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COMPRESSIVE STRENGTH OF PALM OIL CLINKER CONCRETE DUE TO DIFFERENT TEMPERATURE OF FIRE EXPOSURE

VIVIEN NECENT A/L VINSAN

Report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Civil Engineering (Hons)

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

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The true sign of intelligence is not knowledge but imagination.
-Albert Einstein

If the wind not serve, take to the oars.
-Latin proverb

Dedicated to my parents

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First of all, I would like to use this opportunity to deliver my special thanks to the Faculty of Civil Engineering and Earth Resources for providing me the platform to conduct this study at first place. Moreover, I would like to second this very moment to thank and express my warmest and sincere gratitude to my supervisor, Miss Norhaiza Binti Ghazali for his germinal and constructive ideas, his continuous encouragement with deep guidance and support in making this study successful and fruitful. She has always concerned about the progress level of this study and never at all hesitates to spend his times with me for reviewing this project every week. I am truly grateful for his consistent supervision on this study, his tolerance of my naïve mistakes and his persistent ideas in improving this study which has also helped me to deeply understand the need of this study.

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ABSTRACT

A study on Compressive strength of Palm Oil Clinker Concrete (POCC) due to expose of various burning temperature for an hour. The concrete produced by fully replacement of palm oil clinker in coarse aggregates. The POC obtain from local palm oil mill waste. POC Crushed in jaw crusher with desire size. The suitable size of POC for replacement of coarse aggregate was 12.75mm. Crushed POC sieve into size such as passing through 12.75mm sieve and retained at 4.75mm sieve. [1] The perfect design mix proportion with ration of 1:1.34:0.89, to increase the workability and also as a water reducing agent superplasticiser of Sika ViscoCrete® -2199 were added to the mixture with ratio of 0.013. The material was measured in Kilogram (Kg). For an adequate of furnace, the POCC cast into mould size of 100mm X 100mm X100mm. Cast sample were immerged in water for 28 days as water curing to achieve its full strength. The matured sample where burned at temperature 100°C, 200°C, 300°C ,400°C and 500°C with respective samples. The samples are burned in furnace. Burned samples are cool down at room temperature for a day before the compressive strength test. The compressive strength was recorded for conclude the objectives for this study. As a control sample unburned POCC was tested as initial compressive strength of POCC before burning process. The compressive strength of burned samples are compered to unburned POCC as a bench mark.

ABSTRAK

Satu kajian mengenai kekuatan mampatan Konkrit Klinker Kelapa Sawit (KKKS) selepas mendedahkan pelbagai suhu pembakaran selama satu jam. Konkrit yang dihasilkan oleh penggantian sepenuhnya klinker kelapa sawit (KKS) dalam agregat kasar. KKS mendapatkan daripada sisa kilang minyak sawit tempatan. KKS Dihancurkan dalam penghancur rahang dengan saiz keinginan. Saiz yang sesuai KKS untuk menggantikan agregat kasar adalah 12.75mm. Dihancurkan KKS ayak ke dalam saiz seperti melalui 12.75mm ayak dan disimpan di 4.75mm ayak. Yang sempurna bahagian reka bentuk campuran dengan catuan daripada 1: 1.34: 0.89, untuk meningkatkan kebolehkerjaan dan juga sebagai air mengurangkan ejen superplasticiser daripada Sika ViscoCrete® -2199 telah ditambah kepada campuran dengan nisbah 0.013. bahan yang diukur dalam Kilogram (Kg). Bagi yang mencukupi relau, yang KKKS dituang ke dalam saiz acuan 100mm X 100mm X100mm. sampel telah rendam dalam air selama 28 hari sebagai pengawetan air untuk mencapai kekuatan penuh. Sampel matang di mana dibakar pada suhu 100 °C, 200 °C, 300 °C, 400 °C dan 500 °C dengan sampel masing-masing. Sampel dibakar dalam relau. sampel dibakar adalah menyejuk pada suhu bilik selama sehari sebelum ujian kekuatan mampatan. Kekuatan mampatan dicatatkan bagi memuktamadkan objektif untuk kajian ini. Sebagai sampel kawalan yang tidak terbakar KKKS telah diuji kekuatan mampatan awal KKKS sebelum proses pembakaran. Kekuatan mampatan sampel dibakar berbanding dengan KKKS yang tidak terbakar sebagai tanda bangku.

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LIST OF SYMBOLS

°C	Degree Celsius
%	Percentage

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
POC	Palm Oil Clinker
POCC	Palm Oil Clinker Concrete
OPC	ordinary Portland cement
RHN	rebound hammer umber
NDT	Non-destructive test
UPV	Ultrasonic Pulse Velocity\
OPS	Palm Oil Shell
HSLWC	High Strength Lightweight Concrete

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Rapid development causes insufficient of natural sources which increased demand on construction materials. Therefore, construction industry need to find alternative material from natural sources or industrial waste which can be use as construction material. Introducing waste material in concrete will improved some mechanical and chemical properties of concrete. Waste materials such as wood chipping, paper mill, crumb rubber, broken glasses, silica fume, blast furnace slag and coal fly ash were used in concrete (Eurocode2, 2003). In year 2000, Aldridge found that palm oil clinker crushed materials as partial replacement of aggregate can be useful mixture.

Palm oil clinker is a waste from palm oil industry and normally dumped without wisely used. Malaysia plays big role in this palm oil industry and produces largest amount of palm oil products as well as its waste.

Studies found that lightweight concrete can be produced by using Palm Oil Clinker (POC) as an aggregate. The mechanical properties of POC was alike the normal aggregate. The POC was crushed and sieve to obtain desired particle size. Particles with size less than 5 mm are considered as fine aggregate and particles with size in the range of 5 mm to 14 mm are considered as coarse aggregate. The compressive strength of Palm Oil Clinker Concrete (POCC) is more than 17 MPa and meet the requirement for structural lightweight concrete as stated in ASTM: C330 (Bashar S. Mohammed, 2013).

The change in concrete properties due to high temperature depends on the type of coarse aggregate used. The cause aggregate in concrete can be classified into three types. The first type was carbonate aggregates include dolomite and limestone. The second type was siliceous aggregate include materials consisting of silica and include granite and sandstone. The third type was lightweight aggregates are usually produce by heating shale, slate, or clay. The weakness of the concrete is, it lost is compressive strength when expose to fire. The percentage of losses depend on temperature and hours of burning. Lightweight concrete has a potential to be use as non-load bearing structural element such as a dividing wall in a building and it will directly expose to the high temperature during fire.

Fire resistance can be defined as the ability of structural elements to endure fire or to dive protection from it. This embrace the ability to confine a fire and also to continue to perform a given structural function. Fire resistance classification is defined as the duration of time that an assembly of floor, beam column and roof that can withstand a standard fire as defined in ASTME 119.

The fire-resistive properties of building components and structural assemblies are determined by fire test methods. The most widely used and nationally accepted test procedure is that developed by the American Society of Testing and Materials (ASTM). It is designated as ASTM E 119, Standard Methods of Fire Tests of Building Construction and Materials. A standard fire test is conducted by placing a full size assembly in a test furnace. Floor and roof specimens are exposed to a controlled fire from beneath, beams are exposed from the bottom and sides, walls from one side, and columns are exposed to fire from all sides. The temperature is raised in the furnace over a given period of time in accordance with ASTM E 119 standard time-temperature curve. The assembly is evaluated for its ability to contain the fire by limiting flame spread and heating of the unexposed surface while maintaining the applied load. The assembly is given a rating, expressed in hours, based on these conditions of acceptance, (Eurocode 1: Part 1-2)

This study, about compressive strength of POCC were expose to five various burning temperature for an hour. In other hand, to determine the optimum burning temperature on POCC by compressive strength lost after burning process.

1.2 OBJECTIVES OF STUDY

The objective of this study are:

i) To determine the strength of palm oil clinker concrete (POCC) when exposed to five different burning temperature.
ii) To determine the lost in compressive strength of POCC after exposed to fire.

1.3 PROBLEM STATEMENT

Nowadays, construction industries having a lot of revolution in using of light weight concrete. There are many researches have been done in order to find renewable materials to replace the original materials used in concrete. POC one of the new renewable materials used to replace fine and coarse aggregates.

Course Aggregate the main ingredient in concrete provision because it demands rising in construction field therefore, in future the source may runoff by fully used (Jan Philip Plog, 2015). POCC came as a solution for this complication but before it been used in construction field some test need to satisfied the requirement for an example the compressive strength of POCC due to various burning temperature and also the losses in compressive strength of POCC.

1.4 SCOPE OF STUDY

This study will focus on laboratory test to determine the compressive strength of POCC due to different burning temperature and to determine the lost in compressive strength of POCC after exposed to fire Table 1.1 shows the summarize of sample and tests were done in this project.

i) According to Rasel Ahmmad, 2015 the POCC replace the coarse aggregate by 100%.

ii) The concrete grade is 42.5 with ordinary Portland cement and the ratio of concrete mixture of POCC will be 1: 1.34: 0.89, the water ratio was 0.356, everything measured by weight kg/m^3, (Rasel Ahmmad, 2015).

iii) For this mixture need to use superplasticiser (SP) as high range water-reducing admixture, Sika ViscoCrete® -2199, with ratio of 0.013, (Rasel Ahmmad, 2015).

iv) Test the on cured concrete after 28days.

v) The suitable cube size will be 100mm X 100mm X 100mm (Eurocode: 206-1 and R. Ahmmad, 2015) and it adequate the furnace size for burning process.

vi) The variable will be five different temperature 100 °C, 200 °C, 300 °C, 400 °C and 500 °C therefore, the sample will burn in furnace for an hour, (Mommed Mansour kadhum, 2010).

