Effect of Non-Ground Copper Slag on Properties of Concrete

by

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the requirements for the
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ABSTRACT

Copper slag is material that widely used in blasting to prepare the steel for painting purposes. Major problem that arise regarding this materials are the way to dispose this material. Thus, this research was carried out to study the potential of copper slag as cement on properties of the concrete. Mortar specimen with non-ground copper ranging from 0% to 30% of cement weight were tested to determine the compressive strength, tensile strength, and permeability of the concrete. Results demonstrated that there is general an increase in the density and workability of concretes as copper slag quantity increases. Also results showed that the compressive strength of concrete is generally improved, compared with the control mix, with the increase of copper slag up to a certain copper slag content beyond which the strength generally reduces.

Keywords:
copper slag, fine aggregate, concrete, strength, compressive strength, tensile strength.

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Last but not least, I would like to give my special thanks to my family members for their priceless support, encouragement, constant love, valuable advices, and their understanding along this research were carried out.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Copper slag is used in shot blasting to prepare steel surface for painting. The widespread use of leas and other heavy metals in protective paints increases heavy metals in used slag, which is classified as a solid or hazardous waste. Landfill disposal of copper slag is not feasible since a few hundred tones are produces per year per factory. See ***Figure A*** in appendix.

Many investigations relating to the disposal of industrial by-products in concrete have been actively pursued. Theoretically, the disposal of this waste by adding into the concrete can reduce the number of pollution related to the copper slag. However, the research on copper slag has not been extensive. Basically, copper slag has been used as aggregates and back failing material. A few studies have been performed to investigate the stabilization of heavy metal present in copper slag within the cement matrix.

1.2 PROBLEM STATEMENT

Copper slag is one the waste that been categorized as heavy metal. Generally, this material can be found at fabrication yard especially at Malaysian Marine and heavy Engineering (MMHE). Statistically, the amount usage of copper slag had increase day by day without proper disposal.

Thus, this research is to study the effect of the copper slag on the properties of concrete as one of the method to dispose this material.

1.3 OBJECTIVE AND SCOPE OF STUDY

The objectives of this thesis that need to be achieved by the end of the project are:

1. To determine the effect of non-ground copper slag on the properties of concrete.
2. To compare the strength, tensile and porosity of concrete by replacing some portion of cement with copper slag ranging of 0% to 30%.
3. To compare the effect between non-ground and ground copper slag on the properties of concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 COPPER SLAG

Copper slag from a metal fabricating company at Pasir Gudang in Johor was used; its chemical composition ad physical properties are listed in **Table 2.1.** Physically it is angular, black, glassy and shiny with sharp edges.

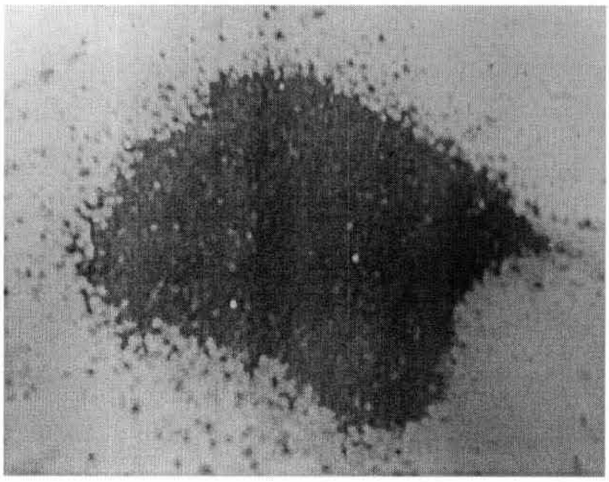

Figure 2.1: Copper slag

As a general rule, the specific gravity will vary with iron content, from a low of 2.8 to as high as 3.8.The unit weight of copper slag is somewhat higher than that of conventional aggregate. The absorption of the material is typically very low (0.13 percent).

Granulated copper slag is more porous and therefore has lower specific gravity and higher absorption than air-cooled copper slag. The granulated copper slag is made up of regularly shaped, angular particles, mostly between 4.75 mm (3/4 in) and 0.075 mm (No. 200 sieve) in size.

Table 2.1: Material composition of copper slag and cement

ITEM	MATERIAL	
	CEMENT	COPPER SLAG
Chemical composition (%)		
Silica	20-25	11.9
Calcium oxide	Min 62.0	2.65
Alumina	4.8-6.0	1.56
Iron oxide	2.4-4.5	73.6
Magnesium oxide	Max 3.5	0.302
Sulfuric anhydrite	2.1-2.4	0.554
CuO	-	2.83
K2O	-	1.13
PbO	-	0.376
ZnO	-	1.91
TiO2	-	0.566
Cr2O3	-	0.0564
MnO	-	0.104
As2O3	-	0.256
SrO	-	0.0804
ZrO2	-	0.0753
MoO3	-	0.808
Tb4O7	-	0.221
Re	-	0.624
Os	-	0.0148

2.2 ORDINARY PORTLAND CEMENT

Ordinary Portland Cement (OPC) is the most common cement used in general concrete construction when there is no exposure to sulphates in the soil or groundwater. Ordinary portland cement is a gray coloured powder. It is capable of bonding mineral fragments into a compact whole when mixed with water. This hydration process results in a progressive stiffening, hardening and strength development.

It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate which controls the set time, and up to 5% minor constituents (as allowed by various standards). As defined by the European Standard EN197.1, "Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates ($3CaO.SiO_2$ and $2CaO.SiO_2$), the remainder consisting of aluminium- and iron-containing clinker phases and other compounds. The ratio of CaO to SiO_2 shall not be less than 2.0. The magnesium content (MgO) shall not exceed 5.0% by mass." (The last two requirements were already set out in the German Standard, issued in 1909). Portland cement clinker is made by heating, in a kiln, a homogeneous mixture of raw materials to a sintering temperature, which is about 1450 °C for modern cements. The aluminium oxide and iron oxide are present as a flux and contribute little to the strength.

For special cements, such as Low Heat (LH) and Sulfate Resistant (SR) types, it is necessary to limit the amount of tricalcium aluminate ($3CaO.Al_2O_3$) formed. The major raw material for the clinker-making is usually limestone ($CaCO_3$). Normally, an impure limestone which contains SiO_2 is used. The $CaCO_3$ content of these limestones can be as low as 80%. Secondary raw materials (materials in the rawmix other than limestone) depend on the purity of the limestone. Some of the secondary raw materials used are: clay, shale, sand, iron ore, bauxite, fly ash and slag. When a cement kiln is fired by coal, the ash of the coal acts as a secondary raw material.

2.3 X-RAY FLUORESCENCE (XRF) TESTING

Energy dispersive X-ray fluorescence technology (ED-XRF) provides one of the simplest, most accurate and most economic analytical methods for the determination of the chemical composition of many types of materials. It is non-destructive and reliable, requires no, or very little, sample preparation and is suitable for solid, liquid and powdered samples. It can be used for a wide range of elements, from sodium (11) to uranium (92), and provides detection limits at the sub-ppm level; it can also measure concentrations of up to 100% easily and simultaneously.

