EFFICIENCY OF ORDINARY PORTLAND CEMENT (OPC) (TYPE 1) IN HIGH PERFORMANCE CONCRETE (HPC) WITH SILICA FUME (SF)

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By

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Dissertation submitted in partial fulfillment
of the requirements for the
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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Approved by,

(Assoc. Prof. Dr. Nasir Shafiq)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JANUARY 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

FOONG KAH YEN @ CHERYL.E.

ABSTRACT

The world's yearly cement production of 1.6 billion tons accounts for about 7% of the global loading of carbon dioxide into the atmosphere. Portland cement, the principle hydraulic cement in use today, is responsible for a large amount of greenhouse gases. Producing a ton of Portland cement requires about 4 Giga Joules energy and the Portland cement clinker manufacture releases approximately 1 ton of carbon dioxide into the atmosphere. Ordinary concrete normally contains about 12% cement and 80% aggregates by mass. Concrete structures are generally designed for a service life of 50 years, but experience shows that in urban and coastal conditions, it deteriorates in 20-30 years or even less. It is suggested that in future structures to be designed and build for a minimum service life of 100-120 years while bridges to have at least 150 years of useful life. The trend towards designing infrastructure based on life-cycle cost will not only maximize the return on the available capital but also on the available natural resources. Thus to determine the efficiency of cement for 28 days in High Performance Concrete (HPC) with Silica Fume (SF) within strength of 50-70MPa is achievable. Enhanced efficiency is not likely to change the condition but replacement of some of the cement by supplementary cementing material such as Silica fume (SF) can substantially reduce CO_2 emissions. The research is estimated to reduce the emission of carbon dioxide (CO_2) into the atmosphere by 15%-20% directly reducing cement consumption in the construction industry within the same rate. Environmental friendly and cost effective HPC is expected to be produced with technical knowledge of Concrete Technology applications in effort in promoting 'GREEN EARTH'.

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First and foremost the author would like to thank God for making this progress report a great success. Without his willingness and faith, this report will not be completed and shared to everyone.

The next would be the author's family especially to father, Mr. W.C. Foong, where he guided the author during the process in writing this report in getting references of the build environment in Malaysia. The guidance he gave was very encouraging and has inspired the author to progress further to make improvements for the concrete technology.

Then the author would like to send greatest compliment and appreciation to supervisor, Associate Professor Dr. Nasir Shafiq. It is great to have him as a supervisor and he taught the author a lot during the process in preparing this progress report. He made the author realize the smallest thing that is to be taken into account for this research. From this the author have learned a lot and this inspires me to continue to contribute to improve the research. Special thanks to Mr.Pierre-Aime Favre from SIKA Kimia Sdn.Bhd. for sponsoring the Silica Fume (SF) for this research. Also a great appreciation to the Concrete Technology Laboratory technicians, Mr. Johan Ariff and Mr. Hafiz as well as to my good PHD friend, Miss Salmia Beddu for advice and support.

This final report mainly states the recent and progress of works that have done. The progress will improve and great discovery will be discovered as time goes by. The author hope that the works stated is shared and benefited the future coming generation in doing this research as the saying goes;

'Research is Research and Application but Sharing the Experience is Countless'

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ABBREVIATIONS AND NOMENCLATURES

C_3S = Tricalcium Silicate

C_2S = Calcium Silicate

HPC = High Performance Concrete

OPC = Ordinary Portland Cement

SF = Silica Fume

μm = micro meter

SP = superplasticizer

W/B = water binder

MIRHA = Microwave Incinerated Rice Husk Ash

SSD = Saturated Surface Dry

MPa = Mega Pascal

CHAPTER 1

INTRODUCTION

1.1 Background of study

Revolutionary developments relating to novel materials for concrete production and to modifications and improvements in the behavior of this traditional material have been taking place in the past two decades. The 21st Century will see the emergence of high-strength, high performance concrete, particularly in the world's infrastructure of roads, buildings and bridges. With the increasing urbanization and improvements in both developed and developing countries will only increase the demand of better quality concrete for the rise of structures with high aesthetic values. The versatility of concrete and its high performance derivatives will satisfy many future needs. The 21st century will be the ideal era whereby it will be the golden age of environmentally friendly supplementary cementing materials for high-performance concrete [1, 2].

Over the years, to produce concrete with improved properties such as higher early strength and enhanced durability is achieved due to gradual increase in the fineness and C_3S (Tricalcium Silicate) content in the Ordinary Portland Cement (Type 1). The increase of C_3S content as compared to the C_2S (Calcium Silicate) content has resulted in a more rapid hydration; hence faster development of strength is achieved. Since concrete mixtures are proportioned on the basis of 28 days compressive strength measurements, this has resulted in the decrease of the cement content and the increase of water cement ratio in a given consistency. The reduction in particle size generally results in the increases of hydration and a higher compressive strength. Greater fineness leads to an increase water demand.

In recent years, further improvements in concrete properties have been achieved in the so-called High Performance Concrete (HPC) that involves better compaction, enhanced paste characteristics, and perfect bond between aggregate- matrix and reduced porosity. In these systems, a substantial reduction in water-to-cement ratio is achieved through the use of super-plasticizers, further enhancements of some properties have been obtained through the addition of mineral micro-fillers (supplementary cementitious or pozzolanic materials such as silica fume and fly-ash) [3, 4, 5].

High Performance Concrete (HPC) is a specialized series of concrete that is designed to provide several benefits in the construction of structures that cannot always be achieved routinely using conventional ingredients, normal mixing and curing practices. In simple saying, HPC is produced where certain characteristics are developed for a particular application and environment so that it will give excellent performance in the structure in which it will be placed, the environment in which it will exposed and with the loads to which it will be subjected during its design life. An example of a characteristic that may be considered critical in an application requiring performance is the early age strength. Concretes possessing this characteristic often achieve higher strength. Therefore, HPC is often of high strength, but high strength concrete may not necessarily be high performance.

Traditionally, interests in the strength of concrete have been focused on those at the age of 28 days and beyond. There are at least 3 factors that contribute to the interest of knowing the strength of the concrete Firstly it is the fast-paced construction schedules that concrete to significant structural loads at certain stages. Second is the development of specialty cements or admixtures that is able to achieve higher strength at early ages and thirdly is the recognition that long-term performance of concrete is greatly affected by its early-age history [6, 7, 8].

1.2 Problem Statement

The concrete of the future will be GREEN, GREEN AND GREEN. Concrete will have low water/binder (W/B) ratio, durable and applicable in various conditions. The most serious problem with the Concrete Industry is that it is a major CO_2 emitter causing global warming. One ton of cement produced equals to one ton of CO_2 emitted. It is estimated about 7% of CO_2 is generated worldwide. Resource productivity considerations will require minimizing Portland cement use to meet the future demands of eco-friendly concretes. Since the concrete grades are increasing rapidly due to market demand, consumption of cement in the construction industry increased about 600-700 kg/m³. The depletion of resources as basic raw materials worsens the condition with the reduction of lime stone deposits. Thus in order to optimize the cement content that is needed most appropriately, it is required to investigate the efficiency of cement through detailed research.

1.3 Objective and Scope of study

The main objective of this research is

- To determine the high efficiency (Cost (RM) / Strength (MPa) / Cement Content (M³)) of cement for producing 28 days concrete of optimum strength 50-80MPa in High Performance Concrete (HPC) with Silica Fume (SF).

The scopes of study of this research are as below:

- To study the theory of basic concrete and High Performance Concrete (HPC) composition understanding.
- To study the current technologies in the concrete industry and development.
- To study different types of concretes available in the market and highlighting the main research purpose on High Performance Concrete (HPC)
- To study ways to obtain the most ideal material for building and infrastructure construction purposes.

1.4 Feasibility

Considering the existing high demand of High Performance Concrete (HPC) faced in the industry relating to the developing concrete industry, improvements should be made to the methods of developing better (HPC) with high early strength. By adjusting the amount of ordinary Portland cement (OPC), and Silica Fume (SF), the project engineers, manufacturer and designers can conduct their planning and development more precisely to increase the quality of HPC. With the improvements, possible increase in construction development should be achieved in buildings and infrastructures. Thus, results in prolonging the lifespan of structures and infrastructures as well as their aesthetic values. Therefore, this project is feasible for study to improve the current trend in the industry.

1.5 Relevancy

This project is relevant to the construction of structures and infrastructure industry especially to the civil engineers, manufacturers, developers and manufacturers in assisting them to proper construction planning management. It also contributes to the development of an ideal grade of concrete to the market. Despite the fact that there are many types of concrete present in the recent market, the demand for better grade with high strength is great and is highly required in developing countries such as Malaysia. With effective time planning and hard effort, it is believed that this research will be a great guideline. It is direct, flexible and most of all cost and aesthetics effective.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 High Performance Concrete (HPC)

According to Hu, Larrard, 'Rheology of Fresh High Performance Concrete' (1995) [9] the HPC has been widely used for the last decade. With superplasticizer, this concrete has a better compactness, owing to the reduction of water. The silica fume used in certain cases increases even more the concrete compactness by filling of some intergrain voids. Hence the HPC presents numerous advantages and the main focus in this research study is high strength.

From Edward, 'Concrete Properties' (2003) [2], in order to cater to the world development and the increasing urbanization, HPC with high strength is highly needed so to sustain the capacity of a structure that is subjected to carry. This saves cost of all parties and promotes technology development to the Concrete Industry.

2.2 Compressive Strength and High Early Strength of Concrete.

From the research study that is to be conducted, the compressive strength of the concrete is to be known by getting the optimum amount of Ordinary Portland Cement (OPC) (Type 1) and Silica Fume (SF) by adjusting the amount of these elements in every mix. Thus, the strength which is the Compressive Strength, of the HPC will be the main focus of my research study.

According to Gambhir 'Concrete Technology' Tata McGraw-Hill Publishing New Delhi (2004) [6], the Compressive Strength of HPC is much higher than those of the normal concrete of the same consistency. Strength of the normal concrete is achieved by superplasticized concrete with reduced cement content. The use of super-plasticizers generally improves the strength of HPC. The strength of concrete normally depends on a number of factors including the properties and proportions of the constituent materials, degree of hydration, rate of loading, method of testing and specimen geometry. The properties of the constituent materials which affect the strength are: the quality of fine and coarse aggregates, the cement paste and the paste-aggregate bond characteristic properties of the interfacial transition zone. These, in turn, depend on the macro- and micro-scopic structural features including total porosity, pore size and shape, pore distribution and morphology of the hydration products as well as the bond between individual components.

HPC with high early strength is a great interest among the build industry. As mentioned by Gambhir, there are at least 3 factors that contributes to the increase of this early high strength that is

1) Fast-paced construction schedules.

2) The development of new concrete products which are getting better in the market. (Marketing and Sales competition).

3) Effects of the early-age history.

In HPC, due to the greater accessibility of cement grain surfaces, the greater early hydration results in up to 24-hours strength of concrete being generally higher than that in the case of normal concrete of the same water-cement ratio. Frequently the greater rate of cement hydration in the well-dispersed system, concretes containing superplasticizer show even higher compressive strengths at 1,3 and 7 days than the normal concrete having the same water –cement ratio.

2.3 Silica Fume Application

From Luther, Smith (1991) [3] and Malhotra, Mehta 'Pozzolanic and Cementitious Materials' Taylor and Francis Group (2004) [5], Silica Fume (SF) can contribute to the compressive strength development of concrete. This is because of the filler effect and excellent pozzolanic properties of the material that translate into a stronger transition zone at the paste-aggregate interface. SF contributes to the development of compressive strength depends on various factors such as percentage of SF, water cement (w/c + SF) ratio, cement content and composition. Very fine particles of SF get absorbed on the top oppositely charged surface of cement particles and prevent them from flocculation. The cement particles are then effectively dispersed and will not trap large amounts of water, which means that the system will have a reduced water requirement for flow.

In addition to the mechanisms, particle packing effect is also responsible for water reduction. Note that Portland cement particles are mostly on the size of 1-50μm. Therefore physical effect of particle packing by the microfine particles of a mineral admixture will reduce the void space and correspondingly the requirement for plasticizing the system. Microfine fillers which contain a very large proportion of very fine particles such as silica fume, it should be obvious that the filler particles themselves must be dispersed with the aid of a plasticizing agent before any benefit from the particle packing effect can materialize. The Figure 1 in the next page shows the Mechanism of bleeding reduction in cement paste by silica fume addition.

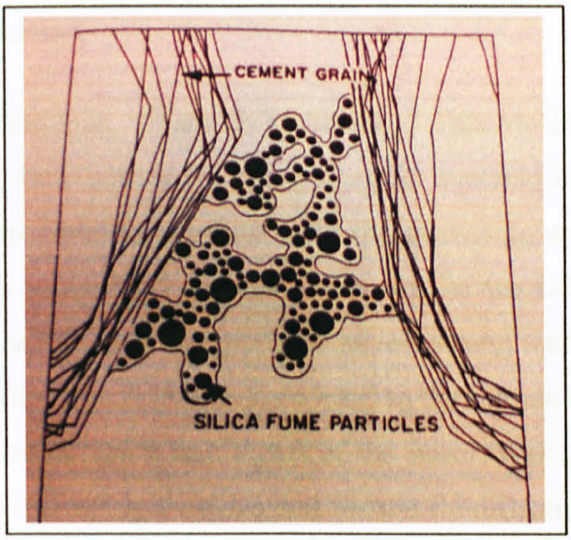


Figure 1 - Mechanism of bleeding reduction in cement paste by silica fume addition

Source - Malhotra, Mehta, 'Pozzolanic and Cementatious Materials' Taylor and Francis Group, 2004.

From the materials that I have researched, the water demand of HPC with SF is directly proportional to the amount of SF used. The strength is also largely offset by the higher water demand, especially for high silica fume content at early ages. In general, the use of the superplasticizer is to achieve proper dispersion of the SF in concrete and to fully utilize its contribution to the strength potential. HPC containing SF has compressive strength development patterns which are different from those of Ordinary Portland Cement (OPC) Concretes. If compared with those of fly-ash concretes, the effect of the pozzolanic reactions of the former is evident in the earlier ages. This is because SF is a very fine material with very high amorphous silica content. The dosage of SF is obviously an important influence to the compressive strength of the concrete. For general construction, the optimum dosage generally varies between 7% and 10%, however, in specialized condition; up to 15% of the SF is incorporated successfully in concrete. The proper selection and proportion of cement also plays an important role in developing mixture proportions for high quality and improved HPC.