Table 1.1: The summary of sample and tests

Type of Concrete	Label of sample	Number of sample	Curing days	Temperature, °C	Burning Process	Compressive Strength test
POCC	S1	3	28	-	-	Yes
POCC	S2	3	28	100	Yes	Yes
POCC	S3	3	28	200	Yes	Yes
POCC	S4	3	28	300	Yes	Yes
POCC	S5	3	28	400	Yes	Yes
POCC	S6	3	28	500	yes	yes

1.5 SIGNIFICANT OF STUDY

Previous studies show that POCC are recommended in producing lightweight concrete. Fire resistance in the important factor need to be consider in structure for responsibility of safe human life**.** The objectives of this study is to determine the POCC's compressive strength when its exposed to fire with various temperature and to determine the losses in compressive strength of POCC due to different fire exposure.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Lightweight concrete is the most widely used in construction industry. Smart tunnel is one of the biggest project in Malaysia and a good example of lightweight concrete structure. There are many waste materials can be used to produce light weight concrete such as fly ash, wood chipping, paper mill, crumb rubber, silica fume and palm oil clinker. Different lightweight materials will produce different properties of lightweight concrete depending on its main materials. For example, lightweight foamed concrete used to cast elements for architectural purposes, pottery, void filling, trench reinstatement, foundation raising, swimming pool popular in Europe, Japan and United Kingdom. In highway construction, lightweight concrete can be applied as soil filling for sub-base, bridge abutments and bridge embankment. The main advantage of lightweight concrete is reduction of dead load, faster building rates in construction and lower haulage. The density of conventional concrete is produces in the ranges of 2200 kg/m3 to 2600 kg/m3. Conventional concrete has many problems due to the density (Gambhir, 2006).

2.2 PALM OIL CLINKER

Palm oil clinker is local waste material which in produced from palm oil extraction industry and it can be an artificial aggregate. According to light weight aggregate classification, palm oil clinker is categorized under unprocessed by- product material. The palm oil clinker begins with sterilization where raw palm oil in transferred from farm to the factory and it's sterilize the palm oil in boiled hot water. The stripping process will take part after sterilization process. Stripping where the trunk oil is stripped in a rotating drum stripper and palm oil fruit are separated from the tusk. The trunk considers as waste and the fruit will proceed with following step, it where squeeze to get palm oil. The remaining part skin and fibrous materials is continue with burning process in furnace at temperature 400°C. This process occurs more than 24 hours to get complete burn. And finally it forms as clinker in hard and solid compound. After that the clinker will crushed in small practical according to the usage. Porous texture condition and low density are main properties that make the clinker suitable to be used as lightweight aggregate (Noor Mohammad, 2001).

POC was crushed and sieved to the desired particle sizes. Particles less than 5 mm are considered as fine aggregate and particles in the range of 5 – 12.5 mm are considered as coarse aggregate. In general, most lightweight aggregate has higher water absorption values compared to conventional aggregate (Bashar s. Mohammed, 2013). The replacement of aggregate of POC will measure by volume due to the difference in weight. This reduce the overall dead load of structure, with subsequent significant amount of saving in the total construction cost. Although POC has a high water absorption, even though higher water absorption were reported for aggregate which have a value of about 37%. However, the high water absorption of POC aggregate can be beneficial to the resulting hardened concrete. It has been reported that lightweight concretes with aggregate (high water absorption) are less sensitive to poor curing as compared to normal weight concrete especially in the early ages due to the internal water supply stored in the lightweight aggregate (Narayanan et al. 2000).

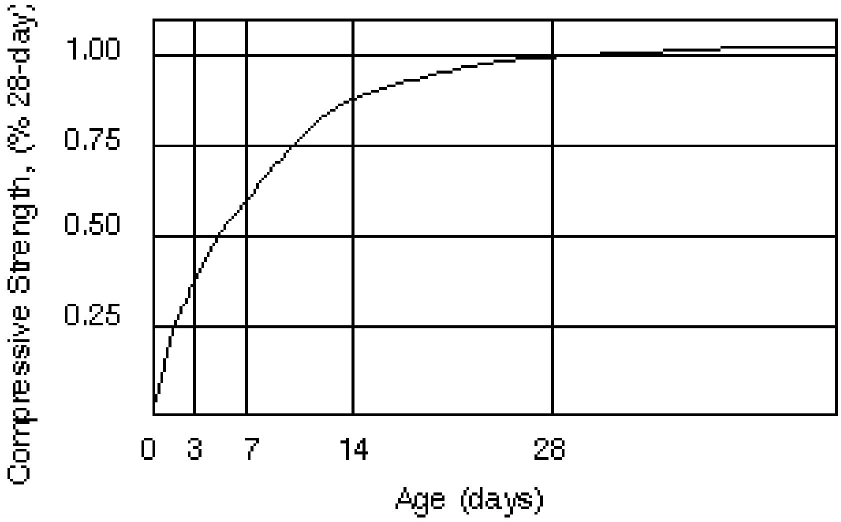

Figure 2.1: The strength of concrete by age

Source: Akeem Ayinde Raheem 2013

Figure 2.1 shows that the cube reaches his strength at age of 28days, so it eases to be conduct an experiment on concrete age of 28days. It will produce most likely to obtained the maximum result. According to the research by Akeem Ayinde Raheem, 2013 concrete nearly reach its full strength at age of 28days. And also Eurocode mention that 28 days required to proceed with compressive test by 70% of concrete strength.

Fresh Portland cement was mixed with the sand prepared by ASTM standard. The ratio of cement and sand was 1:2.75 and 30% to 70% cement (by weight) was replaced by the inclusion of POC. Optimum water cement ratio obtained which was 0.43 and used for the preparation of the specimen. In journal of Kamal Nasharulddin bin Mustapha, 2012, replace 100% of POC as an aggregate.

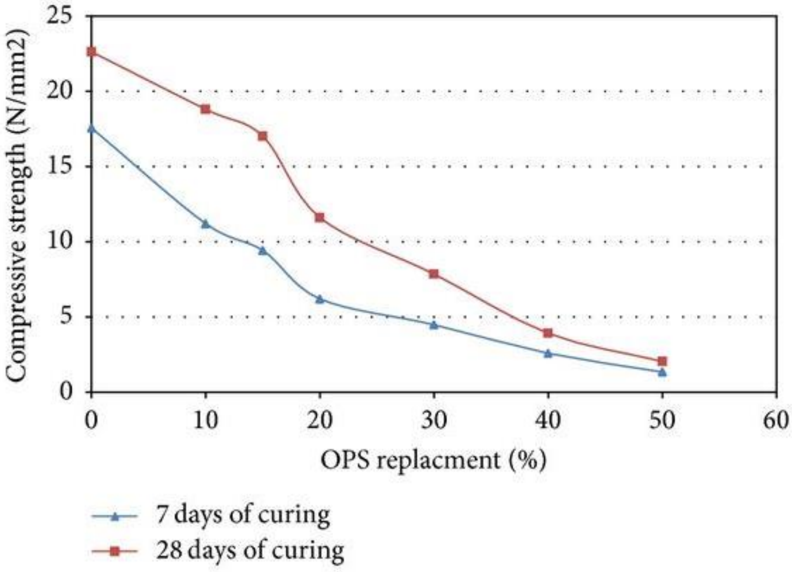

Figure 2.2: The compressive strength of palm oil shell replacement as fine aggregate

Source: Nafisa Tamanna 2014

The result obtains by mixture of palm oil shell by ratio of 1: 3.3: 4.2. The result obtains by investigation on palm oil shell concrete with various percentage of palm oil shell and ratio respectively (Nafisa Tamanna 2014). The Figure 2.2 show that 15% of palm oil shell as fine aggregate and ratio 1: 3.3: 4.2 with 0.75 w/c. is the best substitution of materials to form lightweight concrete.

The journal of Rasel Ahmmad by year 2015 able to obtain perfect design mix for POCC with high strength. Although the journal about comparison between palm oil clinker concrete and palm oil shell concrete as replacement of coarse aggregate. The 42.5 grade ordinary Portland cement (OPC), with a specific gravity of 3.14 g/cm^3, was used in the preparation of the test specimens. The Blaine's specific surface area of the cement was 3510 cm2/g. In lightweight concrete, this OPC acts as the binder material and fills the pores of the coarse and fine aggregates. A high range water-reducing admixture, Sika ViscoCrete® 2199, had been found to be suitable for the concrete mixes in the present investigation. In accordance with BS 5075, the admixture is chloride free and is compatible with all types of Portland cement, including sulphate resistant cement. The use of SP content was kept constant at 1.74% of the cement weight (Rasel Ahmmad, 2015).

The aggregate particles between 4.75 mm and 12.5 mm were considered to be suitable as coarse aggregate in the preparation of concrete. Figure 2.3 show the shape of POC at size in range of coarse aggregate. POC had a specific gravity of 2.08 which is higher than that of Palm Oil Shell (OPS); similarly, its fineness modulus and compacted bulk density of 6.29 and 782.10 kg/m^3 were also found higher compared to OPS. In contrast, the lower 24 h water absorption of 3.56% obtained for POC aggregates is much lower compared to very high water absorption of about 24% for OPS (Rasel Ahmmad, 2015).

Figure 2.3: The shape of Palm oil clinker

Source: Rasel Ahmmad 2015

Five concrete mixes were prepared to investigate the enhancement of the mechanical properties of high strength lightweight concrete (HSLWC) containing OPS and POC as coarse aggregates. The cement content and water to cement ratio for those mixtures were kept constant at 466 kg/m^3 and 0.353, correspondingly. A control mix with only OPS as coarse aggregate was cast for comparison purpose. Since the control concrete contained no POC, this mix was designated as P0 (no partial replacement POC as coarse aggregate). The other four mixes contained POC coarse aggregate by volume replacement of OPS coarse aggregate at 25%, 50%, 75% and 100%. The mixes are referred to as P25, P50, P75 and P100. Concrete cube specimens of 100 mm in size were used for the determination of the ultrasonic pulse velocity (UPV), oven dry density and compressive strength these specimens were covered with plastic sheathing and kept in the moulds for 24 h at a room temperature of 28 ± 2 ℃. These specimens were then cured in water at 24 ± 2 ℃ for 28-d. Three concrete specimens were prepared and tested for each test condition to obtain average values (Rasel Ahmmad, 2015). The Table 2.1 show the design mix and basic properties of concrete and result of slump test for the mixture where used by Rasel Ahmmad for his thesis. The table of design mix consist of cement, water, superplasticizer, water/cement ratio and aggregate (Fine and Coarse).

