INFLUENCE OF LIMESTONE POWDER AND CALCIUM CARBIDE WASTE ON THE PROPERTIES OF SELF COMPACTING CONCRETE

BY

ENEJO, Sunday

M.Tech/SET/2018/7785

DEPARTMENT OF BUILDING

FEDERAL UNIVERSITY OF TECHNOLOGY

MINNA

OCTOBER, 2023

INFLUENCE OF LIMESTONE POWDER AND CALCIUM CARBIDE WASTE ON THE PROPERTIES OF SELF COMPACTING CONCRETE

BY

ENEJO, Sunday

M.Tech/SET/2018/7785

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN CONSTRUCTION TECHNOLOGY

OCTOBER, 2023

DECLARATION

I hereby declare that this thesis titled "**Influence of Limestone Powder and Calcium Carbide Waste on the Properties of Self Compacting Concrete"** is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) and their contributions has been duly acknowledged.

……………………….   ……………………

ENEJO, Sunday   SIGNATURE/DATE

M.TECH/SET/2018/7785
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA, NIGERIA

CERTIFICATION

The thesis titled this thesis titled "**Influence of Limestone Powder and Calcium Carbide Waste on the Properties of Self Compacting Concrete"** by **ENEJO, Sunday (M.Tech/SET/2018/7785)** meets the regulations governing the award of the degree of Masters of Technology (MTech) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literacy presentation.

Dr. J. A. Apeh ________________________
SUPERVISOR **Signature & Date**

Dr. J. A. Apeh, ________________________
Head of Department **Signature & Date**

Prof. O. A. Kemiki ________________________
DEAN, SCHOOL OF ENVIRONMENTAL TECHNOLOGY **Signature & Date**

Engr. Prof. O.K Abubakre ________________________
DEAN, POSTGRADUATE SCHOOL **Signature & Date**

DEDICATION

This work is dedicated to the ALMIGHTY GOD, the maker of Heaven and Earth, the only merciful and gracious One. He gave me the grace to complete this project. May His name be praised forever.

ACKNOWLEDGEMENT

Glory be to God, great things he has done, my appreciation goes to God Almighty for the sustenance throughout my study.

The immense support of my supervisor Dr. J.A Apeh for his unique and immense support, criticism and commitment from the inception to the completion of my study.

I would like to appreciate Postgraduate Program Coordinator Dr. R.A Isa for the follow up and ensuring progress is being made during the whole process.

I want to specially thank Professor R.A Jimoh for his advice and challenge to look at things from innovative perspective during my study. My profound gratitude also goes to all the lecturers in the Department of Building, Prof. A.E Abalaka, Prof. W.P. Akanmu, Dr. B.J. Olawuyi, Dr. E.B Ogunbode, Dr. T.O. Alao, Dr. P.A Bajere, Dr. M. B. Wuna, Dr. A. Aka, Dr. A. A. Bilau, Dr. C.U. Ayegba, Dr. (Mrs.) A. A Bamgbade, Dr. E.A. Agbo, Mr. Y.Y. Garba and Miss H.G Nmadu and to the technical staff members of the Department, Mr. R. O. Saka, Mr. Dan-Azumi and all other academic, technical and administrative staffs of the Department of Building FUT Minna, I'm so much grateful.

I also want to appreciate my wife Mrs. Hannah A. Enejo and all my children Joseph, Josephine, Daniel and Victor for their concern and encouragement.

God bless you all.

