DURABILITY ASPECTS AND MECHANICAL PROPERTIES OF ECC CONTAINING NANO SILICA PARTICLES

By

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MOHD ZULKHAIRI BIN ZULKEFLI
13868

A project dissertation submitted to the
Civil Engineering Programme
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TRONOH, PERAK

SEPTEMBER 2014

CERTIFICATION OF ORIGINALITY

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

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ABSTRACT

In this study, the properties of Engineered Cementitious Composites (ECC) with the addition of Nano Silica is investigated when test on chloride ion penetration, mercury intrusion porosimetry (MIP), flexural strength (four point load bending) and compressive strength. Based on 20 different mix proportions with PVA Fiber up to 2% and Nano Silica up to 3% is use to be molded with different size such cylinder with diameter 100 mm, beam with size of 0.25mm x 0.50mm x 508mm and cube with size of 50mm x 50mm x 50mm . The mixing process based on standard procedure given. The specimen are place on curing tank for water cured for 28 days. After that, durability aspect and mechanical properties of ECC will be determine through several test. Based on the durability test on chloride ion penetration, through charge passed in term of coulomb in term of chloride permeability, the charge passed decreased with the increase of Nano silica content in ECC. But, difference with adding of PVA fiber content in ECC may increase chloride permeability the result on chloride ion penetration showed from very low to low chloride permeability of all specimen. From Mercury Intrusion Porosimetry (MIP) test, accessible porosity reduce with the increasing of Nano silica content. It can explained by that the increasing of Nano silica improve microstructure of ECC by reduce internal porous. While on mechanical performance based on flexural test, The test result show that increase of flexural strength up to 25 % compare to without Nano silica with maximum strain of 175μm/m at 80% of flexural strength increasing of Nano silica content show an increase in ductility of ECC. Also in compressive strength, the mechanical performance improve based on the increase of Nano silica help to strengthen compressive strength of composite. From the result analysis showed increase of compressive strength up to 35% compare to without Nano silica

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Engineered cementitios composite (ECC) is a new type structural material invented by Dr Victor Lee at University Of Michigan. This structural material is known by their plastic deformation and high tensile ductility as compared to fiber reinforced concrete. Many countries have used ECC such as Japan, Korea, Australia and Switzerland applied to their infrastructure and building because of capabilities this material which make the structure safer and sustainability (Rynanen, 2007) .The main ingredients of ECC are cement, sand, fly ash, water, polyvinyl alcohol fiber comes with silica particle

According to New York Times (2007) examined that cement cause pollution which cement plant contribute 5 percent of global emission of carbon dioxide major effect on global warming. In other hand, cement produce a lot through a year as each new bridge, each new infrastructure and building need new cement. A big population country like china produce 45 percent of worldwide output even small country like Ukraine make multiple their use of cement on every 4 years. A studies by Starling (2014) mentioned that production of cement in Malaysia show an increment 4-5% in 2014 as government implement Economic Transformation Project (ETP) include also private sector-driven and property build which increase cement consumption in this country.

Nowadays, exploring on nanoparticle additives to traditional cement become common place to researcher. Quercia and Brouwers (2010) stated that the use of silica fines is a method to reduce the consumption of cement in a concrete mixture such like nano silica particle with high potential to replace cement or use as concrete additive. However, production of nano silica particle is not easy task which need to synthesized in a complex way, resulting in high cost make them non- practical for the construction industry. Moreover, the application of nano silica particle and its impact in not completely understood.

1.2 PROBLEM STATEMENT

The study is conducted mixing ECC by using nano silica particle. In this research, the effect of nano silica particle on durability and mechanical performance are studied in ECC by addition of material to the composite. There always a challenge for researcher to find optimum range of material to achieve excellent behavior.

Since nanomaterial is still an early development to ECC. It is importance to observe and understand the influence of nano silica particle on the properties based on pozzolonic reaction and pore filling. The reaction of pozzolonic activity produce C-S-H gel is the main contribution of the strength in ECC. Moreover, porous is a major problem to ECC reduce the mechanical performance and chemical attack. The characteristic of nano silica particle due to very ultra-fine have a tendancy improve the material properties.

However, there is always a problem when adding a new material to structure material. Regardless, the cost of production nano scale of silica which much higher compare to other addition material. But, it is worthwhile if this material have very significant effect to the performance of ECC.

Therefore in this studies, nano silica particle are adding to the ECC mix with a percentage varies to find optimum range. Moreover, adding PVA fiber in ECC would give understanding the influence of nano silica particle on strain hardening capacity. Therefore, this research is based on the composite with varying percentages of Nano Silica and PVA Fiber.

1.3 OBJECTIVE

The objectives of the research are:

1. To determine the durability aspect of engineered cementitiuos concrete (ECC) containing nano silica particle
2. To evaluate the mechanical properties of engineered cementitious composite (ECC) containing nano silica particle

1.4 SCOPE OF STUDY

This study focus on the material properties of nano silica particle in engineered cementitious composite (ECC) mix. A set of mixture proportion used for this study where ECC reinforced with 0-3% nano silica particle proportional to Polyvinyl alcohol (PVA) fiber used for mix ECC range from 0-2% . Normal Portland cement and fly ash were used in ECC mix. In addition super plasticizer was used to enhance workability. To achieve toughness of matrix interface, fine aggregate were used. ECC characteristics will be determine through durability and mechanical properties. Controlling matrix or binder toughness are important and crucial factor with respect to achieve desires mechanical performance result. These experiment using nanoparticle provide a detailed description of the variation of moduli across the matrix or fiber interface and show the correlation between tensile strength and durability of ECC.

CHAPTER 2: LITERATURE REVIEW

Multiple studies have been conducted regarding Engineered cementitious composite (ECC) on its durability and resist large tensile with the variable of material properties that enhance the performance. The studies identified the unique properties of material use in ECC mix that effect on behavior fiber/matrix interaction and also how self-healing of ECC is significant importance for durability to overcome crack or damage in the structure material. However, very few studies such as (Sakulich & Victor, 2011) has been conducted for nanoparticle which affect the mechanical properties of ECC such nanoparticle additives can replace normal concrete. The use of nano silica particle have a potential for development of ECC which effect on durability and strain capacity has not been illuminate on research studies. Rupasinghe et al. (n.d) said that because of two primary reasons. The principal reason is because of the lack of understanding of the physical and chemical properties of ECC and its structure at the nanoparticle mater length scale. The second reason is the lack of understanding of what nanoparticle effect on ECC. There is a chance of improving execution of cement utilizing nanoparticle materials, however further research is obliged so that these imaginative materials will be utilized basically inside the development part. The vast majority of the work did in this novel region of examination is still at the preparatory stages, and has numerous issues to be tended to. Therefore, in order to understand the effect of nano particle, future research using nano particle using admixture such as silica would be helpful to better understand the effect of nano silica particle on the ECC.

Engineered cementitious composite (ECC) has been known as one of the unique properties due to some features such as high in ductility and durability, self-compacting and high in performance. Thus greatly enhance on this reliability of this material for further development. According to Ranade et al. (2014) stated that ECC is known as structural material that has excellent tensile ductility and damage tolerance. This tensile strain capacity of ECC could be hundred times higher compare with structural concrete. They also mention that even tensile strain capacity higher than normal concrete but not effect on compressive strength which is same as high strength concrete (40-70 MPa). Ṣahraman et al. (2009) has identified increasing of fine aggregate cause low compressive strength of ECC after the specimen have been test at 28 days. The properties of material based on the interaction of mixture with the other additive material so that it can have an excellent capacity. The influence of nano silica particle in the ECC obtain more understanding and information of variation matrix interface. Sakulich and Victor (2011) described that unique properties of ECC can be describe from the nanoscale of material effect on mechanical properties.

While ECC exhibit good ductile properties which can reduce the structure from seismic response and damage tolerance. Therefore, in order to understand why ECC have a good ductility, its draw from the behavior of admixture in ECC. Zhu Yu et al. (2014) mentioned that to have excellent ductility of concrete is important by controlling matrix toughness in ECC mix design. From the result, they found that with the high volume of fly ash in ECC can sustain a long term tensile ductility capabilities. Some of studies showed that low matrix toughness cause in good strain capacity for interface and fiber properties. Figure 2.0 show ECC under flexural test having extreme ductility. Be that as it may, with the changes in instrumentation and breaking down procedures, the understanding of the major properties of hydrated cement paste has been uncovered. Taking after is a review of displaying the execution of normal concrete paste and cement, without any kind of nano materials. Suitable modification should be improved as reflect the conduct of nano silica particle in concrete (Rupasinghe et al., n.d).

Figure 2.0 This image shows the extreme flexing capabilities of ECC under a large bending load. (UM News Services, n.d)

Regarding the ductility of engineered cementitious composite (ECC), several studies carried out the test to investigate the composition on flexural behavior and also strain hardening properties. Strain hardening properties depend on the material use in ECC to achieve high tensile strength and improve the durability than previous design of ECC. Soe et al. (2013) mentioned that the mechanical properties of ECC relies on the type, geometry, and volume fraction of constituent with the characteristic of fiber influence the performance. Zhu et al. (2014) focused on binder such as fly ash. They can concluded that reduce in compressive strength of ECC because of higher single mineral admixture while using a multiple mineral admixture can increase the compressive strength of ECC. Therefore, increase of fly ash in ECC can reduce the compressive strength but its good for tensile strain and enhance multiple cracking capacity.

Consequently, ECC is a kind cementitious composite recently developed by researcher characterized by moderate fiber volume fraction and strain- hardening properties (Fukuyama, 2000). The ultra-ductility conduct of ECC, consolidated with its adaptable transforming requirement, isotropic properties and moderate fiber volume part, which is commonly less than 2% relying upon fiber type and characteristic of interface and matrix, make it particularly suitable for basic components in seismic applications high performance are needed. The introduction of nanomaterial in concrete mixture promising by researcher on better mechanical properties. A most common question asked of engineered cementitious composite on how it can have unique ductile properties by using same ingredients similar fiber reinforced concrete. The answer lies in the composite constituent customizing. A fiber has a few characteristic based on length, quality, elastic modulus, and diameter. Interface has chemical and frictional bond, as well as different attributes and cementitiuos matrix has fracture toughness which customizing methodology choose or overall adjust these mechanical parameter that can be guide by mechanical analysis (Victor & Kanda, n.d). Compare between these two studies, Fukuyama (2000) most relying on fiber modification while Victor and Kanda (n.d) used the adjustment method of mechanical parameter in concrete constituent.

The mechanical properties of Engineered Cementitious Composite (ECC) control by geometry, type, and volume fraction of material use the mixture which influence the characteristic of fiber thus resulting on mechanical properties performance (Khin et al., 2013). Another studies by Maheswaran (2012) using nano silica particle observed that the compressive and tensile increase as increase volume of nano silica particle, which also show the pozzolanic activity of nano silica particle. On their study also stressed out in make nano silica particle more permeability resistance than normal concrete by development on enhance interfacial, capillary absorption and test on chloride ion However, coarse aggregate are not integrate as this material have a tendency to adversely influence the unique ductile behavior of the composite . This fundamentally implies that ECC will bend much the same as a bit of metal under the same anxiety which will result in normal concrete solid to fail and crack.