Table 2.1: The design mix proportion in Kg/m^3 and basic properties of concrete.

Mix	**Cement**	**Water**	**W/C**	**SP**	**Aggregate**			**Slump (mm)**
					Fine	**Coarse**		
					Normal sand	**OPS**	**POC**	
P0(OPS)	466	166	0.353	8.1	847	373	-	55
P25 (POC)	466	166	0.353	8.1	847	280.5	143.1	50
P50 (POC)	466	166	0.353	8.1	847	187	286.2	55
P75 (POC)	466	166	0.353	8.1	847	93.5	429.3	51
P100(POC)	466	166	0.353	8.1	847	-	565	53

Source: Rasel Ahmmad (2015)

Table 2.2: The compressive strength of OPS and POC based at different ages

Mix	**Cube compressive strength f_{ck} at different ages**				
	1 day	**3 days**	**7 days**	**28 days**	**56 days**
P0	28.37	37.44	42.11	43.09	43.52
P25	29.35	39.35	45.37	49.45	49.73
P50	31.60	45.11	48.07	51.62	51.47
P75	32.10	47.63	51.76	55.37	56.82
P100	41.85	51.64	59.86	67.96	69.34

Source: Rasel Ahmmad (2015)

The additional benefit of using crushed POC aggregate as replacement to conventional crushed granite aggregates would enable lower dead load in structural elements. The strength of P100 100% POC as coarse aggregate has highest compressive strength among other specimen (P0, P25, P50, P75). The Table 2.2 show the compressive strength of sample at different ages which is 1day, 3 days, 7 days 28 days and 28 days with different percentage of POC as coarse aggregate. The table shows that design mix proportion of P100 has a best ratio for POCC by achieving highest compressive strength than other design mix (Rasel Ahmmad, 2015).

2.3 CONCRETE COMPRESSIVE TEST

There are few different test can be carryout to identify the different mechanical properties of concrete. Compression Test and Rebound Hammer Number (RHN) Test were used to determine the compressive strength while flexural strength determined by Flexural Test.

Compressive strength of concrete is test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether concreting has been done properly or not.

For cube test two types of specimens either cubes of 150 mm X 150 mm X 150 mm or 100 mm X 100 mm x 100 mm depending upon the size of aggregate are used. For most the works cubic molds of size 150 mm x 150 mm x 150 mm are commonly used. This concrete is poured in the mold and tempered properly so as not to have any voids. After 24 hours these molds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen. These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. The test specimens are stored in moist air for 24hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

According MSZ EN 1992-1-1:2005 the procedure of compression test is shown in Figure 2.4 below (Eurocode 2).

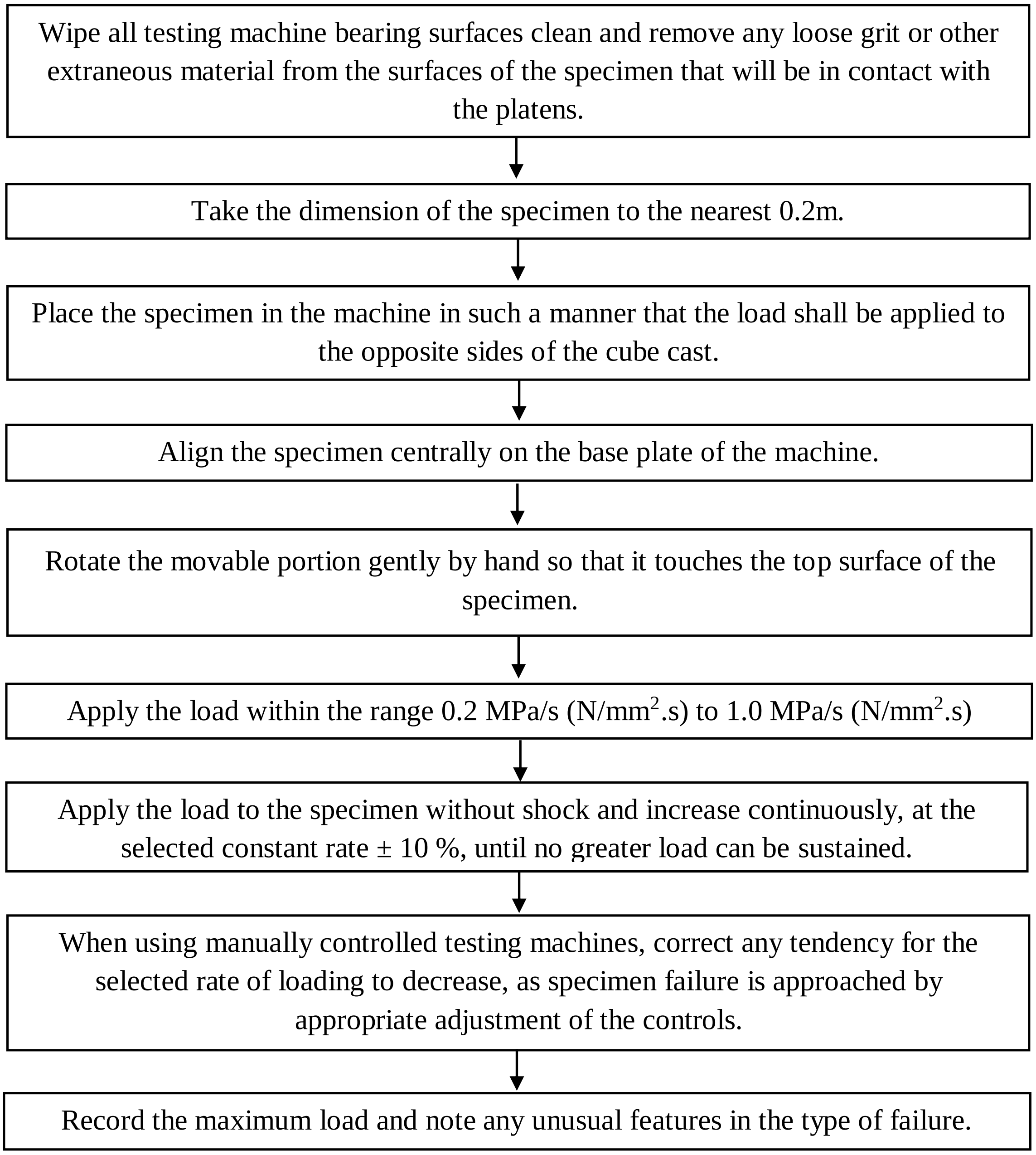

Figure 2.4: Procedure of compressive strength test

Source: Eurocode 2

2.3.1 SIZE OF SAMPLE

Mechanical properties of concrete can be obtained from different test which required different size and shape of samples. The samples could be in cube or in cylinder shapes depending on the type of test. The concrete cube sample was used for the determination of the ultrasonic pulse velocity (UPV), oven dry density and compressive strength test while the cylinder sample was used to determine the modulus of elasticity and more

EN 206-1 permits conformity to the specified compressive strength class to be based on test data from 100 mm cubes. The required value of the minimum characteristic strength based on 100 mm cubes specification. Figure 2.5 shows that image of cube by EN 12390-1:2000. The Table 2.3 shows the 'd' sizes of the cube which determine in Eurocode.

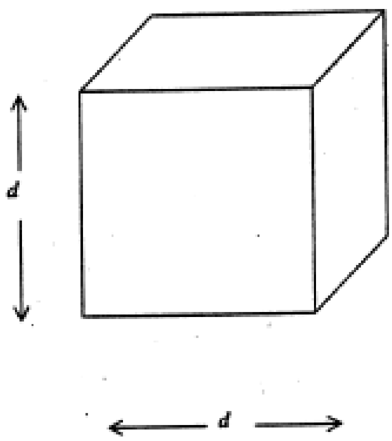

Figure 2.5: The cube shape and size

Source: EN 206-1

The Table 2.3 show the Cube dimension that can be used for tests. The minimum size is 100mm and followed by 150mm, 200mm, 250mm and 300mm. The size will be various for different type of tests.

Table 2.3: The size of cube dimension (EN 12390-1:2000)

Shape	**Cube**				
Size of cubes, d (mm)	100	150	200	250	300

Source: EN 206-1

The size of the cylinder can be determine as shown in Figure 2.6, which is the height was twice of size of diameter. The standard cylinder dimensions are determined at Table 2.4 (EN 12390-1:2000). The minimum 'd' size will be 100mm and followed by 150mm, 200mm, 250and 300mm.

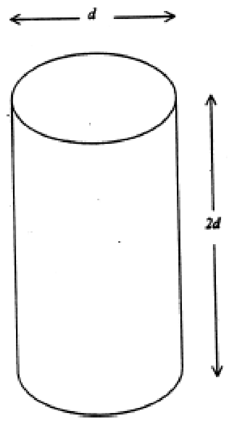

Figure 2.6: The cylinder shape and size

Source: EN 206-1

Table 2.4: The size of cylinder dimension (EN 12390-1:2000)

Shape	**cylinder**				
Size of cylinder, d (mm)	100	150	200	250	300

Source: EN 206-1

2.4 FAILURE MODE

The compressive strength test the cube or cylinder will be fail by crack and break apart. The satisfaction of failure can be determent by shape which is shown in Figure 2.7 for cube. and Figure 2.8 for cylinder shape.