XRF is an elemental analysis technique with unique capabilities including (1) highly accurate determinations for major elements and (2) a broad elemental survey of the sample composition without standards. For example, XRF is used in analysis of rocks and metals with an accuracy of ~0.1% of the major elements. A technique known as Fundamental Parameters can estimate the elemental composition of unknowns without standards. And to top it all off, sometimes the analysis requires minimal sample preparation.

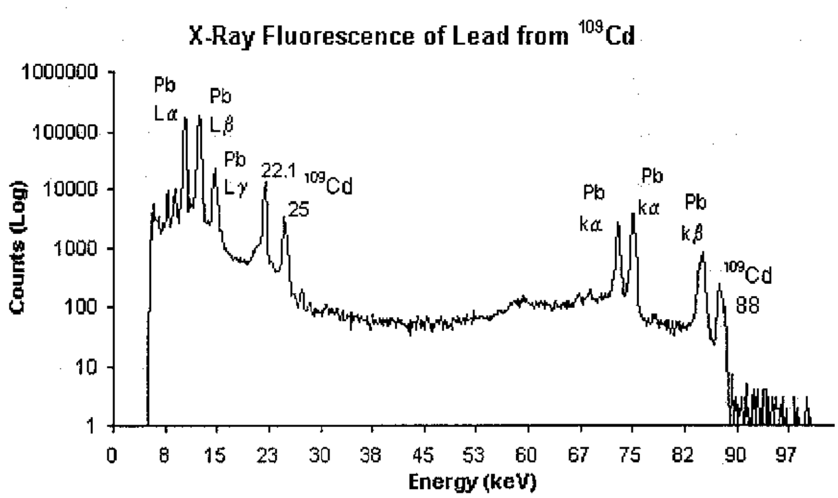

Figure 2.2: X-ray Fluorescence (XRF)

2.4 COMPRESSION TEST

Compressive strength is the capacity of a material to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed. By definition, the compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely.

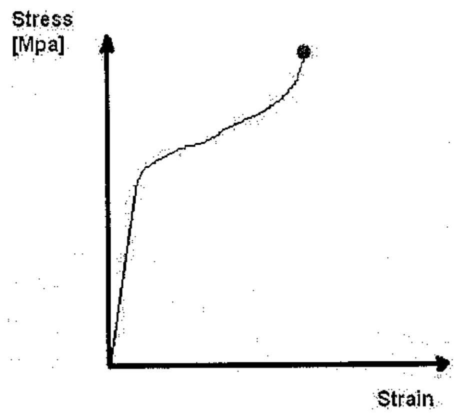

Figure 2.3: Graph of stress versus strain

The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (Usually cylindrical) is shortened as well as spread laterally. A Stress–strain curve is plotted by the instrument and would look similar to the following:

2.5 TENSILE TEST

ASTM C 496 gives required requirement for the testing apparatus, test specimen geometry and load application for determining splitting tensile strength of cylinder test specimen. The testing machine should meet the requirement of ASTM

C 39. The specimen is placed on its side and subjected to a diametral compressive force along its length. If either the upper or lower bearing block of the testing machine is shorter than the cylinder, a bearing bar or plate shall be used that is at least as thick as the distance from the edge of the machine bearing block to the end of the cylinder at least 51 mm wide, and within 0.001 in 0.025 mm of plainness. Bearing strip at least as long as the cylinder and 1/8 in 3.2 mm thick and 25 mm wide shall be placed between the specimen and the loading faces. The load should be applied at a rate of between 686 bad 1380 kPa/min splitting tensile stress.

Failure of these specimens occurs along a vertical place containing the specimen axis and the applied load. The load configuration of this test method induced tensile stresses along the failure plane over approximately two-third to three-fourth of the specimen diameter. The regions of the specimen in the vicinity of the loading strips are subjected to large compression force. However, tensile rather than compressive failure occurs because the stress state at the loading strips is triaxial compression, allowing the concrete to resist higher compressive stresses.

2.6 POROSITY TEST

There are various methods available that have been used to study the pore structure of concrete and mortar, in a broad sense they can be divided into two categories.

- Indirect or Bulk Methods
- Direct Methods

Indirect methods generally give information about the average picture of the whole microstructure of concrete or mortar, on the other hand the direct methods demonstrate the way in which different component phases are arranged in the microstructure. However, there are certain limitations and advantages of each method and technique.

2.6.1 VACUUM SATURATION TECHNIQUE

The total porosity of a porous material, such as concrete, is defined as the fraction of the bulk volume occupied by the voids. The voids may be filled with air and/or water depending upon the degree of pore saturation. For a partially saturated condition, the total porosity is the combination of the part of water filled and air filled voids usually termed as open porosity [Cabrera and Hassan, 1997], which corresponds to the term of empty porosity as used by Ujike and Nagataki (1988).

There are number of methods used to determine the total porosity of concrete and mortar, however, the technique of vacuum saturation is perhaps the simplest, cheap and direct method of measurement. Although the vacuum saturation of concrete is not widely used, evidence shows that the method is gaining acceptance because of providing a closed approach to total or full saturation in a relatively short time period [Cusens and Cabrera, 1987].

2.6.2 Calculation of Porosity

The total porosity (P) and the open porosity (V_e) of concrete and mortar samples were calculated using the following equations [Cabrera and Hassan, 1997].

$$P = \frac{W_{SA} - W_d}{W_{SA} - W_{SW}} 100$$

(6.1)

$$V_e = P\left(1 - \frac{S}{100}\right)$$

(6.2)

Where:

P = Total porosity (%)

V_e = Open porosity (%)

S = Degree of saturation (%)

W_{SA} = Weight of saturated surface dry samples in air (g)

W_{SW} = Weight of saturated surface dry samples in water (g)

W_d = Weight of oven dry samples (g)

CHAPTER 3

METHODOLOGY AND PROJECT WORK

3.1 RESEARCH

At the beginning of the project, author has conducted research by referring to the journal, books and also web. Besides, the author also makes some discussion with Miss Fatin Nabilah, one of the FYP students who are using the same material. For further information regarding the material use, the author has managed a discussion with in charge person at Malaysian Marine and Heavy Engineering (MMHE).

3.2 SET UP THE RAW MATERIAL

One of the main important parts of the project is to set up all the material before mixing take place. To ensure the schedule is one time, the author had organized a trip to MMHE in order to take 400 kg of copper slag. This is because, copper slag is the main material needed in this project.

Beside, the author investigates the place to find the raw material are hardware shop(sand) ,market(jut bag) ,quarry(coarse aggregate) and some raw material already available at lab are grease, cement and others equipment.

3.3 DETAIL OF MIXING SCHEDULED

Table 3.1: Mixing schedule

NO.	PERCENTAGE	DATE
1	Control	22-Aug-07
2	95% of cement + 5% of CS	22-Oct-07
3	90% of cement + 10% of CS	4-Nov-07
4	85% of cement + 15% of CS	15-Jan-08
5	80% of cement + 20% of CS	16-Jan-08
6	75% of cement + 25% of CS	17-Jan-08
7	70% of cement + 30% of CS	18-Jan-08

3.4 CALCULATION AND MIX PROPORTIONAL

Before the author start the project and the laboratory, the author do the calculation to determine the mixing proportional The mix proportions are done by referring to the literature review and discussion with supervisor. This design is very important before the author can proceed to the next step. Based on the mix design, the author can determine the proportion of aggregate, cement, water and copper slag.