ABSTRACT

Among the composite materials in the construction industry, concrete is the most widely used. Among its constituents, cement contributes most to its strength development. This study evaluated the influence of Limestone and Calcium carbide waste contents on the properties of the blended Mixes. Sixteen mixes with Portland Cement (PC) as control and with other Fifteen mixes containing varying content of LP and CCW as a replacement of PC, were prepared and evaluated in terms of consistency, setting times, flow and passing abilities as well as compressive and splitting tensile strengths respectively. Concrete cubes (96 Nos) and cylinders (64 nos) were cast, cured to determine the compressive and splitting tensile strengths at 28 and 56 days respectively. Test results show that consistence of the blended cement slightly increased compared with control value. Similarly, the setting time was elongated compared with control values. The flow ability and passing ability of mixes up to 20 % and 10 % by weight of PC for LP and CCW contents met EFNARC and ACI 237 -07 Provisions while mixes with LP content exceeding 20 % did not meet the aforementioned code provisions. The compressive and splitting tensile strengths also depicts similar trends with mix PC +LP_{20} +CCW_{10} attaining a compressive strength of 46.25 N/mm^2 after 56 days of curing. Beyond the aforementioned LP content of 20 %, compressive strength decreased. Mixes are susceptible to segregation. The pastes of blended mixes exhibited retardation which is useful for concretes requiring long time for setting. Mix, PC + LP_{20} +CCW_{10} which produced a strength of 46.25 N/mm^2 yielded the most synergy between LP and CCW and can be used to attain self-compatibility of Self- compacting concrete (SCC).

TABLE OF CONTENTS

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

One of the major short coming in the use of normal concrete is compaction and placement of the fresh concrete through confined areas and structural elements with congested reinforcements. Self- compacting concrete (SCC) is a type of concrete that can be self- placed in such areas by gravity and needless for compaction. For the use of SCC, the most concern is its stability and segregation of the Mix is ensured without loss in uniformity. Ever since the introduction in the construction industry, in the early 1990s, extensive research on the properties has been undertaken by researchers (Ganeyisi,2010). In order to overcome segregation and bleeding problems so as to improve fluidity of SCC during its transportation and placing, high amount of fine materials such as Portland cement (PC), Fillers, admixtures and viscosity modifying agents (VMA) have been utilized as indicated by researchers (Lachemi *et al*., 2004; Bouzouba and Lachemi, 2001). The work of Ferarris *et al.* (2000) show that to achieve self-compatibility, it is critical for SCC to have a powder content of material (finer than 0.1mm) between 450 – 600 Kg/m^3. Since it is uneconomical to use excessive cement content and also considering the environmental implications, it is imperative that replacement powders are sought, such as Fly Ash (FA), silica fume (SF), Ground granulated blast furnace Slag (GGBFS), Limestone. The works of Ferraris *et al*, (2007) and Bouzouba and Lachemi (2001) have shown that the use of such replacement powder does not only reduce costs but also increase the performance of SCC.

Limestone powder (LP) is one of the Fillers that remarkably improves the physical property of cement paste, studied by researchers (Petity and Wirqun, 2010; Katsaiori *et al.*, 2009). Limestone powder due to its filling effect improves the mechanical and durability property of SCC by providing more compact structure through its pore filling effect. In the presence of FA, it reacts with PC hydration products Ca $(OH)_2$ and SiO_2 by pozzolanic reaction to produce a non-soluble C-S-H structure (Felekoglu and Baradan , 2003). The work of Ghrici *et al.* (2007) show that when LP replaced PC by 20 % and natural pozzolans by 30 %, the use of ternary blends of cementitious materials improve early age and long-term mechanical properties of Mortar. This also enhanced durability properties in terms of resistance to sulphate and Chloride ions attack. The work of Menedez et al. (2003) indicates that the use of ternary blended cements reduces the cost of PC production, thus CO_2 emission and improve early and late age compressive strengths.

The work of Makaratat *et al.* (2011) shows that Calcium carbide waste (CCW) is a by-product from acetylene gas (C_2H_2) production. It is obtained when water reacts with calcium carbide (CaC_2) as shown in equation (1).

$$CaC_2 + 2H_2O \longrightarrow (2)\ C_2H_2 + Ca(OH)_2 \qquad (1.1)$$

Acetylene Gas as a fuel is used in agriculture for repining of Fruits, a most choice for heating appliances such as Welding, Flame strengthening, thermal spraying and other uses (Sun *et al*, 2015). However, in Nigeria, Acetylene gas is used in OXY-Acetylene gas welding. Disposal of the residue waste (CCW) is carelessly done as a waste within the environment which in due course is incorporated into the Soil (Abiya et al, 2015). The concentration of CCW in the Soil above 100 g could drastically reduce the growth rate of Okra plant. However, the work of Wang *et al* (2013) has shown that the main chemical composition of the calcium carbide waste (CCW) is basically the same as that for natural Limestone. Jaturapitakkul and Boonmark (2003) indicate that a pozzolanic reaction could occur between CaC_2 and Rice husk Ash yielding a maximum compressive strength of 15.60 MPa at 28 days.

