UNIVERSITAS INDONESIA

UNIVERSITÉ D'ARTOIS

TINJAUAN MATERIAL KUAT TEKAN RENDAH DAN OBSERVASI FORMULA PUSAT LABORATORIUM JEMBATAN DAN PERKERASAN JALAN RAYA (Laboratoire Central des Ponts et Chaussées-LCPC) DAN EUROVIA

TESIS

L SAMUEL NAINGGOLAN
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FAKULTAS TEKNIK
PROGRAM STUDI TEKNIK SIPIL
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Diajukan sebagai salah satu syarat untuk mendapatkan gelar Magister Teknik

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HALAMAN PERYATAAN ORISINALITAS

Tesis ini adalah hasil karya saya sendiri,

Dan semua sumber baik yang dikutip maupun yang dirujuk

Telah saya nyatakan dengan benar**.**

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Tanggal : 07 Juli 2011

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University of Artois

Have been presented and defended by:

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UNIVERSITE D'ARTOIS - BETHUNE

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Laboratoire Génie Civil et géo-Environnement Lille Nord de France

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ABSTRAK

Material Berkekuatan Tekan Rendah atau disebut juga *Controlled Low Strength Material* (CLSM) adalah material yang dapat terpadatkan (terkompaksi) sendiri, mengandung sifat pengikat khususnya digunakan sebagai material pengurug serta dapat mengisi rongga-rongga pada galian saluran. Material terkompaksi sendiri bukanlah jenis beton dengan kuat tekan rendah tetapi lebih tepat dianggap sebagai material urugan terkompaksi sendiri sebagai pengganti material tanah urugan biasa. Bukan juga disebut *soil-cement* yang membutuhkan pemadatan dan pengeringan.

Ada beberapa keuntungan dari penggunaan material ini antaralain, dapat mengurangi tenaga dan biaya kerja, pekerjaan selesai lebih cepat serta mampu mengisi rongga-rongga yang sempit. Rendahnya kuat tekan material ini memudahkan penggaliannya di kemudian hari bila diperlukan dengan menggunakan peralatan galian yang sederhana.

Tujuan dari riset ini adalah meneliti material kuat tekan rendah/*Controlled Low Strength Material* (CLSM) dan mengevaluasi formula dari Laboratorium Jalan dan Jembatan Nantes - LCPC (*Laboratoire Central des Ponts et Chaussées*, *Centre de Nantes*) dan EUROVIA yang memproduksi material tersebut. Sifat utama dari material ini adalah hasil uji kuat tekannya di bawah 2,1 MPa dalam pengamatan setelah umur 28 hari. Flowability-nya harus di atas 200 mm. Apabila hasil uji tersebut tidak memenuhi sifat yang ditentukan, modifikasi komposisi dari formula yang diuji diperlukan untuk mendapat sifat umum dari material terkompaksi dimaksud. Penelitian ini pada akhirnya akan menentukan formulasi ideal penyusun material terkompaksi sendiri.

Kata kunci : *Controlled Low Strength Material, Flowable Fill, Self-Compacting Material.*

ABSTRACT

Controlled Low Strength Material (CLSM) is a self-compacted, cementitious material used primarily as a backfill, utility bedding and void fill in lieu of compacted fill. Self-compacted material should not be considered as a type of a low strength concrete, but rather a self-compacted backfill material that is used on place of compacted fill. Also, should not be confused with compacted soil-cement, because soil-cement requires compaction and curing.

There are various advantages of using this self-compacted material. These benefits include reduced labor and equipment cost (due to self-leveling properties and no need for compaction), faster construction, and ability to place material in confined spaces. The relatively low strength of this material is easily excavated in future with conventional digging equipment.

The focus of this research is to investigate the CLSM and evaluate the formulation of self-compacted material based on LCPC (Laboratoire Central des Ponts et Chausseres, Centre de Nantes) formulation and EUROVIA. The main properties of the material is its compressive strength shall have under 2,1 MPa in 28th day. The flowability shall above 200 mm. Should the result properties based on LCPC formulation were not satisfied, modification of the formulation is required in order to meet the intended properties of CLSM or self-compacting material. This research will eventually establish its appropriate formulation which produces the self-compacting material.

Keyword : *Controlled Low Strength Material, Flowable Fill, Self-Compacting Material.*

CONTENTS

CHAPTRE 3 METHODOLOGY OF RESEARCH

CHAPTRE 4 RESULTS

CHAPTRE 5 ANALYSIS

CHAPTER 6 CONCLUSION AND RECOMMEDATION

TABLE CONTENT

GRAPHIC CONTENT

FIGURE CONTENT

CHAPTER 1

INTRODUCTION

1.1. Background

Construction nowadays has been developed in many ways in order to produce the quality, reliable, reduced cost, energy safe and sustained development material. From the aspect of material, a new construction procedure was introduced called Controlled Low Strength Material (CLSM). American Concrete Institute (ACI) Committee 229, defines CLSM is a self-compacted, cementitious material used primarily as a backfill in lieu of compacted fill. Named self-compacted for this material requires no compaction or consolidation work during the application. Several terms are currently used to describe this material such as flowable fill, self-compacting material and other various names.

This material used especially for backfill, utility bedding and void filling. Back fill such as backfilling trenches. Bedding material for pipeline, electrical and other type utility bedding. Void filling includes filling sewers, basement and other underground structures.

To produce CLSM has a similarity way as concrete does. The main difference is CLSM has less strength than regular concrete. CLSM applications require compressive strength less than 2,1 MPa. Proportioning CLSM has largely been done by trials until mixtures achieve suitable properties. Many suppliers or contractors have different recipe to produce CLSM. For a permanent recipe of CLSM does not exist, trials mixture are conducted to evaluate how well they meet certain goals for strength, flowability, density and etc. Then, adjustments of composition are then needed to achieve the desired properties.

1.2. Object of the Research

The research that will be conducted is expected to promote application of CLSM and to design mix proportion of CLSM.

The goals of this research are:

1. Review of CLSM.
2. Observation on laboratory research for recipes of CLSM from its producers Laboratoire Central des Ponts et Chaussées (LCPC) and EUROVIA.
3. To establish the new recipes of CLSM as desired property.

1.3. Scope of research

Scope of this research:

1. Main Properties of CLSM with compressive strength less than 2,1 MPa, IPI > 10%, Flow spread > 400mm and Stability (Bleeding Quantity) < 2%.
2. Incorporating Fly Ash Class C.
3. Incorporating Admixture Superplasticizer.

1.4. Methodology of the Research

Research in Laboratory is applied as methodology of research. The specimen is CLSM or self-compacting material.

Figure 1.1. Backfilling Trench

Figure 1.2. Utility Bedding

CHAPTER 2

LITERATURES REVIEW

2.1. Controlled Low-Strength Material

2.1.1. Terms of Controlled Low-Strength Material (CLSM)

Controlled Low Strength Material (CLSM) is a self-compacted, cementing material used primarily as a backfill, utility bedding and void fill in lieu of compacted fill. Backfill includes applications such as backfilling walls or trenches. Utility bedding applications involve the use of CLSM as a bedding material for pipe, electrical, and other types of utilities. Void filling applications include the filling of sewers, basement or other underground structures. The mechanical strength of CLSM is generally low permitting in re-excavation in the future, and the material is flowable, allowing perfect filling of any void.

Based on Norme de France number NFP 98-331, this material used to backfill the trench which has confined space and difficult in placements such as public utilities network (electricity, gas, water, sewer, telephone etc) and where adequate consolidation by vibration cannot be achieved. This material itself has been used since 1990 and it is named "*matériaux auto compactant*" self-compacting material.

According to Béton Prêt Emploi (BPE) / Ready Mix Conrete (Guide Setra- Laboratoire Central des Ponts et Chausseres, Centre de Nantes), the self compacted material product is distinguished by two families, they are:

a. *Product Essorable,* the fluidity necessary for their implementation is ensured by a high initial water ranging from 40 up to 50 percent of mixture volume.
b. *Product Non Essorable,* the fluid property is supported by incorporating specific additives.

Following definition of ACI (American Concrete Institute) 116R " Cement and Concrete Terminology "defines CLSM as materials that result in a compressive strength of 8,3 MPa or less. Most current CLSM applications require compressive strength 2,1 MPa or less allow for future excavation of CLSM.

CLSM should not be considered as a type of a low strength concrete, but rather a self-compacted backfill material that is used on place of compacted fill. Other common names are flowable fill, K-Krete and unshrink-able fill. The name K-Krete itself was a company name formed in 1977 which produced the CLSM mix recipe patented in United States. But, the patent of the mix design recipe was eventually transferred to the National Ready Mix Concrete Association NRMCA) as now is one of the referenced standards for establishment of CLSM.

Few formulation of self-compacted material based on formulation LCPC (Laboratoire Central des Ponts et Chausseres, Centre de Nantes), Eurovia were evaluated and some mix modification made to meet the main properties. The main properties of the material is the compressive strength has maximum 2,1 MPa in 28^{th} day, good flowability and Immediate Bearing Ratio/Indice Portant Immediat more than 10 and also have a good flowabilty above 210 mm.

2.1.2. Benefits of CLSM

There are various advantages of using this self-compacted material. These benefits include reduced labor and equipment cost (due to self leveling properties and no need for compaction), faster construction, and ability to place material in confined spaces. The relatively low strength of this material is easily excavated in future with conventional digging equipment.

Benefits of Self Compacting Material are:

1) Ready available : Using locally available material.

2) Easy to deliver : Truck mixer can deliver specified quantities of CLSM to the jobsite whenever the material is needed.
3) Easy to place : Depending on the type and location of void to be filled. Because it self-levelling (French :auto-placant), it needs little or no spreading or compacting . This speeds construction and reduces labor requirements.
4) Versatile : Can be adjusted to improve flowability. More cement or fly ash to increase strength. Admixtures can be added to adjust setting times and other performance characteristics.
5) Strong and Durable : load carrying capacities of CLSM typically are higher than those of compacted soil or granular fill. CLSM also is less permeable, thus more resistance to erosion. For use as a permanent structural fill, it can be designed to achieve 28 day compressive strength as high as 8,274MPa.
6) Can be excavated : CLSM having compressive strengths of 0,3 MPa and 0,7 MPa is easily excavated with conventional digging equipment.
7) Allows fast return to traffic : Can be placed quickly and support traffic load with several hours.
8) Reduces excavation costs: Allows narrower trencher because it eliminates having to widen trenches to accommodate compaction equipment.
9) Improves worker safety: Workers can place CLSM in a trench without entering the trench, reducing their exposure to possible.
10) Allows all-weather construction: CLSM will displace any standing water left in a trench from rain or melting snow.
11) Reduces equipment needs: Unlike soil or granular backfill, CLSM can be placed without loaders, rollers, or tampers.
12) Makes use of a by-product: Fly Ash is a by-product produced by powerplants that burn coal to generate electricity. CLSM

Containing fly ash benefits the environment by making use of this industrial by-product material.

Although price per cubic yard of flowable fill is more expensive than other backfill materials, flowable fill proves to reduce in-place costs. A briefly case from The City of Houston Department of Public Works and Engineering when they can save more than $12,000 by using flowable fill and the saving was not unusual (www.flowablefill.org).

2.2. Mechanism of CLSM

To get the condition of self compacting material of CLSM, we can reduce the number of Coarse Aggregates, and for the consequence the fine aggregates be more added.

Addition Fine Aggregates will have CLSM in a good flowability for its size filling the void during the construction. That is why a viscosity is required to support this mechanism of these aggregates.

The viscosity has a flow property but remains thick (cohesive), mixed with water will give the CLSM have more mobility. In other words, flowability increased. But, the utilization of excessive water brings the tendency of segregation and bleeding. For that reason, to have a good mixture of CLSM, conducting several trial mixtures to obtain the optimum composition of the aggregates with water and also some other admixture is necessary.

2.3. Properties of CLSM

2.3.1. Workability

Taking from the Concrete Properties by Ramachandran in Admixtures Handbook 1995, the workability in the concrete is determined by the ease and its homogeneity which it can be mixed, transported, compacted and finished. A good workable concrete should not exhibit excessive bleeding or segregation. Same treatment as quality of fresh concrete, CLSM also shall to observe its bleeding and segregation.

Thus workability for the CLSM includes properties such as flowability, and cohesiveness.

The main factors affecting workability is the water content in the concrete mix. A harsh concrete becomes workable by the addition of water. For this factor, we can do the same treatment for CLSM that the water has the influences for its workability. Workability may also be improved by the addition of plasticizers and air entraining agents. The factors that affect workability include quantities of paste and aggregates, plasticity of the cement paste, maximum size and grading of the aggregates, and shape and surface characteristics of the aggregate.