Calculation

Characteristic Strength	:	Compressive 50 N/mm^2 at 28 days
	:	Proportion defective 1 percent
Standard deviation	:	5 N/mm^2
Margin	:	(k=2.33) 2.33 x 5 = 11.6 N/mm^2
Target mean strength	:	50 + 11.6 = 62 N/mm^2
Cement type	:	OPC
Aggregate type: coarse	:	Crushed
Aggregate type: fine	:	Uncrushed
Free water cement ratio	:	0.46
Maximum free-water/cement ratio	:	0.45
Slump	:	Slump 60-180 mm
Maximum aggregate size	:	20 mm
Free water content	:	205kg/m^3
Cement content	:	205 / 0.45 = 455 k/m^3
Maximum cement content	:	-
Minimum cement content	:	370 kg/m^3
Relative density of aggregate (SSD)	:	2.9
Concrete density	:	2733 kg/m^3
Total aggregate content	:	2733 – 455 - 205 = 2073 kg/m^3
Grading of fine aggregate	:	Zone 2
Proportion of fine aggregate	:	40 percent
Fine aggregate content	:	2073 x 0.4 = 829.2 kg/m^3
Coarse aggregate content	:	2073-829.2 = 1243.8 kg/m^3

For cube

Size : 150 x 150 x 150 mm

Total sample : 105 samples

Table 3.2: Mix proportional for cubes

per m³	COPPER (KG)	CEMENT (KG)	WATER (KG)	FINE AGGREGATE (KG)	COURSE AGGREGATE (KG)
		455	205	829	1243
	PER TRIAL MIX = 0.07 m³				
Mix 1	0	32.0	14	58	87
Mix 2	1.6	30.4	14	58	87
Mix 3	3.2	28.8	14	58	87
Mix 4	4.8	27.2	14	58	87
Mix 5	6.4	25.6	14	58	87
Mix 6	8.0	24.0	14	58	87
Mix 7	9.6	22.4	14	58	87

For split slender

Size : 100 x 200 mm

Total sample : 63 samples

Table 3.3: Mix proportional for cylinders

per m³	**COPPER (KG)**	**CEMENT (KG)**	**WATER (KG)**	**FINE AGGREGATE (KG)**	**COURSE AGGREGATE (KG)**
		455	205	829	1243
	PER TRIAL MIX = 0.02 m³				
Mix 1	0	9.10	4.1	17	25
Mix 2	1.6	8.65	4.1	17	25
Mix 3	3.2	8.19	4.1	17	25
Mix 4	4.8	7.74	4.1	17	25
Mix 5	6.4	7.28	4.1	17	25
Mix 6	8.0	6.83	4.1	17	25
Mix 7	9.6	6.37	4.1	17	25

3.5 CONCRETE MIXING

All concrete should be mix thoroughly until it is uniform .The sequence of concrete mix is very important and it must be followed accordingly. It must be follow by the BS 1881 Part 125:1986)

1. Wetted the mixer with water
2. Pour all coarse and fine aggregates into the mixer and mix for 25 seconds to ensure uniform distribution between both materials.
3. Add half of the water and mix for 1 minute.
4. Leave the mixes for 8 minutes to let both coarse and fine aggregates to absorb water.
5. Add cement into the mixer and mix for 1 minute.
6. Add remaining water available and mix for 1 minute.
7. Stop the machine and do hand mixing to ensure homogeneity.
8. Pour the concrete onto the non porous surface.

Precaution

- Room temperature should be approximately 25-27 ^{0}C
- All the fine and coarse aggregate must be in dry condition. If they are wet, find the content of the aggregates to determine the quantity of water required.

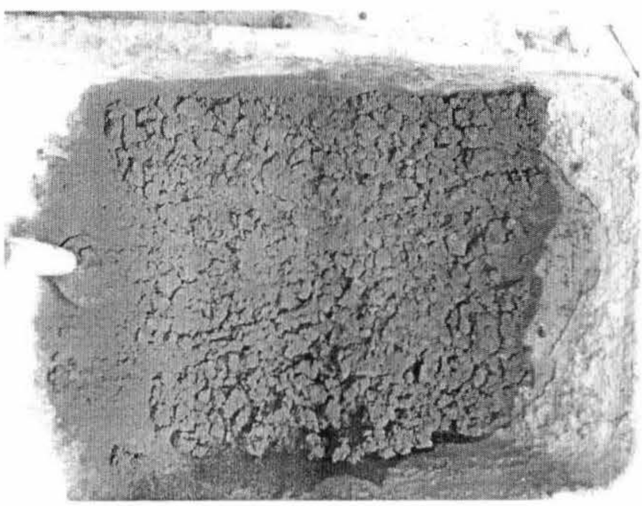

***Figure 3.1**: Concrete Mixing Process*

3.6 CASTING CUBES, SLENDERS AND PLANKS

1. Brush the inner faces of mould with oil and tighten the screws.
2. The concrete mixing are pouring into the form work by 3 layer , at each layer , vibrator are used take out the air that trapped in concrete mix .Trapped air can reduce the concrete strength .
3. After the next day, the cubes, cylinders and planks will take out from the mould and curing process will be conducted.

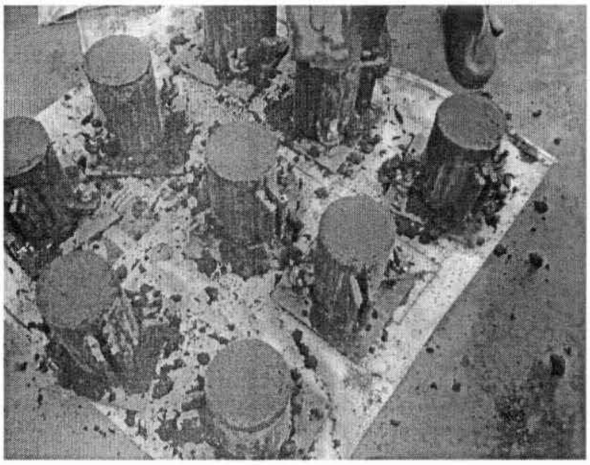

Figure 3.2: Casting of cylinder concrete

3.7 CURING PROCESS

Curing process is to fully hydrate the concrete beam before it acquires strength and hardness because the concrete beam must be *cured* once it has been placed. Curing is the process of keeping concrete under a specific environmental condition until hydration is relatively complete. Good curing is typically considered to provide a moist environment and control temperature.

A moist environment promotes hydration, since increased hydration lowers permeability and increases strength resulting in a higher quality material. Allowing the concrete surface to dry out excessively can result in tensile stresses, which the still-hydrating interior cannot withstand, causing the concrete to crack.

Also, the amount of heat generated by the exothermic chemical process of hydration can be problematic for very large placements. Allowing the concrete to freeze in cold climates before the curing is complete will interrupt the hydration process, reducing the concrete strength and leading to scaling and other damage or failure.