Disposal of most waste materials is one of the environmental problems, world- wide today. However, they can be successfully and economically utilized to improve some fresh and hardened properties of SCC. Co_2 emissions from concrete production accounts for around 8 % man-made CO_2 (Karem, 2012). The blending of cement clinker with supplementary cementitious Materials (SCMs) such as Blast Furnace Slag (BFS), Fly Ash (FA) and Limestone (LP) has been the most promising route to increase the sustainability of the construction industry.

Nowadays, Portland cement (PC), is still the essential component in SCMs system and blended cements are most often binary, while at high replacement levels, the early age mechanical behavior of binary cementitious system becomes an issue. A possible approach to improve early age - mechanical behavior is to develop ternary system in which different SCMs can interact with each other which enhance the performance of concrete. LP is a particularly interesting SCM; it can decrease the cost due to the less demand of gypsum content (De-weerdt, 2011a) and produce almost zero associate CO_2 emissions. Furthermore, the $Ca(OH)_2$ produced from the reaction of CaC2 and water (H2O) will be readily available to supplement that from PC hydration to enhance continuous production of C-S-H from pozzolanic reaction. Therefore, development of LP – CaC_2, filled ternary composite cement in SCC is meaningful. This synergy is explored to form the focus of the study and how it affects its properties.

1.2 Statement of the Problem

The use of high content of PC in SCC increase cost of production, hence the addition of supplementary cementitious materials (SCMs) as a partial substitute for PC significantly lower the production cost of SCC as well as relieve the shortages of cement materials and solid waste pollution. (Wang et al, 2020). SCMs can adjust the fresh properties and improve the durability properties (Xie *et al*, 2021). Specifically, SCMs can effectively enhance microstructure of SCC. Furthermore, it will have superposition effects, when two or more of them are used together.

LP is a by- product of Limestone quarry used in cement -based materials for years. Calcium carbonate ($CaCO_3$) can react with cement (PC) to form Calcium- carbo -aluminate. It has been widely used in cement -based materials, reportedly can influence their properties by filler, nucleation, dilution and chemical effects. Its action mechanism mainly depends on its particle size, and amount, the filler effect refines the microstructure and reduce the porosity of cement= based materials; while its nucleating effect accelerates the hydration of C_3S, increases the amount of hydration products and reduces the porosity of cement-based materials at early ages. The dilution effect reduces the hydration peak of C3S, decreases the amount of hydration products and increase the porosity of cement-based materials. Furthermore, its chemical effect promotes the appearance of third hydration peak. This implies that the combine use of LP in binary and ternary cementitious blends requires more detailed investigations to clarify the effectiveness on the fresh and hardened properties of self- compacting concrete. Furthermore, the free SiO_2 from the continuous addition of LP will continue to react with $Ca\ (OH)_2$ to form non-soluble C-S-H in a pozzolanic reaction of PC with LP.

1.3 Aim and Objectives

1.3.1 Aim

The aim of the study is to assess the effect of LP and CCW contents in the ternary blended cements on the properties of SCC with a view to evaluate the behavior of SCC incorporated with ternary blended cement.

1.3.2 Objectives

To achieve the aim of the study, the following objectives are pursued, i.e.:

to

1.determine the physio-chemical properties of constituent Materials so as to ascertain suitability.

2. measure the fresh and hardened properties of the ternary blends in Mixes containing LP and CCW contents.

3 evaluate the effect(s) of the LP-CCW contents on the properties of SCC blended with LP and CCW.

4. determine the behavior of SCC blended with LP-CCW contents.

.

1.4 Scope of the study.

The study focused on the evaluation of the properties of SCC containing ternary blended cements (PC+LP +CCW). Fresh properties of SCCs were tested for flow and passing abilities, viscosity, initial and final setting times, mechanical properties in terms of compressive and splitting tensile strengths were determined.