The strength of basic concrete, it also need to be considered an ideal of concrete mixture. This area of study have to be more on fiber/matrix interface such it is importance of controlling matrix toughness to have excellent ductility of ECC. Sakulich and Victor (2011) stated that Nano materials possess unique physical and chemical characteristics, which would improve the structure and would also cause some variations in the compositions of the currently existed materials. According to the scale variations of the nano particles applications, and considering the distinctive characteristics of such materials, it is possible to have some developments in the construction industry, applying them in cement production or concrete mixtures, which can be raised due to the mechanical resistance and lifetime of the concrete. The pozzolanic activity of the Nano-Silica particles is distinctively more than that of the micro-Silica ones due to the considerably high surface to volume ratio of them (Esmaili & Andalibi, 2012). On the other hand, research indicate that pozzolonic reaction effect by nanoparticles occupy the nano size pores of the cement paste which influenced the particle size and the proper dispersion of the nanoparticles within the cement paste also of early-age interfacial transition zone improve by adding of nano silica particle (Sobolev et al., 2006)

Esmaili and Andalibi (2012) expanded that the nano silica particles have discernible impact on change on properties of concrete while a few considered impact of nano silica particle on cement fusing fly ash observe that performance of concrete with or without fly ash was fundamentally enhanced with expansion of variable usage of nano silica. Figure 2.1 show the concrete material with their particle size and specific surface area.

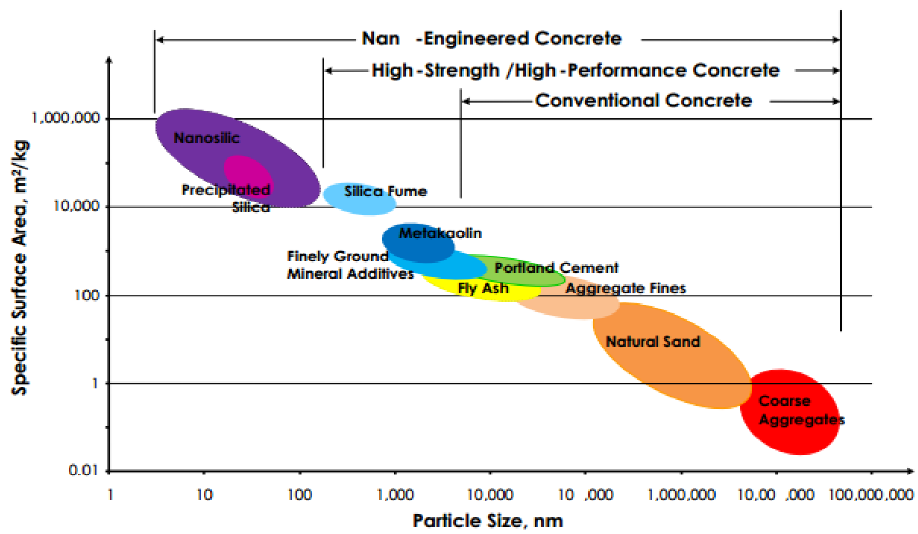


Figure 2.1 Particle size and specific surface area related to concrete materials. (Sobolev, 2006).

They also specified that taking preferences of nano characterization and materials the ideal utilization of nano silica will make another unique mixture that will bring about durability while workability of ECC decreased by mix with the amount of nano-silica reaction with calcium hydroxide cause of hydration between of concrete with water. In order to understand the fiber/matrix interface, Sakulich (2011) describe that important of these fiber/matrix interface prescribe behavior of fiber during loading. The focus on their research were study of silica react with calcium hydroxide which Silica fume is very sensitive with calcium hydroxide, in light of this, it is conceivable to utilize silica fume as a swap for a little extent of Portland cement.. One limitation on Esmaili and andalibi studies is there is no explanation on variation fiber/matrix interface as to evaluate the performance of mechanical and chemical properties of ECC.

Next, the topic attachment in relation compressive strength as indicated by ECC. In a research via Esmaili and Andalibi (2012), they recognized that applying Nano silica particles in cement mixtures can bring about an increment in compressive strength of the concrete in correlation with that of ordinary concrete. However, it likewise decrease in water permeability of the concrete. From their investigation, the structure of the concrete containing nano particles is more uniform than that of the ordinary concrete which specified the joined application of Micro-Silica and Nano-Silica would prompt a higher compressive quality among all examples. This can be identified with diverse part playing of them in cement blends. These particles well work as filler prompting less pores in concrete glue to be involved by calcium silicate production. Sayed et al. (2013) conducted experiment on compressive strength of adding nano silica on ECC Results showed that the optimum percentage adding nano-silica as a replacement of cement improves compressive strength by at 28 days. This result due to the increasing of the bond strength of cement paste-fine aggregate interface by means of the filling.

Somehow, Zhu et al. (2014) acknowledge that as single mineral admixture content increase, the compressive strength getting lower especially with the high volume of fly ash. Sayed et al. (2013) conducted experiment on compressive strength using nano silica particle ECC. Results demonstrated that the ideal rate including nano silica particle as a substitution of bond enhances compressive strength at 28 days. This result because of enhance in bond strength between the cement paste and fine aggregates interface which fill all the void. As talked about prior, exploratory examinations have confirmed that Nano silica enhances the mechanical and toughness parts of cement. In any case, when considering studies on analytical modelling of ECC changed with nano materials, a huge research gap exists. In this way, work completed on modelling the performance of nano altered ECC is limited (Rupasinghe et al., n.d)

Because of ECC is different from conventional concrete, the water cementitios ratio is a more important parameter. In standard ECC, mix design a low water cementitous ratio has determined through micromechanics to satisfy proper interface properties. Increasing water cementitious ratios can reduce its concentration resulting relative loose microstructure and therefore interfacial bon. This weak interface bonding can potentially generate lower fiber-bridging stress, which can results in low ultimate tensile strength and tensile strain capacity. Water cementitious also influence strain capacity. A high w/cm ratio can substantially decrease the plastic viscosity of ECC mortar and may result in poor fiber distribution and low ultimate tensile strength and tensile strain capacity (Şahmaran, et al., 2009). Cementitious materials (e.g., concrete) typically behave as brittle materials with low tensile strength and are prone to cracking. Incorporation of fibers into cementitious materials is a common practice to increase tensile strength and ductility and improve durability. The interfacial interactions between cement hydrates produce high bond strength (Birgisson, 2012). Esmaili and andalibi (2012) understand that thorough nano pozzolonic movement impact on nano silica particle on few day in the after mixing. On their study, they identify issue in utilizing low water to cement ratio (w/c). According to the serious reactivity of Nano-Silica and its high unique surface, utilizing lower w/c ratio can prompt conflict in scattering of the Nano silica particles in overall sample surface and more structuring of the flocs by clustering the nano silica particles in a particular parts of the cement.

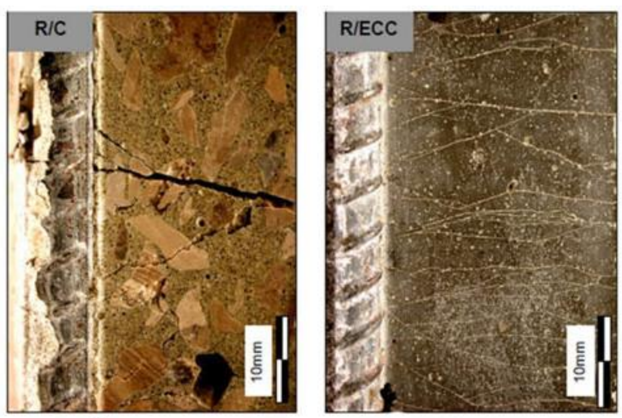


Figure 2.2 Compatibility deformation between steel reinforced concrete (left) and ECC with steel reinforcement (right) after cyclic loading (Victor., 2000)

Through the direct tensile test, ECC were subjected to stress caused a formation of micro cracks for physical reaction on tensile strain. Micro crack is a major problem to any structural material effect on durability and strength of ECC. Figure 2.2 show difference crack formation with different material use. Zhang et al. (2014) has deliberate concrete infrastructure under shrinkage, creep, high temperature cause crack to the structure. So, this crack the mechanical properties and caused a risk to infrastructure as crack will allow the aggressive agent will through concrete cover direct impact on durability and performance of concrete. A studies conducted by Sudharshan et al. (n.d) observed that that the amount of fiber and the type of fiber utilized in a the concrete mixture does not essentially influence the cracking load however has an impact on the rate of crack propagation on their failure loads, and the failure loads were more than double the cracking loads. Compare with all the various researchers with all the studies on properties not straightforward dealt with concrete cracking while the entire attempt made indirectly toward that. An alternate option for repaired crack and damage by repairing. A structure must require repairing or self-healing material. Self-healing behavior is another features ECC as presence of crack to structure reduce mechanical properties and bring a risk to structure of material. Autogenous self-healing of concrete is another alternative solution to repair damage or crack in concrete which much economical and convenient rather using chemical encapsulation. Zhu et al. (2012) have identified that ECC is capable for self-healing because of unique properties which low water-binder ratio produce micro-reservoir of unhydrated cement particle are widely dispersed. In order to reduce environmental impact by using waste material constituent in ECC also associated with sustainability consideration in construction and building material. In fact, cement industry produce 5% of global carbon dioxide which mean a single industry account (Rubenstein, 2012). Fly ash used for ECC mix in order to reduce the usage of cement. Huang et al. (2013) have conducted a series of test to evaluate tensile performance. The result showed increase of fly ash in ECC cause high tensile ductility due to the fact high frictional bond interface between polyvinyl alcohol fiber and matrix.

In addition, fly ash is an element which can enhance for long term development in concrete as its pozzolanic properties (Zhang et al., 2014). From their research also found that the capabilities of fly ash with higher content can enhance self-healing of ECC as pozzolonic properties and synergistic effect of tighter crack width. Nano silica particle with respect to its component in cement microstructure which prompts more compact concrete by filling the current voids, has a wonderful impact in reducing the water absorption like a super pozzolan (Bahadori, & Hosseini, 2011) .Nano silica is a pozzolanic material. The pozzolanic response with the mixture can enhance the strength of concrete more than the other non-pozzolanic nano materials talked about. Then again, Silica fume, which is an alternate manifestation of silica, is utilized as a part of the development business everywhere scales for the creation of elite solid at present. As nano silica likewise has a place with the same material and has a closeness with silica fume seethe, the useful relevance of utilizing nano silica as a part of the construction material use on the future is far higher than for other nano materials (Rupasinghe et al., n.d).

Finally, in measuring durability of ECC, water absorption test is one of the most important test which test conduct by examine total amount of water absorption in a concrete for durability. A study by Bahadori and Hosseini (2011) describe that water absorption is a methodology in which water enters into the concrete voids and immerses the grid pores. Which demonstrates the consequences of water absorption test, in one arrangement the measure of water absorption is decrease with an increment in the amount of nano silica particles. As to truth that, the concrete paste is the most porous part of concrete, the water absorption will increment with expansion in volume of paste in a fixed amount of concrete. Then again, increasing volume of aggregate as a porous constituent with low amount of water absorption can be compelling on concrete water absorption. The better execution of transmission zone is additionally a standout amongst the most noteworthy reasons in better permeability of concrete while reducing volume of aggregate and increment in concrete paste volume which incorporate small changes, are components helping increment of water absorption. While based on research water absorption test conducted by Zhang et al. (2014) examined that with a certain degree, the condition of material micro structure affect by volume of vulnerable pores even it can been seen through methodology of curing which volume of vulnerable pore diminish. It imply that hydration proceed with happen when water curing is present. Previous studies on conducting experiment using nano silica particle. Esmaili and Andalibi (2012) found that to applying nano silica particles in cement mixture supposedly decrease in water permeability of the concrete.