The effects of curing are primarily a function of geometry (the relation between exposed surface area and volume), the permeability of the concrete, curing time, and curing history. Improper curing can lead to several serviceability problems including cracking, increased scaling, and reduced abrasion resistance.

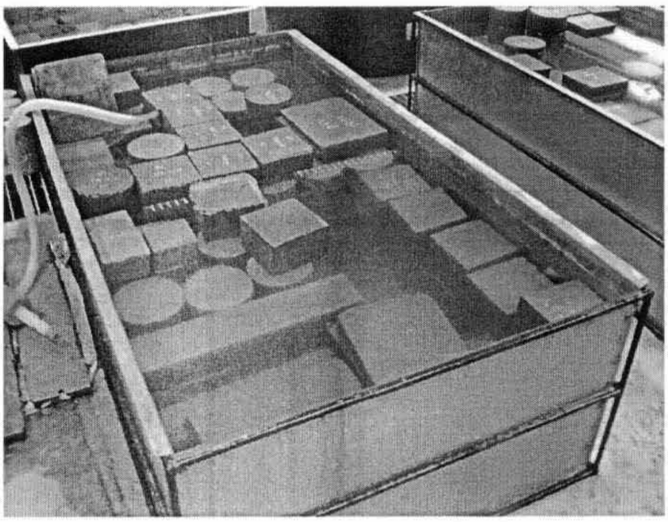

Figure 3.3: Curing process take place

3.8 TEST

3.8.1 Compression Test

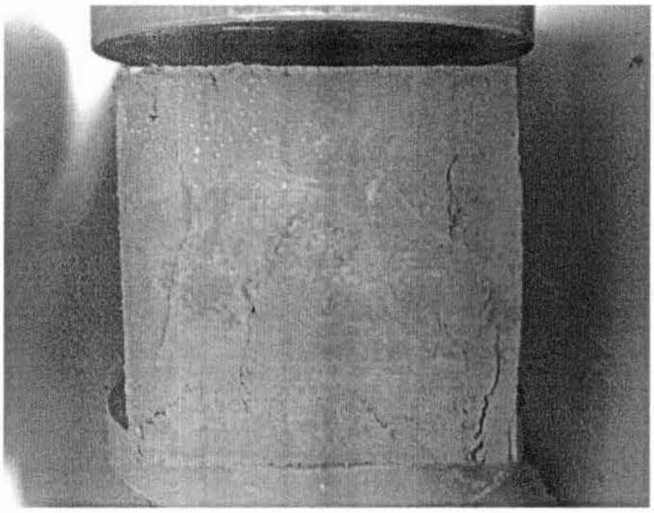

Figure 3.4: Compression Test

This test is carried out to determine the compressive strength for the cube. Below are the procedures for compressive test:

1. Remove the specimen from curing tank and with surface water and grit off specimen
2. Weight each specimen to the nearest kg.
3. Clean the top and the lower platens of the testing machine. Carefully enter the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the cube.
4. Without shock, apply and increase the load continuously rate within the range $0.2N/mm^2$ to $0.4N/mm^2$ until no greater load can be sustained. Record the maximum load applied to the cube.

3.8.2 Splitting Test

In the splitting test, a concrete cylinder of the type used in compressive strength testing, is placed, with its axis horizontal, between platens of a testing machine, and the load is increased until failure take place by splitting in the plane containing the vertical diameter of the specimen. **Figure3.5** shows the type of jigs required for supporting the test specimen in a standard compression test machine as described by BS 1881: 1983 ; ASTM C 496-90 prescribes a similar test. to prevent very high local compressive stresses at the load lines, narrow strips of packing material , such as hardboard or plywood, are interposed between the specimen and the platen. Under these conditions, there is a high horizontal compressive stress at the top and the bottom of the cylinder but, as this is accompanied by a vertical compressive stress of comparable magnitude, there is a state of biaxial compression so that failure does not take place at these positions. instead, failure is initiated by the horizontal uniform tensile stress acting over the remaining cross section of the cylinder.

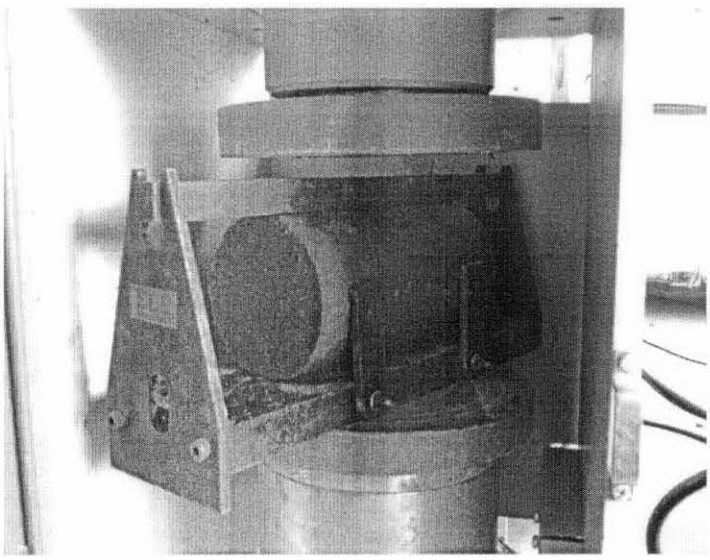

Figure 3.5: Splitting Test

3.8.3 Porosity Test

This test was carried out in order to determine the percentages of void contain in the sample. Subsequently this result can be used to determine the durability of the concrete in long term period.

1. Make a hole by using coring machine.
2. Allocate the sample into the porosity equipment without water and leave it for 30 minutes. Turn it on.
3. Then, switch off the equipment and add with the water. Switch on the equipment and leave it for 6 hours.
4. After that, put the sample into the coring tank for 1 day.
5. Remove the specimens from coring tank, measure the weight in air and in water.
6. Put the sample into the oven for 1 day period.
7. Weight the sample in air only.

CHAPTER 4

RESULT AND DISCUSSION

4.1 RESULT AND DISCUSSION

In order to study the effect of copper slag to the construction material, compressive strength of mortar sample were determined. A plot of compressive strength against the period of 3, 7, 28 and 90 days reveal that the strength of copper slag mortar generally higher than the control mortar.