2.4. Cement Efficiency

As described by Gambhir, 'Concrete Technology' Tata McGraw-Hill Publishing New Delhi (2004) [6], the compressive strength of the concrete increases with decreasing water-cementitious material ratio and with the increasing amount of SF. Thus, it is very important to understand the mechanism of the workability enhancement. The description is so as OPC and fine particles have a strong tendency to flocculate when mixed in water. The flocculation process leads to the formation of an open network of particles. The network voids trap a part of the water, which is then unavailable for surface hydration of cement particles and for the fluidification of the mixture. These effects result in the stiffening or increase in apparent viscosity of the cementitious system. To achieve a homogeneous distribution of the water, and the optimal water cement contact, the cement particles must be properly deflocculated and kept in the state of high dispersion. Due to the dispersion effect, the fluidity in the cement mixture is increased.

The water reducing admixtures perform their function by deflocculating the lumps of the cement grain. In the normal stage, the surfaces of the cement grains contain negative and positive charges. As they bump into each other, they repel and attract. Superplastizicer on the other hand have very large molecules (colloidal size) which dissolve in water to give ions with a very high negative charge (anions). These anions are absorbed into the surface of the cement particles in sufficient number to form a complete monolayer around them to become predominantly negative charged. Thus, they repel each other and flocs do not form. In doing so, water trapped within the original flocs is released and then can contribute to mobility of the cement paste improving the workability (in terms of strength) of the HPC. The representation of the superplasticizer molecule and its mode of absorption on cement grains in Figure 2 are as shown as in the next page;

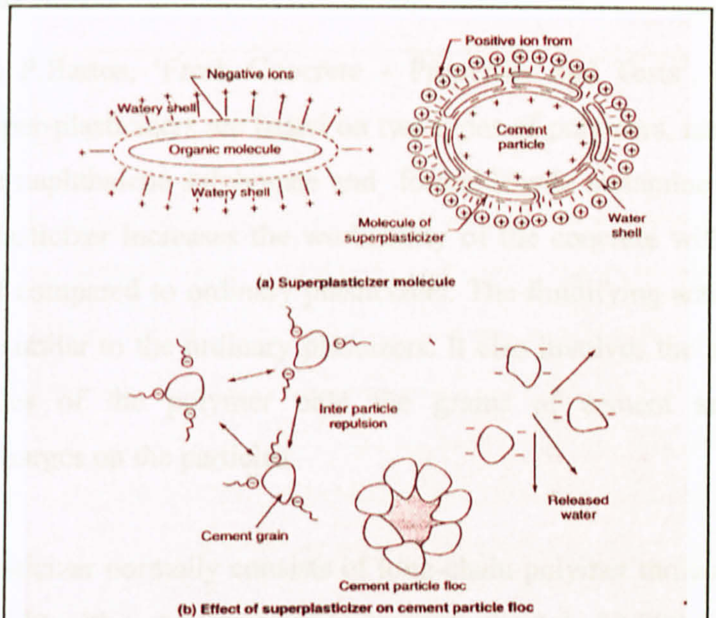


Fig. 5.5 Representation of superplasticizer molecule and mode of adsorption on cement grains

Figure 2 - Representation of superplasticizer molecule and mode of adsorption on cement grains

Source- Gambhir, 'Concrete Technology', TataMcGrawHill Publishing, India.

Thus, can be said that the amount of cement required within a mix is very important as it affects the strength of the HPC that is to be produced. The optimum amount is to be determined to ensure the quality of the HPC produced.

2.5. Superplasticizers

According to P.Bartos, 'Fresh Concrete – Properties and Tests', Paisley College, 1992 [10], super-plasticizers are based on two types of polymers, namely the salts of formaldehyde naphthalene sulphonate and formaldehyde melamine sulphonate. The term super-plasticizer increases the workability of the concrete without undesirable side effects if compared to ordinary plasticizers. The fluidifying action of the super-plasticizer is similar to the ordinary plascizers. It also involves the adsorption of the macromolecules of the polymer onto the grains of cement and changes the electrostatic charges on the particles.

The super-plasticizer normally consists of long-chain polymer molecules of different molecular weight with a maximum of up to approximately 30 000. Investigations by Basile et.al (ref 13) suggested that within the range of molecular weights of the naphthalene sulphonate condensation products investigated the effectiveness of the admixture was governed by the content of the monomer and the fraction with the lower molecular weight. Increase in the molecular weight of the polymer increases the consistency of the paste measured by 'mini slump'. The amount of polymer absorbed on hydrated cement changes the electrical charges and decreases the air-entrainment up to the molecular weight of about 600. There was very little change for molecular weights greater than 600. The super-plasticizers also generate some air-entrainment which affects consistency of cement paste.

The high dosage of super-plasticizers permits greater water reduction. The amount of reduction can vary between 20% to 25% depending on some circumstanced factors. The increase in workability can be so great that fresh mixes of moderate High Performance Concrete (HPC) can be converted into collapsed slump. The increment also shows increase in mobility and compactability. Stability (segregation, bleeding) tends to remain either the same or slightly reduced.

Normal doses of the super-plasticizing admixture do not produce an unacceptable bleeding but overdoses and inappropriate grading of aggregates can lead to substantial bleeding. In such cases a layer of laitance forms on the surface of concrete and the mix stiffens very rapidly. It is possible that the separation of water leaves behind cement particles with absorbed layers of polymer but little free water, thus increasing greatly the viscosity of the cement paste. The rapid stiffening can be so great that fresh concrete mixes will not become plastic even when vibrated with the vibrator apparatus.

The effects of the plasticizing and superplasticising agents are related for concrete of Ordinary Portland Cement (OPC) (Type 1) as basis. This discussion from P.Bartos has certainly met the purpose of my research title in the efficiency of OPC Type 1 in High Performance Concrete (HPC). The possibility of the reduction of water binder (W/B) ratio is to offer potential for producing better high quality HPC. A very high dose of ordinary lignosulphonate based plasticizer increases the slump thus increasing the workability of HPC thus producing high compressive strength in early period thru the optimum amount of OPC Type 1.

Thus, according to SP Shah and SH Ahamad, 'High Performance Concretes and Applications', North Western University, Evanstone, USA and North Carolina State University, USA, 1994 [11] concludes that there is no a prior way of determining the required superplastisizer dosage but in the end, is it done by some sort of trial and error during the mixing procedure. Basically if the strength is the priority criterion, as mentioned as my purpose of this research, the lowest water cement ratio (w/c) ratio should be worked on with the highest superplastisizer rate that is to be adjusted during the concrete mixing process. In general, some intermediate position must be found so that the combination of strength can be optimized.

2.6. Supplementary Cementing Materials.

According to SP Shah and SH Ahmad, 'High Performance Concretes and Applications', North Western University, Evanstone, USA and North Carolina State University, USA, 1994 [12] states that most modern high strength concrete contains one supplementary cementing materials. However to cater for some unexpected and unavoidable incidents, a substitution of the cementing material have to be available. Here in this research the Microwave Incinerated Rice Husk Ash (MIRHA) suits the acceptance limits (chemical requirements of silica 85%) for silica fume (SF) as indicated in Table 1, 'Canadian Specifications for Silica Fume' taken from CSA Standard A23.5 as shown.

Table 1.4 Some Canadian specifications for silica fume (taken from CSA Standard A23.5[9])

Chemical requirements	
SiO_2, min (%)	85
SO_3, max (%)	1.0
Loss in ignition, max (%)	6.0
Physical requirements	
Accelerated pozzolanic activity index, min, (%) of control	85
Fineness, max, (%) retained on 45 μm sieve	10
Soundness – autoclave expansion or contraction (%)	0.2
Relative density, max variation from average (%)	5
Fineness, max variation from average (%)	5
Optional physical requirements	
Increase of drying shrinkage, max (%) of control	0.03
Reactivity with cement alkalis: min reduction (%)	80

Table 1 - 'Canadian Specifications for Silica Fume'

Source - CSA Standard A23.5

From Muhammad Shoaib Ismail and AM Waliuddin, 'Effect of Rice Husk Ash on High Strength Concrete', NED University of Engineering & Technology, Karachi, Pakistan, 1996 [13], the color of the completely burned rice husk in the microwave is blackish. During the research, this product, the burnt rice husk is known as MIRHA. After some investigation on the chemical properties of the MIRHA, the silica content is about 80% - 90% matches the chemical requirements of Silica Fume (SF).

According to Pavlenko, Maihkimin, Bazhenov, Maydeyev, 'Development and Use of Fine Cementless Concretes Consisting of By-Products as one of the Ways for Reducing CO_2 Emissions', CANMET/ACI International Symposium on Sustainable Development of the Cement and Concrete Industry, Ottawa, 1998 [14] states that if cement replacing materials such as Silica Fume (SF) from the metallurgical industry, to be added in a concrete mix of reduced cement content, there is normally little or no CO_2 released into the atmosphere.

CHAPTER 3
METHODOLOGY

3.1 Project Work Flow

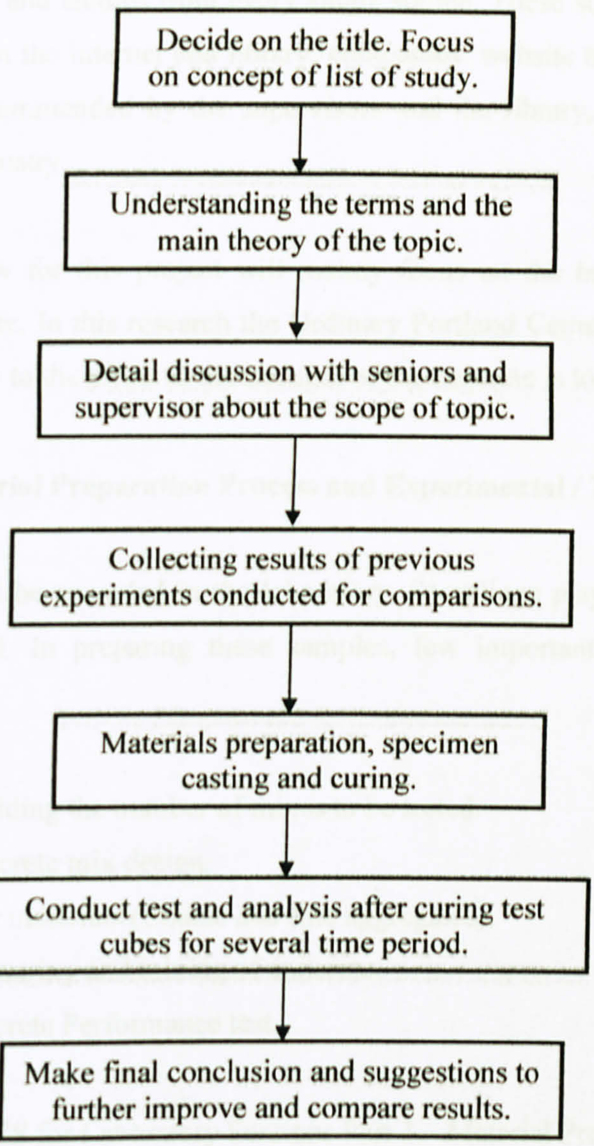


Figure 3: Project Flow Chart

3.2 Research Stages Breakdown

3.2.1. Stage 1: Literature Review on the related subject.

As the start of the research project, an extensive literature review has to be done in order to fully understand the concept of the project. A wide range of knowledge is needed for the project to be successful. In this stage, we have to grasp all the information that is related to the project by conducting research and studies from every single source. These sources can be taken from the journals, papers from the internet and library, companies' website that is related to the industry, reference books recommended by the supervisors and the library, and potential sources from companies in the industry.

The literature review for this project will mainly focus on the basic understanding on High Performance Concrete. In this research the Ordinary Portland Cement (OPC) Type 1 and Silica Fume (SF) efficiency to the effect to the strength of the concrete is to be investigated.

3.2.2. Stage 2: Material Preparation Process and Experimental / Testing Process.

Random testing shall be executed in the laboratory. Samplings play a significant role as good samples are required. In preparing these samples, few important steps shall be taken into account, such as:

a) Deciding the number of mixes to be tested.
b) Concrete mix design.
c) Raw materials (Coarse and fine aggregates).
d) Measuring and mixing of concrete.
e) Concrete Performance test.

Refer to **APPENDICES** for Laboratory Sessions Part 1 – Material Preparations for required laboratory procedures.

3.2.2.1. Deciding number of mixes.

The selection of the number of concrete mixture is important in this research. This is so due to insufficient amount of time that is required to do the mix. As the number of mix is fixed, with good time management, continuous hardship effort and perfect rule obligation, this research will truly be a great guide to designers in the building industry.

3.2.2.2. Concrete Mix Design

During the preliminary stage prior to design process, the nature of the project and surroundings are to be considered. The design process is important to determine the quantity of materials to be used as well of the quality of the product produced.

The results commonly vary but statistically speaking, the variations in test results are of normal distribution to determine standard deviations. Based on statistical analysis, the strength of concrete mix is known as characteristic strength and is interpreted as 5% strength from test results. Thus, cubes from a concrete mix should be stronger in average from the characteristic strength. The differences between average and characteristic strength are known as permissible variation. This is shown in Figure 4.

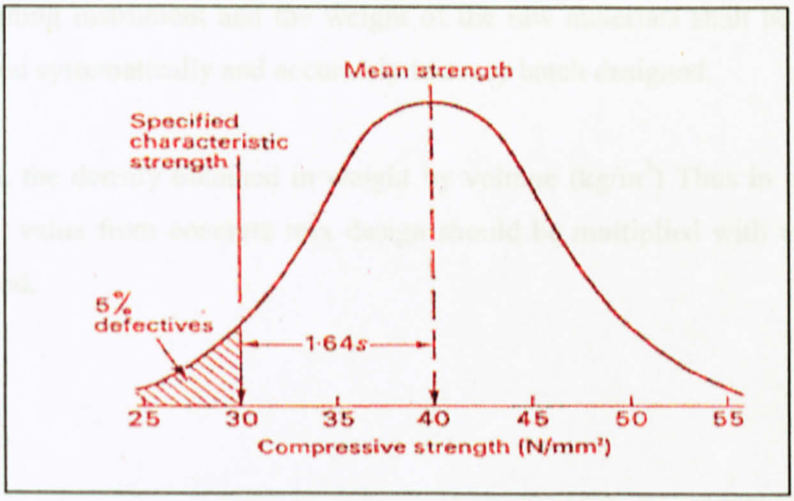


Figure 4 – Normal Distribution for Concrete Strength

3.2.2.3. Raw Materials (Coarse and Fine Aggregates)

i. Aggregate to be used shall be granite rock extracted from quarries and of 10mm to 20mm graded crushed where rough and angular surfaces display variation in properties. The rocks shall be dried before testing.

ii. In preparation of concrete mix, tap water from the lab shall be used.

iii. Sand measuring less than 5mm shall be monitored to enable wet mix having adequate cohesiveness. The sand was sieved manually using the sieve apparatus available in the laboratory. To ensure well-distributed sand particles, overall tests shall be conducted. Generally, selection of zone shall be at self-discretion. The sand is then air-dried to ensure that they are moisture-free and in saturated surface dry (SSD).

vi. Cement to be used shall be only Ordinary Portland Cement (OPC) (Type 1). Usage of other brands may affect the results of testing obtained.

vii. A fix amount of 3% superplasticizer is used and admixture of Silica Fume (SF) is used.

