EFFECT OF DIFFERENT CURING METHOD FOR COCONUT SHELL CONCRETE

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

Faculty of Civil Engineering and Earth Resources
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Dedicated to my parents,

for their love and devotion

making me be who I am today

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ABSTRACT

A study on flexural strength of Coconut Shell Concrete(CSC) by different type of curing method. The concrete produced by using 25% of coconut shell in coarse aggregates satisfies the minimum necessities of concrete. CSC has superior workability because of the smooth surface on one side of the shells. The impact resistance of CSC is high when compared with conventional concrete. Curing is the maintaining of a satisfactory moisture content and temperature in concrete during its early stage so that desired properties may develop. The strength and durability of concrete will be fully achieved if the concrete sample pass through the curing process. This study is focused on flexural strength of CSC which varies by different type of curing method. Two types of concrete mix were chosen for this study which is CSC and Normal Concrete(NC). The mixture of concrete poured in 24 mould as simple beam and pass through two type curing methods for 7 days and 28 days. Flexural tests were carried out to determine the flexural strength using simple beam specimens. It was observed that when CSC pass through two types of curing method, flexural strengths are comparable in between two curing methods. It was observed that when coconut shells as aggregate in proportions of 25% was used in CSC, flexural strengths comparable to that of NC can be obtained.

ABSTRAK

Satu kajian mengenai kekuatan lenturan Konkrit Tempurung Kelapa (KTK) mengikut jenis yang berbeza kaedah pengawetan. Konkrit dihasilkan dengan menggunakan 25% daripada tempurung kelapa dalam agregat kasar memenuhi keperluan minima konkrit. KTK mempunyai kebolehkerjaan yang unggul kerana permukaan licin di sebelah cengkerang. Kesan rintangan KTK adalah tinggi jika dibandingkan dengan konkrit konvensional. Pengawetan adalah mengekalkan daripada kandungan kelembapan memuaskan dan suhu di dalam konkrit semasa peringkat awal agar ciri yang dikehendaki boleh berkembang. Kekuatan dan ketahanan konkrit akan tercapai sepenuhnya jika sampel konkrit melalui proses pengawetan. Kajian ini memberi tumpuan kepada kekuatan lenturan KTK yang berbeza-beza mengikut jenis kaedah pengawetan yang berbeza. Dua jenis campuran konkrit telah dipilih untuk kajian ini yang KTK dan Konkrit Normal (KN). Campuran konkrit dituang di 24 acuan sebagai jenis rasuk mudah dan melalui dua kaedah pengawetan selama 7 hari dan 28 hari. Ujian lenturan telah dijalankan untuk menentukan kekuatan lenturan menggunakan spesimen rasuk mudah. Ia adalah diperhatikan bahawa apabila KTK melalui dua jenis kaedah pengawetan, kekuatan lenturan boleh dibandingkan di antara dua kaedah pengawetan. Ia adalah diperhatikan bahawa apabila tempurung kelapa sebagai agregat dalam perkadaran 25% telah digunakan dalam KTK, kekuatan lenturan setanding dengan KN boleh diperolehi.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
CSC	Coconut Shell Concrete
CEN	European Committee for Standardization
NC	Normal Concrete
SSD	Saturated Surface Dry

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Concrete is a widely used construction material that consists of cement, aggregates, water and admixtures. Aggregates such as gravel and granite were used to produce normal concrete therefore this situation drastically reduces the natural stone deposits and disturb the ecological balance. In order to solve this problem, Yogesh (2013) demonstrated that the aggregates made by crushed coconut shells can be used in concrete by partially replacing the coarse aggregate up to a 25% and it also produce light weight concrete.

Coconut shell is moisture retaining material and the water absorbing capacity is higher compared to the conventional aggregate. Therefore, the amount of cement used may be more when coconut shells were applied as an aggregate compared to conventional aggregate. The presence of sugar in the coconut shell will not affect the setting and strength of concrete as long as it is not in a free sugar form.

The concrete produced by replacing 25% of coconut shell as coarse aggregates known as Coconut Shell Concrete (CSC) and this percentage of replacement satisfies the minimum necessities of concrete mix. CSC has few advantages such as good impact resistance compared with conventional concrete and higher workability due to the smooth surface on one side of the coconut shells (Manindar, 2012).

Even though the coconut shell is moisture retaining material, the curing process still important to maintain the suitable moisture content and temperature in concrete during its early stage so that desired properties may develop. The strength and durability of concrete will be fully achieved if the concrete pass through the curing process. The cement hydration process caused losses of water from concrete due to evaporation since of the self-desiccation by consumption of water during hydration process. Therefore, the losses of water must be prevented and replaced by water from outside.

There are six common types of concrete curing method which is shading of concrete work, covering concrete surfaces with hessian or gunny bags, sprinkling of water, water immersion method, membrane curing and steam curing. In this study, two out of six curing methods were studied which is wet covering method and immersion method. Different curing method will show different concrete strength development.

1.2 PROBLEM STATEMENT

A concrete element must be long lasting until a certain number of years. In order to meet this expected service life, it must be able to withstand structural loading, fatigue, weathering, abrasion, and chemical attack. The materials required to achieve the high level of quality determined by the duration and type of curing method.

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range, (Ahlawat, 2013). The result of this process is increased strength and decreased permeability. Curing is also a key player in mitigating cracks in the concrete, which severely impacts durability. Cracks allow open access for harmful materials to bypass the low permeability concrete near the surface. Good curing can help mitigate the appearance of unexpected cracking.

This study will help to solve the problem by compare the concrete curing method which can increase the strength of concrete. In doing so, three concrete samples need to be required to observe the changes and the readings of the flexural strength for each type of concrete. In general, this investigation needs a lot of laboratory works and also literature review. The outcome of the study will be the comparison and recommendation on best method of curing used for CSC in construction industry.

1.3 OBJECTIVES OF STUDY

The objectives of this study are:

i) To determine the flexural strength of coconut shell concrete in between wet covering and immersion curing method.

ii) To investigate most effective curing method for CSC to be used in construction industry.

1.4 SCOPE OF STUDY

This study will focus on laboratory test to determine the flexural strength of coconut shell concrete due to different curing method and to investigate most effective curing methods used for CSC:

i) Use normal concrete and CSC with 25% of coconut shell replaced in coarse aggregates, (Aruna, 2014).

ii) According to Amrita,2015 the concrete should be cast as a prism in the mould with size of 150mm x 150mm x 600mm to gain the best flexural strength.

iii) Normal concrete and CSC will go through two different curing method which is wet covering method and immersion method. The curing process will be done for 7 days and 28 days.

iv) The flexural strength of the prisms will be tested by flexural strength test under centre point loading

1.5 SIGNIFICANT OF STUDY

Curing of concrete plays a major role in developing the microstructure and pore structure of concrete, (Burg, 1996). On other hand, curing of concrete means maintaining moisture inside the body of concrete during the early ages and beyond in order to develop the desired properties in terms of strength and durability. However, good curing practices are not always consistently followed in most of the cases. Hence, this can lead to a weak concrete strength. This study summarizes two type of curing method for concrete which can help to achieve the highest flexural strength of CSC and also can differentiate the *impact on concrete due to different curing method. The result of this study will help to identify the best curing method that can be used in construction industry as not all type of curing methods can be applied in construction industry.*

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Curing is the process in which protect concrete from loss of moisture and kept within a reasonable temperature range. This process increased the strength and decreased the permeability (Kosmatka, 2011). Curing duration is very important for concrete to achieve its designed lifespan, while excessive curing duration could increase the construction cost and delay the project. On the other hand, Natural resources such as river sand and coarse aggregate is depleting at an alarming level in developing countries. The possibility of utilizing recycled coconut shell aggregates in concrete as coarse aggregate examined in the previous study to produce CSC where 25% of coarse aggregate replaced with coconut shell. CSC known is good in tensile force since it produces high flexural strength compared to compressive strength of normal concrete.