CHAPTER 3: RESEARCH METHODOLOGY& PROJECT ACTIVITIES

The early stage of this study needed to preparation on mixture of ECC sample. After 28 days curing period, the sample will test on durability and mechanical. Following given Figure 3.1 detail of project activities of this studies.

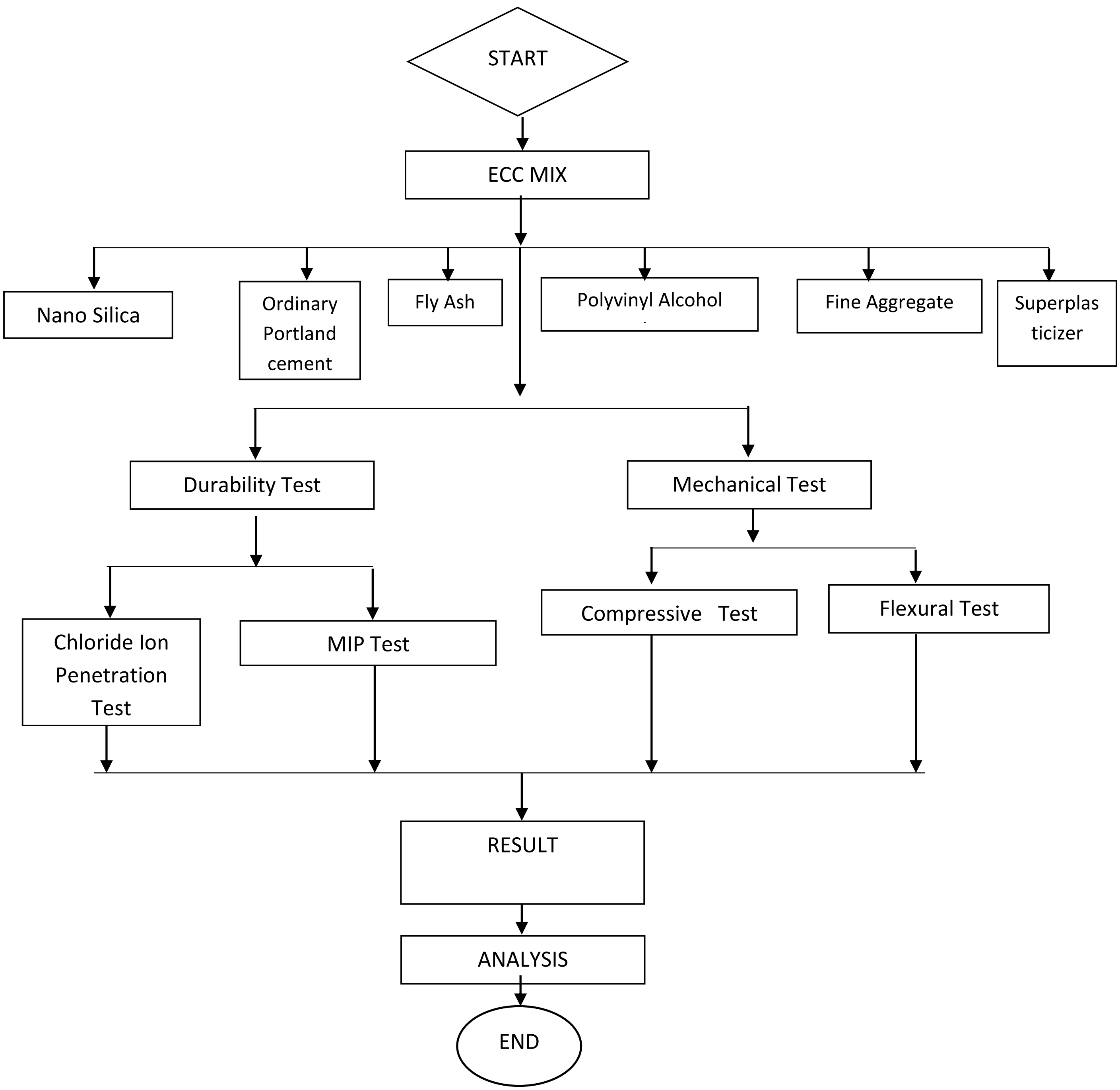


Figure 3.1 Research methodology

3.3. PERFORM LITERATURE STUDY AND PRELIMINARY RESEARCH

In this part of the studies, the purpose is to get more knowledge and stronger fundamental related to the engineered cementitious composite (ECC) using nano silica particle. Several theories need to be understood clearly in order to ensure that the project can be done smoothly and achieving the target. The studies include reviewing on mechanical and chemical properties of ECC, identifying problem relation between the binder and matrix interface and also compare the performance of ECC between binder and additive on mixture. Numbers of sources including internet, books, past thesis are very useful in the way to find out the solution of the problems

3.4 MATERIALS

3.4.1 Cement

Ordinary Portland cement (OPC) of 43 grade having a specific surface of 412.92 m2/kg and conforming to Malaysian Standard MS 522 : Part 1: 1989 Specifications for Ordinary Portland Cement was used. The cement was kept in an airtight container and stored in the humidity-controlled room to prevent cement from being exposed to moisture. Malaysian Standard MS 522: Part 1: 1989 Specifications for Ordinary Portland cement. Chemical composition in ordinary Portland cement consists calcium silicates , aluminum, magnesium and iron containing at clinker phases.

3.4.2 Fly Ash

Characteristic of sieve analysis of well graded curve, with between from fine silt to fine sand sizes, within the range of 0.001mm and 0.6mm. Specific gravity of fly ash found to be 2.3 and 1.99 respectively. Density of this material from less than 1Mg/m. chemical composition in a fly ash is a heterogeneous material. The main chemical component are SiO2, Al_2O_3, Fe_2O_3 and occasionally CaO

3.4.3 Polyvinyl Alcohol (PVA) Fiber

The PVA fibers are made with a high tensile strength with maximum elongation and elastic modulus makes this material applicable for strain-hardening performance. Nominal strength for PVA fiber were 1620 MPa with young modulus of 42.8 GPa. Diameter of this material should be 39 micron and length of 12 mm. while the specific gravity were 1.30. Polyvinyl alcohol produce made from polymerization of vinyl acetate to poly vinyl acetate which a simple chemical structure of hydroxyl group.

3.4.4 Nano silica particle

This material is an important for this studies as main material in mix. Due to fact that chemical reaction between cement and silica create pozzolonic activity with consideration on surface activity. Nano silica particle used in this study have a diameter of particle were 19nm with density of 2.12 g/cm^3. Specific surface for this particle were 160 m^2/g.

3.4.5 Fine aggregate (sand)

The sand used in this study was natural sand or river sand which use in commercial available. specific gravity of this material is 2.68 with fineness modulus of 3.42. This material is dried at room temperature for 24 hours to control the water content in the concrete. Fine Aggregates should passing No.4 (4.75 mm) sieve and predominately retained on the No. 200 (75 μm) sieve according to BS 882: 1992

3.4.6 Water

In this study, normal tap water available in the concrete laboratory was used. Water conforming to the requirements of water for concreting and curing

3.4.7 Super Plasticizer

Super plasticizer Conplast SP430A1 based on comercial available produced in Bangalore was used to produce high workability in concrete and reduce the water cement ratio. The Specific gravity of the Conplast SP430A1 is 1.18 to 1.20 at 20 C.

3.5 MIX DESIGN AND PREPARATION OF SPECIMEN

The proportion of mixture summarize in the Table 1. Polyvinyl alcohol (PVA) fiber replacement ratio 0.5% by mass of total binder (OPC+FA). The use of Nano silica particle in the material also using the same replacement ratio as PVA fiber. Superplasticizer is added to achieve expected workability for ECC mixture.

Table 1: Mix proportion

Sample no.	Sand kg/m^3	OPC kg/m^3	Water kg/m^3	FA kg/m^3	PVA %	NanoSilica %	Sp kg/m^3
M1	467	583	187	700	0%	0%	4.5
M2	467	583	187	700	0.5%	0%	4.5
M3	467	583	187	700	1.0%	0%	4.5
M4	467	583	187	700	1.5%	0%	4.5
M5	467	583	187	700	2.0%	0%	4.5
M6	467	583	187	700	0%	1.0%	4.5
M7	467	583	187	700	0.5%	1.0%	4.5
M8	467	583	187	700	1.0%	1.0%	4.5
M9	467	583	187	700	1.5%	1.0%	4.5
M10	467	583	187	700	2.0%	1.0%	4.5
M11	467	583	187	700	0%	2.0%	4.5
M12	467	583	187	700	0.5%	2.0%	4.5
M13	467	583	187	700	1.0%	2.0%	4.5

Continue table 1,

M14	467	583	187	700	1.5%	2.0%	4.5
M15	467	583	187	700	2.0%	2.0%	4.5
M16	467	583	187	700	0%	3.0%	4.5
M17	467	583	187	700	0.5%	3.0%	4.5
M18	467	583	187	700	1.0%	3.0%	4.5
M19	467	583	187	700	1.5%	3.0%	4.5
M20	467	583	187	700	2.0%	3.0%	4.5

Twenty mold of every ECC sample were prepared in this study. It is fundamental for the mixture to disperse all the constituent of the fiber in the matrix. For the method of preparation, it is proposed to dry mix of solid material for 1-2 min. Then, it essential to add 10% of water and plasticizer proceeded for 2 min. all remaining fiber and water was added physically and progressively to guarantee rational dispersion of matrix. After that, to ensure mixture were expected mix perfectly with binder ensured 5-10 min proceeded mixes completely.

3.6 WORKABILITY TEST

Workability is one of physical parameter for fresh concrete perfectly mix. It is useful indicator to determine the amount of internal work needed without bleeding or segregation. It is important to conduct this test because very significant effect on strength of concrete due to presence of void. However, ECC unlike normal concrete which has properties of self-compacting So, ECC must have require sufficient workability to achieve a possible density in order to achieve a good result on durability aspect and mechanical performance of ECC . Figure 3.2 show test for determining workability by using slump test

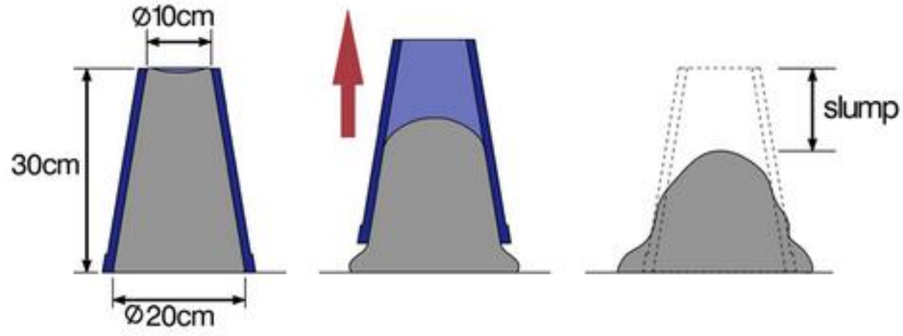


Figure 3.2 Slump Test image retrieved from (mastour.com, n.d **)**

Procedure of slump test based on BS 1881: Part 102, testing for fresh concrete:

1. Sample collect to perform slump test. The cone and plate should be clean, firm and level as show in Figure 3.2
2. The sample were fill in the cone with 1/3 of volume cone. Then, compact with steel rod for 25 times. After it compact, fill sample were fill until top of cone until it overflow with rod 25 times.
3. Level off the surface with steel rod and the cone lift carefully
4. Place cone upside down with the road across on sample.
5. The average distance from top of sample to the height of taken were measure show in Figure 3.3 and 3.4. The sample were rejected if fail in range based on Table 2

Table 2: Workability Test

Test	Accordance	Range of values	
		Min	Max
Slump-flow by Abrams Cone	EN 12350-8:2010	650	800
T50cm slump flow	EN 12350-8:2010	2 seconds	5 seconds
V funnel	EN 12350-9:2010	6 seconds	12 seconds
L box	EN 12350-10:2010	0.8 (h2/h1)	1 (h2/h1)

Figure 3.3 Sample flow measurement

Figure 3.4 Sample Flow

3.7 DURABILITY TEST

The durability of concrete is important to determine the ability of the concrete prevent from potentially aggressive substances passing through or penetrate in capillary of concrete. Every material have their own ability to resist from nature or chemical attack to the structure study through durability. Based on durability consideration behind why testing of parameter like chloride ion penetration and mercury porosity intrusion test.