Consistency of fluidity is another term that has been used to describe the state of fresh concrete. It describes the ease with which a substance flows. This term *consistency* is sometimes used to describe the degree of wetness of concrete. Wet concrete is more workable than the *dry* concrete. One standard test using *vicat apparatus* to measure the consistency of paste, consisting of a needle of diameter 1mm with a plunger of diameter 10mm, stipulated the paste of cement has a normal consistency when the rod settles to a point around 10 mm below the surface in 30 seconds after released needle.

The most extensively used test to measure the consistency as an index of workability property is slump test. For the concrete, the cone lifted slowly, the decrease in the height of center of the concrete to the slumped concrete is measured. Different from concrete, the workability for CLSM can be achieved by measuring the large of the spreading occurs after lifting up the cone quickly (see the slump flowspread test).

2.3.2. Flowability

Flowability is the property that makes CLSM unique as a fill material. This enables the material to be self-leveling, to flow into and readily fill the void, and be self-compacting without need for conventional placing and compacting equipment. (ACI Committee 229). Slump flow test is conducted to see the flowability and deformability of mixture.

The flowability of CLSM is measured by using 10 x 30 cm Abram cone cylinder which refers to EN 12350-2. Fresh CLSM is filled to the top of cylinder and the cylinder is quickly lifted, allowing the material to spread freely on the plate. The flow measured by the average diameter of the longest spread and its perpendicular.

According to ASTM D6103, normal flowable material should have an horizontal flow spread 152 to 203 mm tested in accordance. Low flowable material shall have a maximum of 152 mm. High flowable material shall have a minimum flow of 203 mm with a 75x150 mm size of cylinder cone.

For this research, following the LCPC test, when the fresh mixture has the flowability higher than 210 mm is recommended, since the used molding cylinder (100x300 mm) is bigger than ASTM standard one, the 400 mm of flowability was taken as a good flow.

2.3.3. Indices Portant Immédiate (IPI)

Indices Portant Immédiate is an index represents the bearing penetration of the material. In French known as Indices Portant Immédiate "*Grandeur utilisée pour évaluer l'aptitude d'un sol ou d'un matériau élabore a supporter la circulation des engins de chantiers*" which means IPI is a quantity used to evaluate the capacity of soil or material to bear the traffic of constructions engines. Regarding to the CLSM, this will represent its ability bearing the load for an immediate time.

According to the NF P 94-078, IPI test has two types of test. First is Proctor Normal for soil and second one is Proctor Modified for pavement material. But for the CLSM, no compacting treatment needed as Normal and Modified have. This test applied the CBR machine test to have the bearing resistance of the material in the early age of specimen. The cylinder is 15x21 cm of volume. This test has a purpose to see the bearing capacity of the material, for the reason of some constructions require the immediate setting time of the material. So this material expected can be used after 24 hours placement as a sub-base of road or in footpath construction.

2.3.4. Compressive Strength

Compressive strength is a measure of load carrying ability of CLSM. Most of CLSM applications shall have the long term compressive strength below 2,1 MPa. This is a lower strength compared to concrete and will allow the material when necessary to be excavated in future. If any kind of material do not meet the desired strength, it is necessary to modify the composition. Trial mix is highly suggested to obtain the appropriate mix to have this property.

For the test, the fresh material is molded in cylinder 11x 22 cm, and stored in laboratory with room temperature. Then those specimens will be tested after aged of 7 and 28 day using a compressive strength machine. The strength is the average compressive strength of at least three specimens tested.

	Compressive Strength at 28th day	
Re-excavatibility	Below 0,7 MPa	Between 0,7 and 2,1 MPa
	Ease	Averagely Ease
	Manual	Manual or simple tools

Table 2.1 Excavatable Strength

2.3.5. Bleeding and Segregation

Stability test aims to see the bleeding and sedimentation occurs in fresh mix. When the pasta still plastic (fresh mixture), and the settlement of solids is followed by the formation of a layer of water on the surface. This is known as bleeding or water gain. The stability is concerned particularly of the high content of water. Excessive water content may produce the less of pasta, which affect to the homogeneousity and cohesiveness. Ponding of water on the surface can contribute to the formation of a weak surface layer and can also delay the setting time. The amount of bleeding can be reduced by using proper amounts of fines, high alkali or C_3A contents, increasing cement content and admixture such as pozzolans, calcium chloride or air entraining admixtures (Ramachandran 1995).

This test simply by placing the fresh mix into 1000 ml pycnometer with around 500 ml of volume. Few minutes after, we can observe how deep is the water ponds on its surface. Then after 24 hours, it shall be observed again the amount of water on the surface to get the bleeding suffered by the specimen. The top surface of concrete subsides during bleeding causing what is known as “plastic shrinkage”.

The total amount of bleeding is calculated as a percentage of the initial weight. Based on the research of Lachemi and friends(2009) that using the design and application of CLSM book as a reference , 2% is taken as the suggested maximum limit of the bleeding. In this project, the apparatus for testing the stability, the 1000 pyconometer was used as a simple apparatus to observe the bleeding instead of box apparatus. As well as other material, trial mix and observation is a must to do to get the optimum content of the intended mixture.

Segregation is when there some separation of coarse aggregates from the mixture mass during the handling of this mixture. There is no standard procedure developed for measuring segregation (Concrete Admixture Handbook, 1995). But we can visually observe during the handling, placing and finishing operations. In this research, we can observe when conducting flowspread test and the final product. Segregation may lead to honeycombing occurs as an example.

The primary cause of segregation is the differences in the size of particles and the specific gravity of the mix. The high water content impacts to high flowability, reduction in cement content, or increase in the maximum size of amount aggregate leading to the risk of segregatation. By proper grading of the constituent and handling, this problem can be controlled.

2.3.6. Permeability

Most of excavatable CLSM is similar to compacted granular fills. Mixtures of higher strength and higher fines content of CLSM can achieve low permeability. Permeability is increased when the cementing material is reduced and aggregate content is increased. In this research, no evaluated mixture with its permeability was observed.

2.4. Typical Materials of CLSM

Typically constituents of CLSM contributed by cement, aggregate, water and can be added with some admixtures depends on our desired properties. For the mix proportion itself, none of the standard composition of the CLSM is established. This means, that trial mixtures are needed to determine how well the material meet the general properties of CLSM. Some modification or adjustment then made to achieve those properties.

The table below describes some CLSM producers with their own suggested recipe of mix proportion.

Dosage(kg/m^3)	LCPC	Eurovia	K-Krete	ACI
Sands	816 kg/m^3	861-923 kg/m^3	1305-1661 kg/m^3	1542-1839 kg/m^3
Gravels	1015 kg/ m^3	795-851 kg/m^3	-	-
Cement	140 kg/ m^3	124-133 kg/m^3	24-119 kg/ m^3	29-118 kg/m^3
Water	230 kg/ m^3	333-571 kg/m^3	0,35-0,40 m^3	192-344 kg/m^3
Cementitous	-	-	Fly Ash : 166 -297 kg/m^3	Fly Ash: Max 207 kg/m^3
Admixtures	-	Fibre Synthetique	-	-

Table. 2.2 Producers of CLSM

2.4.1. Cement

Cement is produced from an appropriate combination of a lime-containing material, such as limestone or chalk (calcareous component), and clayey material (the argillaceous component) by burning this mixture and grinding the resulting clinker with the small amount of gypsum. It is not a must to apply cement in the CLSM. But adding cement will provide the cohesion and strength for CLSM mixture. Cement also increases the segregation resistance.

The cement used in this research was type Portland Cement. This is the most common type of cement in general use around the world. Popovics defines Portland Cement is a hydraulic cement which refers to a powdery material that reacts with water and, as a result, produces a strong as well as water-insoluble solid. This material can be made plastic and gradually hardens to form an artificial stone-like material (Concrete Materials 1921).

2.4.1.1. Properties of Cement Portland

The raw materials of portland cement consist principally of limestone or chalk (calcareous component) as the principal source of CaO and clay (argilleous component) as the principal source of SiO_2, Al_2O_3 and Fe_2O_3. Typically tiny portland cement grain consists of a numerous microscopies crystals called clinker minerals which is called cement compounds. Three of fourth of clinker mineral is calcium silicate and the rest is calcium aluminate.

Four compounds can be considered as the four major constituents based on Le Chatelier's research publication 1905 in portland cement clinker recognized (Concrete Material Popovic 1992).

They are:

Name:	Composition:	Symbol:
Tricalcium Silicate	3CaO.SiO2	C3S
Dicalcium Silicate	2CaO.SiO2	C2S
Tricalcium Aluminate	3CaO.Al2O3	C3A
Tetracalcium Aluminoferrite	4CaO.Al2O3.Fe2O3	C4AF

The calcium silicates give the cement its hydraulic character the property hardening by reaction with water.

2.4.1.2. Types of Cement

For the application of concrete has been, it is necessary to produce Portland cement with different properties. The producers create the type of the Portland cement to answer the need of the construction specific treatment. Basically, they are all having the same constituents that only the proportions differentiated.

In Europe, generally cement Portland produced into three type of properties:

1. For general use as ordinary Portland cement,
2. For high-early strength as rapid-hardening Portland cement, and
3. Improved sulfate resistance as sulfate-resistance Portland cement.

Following the ASTM C-130, five main types of Portland cement are recognized, they are:

Type I : For use in general concrete construction.

Type II : To increase resistance of sulfate attack and decrease heat evolution.

Type III : For use when high-early strength required.

Type IV : For use when a low-heat of hydration is required.

Type V : For use when high sulfate resistance is required.

2.4.2. Aggregates

The major constituent of a CLSM mixture is often contributed by aggregates (sands and gravels). The type, grading and shape of aggregates can affect the physical properties such as flowability and compressive strength. Kou,Poon research (2009) concluded that the recycled material can be used for self-compacting concrete production, increasing the recycled fine aggregate showed the increasing of flowability. Moreover, the quality of recycled aggregates is generally inferior to the natural aggregates. They have lower strength than natural aggregates. Viewing their property, invoving recycled aggregates as the material for CLSM may be developed by other interested researcher regarding for environmental.

Lachemi et al. (2009) avoided incorporating the coarse aggregates on their research properties of CLSM incorporating cement kiln dust and slag. They assume that the incorporation of coarse aggregate will give CLSM a difficulty to excavate even at low strength. Other reasonable is the adequate presence of fines provides suitable cohesiveness for high flowable CLSM without segregation.

For this research the aggregates material from laboratory were used as raw material for CLSM.

2.4.2.1. Classification Aggregates

Aggregate distinguished into between fine aggregate, consisting of mostly small particle, and coarse aggregate, consisting of mostly large particle. By the resources, it is classified into natural aggregate and manufactured aggregate (Popovic 1920).

France Regulation NF P 98-331 defines the dimension maximum (D) of the aggregates for CLSM are classified into two types:

1. For the Embankment, either for Lower Backfill or Upper Backfill:
   - D< 1/10 of the trench large.
   - D<1/5 of the thickness of compacted layer.
2. For the area of Embedding:
   - D ≤ 22 mm for the pipelines with Ø ≤ 200 mm.
   - D ≤ 40 mm for the pipelines with Ø ≥ 200 mm

2.4.2.2. Sieve Analysis

Sieve analysis was conducted to analyze the gradation of fine and coarse aggregates. The result of the sieve analysis is to know that the gradation should comply with the standard granulation of the aggregates. Good gradation will bring the optimum density and maximum strength.

Determination of the granulation comply EN 9331-1, with sieve size analysis between 0,063 and 20mm.

The sieve size number used in sieve analysis as below:

Sand : No. 5; 4; 3,15 ;2,5; 2; 1,6; 1,25; 1; 0,8; 0,63; 0,5; 0,315; 0,25; 0,2; 0,16; 0,125; 0,1; 0,08; 0,063 in mm..

Gravels : No. 12,5; 10; 8; 6,3; 5 in mm.

ACI stipulated that aggregate gradation complying with ASTM C 33 specification may be used in CLSM, which is:

- **Fine Aggregate (sands)**

  Fine Aggregate shall consist of natural sand, manufactured sand, or a combination thereof.

  Fine Aggregate shall be graded within limit following:

Sieve	Percent Passing
9,5-mm	100
4,75-mm	95 to 100
2.36-mm	80 to 100
1,18-mm	50 to 85
600- µm	25 to 60
300- µm	5 to 30
150 -µm	0 to 10

Table. 2.3 Gradation Limit of Fine Aggregate

- **Coarse Aggregate (gravels)**

  Coarse Aggregate shall consist of gravel, crushed gravel, crushed stone, or a combination thereof.