Detail: Mix 1 (control)

Table 4.1: Result from mix 1 (control)

Days	3	7	28	90
Cube No.	Average	Average	Average	Average
Weight (kg)	8.08	8.06	8.14	8.12
Max Load (N)	432.33	603.17	914.67	1061.20
Stress	19.22	32.75	40.26	47.16
Pace Rate	6.80	6.80	6.80	6.80

Detail: Mix 2 (95% of cement + 5% cement)

Table 4.2: Result from mix 2 for cube

Days	3	7	28	90
Cube No.	Average	Average	Average	Average
Weight (kg)	8.30	8.41	8.40	8.41
Max Load (N)	706.23	983.43	1214.67	1261.33
Stress	31.39	43.70	53.99	56.05
Pace Rate	6.80	6.80	6.80	6.80

Detail: Mix 3 (90% of cement + 10% cement)

Table 4.3: Result from mix 3 for cube

Days	3	7	28	90
Cube No.	**Average**	**Average**	**Average**	**Average**
Weight (kg)	8.37	8.43	8.45	8.43
Max Load (N)	825.13	1018	1239	1402.33
Stress	36.68	45.25	55.05	62.33
Pace Rate	6.80	6.80	6.80	6.80

Detail: Mix 4 (85% of cement + 15% cement)

Table 4.4: Result from mix 4 for cube

Days	3	7	28	90
Cube No.	**Average**	**Average**	**Average**	**Average**
Weight (kg)	8.39	8.38	8.19	8.52
Max Load (N)	754.97	894.27	625.73	1265.67
Stress	33.55	39.74	40.54	46.27
Pace Rate	6.80	6.80	6.80	6.80

Detail: Mix 5 (80% of cement + 20% cement)

Table 4.5: Result from mix 5 for cube

Days	3	7	28	90
Cube No.	**Average**	**Average**	**Average**	**Average**
Weight (kg)	8.47	8.38	8.39	8.39
Max Load (N)	725.50	823.17	847.67	1194.33
Stress	32.25	36.58	37.67	53.07
Pace Rate	6.80	6.80	6.80	6.80

Detail: Mix 6 (85% of cement + 25% cement)

Table 4.6: Result from mix 6 for cube

Days	3	7	28	90
Cube No.	**Average**	**Average**	**Average**	**Average**
Weight (kg)	8.38	8.45	8.31	8.49
Max Load (N)	642.60	672.70	733.47	1033.47
Stress	28.56	29.90	32.60	45.92
Pace Rate	6.80	6.80	6.80	6.80

Detail: Mix 7 (70% of cement + 30% cement)

Table 4.7: Result from mix 7 for cube

Days	3	7	28	90
Cube No.	Average	Average	Average	Average
Weight (kg)	8.38	8.33	8.50	8.37
Max Load (N)	625.37	666.57	686.93	1077.33
Stress	27.80	29.63	30.53	47.9
Pace Rate	6.80	6.80	6.80	6.80

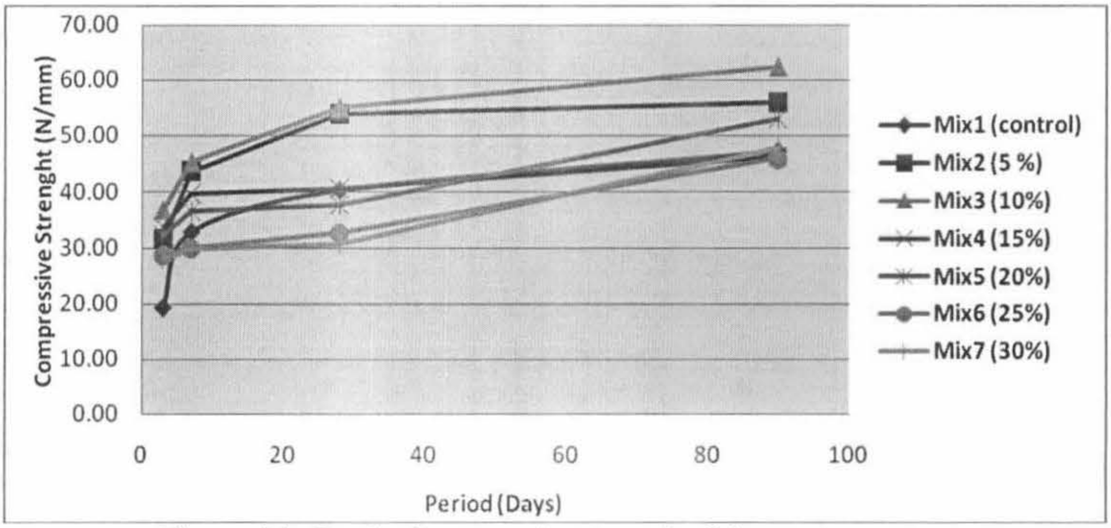

Figure 4.1: Graph of compressive strength of slag mortars

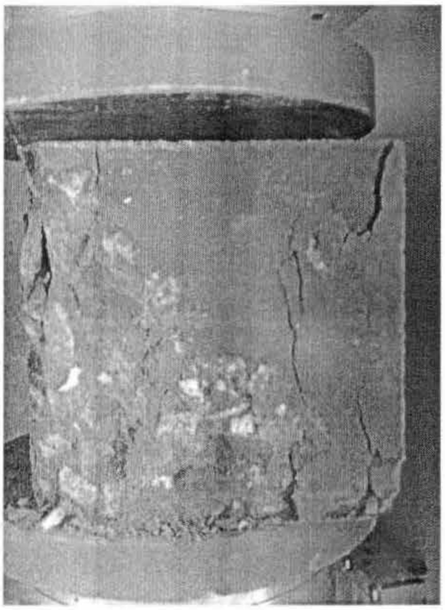

Figure 4.2: Failure in cube due to compression load

Another test that been conducted to study the effect of copper slag is tensile strength. Theoretically, tensile strength of concrete was stated to be eight (8) lower than the compressive strength.

Detail: Mix 1 (control)

Table 4.8: Result from mix 1(control) for cylinder

Days	3	28	90
Cube No.	**Ave.**	**Ave.**	**Ave.**
Weight (kg)	3.72	3.73	3.73
Max Load (N)	75.63	123.37	149.03
Stress	2.41	3.73	4.74
Pace Rate	0.94	0.94	0.94

Detail: Mix 2 (95% of cement + 5% cement)

Table 4.9: Result from mix 2 for cylinder

Days	3	28	90
Cube No.	**Ave.**	**Ave.**	**Ave.**
Weight (kg)	3.76	3.77	3.73
Max Load (N)	84.40	119.90	165.20
Stress	2.69	3.78	5.26
Pace Rate	0.94	0.94	0.94

Detail: Mix 3 (90% of cement + 10% cement)

Table 4.10: Result from mix 3 for cylinder

Days	3	28	90
Cube No.	**Ave.**	**Ave.**	**Ave.**
Weight (kg)	3.80	3.73	3.75
Max Load (N)	85.83	130.90	179.73
Stress	2.73	4.17	5.72
Pace Rate	0.94	0.94	0.94

Detail: Mix 4 (85% of cement + 15% cement)

Table 4.11: Result from mix 4 for cylinder

Days	3	28	90
Cube No.	Ave.	Ave.	Ave.
Weight (kg)	3.84	3.78	3.84
Max Load (N)	95.43	110.97	77.20
Stress	3.04	3.53	2.46
Pace Rate	0.94	0.94	0.94

Detail: Mix 5 (80% of cement + 20% cement)

Table 4.12: Result from mix 5 for cylinder

Days	3	28	90
Cube No.	Ave.	Ave.	Ave.
Weight (kg)	3.80	3.83	3.82
Max Load (N)	83.10	72.77	75.37
Stress	2.65	3.33	2.40
Pace Rate	0.94	0.94	0.94

Detail: Mix 6 (75% of cement + 25% cement)

