresh and hardened concrete was evaluated.

2.2 Major Solid Waste and The Potential Use in Construction

Growth of population, increasing in urbanization, and rising in standards of living due to technological innovations have contributed to increase the quantity of a variety of solid wastes generated by industrial, domestic and agricultural activities. The estimated quantity of solid waste generation was 12 billion tons in the year 2002 (Pappu et al., 2007). Among this amount, 11 billion tons were industrial solid wastes and 1.6 billion tons were municipal solid wastes.

19 billion tons of solid wastes are expected to be generated annually by the year 2025 (Yoshizawa et al., 2004). In Asia, it generates 4.4 billion tons of solid wastes. About 6% of this amount is generated in India (Yoshizawa et al., 2004).

The major solid wastes are generated in Malaysia are from agricultural, industrial, municipal and mining sources. Malaysia is expected to exceed 15,000 tons of solid wastes generation daily.The disposal of these wastes has become a major environmental problem in Malaysia and thus the possibility of recycling the solid wastes for use in construction materials is of increasing importance.

The recycling of solid wastes in civil engineering applications has undergone considerable development over a very long time. The uses of different types of solid waste in construction materials are shown in Table 2.1.

Table 2.1: Types of Solid Waste in Construction

No.	Name of waste	Type of waste	Use in construction materials
1	Fly ash, bottom ash, rice husk ash, palm oil fuel ash, organic fibres	Agro-industrial	Aggregate, concrete, supplementary cementing materials, blended cement, bricks, tiles, blocks, particle boards, insulation boards, cement boards, wall panels, roof sheets, reinforced polymer composites
2	Phosphogypsum, waste glass, granulated blast-furnace slag, waste steel slag, rubber tire	Industrial	Fine and coarse aggregates, blended cement, concrete, bricks, blocks, tiles, ceramic products.
3	Quarry dust	Mining/mineral	Fine and coarse aggregates, concrete, bricks, tiles, blocks, surface finishing materials
4	Construction and demolition debris (concrete rubble, tiles, waste bricks, etc.)	Industrial	Fine and coarse aggregates, concrete, bricks, blocks, sub-base pavement materials

2.3 Chipboard

Chipboard is wood product made from wood waste. To transform chipboard from wood waste into a usable product requires several steps during the manufacturing process. Typically saw dust and wood chips that are produced during the manufacture of other wood products are the raw materials used for manufacturing chipboard. Chipboard is made up from wood chips which bound together with resin and pressed into a flat and rectangular shape. Pieces of wood that is too small, warped, or otherwise defective for use as lumber are splintered into small chips, and mixed with sawdust. The mixture is then heat-formed under pressure to create a smooth and rigid board.

2.3.1 Advantages of Chipboard

The advantage most often cited about chipboard is lower cost. While the initial purchase price of the board itself is only slightly lower than that of comparable plywood, chipboard surface is smoother and the texture allow builders to save money on tooling, while providing a ready-to-laminate surface. Because the wood fibres are not running uniformly down the length of the wood, chipboard is more resistant to warping, and not splinter. Chipboard is available with a flame-retardant treatment, and high-density chipboard can have a water-resistant treatment.

2.3.2 Disadvantages of Chipboard

Normal and medium-density chipboards are not water resistant. When it gets wet, the normal and medium-density chipboard soaks up water due to capillary action of the wood fibres. This causes the wood fibres to swell, and the board appears bumpy and rough. Because the board is made of many small chips, there are many more open fibre ends to soak in water. Because the fibres are in pieces instead of continuous as in solid wood, they don't work together to provide strength. Instead, water-logged fibres are weakened and the board breaks easily.

2.4 Concrete

Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. Concrete has unlimited opportunities for innovative applications, design and construction techniques. Its great versatility and relative economy in filling a wide range of needs has made it is a very competitive building material.

2.4.1 Properties of Fresh and Hardened Concrete

Workability, segregation and bleeding are addressed among the properties of fresh concrete. Among hardened concrete properties are compressive strength and tensile strength.

2.4.1.1 Workability

Workability is often defined the amount of energy, or work, required to fully compact concrete without segregation. This is important for the final strength is a function of compaction. Workability of concrete generally implies the ease with which mix can be handled from the mixer to its finally compacted shape. The measurement of the workability of fresh concrete is of importance in assisting the practicability of compacting the mix and also in maintaining consistency throughout the job. In addition, workability tests are often used as an indirect check on the water content and therefore on the water/cement ratio of concrete. Workability should be distinguished from consistency which term as used in concrete practice, relates to the degree of wetness of concrete. On the other hand, consistency has to do with the force flow relationship alone.