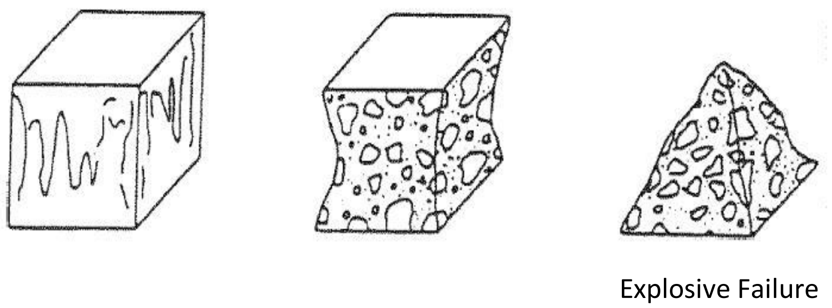

Figure 2.7: The satisfactory failures of cube sample

Source: Eurocode 2

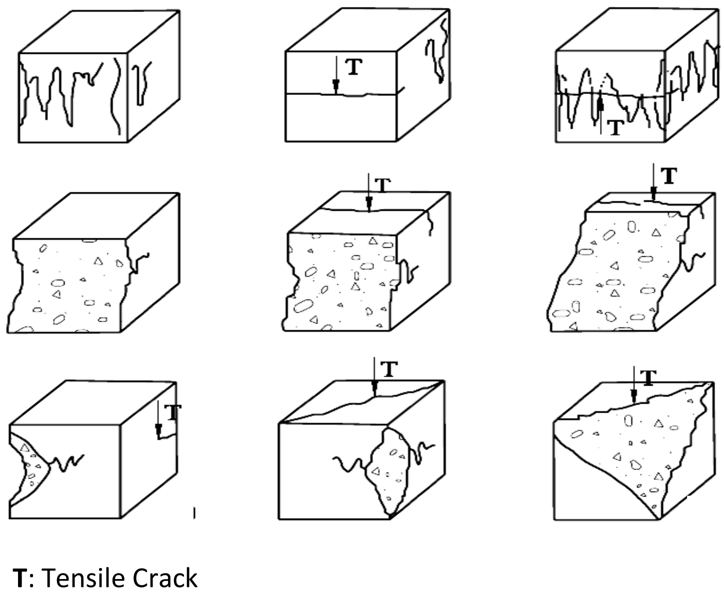

Figure 2.8: The unsatisfactory of cube sample

Source: Eurocode 2

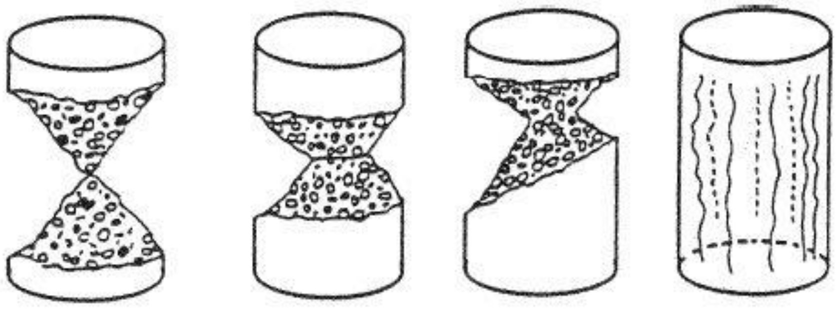

Figure 2.9: The satisfactory failures of cylinder sample

Source: Eurocode 2

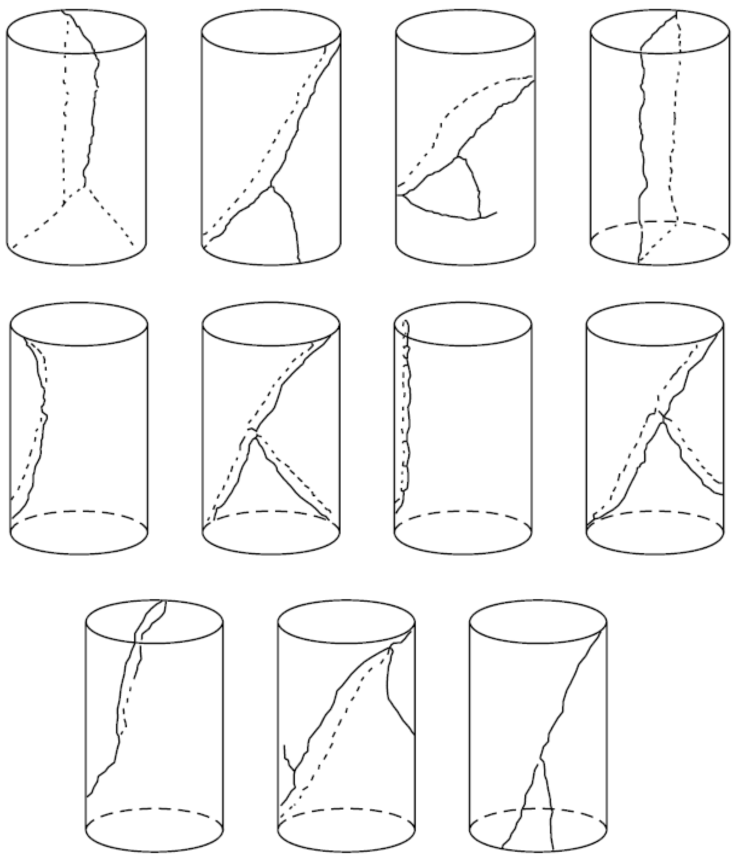

Figure 2.10: The unsatisfactory failure of cylinder sample

Source: Eurocode 2

All concrete when meet compression test need to fail in shape shown in Figure 2.7 for cube and Figure 2.9 for cylinder, it's stated that the compression test conduct in prefect procedure and its satisfy the guidance MSZ EN 1992-1-1:2005 (Eurocode 2). Therefore, unsatisfactory of failure on cube and cylinder at compressive strength test will shape as shown in Figure 2.8 and Figure 2.10.

2.5 ADVANTAGE AND DISADVANTAGE OF POCC

POCC has a several advantages and disadvantages. POC is lightweight material so that it can lower the dead load as how mention by Gambhir, at his journal at year 2006. The POCC has some better physical properties such as lower modulus, lower coefficient of thermal expansion, and easier drilling. POCC also improved in durability because of the reduced likelihood of shrinkage and early thermal cracking due to lower permeability. POCC came as a solution for environmental problems, such as the plam oil industrial waste will reduce by the use of POCC (Kamal Nasharulddin bin Mustapha, 2012)

There are few disadvantages on POCC, which are greater care is required in controlling water content, mixing, and supervision. Reduced resistance to locally concentrated loads (Bashar s. Mohammed, 2013).

2.6 CONCRETE FIRE RESISTANCE

Building codes require designers to provide fire protection for buildings by combining 'active' fire protection systems with 'passive' fire protections systems. Active fire protection systems include smoke detectors, sprinklers and other systems that activate in the presence of smoke or fire. Passive fire protection uses the building components and layout to reduce the risk and spread of fire by providing non-combustible fire rated walls, floors and roofs. These building components help to compartmentalize the building so a fire that starts in one part of a building does not spread to other parts of the building (Erin Ashley, 2007). The concept of combining active and passive fire protection systems is called balanced fire protection design. Implementing balanced fire protection design provides the highest achievable level of protection. The most common method of determining a structural member's performance in a fire is by a series of tests leading to a fire resistance rating. Fire resistance is defined as the ability of the structural member to withstand exposure to a fire without loss of load bearing function or ability to act as a barrier to spread a fire.

The importance of passive systems for reducing smoke and fire spread through compartment. It’s verified that building products or systems meet designated fire and flammability requirements. During a fire test, a structural element must perform its load-bearing function and carry the load for the duration of the test without collapse Fire resistant test conduct with few standards such as ANSI/UL, ASTM, CAN/ULC, and NFPA standards, partnering with and give a standard of testing services in the world.

Fire resistance determine the ability of a material, product, or assembly to withstand a fire or provide protection for a period of time. Its measure surface flame spread of a flame away from the source of ignition across the surface of a material or assembly and evaluate the potential for spreading flames in the event of a fire.

2.6.1 FIRE RESISTANCE ACCORDING TO CODE OF PRACTICE

Eurocode 1 Part 1-2: Actions on structures exposed to fire” (EC1-03) regulates calculation models for the determination of temperature and load effects. Eurocode2 (EC202) (EC2-95) gives three alternatives of design methods:

i) Tabulated data:

Tabulated data gives minimum values for cross-sectional dimensions and the axial distances of the longitudinal reinforcement to the concrete surface. For beams there is a distinction between simply supported and continuous beams. Structures the axial distance of the reinforcement is determined such, that for the fire resistance time, the critical temperature in the steel bars is 500°C. The reinforcement reaches its yield stress if the loads under fire conditions equal 0.7 times the load under cold conditions.

ii) Simplified calculation methods for specific types of members:

Strength of the concrete members at any time for any fire exposure. Methods are based on a reduced cross-section consisting of cooler parts of the member. Therefore, the temperature profiles within the member and data of the temperature dependent changes of the material properties.

iii) Advanced calculation methods:

The advanced calculation methods provide a realistic analysis of the structures exposed to fire. They are based on fundamental physical behaviour leading to a reliable approximation of the expected behaviour under fire conditions.

In Germany, the first draft of "*Deutsches Institut für Normung*", meaning German institute for standardization DIN 4102-22 (DIN-4102-22) has been published but the output of design using DIN 4102-22 is similar as design output using the tabulated data of Eurocode 2 (EC2-95).

The New Zealand Standard the fire resistance of a concrete member can be determined according to stated data, describing the minimum size of the member and the minimum concrete cover of the longitudinal reinforcing bars. Additionally, the code allows the determination of the fire resistance ratings from fire tests of calculation such as that given in “BRANZ Technical Recommendation No.8” (Wad-91) (Daniela Bernhart, 2004).

2.7 FIRE RESISTANT TEST

The most widely used and nationally accepted test procedure is that developed by the American Society of Testing and Materials (ASTM). It is designated as ASTM E119, Standard Methods of Fire Tests of Building Construction and Materials. A standard fire test is conducted by placing a full size assembly in a test furnace. Floor and roof specimens are exposed to a controlled fire from beneath, beams are exposed from the bottom and sides, walls from one side, and columns are exposed to fire from all sides (David N. Bilow, 2008).

i) Furnace:

Test furnaces are the most common method used to evaluate the fire resistance of structural elements. The furnaces' chamber is heated either electronically or by burning liquid fuel. (Adam Levesque, 2006). There are vertical furnaces that are constructed for testing vertical partitions such as walls and doors; horizontal furnaces are used for testing horizontal partitions such as floors and roofs.

ii) Standard Fires:

Most fire resistance tests follow time-temperature curves that serve as 'standard fires' which are idealized simulations of room fires. Since the tests follow established time-temperature curves, the heat load imposed on a test specimen is calculable at any point during testing.

