SOLIDIFICATION AND STABILIZATION OF BOTTOM ASH IN CONCRETE AS FINE AGGREGATE REPLACEMENT

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ABSTRACT

Fine aggregate is a one of main ingredient that uses to produce concrete. Large amount of fine aggregate that used in industry increase the construction cost. This research was conducted to determine the effect of coal bottom ash toward compressive strength of concrete. The experimental was carried out by using coal bottom ash as sand replacement in the concrete mix grade30 with ratio 0%, 10%, 20%, 30%, 40% and 50%. The compressive strength of the concrete by using 100mm x 100mm x 100mm cube size is determined at 7, 28 and 60 days age of curing. The result show the compressive strength of control concrete is high compare to the coal bottom ash concrete. The concrete compressive strength was decrease when the coal bottom ash replacement up to 20% was mix in concrete cube. The strength of concrete will increase when the concrete was immersion in the water curing with long duration time. The increment of strength for 20% coal bottom ash as a sand replacement was increase after 28days compare to other percentages. Meanwhile, the water retention time was measured after 28days curing age for 1week in the water immersion with ratio 1/10. This research also aims to study the performance of concrete containing bottom ash toward leaching characteristic and to investigate the influence of the solidification or stabilization of heavy metal materials. The leaching test for the concrete mix is measured for 1 hour, 1 day, 1 week and 1 month in the water immersion with ratio 1/10. The result from leaching test by using ICP-MS Agilent 7500 test method shown the heavy metal that contain in the concrete was acceptable for environment. So the concrete with coal bottom ash replacement can use in the construction in the Malaysia.

ABSTRAK

Agregat halus adalah salah satu bahan utama yang digunakan untuk menghasilkan konkrit. Jumlah besar Batu halus yang digunakan dalam industri meningkatkan kos pembinaan. Kajian ini telah dijalankan untuk menentukan kesan abu arang batu dasar relau ke arah kekuatan mampatan konkrit. Eksperimen ini dijalankan dengan menggunakan abu dasar realu sebagai pengganti pasir dalam campuran grade30 konkrit dengan nisbah 0 %, 10 %, 20 %, 30 %, 40 % dan 50%. Kekuatan mampatan konkrit dengan saiz kiub 100mm x 100mm x 100mm ditentukan pada 7 , 28 dan 60 hari umur pengawetan . Hasilnya menunjukkan kekuatan mampatan kawalan konkrit adalah tinggi berbanding dengan konkrit abu arang batu dasar relau. Kekuatan mampatan konkrit menurun apabila penggantian abu dasar relau sebanyak 20 % di dalam campuran kiub konkrit. Kekuatan konkrit akan meningkat apabila konkrit di rendaman di dalam pengawetan air dalam tempoh masa yang panjang. Peningkatan kekuatan konkrit pada 20% abu arang batu dasar relau sebagai penggantian pasir meningkatan selepas 28hari berbanding dengan peratusan lain. Sementara itu, masa tahanan air di ukur selepas 28hari unur pengawetan untuk 1minggu dalam rendaman air dengan nisbah 1/10. Kajian ini juga bertujuan untuk mengkaji pencapaian konkrit yang mengandungi abu dasar relau ke arah larut lesap ciri dan untuk menyiasat pengaruh pemejalan atau penstabilan bahan-bahan logam berat. Ujian larut lesap untuk campuran konkrit diukur selama 1 jam, 1 hari, 1 minggu dan 1 bulan di dalam rendaman air dengan nisbah 1/10. Hasil daripada larut lesap ujian dengan menggunakan kaedah ujian ICP -MS Agilent 7500 menunjukkan logam berat yang mengandungi di dalam konkrit boleh diterima untuk alam sekitar. Jadi konkrit dengan gantian abu arang batu dasar relau boleh gunakan dalam pembinaan diMalaysia.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concrete is widely used in global construction to provide a good strength in structure. Concrete is a composite construction material composed primarily of aggregate, cement, and water (Singh et al., 2000). Coal Bottom ash (CBA) has a potential to use as a replacement for fine aggregate in concrete (kadam & Patil, 2013).