3.2.2.4. Measuring and Mixing of Concrete

In general, concrete is mixed according to the appropriate batch related to work and promptness of the construction. The weight measurement method is applied in mixing raw materials such as cement, sand, aggregates and water. This method requires a stringent quality control. Appropriate weighing instrument and the weight of the raw materials shall be determined and this is implemented systematically and accurately to every batch designed.

From mix design, the density obtained in weight by volume (kg/m^3) Thus in order to measure material quantity, value from concrete mix design should be multiplied with value of concrete density to be mixed.

Arithmetically, this can be computed as shown using the Formula 1 below:

$$\frac{\text{Weight}}{\text{Density}}\ \text{X Density} = \text{Weight=kg}$$

Formula 1: Formula to measure material quantity

Concrete is mixed by using the concrete mixer where the process is divided into two processes due to the size of the mixer. In this research, the latter technique shall apply by using laboratory facilities.

The raw materials shall be weighed and placed into the machine. The machine shall be rotated until the materials are completely mixed. Then the mix shall be taken out and water shall be measured and poured into the mixer. Finally, the mix is shoveled back into the mixer and it shall be rotated again. When water and materials are thoroughly mixed, it shall be formed into cube specimens after conducting slump test to suit the selection of the concrete mix design.

3.2.2.5. Concrete Test

One of the concrete characteristics that has made it been widely used is due to its' high compressibility in withstanding burden. The concrete performance test has always been referred to the compressibility in withstanding concrete cube load with a dimension of 150mm x 150mm x 150mm at the age of 28 days.

There are many techniques known to be applied in order to obtain compressive strength of concrete whether directly or indirectly, non-destructive test etc. In this research, the method applied shall be non-destructive which is the Cube Compressive Test with a dimension of 150mm x 150mm x 150mm and tested at the age of 3, 7, and 28 days respectively.

3.2.2.5.1. Mixing Concrete

The mixing and sampling of fresh concrete in the laboratory was based on BS1881: Part 125: 1986 by using a non-porous platform, a pair of shovel, a steel scoop and concrete mixer. The cement, sand, course aggregate and Silica Fume (SF) is first weighted and then mixed together with water and super-plasticizer by using concrete mixer at room temperature. The image can be shown in Figure 5 and 6.

Figure 5: Manual mixing

Figure 6: The Mix

The same procedures are then repeated for each sample mix proposed

Refer to **APPENDICES** for each mix design requirements.

3.2.2.5.2. Slump Test for Workability

After mixing concrete, the fresh concrete is to be tested for its workability by slump test as recommended by BS1881: Part 102:1983. The mix was filled into a clean truncated mould (diameter at top: 100mm, diameter at bottom: 200mm, height: 300mm) by four equal layers and each layer was rod 25 times with a round steel rod. After the top layer has been rod, the access concrete at the top of the moulds was stroked away. Then, the moulds were lifted carefully vertically and the differences between the height of the slumped concrete and mould were measured as its workability.

After the mixing and slump test, the mix are then cast and cured in 6 nos. of 150mm x 150mm x 150mm internal size moulds for compressive strength test as can be observed in Figure 7.

Figure 7: Mould Preparation

The casting of cubes as recommended by BS1881: Part III: 1983 by using vibrator machine as shown in Figure 8.


Figure 8: Vibrator Machine


Figure 9: Casting Process

The moulds were filled with concrete mixed earlier into three layers and each layer was tamped 25 times. The access concrete on the top of the mould were then stroked away in order to level its surface as shown in Figure 9 above. After that, it is covered with polythene sheet for 24 hours at room temperature as shown in Figure 10. Finally, after 24 hours, the samples are carefully removed from the moulds and put into the curing tank at room temperature as shown in Figure 11 and 12.


Figure 10: Cubes covered with polythene sheet to contain moisture

Figure 11: 'Open Mould'

Figure 12: Curing in water tank

3.2.2.5.3. Compression Test

The main objective of this test is to obtain the concrete strength (crushing strength). Observations shall also be made on factors of cube density and failures. The concrete mix shall be placed into the mould, which has been applied with mould oil to ease opening. Concrete shall be compacted into three layers using steel rods 25mm in size with 35 blows per layer and the surface shall be leveled using trowel.

After 24 hours, the mould shall be opened and the cubes shall be treated in a pond. All tests shall comply with the requirements of BS: 1881, Part 4, and MS 26: 1971. Prior to the test, the cubes or specimens shall be weighed to obtain density and placed onto the lower steel platen plate with both smooth surfaces facing the top and bottom platen plates. The load weight constantly applied shall be 4.5-9.0 KN/sec. until the specimen fails lastly the crush strength is recorded.

The load failure shall be recorded according the reading meter. By ascertaining the load failure and surface area, the concrete strength can be obtained. Observations shall also be made to the modes of failure and the aggregate arrangements of the concrete. This is as shown in Figure 13.

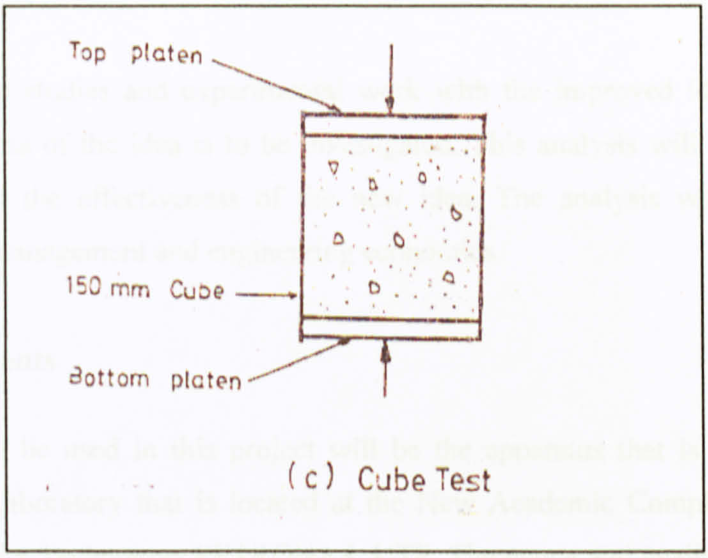


Figure 13: Cube Test

Refer to **APPENDICES** for the Compression Test Photos in Laboratory Sessions

3.2.2.5.4. Half- Testing Mixing Method

For the past 3 months, I have completed the required laboratory sessions at the Concrete Technology Laboratory. Due to the number of public holidays during the early months and lack of time in the final report submission, the results were minor affected in terms of manpower to conduct the mixing process. As many as 2 mixes were done in a day in three continuous days and includes Saturday to complete the required mixes. Thus by seeing this condition, the Half-Testing Mixing Method is used to obtain the strength of the High Performance Concrete (HPC).

The Half-Testing Method is a method whereby is structured by myself to assist in obtaining the results efficiently meeting the required time period. It is a method where I first divide the total 6 mixes into 2 major sets and further sub-setting them into another 2 for laboratory batching, mixing, and curing processes. This method aims to save time and to obtain more accurate results. There will be fewer delays as we are looking at the high construction cost and speed. The method is applied and it has proven to be quite effective and fast.

3.2.3. Stage 3: Analysis and Conclusion of the Research Project.

After conducting all the studies and experimental work with the improved ideas, a thorough analysis of the worthiness of the idea is to be investigated. This analysis will include the cost factor, time factor, and the effectiveness of the new idea. The analysis will include basic knowledge in strategic management and engineering economics.

3.3: Tools and Equipments

The main tool that will be used in this project will be the apparatus that is available in the Concrete Technology Laboratory that is located at the New Academic Complex, Building 13 ground floor in University Technology PETRONAS, UTP. The venue and available apparatus to mix, cure and test the concrete cubes are available in the laboratory. Therefore, it is convenient to conduct the research. The Compressive Strength Machine can be observed in Figure 14 and Figure 15.

Figure 14: Compressive Strength Machine (Automatic)

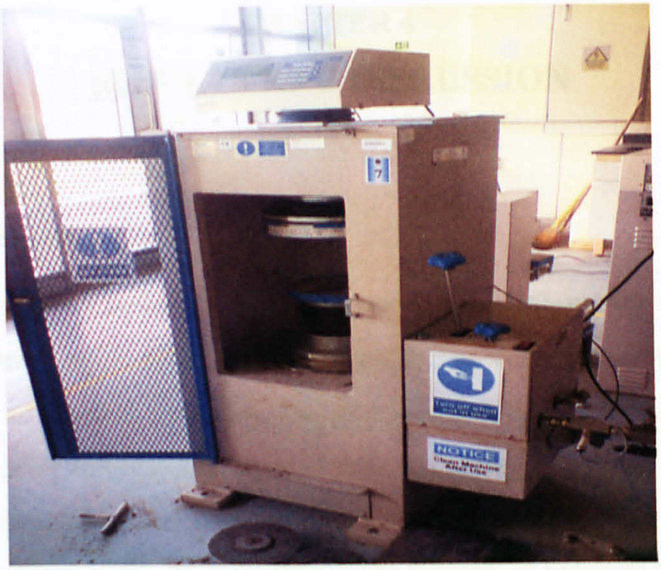


Figure 15: Compressive Strength Machine (Manual)

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Results and Discussion.

In order to determine the optimum strength of the High Performance Concrete (HPC), this chapter is divided into 5 main parts which includes; The Sieve Analysis Test, Mix Design, Laboratory Results, and Cement Consumption in mixes and the Cost Analysis of unit strength (RM/MPa). Tests are done and result data are compiled in table forms and simple line graphs are constructed to conduct result analysis. Discussions and interpretations are made at every part of this chapter. Below are the results obtained during the laboratory sessions and the results are then discussed:

4.1.1 Sieve Analysis

Sieve Analysis Test was conducted during the laboratory sessions. The test includes fine aggregates (sand) and coarse aggregates (stones, max.20mm). The results are obtained and were arranged in Table 2.

AGGREGATES	MAXIMUM ZONE (BS 822)		MINIMUM ZONE (BS822)		TEST ANALYSIS	
FINE (SAND)	sieve size (mm)	Percentage passing (%)	sieve size (mm)	Percentage passing (%)	sieve size (mm)	Percentage passing (%)
	0.15	10	0.15	0	0.15	0
	0.3	15	0.3	2	0.3	2
	0.6	80	0.6	20	0.6	20
	1.18	90	1.18	50	1.18	62
	2.36	95	2.36	70	2.36	87
	5	98	5	90	5	92
	10	100	10	100	10	100
COARSE (STONES) MAX.20MM	sieve size (mm)	Percentage passing (%)	sieve size (mm)	Percentage passing (%)	sieve size (mm)	Percentage passing (%)
	pan	0	pan	0	pan	0
	2.36	0	2.36	0	2.36	1
	3.35	3	3.35	0	3.35	3
	5	30	5	0	5	16
	10	80	10	30	10	61
	14	90	14	70	14	82
	20	100	20	90	20	90

Table 2: Sieve Analysis Test Proportional Chart

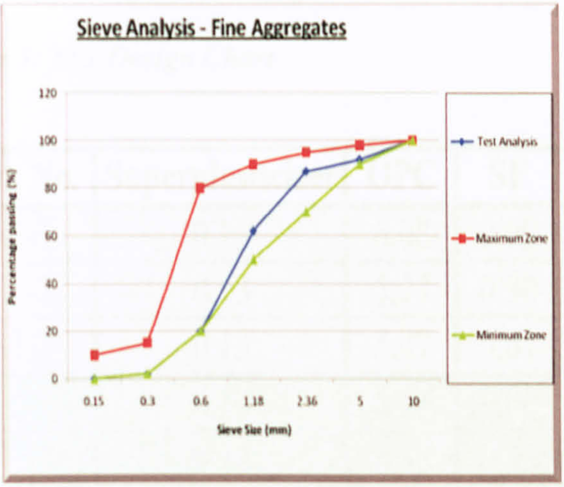


Figure 16

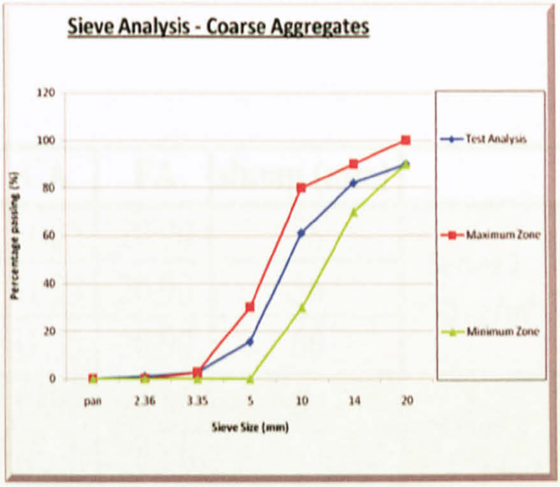


Figure 17

Figure 16: Sieve Analysis – Fine Aggregates (Sand)

Figure17: Sieve Analysis – Coarse Aggregate (Stones Max.20mm)

As can be observed from Figure 16 and Figure 17, it can be said that the Test Analysis plot (blue line) lies between the maximum zone and the minimum zone set by the standard, BS882 in both figures. This shows that the aggregates used in producing the mixes have high interlocking particles capacity. The aggregates are said to be well packed and reduces the risk of segregation. Less segregation of aggregates will increase the strength of the concrete thus enhancing its durability.