2.4.1.2 Segregation

Segregation refers to a separation of the components of fresh concrete, resulting in a non-uniform mix. This can be seen as a separation of coarse aggregate from the mortar, caused from either the settling of heavy aggregate to the bottom or the separation of the aggregate from the mix due to improper placement.

2.4.1.3 Bleeding

Bleeding is defined as the appearance of water on the surface of concrete after it has consolidated but before it is set. Since mixing water is the lightest component of the concrete, this is a special form of segregation. Bleeding is generally the result of aggregates settling into the mix and releasing their mixing water. Some bleeding is normal for good concrete.

If bleeding becomes too localized, channels form resulting in "craters". The upper layers become too rich in cement with a high water cement ratio causing a weak, porous structure. Salt may crystallize on the surface which affects bonding with additional lifts of concrete. This formation should always be removed by brushing and washing the surface. The water pockets may form under large aggregates and reinforcing bars reducing the bond.

2.4.1.4 Strength of Concrete

The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested at 28 days. The characteristic strength is defined as the strength of the concrete below which not more than 5 % of the test results are expected to fall. This concept assumes a normal distribution of the strengths of the samples of concrete.

The following sketch shows an idealized distribution of the values of compressive strength for a sizeable number of test cubes. The horizontal axis represents the values of compressive strength. The vertical axis represents the number of test samples for a particular compressive strength. This is also termed as frequency. The average of the values of compressive strength (mean strength) is represented as f_{cm}. The characteristic strength (f_{ck}) is the value in the x-axis below which 5 % of the total area under the curve falls. The value of f_{ck} is lower than f_{cm} by

1.65σ, where σ is the standard deviation of the normal distribution. Figure 2.1 shows idealized normal distribution of concrete strength.

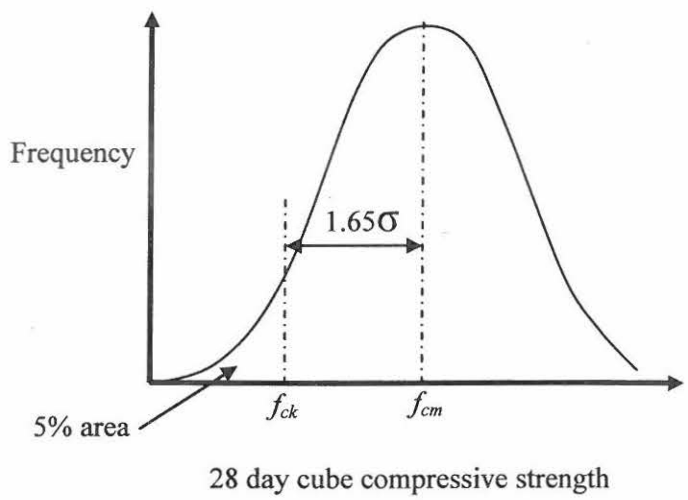

Figure 2.1: Idealized Normal Distribution of Concrete Strength

2.4.1.5 Stiffness of Concrete

The stiffness of concrete is required to estimate the deflection of members. The stiffness is given by the modulus of elasticity. For a non-linear stress (f_c) versus strain (ε_c) behaviour of concrete the modulus can be initial, tangential or secant modulus.

IS:1343 - 1980 recommends a secant modulus at a stress level of about $0.3f_{ck}$. The modulus is expressed in terms of the characteristic compressive strength and not the design compressive strength. The following figure shows the secant modulus in the compressive stress-strain curve for concrete.