Coal Bottom ash produces by coal combustion processes that burn at a very high volume of coal annually to generate electricity (Hui et al., 2005). Kurama and Kaya (2008) stated that CBA was collected at the bottom of boiler contain with grain sizes coarse from coarse sand to fine gravel size. J. Rogbeck and A.Knutz (1996) said the usually not have pozzolanic effect. Targan (2003) find that, the CBA can be used as a replacement for aggregate in cement brick because CBA has a low cost material compare the usually aggregate that use in concrete brick. Besides that, Luz et al. (2003) stated, the reason using bottom ash because it economic, environmental and technical advantages and able to absorb water and dissolved foreign elements. In addition, it can avoid from the wastage disposed in landfills and environmental pollution.

1.2 RESEARCH OBJECTIVES

The objectives of this research are:

i. To determine the effect of bottom ash toward compressive strength of concrete
ii. To study the performance of concrete containing bottom ash toward leaching characteristic.
iii. To investigate the influence of the solidification or stabilization of heavy metal materials.

1.3 PROBLEM STATEMENT

Malaysia is the one of country that used coal as a power generation for electricity. Increasing of amount of coal ash wastage was disposed in landfills that produce in industry from year to year raises problems to our country and another country such as India and china. Zhao et al. (2010) found that the total amount of coal ash that disposes in landfill was exceeding 550Mt per year. The finding from (Aggarwal et al., 2007) stated the dispose of coal ash becomes environmental pollution problem because this waste from coal is not reused and recycles in any works. Therefore, it will reduce the cost for concrete and environmental problems (Luz et al., 2006). However, the effect of bottom ash towards of durability performance properties of cement brick depends on leaching characteristic and solidification/ stabilization process.

1.4 SCOPE OF STUDY

The research acknowledges to finding the good quality of CBA filler that affect the performance of mixtures by investigating the influence various ratio mixtures of CBA. In concrete, CBA is used as a replacement for sand. For this research, the concrete mix is using levels ratio of 10%, 20% 30%, 40% and 50% of CBA as a sand replacement in concrete that generate from combustion of coal process at Kampar Selangor. The CBA-concrete at ages due to 7, 28 and 60 days of curing are investigated to determine the compressive strength after the replacement of bottom ash. The major obstacle in use of CBA in a concrete is that the chemical properties of CBA are different from place to place and are depends upon the origin of the raw material. In additional, this study also aimed to investigate performance of concrete containing bottom ash toward leaching characteristic and toward the solidification/stabilization to determine the heavy metal content in a concrete material.

1.5 SIGNIFICANT OF STUDY

The bottom ash used to replace the sand material in concrete block mixed was used to provide a good strength and durability of concrete. Furthermore, bottom coal ash also used to generate the new product by changed the concrete block material. Besides that, Luz et al. (2003) stated, the reason using bottom ash because it economic, environmental and technical advantages and able to absorb water and dissolved foreign element. In addition, it can avoid from the wastage disposed in landfills and environmental pollution. (Tangent et al., 2003) said the used of bottom ash material also can reduce the cost of construction project due to less use of aggregate.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In chapter two, it is about searched the related and relevant literature to a research project that had been chosen. It is also, summarize the literature and find the evidences which can answer the research objectives and research questions. Based on the literature that had been found, further research is made on Effect of Coal Bottom Ash toward Concrete Performance.

2.2 DURABILITY OF CONCRETE USING VARIOUS RATIO OF REPLACEMENT.

The influence of the various ratio mixtures of CBA, Kadam and Patil (2013) observed that the compressive strength and density of concrete decrease due to increase of CBA replacement compared to control concrete. The replacement of fine aggregates was 0, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% by weight at 7, 28, 56 and 112 days. The strength of bottom ash concrete gains a slower rate in the initial period and faster rate after 28 days due to pozzolanic action on bottom ash. According to Yuksel et al., (2007) the five test has been done with different replacement percentages as 10%, 20% 30%, 40% and 50% of CBA based on weight of the fine aggregate with 90days compressive strength. In addition Razaob (2010) and Muhammad (2010) conducted the research with 25%, 50% and 100% ratio of sand replacement at 7, 28, 60 and 90 days age and 7, 14, 28 and 60 days age. The test results showed the increment of CBA replacement will increase the porosity of the concrete. So it can conclude the compression strength and the values of slump test decrease due to increment of CBA replacement.