2.2 COCONUT SHELL CONCRETE

Lightweight aggregate plays important role towards sustainable concrete, lightweight aggregates contributes to sustainable development by lowering transportation requirements, optimizing structural efficiency that results in a reduction of overall amount building material used, conserving energy, studied the strength of coconut shells replacement and study the transport properties of concrete with coconut shell as coarse aggregate replacement, (Amarnath, 2012). Moisture content and water absorption were 4.20% and 24% respectively and these values more compared to conventional aggregate. Coconut shell exhibits more resistance against crushing, impact and abrasion compared to conventional aggregate. Density of coconut shell is in the range of 550-650 kg/m3 and these are within the specified limits for lightweight aggregate, (Amarnath, 2012). There is no need to treat the coconut shell before use as an aggregate except for water absorption.

The material used in this concrete mix was normal aggregate crushed to maximum size 20mm used as coarse aggregate. River sand passing through 4.75mm was used as fine aggregate. The specific gravities of coarse and fine aggregates were 2.65 and 2.63 respectively. The freshly discarded coconut shells collected from a local mill. The coconut shells were crushed using concrete hammers to a size such that it passes through a 20mm sieve and retained on 4.75mm sieve. Crushed shells washed to remove fibers and mud from them. The washed shells dried in sunlight for 2 days. The crushed edges were rough and spiky. The surface texture of the shell was fairly smooth on concave and rough on convex faces. Coconut shell aggregates used were in saturated surface dry condition. Further broken the shells into small chips manually using hammer and sieved through 12mm sieve. The material passed through 12mm sieve used to replace coarse aggregate with coconut shells. Water absorption of the coconut shells was 8% and specific gravity at saturated surface dry condition of the material found as 1.33, (Aruna, 2014).

The compressive strength, split tensile strength and flexural strength evaluated for various percentages of coconut shell aggregate, namely 15%, 20%, 25 %, 30 % and 35 % by volume of coarse aggregate. Table 2.1 show the results with 15%, 20%, 25%, 30% and 35% replacement of coconut shell aggregate.

Table 2.1: Results by percentages of coconut shell replaced by volume in aggregate

Test	Percentages of coconut shell replaced by volume in aggregate				
Mechanical property @ 28days	15%	20%	25%	30%	35%
Compressive strength (N/mm^2)	24.6	20.4	20.9	21.2	21
Split tensile strength (N/mm^2)	2.57	1.98	2.45	2.45	2.41
Flexural strength (N/mm^2)	2.89	2.6	3.1	3.23	3.32

Source: Aruna (2007)

2.3 CURING PROCESS

The term "curing" is frequently used to describe the process by which hydraulic-cement concrete matures and develops hardened properties over time as a result of the continued hydration of the cement in the presence of sufficient water and heat. While all concrete cures to varying levels of maturity with time, the rate at which this development takes place depends on the natural environment surrounding the concrete and on the measures taken to modify this environment by limiting the loss of water, heat or both from the concrete or by externally providing moisture and heat. The term "curing" is also used to describe the action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic-cement hydration and if applicable, pozzolanic reactions to occur so that the potential properties of the mixture may develop, (ACI, 2010).

As has been stated, increasing the effectiveness of curing improves the mechanical and durability properties of concrete. The challenge is to determine a method that ensures curing effectiveness necessary to achieve the required level of performance for a specific application, taking into account all pertinent parameters. Furthermore, a suitable method should be cost effective without causing unnecessary delays on the job site. In order to deal with the challenge given, curing mechanism has to be investigated in depth. In the beginning a complete definition of curing is essential.

A mixture is properly proportioned and adequately cured when the potential properties of the mixture are achieved and equal or exceed the desired properties of the concrete. The curing period is defined as the time period beginning at placing, through consolidation and finishing, and extending until the desired concrete properties have developed. The objectives of curing are to prevent the loss of moisture from concrete and, when needed, supply additional moisture and maintain a favorable concrete temperature for a sufficient period of time. Proper curing allows the cementitious material within the concrete to properly hydrate. Hydration refers to the chemical and physical changes that take place when portland cement reacts with water or participates in a pozzolanic reaction. Both at depth and near the surface, curing has a significant influence on the properties of hardened concrete, such as strength, permeability, abrasion resistance, volume stability, and resistance to freezing and thawing, and deicing chemicals, (Taylor, 2007).

Proper curing conditions defined to moisture and including temperature. The provided temperature is maintained above freezing, the maintenance of a minimum temperature is technically not necessary. However, a minimum temperature is certainly of practical importance to assure a minimum rate of hydration so that the properties may develop over a reasonably short time. No matter what curing requirement, standard, or other criterion is specified for a given project, rarely on a construction site is sufficient attention given to ensuring that proper curing procedures are followed.

By having a proper curing, concrete becomes stronger, more impermeable, and more resistant to stress, abrasion, and freezing and thawing. The improvement is rapid at early ages but continues more slowly thereafter for an indefinite period. Figure 2.1 shows the strength gains of concrete with age for different moist curing periods, (Gonnerman, 1998) and Figure 2.2 shows the relative strength gains of concrete cured at different temperatures, (Burg, 1996).

There are many types of curing that can be applied to ensure the relative humidity and durability of the concrete can be controlled. Among all types of curing methods ponding and immersion, wet covering, plastic sheets and steam curing are the types of curing methods that usually being applied in the construction industries.

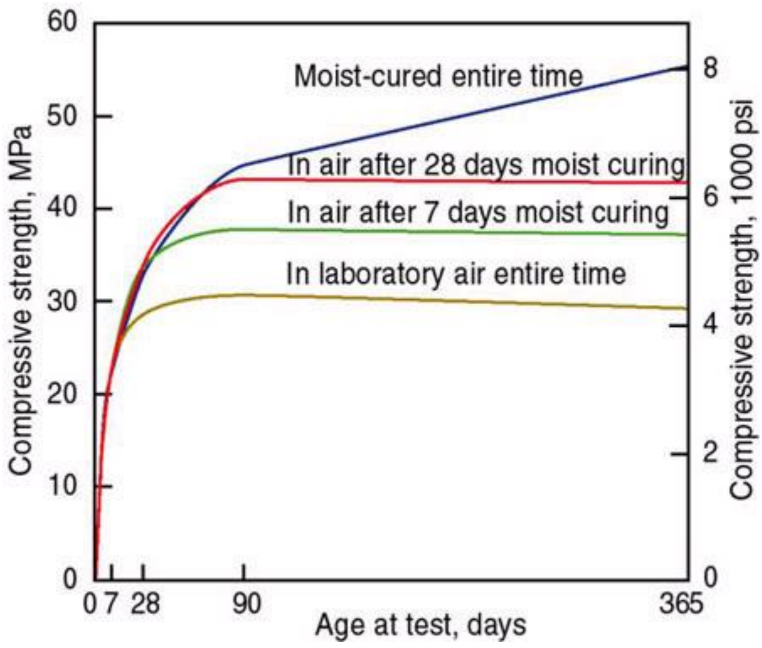

Figure 2.1: The strength gains of concrete with age for different moist curing periods

Source: Gonnerman (1998)

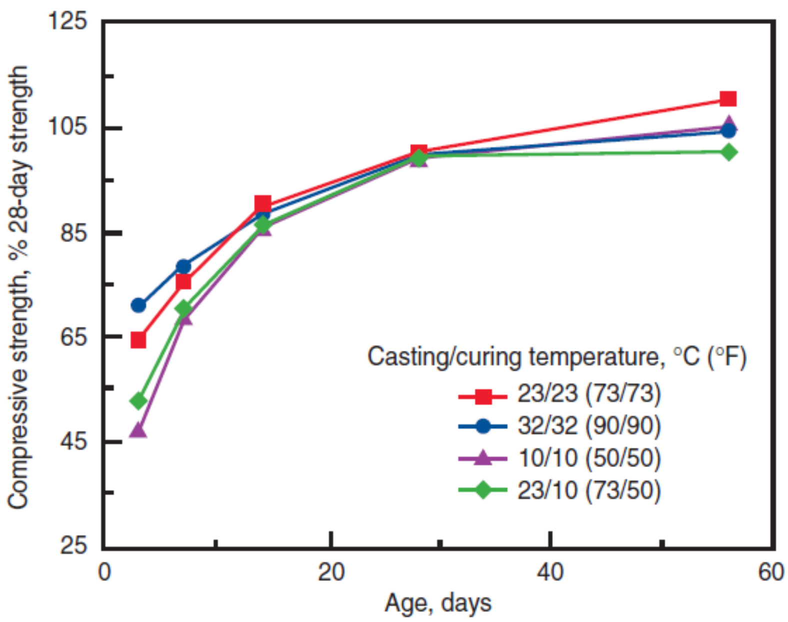

Figure 2.2: The relative strength gains of concrete cured at different temperatures