  Coarse Aggregate shall be graded within limit following:

Sieve	Percent Passing
19,0-mm	100
12,5-mm	90 to 100
9,75-mm	40 to 70
4,75-mm	0 to 15

Table. 2.4 Gradation Limit of Coarse Aggregate

2.4.3. Water

Water that is acceptable for concrete mixture is acceptable for CLSM mixtures. Water has a three general function when incorporated in mixtures, they are : 1. As mixing water to have a chemical reaction with cement; 2. For curing and 3. For washing.

The mixing water shall be clear and apparently clean. It shall not be used when it contains quantities of substances which discolor it or make it smell or taste, for it may reduce the quality of mixture. Water has to be free from sugar, tannic acid, vegetable matter, oil, and sulfates, may interfere with the hydration of the cement, thus delaying setting and reducing the strength of the concrete(Popovic 1920). The use of non-fresh water will yield lower compressive strength in comparison with tap water. This can be a new potential of next research by using non-fresh water to be added in CLSM mixture (Al-harthy, Taha, 2003) since it requires a low strength property.

2.4.4. Fly Ash

2.4.4.1. General

Fly ash is the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses. This is classified as by-product for the resource it has a benefit and can be applied to another application such as constituent of CLSM. Fly ash has the hydraulic behavior influenced by its carbon and silica content and the fineness.

For the CLSM, this material is used to improve flowability. This may also increases strength and reduces bleeding, shrinkage and permeability. For its pozzolanic (cementing) property, this material can substitute the application of cement or incorporated together in the mixture.

Two kinds of Fly ash are produced from combustion of coal:

- **Class C –** High, more than 10% calcium content, derived from sub-bituminous coal. The use of this class may or may not extend setting time and there are results that show reduction of setting time.

Content of Class C : (SiO_2 + Al_2O_3+Fe_2O_3) > 50 %

- **Class F** – Low, less than 10 % calcium content, derived from bituminous coal. The use of this class may retard the setting time of concrete.

  Content of Class F : (SiO_2 + Al_2O_3+Fe_2O_3) > 70 %

The effect of fly ash in fresh concrete can improve the workability and pump-ability because of the increase of paste content, increase in the mount of the fines and spherical shape of the fly ash particle (Popovic 1920).

Along with the cementing property that fly ash has, which can substitute the role of the cement, application of the fly ash has the benefit for reducing cost on cement exploitation, also minimize the environmental hazard caused by unused fly ash product.

2.4.4.2. Properties

Fly ash has the chemical and physical properties. Chemical properties are the carbon and silica content includes pozzolanic activity. Higher unburned carbon content of fly ash may increase the water demand. The majority of fly ash particle are spherical in shape. Modern ashes are typically finer than ashes collected in the past.

Physical properties, most size of the fly ash pass the no.325 (45µm) sieve.

2.4.5. Admixtures

The RILEM **(Reunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions)** defines admixtures as inorganic (including minerals) or organic materials in solid or liquid state, added to the normal components of the mix, in most cases up to a maximum of 5% by weight of the cement or cementing materials. Materials such as fly ash, slag, pozzolans or silica fume which can be constituents of cement or concrete, and also products acting as reinforcement, are not classified as chemical admixtures(Concrete Admixture Handbook).

The ASTM C 125 states a concrete admixture or additive is referred to as “a material other then water, aggregates, hydraulic cement , and fiber reinforcement used an ingredient of concrete or mortar and added to the batch immediately before and during mixing.”

Irving Kett (Engineering Concrete Book) defines the categories of admixtures as follow:

2.4.5.1. Air Entraining Agents

This is the oldest and probably the most valuable of all mixtures. Beside the workability advantage, this is primarily utilized to resist the frost. The usual method for producing air-entrainment is to add a foaming agent prior to mixing.

2.4.5.2. Chemical Admixtures

Seven types of chemical admixture recognized, A to G, they are:

– Type A is a water-reducing admixture which as the name implies requires a lower w/c to obtain a desired concrete slump.
– Types B and C are retarding and accelerating admixtures respectively. As the designations imply they either slow down or speed up the initial set and the final hardening of the fresh concrete.
– Types D and E are combined water reducers as well as retarding and accelerating admixtures. In other words Type D is a combination of Types A and B admixtures while Type E combines the characteristics of Types A and C admixtures.

– Type F is a high-range water-reducer, often referred to as a "superplasticizer" which is required to lower the water requirement of the concrete.

– Type G is a combined superplasticizer and retarding admixture.

2.4.5.3. Mineral admixtures

These admixtures are composed of fine solid particles that are added to the concrete mix to improve workability, durability, and to provide additional cementitious materials at a lower cost than portland cement. Materials included in this category are fly ash, silica fume, and pozzolans. Finely ground slags also are included in this class of substances. These mineral admixtures are likewise, in many cases, the waste products of other industrial activities, often associated with coal burning. This is part of a process in which engineers are increasingly recycling existing structures and utilizing materials formerly considered suitable only for disposal to advantage.

2.4.5.4. Miscellaneous admixtures

These do not fall under either of the above categories which have been developed for special purposes. These include such diverse applications as grouting, bonding, as well as corrosion inhibitors to reduce rust formation in reinforcing steel.

2.4.6. Superplasticizer

Superplasticizers as above categorized as type G has been usually applied in purpose to increase the flowing property of the concrete. This was first introduced in Japan late 60's and Germany early 70's. The other advantage of using super-plasticizer is material will have a good workability for easy placement, and producing high strength concrete with normal workability (Ramachandran and Malhotra 1984).

The flowabilty achieved by the property of the superplasticizers that its ability to disperse the cement particles.

Superplasticizer are linear polymers containing sulfonic acid groups attached to the polymer backbone at regular interval (Verbeck 1968).

There are four groups most classified of Superplasticizer:

1. Sulfonated melamine-formaldehyde condensates (SMF).
2. Sulfonated naphtahalene-formaldehyde condensates (SNF).
3. Modified lignoslfonates (MLS).
4. Polycarboxylate derivatives.

The Sulfonic acid groups are responsible for neutralizing the surface charge on the cement particles and causing dispersion, and releasing water tied up in the cement particle agglomeration and thereafter reducing viscosity of the paste and concrete (Mindness and Young 1981). Excessive amount of Superplasticizers application in mixture may produce undesirable effects such as bleeding, segregation and low strength in concrete. Therefore, trial mixing to get the optimum suggested dosage as well as other materials is highly recommended to meet the intended application.

One of the mixture observed applied the superplasticizer category Polycarboxylate derivatives (number 4). It is a fiber polymer product of SIKA. This material is proposed by EUROVIA aims to reduce the cracking occurred.

2.4.7. Other Raw Materials for CLSM Concerning Sustainable Development

Some researchers have conducted several researches by using waste material or by-product as raw material for CLSM. Due to the global issue of world change climate, many engineers are encouraged to find the new method of construction as the substitute of the conventional material. Ecology conservation, energy and cost saving are emphasized in this case.

Investigating recycling waste material has been taking place to find the appropriate reusable waste from industrials, constructions and demolitions. The waste materials produced by manufactures which can be reusable for certain applications classified as by-products. Fly ash is one of a by-product material which has been mentioned above.

Bottom ash is another by-product material of coal combustion as well as fly-ash. Bottom ash is formed by large noncombustible particles that cannot be carried by hot gases. This is collected from the bottom of the furnace burning coal in power plants. Bottom ash particles are typically porous and angular in shape. Razak et al.(2009) used bottom ash as material to produce CLSM. Their investigation found successfully that bottom ashes are suitable for CLSM with the strength in the range of 0,125 – 1,731 MPa which meant their designed mixes are excavatable.

Other variant of by-products is CKD (Cement Kiln Dust) had been investigated by some researchers. CKD is finely divided, dry particulate material carried out from a cement kiln by exhaust gases, and captured by the kiln's air pollution control system. The compositions of CKDs are similar to that cement as they contain alumina, silica, calcium oxide, alkalis and sulfates. Lachemi et al. (2009) quoted from Al–Jabri study that CLSM incorporated with the 296kg/m^3 CKD without cement shows the satisfactory strength at 28th days with 1.04 Mpa. They studied the potential combination CKD with slag to replace the use of cement. Slag is a by-product of metal smelting in the process of refining metals. They found that the CKD-based mixtures displayed excellent flow properties. But the increase of incorporating of slag with constant CKD, the strength was also increased. Therefore, they propose the content of slag should be less than 50 kg/m^3 and keep the CKD in 200 kg/m^3.

The other case of waste material studied by researcher is LCD front panel. LCD is typically applied as monitor of television and computer. Since Taiwan has been the world's leading manufacturer of TFT-LCD panel production account approximately 39,2% of the total world output. Large amount of waste in the form of by-products is produced during the manufacturing process. This had become a threat to natural resources and ecosystem problem in Taiwan. Research work had been undertaken to manage this waste problem by finding its possibility to be a material of CLSM. Wan her-Yung observed that adding waste LCD glass into CLSM meet the engineering property requirement including high fluidity up to 410 mm and low strength 2.40 MPa. The observation stated that increasing of incorporating of LCD glass replacing the sand in ratio of 0%, 10%, 20% and 30% will decrease the strength of CLSM. This study is not only offering an economical for substituting the fine aggregates (sands) but also it has been an alternative way to the management of waste LCD glass, thus contributing to the pursuit of sustainable development.

Incorporating sludge Acid Mined Drained (AMD) and fly ash used in CLSM has been also investigated by Gabr and Bowders. Acid mine drainage (AMD), or acid rock drainage (ARD), refers to the outflow of acidic water from (usually abandoned) metal mines or coal mines. Sludge is a lime-based waste product that when combined with fly ash, exhibit self-hardening characteristics similar to cement. They recommend the mix ratio for satisfaction of excavatability requirements as well as the hardening time and stability criteria is 10% AMD, 2,5% PC, 87,5% FA with water content 40%.

CHAPTER 3

METHOD OF RESEARCH

3.1. Plan of Laboratory Research

Regarding to our object of this research is studying the review of CLSM, is also to evaluate the few recipe samples from CLSM producers. They are recipes of LCPC (Laboratoire Central des Ponts et Chausseres, Centre de Nantes) and Eurovia were obtained by conducting a several tests to get their general properties of CLSM. Both are French companies which have produced the recipe for CLSM. Observation by testing their recipes were made and should the undesirable properties found, modifications of recipes were necessary to take in order to meet the desired properties.

The process of evaluation of CLSM as presented below.

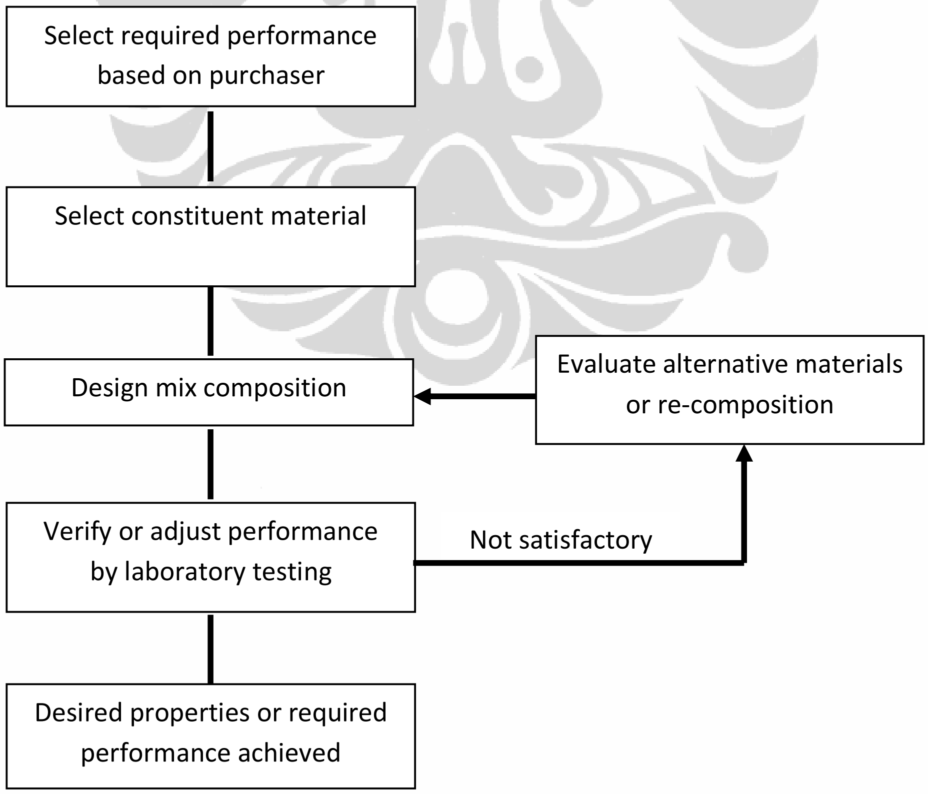


Figure 3.1 Process of CLSM Evaluation

3.2. Site of Research

The research conducted in Laboratory of Faculte Science d'Applique (FSA) , Universite d'Artois, Bethune – France.