Table 4.13: Result from mix 6 for cylinder

Days	3	28	90
Cube No.	Ave.	Ave.	Ave.
Weight (kg)	3.80	3.83	3.8
Max Load (N)	75.60	87.47	72.73
Stress	2.41	2.78	2.06
Pace Rate	0.94	0.94	0.94

Detail: Mix 7 (70% of cement + 30% cement)

Table 4.14: Result from mix 7 for cylinder

Days	3	28	90
Cube No.	Ave.	Ave.	Ave.
Weight (kg)	3.80	3.78	3.87
Max Load (N)	73.13	86.47	80.67
Stress	2.33	2.75	2.28
Pace Rate	0.94	0.94	0.94

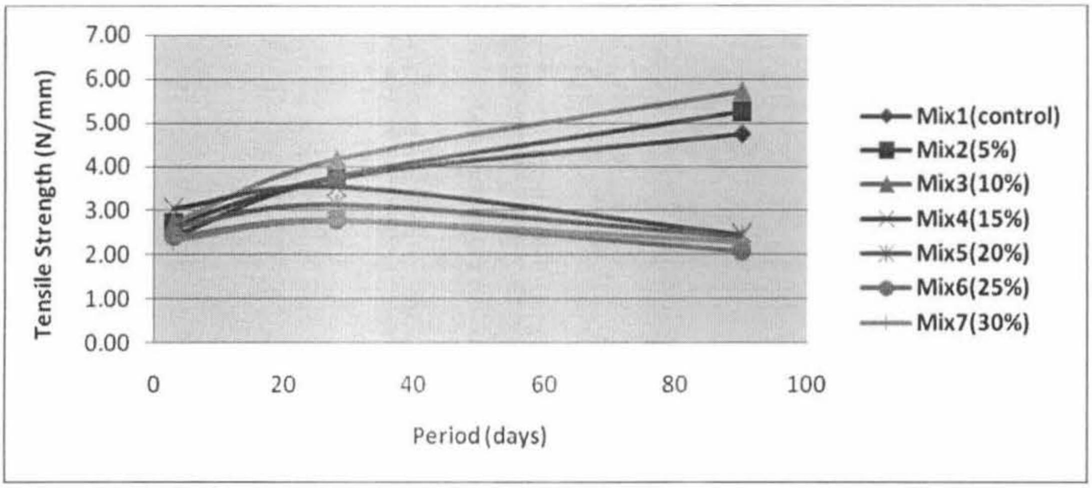

Figure 4.3: Graph of tensile strength of slag mortars

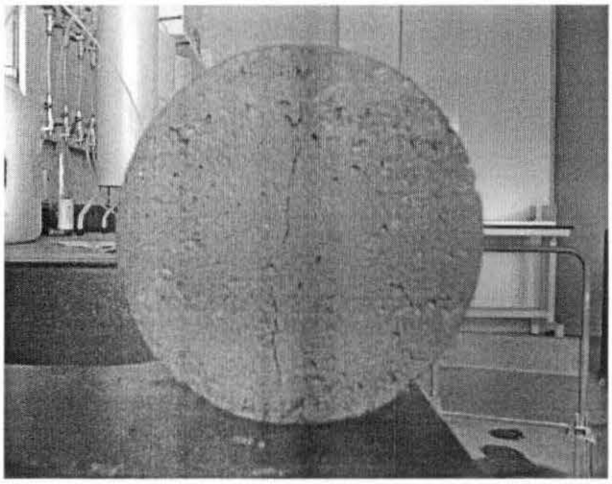

Figure 4.4: Failure in cylinder due to tensile load

The higher strength could be attributing by the composition of silica and other composition in the copper slag. Some of the composition that exists in the copper slag helps to reduce the porosity and by the same time also decrease the permeability of the concrete. Those behaviors will increase the compressive and tensile strength of the concrete.

Besides, porosity test also been conducted in order to determine the long term strength of the concrete.

Detail: Mix 1 (control)

Table 4.15: Result from mix 1 for slab

Days	7			28		
	weight in air	weight in water	weight dry	weight in air	weight in water	weight dry
1	266.6	117.2	250.9	267.6	120.2	252.9
2	269.5	118	253.5	293.3	133.8	274
3	262.1	118.6	246	269.3	125.1	255.3
Average	266.07	117.93	250.13	276.73	126.37	260.73
POROSITY(%)	10.76			10.49		

Detail: Mix 2 (95% of cement + 5% cement)

Table 4.16: Result from mix 2 for slab

Days	7			28		
	weight in air	weight in water	weight dry	weight in air	weight in water	weight dry
1	269.8	121.2	253.9	243.8	111.9	230.5
2	267.6	120.2	252.9	231.1	103.6	217.4
3	278.4	127	263.3	225.7	100.3	212.4
Average	271.93	122.80	256.70	233.53	105.27	220.10
POROSITY(%)	10.21			10.47		

Detail: Mix 3 (90% of cement + 10% cement)

Table 4.17: Result from mix 3 for slab

Days	7			28		
	weight in air	weight in water	weight dry	weight in air	weight in water	weight dry
1	295.4	136.7	278.5	290.8	134.2	276.4
2	290.7	134.3	274.6	296	120.1	280.7
3	292.8	136.6	278.1	282.9	128.5	268.3
Average	292.97	135.87	277.07	289.90	127.60	275.13
POROSITY(%)	10.12			9.1		

Detail: Mix 4 (85% of cement + 15% cement)

Table 4.18: Result from mix 4 for slab

Days	7			28		
	weight in air	weight in water	weight dry	weight in air	weight in water	weight dry
1	237.2	101.6	222.4	285.7	134.8	270.5
2	244.4	105.7	228.9	291.3	138.7	276.7
3	233	98.6	217.7	291.1	138.3	275.8
Average	238.20	101.97	223.00	289.37	137.27	274.33
POROSITY(%)	11.15			9.89		

Detail: Mix 5 (80% of cement + 20% cement)

Table 4.19: Result from mix 5 for slab

Days	7			28		
	weight in air	weight in water	weight dry	weight in air	weight in water	weight dry
1	282.2	128.4	265.8	296	141	280
2	280.7	128.4	265	290.7	138.8	276.1
3	286.5	132.5	271.3	283	133.3	267.5
Average	283.13	129.77	267.37	289.90	137.70	274.53
POROSITY(%)	10.28			10.09		

Detail: Mix 6 (75% of cement + 25% cement)

Table 4.20: Result from mix 6 for slab

Days	7			28		
	weight in air	weight in water	weight dry	weight in air	weight in water	weight dry
1	296.2	136.5	279.6	275.3	142.3	261.2
2	298.4	137.8	281.7	269.3	135.1	255.3
3	299.5	138.2	282.8	265.5	127.4	252.6
Average	298.03	137.50	281.37	270.03	134.93	256.37
POROSITY(%)	10.38			10.11		

Detail: Mix 7 (70% of cement + 30% cement)

Table 4.21: Result from mix 7 for slab

Days	7			28		
	weight in air	weight in water	weight dry	weight in air	weight in water	weight dry
1	298.4	137.2	278.6	297.4	140.3	278.8
2	293.3	133.8	274	297.2	140.2	278.5
3	288.5	131.7	270.4	290.3	136.4	272.5
Average	293.40	134.23	274.33	294.97	138.97	276.60
POROSITY(%)	11.98			11.78		