4.1. 2 Mix Proportion Design

Table 3: Mix Design Chart

Mix No.	Superplasticizer	OPC	SF	CA	FA	slump (mm)	
S1-1	0.13	6.08	0.00	31.35	20.90	58	Series 1 250 kg/m³
S1-2	0.13	5.77	0.30	31.35	20.90	56	
S1-3	0.13	5.47	0.61	31.35	20.90	60	
S2-1	0.14	6.68	0.00	30.98	20.66	60	Series 2 275 kg/m³
S2-2	0.14	6.35	0.33	30.98	20.66	54	
S2-3	0.14	6.01	0.67	30.98	20.66	56	

Legends:

OPC	Ordinary Portland Cement (OPC)(Type 1)
SF	Silica Fume
CA	Coarse Aggregates (Stones, Max.20mm)
FA	Fine Aggregates (Sand)

BATCH 1 = 3 DAYS AND 7 DAYS
BATCH 2 = 28 DAYS
MIX 1 = 100% OPC
MIX 2 = 95% OPC + 5% SF
MIX 3 = 90% OPC + 10% SF
Superplasticizer is 3%
Total mixes = 12 mixes in 2 semesters.

The Mix Design Chart is a very important chart as it is the main guidelines for the designer to conduct and produce good concrete mixes. There are also certain standards that are needed to be applied and followed so to avoid any unwanted reactions such as bleeding or coloration of concrete in the later experiment processes. The proportion of the aggregates and chemical admixtures are basically calculated and is carried out from trial and error. The water binder (W/B) ratio for this research is made for sure not to exceed 0.5. The slump is controlled within the range of 30-70mm.

4.1. 3. Laboratory Results

The Compressive Strength of the mixes is obtained from the Compressive Strength Machine. The results are cumulated and are arranged in Tables as shown below:

Table 4: Mix Samples Series 1 and Series 2

MIX SAMPLES			DAYS		
			3	7	28
Series 1 250 kg/m³	S1-1	100% OPC	14.65	18.22	62.07
	S1-2	95% OPC + 5% SF	38.18	43.12	62.20
	S1-3	90% OPC + 10% SF	37.13	43.62	62.30
Series 2 275 kg/m³	S2-1	100% OPC	33.10	40.14	62.42
	S2-2	95% OPC + 5% SF	46.70	50.50	63.42
	S2-3	90%OPC + 10% SF	46.75	51.08	63.70

Table 5 : Experimental Mix Samples (28 days)

Mix Samples	PC Control Mix	PC + 5% CSF	PC + 10% CSF
315 kg/m³	50	54	67
360 kg/m³	56	67	75

(Alexander. Magee, 1999)

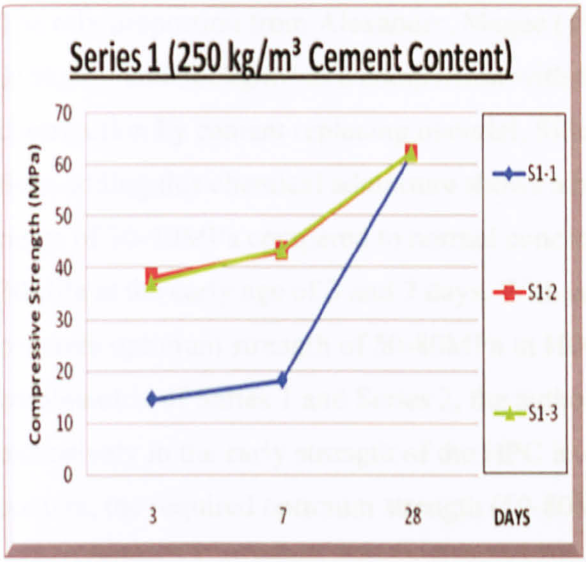


Figure 18

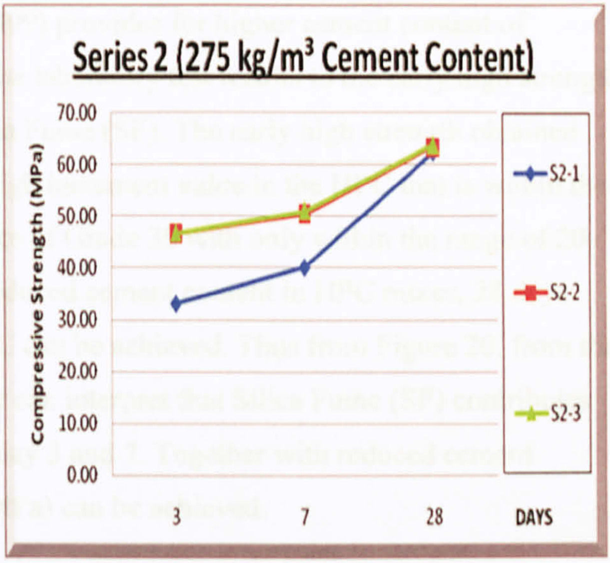


Figure 19

Figure 18: Series 1 – 250 kg/m³ Cement Content
Figure 19: Series 2 - 275 kg/m³ Cement Content

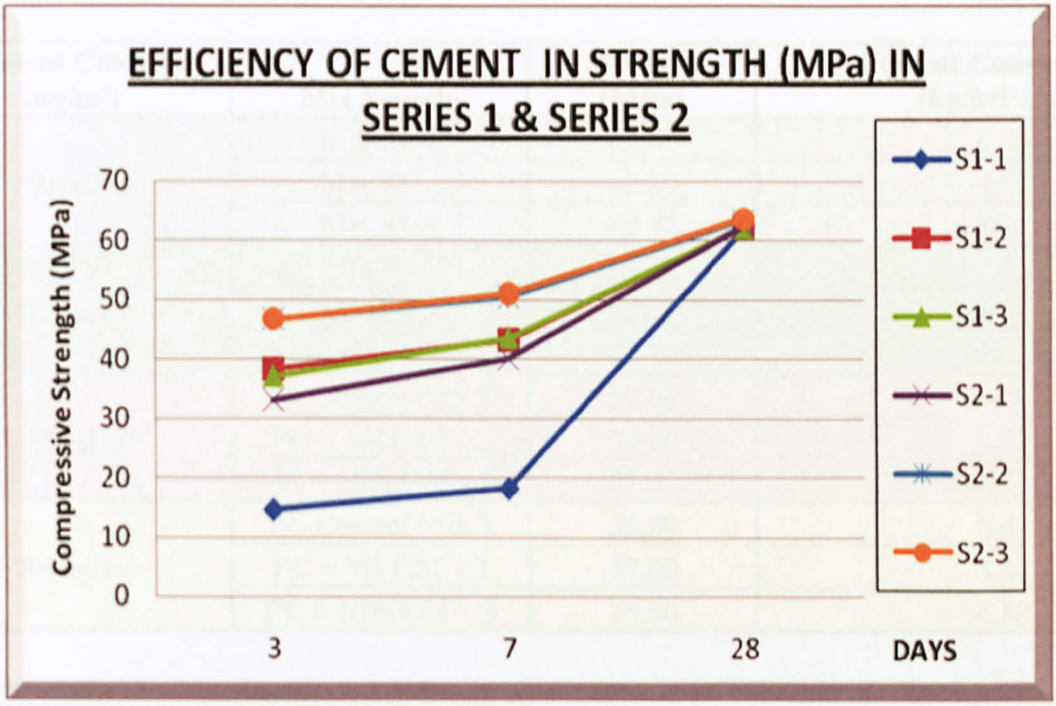


Figure 20: Efficiency of Cement in Compressive Strength (MPa) in Series 1 and Series 2

The mix proportion from Alexander, Magee (1999) provides for higher cement content of 315kg/m^3 and 360kg/m^3 as a comparison with the laboratory test results to the early high strength contribution by cement replacing material, Silica Fume (SF). The early high strength obtained from adding this chemical admixture shows a high increment value in the HPC that is within the range of 30-40MPa compared to normal concrete of Grade 30 with only within the range of 20-30MPa at the early age of 3 and 7 days. With reduced cement content in HPC mixes, 28 days concrete optimum strength of 50-80MPa in HPC can be achieved. Thus from Figure 20, from the combination of Series 1 and Series 2, the author can interpret that Silica Fume (SF) contributes extensively in the early strength of the HPC in day 3 and 7. Together with reduced cement content, the required optimum strength (50-80MPa) can be achieved.

4. 1. 4 Cement Consumption in Mixes

The cement consumed in each mix is calculated and the results are arranged in a table below:

Table 6: Cement Consumption in Mix of 4 Series.

Cement Content (kg/m^3)	Mix Sample	Strength (MPa)	Cement Consumption (kg/MPa/m^3)
250 kg/m^3	Mix S1-1	62.07	4.03
	Mix S1-2	62.20	4.02
	Mix S1-3	62.30	4.01
275 kg/m^3	Mix S2-1	62.42	4.40
	Mix S2-2	63.42	4.34
	Mix S2-3	63.70	4.32
315 kg/m^3	PC Control Mix 2	50.00	6.30
	PC + 5% CSF - 2	54.00	5.83
	PC + 10% CSF - 2	67.00	4.70
360 kg/m^3	PC Control Mix 3	56.00	6.43
	PC + 5% CSF - 3	67.00	5.37
	PC + 10% CSF - 3	75.00	4.80

Legend:

Mix Proportions from Laboratory Test

Mix Proportions from Alexander. Magee (1999)

The cement consumption in Series 1, Series 2 and Mix Proportion by Alexander. Magee (1999) [15] from Table 17-20, decreases in every mix with a percentage reduction of cement consumption within the range of 10 -15%. With every decrement, the amount of cement replacing material, Silica Fume (SF) will increase contributing greatly to the 28 days strength of the concrete. Thus, the HPC is actually getting more durable in terms of high strength with the reduction of cement consumption into the mix achieving the optimum required strength within 50-80MPa.

4. 1. 5 Cost Analysis (Cost (RM) / Strength (MPa))

To determine the economical value of the High Performance Concrete (HPC) with Silica Fume (SF), with the obtained efficiency of OPC and SF, the author is able to estimate the cost (RM) in every unit strength (MPa). The cost/strength is arranged in Table 12.

Table 7: Cost (RM) / Strength (MPa) in 3 Mixes.

Mixes	Mix Sample	Cement Content (kg/m³)	Strength (MPa)	Cement Consumption (kg/MPa/m³)	Cost (RM) / Strength (MPa)
100 % OPC	Mix S1-1	250	62.07	4.03	5.72
	Mix S2-1	275	62.42	4.40	5.93
	PC Control Mix 2	315	50.00	6.30	6.13
	PC Control Mix 3	360	56.00	6.43	8.40
95% OPC + 5% SF	Mix S1-2	250	62.20	4.02	6.03
	Mix S2-2	275	63.42	4.34	6.19
	PC + 5% CSF - 2	315	54.00	5.83	7.40
	PC + 5% CSF - 3	360	67.00	5.37	7.22
90% OPC + 10% SF	Mix S1-3	250	62.30	4.01	6.34
	Mix S2-3	275	63.70	4.32	6.51
	PC + 10% CSF - 2	315	67.00	4.70	6.86
	PC + 10% CSF - 3	360	75.00	4.80	6.70

To achieve the objective of cost effective HPC, a simple cost analysis is done by comparing the prices of the higher cement content mixes with the lower cement content mixes that uses the same amount of aggregates, superplasticizer, and cement replacing material, Silica Fume (SF). Although the silica fume is fully sponsored by SIKA Kimia Sdn.Bhd. however some estimation and market basic price is used to calculate the cost of the materials. The equipments are available ready in the laboratory and labor is obtained through voluntary basis. Thus they are not taken into calculations. From Table 12, stated the price and the cement content of the mixes, so why pay more when you can pay less for a more environmental friendly and good strength HPC?

4. 1. 6 Matrix Table

(Comparison of Cement Consumption (KG/MPa/M³) with Cost (RM/MPa/M³))

The Matrix Table is simply a summary or a comparison chart between the consumption of cement in the mixes with the cost, which is simply the market price that is currently obtained and available in the Concrete Industry Market. Table 8 covers the research objectives and goals of **'ECOcrete'** proven to be Ecological friendly, Efficient Cement Output, Effective Cash Output and Energy Saving. It is also a good guidelines for designers to select their ideal concrete mix

Table 8: The Matrix Table.

COST (RM/MPa/M³)	Cement Consumption (KG/MPa/M³)				
	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	6.0 - 6.5
5.0 - 5.5					
5.5 - 6.0	S1-1 S2-2				
6.0 - 6.5	S1-2 S2-2 S1-3				PC2
6.5 - 7.0	S2-3	PC10SF2 PC10SF3			
7.0 - 7.5			PC5SF3	PC5SF2	
7.5 - 8.0					
8.0 - 8.5					PC3

ECO - FRIENDLY MIXES

ACCEPTABLE MIXES

NON ECO - FRIENDLY MIXES

4. 1. 7 Energy Consumption.

During the manufacturing of cement, energy is consumed. The amount of this energy consumption is important to be known as it affects the people globally. Reduce energy reduce emission of carbon dioxide CO_2 gas. The energy consumed in this project can be determined as below:

Table 9: Energy Content Charged to Concrete.

CONCRETE PROPERTIES	ENERGY CONTENT CHARGED TO CONCRETE	
	kwh/m³	kwh/tonne
Cement (250-500 kg/m³)	330-660	137-275
Aggregate (1750-1950 kg/m³)	20	8
Production in Handling Concrete	90	37
TOTAL	440-770	182-320

MONTEIRO, CE60

4.1.7.1 Amount of Energy Saved from Research.

In every tonne of cement produced;

Research Results	= 180-200 kwh/tonne
Contemporary Results	= 210-260 kwh/tonne
Energy Saving	= 30 kwh/tonne

4.1.7.2 Global Energy Saving.

With Concrete Production of 17 Billion Tonne per-year.

Global Energy Saving = **5.1 Trillion Tonne KWH per-year.**

4.2 Overall Discussion

Results obtained are purely from laboratory works and no 'plagiarism' or 'forgery' is done to alter the effectiveness of the results. From the overall observation from the results of the sections, it can be summarized that with reduced cement content in the High Performance Concrete (HPC) mix with Silica Fume (SF), optimum strength required that is within 50-80MPa can be achieved.