From the journal of Md. Akhtar Hossain on year 2006 had a research on fire exposure on cement mortar of fly ash. The ratio of cement and sand was 1:2.75 and 30% to 70% cement (by weight) was replaced by the inclusion of fly ash. Optimum water cement ratio obtained which was 0.43. The mortar was casted in the mould for preparing 2" cube models. During casting the mortar in the mould, mild steel bar of 1/8/ diameter was centrally penetrated in the mortar up to a certain depth and mould was kept in wet place for 24 hours, then prepared cubes were removed from the mould and placed in water for 28 days at room temperature. The time eighteen cubes where prepared (6 set). These where heated for 1 hour at 6 different temperatures: 25°C, 50°C, 100°C, 200°C, 300°C, 400°C and 600°C. After heated for an hour the cube leaves it to cool down in room temperature for a day (24hours) (Md. Akhtar Hossain, 2006). The Table 2.5 show the compressive and bond Strength of cement mortar with the consideration of various rate of fly ash at different temperature.

Table 2.5: The compressive and bond Strength of cement mortar with the inclusion of different percentage of fly ash at different temperature.

Percentage of Fly Ash	Mixing Proportion	Bar Dia (inch)	Temperature (°C)	Average Compressive Strength (psi)	Average Bond Strength (psi)
30	1:2.75	1/8	25	3326	111
			50	3786	128
			100	4000	134
			200	4348	148
			400	3210	95
			600	2628	4
40	1:2.75	1/8	25	3784	119
			50	4000	132
			100	4510	140
			200	5120	155
			400	3649	110
			600	2828	6
50	1:2.75	1/8	25	4129	128
			50	4484	138
			100	4896	144
			200	5220	159
			400	3649	116
			600	2821	10
60	1:2.75	1/8	25	3847	116
			50	3992	130
			100	4218	139
			200	4489	151
			400	3749	107
			600	2910	2
70	1:2.75	1/8	25	3188	104
			50	3457	111
			100	3794	117
			200	4100	128
			400	3048	99
			600	2918	0

Source: Md. Akhtar Hossain (2006)

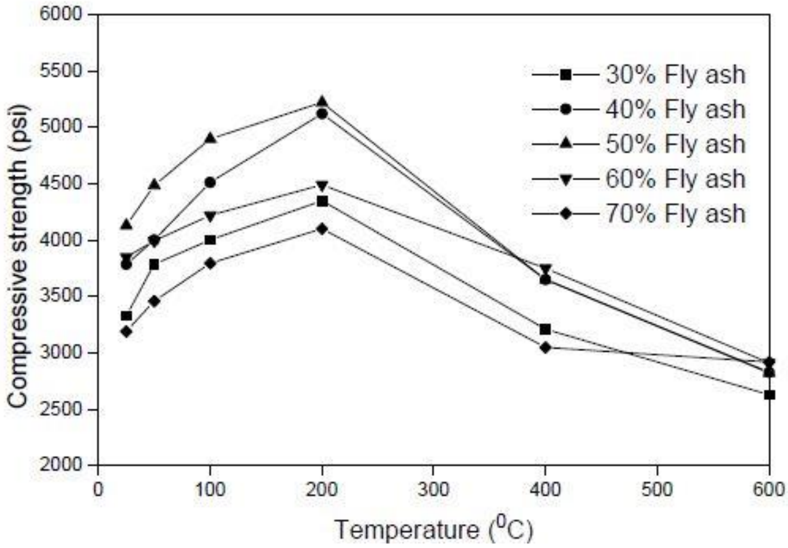

Figure 2.11: The compressive strength by temperature

Source: Md. Akhtar Hossain 2006

The Table 2.5 can determine that concrete cube can sustain certain amount of temperature which able to maintain high compressive strength (Md. Akhtar Hossain, 2006). The mortar with 70% fly ash have highest compressive strength after burned 600 °C. The Figure 2.11 shows that, when cube expose with higher temperature cause weaken the cube and producing low capacity in compressive strength.

2.8 EFFECT OF FIRE TO CONCRETE

The change in concrete properties due to high temperature depends on the type of coarse aggregate used. Aggregate used in concrete can be classified into three types: carbonate, siliceous and lightweight. Carbonate aggregates include limestone and dolomite. Siliceous aggregate includes materials consisting of silica and include granite and sandstone. Lightweight aggregates are usually manufactured by heating shale, slate, or clay.

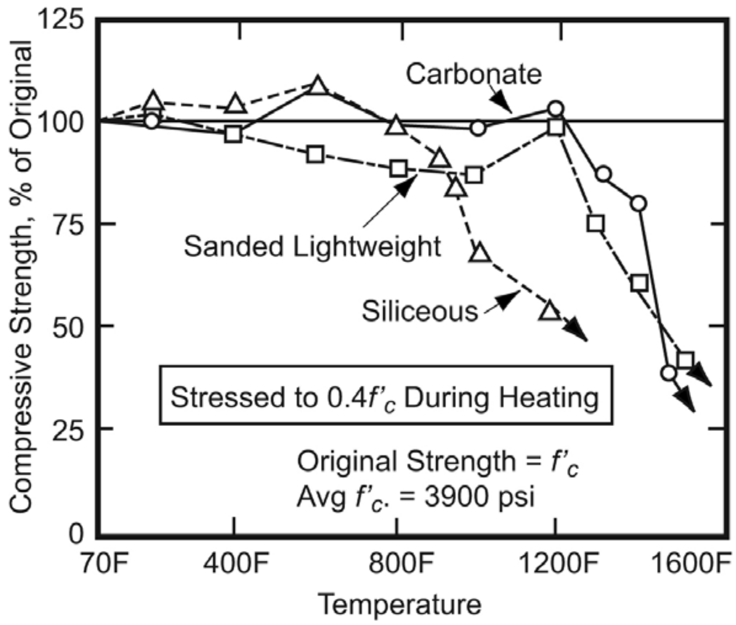

Figure 2.12: The effect of high temperature on compressive strength concrete

Source: David N. Bilow 2008

The specimens represented in the figure were stressed to 40% of their compressive strength during the heating period. After the designated test temperature was reached, the load was increased gradually until the specimen failed. The figure shows that the strength of concrete containing siliceous aggregate begins to drop off at about 400 °C and is reduced to about 55% at 600 °C. Concrete containing lightweight aggregates and carbonate aggregates retain most of their compressive strength up to about 600 °C as shown in Figure 2.12. Lightweight concrete has insulating properties, and transmits heat at a slower rate than normal weight concrete with the same thickness, and therefore generally provides increased fire resistance (David N. Bilow, 2008).

Table 2.6: The criteria of test material

Size of the Specimen (m)	Cube (0.1x0.1x0.1)	Beam (0.3x0.1x 0.1)
Temperature range (°C)	200 to 800	
Time duration	-	
Time temperature curve	Furnace temperature curve	
Rate of heating (For an hour)	10°C/min	
Rate of Cooling/ coolant	Natural cooling to room temperature	
Time duration b/w hot test & load test	2 days	

Source: Gai – fei Peng (2006)

From the journal by Gai-Fei Peng at year 2006, carried out an investigation to explore the relationship between occurrence of explosive spalling and residual mechanical properties of fiber toughened high performance concrete exposed to high temperatures. The residual mechanical properties measured includes compressive strength, tensile splitting strength, and fracture energy. A series of concretes were prepared using ordinary Portland cement and crushed limestone. Steel fiber, polypropylene fiber, and hybrid fiber (polypropylene fiber and steel fiber) were added to enhance fracture energy of the concretes. After exposure to high temperatures ranged from 200 to 800 °C, the residual mechanical properties of fiber toughened high-performance concrete were investigated which shown in Table 2.6. The cube and beam are undergone with test according process as shown in table the fiber concrete, although residual strength was decreased by exposure to high temperatures over 400 °C, residual fracture energy was significantly higher than that before heating.

Concrete cubes (150x150x150 mm) were tested at ages 30, 60 and 90 days. The relation between compressive strengths and fire flame temperatures for both plain and steel reinforced concrete. The percentage of residual compressive strengths were (4I -94 %) for plain concrete and (42-96 %) for steel reinforced concrete for all periods of exposure. Surface cracks of about (1 mm) width took place on the concrete specimens. This may be due to hydration conditions of iron oxide component and other mineral constituents of the fine and coarse aggregates. The surface cracks increased in number, length and depth due to temperature rise. Can be seen that large proportion of the decrease in compressive strength occurs at the first 1.0-hour period of exposure. It can be seen that the adverse effect of fire is pronounced. Also on plain concrete more than on steel reinforced concrete, while the effect is equal when the period of fire exposure reaches two hours or increase higher temperature exposure. The Figure 2.13 show the relationship between temperature and density. This effect is still noticeable at 300 ℃ but above 500 ℃ all the specimens behave similarly. It is to be noted that below about 300 ℃ the mechanical properties of steel are little affected by temperature (Mommed Mansour kadhum, 2010).