Source: Burg (1996)

2.3.1 Hydraulic-Cement Hydration

Concrete is initially in plastic condition. Hydration is a chemical reaction and where the concrete paste producing strength and stiffness of the structure. Hydraulic-cement is a type of reduced to fine material that develops binding forces due to a reaction with water. Cements that harden by reaction with water and form a water-resistant product is by the chemical reaction. Portland cement is a hydraulic cement that is capable of setting, hardening and remains stable under water. It is also composed of calcium silicates and some amount of gypsum. The type, amount, size, shape and distribution of phases present in a solid material constitute its structure. Concrete consists of sand, coarse aggregates, cement paste and voids. The structure of the aggregates in concrete is important but it can be characterized as a macrostructure which is visible to the human eyes.

2.3.2 Mechanical and Durability Properties of Concrete

Mechanical properties of concrete are closely related to its porosity and pore dispersion as the addition of mineral admixture considerably refines the pore configuration by reducing the pore size and porosity. Drying shrinkage property of cement pastes or concrete is usually associated with the loss of adsorbed water from the material. This property is very much significant in porous concrete, especially aerated concrete due to higher total porosity and specific surface of pores. Decrease in the pore radius results in a higher percentage of pores and results in increased shrinkage. However, this property is usually related to the aggregate quality and volume. Therefore, shrinkage in the paste is higher than concrete.

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Durability is defined as the capability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. It normally refers to the duration or life span of trouble-free performance. Different concretes require different degrees of durability depending on the exposure environment and properties desired. For example, concrete exposed to tidal seawater will have different requirements than indoor concrete. Concrete will remain durable if the cement paste structure is dense and of low permeability and also under extreme condition as it has entrained air to resist freeze-thaw cycle. Durability of concrete is also maintained when the concrete made with graded aggregate that are strong the ingredients in the mix contain minimum impurities such as alkalis, chlorides, sulphates and silt.

2.4 Categories of Curing Methods

There are two categories commonly used as concrete curing methods which can is water-adding technique and water-retaining technique. The first technique provides concrete with water or moisture continuously or frequently through water ponding, fogging, sprinkling, steaming, or covering with saturated material. The second technique prevents excessive temperature and water loss from concrete by means of sealing materials, such as plastic sheets or by application of membrane-forming curing compounds to the freshly placed concrete. Among water-adding techniques, ponding or immersion is considered as the most effective method for facilitating cement hydration, but it is seldom used because of the labour, time, and cost as well as the feasibility to build a water pond on some concrete structures. Fog spray or sprinkling is a relative inexpensive and effective curing method. However, it can be used only when adequate water is available and ambient temperature is well above freezing.

Materials that hold sufficient moisture, such as burlap, cotton mats, rugs, curing, sand and sawdust, and straw or hay, are also frequently used to cover the surface of concrete pavements. The moisture held in these materials can be released slowly for concrete curing. However, when these materials dry out, periodic moistening is required. Covering pavement surfaces with these materials requires considerable labour and time.

In water-retaining techniques, sealing materials such as plastic film and reinforced papers are often used to cover concrete surfaces for early age curing. Unfortunately, these techniques are not well suited for high-production operations such as paving, large floor placements and so on, (Huo, 2005). Nowadays many contractors rely on curing compounds to help create the proper environment needed for cement hydration and the development of durable concrete. Liquid membrane-forming curing compounds are the most widely used materials for curing of concrete pavements and bridge decks. Curing compounds are economical, easy to apply, and maintenance free. The curing compound is a liquid that can be applied as a coating to the surface of newly placed concrete to retard the loss of water, or in the case of pigmented compounds, also to reflect heat as to provide an opportunity for the concrete to develop its properties in a favourable temperature and moisture environment.

2.4.1 Ponding and Immersion

Ponding is a quick, inexpensive and effective form of curing when there is a ready supply water and the pond does not interfere with subsequent building operations. On flat surfaces, such as pavements and floors, concrete cured by ponding. Earth or sand dikes around the perimeter of the concrete surface can retain a pond of water. Ponding is an ideal method for preventing loss of moisture from the concrete; it is also effective for maintaining a uniform temperature in the concrete.

The curing water should not be more than about 11°C cooler than the concrete to prevent thermal stresses that could result in cracking. Since ponding requires considerable labor and supervision, the method is generally used only for small jobs. It has the added advantage of helping to maintain a uniform temperature on the surface of the slab. There is thus less likelihood of early age thermal cracking in slabs that are cured by water ponding.

The most thorough method of curing with water consists of total immersion of the finished concrete element. This method is commonly used in the laboratory for curing concrete test specimens. Where appearance of the concrete is important, the water used for curing by ponding or immersion must be free of substances that will stain or discolor the concrete. The material used for dikes may also discolor the concrete, (Ajay, 2013). Figure 2.3 shows water immersion concrete curing method.

Figure 2.3: Water immersion concrete curing method

Source: Ajay (2013)

2.4.2 Wet Covering

Burlaps, cotton mats and other covering of absorbent material will hold water on the surface whether horizontal or vertical these materials must be free from of injurious amount of substances such as sugar or fertilizer that do harm to the concrete or cause deterioration. Burlap should be thoroughly rinsed in water to remove soluble substances or to make it more absorbent. Burlap that has been treated to resist rot and fire should be considered when it is to be soared between jobs. The heavier the burlap the more water it will hold and the less frequently it will need to be wetted. Double thickness may be used advantageously. Lapping the strips by half widths when placing will give greater moisture retention and aid in preventing displacement during high wind or heavy rain.

Cotton mats hold water longer than burlap with less risk of drying out. It is handled much the same as burlap except that due to it greater mass application to a freshly finished surface must wait until the concrete has hardened to greater degree than for burlap. Wet, moisture-retaining fabric coverings should be placed as soon as the concrete has hardened sufficiently to prevent surface damage. During the waiting period other curing methods are used, such as fogging or the use of membrane forming finishing aids. Care should be taken to cover the entire surface with wet fabric, including the edges of slabs. The coverings should be kept continuously moist so that a film of water remains on the concrete surface throughout the curing period. Use of polyethylene film over wet burlap is a good practice; it will eliminate the need for continuous watering of the covering. Periodically rewetting the fabric under the plastic before it dries out should be sufficient. Alternate cycles of wetting and drying during the early curing period may cause crazing of the surface, (Bragg, 2010). Figure 2.4 shows wet covering concrete curing method.

Figure 2.4: Wet covering concrete curing method

Source: Bragg (2010)

2.4.3 Plastic Sheets

Plastic sheet materials such as polyethylene film can be used to cure concrete. Polyethylene film is a lightweight, effective moisture retarder and is easily applied to complex as well as simple shapes. Curing with polyethylene film or impervious paper can cause patchy discoloration especially if the concrete contains calcium chloride and has been finished by hard steel trowelling. This discoloration is more pronounced when the film becomes wrinkled, but it is difficult and time consuming on a large project to place sheet materials without wrinkles. Flooding the surface under the covering may prevent discoloration, but other means of curing should be used when uniform colour is important. Polyethylene film should confirm American Society for Testing and Materials (ASTM) C 171, which specifies a 0.10mm thickness for curing concrete but lists only clear and white opaque film. However, black film is available and is satisfactory under some conditions. White film should be used for curing exterior concrete during hot weather to reflect the sun rays. Black film can be used during cool weather or for interior locations. Clear film has little effect on heat absorption. Wrapping curing is more efficient than dry-air curing as it results in greater compressive strength, ultrasonic pulse velocity and dynamic modulus of elasticity and lower surface absorption, (Safuddin, 2007). This is because wrapped curing moisture movement from the concrete surface was hindered due to the impervious layer of the film and as a result good amount of moisture was available to be used throughout the hydration process. Figure 2.5 shows wet covering concrete curing method.