Thus, from this, it shows that cement, as the main element in producing concrete, can be reduced to produce an environmental friendly and cost effective HPC. As calculated from Table 17-20, cement consumption can be reduced as much as 10-15% directly contributing to carbon dioxide, CO_2 gas reduction into the atmosphere. Similar traits and quality of strength can be achieved and developers now have to pay less for reduced cement mixes to build high-rise buildings and huge bridges as well as wider expressways.

SF plays its role as the cement replacing material. It contributed greatly to the high early strength of the HPC. High early strength is good for the construction industry as the duration of the construction can be reduced and be completed within the time required. In simple saying, why pay more when you can pay less for a more environmental friendly and high strength HPC.

CHAPTER 5
CONCLUSION

The conclusions to this research are as below:

- High Performance Concrete (HPC) with optimum Compressive Strength of 50 – 80MPa with reduced cement mixes is achieved.

- Better Compressive Strengths are obtained from laboratory research works compared to the experimental results obtained by Alexander. Magee (1999).

- Cement consumption is reduced within 10% - 15% from testings conducted directly reducing emission of CO_2 by 10% - 15% to the atmosphere.

- Silica Fume (SF) has played an important role in contributing high early strength (3days) to HPC and is considered a good cementing replacing material in determining the efficiency of cement.

- HPC produced is cost effective and environmentally friendly.

- HPC can be durable and be improved to be environmental friendly.

- Effort in promoting and catering to the necessity to GREEN EARTH is being approached.

CHAPTER 6

RECOMMENDATION

As far as concerned, the research in still at her early stage. The recommendations will improve as the research goes on in the future. The recommendation considered based on the manpower, time, cost, economic and environment.

6.1 Manpower

It is advisable in the future, to conduct research in the concrete field, laboratory works should be done in groups either with the same topic title or different for each student. This will not only save time but also the usage of the laboratory materials and apparatus. A student will also be able to major in an experimental title as they liked making the analysis more accurate.

At least 3 students were to be in a group and work together for the mixing processes. The laboratory technicians besides handling and guiding the students to conduct the apparatus, they should also help the student for the mixing processes as these processes are huge in quantity, heavy and dangerous if not handled with care. With this consideration, the amount of mixes to complete will be shortened and adds to the effectiveness of the Half- Testing Method.

6.2 Time, cost and economic

The time of sample specimen for batching and curing has to be observed carefully so to obtain better results. The cost has to be reasonable and feasible in gaining economic profit.

6.3 Environment

Materials used in the production of High Performance Concrete (HPC) have to have its environmental friendly values. Regardless on this particular material, other field's of research it is also important we incorporate this important factor. With this valued factor, we are able to avoid problems such as pollution in water, noise and air as well as adding economical value to the product produced.

6.4 HEALTH, SAFETY AND ENVIRONMENT (HSE)

As this research is conducted experimentally in the laboratory, it is very important that the basic knowledge of the health, safety and environment is to be incorporated in the process.

When the research was conducted, the concrete technology laboratory basic rules and regulations were understood and were put into application. This is very important as the rules works as a guidelines to avoid any unwanted accidents in the laboratory. Basic rules such as washing after using and putting back to the rightful place need to be practiced. Basic house-keeping such as sweeping away particle materials and dust need to be done to avoid negative health effects.

During the author's recent laboratory sessions in the Concrete Technology Laboratory, being new to the laboratory, the author familiar herself with the position of the tools that was placed in the laboratory. This is so that when a session is conducted; there will be no need to search for the tools. This delays the experiment process. Next, the author familiar herself with the layout of the laboratory. This is important so that exit entrances can be identified and an escape can be done quickly if any unwanted explosion scenario is to happen.

The bottom line is, obey all rules if you don't want to get hurt. The rules are irrelevant at times but from my point it is there for a reason. Accidents cannot be predicted and most humans are very careless. So precaution and prevention is better than serving our ignorance.

CHAPTER 7

REFERENCES

[1] Malhotra. V. M. and Mehta. P. Kumar, *Pozzolanic and Cementitious Materials*, Taylor and Francis Group, 2004, Advances in Concrete Technology Volume 1, Mechanisms by which Mineral Admixtures Improve Properties of Concrete, Chapter 4, Rheological Behavior of Concrete Strength, pp. 35-40.

[2] Nawy. G. Edward, *Concrete Properties*, Committee on Properties of Concrete, A2E03, 2003.

[3] Luther, Smith, *Silica Fume (Microsilica) Fundamentals for Use In Concrete*, American Society of Civil Engineers, pp. 75-106, 1991.

[4] Federal Highway Administration, *Silica Fume*, Infrastructure, U.S. Department of Transportation, Materials Group, 2008.

[5] Malhotra. V. M. and Mehta. P. Kumar, *Pozzolanic and Cementitious Materials*, Taylor and Francis Group, 2004 Advances in Concrete Technology Volume 1, Effect of Mineral Admixtures on Properties of Hardened Concrete, Chapter 6, Compressive Strength, pp. 70-88.

[6] Gambhir. M. L., *Concrete Technology*, Tata McGraw-Hill Publishing New Delhi,Third Edition, Rayat Institute of Engineering and Information Technology Railmajra, High Performance Concretes, Chapter 16, pp.456-508.

[7] Neville. A. M, *Properties of Concrete*, Pearson Education Limited, Fourth Edition, The Royal Academy of Engineering, Concretes with Particular Properties, Chapter 13, pp.674-687.

[8] Mir. M. Ali., *Evolution of Concrete Skyscrapers*, University of Illinois, 1996.

[9] Chong, Larrard, *The Rheology of Fresh High-Performance Concrete*, Cement and Concrete Research, 1996, Volume 26, No.2, pp. 283-294

[10] P. Bartos, *Fresh Concrete*, Properties and Tests, Paisley College, 1992, Chapter 5 Admixtures, Superplasticizers, pp.196

[11] W. Day. Ken, *Production of High Performance Concrete (HPC),* Concrete Advice Pty. Ltd, 1997, General Report, No.38.

[12] SP Shah. SH Ahmad, *High Performance Concretes and Applications,* Edward and Arnold Hodder Headline Group, 1994, superplastisizer dosage, pp.9

[13] Ismail. Waliuddin, *Effect of Rice Husk Ash on High Strength Concrete,* Elsevier Science Limited, NED University of Engineering and Technology Karachi Pakistan, 1996

[14] Pavlenko, Maihkimin, Bazhenov, Maydeyev, *Development and Use of Fine Cementless Concretes Consisting of By-Products as one of the Ways for Reducing CO_2 Emissions*, CANMET/ACI International Symposium on Sustainable Development of the Cement and Concrete Industry, Ottawa, pp. 267-280, 1998

[15] Alexander. Magee, *Durability Performance of Concrete Containing Condensed Silica Fume*, Department of Civil Engineering , University of Cape Town,Rondebosch 7701, South Africa, Cement and Concrete Research, 1999, Table 1, Mix Proportions used for experimental study, pp.918

[16] P. K. Mehta, *Reducing the Environment Impact of Concrete',* American Concrete Institute, Concrete International, 2001, pp.62

APPENDICES

Appendix 1: Laboratory Session Work Progress.

1.1 Material Preparations

Figure 21: 10 bags (20kg) Silica Fume (SF) by SIKA Kimia.

Figure 22: Sieve Analysis Test

Figure 23: Manual Sieving

Figure 24: Drying materials& labelling

1.2 Mixing and Casting Process

Figure 25: Mould Preparation

Figure 26: Slump Test

Figure 27: Casting Process

Figure 28: Maintain Moisture with polythene sheet

1.3 'Open Mould' and Curing

Figure 29: 'Open Mould'