3.3. Referenced Standards and Tools of Research

Research by literature review and laboratory conducted in conforming standard referenced and using the standard laboratory equipment following:

1. French Regulation (Norme de France);
2. European Regulation (Norme d'Europeen);
3. American Concrete Institute (ACI);
4. American Society of Testing Materials (ASTM).

3.4. Standards Material Test

1. Sieve Analysis: EN 933-1 and 933-2
2. Density of Fine Aggregate: EN 1097-6
3. Slump Flow Spread Test: EN 12350-2
4. Immediate Bearing Ratio (Index Portance Immediat): NF P 94-078
5. Compressive Strength: EN 12390-3
6. Stability Test: The Design and Application of CLSM, ASTM International 1998

3.5. Testing Tools and Equipments

The general tools were used on the tests in the laboratory:

No.	Name / Function	Mark
1.	Weight Scale	Bioblock Scientific
2.	Sieve Set	Controlab
3.	Sieve Shaker	Controlab
4.	Slump Apparatus	Controlab
5.	Pycnometer	Vit Lab
6.	Mixer	FSA Lab.
7.	Oven	FIRLABO
8.	Capping Set	Controlab
9.	Cylinder Rigid (15x20)cm	FSA Lab.
10.	Cylinder Non Rigid (11x22)cm	FSA Lab.
11.	Stopwatch	Controlab

Table 3.1 Testing Tools and Equipments

3.6. Raw material of CLSM

Raw materials of **CLSM** used in research:

a. Cement

- Type : CEM I 52,5 R CE CP2 NF
- Brand : HOLCIM
- Source : Laboratory of FSA

b. Fine Aggregate

- Type : Natural Sands (0/5)
- Source : Laboratory of FSA

c. Coarse Aggregate

- Type : Split Gravel (5/20)
- Source : Laboratory of FSA

d. Water

- Type : Tap Water
- Source : Laboratory of FSA

e. Cementing / Pozzolanic

- Type : Fly Ash Class C
- Source : Laboratory FSA

f. Admixtures

- Type : Fiber Polypropylene
- Brand : SIKA
- Source : Laboratory FSA

3.7. Properties of Aggregates

The Properties of aggregates complying with EN 331, three tests were conducted as follow:

3.7.1. Sieve Analysis

- **Fine Aggregate**

  1. Principle

To determine the granulation of the material which has the dimension between 0,063 and 9,5 mm.

2. **Equipments and Materials**
    - Balance scale.
    - Sieve set and pan.
    - Sieve shaker.
    - Fine Aggregate 1000 gr.
3. **Test Procedures**
    - Arrange the sieve set according to the required dimension.
    - Place all the sequenced sieves set on the sieve shaker.
    - Pour the material into the sieve.
    - Start the sieve shaker machine.
    - Shake the material for 1 minute.
    - Weight all the rejected material from each of the sieve.
    - Calculate all the rejected as well as the passing cumulative percentage.
    - Draw the curve of the passing percentage and compared with the standard gradation of the aggregate.

- **Coarse Agregate**
    1. **Principle**

       To determine the granulation of the material which has the dimension between 0,063 and 19 mm.
    2. **Equipments and Materials**
        - Balance scale.
        - Sieve set and pan.
        - Sieve shaker .
        - Gravel 1500 gr.
    3. **Procedures:** same procedures with fine aggregate.

Figure 3.2 Sieve Analysis Test

3.7.2. Mass Volume Absolute and Apparent

3.7.2.1. Mass Volume Absolute and Mass Volume Apparent of Sands (EN 1097-6)

1. Principle

This test method provides the determination of the Mass Volume Absolute (ρ_{abs}) and Mass Volume Apparent (ρ_{app}) of the sands.

2. Mass Volume Absolute

2.1. Equipments and Materials

- 1000 ml Pycnometer.
- Balance scale.
- 200 grams of sands.

2.2. Test Procedures

- Pour the water into the pycnometre around half of one liter and measure its weight.
- Put the 200 grams of sands into the pycnometre, shake a bit to eliminate the bubbles inside and measure its weight.

- Make three times of test to have an average volume absolute of sands.

2.3. Expression of results

The volume absolute achieved by formulation :

$$y = \frac{Ms}{(N2 + Ms - N1)}$$

Where: Ms = dry weight of sands (gr)
N2 = weight of water in pycnometre
N1= weight of water and sands in piycnometre

3. Mass Volume Apparent of Sands

3.1. Equipments and Materials

- Rigid cylinder 18x18,7 cm.
- Metal Tamping Rod.
- Funnel.
- Sands.

3.2. Test Procedures

- Pour in the sands into the cylinder through the funnel neither too fast nor too slow with the interval of surface around 10 cm from its fall.
- Fill it layer by layer and make sure the sands spreading all on the surface to get more density.
- Measure the weight of cylinder with sands inside.
- Do the test three times to get the average of mass volume apparent of the sand.

3.3. Expression of Results

The volume apparent achieved by formulation:

$$yapp = \frac{Ms}{V\ app}$$

Where:

Y app = mass volume apparent (gr/cm^3)
Vapp. = volume apparent (cylinder volume)

3.7.2.2. Mass Volume Absolute and Mass Volume Apparent of Gravel (EN 1097-6)

1. **Principle:** This test method provides the determination of the Mass Volume Absolute (ρ_{abs}) and Mass Volume Apparent (ρ_{app}) of the gravel.
2. **Mass Volume Absolute**

2.1. Equipment and Materials

- Oven
- Suitable balance and apparatus for suspending sample in water / Hidrostatique balance scale.
- Gravel around 8 kg of weight.

2.2.Test Procedure

- Select by quartering or use of a sample splitter approximately 8 kg of aggregate.
- Thoroughly wash the sample to remove all dust or other coatings from the particles.
- Dry the sample to a constant weight at a temperature of 100 to 110°C (212 to 230°F).
- Cool at room temperature for about 15 min. and then immerse in water at room temperature for approximately 30 min.
- Weigh the sample in this saturated surface dry condition to the nearest 0.5 g.
- Immediately after weighing, place the sample in a wire basket, suspend in water, and obtain the buoyant weight.

- Remove sample from basket and wipe the particles until all wet surface are removed and obtain the weight.

2.3.Expression of results

- A = Weight of oven-dry sample in air (g)
- B = Weight of saturated-surface-dry sample in air (g)
- C = Weight of saturated sample in water (g)
- Bulk specific gravity (oven-dry) = $\frac{A}{B} - C$
- Bulk specific gravity (SSD) = $\frac{B}{B-C}$
- Apparent specific gravity = $\frac{A}{A-C}$
- Absorption in percent = $\frac{(B-A)X100}{A}$

3. **Mass Volume Apparent:** this test procedure is the same as the mass volume absolute of sand.

Figure 3.3 Mass Volume Apparent Test

3.8. Evaluated Mix Composition of CLSM

Determination of Mix Composition

For the reason of insufficient time for executing more numbers of trials, only five mix designs were conducted as follows:

3.8.1. This is the mixture recipe from **LCPC (Laboratoire Central des Ponts et Chausses)** with the formule name MACES 140. Mixture Code = Mix#1.

Dry Content	Dosage (kg/m^3)	Dosage in 20L	%
Sand	816	16,32	42,19
Gravel	1015	20,30	51,78
CPA-CEM 152,5 R	140	2,80	6,03
Water	230	4,60	31,21
w/c ratio= 1,64			

Table 3.2. Mix Design No.1

3.8.2. Second mix is the modified mix#1 mixture of **LCPC.** 140 dosage of cement was reduced into 70, and replace its volume by adding gravel. Mixture Code = Mix#2.

Dry Content	Dosage (kg/m^3)	Dosage in 20L	%
Sand	816	16,32	42,19
Gravel	1074	21,48	54,80
CPA-CEM 152,5 R	70	1,40	3,02
Water	230	4,6	31,21
w/c ratio= 3,29			

Table 3.3 Mix Design No.2

3.8.3. This is the modified mixture from 2nd mix composition, reducing the 70 dosage of cement into 20, and replace its volume by adding 20 of fly ash and the rest is sand. Mixture Code = Mix#3.

Dry Content	Dosage (kg/m^3)	Dosage in 20L	%
Sand	837,5	16,75	43,30
Gravel	1074	21,48	54,80
CPA-CEM 152,5 R	20	0,40	0,86
Water	230	0,40	1,04
Fly Ash	20	4,6	31,21
w/c ratio = 11,50			

Table 3.4 Mix Design No.3

3.8.4. The 4th composition is to evaluate the mix composition by **EUROVIA** that proposes adding fibre as a superplasticizer and 40% up to 50% range content of water. 50% was taken for the first trial mix. Mixture Code = Mix#4.

Dry Content	Dosage (kg/m^3)	Dosage in 20L	%
Sand	861,5	17,20 kg	48,36
Gravel	795,1	15,87 kg	44,64
CPA-CEM 152,5 R	124,7	2,49 kg	**7,00**
Water	333,1	6,65 kg	**50,00**
Fiber Synthetique	0,012	12 g	
w/c ratio = 2,67			

Table 3.5 Mix Design No.4

3.8.5. The 5th composition was the same reference to **EUROVIA** mix recipe, but the content of water reduced from 50% to 40 %. Mixture Code = Mix#5.

Dry Content	Dosage (kg/m^3)	Dosage in 20L	%
Sand	923	18,44 kg	48,36
Gravel	851,8	17,02 kg	44,64
CPA-CEM 152,5 R	133,6	2,67 kg	**7,00**
Water	285,7	5,70 kg	**40,00**
Fiber Synthetique	0,012	12 g	
w/c ratio = 2,14			

Table 3.6 Mix Design No.5

Figure 3.4 Fly Ash Class C

Figure 3.5 Fiber Synthetic

3.9. Procedures of Specimens Molding

- Obtain all the aggregates as mix proportion required.
- Prepare six un-rigid cylinder 11x22cm to cast the mixture for strength test.
- Prepare one rigid cylinder to cast the mixture for IPI test.
- Prepare 1 liter pycnometer for stability test.
- Prepare 1 liter plastic cylinder for density of specimen.
- Place the Fine Aggregate and Coarse Aggregate into the mixer. Mix both of aggregates in one minute.
- Add in the 10% of total water required and mix for a minute.
- Stop the mixer machine and let the mix rest for 10 minutes.
- Then place in the powder /cement or combination with fly ash if any and mix for 1.5 minutes.
- Place in all the remains water into the mixer for one minute during the mixing is taking place.
- Mix for 30 seconds and stop the mix machine.
- Place in the fresh mix or specimen into the bucket about 5 liter do the slump flow spread test (see slump flow spread test).
- Place in the fresh mix into the rigid cylinder. Cover the surface with plastic material and the specimen for 24 hours test of IPI (see filling method of LCPC).
- Place in the fresh mix into the plastic cylinder for determine the density of specimen (see density test).
- Place in the fresh mix into the six un-rigid cylinder cast. Three of them are prepared for 7th day and the rest for 28th strength test. Keep in the room temperature.
- When the all specimens have reach the hardened state at 7th day, first three will be tested on compressive strength and the other three specimens are immersed in the water for the next strength test of 28th day.

- Place around 50 ml of fresh into the 1liter pycnometer to do the stability test (See the stability test).

Figure 3.6 Casting Specimen 11x22 cm for Compressive Strength

Figure 3.7 Casting Specimen 15x20 cm for IPI Test

3.10. Implementation of the Tests

3.10.1. Filling method of LCPC

Principle

This method is adopted from LCPC test as a procedure to fill the rigid cylinder mold prepared for IPI test. The Abraham cone was utilized as the funnel to pass the fresh mix filling through down the rigid cylinder mold. The height of the surface from the base of Abraham cone is 20 cm.

Equipment and Materials

- Mold / CBR Cylinder (rigid metal) with volume: 10 x 20 cm.
- Abraham cone 100x300 mm.
- Fresh mixture of CLSM
- Bucket for transferring the fresh mix from mixer into the CBR rigid cylinder.

Procedures

- After taking the density of fresh mix and conducting the flow spread test, fill the bucket with the fresh mix immediately and fill it into the rigid cylinder mold by passing through the abraham cone.
- Before filling the CBR rigid cylinder, the fresh mix that already placed in the abraham cone should be suspended by holding the flow of the mix at the base of the cone. After few seconds of filling the Abraham cone, open the flow quickly and observe the flow filling of the material into the cylinder.