Figure 2.5: Plastic sheet concrete curing method

Source: Safuddin (2007)

2.4.4 Steam Curing

Steam curing is advantageous where early strength gain in concrete is important or where additional heat is required to accomplish hydration, as in cold weather. Two methods of steam curing are used which is low pressure steam curing and high pressure steam curing.

Low pressure steam curing which mean by steam curing at atmospheric pressure can be continuous or intermittent. In the continuous process the product moves on the conveyor belts from one end of a long curing chamber to the other end, the length of the chamber and he speed of the conveyors being so designed that the products remain in the curing chamber for the required time. On the other hand, in the intermittent process, the concrete products are stacked in the steam chamber and the steam is allowed in to the closed chamber. The steam curing cycle can be divided in to three stages which is the heating stage, steam treatment and cooling stage.

High pressure steam curing is used in the case of normal steam curing at atmospheric pressure, the ultimate strength of concrete may be adversely affected if the temperature is raised rapidly. High pressure steam curing is done in the cylindrical steel chamber called autoclaves. The steam is let in gradually until the prescribed pressure or temperature is reached. This heating stage should be completed and the prescribed pressure reached in three hours. The period of treatment under full pressure depend upon the strength requirements. This period is 7 to 10 hours for hollow block products and 8 to 10 hours for slab or beam elements, the period increasing with the thickness of concrete. The steam is cut off and the pressure released after the completion of this stage and the products are left in the autoclaves for two hours for cooling gradually, (Vivek, 2013). Figure 2.6 shows steam curing method for concrete. High pressure steam curing is usually applied to the precast products when any of the following characteristics is desired:

i) High early strength- With high-pressure steam, curing the compressive strength at 24 hours is at least equal to that of 28 days normally cured products.

ii) High durability- High-pressure steam curing results in an increased resistance to sulphate and other form of chemical attack, and to freezing and thawing.

Figure 2.6: Steam curing method for concrete

Source: Vivek (2013)

2.4.5 Membrane-Forming Curing Compound

Liquid membrane-forming compounds consisting of waxes, resins, chlorinated rubber and other materials used to retard or reduce evaporation of moisture from concrete. They are the most practical and most widely used method for curing not only freshly placed concrete but also for extending curing of concrete after removal of forms or after initial moist curing. Curing compounds should be able to maintain the relative humidity of the concrete surface above 80% for seven days to sustain cement hydration.

Membrane-forming curing compounds are of two general types: clear, or translucent; and white pigmented. Clear or translucent compounds may contain a fugitive dye that makes it easier to check visually for complete coverage of the concrete surface when the compound is applied. The dye fades away soon after application. On hot, sunny days, use of white-pigmented compounds recommended; they reduce solar-heat gain, thus reducing the concrete temperature. Pigmented compounds should be kept agitated in the container to prevent pigment from settling out.

Curing compounds should be applied by hand-operated or power-driven spray equipment immediately after final finishing of the concrete. The concrete surface should be damp when the coating is applied. On dry, windy days, or during periods when adverse weather conditions could result in plastic shrinkage cracking, application of a curing compound immediately after final finishing and before all free water on the surface has evaporated will help prevent the formation of cracks. Power-driven spray equipment is recommended for uniform application of curing compounds on large paving projects. Spray nozzles and windshields on such equipment should be arranged to prevent wind-blown loss of curing compound. Complete coverage of the surface must be attained because even small pinholes in the membrane will increase the evaporation of moisture from the concrete, (Devender, 2014).

Curing compounds might prevent bonding between hardened concrete and a freshly placed concrete overlay. Most curing compounds are not compatible with adhesives used with floor covering materials. Consequently, they should either be tested for compatibility, or not used when bonding of overlying materials is necessary. For example, a curing compound should not be applied to the base slab of a two-course floor. Similarly, some curing compounds may affect the adhesion of paint to concrete floors. Curing compound manufacturers should be consulted to determine if their product is suitable for the intended application. Curing compounds should be uniform and easy to maintain in a thoroughly mixed solution. They should not sag, run off peaks, or collect in grooves. Caution is necessary when using curing compounds containing solvents of high volatility in confined spaces or near sensitive occupied spaces such as hospitals because evaporating volatiles may cause respiratory problems. Figure 2.7 shows membrane-forming curing compound method.

Figure 2.7: Membrane-forming curing compound method

Source: Devender (2014)

2.4.6 Sprinkling or Fog Curing

Fogging and sprinkling with water are excellent methods of curing when the ambient temperature is well above freezing and the humidity is low, while during hot weather, it helps to reduce the temperature of the concrete, (Hanson, 2005). A fine fog mist is frequently applied through a system of nozzles or sprayers to raise the relative humidity of the air over flatwork, thus slowing evaporation from the surface. As with other methods of moist curing, it is important that the sprinklers keep the concrete permanently wet. However, the sprinklers do not have to be on permanently; they may be on an intermittent timer. Fogging is applied to minimize plastic shrinkage cracking until finishing operations are complete.

Once the concrete has set sufficiently to prevent water erosion, ordinary lawn sprinklers are effective if good coverage is provided and water runoff is of no concern. Soaker hoses are useful on surfaces that are vertical or nearly so. The cost of sprinkling may be a disadvantage. The method requires an ample water supply and careful supervision. If sprinkling is done at intervals, the concrete must be prevented from drying between applications of water by using burlap or similar materials; otherwise alternate cycles of wetting and drying can cause surface crazing or cracking. The alternative is to have a closed system where the water is collected and recycled. Sprinkler systems may be affected by windy conditions and supervision is required to see that all of the concrete is being kept moist and that no part of it is being subjected to alternated wetting and drying. Figure 2.8 shows sprinkling curing method.

Figure 2.8: Sprinkling curing method

Source: Hanson (2005)

2.4.7 Impervious Paper

Impervious paper for curing concrete consists of two sheets of kraft paper cemented together by a bituminous adhesive with fiber reinforcement. Such paper, conforming to ASTM C 171, is an efficient means of curing horizontal surfaces and structural concrete of relatively simple shapes, (Hanson, 2005). An important advantage of this method is that periodic additions of water are not required. Curing with impervious paper enhances the hydration of cement by preventing loss of moisture from the concrete. As soon as the concrete has hardened sufficiently to prevent surface damage, it should be thoroughly wetted and the widest paper available applied. Edges of adjacent sheets should be overlapped about 150 mm and tightly sealed with sand, wood planks, pressure-sensitive tape, mastic, or glue. The sheets must be weighted to maintain close contact with the concrete surface during the entire curing period. Impervious paper can be reused if it effectively retains moisture. Tears and holes can easily be repaired with curing-paper patches. When the condition of the paper is questionable, additional use can be obtained by using it in double thickness. In addition to curing, impervious paper provides some protection to the concrete against damage from subsequent construction activity as well as protection from the direct sun. It should be light in color and non-staining to the concrete. Paper with a white upper surface is preferable for curing exterior concrete during hot weather.

2.5 EUROCODE: STANDARD AND SPECIFICATION ABOUT CURING

The document prEN 13670:2006: “Execution of concrete structures” is a Prestandard developed by the European Committee for Standardization (CEN). The complete part of the code referring to curing specifications can be found in Appendix A. In this paragraph only special remarks on the code are discussed. The code is defining the duration of application as the major factor for defining curing adequacy, without reporting any curing efficiency differences between various curing methods. Furthermore, the code distinguishes for classes of curing based on the percentage of specified characteristic 28 days’ compressive strength as in Figure 2.9.

(6) The duration of applied curing shall be a function of the development of the concrete properties in the surface zone.

This development is described by curing classes defined by curing period or percentage of the specified characteristic 28 day compressive strength according to table 4.