For the durability test, the mold use for this test is available on laboratory which is steel mold in cylinder shape with radius of 100mm and height of 200mm. The mold were applied with oil before sample placed. The test were carried out with 25 of sample and each proportion need to test 2 sample. This sample were used for chloride ion penetration and mercury porosity intrusion test. Detail of dimension mold are provided in Figure 3.5 below

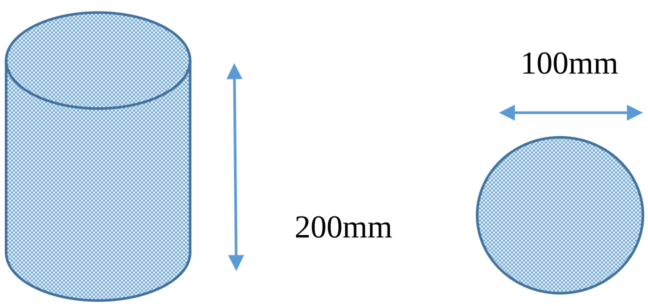


Figure 3.5 Cylinder mold

3.7 CHLORIDE ION PENETRATION TEST

The Chloride ion penetration were based on ASTM C 1202 for determining chloride penetrate through the sample. Hameed et al (n.d) mentioned that a permeable concrete is more vulnerable to particle entrance as aware of that are affected chemical attack such as leaching and sulphate attack. In the event that legitimately cured, most concrete get to be essentially less penetrable with time. On their studies, they also stated that it is essential to determine the age at which the penetrability is measured. There is no generally acknowledged standard test strategy for measuring the pervasion properties of cement. The RCPT system also known as Rapid Chloride Permeability test is the quickest method for those specified and is regularly utilized for determination and quality control purposes. The apparatus shown in the Figure 3.6 use to determine the chloride ion charge passing through concrete.

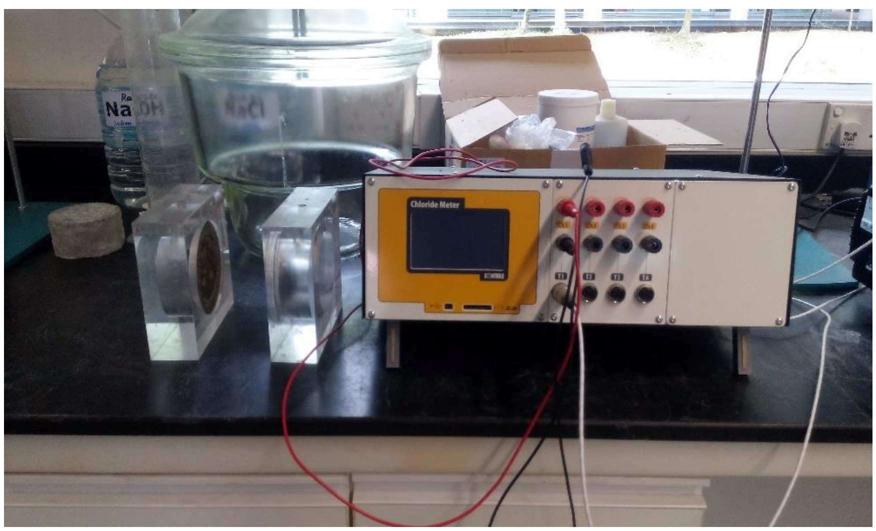


Figure 3.6 RCPI Machine

The methodology of this test method for measuring the resistance of ECC sample to chloride particle entrance has no interrupt to any error on the value that the estimation of this resistance can be characterized just as far as a test technique.

The method depends on the results from a test in which electrical current passes through ECC sample with a period of a six-hour. The details of positive charge ion passing through concrete as shown in Figure 3.7.

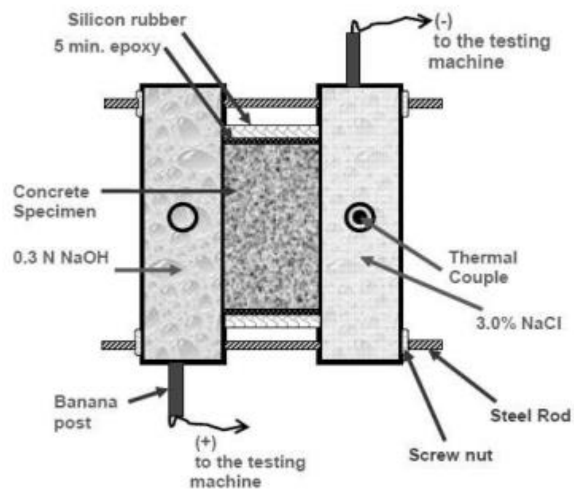


Figure 3.7 RCPI Method (Chandramaouli, 2010)

Based on theories, the higher the coulombs which the charge passing through the ECC sample, the more permeable the concrete which mean that sample were easily attack by sulphate or some other chemical. Chloride test has shown good correlation with this test as trapezoidal rule need to apply for calculate the average current flowing through one cell. From the result obtained, charge passing in coulombs can convert into chloride permeability rating as shown in Table 3.

The following formula, based on the trapezoidal rule,

$$Q = 900(I0+2I30+2I60+2I90+2I120+\ldots+2I300+2I330+I360)$$

Where,

Q = current flowing through one cell (coulombs)

I0 = Current reading in amperes immediately after voltage is applied, and

It = Current reading in amperes at t minutes after voltage is applied

Table 3: Chloride Rating (Chandramaouli, 2010)

Charge passing in coulombs	**Chloride permeability rating**
Greater than 4000	High
2001 to 4000	Moderate
1001 to 2000	low
100 to 1000	Very low
Less than 100	Negligible

3.8 MERCURY INTRUSION POROSIMETRY (MIP) TEST

A studies conducted by Kumar and Bhattacharjee (1997) examine that with the change degree of hydration and chemical reaction in mixture of sample due to aggressive environment can relate pore system. The strength of ECC affect due to existence of pore structure rely on size distribution. In the other hand, they also mentioned that Mercury intrusion Porosimetry (MIP) is a mechanism to analyze the characteristic of pore system based on porosity and pore size distribution. Hence, with the information data base on the MIP, ECC specimen were possible to examine on their performance. Figure 3.8 show example of the intrusion of mercury by mechanically applied forced into structure with Analysis is the progressive intrusion of mercury into a pore structure of concrete specimen under condition controlled pressures.

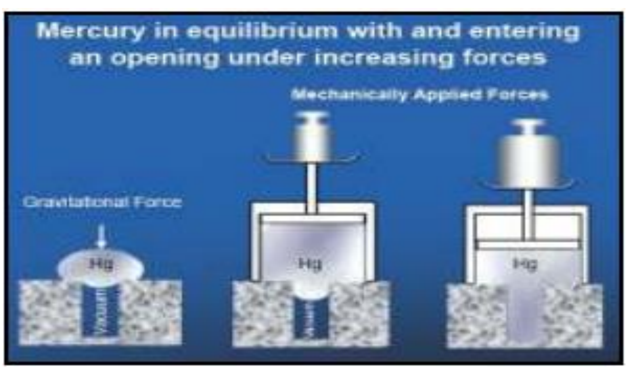


Figure 3.8 Intrusion of mercury retrieved from (www.micromeritics.com n,d)

Porosity, which is a measure of level of permeability of materials is characterized as the proportion of volume of pores to that of the total volume of material. Pore size distribution also known as radius of pore and the correlation between cumulative pore volume represented as pore structure of material The pore structure in ECC specimen were compare with each other to analyze the result through behavior of specimen under MIP test. Pore size distribution also known as radius of pore and the correlation between cumulative pore volumes represented as pore structure of material.

Based on the pressure versus intrusion data which provide volume and size distributions using the Washburn equation. Pore. The governing equation for Mercury intrusion Porosimetry (MIP) analysis to obtain pore size distribution is shown in Equation 1

$$d_p = \frac{-4\gamma \cos\theta}{p} \qquad (1)$$

d_p = the pore diameter (μm)

γ = the surface tension of mercury

θ = the contact angle and

p = the external pressure.

The volume of pore in corresponding size known by calculating the data volume of mercury that intrudes into the ECC sample with each pressure change. Figure 3.9 shows a mercury intrusion porosimeter.

Figure 3.9 MIP Machine retrieved from (www.cyto.purdue.edu , n.d)

3.9 FLEXURAL TEST

Beam sample size 25mm x 50mm x 508mm. Universal testing machine use for flexural strength test according to BS1881-118. Beam sample were casting in a molded made by wood and plastic based on given specification size as shown in Figure 3.10. Then curing period takes place. The flexural were performed on the sample at the ages of on 28 days. For each mix proportion, 3 similar sample were prepared with the same mixture. The flexural strength test is an important to determine strength development for this studies.

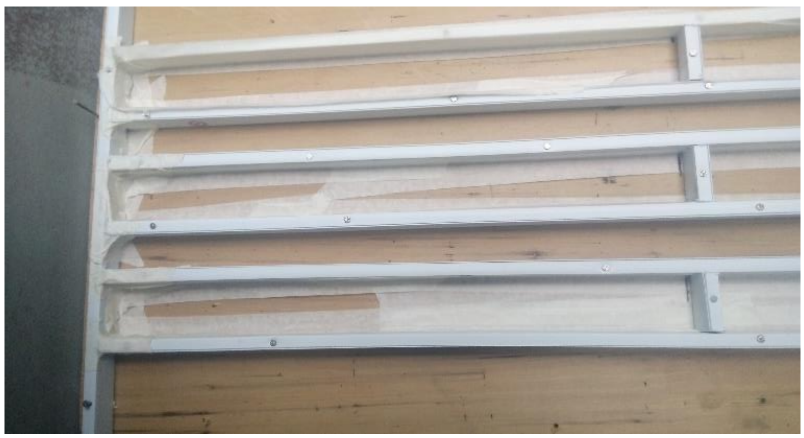


Figure 3.10 Flexural formwork

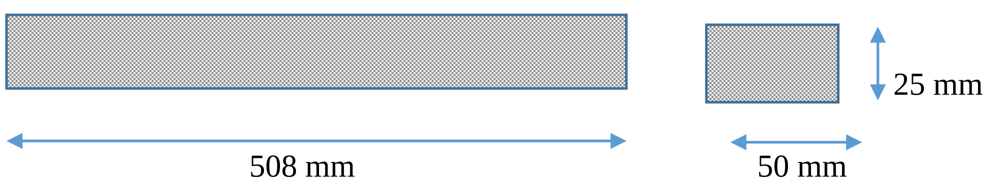


Figure 3.11 Beam mold

The universal testing machine by using simply supported system as shown in figure above to use to determine the flexural strength of sample. The load was applied through under controlled condition until the beam crack or unable to sustain load. Figure 3.11 show the dimension of mold use for flexural test.