However, the strength of concrete will be decreased if too much CBA content was used up to 20% in the concrete mix due to the lower compression strength and high water absorption. According to Kadam and Patil (2013) the optimum replacement levels of CBA are 20% for a good compressive strength at 7, 28, 56 and 112 days. But at the 30% to 100% replacement of CBA the compressive flexural, split and water permeability test are approximately same as that of the controlled concrete and the compressive strengths were decreased. Besides that, Barbosa et al., (2011) stated the bottom ash replacement at 10% and 20% could be used in real condition without insulation and with limited moistening. This finding was support by Yuksel et al., (2007), the maximum strength for concrete containing CBA occurred at the replacement level of 20 %. The main factors affecting the concrete durability was a chemical and physical property of BA. So, it can conclude it is possible to produce durable concrete by using CBA as fine aggregate replacement.

According to Kadam and Patil (2013), Muhammad (2010), Rogbeck and Knutz (1996) and Aggarwal et al., (2007) by using CBA as a sand replacement the water absorption and porosity of concrete was increased compared to that the control concrete. The increment of the replacement level of the fine aggregates with the bottom ash decrease the workability of concrete due to greater amount of water absorption. In addition Razaob (2010) was conclude that the replacement of CBA reduce the performance of cement brick in side of strength, but it produces more ductile and lightweight concrete with high workability of mixture which is suitable for application of structures that are more resistant to high impact and able to sustain failure longer compared to the ordinary concrete.

2.3 LEACHING AND SOLIDIFICATION/STABILIZATION OF BOTTOM ASH.

The leaching testing is used to determine the heavy metal content in a concrete material after the replacement of bottom ash. Solidification/stabilization (s/s) is a process of reduction the leaching and limit of heavy metal solubility of their contaminants that can improve the chemical and physical characteristic of waste materials (Luz et al., 2006).

According to Anastasiadou et al., (2012) the bottom ash sample showed lower concentrations of heavy metals compare to regulatory limits. This finding also support by Skodras et al., (2009), the bottom ash samples acceptable for safe disposal since passed the EPA-TCLP test because did not exceeds the maximum US EPA. The concentrations of heavy metals in the leachates are much lower than the US EPA. Based on chemical analysis, the leachate presenting the lowest PH value was increase the leaching rate of inorganic. Furthermore, the solidified bottom ash possessed good chemical stability and kept below the limits of the hazardous substances in existing regulations (Park, 2007). Thus, as mentioned Barbosa et al., (2011) stated based on the s/s, the bottom ashes will be classified as non-hazardous material. This is because the bottom ash has a lowest emission level of metals through leaching due to the concentrations of sulfates, fluorides, chlorides, and TDS. The concentrations were above the limits of insert materials and below the limit of non-hazardous materials. When the concentrations of heavy metals in the leachates test were compared with the drinking water standard (DWSS), the bottom ash mixtures at the groundwater have a little potential for risk has been verified by Jo et al., (2008).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter explains about the properties of materials that used to produce six series of concrete with different percentage of Coal Bottom Ash (CBA) as a fine aggregate replacement and the experimental that was carried to achieve the research objectives. The laboratory test were carried out four experimental which is Sieve Analysis, Compressive Strength due to different curing age, Water retention Time, Leaching test (ICP-MS Agilent 7500) and X-ray Fluorescence. The experimental was conducted at the concrete and structure civil engineering University Malaysia Pahang laboratory and Central Laboratory University Malaysia Pahang.

3.2 EXPERIMENTAL PROGRAM

The methodology process flow for an evaluation of coal bottom ash as a replacement on concrete as illustrated in figure 3.1.