Table 4 - Curing Classes

	Curing class 1	Curing class 2	Curing class 3	Curing class 4
Period (hours)	12 [1)]	/	/	/
Percentage of specified characteristic 28 days compressive strength	/	35 %	50 %	70 %

[1)] Provided the set does not exceed 5 hours, and the surface concrete temperature is equal to or above 5 °C

Figure 2.9: Execution of concrete structures

Source: prEN 13670 (2006)

2.6 FLEXURAL STRENGTH TEST

Flexural strength testing is used to determine the flexural or bending properties of a material. Maximum stress and strain are calculated on the incremental load applied. Results are shown in a graphical format with tabular results including the flexural strength for fractured samples and the yield strength for the samples that did not fracture.

There are two types of flexural strength tests can be performed on concrete beams. The first is covered by ASTM C-78 and AASHO T-97 which utilizes third point loading and the second is ASTM C-293 which involves center point loading.

2.6.1 Third Point Loading Test

The concrete strength used in the design of concrete pavements is based on AASHTO Test Method T-97 or ASTM C78, Flexural strength test of concrete using a prism with third-point loading done as shown in Figure 2.10. These flexural tests also called Modulus of Rupture tests or Third-Point Loading tests are performed using concrete beams that have been cast and cured in the field, to mimic field conditions. For AASHTO thickness design, it is important that the **third point loading 28-day** flexural strength be used use in the AASHTO equation.

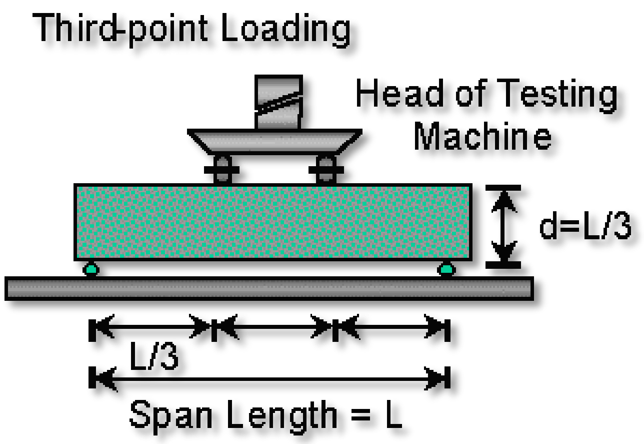

Figure 2.10: Third point loading test

Source: ASTM (1962)

2.6.2 Centre Point Loading Test

Some laboratory uses the **centre-point flexural strength** test AASHTO T-177 or ASTM C293 to determine their concrete strength as in Figure 2.11. Centre-point loading forces the beam to fail directly under the centre of the loading. This may or may not be the weakest point in the beam. In third point loading, the entire middle one-third of the beam is stressed uniformly and thus the beam fails at its weakest point in the middle one-third of the beam. By forcing the beam to fail at the centre, the centre-point flexural test results are somewhat higher than the third-point test results. Typically, the centre point results are about 15% greater. Though this relationship is not exact, it does provide a reasonable estimate of the concrete's average strength.

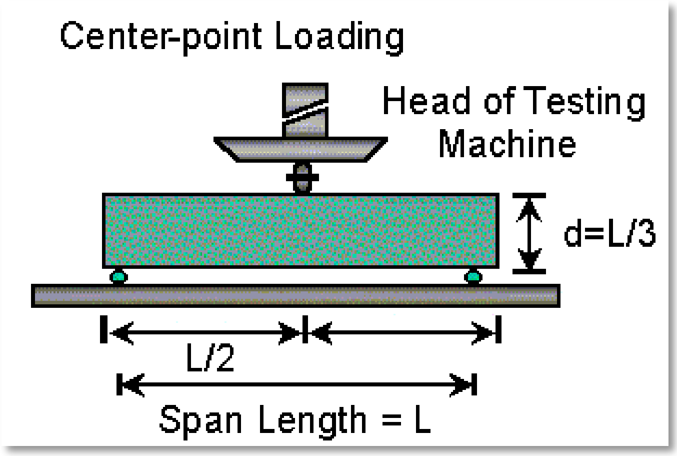

Figure 2.11: Centre point loading test

Source: ASTM (1962)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this study, the main objective is to determine the effective curing method for CSC. Total 24 samples of prism were casted and tested using centre point loading Test. Figure 3.1 shows detail flow chart of the methodology used in this study.

3.2 FLOW CHART

Figure 3.1 below shows the outline of the investigation in determining the effective curing methods of concrete in simple beam:

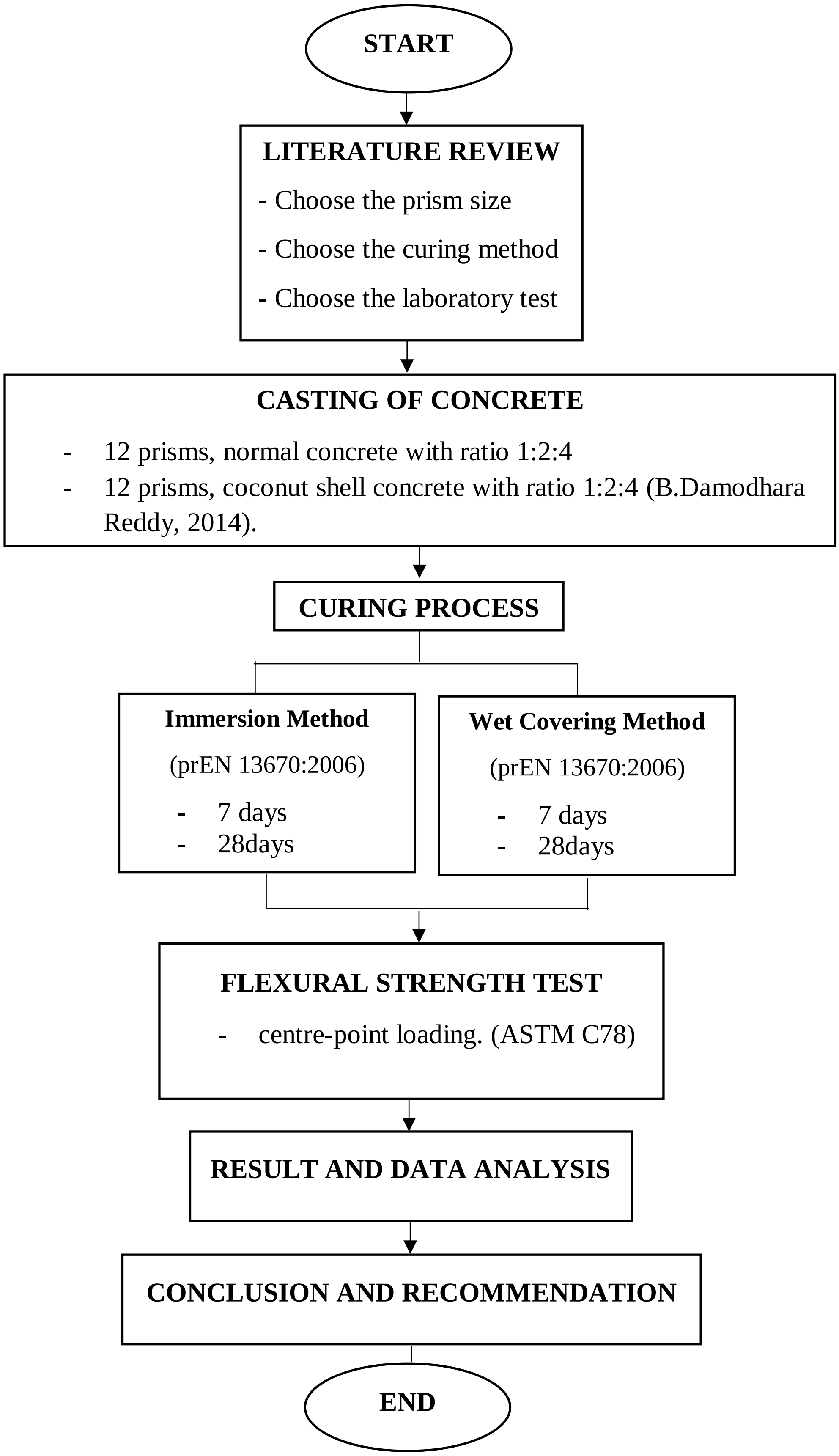

Figure 3.1: Flow of Methodology

3.3 MATERIAL PREPARATION

The material used for CSC is water, cement, sand, coarse aggregate and coconut shell. Sieve the coarse aggregate to maximum size 20mm and minimum size of 16mm. on other hand, well graded sand passing through 4.75mm was used as fine aggregate. The coconut shells were collected from a local oil mill in Kuantan and the collected coconut shells were crushed using concrete hammers to a small size such that it passes through a 20 mm sieve and retained on 4.75 mm sieve. After the crushed coconut shell were separated within the size range, it was washed to remove fibers and mud from them. The washed shells were dried well in sunlight for 2 days as shown in Figure 3.3. The physical characteristic of the crushed edges was rough and spiky while the surface texture of the crushed shell was fairly smooth on concave faces and rough on convex faces. Coconut shells that will be used as aggregates were in saturated surface dry condition. Further broken the shells into small chips manually using hammer and sieved through 12 mm sieve as shown in Figure 3.2. The material passed through 12 mm sieve was used to replace 25% coarse aggregate by volume with coconut shells.