Expression of Results

There is no quantity result of this method. This is just only a visual observation that how good is the filling flow of the material into the CBR cylinder. Usually if it has been already in a good flowability that it will also has a good flow of filling into the cylinder. This filling observation shall indicate the workability of the mixture in place and how the material acts as a self compacting material.

Figure 3.8 Filling Method

3.10.2. Fresh CLSM Test

3.10.2.1. Slump Flow Spread Test

1. Principle

The slump flow test aims at investigating the filling ability of CLSM. It measures flow spread which indicates the free, unrestricted deformability.

2. Equipment and Materials

- Base plate of size at least 900 × 900 mm, made of impermeable and rigid material (steel or plywood) with smooth and plane test surface, as shown in Figure 3.5.
- Abrams cone with the internal upper/lower diameter equal to 100/200 mm and the height of 300 mm, as shown in Figure X.
- Ruler (graduated in mm) for measuring the diameters of the flow spread.

- Bucket with a capacity of larger than 6 liters for sampling fresh concrete.
- Moist sponge or towel for wetting the inner surface of the cone and the test surface of the base plate.
- Rag for cleaning spilled concrete if any.

3. Test procedure

- Place the cleaned base plate in a stable and level position.
- Fill the bucket with 6~7 litres of representative fresh CLSM.
- Place the cone in the centre on the 200 mm circle of the base plate. The cone is kept in position by hand pressing.
- Fill the cone with the sample from the bucket without any external compacting action such as rodding or vibrating. The surplus concrete above the top of the cone should be struck off, and any concrete remaining on the base plate should be removed.
- Check and make sure that the test surface is neither too wet nor too dry. No dry area on the base plate is allowed and any surplus of the water should be removed – the moisture state of the plate has to be 'just wet'.
- 3.6 After a short rest (no more than 30 seconds for cleaning and checking the moist state of the test surface), lift the cone perpendicular to the base plate in a single movement, in such a manner that the concrete is allowed to flow out freely without obstruction from the cone.

- Measure the largest diameter of the flow spread, *d*max, and the one perpendicular to it, *d*perp, using the ruler (reading to nearest 5 mm). Care should be taken to prevent the ruler from bending.
- Clean the base plate and the cone after testing.

4. Expression of results

The slump flow spread *S* is the average of diameters *d*max and *d*perp, as shown in Equation (1). *S* is expressed in mm to the nearest 5 mm.

$$S = \frac{(dmax+dperp)}{2}$$

Figure 3.9 Slump Flow Test Equipment

3.10.2.2. Density of CLSM

1. Principle

To determine the density of fresh CLSM specimen.

2. Equipments and Materials

- Balance scale.
- 1 liter volume plastic cylinder.
- Fresh Specimen right after mixed.

3. Test Procedures

- Place in the fresh mixture into the 1 liter volume plastic cylinder.
- Measure the weight of plastic cylinder filled by fresh mixture.
- Calculate the net Density of fresh CLSM in kg/l.

Figure 3.10 Weighing Density of Fresh CLSM

3.10.3. Hardened CLSM Test

3.10.3.1. Immediate Bearing Ratio / IPI test of 24 hours

1. **Principle**

   This test method provides the determination of the Immediate Bearing Ratio / Indice Portant Immediat in percentage using the CBR machine test. It measures the efforts applied on the cylinder punch to penetrate the specimen with constant speed.

2. **Equipment**

   - Mold / CBR Cylinder (rigid metal) with volume: 10 x 20 cm.
   - CBR Test Machine.
   - Gages –Two dial gages, one for load and other for penetration measure, reading to 0,01 mm.

3. Test procedure

- Place the specimen in a stable and level position with surface touch the penetration piston.
- Place the gage dial reading for depth of penetration and loading charge on zero position.
- Apply the load on the penetration piston so that the rate of penetration 1.27 mm/min.
- Record the loading at penetration 0,625; 1; 1,25; 2; 2,5; 3; 3,5; 4; 4,5; 5; 5,5; 6,5; 7; 7,5; 8; 8,5; 9; 9,5; 10.
- Calculate the penetration effort represented by gauge dial reading and conform to the conversion reference.
- The index of IPI achieved by calculating the penetration effort by using formula as described in point 4.
- Plot the stress-penetration curve.

4. Expression of results

The IPI test has the equation as below:

$$\frac{Effort\ of\ the\ penetration\ at\ 2{,}5\ mm\ depth\ (in\ kN)}{13{,}35} \times 100$$

$$\frac{Effort\ of\ the\ penetration\ at\ 5\ mm\ depth\ (in\ kN)}{19{,}93} \times 100$$

a. The IPI is taken from the higher one of the both penetration (2,5 and 5 mm).

b. 13,35 kN and 19,93 kN is the achieved value of the conventional material penetration used as a reference in depth for 2,5mm and 5 mm respectively.

Figure 3.11 CBR Test Machine

3.10.3.2. Stability Test

1. **Principle**

   This test method provides the determination of the stability of CLSM. This test aims to see the bleeding quantity occurred. A 1000 ml pyconometer was used around 500 ml of fresh mixture was placed within.

2. **Equipment and materials**

   - 1000 ml Pyconmeter.
   - 500 ml of fresh mix.
   - Plastic for covering the pcynometer.

3. **Test procedure**

   - Obtain 500 ml of fresh mix from mixer and place in to the pycnometer.
   - Cover the top with the plastic.
     - Keep in room temperature.

- Observe the pond of water on the surface of the specimen to see the bleeding after few minutes the next 24 hours respectively through the scale of pyconmeter.

4. Expression of results

Calculate percentage of the bleeding by using the formula below:

$$s = \frac{vp}{vs} x\ 100\%$$

S= percentage of bleeding

vp= volume of water ponds on the surface of specimen (ml)

vs = volume of initial total specimen (ml)

Figure 3.12 Stability Test

3.10.3.3. Compressive Strength Test (EN 12390-3)

1. Principle

This test method provides the determination of the Compressive Strength of a cylinder cast material of specimen using the compressive test machine. This measures the strength resistance against the loading press. This test applied on the 7th and 28th age of specimens.

2. Equipment and materials

- Mold /Cylinder non rigid with volume: 11x22 cm.
- Testing machine capable of applying load continuously at the rate of 5 kN/s.
- A desktop computer set connected with testing machine to run and control the testing parameter.
- Sulfur capping kit for capping the specimen.
- Three of hardened molded specimen (7th and 28th age).

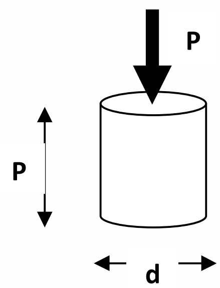
3. Test procedure

- Remove the hardened specimen from its cylinder cast.
- Then layer the surface of the specimen with sulfur capping material to have the smooth and plan surface on the both side of specimen using the capping kit.
- Place capped specimen in a stable and level position in the testing machine.
- Apply the test with the loading speed 5kN per second by commanding the stress software from computer.
- Read the result from computer that indicates the maximum strength that the specimen can resist.

4. Expression of results

Formula of stress resistance:

$$\sigma = \frac{P}{A} = \frac{P}{\frac{1}{4}\pi\, d^2} \quad (kN/cm^2)$$



Where: σ = stress (kN/cm^2) / Mpa; (1MPa = $1N/m^2$)

A = Large of the specimen surface;

d = diameter of the specimen.

Figure 3.13 Compressive Strength Machine

CHAPTER 4

TESTS RESULTS

This chapter contains of results of five mixes evaluation presented by tables, figures and graphics.

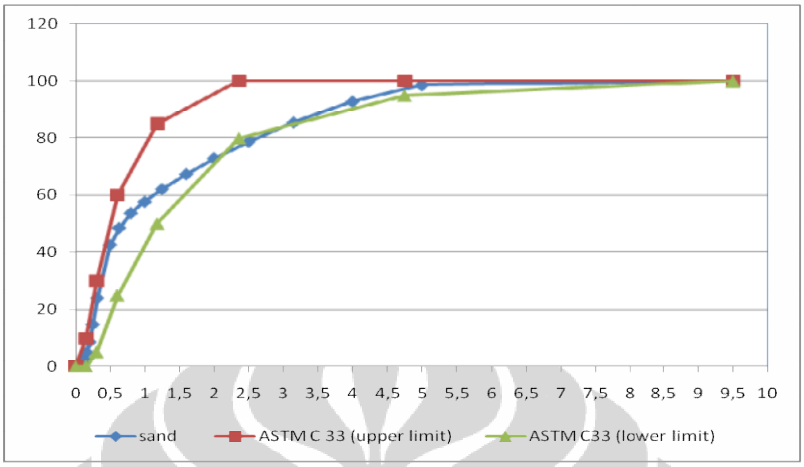
4. 1. Sieve Analysis

4.1.1. Fine Aggregate (sands) 1000 gram

Bellow is the result of sands sieve analysis and gradation.

Sieve (mm)	Rejected Weight	Rejected Cumulative (%	Passing Sieve Cumulative (%)
5	13,5	1,36	98,64
4	70,3	7,06	92,94
3,15	144	14,47	85,53
2,5	211,4	21,24	78,76
2	269,4	27,07	72,93
1,6	324,7	32,62	67,38
1,25	376,9	37,87	62,13
1	421,3	42,33	57,67
0,8	460,4	46,26	53,74
0,63	513	51,54	48,46
0,5	571,6	57,43	42,57
0,315	756	75,96	24,04
0,25	848,5	85,25	14,75
0,2	909,9	91,42	8,58
0,16	946,7	95,12	4,88
0,125	968,5	97,31	2,69
0,1	983	98,76	1,24
0,08	988,9	99,36	0,64
0,063	992,6	99,73	0,27
pan	995,3	100,00	0,00

Table 4.1 Sand Sieve Analysis



Graphic 4.1 Gradation of Sands

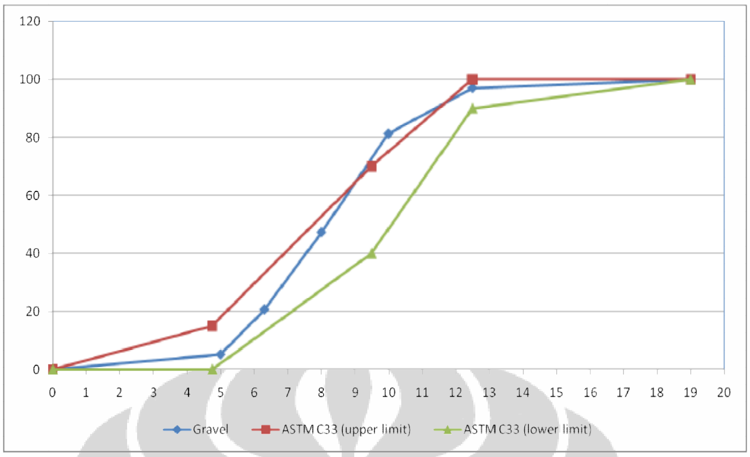
From the table of gradation above, we can see that the sand obtained from laboratory used in this evaluation generally approach the ASTM C 33 gradation limit as has been mentioned in chapter 2.4.2.2.1, but in some cases one sieve result no.2,36mm did not meet the requirement.

4.1.2. Coarse Aggregate (gravels) 1500 gram

Bellow is the result of sieve analysis of gravel and the gradation.

Sieve (mm)	Rejected Weight (gr)	Rejected Cumulative (%)	Passing Sieve Cumulative (%)
12,5	44,8	2,99	97,01
10	281,9	18,80	81,20
8	790,8	52,75	47,25
6,3	1189,6	79,35	20,65
5	1422,1	94,86	5,14
pan	1499,2	100,00	0,00

Table 4.2 Gravel Sieve Analysis



Graphic 4.2 Gradation of Gravel

From the table of gradation above, same with the sand sieve analysis, the gravel obtained from the same laboratory used in this evaluation generally approach the ASTM C 33 gradation, but only result between sieve no. 9,5mm and 12,5mm did not meet the requirement. For the CLSM that requires low strength, the use of aggregate that no meeting of ASTM C 33 gradation the requirement has become increasingly in common in CLSM applications.