1.5 Significance of the Study

In the provision of greater sustainability in the construction industry, use of filling materials and mineral admixtures, substituting additives in concrete meets this great expectation. In terms of cost, recycling the industrial wastes, rehabilitation in durability and mechanical performance in concrete will therefore put a pressure on the utilization of such materials. The study aimed at assessment of the properties of SCCs produced with binary and ternary systems of PC, LP and CCW. For this purpose, two series of concrete mixtures were prepared. One series are binary mixtures where PC is replaced with LP , CCW at 0, 5, 10, 15 & 20 % respectively while the second series consists of PC being replaced with a combination of LP + CCW at 10-20, 20-10, 15-30, 30-15, 20-40 respectively in mass/weight. Fresh properties of SCC were tested for flow ability, passing ability, viscosity, initial and final setting times, while the mechanical properties in terms of compressive and tensile splitting strengths were determined. Furthermore, the absorption and sorptivity values were assessed so as to determine their transport abilities.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Self-compacting Concrete

Self-compacting concrete (SCC) is a higher flow able, non-segregating concrete that spread into place evenly and fill the form work, encapsulate reinforcement bars without any mechanical vibrations (ACI 2005). Also, it has been defined as a higher workable concrete that can flow through congested reinforcements, or geometrical complex structural elements under its own weight and adequately fill voids without segregation or excessive bleeding without the need for vibration (ACI, 2005). Its application is significant in the way it is specified, produced and placed. The use of SCC has brought about increased productivity, improved Job site safety and improved hardened properties in construction. However, its material cost is generally higher when compared with the conventionally placed concrete and its production greater technical expertise and quality control measures. The proper selection of constituents and mixture proportioning, SCC is crucial for ensuring that the advantageous properties of SCC can be achieved economically (Cholalingam, 2012); Ramin, 2014; Tatersall & Banfill (2016). The effects of industrial constituents and changes in mixture proportions are often greater in SCC than in conventionally placed concrete. Well established guidelines on the effects of constituent characteristics and mixture proportions on SCC performance are needed in order to design and control SCC effectively (Tattersall & Banfill 2016).

2.1.1 Constituent Materials for SCC.

Although SCC can be produced with a wide range of materials, its proper selection is essential for its optimization. When compared with conventional concrete, SCC is generally much more sensitive to changes in material properties. The sections below described the characteristics of SCC Materials, SCMs, Aggregates and admixtures required for SCC production.

2.1.1.1 *C*ement

SCC often has higher SCMs contents than that for conventionally placed concrete in order to achieve adequate flow ability. The draw- back of high SCMs content include higher cost, higher heat of hydration, increased susceptibility to shrinkage. All structural types of PC are generally acceptable for SCC (EFNARC, 2005). Vikan et al (2005) affirmed that the admixture performance can be strongly dependent on cement characteristics in accordance with evaluation carried out by studying six (6) different cements.

*2.1.1.2 S*upplementary Cementitious materials (SCMs)

SCMs are often used in SCC to decrease cost, improve workability, reduce heat of hydration and improve durability. The use of SCMs without C_3S, C_3A or C_4AF enables easy control of rheology. Furthermore, high degrees of fineness of powders reduce the size and volume of voids which lowers bleeding and segregation (Mehta and Monteiro, 2014). Due to the reduction in early strength development, mixtures with Calcium Carbide Residue (CCR), FA or Slag, the strength of such mixtures need to be evaluated, at ages beyond 28 days. In some cases, SCMs are used to reduce strength at certain ages because the amount of powder materials needed for workability would result in excessive strength if made up of only PC (Domone, 2006). As by-products, SCCMs may exhibit undesirable levels of variability.