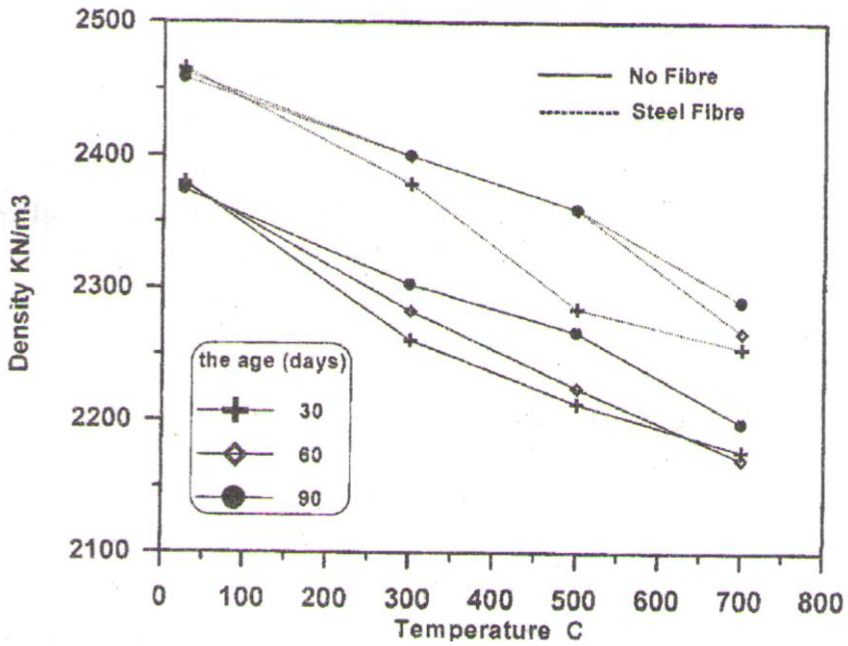

Figure 2.13: The effect of fire flame on the density of plain and steel fibre reinforcement concrete at an hour period of exposure

Source: Mommed Mansour kadhum 2010

The Figure 2.13 show the effect of fire flame on the density of plain steel fibre reinforced concrete. Compare the two cases (with and without steel fibers), it is clear that at a 300 °C, the increase in compressive strength was about (21.4 and 23.0%) and (19.8 and 22.2%) at ages of 30 and 60 days and exposure period 1.0 hour and 1.5 hours respectively. At temperature of 500 °C, the effect of fibers is clear in increasing the compressive strength of (31.7 and 33.0%) and (29.8 and 31.6%) at ages of 30 and 60 days and exposure period 1.0 and 1.5 respectively. At temperature of 600°C and exposure period 1.0, 1.5 hour and at age of 30 and 60 days, the effect of fibers is clear in increasing the compressive strength of (49.7 and 51%) and (47.3 and 49.1%) respectively compare with that for non- fibred concrete. From the results, it can be concluded that the concrete with steel fiber resist fire more than that without fiber at a temperature of 600°C. This can figure out that this kind of fiber (steel) is good on the temperature of 600°C, as a result in Table 2.7 (Mommed Mansour kadhum 2010).

Table 2.7: The test values of compressive strength of plain and fibers reinforced high strength concrete specimens before and after exposure to fire

Age at Exposure (days)	**Period of Exposure (hours)**	**Compressive Strength (MPa)**				**Steel Fiber Content**
		Temperature °C				
		25	**300**	**500**	**600**	
30	1.0	81	59.3	48.6	32.4	No Fibers
			72.2	64.0	48.5	1.5% Steel Fibers Content
	1.5	86.5	52.8	44.3	29.2	No Fibers
			63.3	57.5	43.0	1.5% Steel Fibers Content
60	1.0	84.5	65.1	53.4	38.8	No Fibers
			80.1	71.0	58.6	1.5% Steel Fibers Content
	1.5	91	57.4	50.2	33.8	No Fibers
			70.2	66.1	50.4	1.5% Steel Fiber Content

Source: Mommed Mansour kadhum (2010)

From the journal of Forensic investigation of fire-affected reinforced concrete buildings by Aweyera,2014 were clearly mention about burned structure safe to use when the compressive strength reduces up to 40%. Non-Destructive Test (NDT) methods are increasingly applied for the investigation of concrete structures, described NDT as a method of test that does not impair the intended performance of the element or member under investigation. It could be done during and after construction, in-service or maintenance. These tests are conducted during construction in order to ensure quality control and monitoring of strength in fresh concrete works and also existing structures to establish their structural adequacy and material deterioration against time or environment. Although standard control cubes are used to determine the strength of concrete produced on site, they cannot be true representative of the in situ concrete in a structure. Extraction and testing of cores taken from the concrete structure is another option available to an investigation. which an estimate of concrete strength may be made. Most used NDT methods in concrete structures include visual inspection, Schmidt or rebound hammer test and the Ultrasonic Pulse Velocity (UPV) test.

The compressive strength is one of the prime qualities by which concrete is judged; it is probably the most investigated property at high temperatures. The residual strength of a fire-damaged concrete structure has to be determined in order to make decisions for renovation work. The revealed that corrosion in concrete is the most serious and commonly encountered durability problem mostly after fire. Corrosion can crack the concrete cover and make it spall and it could also reduce the area of steel embedded in it. Several other defects emanate during fire occurrence in concrete structures. This study is aimed at forensic investigation of fire-affected reinforced concrete structures, the tests conducted entails visual inspection to check defects on the concrete and also rebound hammer and ultrasonic pulse velocity tests which was used to estimate the residual strength of the structural members. The Rebound Hammer Number (RHN) results respectively with the concrete compressive strength. Using the average UPV and RHN results obtained for site A, it was deduced that the fire-affected part of the building lost 26 – 40% of its strength. The model used for estimating the temperature revealed that the building might have been subjected to a temperature range of 280°C – 450°C. Figure 2.14 shows the result of NDT conducted at Site A. More so, the observed physical defects on the building includes spalling and blemishes on concrete surface, cracks and delamination of plaster of slab in some areas. Considering the BS British Standards Institution, BS 1881 part 202, Recommendations for surface hardness by rebound hammer. This recommendation for NDT, it was deduced that the affected concrete members are still good but requires renovation for safety purpose.

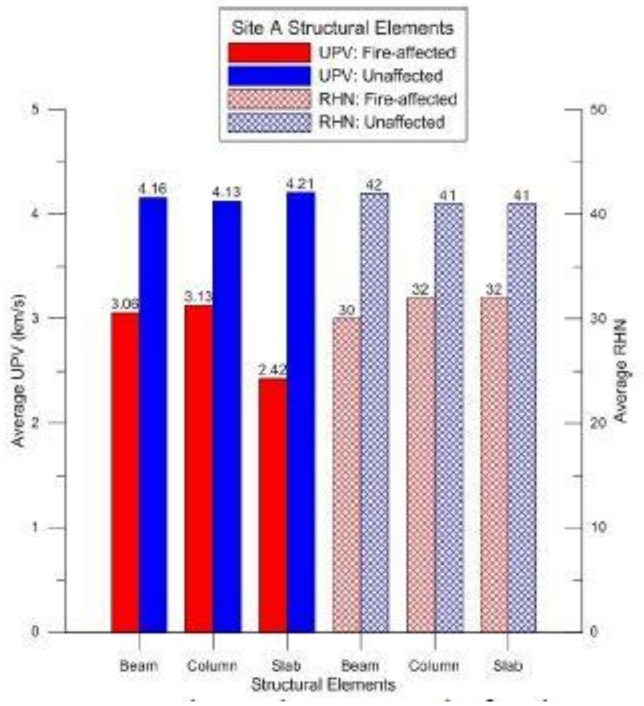

Figure 2.14 NDT conducted at Site A

Source: Aweyera 2014

Using the average UPV and RHN results obtained for site A, it was deduced that the fire-affected part of the building lost 26 – 40% of its strength. The model used for estimating the temperature revealed that the building might have been subjected to a temperature range of 280°C – 450°C. Concrete elements subjected to temperature up to 450°C or 500°C are still safe for use because at this temperature concrete moisture would have been absolved by fire and cracks will occur due to expansion and contraction of constituent materials but the entire structure will be serviceable.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter explain about the effective way to complete the investigation fully without any interruption or disarranged. Methodology is playing role as pre-plan of this study. Based on pervious study, methodology precise all the information and narrow the path to completed the study without any obstacle.

3.2 FLOW CHART OF THE METHODOLOGY

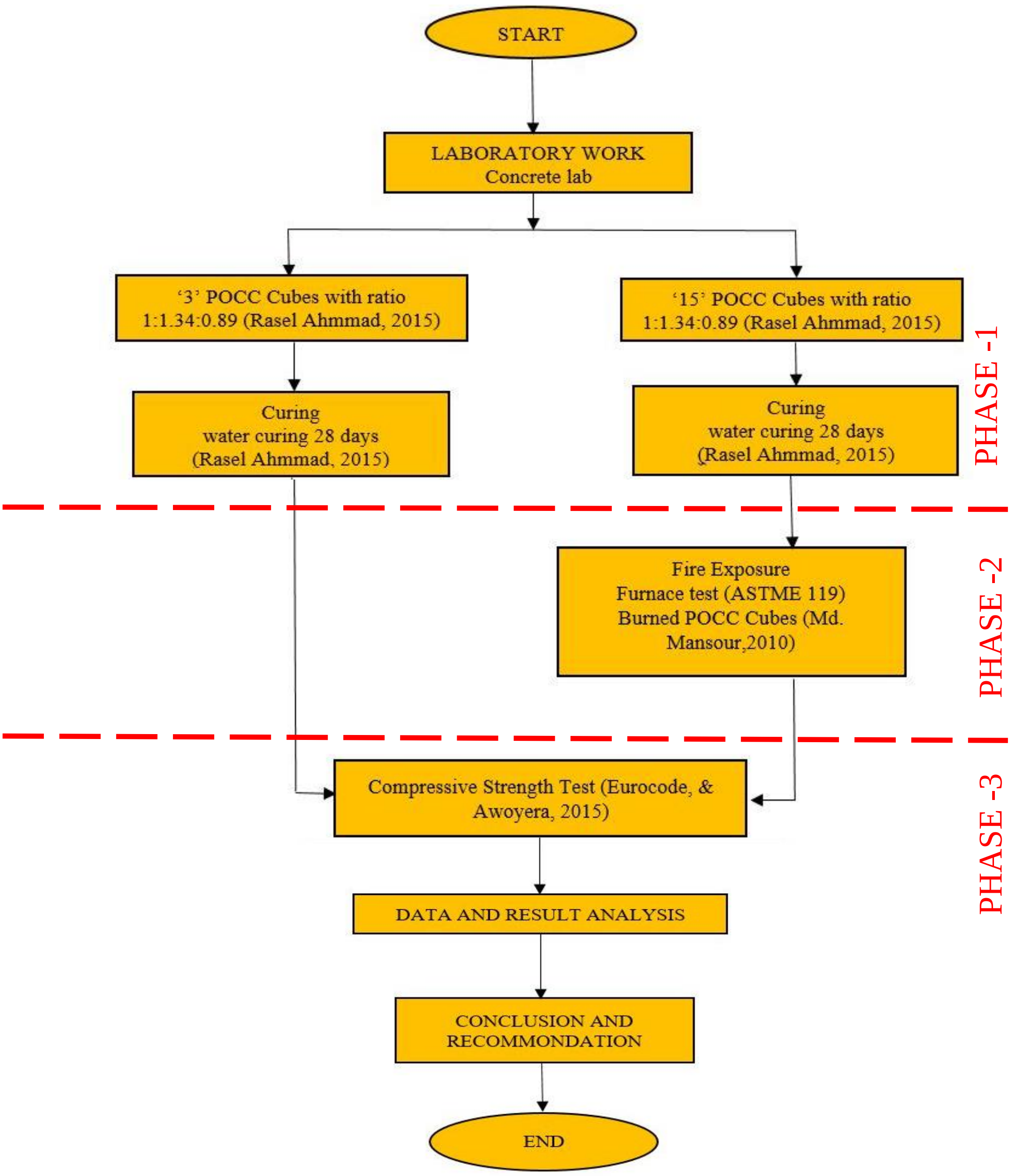

Figure 3.1: The flow chart of the methodology

The flow chart in Figure 3.1 divided into 3 phase to ease this study, which is named at phase 1, phase 2 and phase 3. The phase 1 about the material preparation and casting. The phase 2 about burning process to variable samples and phase 3 is about testing, which is compressive stress test. Based on pervious study palm oil clinker is a suitable material to form lightweight concrete.