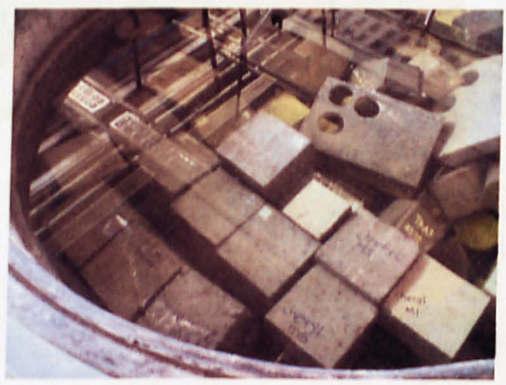


Figure 30: Curing Process

1.4 Compressive Strength Test

Figure 31: 3 Cube Specimens

Figure 32: Testing process

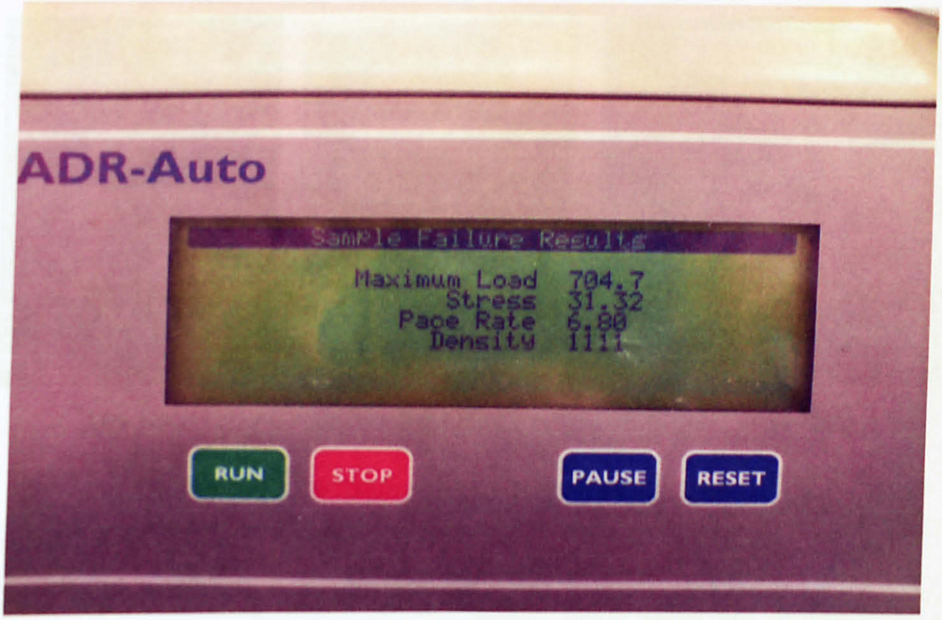


Figure 33: Results of Compressive Strength Test

1.5 Conditions of 6 mixes after testing process.

Mix S1-1

Mix S1-2

Mix S1-3

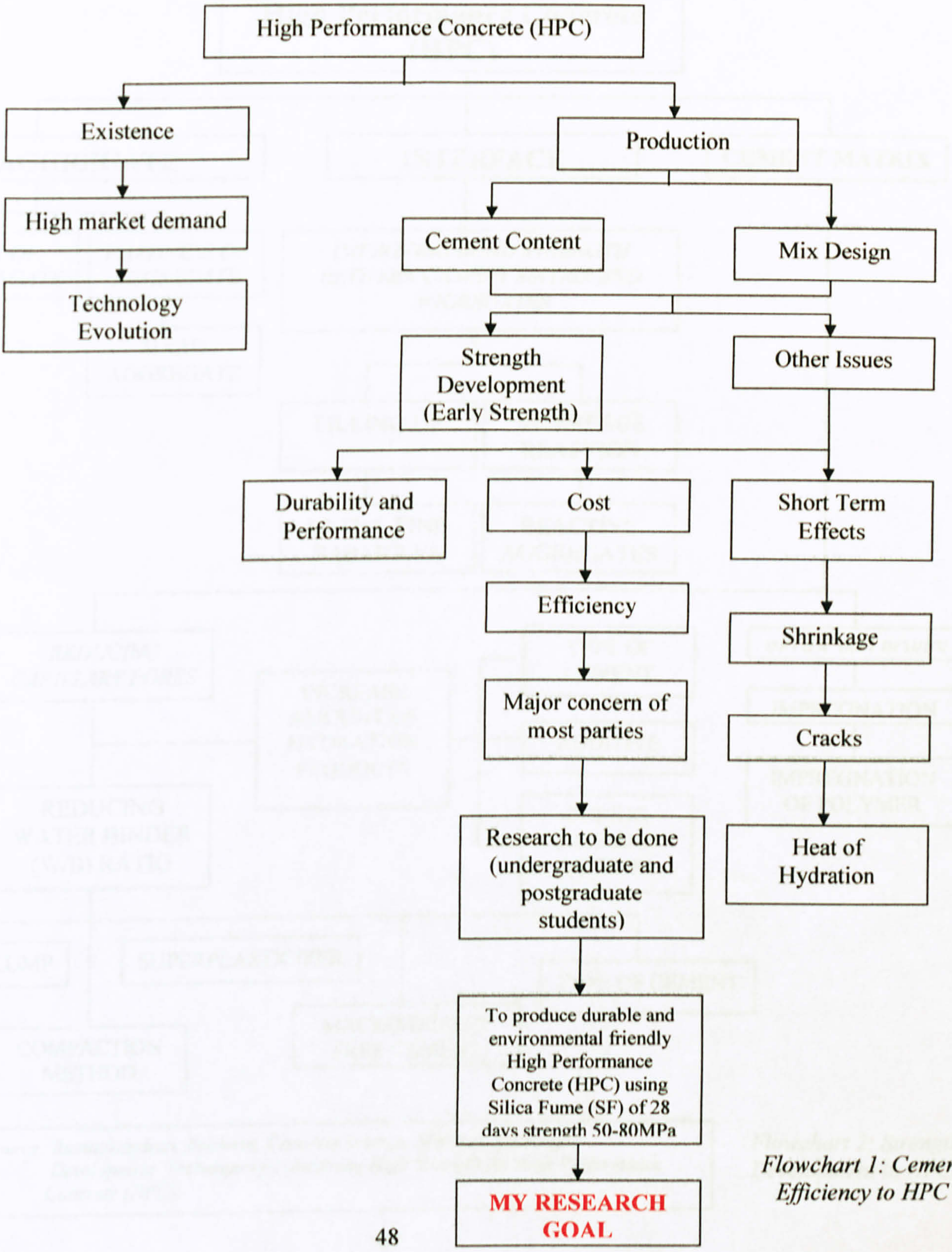
Mix S2-1

Mix S2-2

Mix S2-3

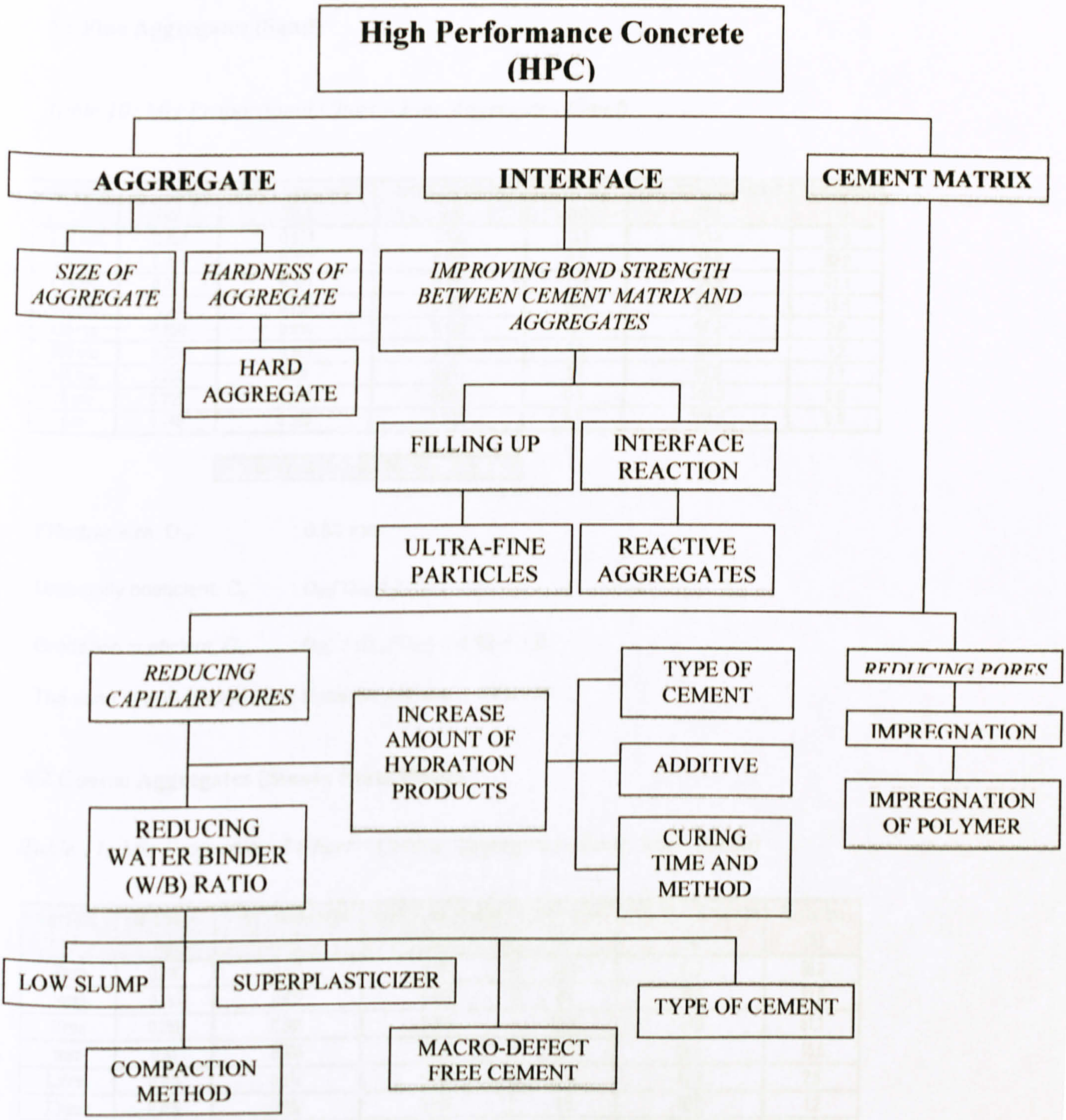
Figure 34: Conditions of 6 mixes after testing process

Appendix 2: Cement Efficiency to High Performance Concrete Flowchart.



Flowchart 1: Cement Efficiency to HPC

Appendix 3: Strength Development in High Performance Concrete (HPC)



Source: Ramachandran, Feldman, Concrete Science, Methods of Strength Development, Techniques for Attaining High Strength for High Performance Concrete (HPC),

Flowchart 2: Strength Development in HPC

Appendix 4: Sieve Analysis – Mix Proportional Curves

4.1 Fine Aggregates (Sand)

Table 10: Mix Proportional Chart – Fine Aggregates (Sand)

sieve size	sieve weight (kg)	sieve + sand weight (kg)	retained sand weight (kg)	% retained (%)	cumulative % retained (%)	% passing (%)
2.36 mm	0.389	0.521	0.132	13.2	13.2	86.8
2.0 mm	0.389	0.437	0.048	4.8	18.0	82.0
1.18 mm	0.351	0.561	0.210	21.0	38.9	61.1
600 mic	0.33	0.786	0.456	45.5	84.5	15.5
425 mic	0.386	0.514	0.128	12.8	97.2	2.8
300 mic	0.286	0.302	0.016	1.6	98.8	1.2
150 mic	0.269	0.28	0.011	1.1	99.9	0.1
75 mic	0.255	0.256	0.001	0.1	100.0	0.0
pan	0.248	0.248	0.000	0.0	100.0	0.0

Total weight of sand: 1.002

Effective size, D_{10} : 0.53 mm

Uniformity coeficient, C_u : $D_{60}/ D_{10} = 2.17$

Gradation coeficient, C_k : $D_{30}^2 / (D_{60}*D_{10}) = 0.92 \sim 1.0$

The sand is well-graded sand since Cu < 6 and 1 < Ck < 3

4.2 Coarse Aggregates (Stones Max.20mm)

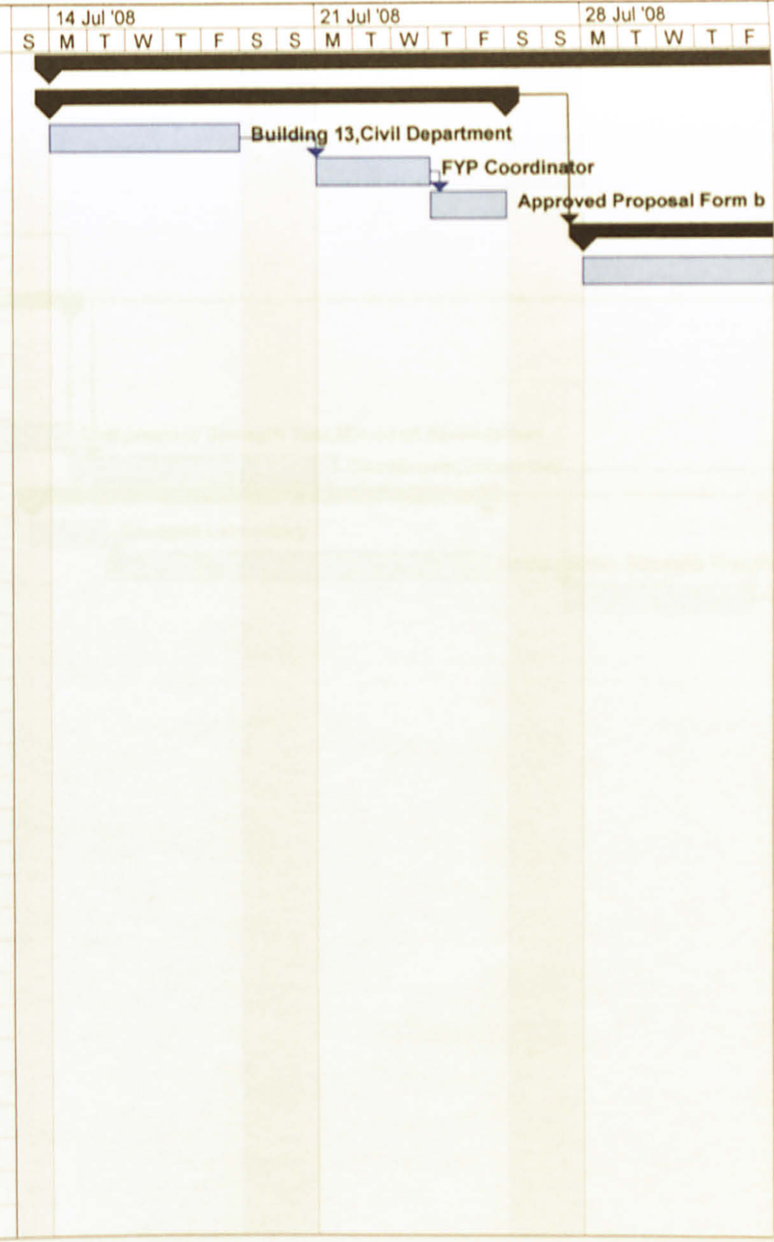
Table 11: Mix Proportional Chart – Coarse Aggregates (Stone, Max. 20mm)

sieve size	sieve weight (kg)	sieve + sand weight (kg)	retained sand weight (kg)	% retained (%)	cumulative % retained (%)	% passing (%)
20mm	0.390	0.521	0.131	13.1	13.2	86.8
14mm	0.389	0.437	0.048	4.8	18.0	82.0
10mm	0.351	0.561	0.210	21.0	38.9	61.1
5mm	0.33	0.786	0.456	45.5	84.5	15.5
3.35mm	0.386	0.514	0.128	12.8	97.2	2.8
2.36mm	0.286	0.302	0.016	1.6	98.8	1.2
pan	0.269	0.28	0.011	1.1	99.9	0.1

Total weight of coarse aggregate (uncrushed): 1.000

APPENDIX 5: RESEARCH PLANNING FOR 2 SEMESTERS

ID	Task Name	Duration	Start	Finish	Predecessors
1	**SEMESTER 1**	**128 days**	**Mon 14/07/08**	**Mon 19/01/09**	
2	**Selection of Topic and Supervisor**	**10 days**	**Mon 14/07/08**	**Fri 25/07/08**	
3	Topic Search and Meeting withLecturer	5 days	Mon 14/07/08	Fri 18/07/08	
4	Fill in the Proposal Form	3 days	Mon 21/07/08	Wed 23/07/08	3
5	Acceptance by Supervisor and Coordinator	2 days	Thu 24/07/08	Fri 25/07/08	4
6	**Preliminary Research work**	**15 days**	**Mon 28/07/08**	**Fri 15/08/08**	**2**
7	Data Collecting and Journal Reading	15 days	Mon 28/07/08	Fri 15/08/08	
8	**Laboratory Session 1**	**15 days**	**Mon 18/08/08**	**Mon 08/09/08**	**6**
9	Material Request	3 days	Mon 18/08/08	Wed 20/08/08	
10	Laboratory Reservation	2 days	Thu 21/08/08	Fri 22/08/08	9
11	Mixing and Casting (Mix 1)	1 day	Mon 25/08/08	Mon 25/08/08	10
12	Cube Test and Data Analysis	9 days	Tue 26/08/08	Mon 08/09/08	11
13	**Submission of Combined Progress Report 1**	5 days	Tue 09/09/08	Mon 15/09/08	6,8
14	**Laboratory Session 2**	**10 days**	**Mon 08/09/08**	**Fri 19/09/08**	
15	Mixing and Casting (Mix 2 & 3)	2 days	Mon 08/09/08	Tue 09/09/08	
16	Cube Test and Data Analysis	8 days	Wed 10/09/08	Fri 19/09/08	15
17	**Submission of Final Draft**	**5 days**	**Mon 22/09/08**	**Fri 26/09/08**	**14**
18	**Oral Presentation 1**	**5 days**	**Tue 07/10/08**	**Mon 13/10/08**	**17**
19	**Submission of Final Report**	**5 days**	**Tue 14/10/08**	**Mon 20/10/08**	**18**
20	**STUDY WEEK**	**5 days**	**Tue 21/10/08**	**Tue 28/10/08**	**19**
21	**FINAL EXAMINATION**	**17 days**	**Wed 29/10/08**	**Thu 20/11/08**	**20**
22	**SEMESTER BREAK**	**42 days**	**Fri 21/11/08**	**Mon 19/01/09**	**21**
23	Research and Literature Review	42 days	Fri 21/11/08	Mon 19/01/09	
24	**SEMESTER 2**	**58 days**	**Mon 02/02/09**	**Mon 04/05/09**	**1**
25	**Laboratory Session 3**	**7 days**	**Mon 02/02/09**	**Thu 12/02/09**	
26	Mixing and Casting (Mix 4 & 5)	2 days	Mon 02/02/09	Wed 04/02/09	
27	Cube Test and Data Analysis	5 days	Thu 05/02/09	Thu 12/02/09	26
28	**Submission of Combined Progress Report 2**	**5 days**	**Fri 13/02/09**	**Thu 19/02/09**	**13,25**
29	**Laboratory Session 4**	**6 days**	**Wed 04/02/09**	**Thu 12/02/09**	
30	Mixing and Casting (Mix 6)	1 day	Wed 04/02/09	Wed 04/02/09	
31	Cube Test and Data Analysis	5 days	Thu 05/02/09	Thu 12/02/09	30
32	**Overall Result Analysis and Interpretation**	**5 days**	**Mon 30/03/09**	**Fri 03/04/09**	**29,8,14,25**
33	**Poster Exhibition**	**5 days**	**Mon 06/04/09**	**Fri 10/04/09**	**32**
34	**Submission of Final Draft (soft bound)**	**5 days**	**Mon 13/04/09**	**Fri 17/04/09**	**33**
35	**Oral Presentation 2**	**5 days**	**Mon 20/04/09**	**Fri 24/04/09**	**34**
36	**Submission of Project Dissertation (hard bound)**	**5 days**	**Mon 27/04/09**	**Mon 04/05/09**	**35**