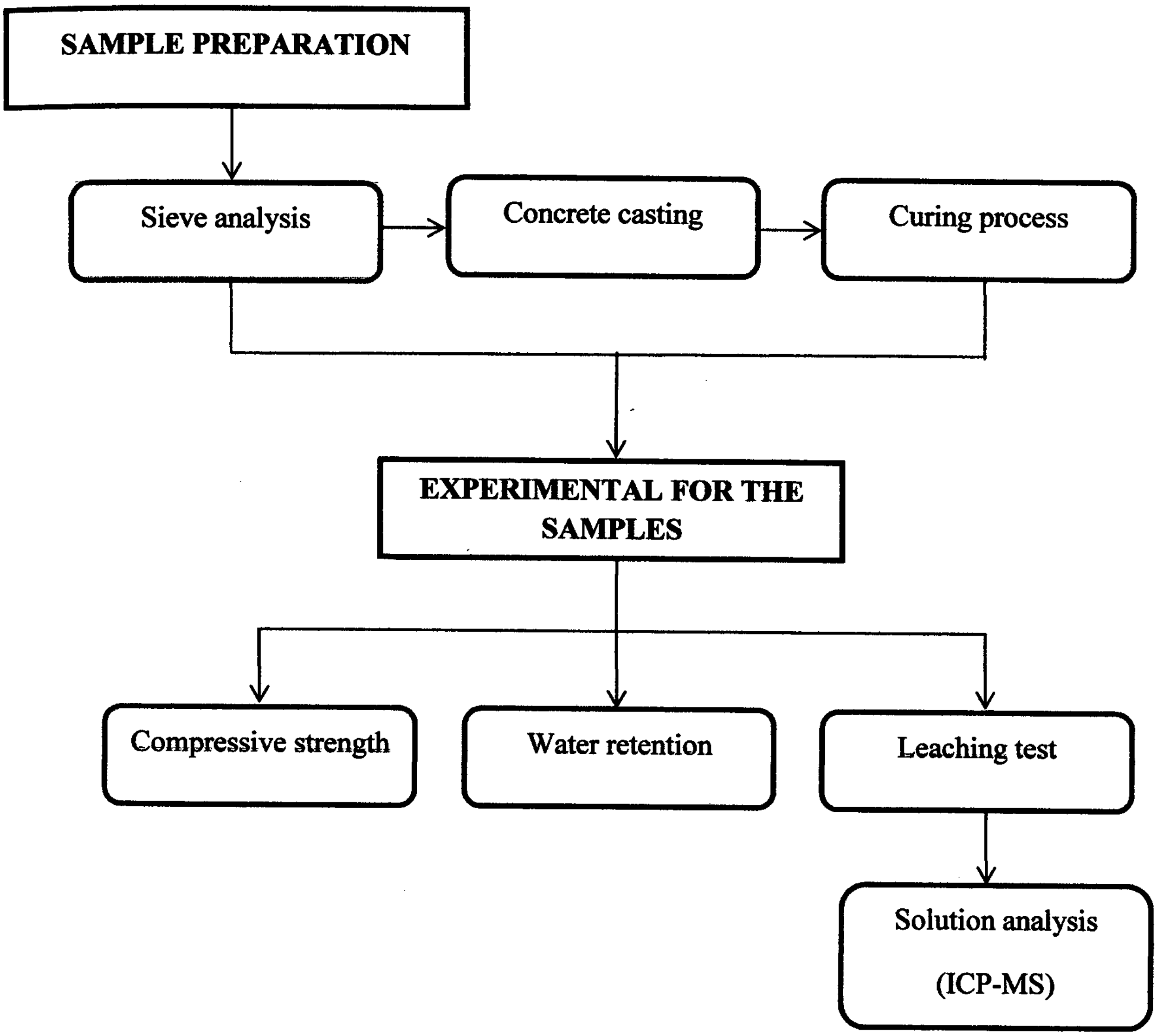

Figure 3.1: Experimental flow chart

3.3 MATERIAL PREPARATION

3.3.1 Water

Water is a chemical compound with the chemical formula H2O. A water molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at temperatures above 0 °C (273.15 K, 32 °F) at sea level, but it often co-exists on Earth with its solid state, ice, and gaseous state (water vapour or steam). Water also exists in a liquid crystal state near hydrophilic surfaces.