Prepare the formwork of prisms with the size of 150 x 150 x 600 mm. Apply some oil as a lubricant on the surface of the prism's formwork to make sure the formwork easily dismantled before proceed to curing process and any damages on prisms could be reduced.

Figure 3.2: Crushed coconut shells

Figure 3.3: Coconut shell dried in sunlight

3.4 CONCRETING WORK

CSC is the mixture of cement, water, sand and aggregates which consist of 25% of coconut shell and 75% of gravel. The two type of different mixes were batched in order to investigate the effectiveness of curing method for coconut shell concrete. Control mix which is a normal concrete mix without coconut shell was made. On other hand, coarse aggregate was then replaced with coconut shell by 25% of coconut shell with aggregates (Aruna, 2014). Free water to cement ratio was maintained constant at 0.5 for both type of concrete mixes. A concrete grade of 25Mpa with nominal mix of 1:2:4 was used and another different mix was made with 25% replacement of coarse aggregate with coconut shells. Once the concrete is mixed well, the concrete mixture poured in the prepared formwork and small vibrator poker used to the concrete in the formwork to let the mixture settled down by avoiding the voids and empty spaces in the formwork. Use the vibrator poker for about 5 minutes until the concrete mixture fully compact in the formwork. The formworks were kept in the safe place for 24 hours as shown in Figure 3.4.

Figure 3.4: Coconut shell concrete in mould

3.5 CURING METHODS

Concrete curing process is the next process after concreting works, where this will happen after the concrete hardened in mould approximately after 24 hours. The formwork of the prisms was dismantled and distributed according curing method in Table 3.1. For CSC, 12 prisms that were cast distributed evenly where on seventh day 3 prisms for wet covering method and 3 prisms for immersion method. While on twenty eighth day, 3 prisms for wet covering method and 3 prisms for immersion method. Same distribution method as CSC used for NC.

Table 3.1: Distribution of sample beam according curing method

Day of Curing	Curing Method	Number of Sample Beam	
		Normal Concrete	Coconut Shell Concrete
7 days	Immersion	3	3
	Wet Covering	3	3
28 days	Immersion	3	3
	Wet Covering	3	3
TOTAL		24	

3.6 FLEXURAL STRENGTH TEST

The test for flexural strength of concrete beams under center point loading utilizes a beam testing machine which permits the load to be applied normal to the loaded surface of the beam. The sample beam is tested on its side with respect to its molded position. The beam is centered on the bearing supports. The dial indicator of the proving ring is placed at the zero reading. Load application blocks are brought into contact with the beam’s upper surface at the third points. The contact surfaces of the sample beam should be capped with a concrete capping compound if full contact does not develop between supports, load blocks and the test beam as shown in Figure 3.5.

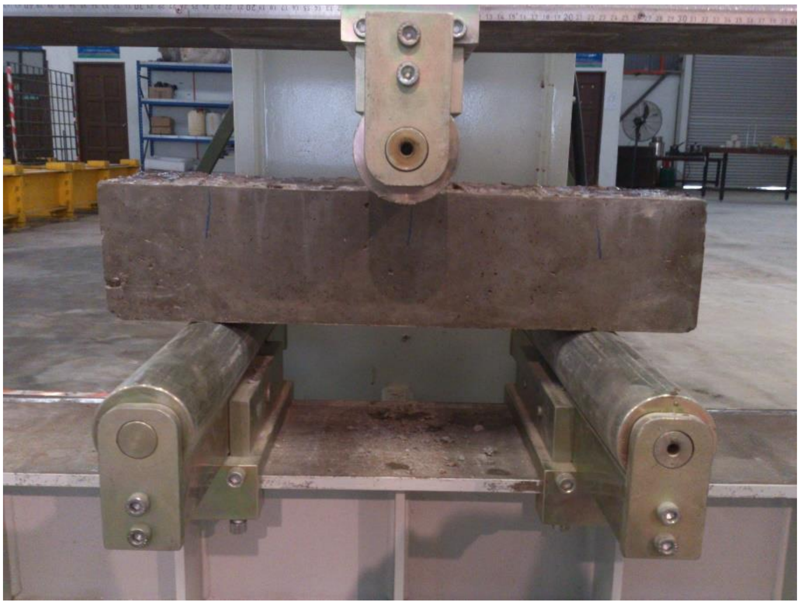

Figure 3.5: Prism before flexural test

The load is applied at a uniform rate and in a way to a void shock. The load may be applied rapidly up to approximately 50 percent of the anticipated breaking load after which it shall be applied at such a rate that the increase in extreme fiber stress does not exceed 150 psi per minute as shown in Figure 3.6. The load required to cause specimen failure is obtained from the dial indicator's final reading and the proving ring calibration curve. Measurements to the nearest 0.1 inch determine the specimen's average width and depth at the section of failure as shown in Figure 3.7. Reports and calculations are then made.

Figure 3.6: Sample reading for NC after flexural test

Figure 3.7: Prism after flexural test

CHAPTER 4

RESULT AND ANALYSIS

4.1 INTRODUCTION

The main objective of this study is to know the most effective curing methods to coconut shell concrete. The samples of prism were cast and cured under two type of different curing method before testing. In this study, three-point flexural strength test was done to analysis the result and data. The result from the flexural test were developed into tables and bar chart for analysis purpose.

4.2 FLEXURAL STRENGTH AT DAY 7

The result of flexural strength test on normal concrete and coconut shell concrete after cured by using two different curing method on day 7 are shown in Table 4.1. For NCIMA, NCIMB and NCIMC it produced 7.882 MPa, 8.370 MPa and 7.250 MPa respectively. While for NCWCA, NCWCB and NCWCC it produced 6.651 MPa, 7.814 MPa and 6.310 MPa respectively.

The flexural strength produced for CSC is different where, for CSIMA, CSIMB and CSIMC it produced 6.228 MPa, 6.105 MPa and 5.820 MPa. While for CSWCA, CSWCB and CSWCC it produced 5.699 MPa, 6.158 MPa and 6.108 MPa respectively.