A pair of supporting roller on bottom while on top of beam were placed loading roller to spread load across the sample as shown in Figure 3.12

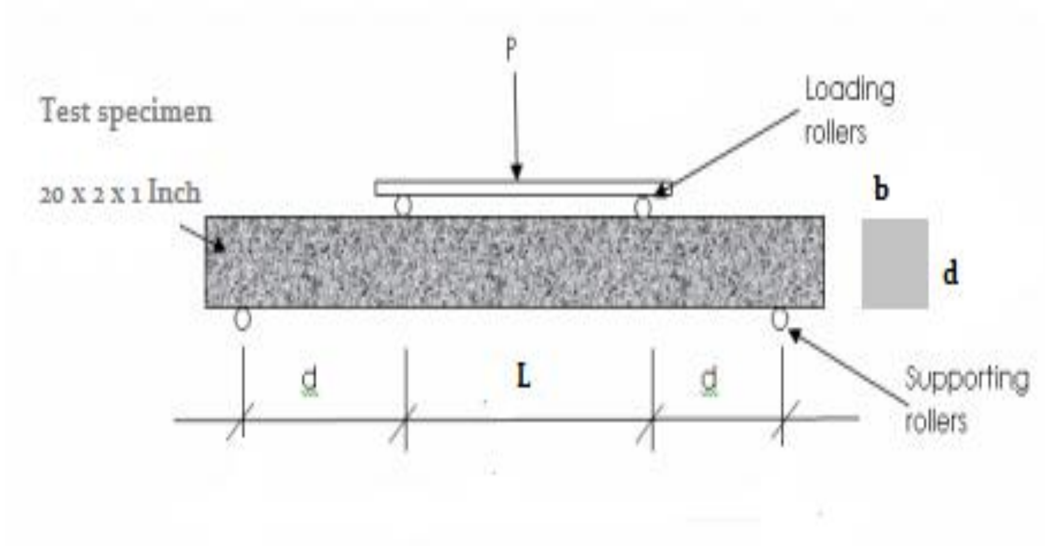


Figure 3.12 Flexural (Four Point Load) Test

The flexural strength was then calculated using the equation 2 below:

Where,

$$f = \frac{PL}{bd^2} \qquad (2)$$

P = breaking load (in N); d1 and d2 = lateral dimensions of the cross sections (in mm)

l = distance between the supporting rollers (in mm)

4.0 COMPRESSIVE TEST

Sample size for compressive test is 50mmx50mmx50mm. Figure 3.13 show sample mold for compressive test. Universal testing machine use for this test according to ASTM C39 for sampling and testing unit. The compressive strength of all ECC mixture (20 samples) are determined after curing period. Each mixture consist of three sample and result will analyze based on average of this three sample the sample are marked according to sample mixture. The sample are placed in curing tank as shown in Figure 3.14 for 28 days to cured as standard condition

Figure 3.13 Compressive mold

Figure 3.14 Curing tank

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 CHLORIDE PERMEABILITY

The test performed according to AASHTO T277 and ASTM C1202. The sample cylinder with a 100 mm diameter were cut by concrete cutter into 50 mm (2 in.) described in standard size in order to performed this test. After that, epoxy were coated on side of the cylindrical specimen sample until epoxy was dried. Then, the specimen were placed in a vacuum chamber for 3 hours and 1 hour for vacuum saturated as shown in Figure 4.0 below and specimen allowed to soak for 18 hour.

Figure 4.0 Vacuum pump, desiccator and sample core

It is then placed in the test device using acrylic silicone function to make bond between the specimen and device and also to prevent solution from leakage. The left-hand side or red wire connect between device and test cell of the test cell is filled with a 3% NaCl solution. The right-hand side or black wire connected to the test cell is filled with 0.3N NaOH solution. A 60-volt potential is applied for 6 hours to measure the reading for every 30 minutes. The sample were removed after 6 hours and amount of coulomb at the end of 6 hours used to determine the chloride ion penetration. Figure 4.1 show the preparation for chloride ion penetration test

Figure 4.1 RCPI Test Setup

The current passed was measured after 6 hour for each sample and readings in Coulombs were tabulated as shown in Table 4. The comparative study for different mix, inclusion of fiber, and nano silica particle after curing period are shown graphically in Figure 4.2.

Table 4: Charge Passed

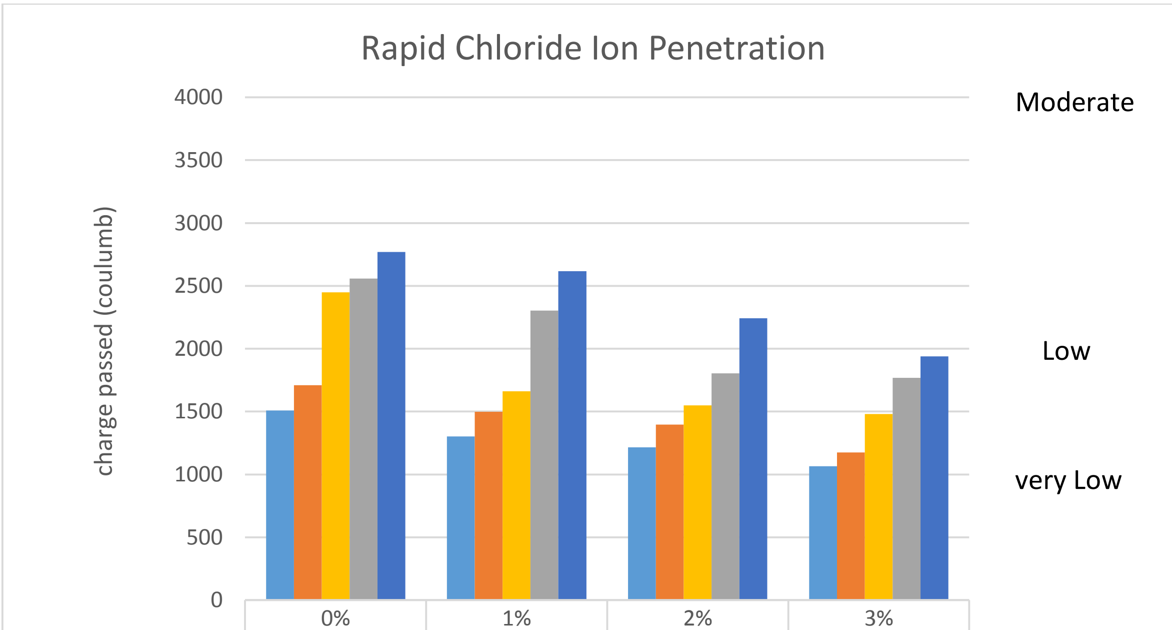
sample	Polyvinyl alcohol (PVA) fiber (%)	Nano silica (%)	Charge passed (coulomb) at 28 days	Chloride permeability as per ASTM C 1202 at 28 days
M1	0	0	1510	Low
M2	0.5	0	1710	Low
M3	1.0	0	2448	Moderate
M4	1.5	0	2558	Moderate
M5	2.0	0	2770	Moderate
M6	0	1	1302	Low
M7	0.5	1	1498	Low

Continue table 4,

M8	1.0	1	1662	Low
M9	1.5	1	2304	Low
M10	2.0	1	2618	Moderate
M11	0	2	1216	Low
M12	0.5	2	1398	Low
M13	1.0	2	1550	Low
M14	1.5	2	1804	Low
M15	2.0	2	2242	Moderate
M16	0	3	1065	Low
M17	0.5	3	1175	Low
M18	1.0	3	1480	Low
M19	1.5	3	1768	Low
M20	2.0	3	1939	Low

From the table above chloride permeability of all sample show the result charge passed and the permeability of chloride into ECC. From Table 5 showed that relation between value of charge passed and permeability of chloride from low to high. Each sample have different PVA content from 0-2% and nano silica particle varies from 0-3% show different value of charge passed. Based on table, sample M5, M10, M15, and M20 with highest content of polyvinyl alcohol (PVA) fiber show the highest charge passed value compared to other sample have lower content of PVA fiber. From the table based on ECC without nano silica particle, ECC marked M1, M2, M3, M4 and M5 has different of PVA fiber volume.

However, the charge passed of M5 specimen is much higher compare to M1, M2, M3, and M4. It can been seen that the number of coulomb increase with the volume of PVA fiber added on ECC mix. As expected, higher PVA fiber content make ECC more porous which provide more charge passed through the sample



	0%	1%	2%	3%
0% of PVA fiber	1510	1302	1216	1065
0.5% PVA fiber	1710	1498	1398	1175
1.0% of PVA fiber	2448	1662	1550	1480
1.5% of PVA fiber	2558	2304	1804	1768
2% of PVA fiber	2770	2618	2242	1939

Figure 4.2 Chloride permeability

Figure 4.2 show relation between the nano silica particle and charge passed based on 1%, 2% and 3% of nano silica particle content in engineered cementitious composite (ECC). It can be seen that charge passed decrease as nano silica particle content increase which can be compared through the mixture M5 with 1% of nano silica content has low chloride permeability while M20 with 3% of nano silica content is very low chloride permeability. Similarly, the result from all sample with 3% of nano silica content has very low chloride permeability while other sample has low chloride permeability.

From Table 4 summarize the chloride permeability based on charge passed from moderate to very low of permeability based on ASTM C1202 by compared the value in chart table 4. This low value of chloride ion penetrability of engineered cementitous composite (ECC) was expected because of the porous nature of ECC. The chloride resistance of concrete are based on the criteria of pore size, pore distribution and interconnectivity of pore system which effect on porosity of concrete It were found engineered cementitous composite (ECC) containing nano silica particle reduce the chloride permeability by increasing the percentage of nano silica in ECC mixture. The increasing of nano silica particle may increase the pozzolonic reaction contribute to fill the void and pore in cement matrix. The use of nano silica particle improved the durability from the pozzolonic activity. The reaction between nano silica particle and calcium hydroxide (CH) produce calcium-silicate-hydrate (C-S-H) gel reduce the pore volume which it fill internal capillary pore makes ECC more compact, dense and uniform structure.

4.2 MERCURY INTRUSION POROSIMETRY (MIP) TEST

The test conducting 28 days after curing. This test used to measure the porosity and pore size distribution. The sample are prepare by measure the density and mass for every each as shown in Table 5.