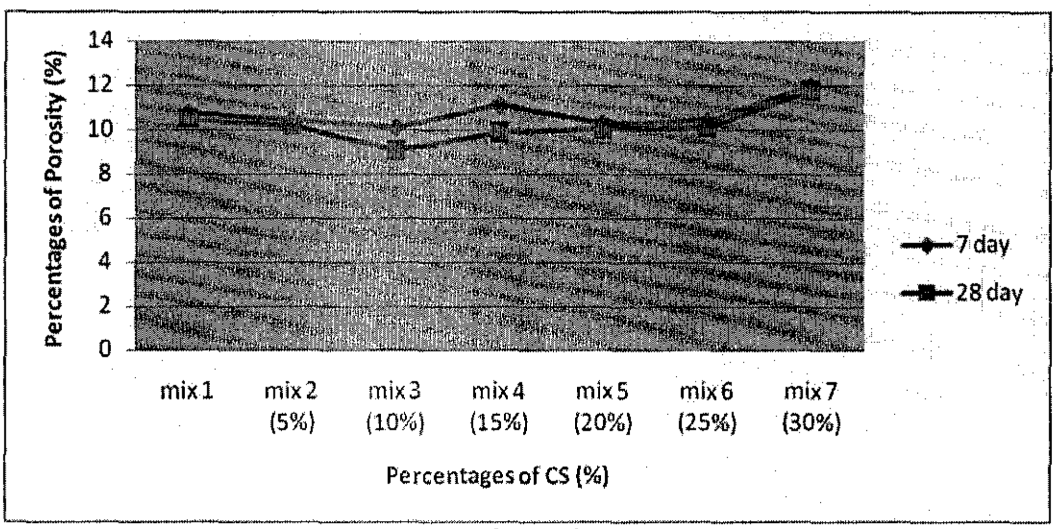

Figure 4.5: Graph of porosity of slag mortars

This graph showed that the mix 2 by replacing the cement with 5 percent of copper slag give the lowest reduction of porosity compared with others mix. The reducing of pores inside the cement leads the increasing of the compressive and tensile strength of the concrete. This situation may due to the existence of heavy metals inside the copper slag.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the research that have been done by collecting information from the articles, journal and books, it showed that that copper slag is the best material can be used to replace the cement in order to produce high strength concrete. Thus, after the on going research being done, it showed that this material has increased the properties of the concrete. In order to realize this study, further research will be made to clarify the behavior of copper slag in concrete.

This study has shown that the used of copper slag can increased the strength of a concrete. Based on the results, an optimum strength of concrete is at10% of copper slag usage. Thus, copper slag can be used safely in the concrete as one of the method to dispose this material

Findings from this research will lead to a new are in building construction technology. The use of copper slag will be a cost effective alternative to concrete in order to increase the properties of the concrete. Hopefully with findings from this research, copper slag can be reuse in proper way without any environmental issues.

5.2 RECOMMENDATION

In this final year project ,the author determine that there are still have a problem while the author conduct the project that can affected the schedule and the results of laboratory .The problem are :

Water cement ratio decrease

During the mixing of concrete, author notice that water/cement ratio is decrease due to time. This occurs when author decide to combine mixing for cube and slender. Thus, the time use to casting all cube and slender take long time and may cause the water to evaporate. Subsequently, water/cement ratio will decrease and the mix becoming dry. This may give effect to the result of compressive strength and tensile strength. To avoid this from occurs; the author had divided the mixing between cube and cylinder.

Laboratory apparatus

Laboratory apparatus is not sufficient because when the peak hour of laboratory usage, the author must consecutively with others student because lack of equipment .In example in the lab, only 1 hammer present in the laboratory. It makes more time required for laboratory work because lack of equipment facilities in the lab.

Aggregate used

To ensure the accuracy of the research, the mix that been made must using the same size of aggregate. Basically, there is a lot of type of aggregates behind the laboratory.

Future Research

In order to ensure this material can be used widely in concrete as a replacement for concrete, further research should be done respectively. Others research can be carried out are to study the effect of copper slag on structural behavior of the concrete. These are the proposed studies;

- Static load dynamic
- Durability load
- Chloride migration
- Micro structured using ACM

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APPENDIX

Figure A: Copper slag at MMHE

Figure B: Informal discussion with MMHE personnel

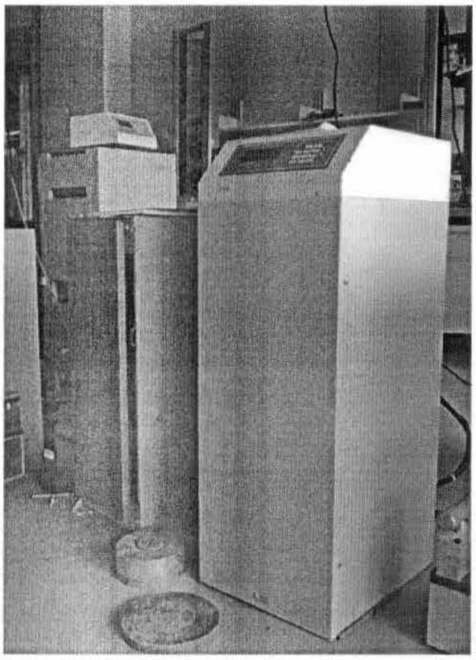

Figure C: Equipment use for compressive and tensile test

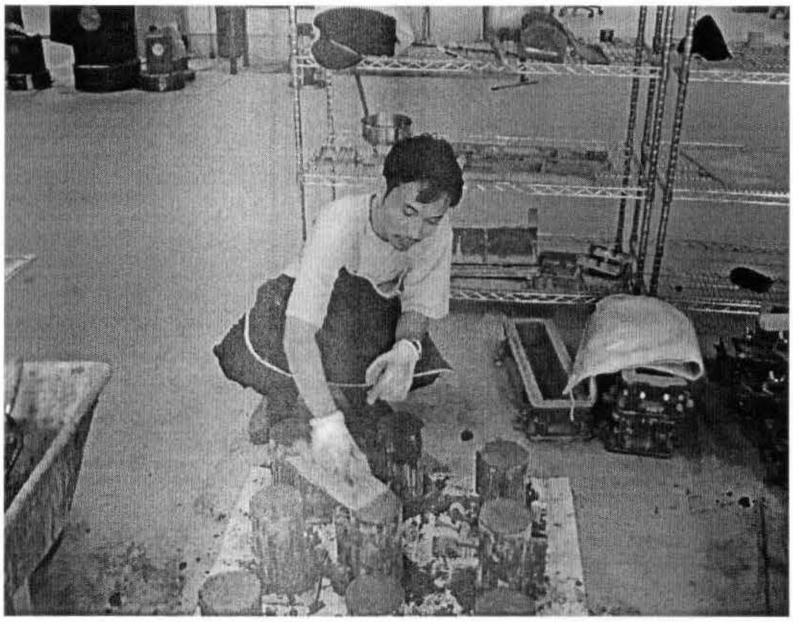

Figure D: Casting the concrete into the mould

FULL RESULT FOR COMPRESSION TEST

Mix 1

Days	3				7				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	7.99	8.13	8.12	8.08	8.06	8.1	8.02	8.06	8.15	8.2	8.06	8.14	8.21	8.06	8.1	8.12
Maximun Load (N)	536.5	446.4	314.1	432.33	353.5	834	622	603.17	925.4	855.2	963.4	914.67	1143	1220	820.6	1061.20
Stress	23.85	19.84	13.96	19.22	33.49	37.07	27.69	32.75	41.14	38.02	41.63	40.26	50.8	54.21	36.47	47.16
Pace Rate	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80