4.2. Mass Volume Absolute and Mass Apparent of Fine and Coarse Aggregates

4.2.1. Mass Volume Absolute Fine Aggregate

Mass Volume Absolute Fine Aggregate					
Sample	: Sands				
Source	: FSA Laboratory				
Date tested	: **28-Mar-11**				
			I	II	III
Weight of sand = Ms		(gr)	204,25	205,62	205,46
Weight of water = N1		(gr)	1210,35	1210,00	1211,95
Weight of water + sand =N2		(gr)	1336,56	1337,58	1339,13
yi= Ms /(N2+Ms-N1)		(gr)	2,617	2,635	2,625
Average = ŷ =		(gr)		2,626	

Table 4.3 Table of Mass Volume Absolute Fine Aggregate

From the table, mass volume absolute for fine aggregate obtained is : 2,626 gr/cm^3.

4.2.2. Mass Volume Apparent Fine Aggregate

Mass Volume Apparent Fine Aggregate				
Sample	: Sands			
Source	: FSA Laboratory			
Date tested	: **29-Mar-11**			
		I	II	III
Weight of measure Sands +Cylynder	gr	12465,00	12618,30	12613,40
Weight of Cylinder	gr		3934,50	
Weight of Sands	gr	8530,50	8683,80	8678,90
Vol Cylinder	cm3		4756,16	
Mass Vol. apparent	gr/cm3	1,794	1,826	1,825
Average	gr/cm3		1,815	

Table 4.4 Table of Mass Volume Apparent Fine Aggregate

The mass volume apparent obtained for fine aggregate is: 1,815 gr/cm^3.

4.2.3. Mass Volume Absolute Coarse Aggregate

Mass Volume Absolute Coarse Agregates (CA)					
Sample	: Coarse Agregates				
Source	: FSA Laboratory				
Date tested	: **28-Mar-11**				
			I	II	III
A) Weight of oven-dry sample in air		(gr)	500,00	500,00	500,70
B) Weight of SSD in air		(gr)	527,80	523,20	520,60
C) Weight SSD sample in water		(gr)	308,20	312,57	313,43
Weight of basket		(gr)	849,20	849,20	849,20
Weight of CA + Basket		(gr)	1377,00	1372,40	1369,80
Bulks Specific Gravity (oven dry)	A / (B-C)		2,277	2,374	2,417
Average				2,356	
Bulk Specific Gravity (SSD)	B/ (B-C)		2,403	2,484	2,513
Average				2,467	
Apparent Specific Gravity (SSD)	A / (A-C)		2,607	2,668	2,674
Average				2,649	
Absortion (%)	((B-A)/A)x100%		0,056	0,046	0,040
Average				0,047	

Table 4.5 Table of Mass Volume Absolute Coarse Aggregate

4.2.4. Mass Volume Apparent Coarse Aggregate

Mass Volume Apparent Coarse Agregates					
Sample	:	Coarse Agregate/ Grave			
Source	:	FSA Laboratory			
Date tested	:	**29-Mar-11**			
			I	II	III
Weight of measure Sands +Cylynder		gr	11512,80	11587,40	11545,10
Weight of Cylinder		gr		3934,50	
Weight of CA		gr	7578,30	7652,90	7610,60
Vol Cylinder		cm3		4756,16	
Mass Vol. apparent		gr/cm3	1,593	1,609	1,600
Average		gr/cm3		1,601	

Table 4.6 Table of Mass Volume Apparent Coarse Aggregate

4.3. Mix Properties

4.3.1 Mix#1

Mix Design				
	kg/m^3	kg in 20 L	Vol. in Lit.	%
Sands	816	16,32	6,22	42,19
Gravillon	1015	20,30	7,63	51,78
Cement	140	2,80	0,89	6,03
Water	230	4,60	4,60	31,21
w/c ratio	1,64			

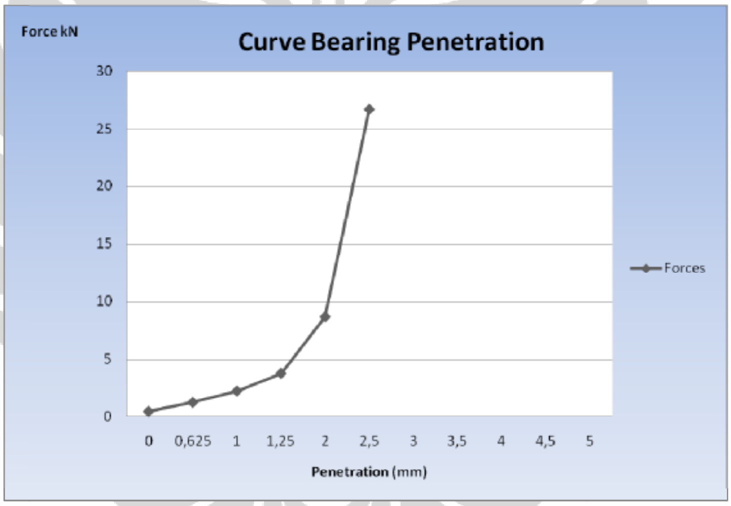
Table 4.7 Mix#1 Design

- Unit Weight of Fresh Specimen Mix#1= NA
- Flow Spread Mix#1= 415 mm > 400 mm.
- Indice Portant Immediat Mix#1= 64,94 % at 2,5mm > 10%.

Deformation (mm)	Comparateur Dynamo (1/100 mm)	Comparateur Dynamo (mm)	Force (kN)	IPI at 2,5 mm = kN*100/13,35	IPI at 5 mm = kN*100/19,93
0,625	2	0,02	0,44	3,30	2,21
1	5,5	0,055	1,22	9,14	6,12
1,25	10	0,1	2,22	16,63	11,14
2	17	0,17	3,78	28,31	18,97
2,5	39	0,39	8,67	64,94	43,50
3	120	1,2	26,67	199,78	133,82

Table 4.8 IPI Mix#1

Figure 4.1 IPI Test Mix#1



Graphic 4.3. Penetration Curve Mix#1

- Stability Mix#1= (1ml/500 ml)x100% = 0,2%

Figure 4.2 Stability Test Mix#1

- Compressive Strength 7th day Mix#1= 3,118 MPa .

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	5,03	4,43	4,94	kg
R'c	3,293	2,718	3,344	MPa
Average		3,118		MPa

Table 4.9 Compressive Strength 7th day Mix#1

- Compressive Strength 28th day Mix#1= 4,79 MPa > 2,1 MPa.

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	5,07	4,79	4,97	kg
R'c	4,024	4,577	5,755	Mpa
Average		4,785		MPa

Table 4.10 Compressive Strength 28th day Mix#1

Figure 4.3 Compressive Strength Test 28th day Mix#1

4.3.2. Mix#2

Mix Design				
	kg/m^3	kg in 20 L	Vol. in Lit.	%
Sands	816	16,32	6,22	42,19
Gravillon	**1074**	**21,48**	8,08	54,80
Cement	**70**	**1,40**	0,44	3,02
Water	230	4,60	4,6	31,21
w/c ration	3,29			

Table 4.11 Mix#2 Design

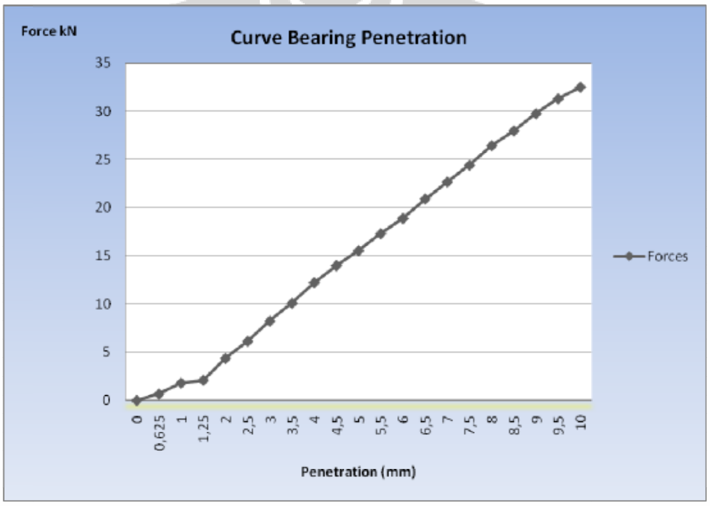
- Unit Weight of Fresh Specimen Mix#2= 2,26 kg/m^3.

- Flow Spread Mix#2= 435mm > 400mm.
- Indice Portant Immediat Mix#2= 78,07% at 5 mm > 10%.

Deformation (mm)	Comparateur Dynamo (1/100 mm)	Comparateur Dynamo (mm)	Force (kN)	IPI at 2,5 mm = kN*100/13,35	IPI at 5 mm = kN*100/19,93
0,625	3	0,03	0,67	5,02	3,36
1	8,2	0,082	1,82	13,63	9,13
1,25	9,5	0,095	2,11	15,81	10,59
2	19,5	0,195	4,33	32,43	21,73
2,5	27,5	0,275	6,11	45,77	30,66
3	37	0,37	8,22	61,57	41,24
3,5	45,5	0,455	10,08	75,51	50,58
4	55	0,55	12,22	91,54	61,31
4,5	63	0,63	14	104,87	70,25
5	70	0,7	15,56	116,55	78,07
5,5	78	0,78	17,33	129,81	86,95
6	85	0,85	18,89	141,50	94,78
6,5	94	0,94	20,89	156,48	104,82
7	102	1,02	22,67	169,81	113,75
7,5	110	1,1	24,4	182,77	122,43
8	119	1,19	26,44	198,05	132,66
8,5	126	1,26	28	209,74	140,49
9	134	1,34	29,78	223,07	149,42
9,5	141	1,41	31,33	234,68	157,20
10	146,5	1,465	32,55	243,82	163,32

Table 4.12 IPI Mix#2

Figure 4.4 IPI Test Mix#2



Graphic 4.4 Penetration Curve Mix#2

- Stability Mix#2= (1ml/500 ml)x100% = 0,2% < 2%.
- Compressive Strength 7th day Mix#2= 0,613 MPa .

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,56	4,5	4,52	kg
R'c	0,337	0,715	0,789	MPa
Average	0,613			MPa

Table 4.13 Compressive Strength 7th Day Mix#2

Figure 4.5 Compressive Strength Test 7th Day Mix#2

- Compressive Strength 28th day Mix#2= 1,226 MPa < 2,1 MPa.

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,7	4,74	4,63	kg
R'c	1,247	1,287	1,145	MPa
Average	1,226			MPa

Table 4.14 Compressive Strength 28th Day Mix#2

Figure 4.6 Compressive Strength Test 28th Day Mix#2

4.3.3. Mix#3

Mix Design				
	kg/m³	kg in 20 L	Vol. in Lit.	%
Sands	837,5	16,75	6,38	43,30
Gravillon	1074	21,48	8,08	54,80
Cement	**20**	**0,40**	0,13	0,86
Fly Ash	**20**	**0,40**	0,15	1,04
Water	230	4,60	4,60	31,21
w/c ratio	11,5			

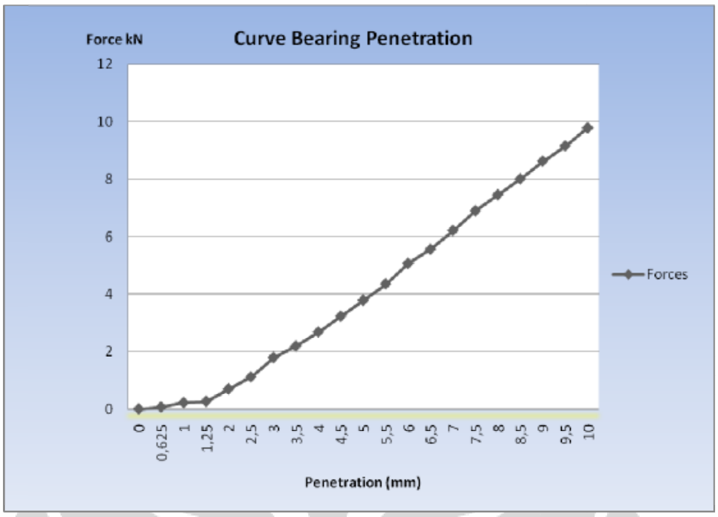
Table 4.15 Mix#3 Design

- Unit Weight of Fresh Specimen Mix#3 = 2,04 kg/m³.
- Flow Spread Mix#3= 410 mm > 400 mm.
- Indice Portant Immediat Mix#3= 18,97% at 5 mm > 10%.