Task
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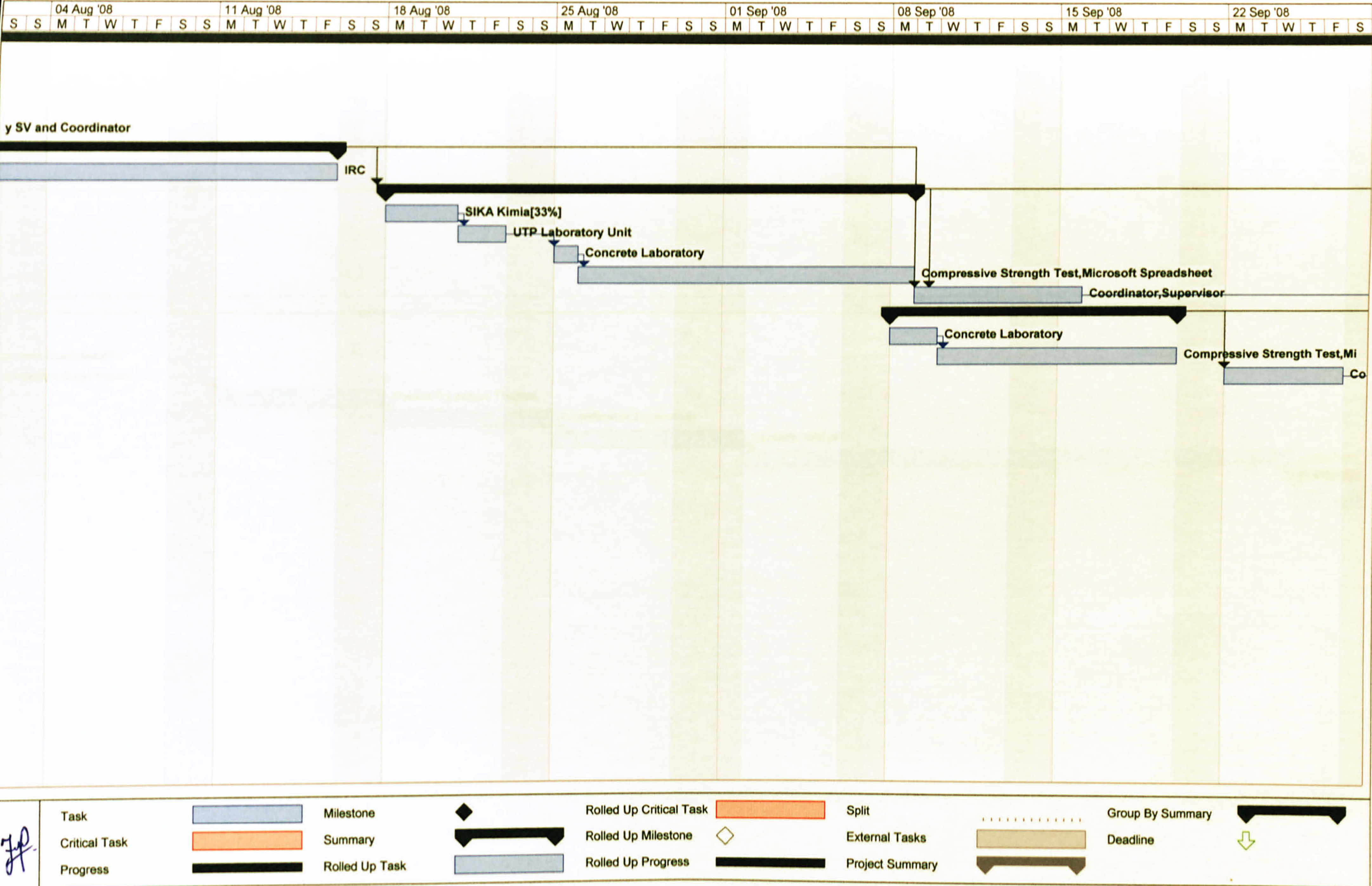
Project Summary
Group By Summary
Deadline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UTP Laboratory Unit
Concrete Laboratory
Compressive Strength Test,Microsoft Spreadsheet
Coordinator,Supervisor
Concrete Laboratory
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Task
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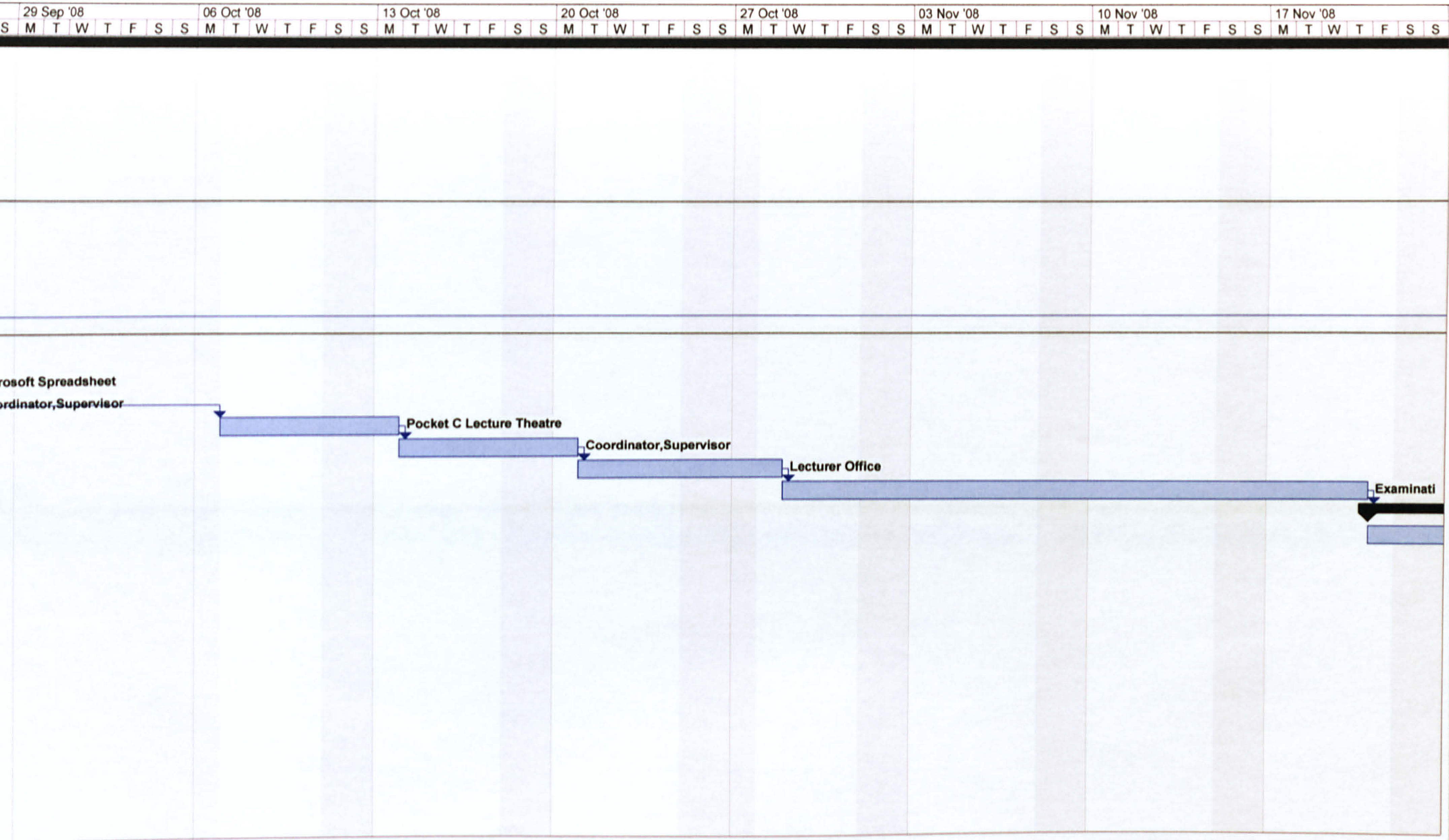
Group By Summary
Deadline



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Critical Task	Summary	Rolled Up Milestone	External Tasks
Progress	Rolled Up Task	Rolled Up Progress	Project Summary
			Group By Summary
			Deadline

24 Nov '08	01 Dec '08	08 Dec '08	15 Dec '08	22 Dec '08	29 Dec '08	05 Jan '09	12 Jan '09	19
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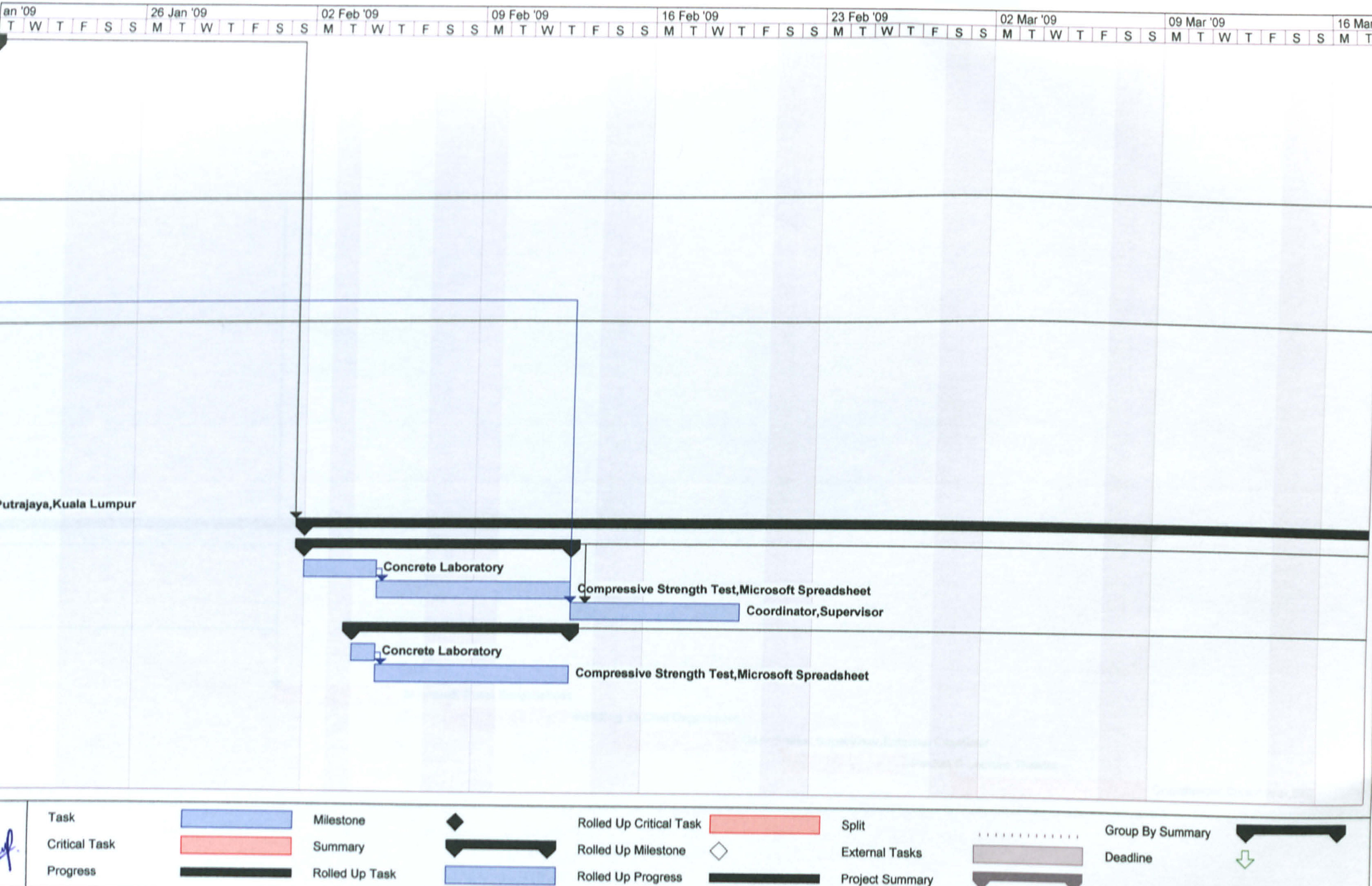
on Hall

Task		Milestone		Rolled Up Critical Task		Split		Group By Summary	
Critical Task		Summary		Rolled Up Milestone		External Tasks		Deadline	
Progress		Rolled Up Task		Rolled Up Progress		Project Summary			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23 Feb '09
02 Mar '09
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16 Mar '
Putrajaya,Kuala Lumpur
Concrete Laboratory
Compressive Strength Test,Microsoft Spreadsheet
Coordinator,Supervisor
Concrete Laboratory
Compressive Strength Test,Microsoft Spreadsheet
Task
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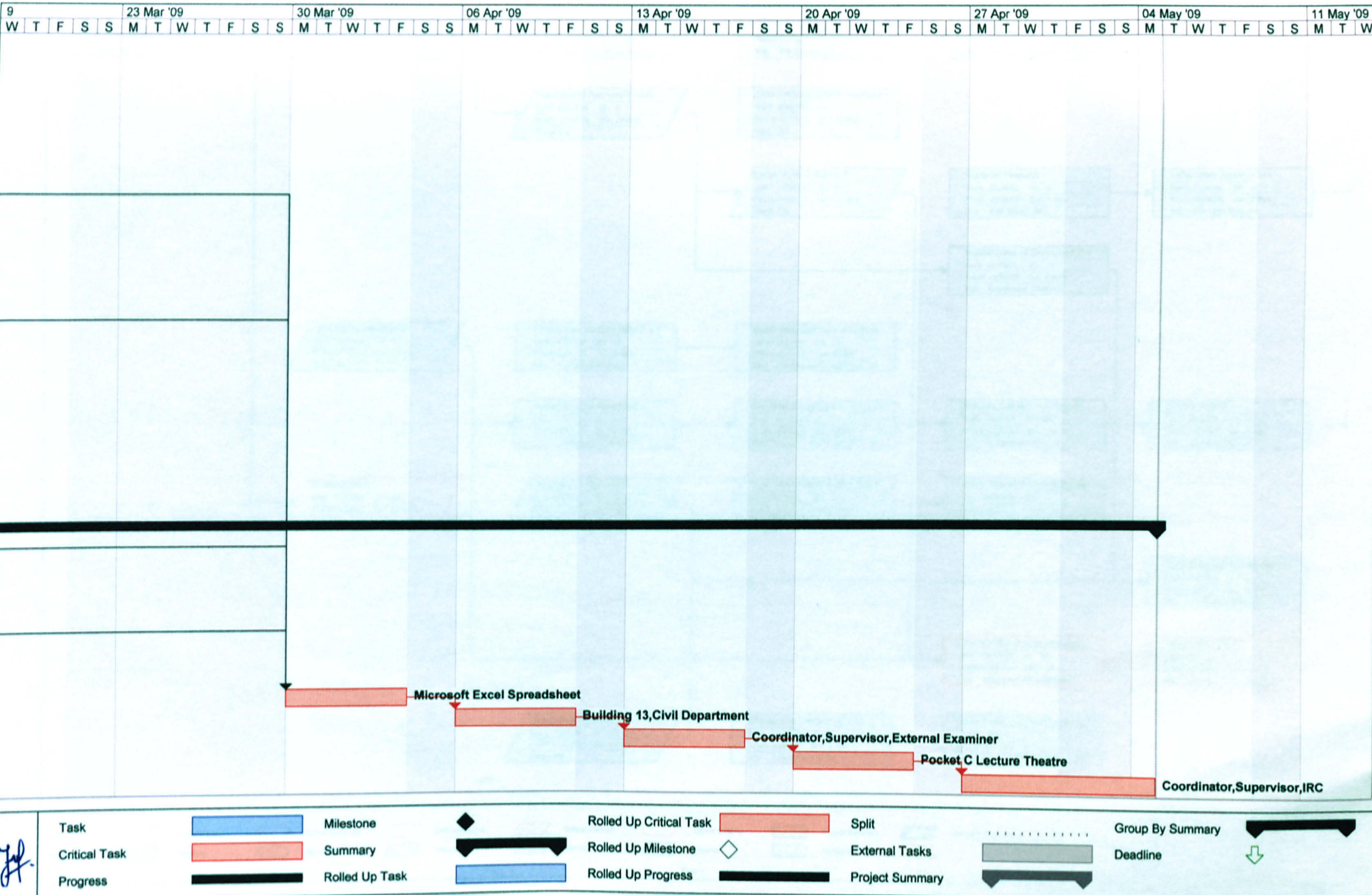
Split
External Tasks
Project Summary
Group By Summary
Deadline