3.3.2 Ordinary Portland Cement (OPC)

Portland cement is also essentially silicate cement, which produce by firing to partial fusion, at a temperature if approximately 1500 degree Celsius, a well-homogenized and finely ground mixture of limestone or chalk (calcium carbonate) and an appropriate quantity of clay or shale.

3.3.3 Coal Bottom Ash (CBA)

CBA was collected at the bottom of boiler contain with grain sizes coarse from coarse sand to fine gravel size. The CBA can be used as a replacement for aggregate in cement brick because CBA has a low cost material compare the usually aggregate that use in concrete mix. The size of bottom ash that used for this research is bottom ash that retain at 5mm and below.

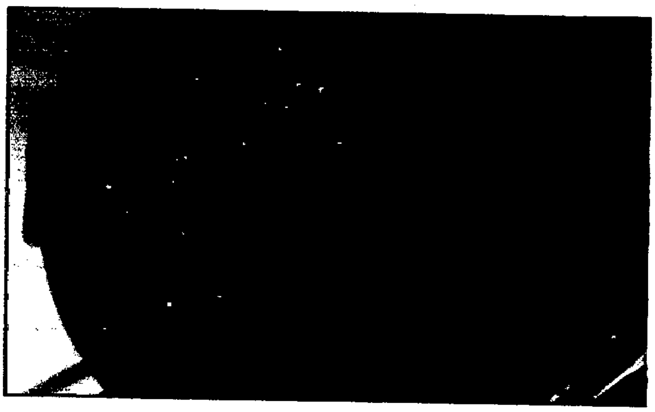

Figure 3.2: Coal bottom ash

3.3.4 Fine Aggregate/ sand

Sand is granular material. It is composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions. Fine aggregate is defined as material that will pass a No. 4 sieve and will, for the most part, be retained on a No. 200 sieve. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. The size of fine aggregate that used for this research is fine aggregate that retain at 5mm and below.

Figure 3.3: Fine aggregate (sand)

3.3.5 Coarse aggregate

The coarse aggregate is a crushed gravel or stone. Coarse aggregates are aggregate that are retained on 20mm. Coarse aggregates are classified into single-size aggregate and graded aggregate group. Single-size aggregate is based on a nominal size specification. It contains about 85 to 100 percent of the material which passes through that specified size of the sieve and zero to 25% of which is retained in the next lower sieve. A graded aggregate contains more than one single-size aggregate. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. The size of fine aggregate that used for this research is fine aggregate that retain at 10mm.

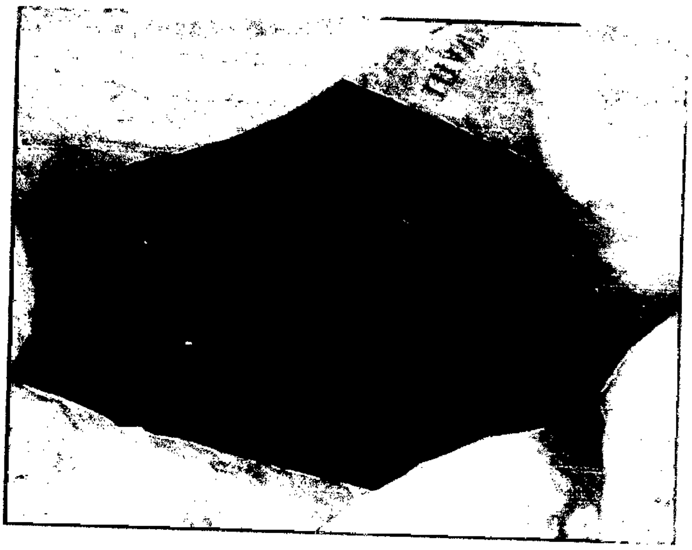

Figure 3.4: Coarse aggregate

3.4 MIX DESIGN

The concrete grade that used in this research is grade 30. Designing a concrete mix design consists of selecting the correct proportions of cement, fine and coarse aggregate and water to produce concrete having the specified properties. The maximum crushed aggregate that used in this research is 100mm with 30-60mm required slump test. The calculation of concrete mix design is shown in the appendix.