Deformation (mm)	Comparateur Dynamo (1/100 mm)	Comparateur Dynamo (mm)	Force (kN)	IPI at 2,5 mm = kN*100/13,35	IPI at 5 mm = kN*100/19,93
0,625	0,3	0,003	0,066	0,49	0,33
1	1	0,01	0,220	1,65	1,10
1,25	1,2	0,012	0,264	1,98	1,32
2	3,1	0,031	0,692	5,18	3,47
2,5	5	0,05	1,110	8,31	5,57
3	8	0,08	1,780	13,33	8,93
3,5	9,8	0,098	2,176	16,30	10,92
4	12	0,12	2,670	20,00	13,40
4,5	14,5	0,145	3,220	24,12	16,16
5	17	0,17	3,780	28,31	18,97
5,5	19,5	0,195	4,352	32,60	21,84
6	22,8	0,228	5,066	37,95	25,42
6,5	25	0,25	5,560	41,65	27,90
7	28	0,28	6,220	46,59	31,21
7,5	31	0,31	6,890	51,61	34,57
8	11,5	0,115	7,445	55,77	37,36
8,5	36	0,36	8,000	59,93	40,14
9	38,8	0,388	8,624	64,60	43,27
9,5	41,2	0,412	9,154	68,57	45,93
10	44	0,44	9,780	73,26	49,07

Table 4.16 IPI Mix#3

Figure 4.7 IPI Test Mix#3



Graphic 4.4 Penetration Curve Mix#3

- Stability Mix#3= (1ml/500 ml)x100% = 0,2% < 2%.

Figure 4.8 Stability Test Mix#3

- Compressive Strength 7th day Mix#3= 0,24 MPa .

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,29	4,32	broke	kg
R'c	0,206	0,285	NA	MPa
Average	0,246			MPa

Table 4.17 Compressive Strength 7th Day Mix#3

Figure 4.9 Compressive Strength 7th Day Test Mix#3

- Compressive Strength 28th day Mix#3= 0,388 MPa < 2,1 MPa.

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,55	4,52	4,55	kg
R'c	0,427	0,423	0,314	Mpa
Average	0,388			MPa

Table 4.18 Compressive Strength 28th Day Mix#3

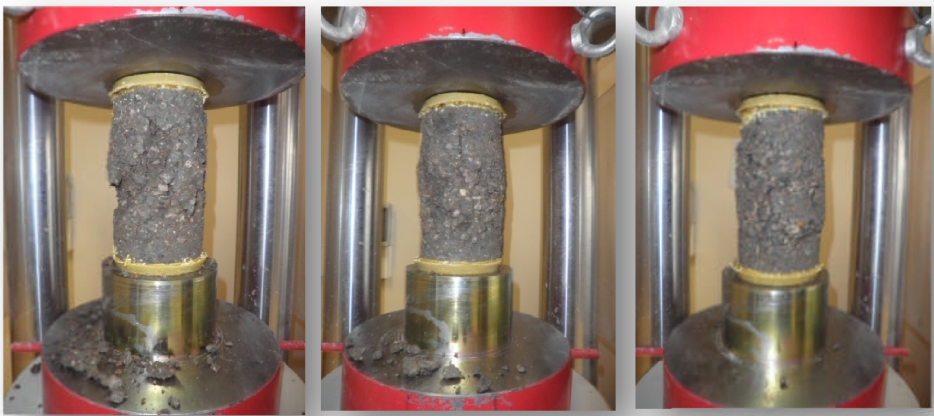


Figure 4.10 Compressive Strength 28th Day Mix#3

4.3.4. Mix#4

Mix Design				
	kg/m^3	kg in 20 L	Vol.in Lit.	%
Sands	861,5	17,20	0,790	48,36
Gravillon	795,1	15,88	5,969	44,64
Cement	124,7	2,49	6,554	7,00
Water	333,3	6,66	6,657	50
w/c ratio	2,67			

Table 4.19 Mix#4 Design

- Unit Weight of Fresh Specimen Mix#4= 2,05 kg/m^3
- Flow Spread Mix#4= 585mm > 400mm.

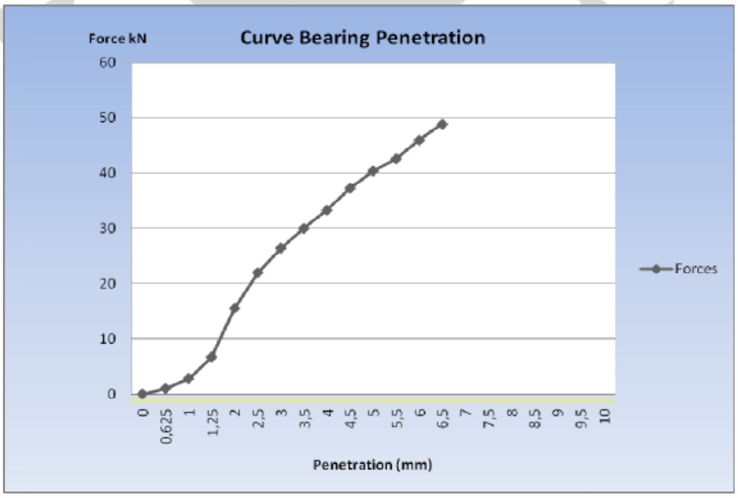
Figure 4.11 Flow Spread of Mix#4

- Indice Portant Immediat Mix#4= 202,91% at 5 mm > 10%.

Figure 4.12 IPI Test Mix#4

Deformation (mm)	Comparateur Dynamo (1/100 mm)	Comparateur Dynamo (mm)	Force (kN)	IPI at 2,5 mm = kN*100/13,35	IPI at 5 mm = kN*100/19,93
0,625	4,5	0,045	0,990	7,42	4,97
1	12,5	0,125	2,780	20,82	13,95
1,25	30	0,3	6,670	49,96	33,47
2	77	0,77	15,560	116,55	78,07
2,5	100	1	22,000	164,79	110,39
3	119	1,19	26,440	198,05	132,66
3,5	135	1,35	30,000	224,72	150,53
4	150	1,5	33,330	249,66	167,24
4,5	168	1,68	37,330	279,63	187,31
5	182	1,82	40,440	302,92	202,91
5,5	195	1,95	42,670	319,63	214,10
6	207	2,07	46,000	344,57	230,81
6,5	220	2,2	48,890	366,22	245,31
7		0		0,00	0,00
7,5		0		0,00	0,00

Table 4.20 IPI Mix#4



Graphic 4.5 Penetration Curve Mix#4

- Stability Mix#4= (2ml/500 ml)x100% = 0,4% < 2%

Figure 4.13 Stability Test Mix#4

- Compressive Strength 7th day Mix#4= 1,663 MPa

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,7	4,58	4,63	kg
R'c	1,821	1,505	1,717	Mpa
Average		1,663		MPa

Table 4.21 Compressive Strength 7th Day Mix#4

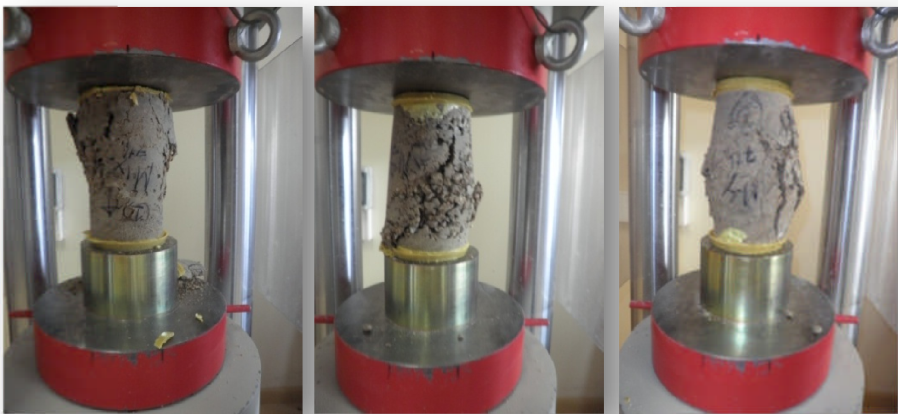


Figure 4.14 Compressive Strength 7th Day Test Mix#4

- Compressive Strength 28th day Mix#4= 2,459 > 2,1 MPa.

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,76	4,64	4,59	kg
R'c	2,721	2,512	2,145	Mpa
Average	2,459			MPa

Table 4.22 Compressive Strength 28th Day Mix#4

Figure 4.15 Compressive Strength 28th Day Test Mix#4

4.3.5. Mix#5

Mix Design				
	kg/m3	kg in 20 L	Vol.in Lit.	%
Sands	923,0	18,45	0,85	48,36
Gravillon	851,9	17,03	6,40	44,64
Cement	133,6	2,67	7,03	7,00
Water	285,7	5,71	5,71	40
w/c ratio	2,14			

Table 4.23 Mix#5 Design

- Flow Spread Mix#5= 560 mm > 400 mm.

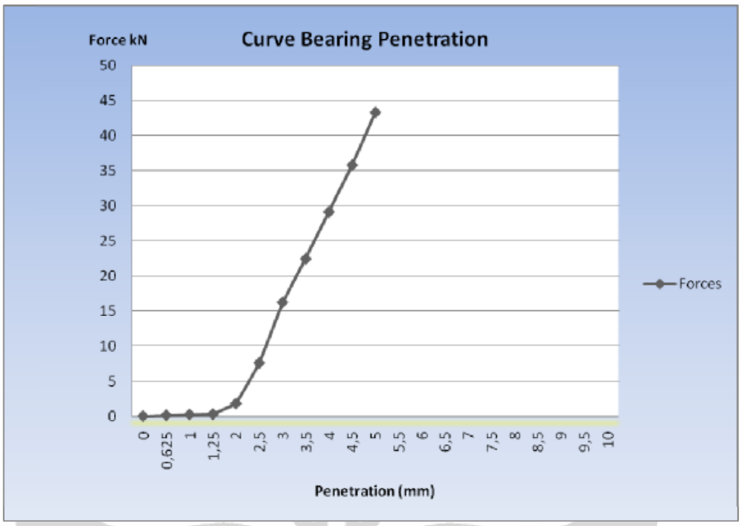
Figure 4.16 Flow Spread of Mix#5

- Indice Portant Immediat Mix#5= 217,41% at 5 mm > 10%.

Deformation (mm)	Comparateur Dynamo (1/100 mm)	Comparateur Dynamo (mm)	Force (kN)	IPI at 2,5 mm = kN*100/13,35	IPI at 5 mm = kN*100/19,93
0,625	0,5	0,005	0,110	0,82	0,55
1	1	0,01	0,220	1,65	1,10
1,25	1,2	0,012	0,264	1,98	1,32
2	8	0,08	1,780	13,33	8,93
2,5	34	0,34	7,560	56,63	37,93
3	73	0,73	16,220	121,50	81,38
3,5	101	1,01	22,440	168,09	112,59
4	131	1,31	29,110	218,05	146,06
4,5	161	1,61	35,780	268,01	179,53
5	195	1,95	43,330	324,57	217,41
5,5					
6					

Table 4.24 IPI Mix#5

Figure 4.17 IPI Test Mix#5



Graphic 4.6 Penetration Curve Mix#5

- Unit Weight of Fresh Specimen Mix#5= 2,13 kg/m^3.
- Stability Mix#5= (4ml/500 ml)x100% = 0,8% < 2%.

Figure 4.18 Stability Test Mix#5

- Compressive Strength 7^{th} day Mix#5= 2,916 MPa > 2,1 MPa.

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,70	4,71	4,82	kg
R'c	3,146	2,883	2,718	Mpa
Average	2,916			MPa

Table 4.25 Compressive Strength 7^{th} Day Mix#5

Figure 4.19 Compressive Strength 7^{th} Day Test Mix#5

- Compressive Strength day Mix#5= 4,115 MPa > 2,1 MPa.

	Smpl 1	Smpl 2	Smpl 3	Unit
weight	4,87	4,93	4,74	kg
R'c	4,857	4,254	3,234	MPa
Average	4,115			MPa

Table 4.26 Compressive Strength 28^{th} Day Mix#5

Figure 4.20 Compressive Strength 28th Day Test Mix#5

CHAPTER 5

ANALYSIS OF RESULTS

This chapter contains analysis of the results of conducted mixtures tests. The results will be compared to the general required properties of CLMS which indicate whether they complying with those specified requirements primarily the strength and the flowability.

The following tables summarize the properties of tests result.