9
23 Mar '09
30 Mar '09
06 Apr '09
13 Apr '09
20 Apr '09
27 Apr '09
04 May '09
11 May '09
Microsoft Excel Spreadsheet
Building 13,Civil Department
Coordinator,Supervisor,External Examiner
Pocket C Lecture Theatre
Coordinator,Supervisor,IRC
Task
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Progress
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Rolled Up Milestone
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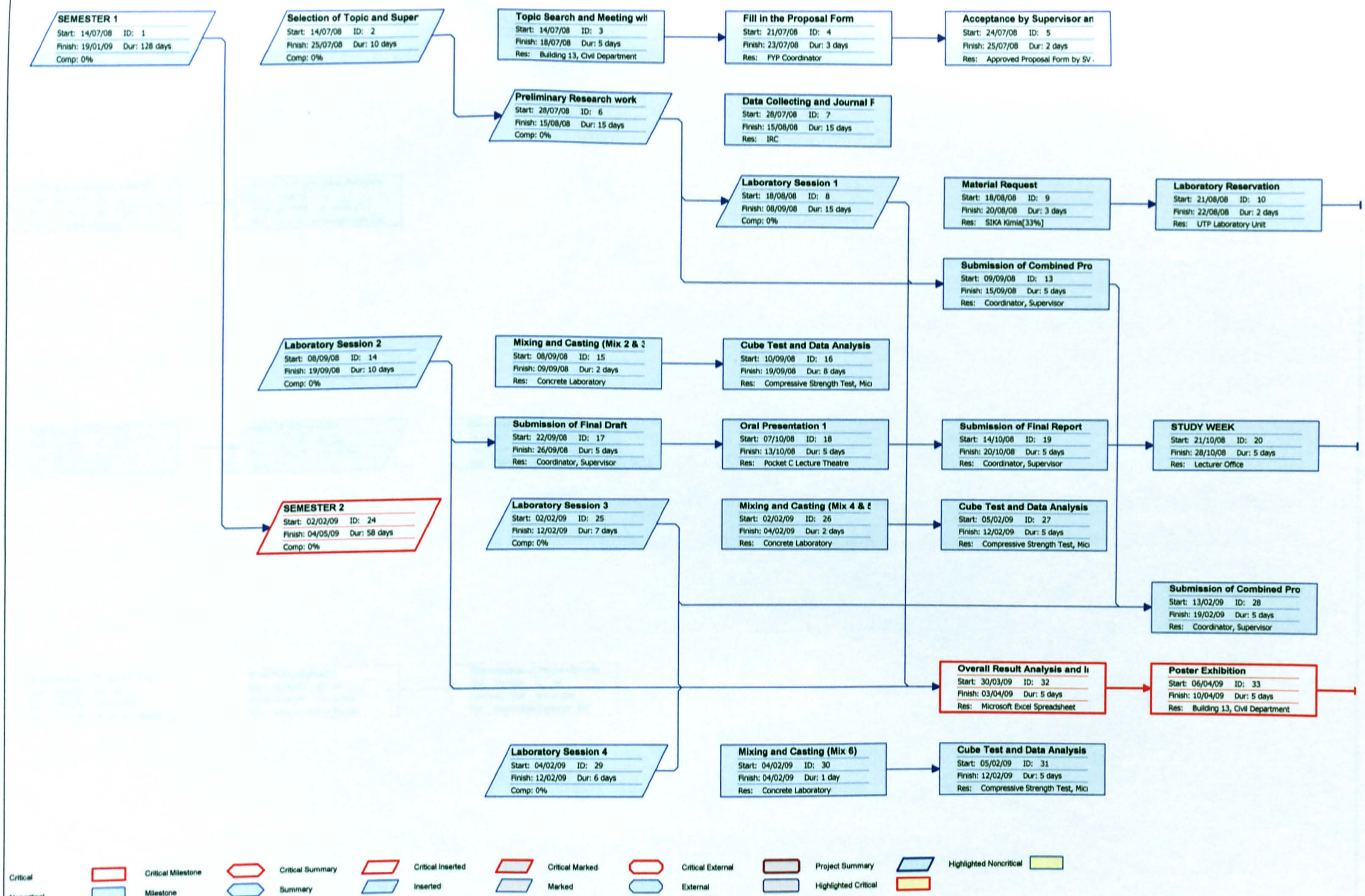
Project Summary
Group By Summary
Deadline



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Finish: 19/01/09 Dur: 128 days
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Selection of Topic and Super
Start: 14/07/08 ID: 2
Finish: 25/07/08 Dur: 10 days
Comp: 0%
Topic Search and Meeting wi
Start: 14/07/08 ID: 3
Finish: 18/07/08 Dur: 5 days
Res: Building 13, Civil Department
Fill in the Proposal Form
Start: 21/07/08 ID: 4
Finish: 23/07/08 Dur: 3 days
Res: FYP Coordinator
Acceptance by Supervisor an
Start: 24/07/08 ID: 5
Finish: 25/07/08 Dur: 2 days
Res: Approved Proposal Form by SV
Preliminary Research work
Start: 28/07/08 ID: 6
Finish: 15/08/08 Dur: 15 days
Comp: 0%
Data Collecting and Journal F
Start: 28/07/08 ID: 7
Finish: 15/08/08 Dur: 15 days
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Laboratory Session 1
Start: 18/08/08 ID: 8
Finish: 08/09/08 Dur: 15 days
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Material Request
Start: 18/08/08 ID: 9
Finish: 20/08/08 Dur: 3 days
Res: SIKA Kimia[33%]
Laboratory Reservation
Start: 21/08/08 ID: 10
Finish: 22/08/08 Dur: 2 days
Res: UTP Laboratory Unit
Submission of Combined Pro
Start: 09/09/08 ID: 13
Finish: 15/09/08 Dur: 5 days
Res: Coordinator, Supervisor
Laboratory Session 2
Start: 08/09/08 ID: 14
Finish: 19/09/08 Dur: 10 days
Comp: 0%
Mixing and Casting (Mix 2 & 3
Start: 08/09/08 ID: 15
Finish: 09/09/08 Dur: 2 days
Res: Concrete Laboratory
Cube Test and Data Analysis
Start: 10/09/08 ID: 16
Finish: 19/09/08 Dur: 8 days
Res: Compressive Strength Test, Mici
Submission of Final Draft
Start: 22/09/08 ID: 17
Finish: 26/09/08 Dur: 5 days
Res: Coordinator, Supervisor
Oral Presentation 1
Start: 07/10/08 ID: 18
Finish: 13/10/08 Dur: 5 days
Res: Pocket C Lecture Theatre
Submission of Final Report
Start: 14/10/08 ID: 19
Finish: 20/10/08 Dur: 5 days
Res: Coordinator, Supervisor
STUDY WEEK
Start: 21/10/08 ID: 20
Finish: 28/10/08 Dur: 5 days
Res: Lecturer Office
SEMESTER 2
Start: 02/02/09 ID: 24
Finish: 04/05/09 Dur: 58 days
Comp: 0%
Laboratory Session 3
Start: 02/02/09 ID: 25
Finish: 12/02/09 Dur: 7 days
Comp: 0%
Mixing and Casting (Mix 4 & 5
Start: 02/02/09 ID: 26
Finish: 04/02/09 Dur: 2 days
Res: Concrete Laboratory
Cube Test and Data Analysis
Start: 05/02/09 ID: 27
Finish: 12/02/09 Dur: 5 days
Res: Compressive Strength Test, Mici
Submission of Combined Pro
Start: 13/02/09 ID: 28
Finish: 19/02/09 Dur: 5 days
Res: Coordinator, Supervisor
Overall Result Analysis and I
Start: 30/03/09 ID: 32
Finish: 03/04/09 Dur: 5 days
Res: Microsoft Excel Spreadsheet
Poster Exhibition
Start: 06/04/09 ID: 33
Finish: 10/04/09 Dur: 5 days
Res: Building 13, Civil Department
Laboratory Session 4
Start: 04/02/09 ID: 29
Finish: 12/02/09 Dur: 6 days
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Mixing and Casting (Mix 6)
Start: 04/02/09 ID: 30
Finish: 04/02/09 Dur: 1 day
Res: Concrete Laboratory
Cube Test and Data Analysis
Start: 05/02/09 ID: 31
Finish: 12/02/09 Dur: 5 days
Res: Compressive Strength Test, Mici
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Noncritical
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Critical Summary
Summary
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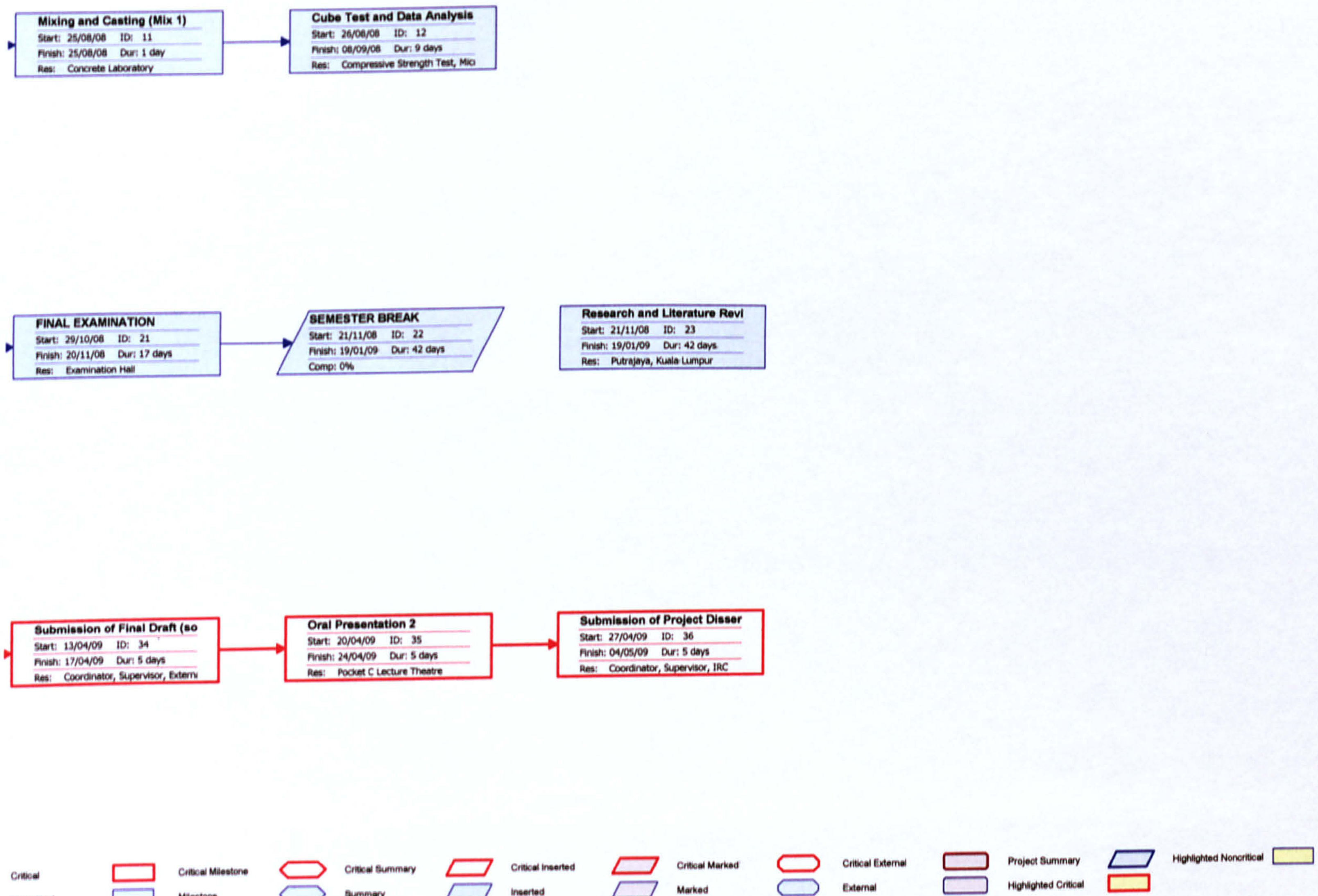
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FINAL EXAMINATION
Start: 29/10/08 ID: 21
Finish: 20/11/08 Dur: 17 days
Res: Examination Hall
SEMESTER BREAK
Start: 21/11/08 ID: 22
Finish: 19/01/09 Dur: 42 days
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Finish: 19/01/09 Dur: 42 days
Res: Putrajaya, Kuala Lumpur
Submission of Final Draft (so
Start: 13/04/09 ID: 34
Finish: 17/04/09 Dur: 5 days
Res: Coordinator, Supervisor, Extern
Oral Presentation 2
Start: 20/04/09 ID: 35
Finish: 24/04/09 Dur: 5 days
Res: Pocket C Lecture Theatre
Submission of Project Disser
Start: 27/04/09 ID: 36
Finish: 04/05/09 Dur: 5 days
Res: Coordinator, Supervisor, IRC
Critical
Noncritical
Critical Milestone
Milestone
Critical Summary
Summary
Critical Inserted
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Critical Marked
Marked
Critical External
External
Project Summary
Highlighted Critical
Highlighted Noncritical