3.3 MATERIAL PREPARATION

The palm oil clinker is can be replaced for coarse aggregate. The POC obtained from local palm oil industry and crushed into smaller size. The Jaw Crusher machine were used to crush the POC. The crushed POC sieve by using mechanical sieve shaker which pass through sieve size 12.5mm and remain at sieve 4.5mm (Rasel Ahmmad, 2015). The sieve POC used for concreting work off POCC.

3.4 CONCRETING WORK

The samples will be cast with determined ratio by Rasel Ahmmad at his journal. The POC fully replaced as a coarse aggregate at ratio 1:1.34:0.89 with 35.6% of water from the cement weight. The POC crushed by using Jaw Crusher into coarse aggregate size which is 5mm to 12.5mm. The crushed POC sieved at range 5 mm to 12.5mm, POC which pass through sieve size 12.5mm and retained at sieve size 5mm are used as coarse aggregate. To ease for workability Rasel Ahmmad added add mixture Superplasticiser (SP) of Sika ViscoCrete®-2119 with 1.74% form cement weight. The Figure 3.2 show the mixing process of the POCC. The POCC casted into mold size 100mm x 100mm x 100mm (Eurocode: 206 - 1). The 18 POCC cubes cast and immerged in water for 28 days for water curing process as shown in Figure 3.4. All the 18 samples must be label by number in order to proceed to following steps. Figure 3.3 shows labeled casted POCC according to the control and variable samples.

Figure 3.2: Mixing POCC with ratio of 1:1.34:0.89

Figure 3.3: Label the casted POCC sample

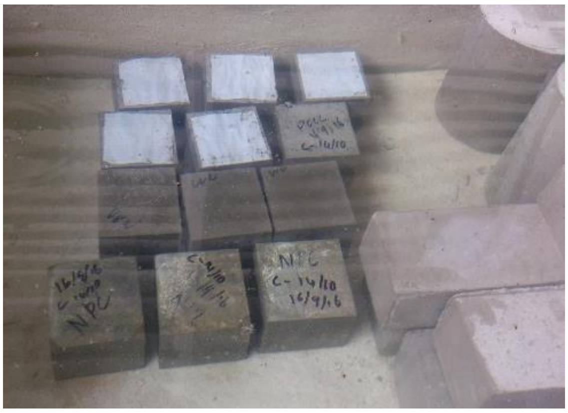

Figure 3.4: Curing process of POCC, immersed in water

3.5 BURNING PROCESS

The phase 2 proceed burning process which is variable for this study. 15 cubes of POCC burned at determined temperature for an hour. The variable was the temperature which is 100°C, 200°C, 300°C, 400°C and 500°C. The matured POCC cubes at age 28 days are proceed with burning process at furnace. There are 3 POCC cubes will be burned at each temperature in furnace for an hour. In the Figure 3.5 shows that POCC sample placed at furnace for burning process.

Figure 3.5: POCC sample placed at furnace for burning process.

Figure 3.6 shows POCC after burning process at furnace. All the matured POCC sample burned with temperature as determine on label of sample as stated in Table 3.1 The table 3.1 show the summarize of laboratory testing (burned with various temperature and age of compressive test on POCC Samples. Burned POCC cooldown in room temperature for a day or 24 hours before followed by compressive strength test.

Figure 3.6: Burned POCC at furnace

Table 3.1: Summarize of laboratory testing on POCC

Type of Concrete	Label of sample	Number of cubes	Curing days	Temperature, °C	Burning Process	Compressive Strength test
POCC	S1	3	28	-	-	Yes
	S2	3	28	100	Yes	Yes
	S3	3	28	200	Yes	Yes
	S4	3	28	300	Yes	Yes
	S5	3	28	400	Yes	Yes
	S6	3	28	500	yes	yes

3.6 TESTING

The phase 3 determined the compressive strength of POCC of all samples. In order to determine the compressive strength for burned and unburned POCC, need to crushed by using compressive strength test. Matured POCC after curing process at age 28 days was proceed with the test to known the initial compressive strength of POCC which is before burning process. The Control sample which is not burned and proceed with compressive strength test to know initial compressive strength of POCC. The 15 samples of POCC which burned with various temperature are cooldown for a day before proceed with compressive strength test. The POCC sample placed at middle of based placed of compressive strength test machine and initiate compressive test. Figure 3.7 shows burned

POCC undergone compressive strength test. The average compressive strength value from 3 samples are taken as a result for each variables.

Figure 3.7: Burned POCC carried Compressive strength test

CHAPTER 4

RESULTS AND ANALYSIS

4.1 INTRODUCTION

This chapter describes obtained data and analysis of laboratory test onto POCC. The POCC was cast and water curing for 28 days to attain full strength. The matured POCC tested to achieve the objectives of this study.

4.2 COMPRESSIVE STRENGTH

The table 4.1 show the compressive strength of POCC at age 28days. The 3 cube of POCC are used for each variable to obtain average compressive strength. As a control sample 3 POCC cubes are carryout compressive strength test without burn in furnace to attain an average compressive strength. Burning temperature will be variable for this study, 100°C ,200°C, 300°C, 400°C and 500°C as a temperature. To obtain compressive strength for each temperature, 3 POCC cubes burned and average of compressive strength result as on table.

Table 4.1: Compressive Strength of POCC after burning process with different temperature

Sample	**Control**	**Variable**				
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Temperature (°C)	-	100	200	300	400	500
Compressive Strength (N/mm^2)	67.56	60.97	57.82	52.49	51.00	44.41

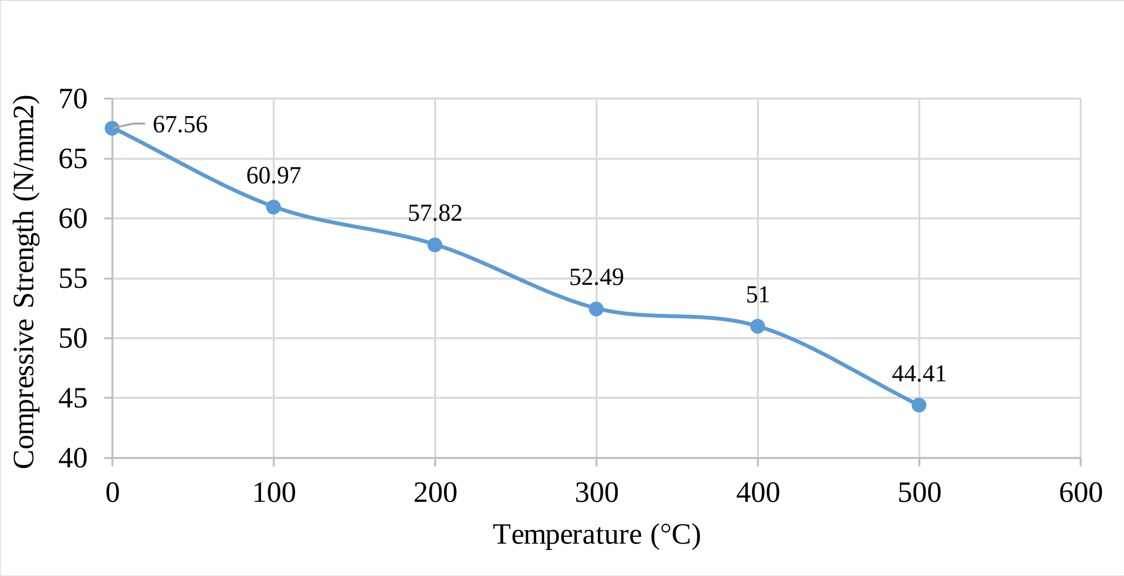

Figure 4.1: Graph of Compressive Strength versus temperature.

Figure 4.1 shows the average compressive strength of POCC samples before and after burning process. The samples were burned with five various temperatures which are 100°C, 200°C, 300°C, 400°C and 500°C. Each burning process was done within 1 hour using furnace.

The control sample (S1), was not burned and its compressive strength was 67.56 N/mm^2 and this is the highest Compression strength then other samples. When the first variable S2 were burned with temperature 100°C, the graph dropped to 60.97 N/mm^2. The second variable S3 Burned in temperature 200°C and its compressive strength fall to 57.82 N/mm^2.

The third variable S4 compressive strength is 52.49 N/mm^2 after it burned at temperature 300°C. The compressive strength of forth variable S5 after burned at temperature 400°C is recorded 51.00 N/mm^2 and it cause slightly drop between S4 to S5 in line graph. The fifth variable S6 of compressive strength after burned at temperature 500 °C is 44.41 N/mm^2 and recorded the lowest compressive strength in the graph. There is steep drop after S5 to S6.

In conclusion, the compressive strength of POCC decrease due to the increases of the burning temperature.