3.5 TESTING METHOD

3.5.1 Sieve analysis

Sieve analysis is a method used determining the relationship between the particle size distribution of fine and coarse aggregates and fine grained soils for all construction except concrete construction. The results are used to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

In this research the required size for coarse aggregate is 10mm and for fine aggregate is that passing 5mm and below. The coarse aggregate grading process is using sieve, 20mm, 14mm, 10mm, 5mm and 2.36mm. While for fine aggregate using sieve no 10mm, 5mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm. This sieve analysis grading limits for coarse aggregate and fine aggregate was accordance BS 882.1992.

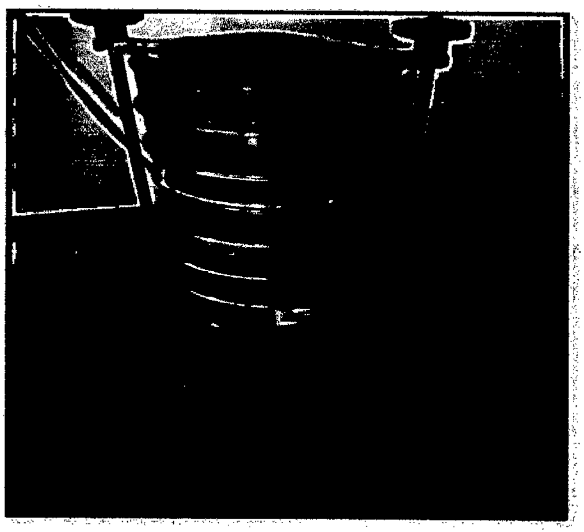

Figure 3.5: Sieve analysis

3.5.2 Water retention time

To determine the absorptive capacity of the concrete cube for water, the concrete samples were kept in water for a period of 1 week. The solid/liquid ratio in these tests was always 1/10. Each sample was weighed before and after immersion. The following equation was used to determine water retention capacity:

$$\text{Water retention (\%)} = \frac{mf - mi}{mi} \times 100$$

Where mi is the weight of the cube immediately after firing and mf is the weight of the same cube after 1week of immersion in water. This was based on the Turkish and ASTM standards for testing these bricks.

3.5.3 Compressive strength

Compressive strength is aim to determine the compressive strength of the given concrete cube. Compressive strength test results are primarily used to determine that the concrete mixture as delivered meets the requirements of the specified strength, $f'c$ in the job specification. The compressive strength is conducted at ump concrete laboratory by using British standard (ASTM C-29). The samples concrete cube that used is 100mm x 100mm x 100mm with 7, 28 and 60 days age of curing. The concrete cube has taken out from the curing tank after 7, 28 and 60 days and removed the surface water using a cloth. The dimensions of the bricks cube are measured and it placed in the compression testing machine. The load are apply till the cube completely crushes or fails and the load failure is note down. The compressive strength of the given concrete cube is determined by using the following relation:

$$\text{Compressive strength} = \frac{\text{Load failure (P) in N}}{\text{Bearing area (A) in mm2}}$$