2.1.1.3 Aggregates

2.1.1.3 Powder content

One of the major pit falls of SCC is to avoid segregation resistance. To achieve an SCC with a high segregation resistance requires a high content of powder materials. These are particles of cement and fillers of diameter less than 0.125 u m (Skarendahi, 2000). PC content for SCC ranges from 450 – 600 Kg/m^3 of fillers. Limestone and other fillers which may be inert or cementitious can also be used (EFNARC, 2005). sometimes, viscosity modifying agents (VMA) are used to modify the contents of expensive fillers. Fillers increase the viscosity of water, thereby increasing segregation resistance (Goaszewski & Szwabowski, 2004)

2.1.1.3 *Aggregates*

Aggregates are inert materials used in concrete generally. It is the solid content of concrete. It has the paste content as its driver. It is made up of coarse and fine contents. The fine aggregates are materials less than 0.125 mm, while coarse aggregates are material with sizes ranging from 4.5 mm to 32 or 40 mm in diameters. Aggregates can be crushed, uncrushed. They are mostly gotten from quarry and natural effects such as rain, moving water that breaks down to pieces larger stones/rocks to form aggregates-like natural gravel and granite are used in construction work. In the design mix of SCC, it is recommended that the quantity of aggregates (fine and coarse) are stipulated to ensure that its properties especially fresh properties are within specified values (EFNARC, 2005). This code recommends that fine aggregate content should be between 40 – 50 % of mortar volume and coarse aggregate content should be 30 to 34% of concrete volume. This is to enhance the properties of SCC so as to obtain a good performance concrete. Also, the size and morphology of aggregate used in SCC plays a very important role in improving its properties generally. Aggregate sizes up to 25 mm in diameter are used in SCC. Use of higher sizes (> 25 mm) are discouraged because of their weight for the paste content to move them along during flow so as to avoid segregation. The shape of aggregates is also considered during the mix design. This is to enhance cohesion of the particles and improve bonding to the paste mass. Aggregates that are angular are preferable as they bond easily to the paste and form a compact whole compared with rounded aggregates that are less in bonding to the paste matrix and also less in form as a compact whole because of its round shape. When two or more round shape particles are compacted, more space is created between them compared with that of the angular shape aggregates and this has an effect on the strength of the mixes.

Studies have shown that concrete mixes prepared with crushed aggregates showed higher strength compared with uncrushed aggregates. This also affects its modulus of elasticity. It has also been established that low size of aggregates improved strength properties of concrete compared with larger sizes. The work of Khaleel (2011) show that aggregate size, texture and type of coarse aggregate has influence on the properties of SCC. The study further showed that concrete prepared with mixes containing Limestone increased in strength and modulus of elasticity compared with mixes containing gravel. From the fore going, it is imperative that viscosity play a vital role in the performance of SCC on one hand, a lower viscosity is required to allow concrete to deform and easy flow at a reasonable rate. On the other hand, it requires a sufficient high viscosity to avoid segregation. It is then imperative to strike a balance between these two conflicting extreme requirements which is vital for

SCC Mix proportioning. This balance can be achieved with a fundamental understanding of the theology of fresh concrete.

For the deformability requirements to be satisfied, 25 mm maximum size of aggregate is specified. Similarly, quantity of aggregates is to be reduced too. This is because, they require a lot of energy in moving them through the paste volume. Reduction in the coarse aggregates content is balanced in the increase in paste volume which has the effect in increasing the aggregate inter-particle distance thereby lowering the possibility of constant collision and lowering the aggregate-aggregate friction. It should be well noted that amount of the aggregate content reduction has to be balanced with structural requirement as coarse aggregate serve a very useful purpose in controlling creep and shrinkage as well as stiffness and ductility of the hardened concrete.

2.2. Main supplementary Cementitious materials used for the Study

2.2.1 Limestone Powder (LP)

Being a by-product of Limestone quarry, LP has been used in cement-based materials for many years. It was reported that Calcium carbonate (CaCO3) could react with cement to form calcium carbo aluminate (Bassey, 1938). The formation of Calcium Carbo aluminate was influenced by the amount and fineness of LP, but with little effect on compressive strength of concrete (Soroka and setter, 1997). However, Daniels (1948) showed that the inclusion of LP in concrete increased its compressive strength. It was also shown that it has a filler effect by an expert committee in Norwegian Government (Hognestad,1954). The accelerating effect of LP was also reported (Soroka and Setter, 1997). With more other studies conducted, it is well established that LP in PC can promote the precipitation of C-S-H and accelerate the hydration of PC.