5.1. Summary Table for the Flowability

Number of Mix	Sand (kg/m^3)	Gravel (kg/m^3)	Cement (kg/m^3)	Water (kg/m^3)	Fly Ash (kg/m^3)	Admixture (kg/m^3)	w/c ratio	Slump Flow (mm)
Mix 1	816	1015	140	230	-	-	1,64	415
Mix 2	816	1074	70	230	-	-	3,29	435
Mix 3	837,5	1074	20	230	20	-	11,50	410
Mix 4	861,484	795,072	124,687	333,333	-	0,012	2,67	585
Mix 5	923,018	851,863	133,593	285,714	-	0,012	2,14	560

Table 5.1 Summary for Flowability

5.2. Summary Table for the Indice Portant Immédiat (IPI)

Number of Mix	Sand (kg/m^3)	Gravel (kg/m^3)	Cement (kg/m^3)	Water (kg/m^3)	Fly Ash (kg/m^3)	Admixture (kg/m^3)	w/c ratio	IPI > 10 (%)	
Mix 1	816	1015	140	230	-	-	1,64	64,94	at 2,5 mm
Mix 2	816	1074	70	230	-	-	3,29	78,07	at 5,0 mm
Mix 3	837,5	1074	20	230	20	-	11,50	18,97	at 5,0 mm
Mix 4	861,484	795,072	124,687	333,333	-	0,012	2,67	202,91	at 5,0 mm
Mix 5	923,018	851,863	133,593	285,714	-	0,012	2,14	217,42	at 5,0 mm

Table 5.2 Summary for IPI

5.3. Summary Table for the Stability

Number of Mix	Sand (kg/m^3)	Gravel (kg/m^3)	Cement (kg/m^3)	Water (kg/m^3)	Fly Ash (kg/m^3)	Admixture (kg/m^3)	w/c ratio	Stability (%)
Mix 1	816	1015	140	230	-	-	1,64	0,2
Mix 2	816	1074	70	230	-	-	3,29	0,2
Mix 3	837,5	1074	20	230	20	-	11,50	0
Mix 4	861,484	795,072	124,687	333,333	-	0,012	2,67	0,4
Mix 5	923,018	851,863	133,593	285,714	-	0,012	2,14	0,8

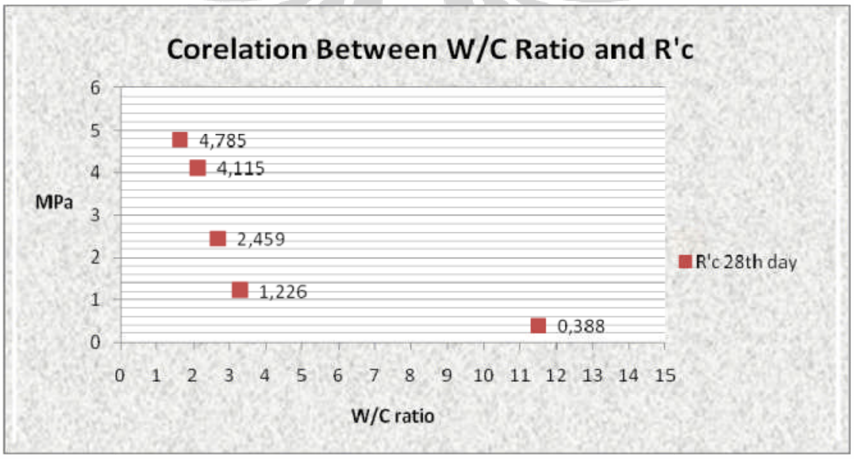
Table 5.3 Summary Stability

5.4. Summary Table for the Compressive Strength

Number of Mix	Sand (kg/m^3)	Gravel (kg/m^3)	Cement (kg/m^3)	Water (kg/m^3)	Fly Ash (kg/m^3)	Admixture (kg/m^3)	w/c ratio	R'c 7^{th} Day (MPa)	R'c 28^{th} Day (MPa)
Mix 1	816	1015	140	230	-	-	1,64	3,118	4,785
Mix 2	816	1074	70	230	-	-	3,29	0,613	1,226
Mix 3	837,5	1074	20	230	20	-	11,50	0,245	0,388
Mix 4	861,484	795,072	124,687	333,333	-	0,012	2,67	1,663	2,459
Mix 5	923,018	851,863	133,593	285,714	-	0,012	2,14	2,916	4,115

Table 5.4 Summary for Compressive Strength

5.5. Correlation between W/C Ratio and Compressive Strength (28^{th} day)



Graphic 5.1 Correlation w/c ratio and Compressive Strength

The table above is the correlation between the water cement ratio and the compressive strength of hardened mixtures in aged of 28^{th} day. The graphic describes that the increase of water-cement ratio, the strength tends to decrease.

5.6. Analysis of Mix#1

This is the recipe from Laboratoire Central des Ponts et Chaussees (LCPC) and no admixtures added in this mixture. The flow spread test from the flowability table above shows that it has the 415 mm flow which is higher than the specified limit 400 mm. The Index Bearing Ratio (64,94%) more than the required minimum 10% indicates that this material will be able as footpath construction immediately after 24 hours. For the stability, this mixture exhibited only 1 ml of bleeding occurred during the 24 hours observation means that bleed capacity still under maximum 2% suggested bleeding.

In terms of workability, this CLSM is an ease and homogeneity mixture to be mixed, transported and finished. From all the mixtures evaluated, this mixture has the highest content of cement 140 kg/m^3 and lowest w/c ratio that giving the influence of the strength and bleeding respectively. This CLMS is a workable mixture since it has less of bleeding and segregation. In other side, the result of the compressive resistance in 28th day 4,785 MPa is higher than the 2,1 MPa the specified limit. This brings that the CLSM will not be easily excavated with conventional digging equipment in the future. For this reason, we can conclude that this mixture does not meet the primary property the compressive strength.

Figure 5.1 Hardened Mix#1 of 7^{th} day after Compressive Strength Test

5.7. Analysis of Mix#2

For the mix#1 did not meet on of the desired properties, modification of first mix proportion was taking place. Only the cement content reduced from 140 kg/m^3 into 70 kg/m^3 thus the w/c ratio increased. The reason of reducing cement content is to decrease the compressive strength of CLSM, and the half amount of cement reduced is specified as the trial amount. Water content and Fine Aggregate were kept as previous mix except the coarse aggregate content increased from 1015 kg/m^3 into 1074 kg/m^3 to replace the volume of reduced cement. As the result, the strength was decreased from 4,78MPa into 1,226 MPa of 28th age of days. With the water content 230 gave the flowability increased from 415 into 435. The result of Index Bearing Ratio 78% is above of required property can be immediately applicable. We can consider this CLMS meets the all primary desired properties, can be immediately applied and excavatable with hand tool.

Figure 5.2 Hardened Mix#2 at 7th day before Compressive Strength Test

5.8. Analysis of Mix#3

Finding the mix no.2 had met the desired property, involving other cementing material such as fly ash incorporated with the CLSM mixture was conducted. The mixture which modified was recipe mix#2. The fly ash was added 20kg/m^3 and the cement reduced from 70 kg/m^3 to 20 kg/m^3. The content water in 230 kg and the amount of gravel in 1074 kg/ m^3 were kept as before. Hence, the strength was decreased into 0,388MPa in 28th day. From the stability test, there was no water pond on the surface occurred. Literature said that the inclusion of fly ashes in a mix reduce bleeding and segregation. But the stability observation showed that it had no good pasta that some of aggregates were not binded enough by pasta. This led to less of homogeneousity after 7th day observation of specimen. Therefore, the product exhibits the honeycombing caused by the less of cohesiveness. This resulting the 7th day hardened CLSM was fragile. In some case, this is the advantage for being low strength material that allows it excavatable by hand tools, but not enough solid or cohesive due to the less of cement or fly ash content. With 410 mm of flow spread and IPI with 18,97%, this mixture was enough considered as the desired CLSM but it shall be recommended to increase more content of cement or fly ash to have more cohesiveness and less segregation of mixture.

Figure 5.3 Hardened Mix#3 at 7th day before Compressive Strength Test

5.9. Analysis of Mix#4

This mix was taken from the producer of CLSM EUROVIA. The suggested water content is ranging from 40% up to 50% of the mixture. For this evaluation, this mixture involved 50% water content. This mixture also added an admixture, the plasticizer in order to generate the flowability and to avoid the crack stated by the producer EUROVIA. 12 gram of fibre from SIKA as the plasticizer was incorporated into the mixture. From the table result above, with flow spread 585mm which is the highest flow spread among all mixtures, IPI 202,91%, stability 0,4%, most of all the properties are met, except the compressive strength of 28th day 2,489MP higher than 2,1 MPa.

Figure 5.4 Hardened Mix#4 at 28th day before
Compressive Strength Test

5.10. Analysis of Mix#5

This mixture was the same with source of mix#4 but with 40% water content which had an impact increasing of other constituents. This mixture had gained higher compressive strength of 28^{th} day (4,115 MPa) than mix#4(2,459 MPa). Similarly to mix#4, this mixture with flowspread 560mm, IPI 217,2%, the stability 0,8 % had met three of four the required properties except the compressive strength. Visual observation from the picture below, the final product of 7^{th} day hardened mixture shows the good of cohesiveness and homogeneousity. During the making of this mixture, it was easily handling the mixture up to finishing. As literature states (Chemical Admixture for Concrete,1999), the superplasticizer increase the workability of the mixtures indicated by its flowspread.

Figure 5.4 Hardened Mix#4 at 28^{th} day before Compressive Strength Test

5.11. Comparison to the CLSM Producers References

The following table shows the comparison between the own mixture produced with the K-Krete and ACI come from the literature review as the referenced producers of CLSM.

No. Mix Content	Mix#1 (kg/m^3)	Mix#2 (kg/m^3)	Mix#3 (kg/m^3)	Mix#4 (kg/m^3)	Mix#5 (kg/m^3)	Reference Comparison K-Krete	ACI
Sand	816	816	837,5	861,484	923,018	1305-1661 kg/m3	1542-1839 kg/m3
Gravel	1015	1074	1074	795,072	851,863	-	-
Cement	140	70	20	124,687	133,593	24-119 kg/m3	29-118 kg/m3
Water	230	230	230	333,333	285,714	0,35-0,40 m^3	192-344 kg/m^3
Fly Ash	-	-	20	-	-	166 -297 kg/m3	Max 207 kg/m^3
Admixture	-	-	-	0,012	0,012	-	-

Table 5.5 Comparison to Referenced Producers of CLSM

CHAPTER 6
CONCLUSION AND RECCOMENDATION

6.1. CONCLUSION

Along with the literatures review of Controlled Low Strength Material (CLSM), evaluation and modification for CLSM recipes came from their producers, LCPC and EUROVIA were conducted. Five designated mixtures were tested and evaluated to see the desired properties primarily the compressive strength under 2,1MPa that can be easily excavated and flow above 400 mm that allow this material flowing into the site without any vibration or compaction primary to the with the analysis can be drawn the conclusions.

From the analysis of the tests results chapter 5, conclusions can be drawn as following points:

1. All the mixtures displayed excellent flow properties which have above the specified flow-spread 400mm. Water content of those mixtures have the influence to generate the flowability.
2. All mixtures except mix#3, tends to increase its flow when the w/c ratio increase.
3. All mixtures have the load bearing capacity above 10% the specified property, 24 hours after finishing.
4. Highest bleeding from all mixtures occurred in mix#5 with 0,8%. Nevertheless, all the mixtures exhibit the bleeding under the tolerate number of stability 2%.
5. The stability analysis of mix#3, involving the fly ashes into the mixture have proven that this material can reduce bleeding as the literature review stated, but since it had less of pasta that led the specimen looked fragile, more addition by trial of cement and/or fly ashes can be a solution.

6. Involving the fiber synthetic for mix#4 and mix#5 generated the less of crack and gave more cohesive than other mixtures.
7. From the graphic 5.1. the correlation between water-cement ratio and the compressive strength in table 5.5, shows when w/c ratio increased, the compressive strength tends to decrease.
8. From all the mixture evaluated, only two mixes have the acceptable properties (compressive strength < 2MPa and flowability > 400mm), they are:
   1) Mix#2 with constituents:
      - Sand : 816kg/m^3;
      - Gravel :1074kg/m^3;
      - Cement : 70kg/m^3;
      - Water :230 kg/m^3;
      - w/c ratio : 3,29;
      - with R'c: 1,226 MPa and, flowspread:435mm.
   2) Mix#3 with constituents:
      - Sand : 837,5kg/m^3;
      - Gravel :1074kg/m^3;
      - Cement : 20kg/m^3;
      - Fly ash : 20kg/m^3;
      - Water : 230kg/m^3;
      - w/c ratio : 11,5;
      - with R'c: 0,388 MPa and Flow : 410mm.

   After meeting all the desired properties, this two modified mixtures based on LCPC formula, are suitable for use as an excavatable CLSM.

6.2. RECOMMENDATION

1. More by-products or recycled materials shall be explored utilized in CLSM by other researchers in terms of sustainable development and reducing disposal problems.
2. Incorporating the admixture fiber synthetics with mix#3 which has content of fly ash and cement shall be evaluated.
3. Following properties shall be also investigated:
   a. Modulus Elasticity;
   b. Tensile Strength;
   c. Porosity.

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