Type of Concrete	Curing Method	Sample	Flexural Strength (MPa)	Average Flexural Strength (MPa)
Normal Concrete	Immersion	NCIMA	7.882	7.566
		NCIMB	8.370	
		NCIMC	7.250*	
	Wet Covering	NCWCA	6.651	6.481
		NCWCB	7.814*	
		NCWCC	6.310	
Coconut Shell Concrete	Immersion	CSIMA	6.228	6.167
		CSIMB	6.105	
		CSIMC	5.820*	
	Wet Covering	CSWCA	5.699*	6.133
		CSWCB	6.158	
		CSWCC	6.108	

Table 4.1: Result of flexural strength test at day 7

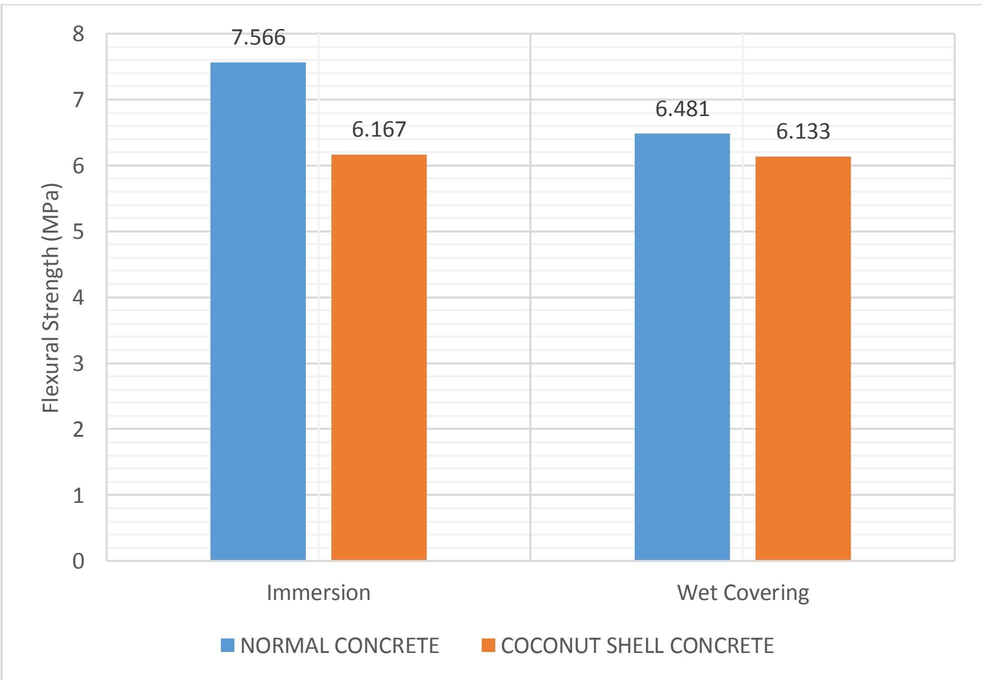

Figure 4.1: Bar chart of flexural strength test at day 7

In Figure 4.1, the bar chart illustrates the result of flexural strength test for both type of the concrete that were tested. Normal concrete using immersion curing method achieved highest flexure strength result for seventh day of curing which is 7.566 MPa. Normal concrete using the wet covering curing method could not achieve the strength as resulted by normal concrete for immersion curing method.

Flexural strength resulted for coconut shell concrete is lower than normal concrete for both type of curing method which is 6.481 MPa for immersion curing method and 6.133 MPa for wet covering curing method. The lowest flexural strength achieved on seventh day of curing is coconut shell concrete using wet covering curing method.

As compared to both type of curing method on seventh day for coconut shell concrete, immersion curing method shows slightly higher flexural strength than wet covering method. At the same time, flexural strength of coconut shell concrete could not achieve the flexural strength of normal concrete on seventh day of curing.

4.3 Flexural Strength at Day 28

The result of flexural strength test on normal concrete and coconut shell concrete after cured by using two different curing method on day 28 are shown in Table 4.2. For NCIMA, NCIMB and NCIMC it produced 8.295 MPa, 7.921 MPa and 8.012 MPa respectively. While for NCWCA, NCWCB and NCWCC it produced 7.921 MPa, 6.856 MPa and 8.269 MPa respectively.

The flexural strength produced for CSC is different where, for CSIMA, CSIMB and CSIMC it produced 8.582 MPa, 7.707 MPa and 7.392 MPa. While for CSWCA, CSWCB and CSWCC it produced 7.029 MPa, 6.956 MPa and 7.672 MPa respectively.

Type of Concrete	Curing Method	Sample	Flexural Strength (MPa)	Average Flexural Strength (MPa)
Normal Concrete	Immersion	NCIMA	8.295	8.154
		NCIMB	7.921*	
		NCIMC	8.012	
	Wet Covering	NCWCA	7.921	8.095
		NCWCB	6.856*	
		NCWCC	8.269	
Coconut Shell Concrete	Immersion	CSIMA	8.582*	7.550
		CSIMB	7.707	
		CSIMC	7.392	
	Wet Covering	CSWCA	7.029	6.993
		CSWCB	6.956	
		CSWCC	7.672*	

Table 4.2: Result of flexural strength test at day 28

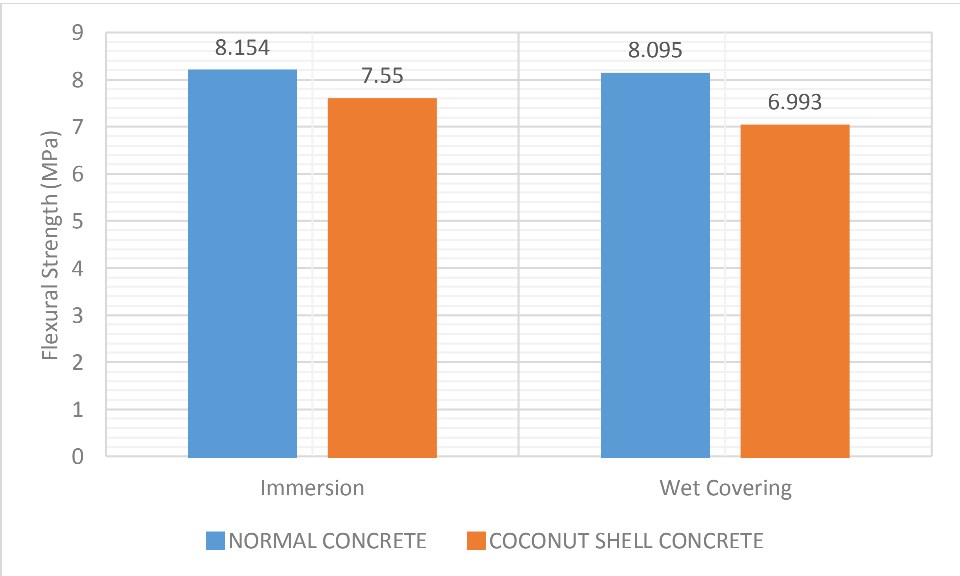

Figure 4.2: Bar chart of flexural strength test at day 28

Result of flexural strength test for both of the concretes tested is shown in Figure 4.2. Normal concrete using immersion curing method attained highest flexure strength result for twenty eighth day which is 8.154 MPa. Normal concrete using the wet covering curing method achieved the strength with little different which is lower than the flexural strength as resulted by normal concrete for immersion curing method.

Flexural strength resulted for coconut shell concrete is less than normal concrete for both type of curing method which is 7.55 MPa for immersion curing method and 6.993 MPa for wet covering curing method. The least flexural strength achieved on twenty eighth of curing is coconut shell concrete using wet covering curing method.

As compared to both type of curing method on twenty eighth day for coconut shell concrete, immersion curing method shows slightly higher flexural strength than wet covering method. At the same time, flexural strength of coconut shell concrete could not achieve the flexural strength of normal concrete on twenty eighth day of curing.