Table 5: Accessible Porosity

Nano Silica (%)	Mix ID	Accessible Porosity (%)
0	M1	3.71
	M2	4.42
	M3	4.42
	M4	4.7
	M5	5.5

Continue table 5,

1	M6	3
	M7	3.41
	M8	3.48
	M9	3.93
	M10	4.74
2	M11	2.24
	M12	2.92
	M13	3.92
	M14	4.14
	M15	4.71

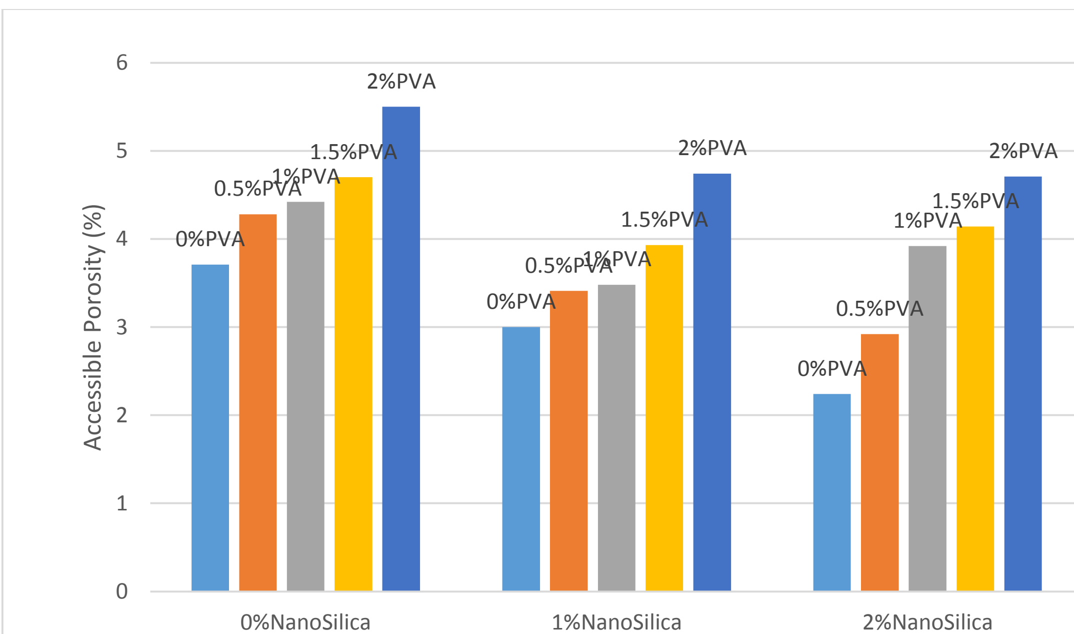


Figure 4.3. Accessible porosity

Figure 4.3 represent the accessible porosity for ECC containing nano silica range from 0-1.5%. The sample were collected based on 15 sample. The accessible porosity is defined as percentage of pore compare to volume of sample, which is contributing the durability of sample due to porous. The accessible porosity for each sample difference as the sample have different mix proportion.

After water–curing for 28 days, the specimen were weighted and density for each sample were taken before tested. From the Figure 4.3, the accessible porosity for M5 larger than M1, M2, M3, M4, suggesting poor durability aspect for M5. The influence of PVA fiber in ECC makes more porous. Therefore, increasing PVA fiber content in ECC increase the accessible porosity. The volume of penetrable pore in ECC increase as PVA fiber increase. However, it can observed that accessible porosity reduce with the increasing of Nano silica content. It can explained by that the increasing of Nano silica change ECC porosity. Regardless to PVA fiber. For example compare to M1, the accessible porosity of M6, and M11, increase 0.71% and 0.79% respectively. From 0%-3% of Nano silica content, the lowest accessible porosity is ECC with 3% of Nano silica content. The test have been confirm from chloride ion penetration which on nano silica contribute to pozzolonic reaction create C-S-H gel make structure of ECC denser and compact. This is confirmed by Said, Zeidan, Bassuoni and Tian (2012), with the addition of Nano Silica improve the mechanism that contribute the durability of concrete. The following show reaction which produce C-S-H gel.

$$2C_3S + 11H_2O \rightarrow C\text{-}S\text{-}H + 3Ca(OH)_2$$

$$2C_3S + 9H_2O \rightarrow C\text{-}S\text{-}H + Ca(OH)_2$$

$$2SiO_2 + 3Ca(OH)_2 \rightarrow 3CaO.\ 2SiO_2\ .\ H_2O$$

Based on following reaction compare with the result. It was observed that the efficiency of nano silica particle increase the amount of C-S-H gel due to ultra-finer particle size create a large surface for reaction. C-S-H gel has the important characteristic to expand outward into the porosity intend to reduce from chemical attack. This gel fill internal capillary pore make structure more compact and dense.

4.2 FLEXURAL STRENGTH

The beam specimen was performed by four point bending test to determine the flexural properties of engineered cementitous composite (ECC) containing nano silica particle based on standard ASTM C78 using universal Testing Machine (UTM) performed after curing period. To study the behavior of ECC, the beam specimen size 20 inch x 1 inch x 2 inch were placed by linear variable differential transformer (LVDT) at mid span of the beam. While strain gauge also locate below the mid span was glued to the surface with connecting wire to data logger to develop stress versus strain graph. As trial test been done show a significant with under control of load and displacement. The specimen used convenient set up and a loading rate 0.1 mm/min used for this test. The specimen setup shown in Figure 4.4.

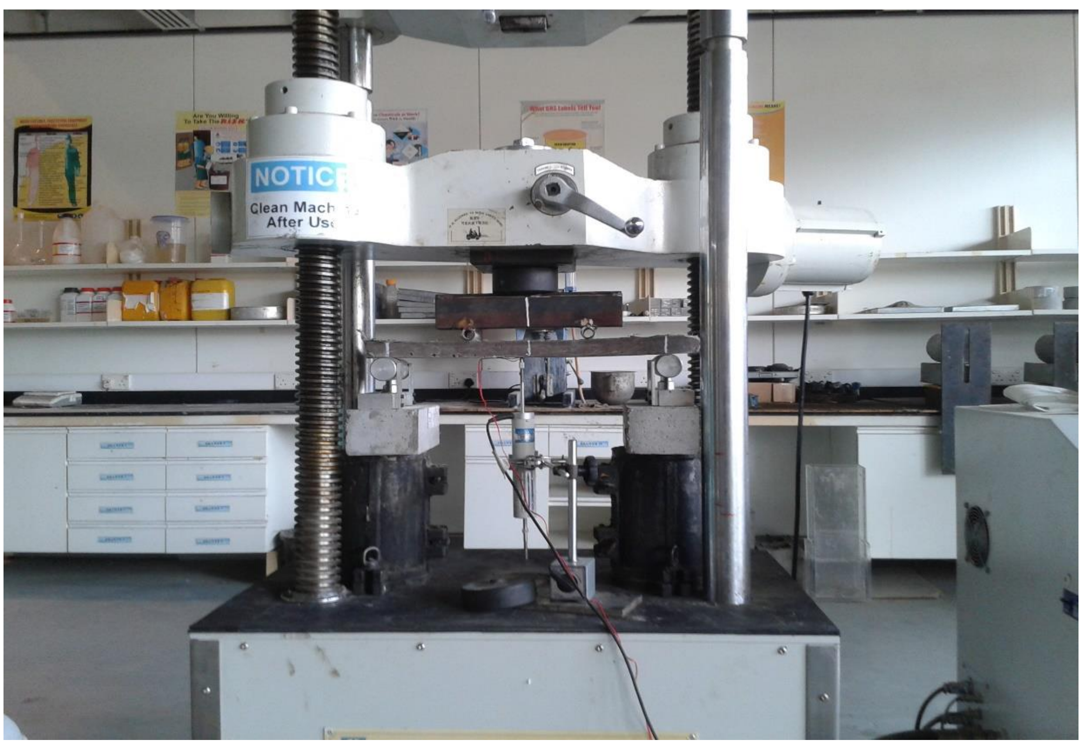


Figure 4.4. Flexural Test setup

Table 6: Flexural Strength and strain at first crack

Nano Silica (%)	Mix ID	Flexural strength at first crack (MPa)	Flexural strain at 80% first crack (μm/m)
	M1	4.60	77.7
	M2	4.13	85.4
0	M3	4.10	98
	M4	3.61	98.7
	M5	3.00	112
	M6	5.45	100.8
	M7	5.10	104.3
1	M8	4.22	115.5
	M9	4.70	143.5
	M10	4.50	129.5
	M11	5.56	110.6
	M12	5.34	116.2
2	M13	4.02	108.5
	M14	4.47	143.5
	M15	4.22	154
	M16	6.14	123.2
	M17	5.64	140
	M18	4.74	154
	M19	4.10	167.3
	M20	5.20	175.7