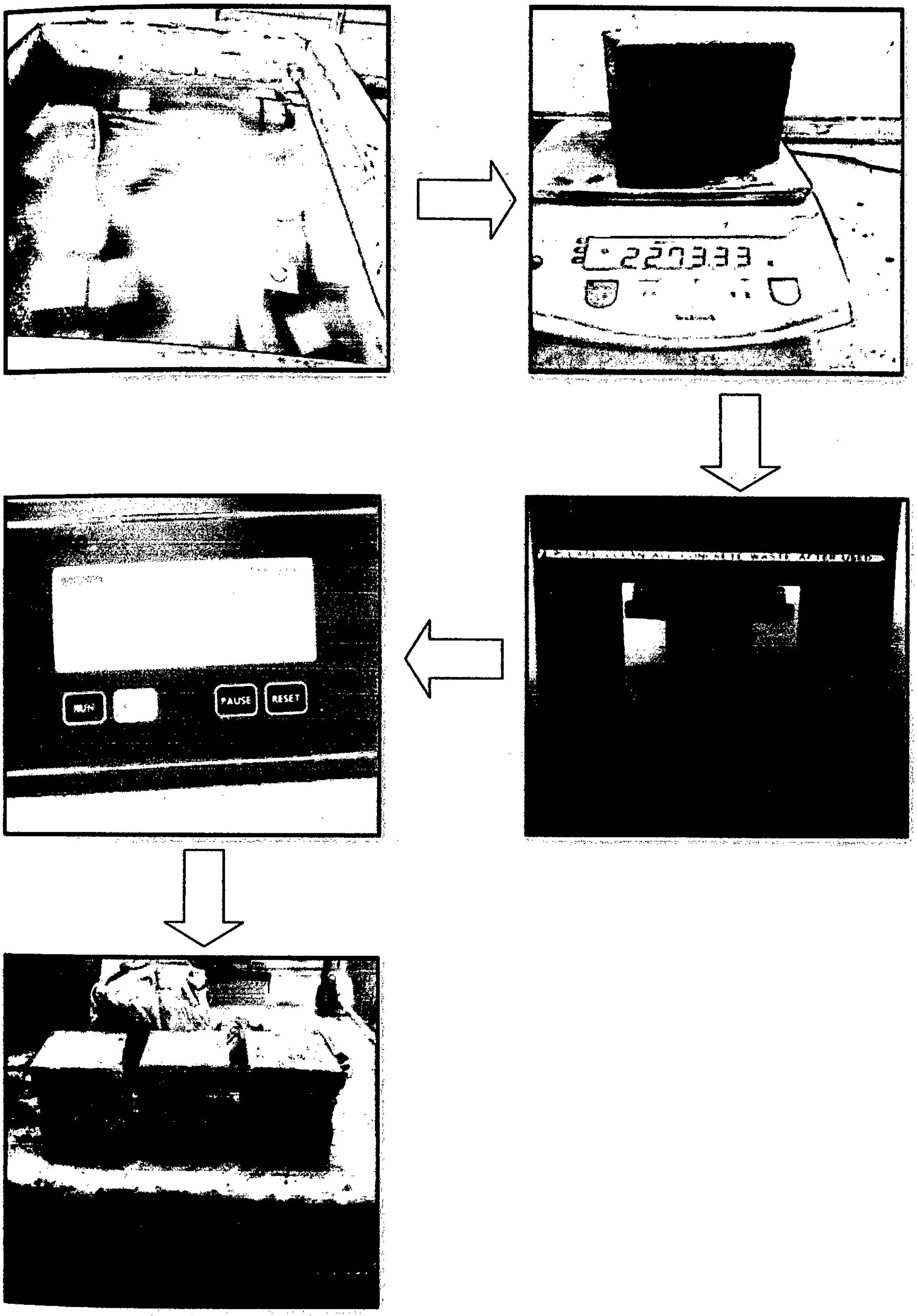

Figure 3.6: Flow of compressive strength experiment

3.5.4 X-ray Fluorescence

X-ray fluorescence (XRF) spectrometer is an x-ray instrument used for routine, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. It works on wavelength-dispersive spectroscopic principles that are similar to an electron microprobe (EPMA). However, an XRF cannot generally make analyses at the small spot sizes typical of EPMA work (2-5 microns), so it is typically used for bulk analyses of larger fractions of geological materials. The relative ease and low cost of sample preparation, and the stability and ease of use of x-ray spectrometers make this one of the most widely used methods for analysis of major and trace elements in rocks, minerals, and sediment.