Mix 2

Days	3				7				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	8.33	8.37	8.2	8.30	8.55	8.31	8.37	8.41	8.4	8.55	8.25	8.40	8.44	8.47	8.32	8.41
Maximun Load (N)	755.8	668.4	694.5	706.23	981	961.3	1008	983.43	1192	1295	1157	1214.67	1305	1237	1242	1261.33
Stress	33.59	29.71	30.87	31.39	43.6	42.72	44.79	43.70	52.96	57.57	51.44	53.99	57.98	54.97	55.19	56.05
Pace Rate	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80

Mix 3

Days	3				7				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	8.35	8.26	8.5	8.37	8.59	8.32	8.38	8.43	8.52	8.47	8.36	8.45	8.57	8.41	8.3	8.43
Maximun Load (N)	794.7	865.7	815	825.13	1027	1022	1005	1018.00	1225	1257	1235	1239.00	1349	1444	1414	1402.33
Stress	35.32	38.48	36.23	36.68	45.63	45.44	44.67	45.25	0.00	0.00	0.00	0.00	59.96	64.19	62.85	62.33
Pace Rate	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80

Mix 4

Days	3				7				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	8.38	8.23	8.56	8.39	8.53	8.1	8.52	8.38	8.08	8.32	8.17	8.19	8.44	8.57	8.56	8.52
Maximun Load (N)	774	701.3	789.6	754.97	903	875.9	903.9	894.27	8.68	958.8	909.7	625.73	1121	1332	1344	1265.67
Stress	34.4	31.17	35.09	33.55	40.13	38.93	40.17	39.74	38.59	42.61	40.43	40.54	19.83	59.21	59.76	46.27
Pace Rate	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80

Mix 5

Days	3				7				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	8.6	8.42	8.38	8.47	8.47	8.43	8.25	8.38	8.38	8.32	8.46	8.39	8.48	8.4	8.29	8.39
Maximun Load (N)	746.8	725.5	704.2	725.50	829.1	797	843.4	823.17	829.2	843.4	870.4	847.67	1188	1277	1118	1194.33
Stress	33.19	32.25	31.3	32.25	36.85	35.42	37.48	36.58	36.85	37.49	38.68	37.67	52.82	56.73	49.67	53.07
Pace Rate	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80

Mix 6

Days	3				7				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	8.34	8.49	8.32	8.38	8.54	8.41	8.4	8.45	8.32	8.35	8.26	8.31	8.56	8.4	8.52	8.49
Maximun Load (N)	637.1	664.8	625.9	642.60	651.9	695	671.2	672.70	757.9	703.2	739.3	733.47	1039	984.4	1077	1033.47
Stress	0.00	0.00	0.00	0.00	28.97	30.89	29.83	29.90	0.00	31.26	32.86	21.37	46.13	43.75	47.87	45.92
Pace Rate	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80

Mix 7

Days	3				7				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	8.36	8.5	8.27	8.38	8.26	8.36	8.36	8.33	8.45	8.52	8.53	8.50	8.32	8.37	8.42	8.37
Maximun Load (N)	657.8	597.4	620.9	625.37	726	613.2	660.5	666.57	759.4	690.7	610.7	686.93	1061	1093	1078	1077.33
Stress	0.00	0.00	27.6	9.20	32.27	27.25	29.36	29.63	33.75	30.7	4152.76	1405.74	47.16	48.59	47.95	47.90
Pace Rate	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80	6.8	6.8	6.8	6.80

FULL RESULT FOR TENSILE TEST

Mix 1

Days	3				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	3.71	3.69	3.75	3.72	3.73	3.72	3.73	3.73	3.75	3.74	3.71	3.73
Maximun Load (N)	75.6	77.8	73.5	75.63	105.1	119.3	145.7	123.37	112.4	149.3	185.4	149.03
Stress	2.406	2.475	2.34	2.41	3.345	3.796	4.039	3.73	3.578	4.751	5.903	4.74
Pace Rate	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Mix 2

Days	3				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	3.76	3.77	3.74	3.76	3.8	3.77	3.75	3.77	3.75	3.74	3.71	3.73
Maximun Load (N)	96	83.9	73.3	84.40	121.8	124.4	113.5	119.90	180.5	162.3	152.8	165.20
Stress	3.055	2.67	2.334	2.69	3.877	3.865	3.612	3.78	0.000	0.000	0.000	0.00
Pace Rate	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Mix 3

Days	3				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	3.79	3.83	3.78	3.80	3.75	3.77	3.68	3.73	3.72	3.8	3.74	3.75
Maximun Load (N)	85.5	87.1	84.9	85.83	135.8	126.4	130.5	130.90	185.6	175.8	177.8	179.73
Stress	80.37	81.87	79.81	80.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pace Rate	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Mix 4

Days	3				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	3.83	3.84	3.84	3.84	3.83	3.87	3.9	3.87	3.83	3.85	3.83	3.84
Maximun Load (N)	85.4	98.8	102.1	95.43	117.9	117.8	97.2	110.97	75.6	78	78	77.20
Stress	2.72	3.145	3.249	3.04	3.752	3.75	3.093	3.53	2.405	2.481	2.484	2.46
Pace Rate	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Mix 5

Days	3				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	3.82	3.8	3.79	3.80	3.77	3.73	3.78	3.76	3.85	3.79	3.82	3.82
Maximun Load (N)	79.5	85.2	84.6	83.10	113	101.7	3.597	72.77	76	74.6	75.5	75.37
Stress	2.532	2.711	2.692	2.65	3.597	3.237	2.568	3.13	2.42	2.376	2.403	2.40
Pace Rate	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Mix 6

Days	3				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	3.79	3.79	3.82	3.80	3.83	3.8	3.85	3.83	3.79	3.83	3.77	3.80
Maximun Load (N)	72.8	78.2	75.8	75.60	91.1	77.2	94.1	87.47	72.3	72.2	73.7	72.73
Stress	273.49	293.77	284.76	284.00	2.899	2.456	2.996	2.78	2.03	2.043	2.084	2.06
Pace Rate	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Mix 7

Days	3				28				90			
Cube No.	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.
Weight (kg)	3.86	3.84	3.71	3.80	3.84	3.78	3.71	3.78	3.82	3.85	3.93	3.87
Maximun Load (N)	65.6	73.1	80.7	73.13	86.1	88.3	85	86.47	88.1	85.6	68.3	80.67
Stress	2.088	2.328	2.57	2.33	2.742	2.812	2.707	2.75	2.492	2.422	1.932	2.28
Pace Rate	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94