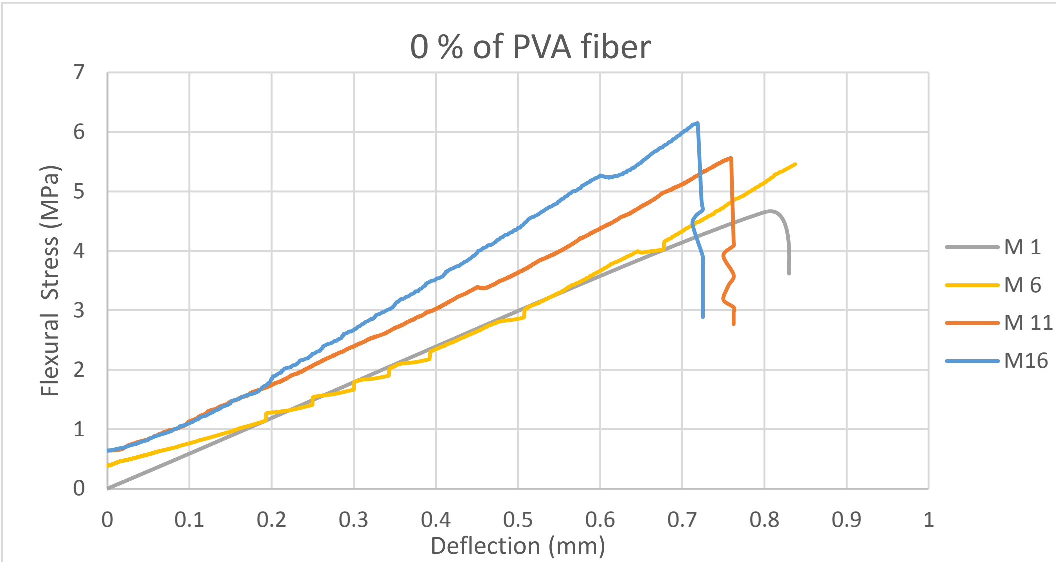


Figure 4.5. Deflection graph A1

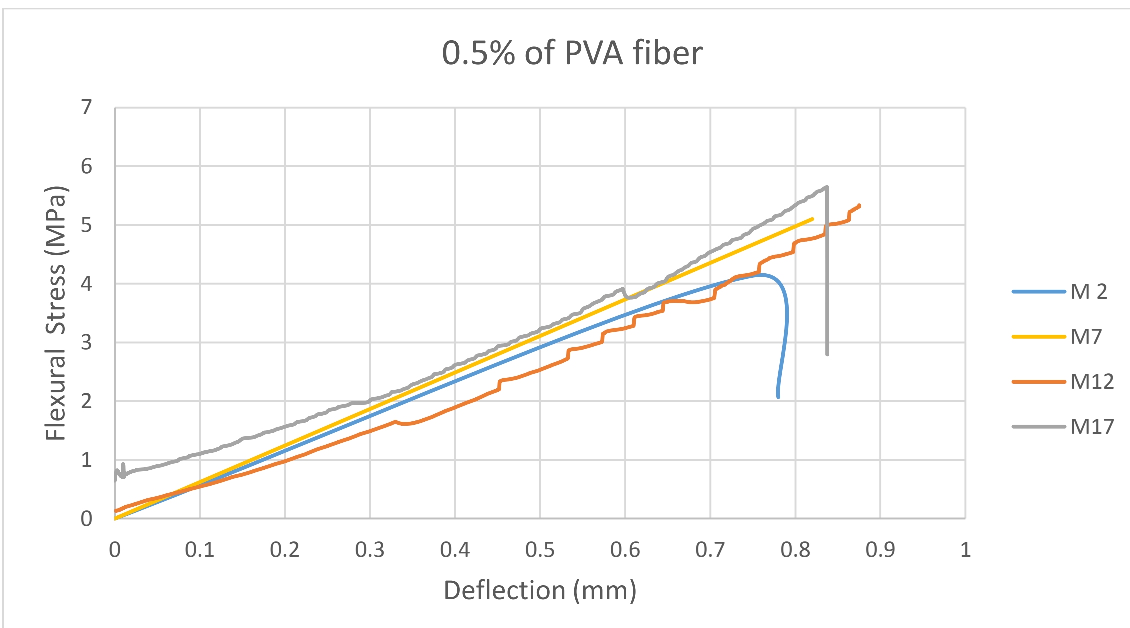


Figure 4.6. Deflection graph A2

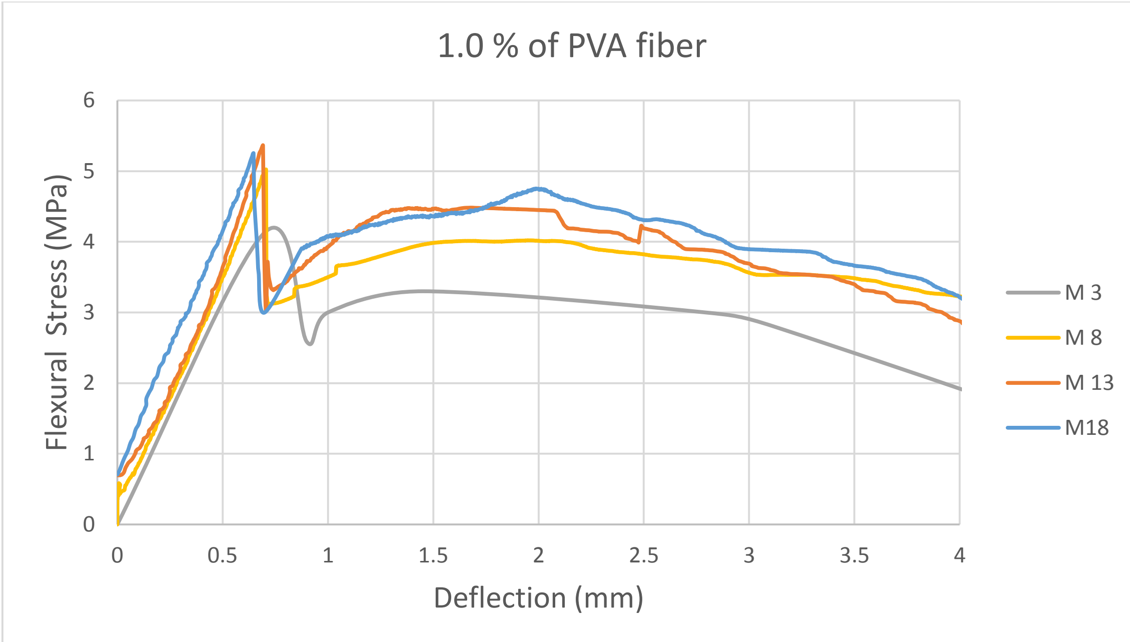


Figure 4.7. Deflection graph A3

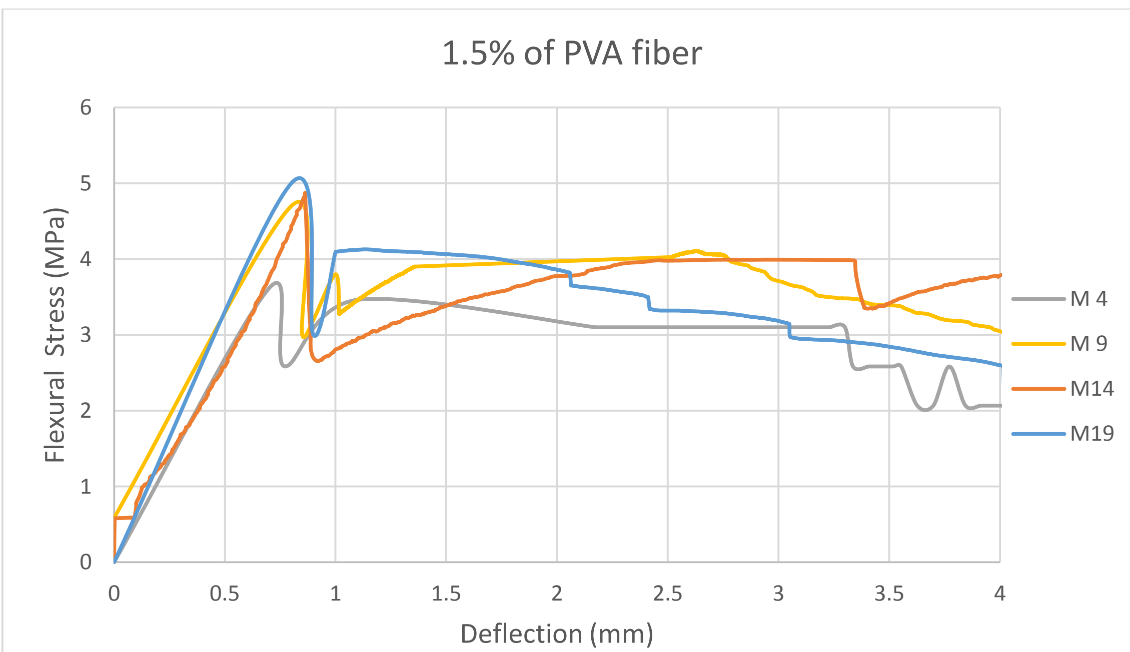


Figure 4.8. Deflection graph A4

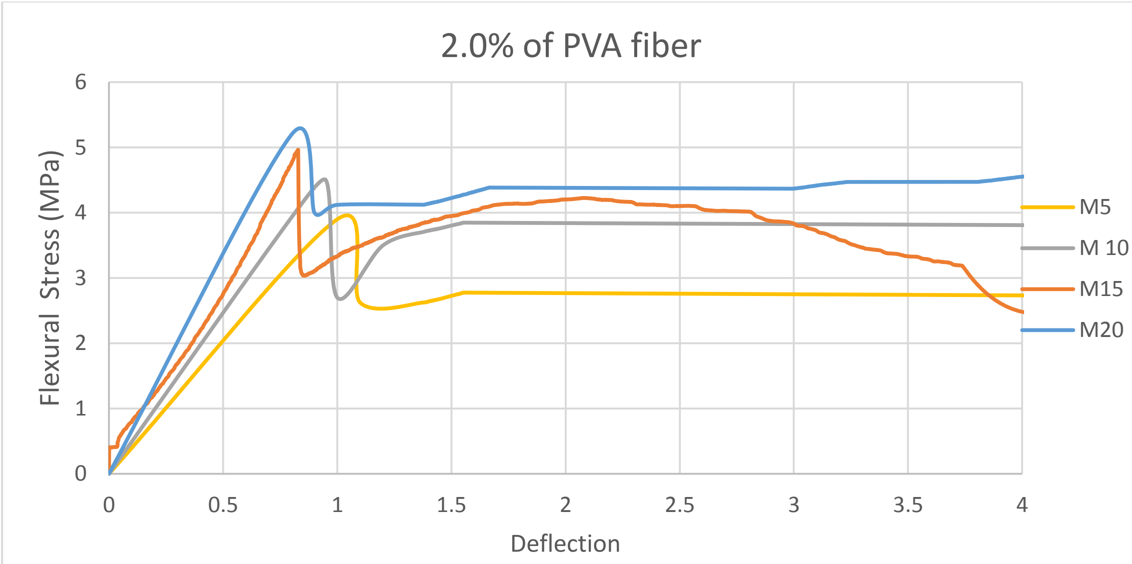


Figure 4.9. Deflection graph A5

Table 6 show the test result of flexural strength and deflection at peak stress. Each result is the average of three specimen by the same set up with loading rate at 0.1mm/sec. As seen in a table with severe bending load, all sample deform similarly ductility in form of plastic deformation. The average flexural strength from 3 to 6 MPa. The test result and calculation taken from four point bending test. The flexural strength depend on two variable of PVA fiber content and Nano silica content. From the table above, the flexural strength reduce as content of PVA fiber increase. For example, compare with the same content of nano silica but different of PVA content in ECC which M1, the flexural strength of M2, M3, M4 and M5 reduce 10%, 10%, 21% and 34% respectively. However, specimen without PVA fiber have more flexural strength compare to other specimen. While sample M5, M10, M15 and M20 with 2% of PVA fiber have lowest flexural strength compare to other specimen. Based on all specimen, Increasing of nano silica content improve the flexural strength. For example, compare to M1, the flexural strength of M6, M1, and M16 increase 15%, 17% and 25 % respectively. This confirms previous literatures that the addition of Nano Silica will improve the flexural strength of ECC.

Figure 4.5, 4.6, 4.7, 4.8 and 4.9 show all specimen under bending load deforms as plastic deformation. The load-deflection curve obtain from the specimen show the relation between the stiffness and the content of nano silica particle. The different in mix proportion lead to the difference fiber distribution which the main factor for ductility of ECC. It can be easily noted that ECC with 0-0.5% of PVA fiber failure at first crack. While ECC with 1-2% of PVA fiber show greatly improved in bending performance. J.zhang and x.ju (2014) stated that the increase in bending performance based on load carrying capacity and ductility with the increase of PVA fiber content. Another factor that contribution to load carrying capacity of ECC is due to nano silica content. In other hand, improvement of transition zone due to pozzolanic activity increase the load carrying capacity proportional to deflection described the enhancement of strength by nano silica particle. From the figure, the load-deflection curve obtain from the specimen show the relation between the stiffness and the content of nano silica particle.

Based on flexural test performance, pozzolanic reaction play important role to strengthen the ECC. The ability of calcium silicate hydrate(c-s-h) gel a product from pozzolanic reaction give positive affect to structural characteristic and mechanical performance of ECC. it should be mentioned that although all specimen were test from scope of study from 0-3% nano silica content show trend increasing in flexural performance, it should be consider examine the optimum use of nano silica in ECC. however, based on the test result show the largest value (6.14 Mpa) of flexural strength at first crack obtain from M16 with 3% of nano silica content and 0% of PVA fiber. From Figure 4.10, the crack can be observe from the sample under loading. Several crack appear below surface of the specimen when load applied to the specimen. The properties of ECC were determined that it can still carrying load even under deflection or crack appear. The first crack start from the mid span as increase of flexural stress. Increase in crack width from small spacing crack until specimen failure. According to K.T soe et al, ECC material has a first crack strength between 4-7Mpa. Based on test result, all specimen exhibit the flexural behavior ECC. Figure 4.11 show the crack of ECC specimen at the mid span result in bending failure depend on fiber bridging strength.

Figure 4.10. ECC specimen under loading

Figure 4.11 Mid-span crack

Figure 4.12 Small crack on specific time

Figure 4.13. Large Crack on specific time

4.3 COMPRESSIVE STRENGTH

Table 7 present the average of the compressive strength as determined from 3 cubic specimen show in Figure 4.15 after curing period using standard procedure described in ASTM C140 using compression testing machine show in Figure 4.14. Based on result of compressive test as expected, increasing of nano silica particle increase the compressive strength of ECC. However, increasing of PVA fiber reduce the compressive strength of ECC.