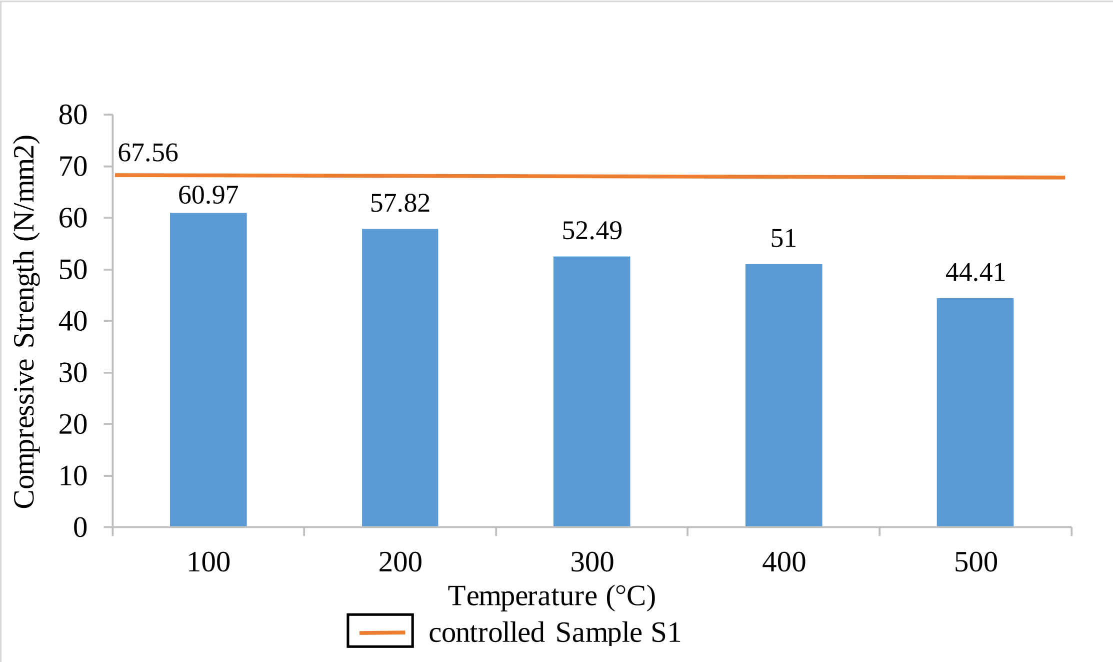

Figure 4.2: Bar chart of Compressive Strength of POCC due to temperature

Figure 4.2 illustrate the compressive strength of POCC towards control sample, S1 in form of bar chart. The vertical axis referring to compressive strength and followed by temperature on horizontal axis. The control sample will be benchmark were in straight line at 67.56 N/mm^2 of its compressive strength. The bar graph shows that the compressive strength reduced when the POCC burned temperature increase. There is no POCC excite them benchmark line, its show that the POCC reduce the compressive strength due to increase of burning temperature.

The S2 was 62.97 N/mm^2 the closest to the control sample then other samples. The sample S3 and S4 also lesser than control sample S1 by compressive strength of 57.82 N/mm^2 and 52.49 N/mm^2 respectively. Sample S5 is recorded 51.00 N/mm^2 but this slightly less then S4 and still below the control sample. The S6 is the lowest in the bar graph, the compressive strength was 44.41N/mm^2 and the gap between control sample was bigger than other samples.

In conclusion, POCC's compressive strength decrease with burning temperature increase and there were no samples excite or touch the control sample line.

4.3 DIFFERENCES OF COMPRESSIVE STRENGTH

The differences in compressive strength of POCC between burned and control sample are shown in table 4.2. The differences between control sample and variable samples are measure in percentage for ease to visualise. The negative sign indicates that the loss of compressive strength from the initial strength.

Table 4.2: Differences of compressive strength

Sample		**Temperature (°C)**	**Different of compressive Strength (%)**
Variable	S2	100	-9.79
	S3	200	-14.45
	S4	300	-22.34
	S5	400	-24.55
	S6	500	-34.30

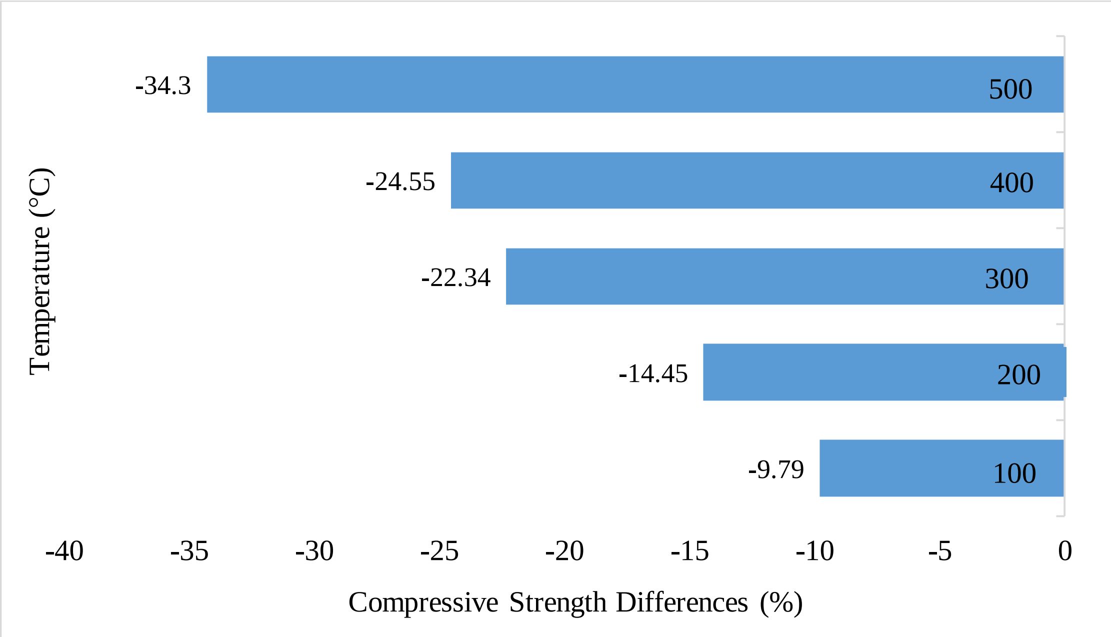

Figure 4.3: Bar chart of Compressive Strength Differences

The bar chart in Figure 4.3 shows differences of compressive strength between control sample and variable samples. The compressive strength differences for S2 was the lowest in this bar chat with -9.79 %. Meanwhile the sample S6 were highest different with -34.3 % form the control sample.

The sample S3 were at -14.45% in the Bar Chart. The S4 rise up to -22.34% differences between control sample. The compressive strength of differences for sample S5 between control sample S1 was -24.55% as stated in the bar chart. The differences of compressive strength between S5- and S4 are very little. The differences of S6 towards control sample are -34.4% it has the highest percentage of the compressive strength differences.

Table 4.3: Compressive strength losses at temperature 450°C

Sample	Percentage of compressive strength losses at 450°C
Normal concrete (Awoyera,2014)	40 (%)
POCC (Study)	30 (%)

From the previous study, Normal concrete lost its compressive strength up 40% when it exposed to fire at temperature 450°C (Awoyera,2014). When the POCC exposed to fire at temperature 450°C, it lost 30% of compressive strength from initial strength. Therefore, compare to normal concrete POCC is good for concrete cover especially when exposure of fire.

In conclusion, when the POCC burning temperature increase weaker or lesser the compressive strength as well the percentage differences of the compressive strength between control variable are increase.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

From the study, coarse aggregate was replaced with palm oil clinker, by Kilogram (Kg). The samples were cast with determined ratio and the samples tested on matured cubes which was after 28 days of curing. The samples burned for an hour with various temperature to determine the compressive strength of POCC. The result shows the compressive strength of POCC reduce with increases of burning temperature. The compressive strength was highest when the POCC unburned with 67.56 N/mm^2. POCC were burned with temperature 500°C behold Compressive strength of 44.41 N/mm^2. The burned POCC with burning temperature of 100°C, 200°C, 300°C and 400°C hold Compressive strength 60.97 N/mm^2, 57.82N/mm^2, 52.49 N/mm^2, 51.00 N/mm^2 and 44.41 N/mm^2 respectively as shown in table 5.1.

Table 5.1: Compressive strength of POCC after burned

Temperature (°C)	100	200	300	400	500
Compressive Strength (N/mm^2)	60.97	57.82	52.49	51.00	44.41

The POCC burned with temperature up to 500°C but the differences between control sample 34.4%. It shows that POCC still in range 26-40% of losses. Awoyera (2014) research shows the deduced fire-affected part of the building loss of is strength are still safe for use because at this temperature concrete moisture would have been absolved by fire and cracks will occur due to expansion and contraction of constituent materials but the entire structure will be serviceable. The range to lose compressive strength up to 40% from initial strength it takes 450°C for normal concrete cubes. Although POCC burned 500°C the compressive strength still less than 40% which is 34.4%. It shows that POCC have higher compressive strength than normal concrete. For this study the Optimum burning temperature is 500°C. Although the compressive strength reduces 34.4% from its initial compressive strength it is safe but still need to renovate.

Table 5.2: Losses in Compressive strength

Temperature (°C)	100	200	300	400	500
Different of Compressive strength (%)	-9.79	-14.45	-22.34	-24.55	-34.30

5.2 RECOMMENDATION

i) Test on POCC, the burning temperature should increase to known the result for higher burning temperature.

ii) Implement the POCC mixture to the structure element.

iii) Burning process should carry out to the POCC structure element.

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APPENDICES

The design mix proportion of POCC in Kg

Cube size: 0.1m X 0.1m X 0.1m = $0.001m^3$

Per cube size: $0.001m^3$

Design mix proportion for per cube. (Kg)

Mix	Cement	Water	Sand	POCC	SP	Slump (mm)
POCC	0.466	0.166	0.847	0.565	0.0081	53

Design mix proportion for 3 POCC Cubes (Kg)

Mix	Cement	Water	Sand	POCC	SP	Slump (mm)
POCC	1.398	0.498	2.541	1.695	0.0243	53

Design mix proportion for 18 POCC Cubes (Kg)

Mix	Cement	Water	Sand	POCC	SP	Slump (mm)
POCC	8.388	2.988	15.246	10.17	0.1458	53