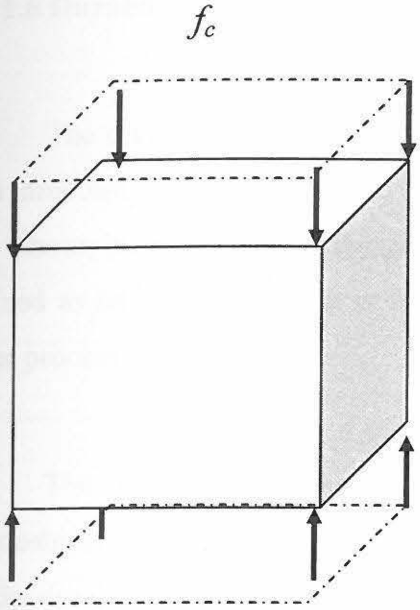

Figure 2.2: Concrete Cube Under Compression

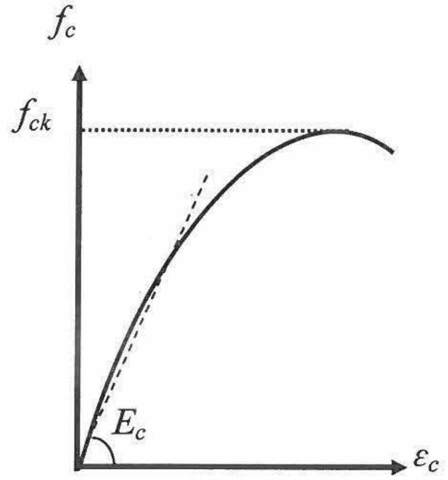

Figure 2.3: Compressive Stress-Strain Curve for Concrete

The modulus of elasticity for short term loading (neglecting the effect of creep) is given by the Equation 2.1.

$$E_c=5000\sqrt{f_{ck}} \quad \text{-----------} \quad \text{(Equation 2.1)}$$

Here,

E_c = short-term static modulus of elasticity in N/mm^2

f_{ck} = characteristic compressive strength of cubes in N/mm^2.

2.4.1.6 Durability of Concrete

The durability of concrete is of vital importance regarding the life cycle cost of a structure. The life cycle cost includes not only the initial cost of the materials and labour, but also the cost of maintenance and repair. The durability of concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration.

The durability of concrete is intrinsically related to its water tightness or permeability. The selection of proper materials and good quality control are essential for the durability of concrete.

2.4.1.7 Impermeability

Impermeability is the resistance of the concrete to the flow of water through the pores. The excess water during concreting leaves a large number of continuous pores leading to permeability. Since permeability reduces the durability of concrete, it should be kept very low by using low water-cement ratio, dense and well-graded aggregates, proper compaction and continuous curing at low temperature conditions. The cement content should be sufficient to provide the adequate workability with a low water cement ratio and with the available compaction method.

2.5 Effect of Chipboard to Workability of Fresh Concrete

Chipboard concrete mixes exhibit less workability than that of plain concrete of the same water-cement ratio, and increases with higher content of chipboard (Felix F. Udoeyo, 2006). The characteristic of the chipboard is absorbing the water and the more percentage of chipboard was replaced in concrete, it becomes quite difficult to compact and the surface on the cube cannot be flattened out well because the reduction of water was occurred. Lack of water also causes compacted concrete is difficult because there are spaces between the chipboard and aggregate (Rohazak, 2011).

According to Norshafida, 2009, the vebe time was increased due to lack of water in the mixture, causing the volume of concrete is less dense as chipboard absorbs water during the process of the concrete mix. When a higher percentage of chipboard waste is used, the compacting factor becomes decrease. The compaction factor is decreasing because when more chipboard was added, it reduces the quantity of water in the mixed due to the chipboard is absorbing water and the concrete become didn't compact and the density of concrete also decreases (Rohazak, 2011).

The stickiness of the concrete mix with replacement of chipboard causes the lower workability compare with pure concrete mix. The more content of chipboard in concrete, can make the concrete contain less water because the chipboard absorbing water too much (Yong Woo Soon, 2009). The shapes of particles influence cement hydration with surface/ volume ratio relative to spherical particles results in greater rates of hydration (Jeffrey & Edward, 2006).

2.6 Effect of Chipboard to Concrete Strength

The compressive strength generally increases with age but decreases with increases in the chipboard content. Comparisons of the strength of chipboard concrete with those of the control concrete of corresponding ages show that the strength of chipboard concrete is generally less than those of the plain concrete (Hilary Inyang, 2006). The compressive strength of chipboard concrete decreases with an increase in chipboard content (David T. Young, 2006).

According to Elinwa and Mahmood, 2002, findings that show the use of chipboard as a partial replacement material in concrete at all levels of replacement ranged between 5 % and 30 % it reduces the compressive strength of the concrete mix produced relative to neat concrete for all curing times.