4.4 OVERALL RESULT OF FLEXURAL STRENGTH TEST

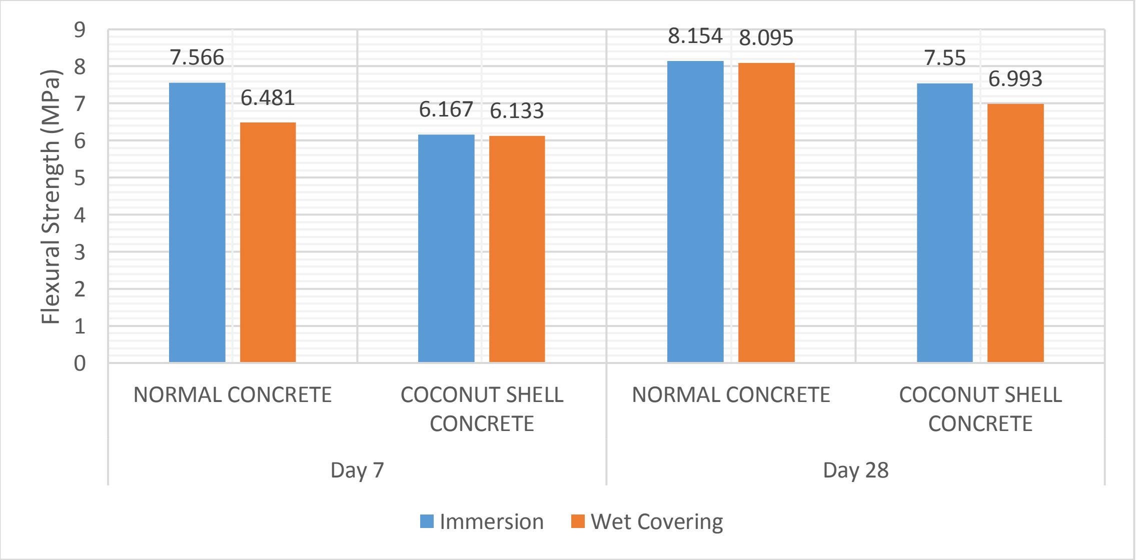

Figure 4.3: Bar chart of overall result for flexural strength test

The bar chart in Figure 4.3 shows the overall result of flexural strength test for two types of concrete in two different curing method. At seventh day of immersion curing method, there is a huge different in flexural strength for normal concrete and coconut shell concrete. Meanwhile, for wet covering method it only shows little different in flexural strength for normal concrete and coconut shell concrete.

On twenty eighth day of curing using immersion method, flexural strength of coconut shell concrete rose up from huge different to less different which is almost near with flexural strength of normal concrete. However, for wet covering curing method the flexural strength of normal concrete rapidly increases compared to coconut shell concrete which is slightly increase from the seventh day flexural strength.

In conclusion, the best curing method for coconut shell concrete is immersion curing method because it shows the greatest flexural strength for coconut shell concrete compared to wet covering curing method.

4.5 DIFFERENCES OF FLEXURAL STRENGTH

The differences of flexural strength test on normal concrete and coconut shell concrete after cured by using two different curing method on day 7 and day 28 are shown in Table 4.3

Table 4.3: Differences of flexural strength

Curing Method	Difference of Flexure Strength (%)	
	Day 7	Day 28
Immersion	-18.49	-7.41
Wet Covering	-5.37	-13.61

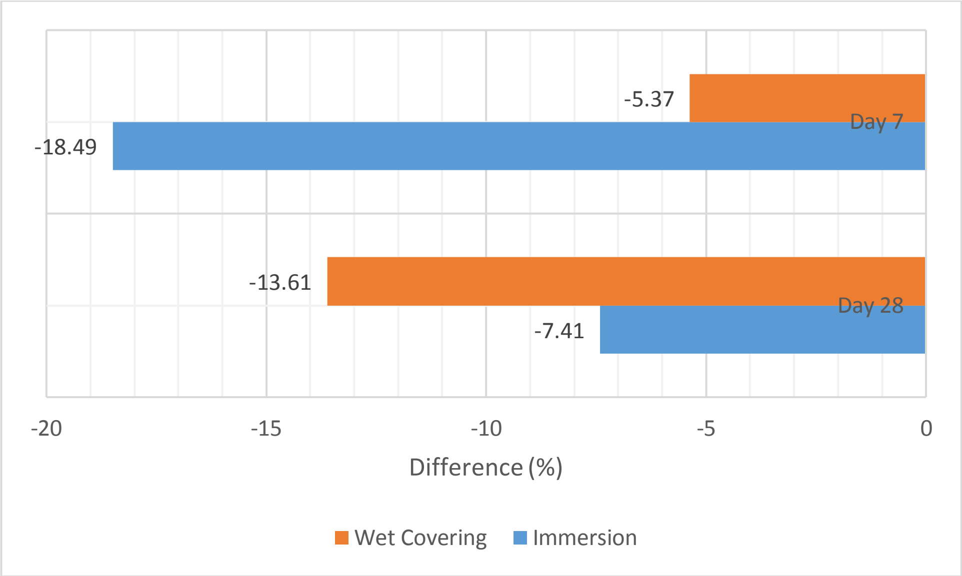

Figure 4.4: Bar chart of differences in flexural strength

The bar chart in Figure 4.4 shows the differences of flexural strength for coconut shell concrete compared to normal concrete. Wet covering method on seventh day shows the least different in percentages which is 5.37% less flexural strength than normal concrete. The percentages of differences getting higher on twenty eighth day which is 13.61% less strength than normal concrete

On the other hand, coconut shell concrete cured using immersion curing method on seventh day shows the highest differences of strength which is 18.49% less flexural strength compare to normal concrete. However, the differences reduced to 7.41% as the coconut shell concrete were cured for twenty-eight days. Thus, coconut shell concrete by using immersion curing method shows the smallest differences on twenty eighth day of curing.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter is deliberating about the conclusions and recommendations on this study. The conclusions are based on the result and analysis of the study and it will indicate whether the conclusions meet the proposed objectives of the study, meanwhile the recommendation is about what are the necessary things that can be done in order to improvise this study in the near future. Essentially, this study is about effect of different curing method for CSC and the most efficient curing method for CSC.

5.2 CONCLUSION

In this study, coarse aggregate was replaced with coconut shell, by volume. Specimens were cast by replacing 25% of coarse aggregate with coconut shells. Tests were conducted on the cast specimens after 7 days and 28 days as mentioned in the prEN 13670:2006. Tests for flexural strength were conducted and results were obtained. The flexural strength of CSC on day 7 is approximately 6.167 MPa for immersion curing method and 6.133 MPa for wet covering curing method. The flexural strength of CSC on day 28 is approximately 7.550 MPa for immersion curing method and 6.993 MPa for wet covering curing method. The flexural strength for CSC failed to achieve as the flexural strength of normal concrete.

On other hand, we can conclude that the most effective curing method for CSC is immersion curing method because it shows the greatest flexural strength for CSC compared to wet covering curing method.

5.3 RECOMMENDATIONS

As a final note, it is important to have some necessary suggestions in which this study could be brought to another level in the near future. The recommendations are listed here as followings:

i) It is recommended to modified the materials for CSC to increase the flexural strength
ii) Alternatively, it would be beneficial for further study to continue by analyzing the results of this study and come up with more efficient and economical to reduce the cost.
iii) In addition, this study should be extending the period of curing to compare the flexural strength.

In a nutshell, all the conclusions that were drawn met the proposed objectives of this study.

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APPENDIX

PrEN 13670:2006 "Execution of Concrete Structure"

The document prEN 13670:2006: "Execution of concrete structures" is a Pre-standard developed by the European Committee for Standardization (CEN). The complete part of the code referring to curing specifications is presented in this appendix.

8.5 Curing and protection

(1) Concrete in its early life shall be cured and protected:

- to minimize plastic shrinkage
- to ensure adequate surface strength
- to ensure adequate surface zone durability
- from freezing
- from harmful vibration, impact or damage

(2) If concrete in its early life need to be protected against harmful contact with aggressive agents (e.g. chlorides), such requirements shall be stated in the execution specification.

(3) Methods of curing shall achieve low evaporation rates from the concrete surface or keep the surface permanently wet.

Natural curing is sufficient when conditions throughout the required curing period are such that evaporation rates from the concrete surface are low, e.g. in damp, rainy or foggy weather.

(4) On completion of compaction and finishing operations on the concrete and where necessary, the surface shall be cured without delay. If needed to prevent plastic shrinkage cracking on free surfaces, temporary curing shall be applied prior to finishing.

(5) If high strength concrete or self-compacting concrete is used, special consideration should be given to prevent plastic shrinkage cracking

(6) The duration of applied curing shall be a function of the development of the concrete properties in the surface zone.

This development is described by curing classes defined by curing period or percentage of the specified characteristic 28 day compressive strength according to table 4.

Table 4 - Curing Classes

	Curing class 1	Curing class 2	Curing class 3	Curing class 4
Period (hours)	12 [1)]	/	/	/
Percentage of specified characteristic 28 days compressive strength	/	35 %	50 %	70 %

[1)] Provided the set does not exceed 5 hours, and the surface concrete temperature is equal to or above 5 °C