Figure 4.14. Sample under compression test

Figure 4.15. Sample for compression test

Table 7: Compressive Strength Result

Nano Silica (%)	Mix ID	Compressive strength (MPa)
0	M1	65
	M2	73
	M3	78
	M4	82
	M5	98
1	M6	68
	M7	78
	M8	79
	M9	84
	M10	100
2	M11	77
	M12	80
	M13	85
	M14	93
	M15	102
3	M16	90
	M17	93
	M18	95
	M19	97
	M20	101

The average of compressive strength from 65 to 102 MPa. According to M. Șahraman et al. (2009) mentioned that compressive strength for more than 40 MPa were enough to use in structural application to support loading. The compressive strength depend on two variable of PVA fiber content and nano silica content. Regardless to PVA fiber. The table show trend increasing of compressive strength from 0-3% nano silica content. For example compare to M1, the compressive strength of M6, M11, and M16 increase 4%, 18% and 22% respectively. In spite of fact the increasing of nano silica particle main contribution for pozzolanic reaction on which make the specimen more compact and dense compare to normal ECC, the compressive strength of ECC containing nano silica particle is expected to produce higher strength. As the specimen involving with nano silica particle improve on interfacial transition zone, and enhanced hydration. However, increasing of nano silica content increase rate for drying shrinkage. The reason using of superplasticizer to avoid particle segregation due increasing of nano silica without effecting workability but enhance the high strength of ECC and lower permeability. Sayed et al. (2013) conducted experiment on compressive strength of adding nano silica on ECC Results showed that the optimum percentage adding nano-silica as a replacement of cement improves compressive strength by at 28 days. This result due to the increasing of the bond strength of cement paste-fine aggregate interface by means of the filling. Figure 4.16 show the crack of sample after being subjected compressive test

Figure 4.16. Compressive test sample failure

Figure 4.17 show the result of compressive strength of ECC mixture from 0-3% nano silica content. It can be observed that ECC with 3% of nano silica content was the higher strength for compressive strength. . However when tested under the same nano silica content but different PVA fiber content, the strength of concrete was not very significant compare to other sample. Based on the result, the influence of nano silica with different content examine that addition of nano silica primarily increase the mechanical properties of ECC. Such Increasing of strength caused by dense and compact of structure accumulated by pozzolanic reaction. This improvement due to nano size of silica wth high reactivity produce C-S-H gel which fill the internal pore and create a strong bond on matrix.

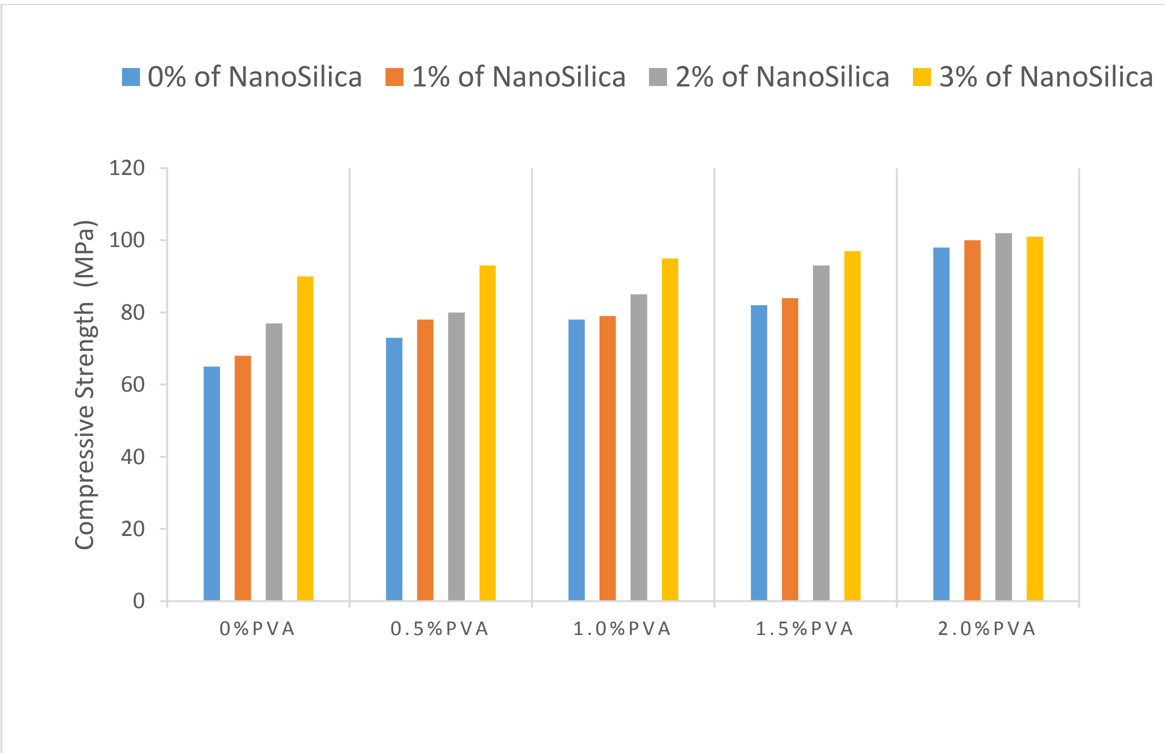


Figure 4.17. Compressive strength chart

CHAPTER 5: CONCLUSION

Engineered cementitous composite (ECC) exhibit excellent properties in durability and ductility was developed to utilize the problem with structure element. On this studies, the use on nano silica particle apply to ECC with the PVA fiber reinforced.Durability and mechanical properties of ECC containing nano silica particle were determined through rapid chloride ion penetration, flexural, and compressive test with 20 sample range 0-3% of nano silica content and 0-2% of PVA fiber added in mixture. From durability aspect through rapid chloride ion penetration test, ECC with 3% of nano silica content exhibit very low chloride permeability with 20% reduce the chloride penetration. The test result indicate that increasing of nano silica content in ECC reduce the chloride permeability. On the other test, the accessible porosity were measure by mercury intrusion porosimetry (MIP) test., it can observed that accessible porosity reduce with the increasing of Nano silica content. It can explained by that the increasing of Nano silica improve microstructure of ECC by reduce internal porous. Therefore the first objective is achieved.

Prior to mechanical properties of ECC, flexural test and compressive strength were conducted. From flexural test, stress-deflection graph were plotted and flexural strain table were tabulated to measure the ductility and strength performance. As percentage of nano silica increase with the flexural strength of ECC also increase. Moreover, strain hardening capacity of ECC is improved by nano silica. While, PVA fiber has more obvious effect on improving deflection of ECC. However, increasing of PVA fiber in ECC reduce the flexural strength. The compressive strength of ECC increase as with two combination of different material especially at early age. For example, the compressive strength of M20 higher than M1 increase 35% of compressive strength of ECC. Second objective is achieved. At the end of this study, understanding on behavior of material properties and durability of ECC containing nano silica particle with possible to design more suitable mix proportion of ECC to obtain good in strength and excellent ductility. The selection of this material by studies on pozzolanic reaction with the cement paste. Further research are required to study this material application in concrete.

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APPENDIX A: MATERIAL TECHNICAL DATA SHEET

kuraray

Kuraray Co., Ltd.
OTE CENTER BLDG., 1-13, Otemachi,
Chiyoda-ku, Tokyo 100-8115, Japan
Phone. +81-3-6701-1366
Fax. +81-3-6701-1376

Jan 21, 2013

To whom it may concern:

CERTIFICATE OF ANALYSIS

We certify that the following article shipped to Kemas Kurnia(M)Sdn.Bhd. conforms to the quality below.

1. Article : Kuralon K-II (PVA) fiber RFS400x18
2. Quantity : 225kgs
3. Shipping Date : Jan 21, 2013
4. Customer : Kemas Kurnia(M)Sdn.Bhd.
5. Test Data

Production Lot No.	21005	SPEC
Quantity (kgs)	225	
(1) Diameter (dtex)	396	400±70
(2) Length (mm)	18.3	18.0±2.0
(3) Tensile Strength (cN/dtex)	8.4	7.5±1.4
(conversion: MPa)	1092	975±185
(4) Elongation (%)	8.6	9.0±3.0

Remark:

The Net Weight per each Paper-Bag calculated including Commercial Moisture Regain by the following formula:

Commercial weight = Actual weight x [1+5%(C.M.R.)] / 1+(A.M.R.)]

* C.M.R. = Commercial Moisture Regain

* A.M.R. = Actual Moisture Regain

Kuraray Co., Ltd.
Fibers and Materials Dept.II
Fibers and Industrial Materials Division
Fibers and Textiles Company

RISALAH DATA KESELAMATAN KIMIA
MATERIAL SAFETY DATA SHEET

Sika® ViscoCrete®-2044

Tarikh penyediaan / Date prepared	**: 30 August 2007**	**Nombor rujukan / Reference No.**	**: 319 - 002**

BAHAGIAN 1 : PENGENALPASTIAN PRODUK KIMIA DAN SYARIKAT
SECTION 1 : CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

1.1 Maklumat Produk / Product Details

Nama Produk / Product Name	: Sika® ViscoCrete®-2044
Nama Dagangan / Trade Name	: Sika® ViscoCrete®-2044
Nama Kimia Chemical Name	: Larutan akueus polikarboksilat terubahsuai. : Aqueous solution of modified polycarboxylates.
Huraian Produk / Product Description	:'Superplasticizer' generasi ketiga untuk konkrit dan mortar : Third generation superplasticizer for concrete and mortar.
Berat Molekul / Molecular Weight	: Tiada / N/A
Kumpulan Bahan Kimia Chemical Family	: Tiada kaitan : Not applicable
Kegunaan Use	: Rujuk kepada risalah data produk : Refer to product data sheet

1.2 Pengenalpastian Syarikat / Company Identification

Nama dan alamat pengilang / Manufacturer's Name and Address	: Sika Kimia Sdn Bhd Lot 689, Kawasan Perindustrian Nilai, 71800 Nilai, Negeri Sembilan
Nombor telefon / Telephone No.	: (606) 7991762
Nombor telefon kecemasan / Emergency Telephone No.	: (606) 7991762
Nama dan alamat pengimpot / pengeluar tempatan Importer's / Distributor's Name and Address	: Sika Kimia Sdn Bhd Lot 689, Kawasan Perindustrian Nilai, 71800 Nilai, Negeri Sembilan
Nombor telefon / Telephone No.	: (606) 7991762
Nombor telefon kecemasan / Emergency Telephone No.	: (606) 7991762

1.3 Titik Hubungan / Contact Point

Gelaran Jawatan / Designation	: Pengurus Persekitaran, Keselamatan & Kesihatan / Environmental, Health & Safety Manager.
Nombor telefon / Telephone No.	: (606) 7991762

Nota / Note : **Titik hubungan yang diberikan hendaklah terus kepada seseorang yang boleh memperjelas maklumat lanjut dan / atau bibliografi mengenai sesuatu produk / bahan kimia.**
The contact point given should direct a caller to someone who can clarify information or provide further information and / or a bibliography of the product. The titles of a position or section should be inserted.

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Cement Quality

The quality of Portland cement is defined by Malaysian Standard MS 522, which is loosely based on the British standard BS 12. This is however now superseded by EN 196, which is the European Union standard. These standards specify a series of test for which the cement will have to conform to. The most common being :

a) fineness - blaine method
b) chemical composition
c) strength - mortar / concrete cubes
d) setting time - vicat method
e) soundness - Le'Chatelier method

A typical chemical composition of clinker and cement is provided below.

Item	Clinker (%)	Cement (%)
Oxide Composition		
SiO_2	21.66	21.28
Al_2O_3	5.80	5.60
Fe_2O_3	3.68	3.36
CaO	65.19	64.64
MgO	2.86	2.06
SO_3	0.20	2.14
Total Alkalis	0.07	0.05
Insoluble Residue	0.10	0.22
Loss on Ignition	0.27	0.64
Modulus		
Lime Saturation Factor	0.93	0.92
Silica Modulus	2.28	2.38