3.5.5 Leaching tests (ICP-MS Agilent 7500)

The ICP-Ms Agilent 7500 was applied to the solid samples in order to determine the potential leachability of their trace elements. The concrete samples were placed in distilled water at a solid/liquid ratio of 1/10. The cube was kept in water for 1 h, 1 day, 1 week and 1month to observe the amounts of metals leaching into solution. At the end of each immersion period, solution samples were obtained using 0.45 membrane filters and were analyzed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS Agilent 7500). The chemical analyses of the resulting leachates for 9 trace elements (As, Cd, Cu, Zn, Se, Fe, Pb, AI and Zn) and for Hg were performed by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS Agilent 7500).

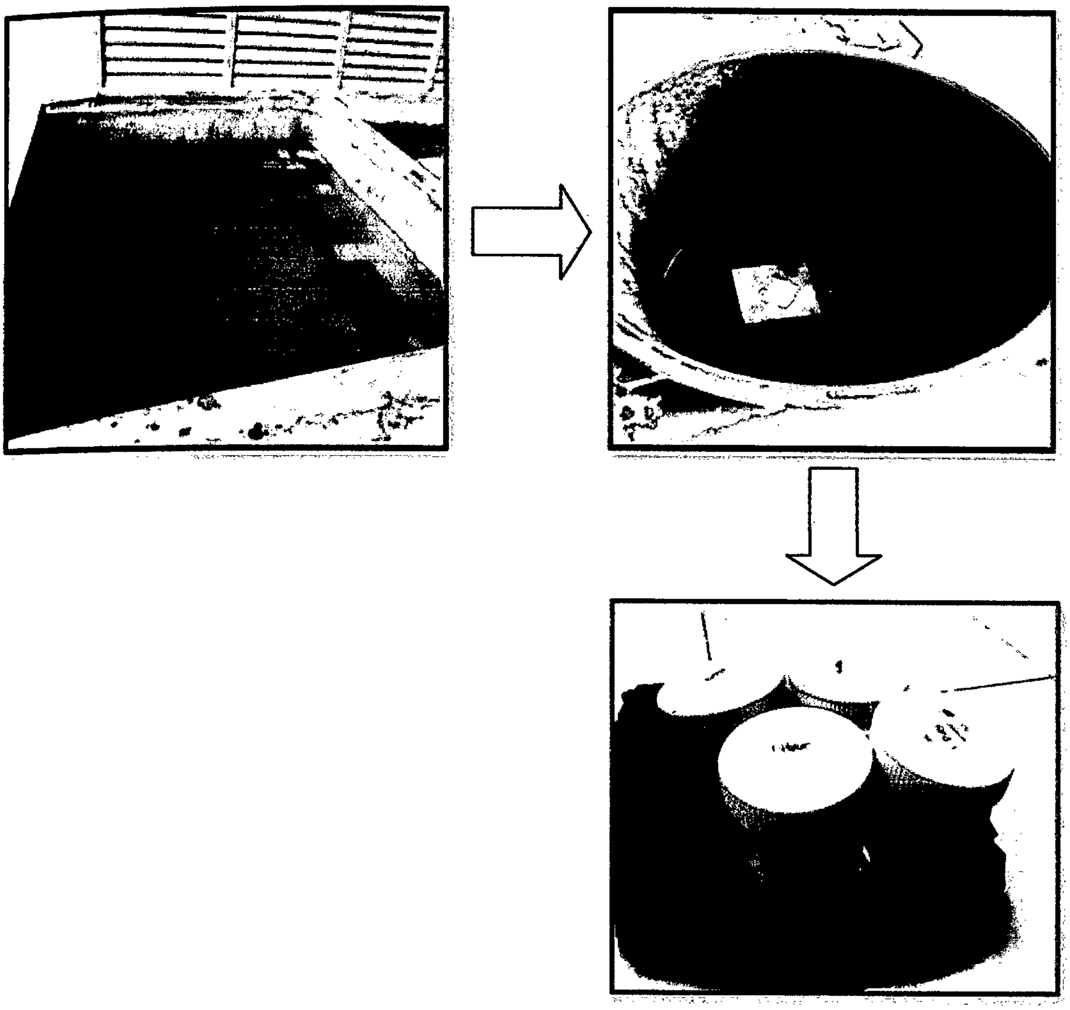

Figure 3.7: Flow of leaching test