The effects of LP on the workability, strength (Malhotra and Carette (1985) and Judi *et al*,2012), and durability of concrete were also studied. More studies on LP led to the formation of Portland- limestone cement and designated as general use limestone (GUL) cement).

2.2.1.1 Action Mechanism of Limestone Powder in cement- based Materials.

To explain the action mechanism of LP in cement-based materials, different approaches were evolved. Some researchers (Martin et al, 2006) grouped the action mechanism of LP in cement-based materials into the mechanism of Filler effect (including Filler effect, Nucleation and dilution effect) and chemical effect, while on the other hand, other researchers specified Filler, Nucleation, dilution effects and chemical effects as distinctive mechanisms (Lothenbach *et al*, 2011). Therefore, it is imperative to clarify the action mechanisms of LP in cement-based materials. Hence, in this study, to define the action mechanisms of LP in cement -based materials, they are grouped as Filler effect, Nucleation effect, dilution effect and chemical effect respectively.

2.2.1.2 Filler effect

The Filler effect of LP is mainly related to its particle size. Practically, the packing density of a material is lower if its particle size is coarser or comparable to that of PC, and higher if the particle size is finer than that of PC. This implies that if the particle size of LP is finer than that of PC, incorporation of LP will fill the voids between PC particles and improve the particle size distribution (PSD) and finally increase the packing density of cement-based materials (Sellenoid *et al,* 1982). Consequently, the incorporation of LP reduced the water requirement of concrete and increased the compressive strength and durability of concrete. It should be noted that, even though the incorporation of LP could fill the voids between PC particles, it will reduce the flow ability of cement-based materials, If the particle size of LP is too small since its specific surface area is high. This is true because with high specific surface area of LP, this increase reaction of LP with calcium hydroxide (Ca $(OH)_2$, by-product of PC hydration leading to formation of C-S-H product s which are precipitated in the solution system and which are denser thereby inhibiting flow ability of SCC. Li et al (2016) has shown that the flow ability of Ultra high-performance Concrete (UHPC) decrease by 27 % when 3% Nano- Limestone is incorporated into UHPC.

2.1.3 Nucleation Effect

The Nucleation effect of LP was introduced in literature by (Soroka & Setter, 1997). Subsequently, researchers have confirmed that LP provide nucleation sites for hydration products so that they can precipitate, accelerates hydration reaction (Craeye *et al* 2010) and improves the hydration degree of cement, which is due to enhanced precipitation of C-S—H on the surface of LP as a result of similarity between planar configuration of Ca and O atoms in calcite and CaO layers in C-S-H (Roder et al, 2009). The particle size surface structures and amount of LP influence its nucleation effect. The surface energy and absorption capacity of LP particles increases as its particle size decreases. The surface of the hydration products of LP seems to be developed with similar structures which refer to Ca and O atoms in calcite and CaO layers in C- S- H. With the increase of LP contents, more nucleation sites would be available and more hydration products could be absorbed. However, it is not clear which factors dominates in the nucleation effect of LP.

2.2.4 Dilution Effect

The amount of LP in the matrix dominates the dilution effect; only, only a small fraction actually takes part in the reaction due to the presence of small quantity of alumina present in PC, therefore, increase in LP content as a substitute to cement decreases the content of the PC Clinker and the hydration products. Moreover, with same water binder ratio, since LP is inert and does not have cementitious or pozzolanic properties leads to its increase in the matrix solution. Since PC clinker (C_3S, C_2S, C_4AF) are reduced due to reduction in PC content, less quantity will be available to react with LP to produce less C-S-H. This is called the dilution effect. As a result, the hydration degree of PC decreases at early age. However, this increases slightly at later age due to reaction between LP and CH, by-product of PC hydration.

2.2.1.5 *C*hemical Effect

The particle size of LP is the main factor that influence the chemical effect on the mixture. Others include content of alumina from C_3A and C_3AF in PC as well as SCMs. When particle size of LP decreases, the dissolution rate increases resulting to an increase in the concentration of Calcium carbonate in pore solution which promotes the chemical effect of LP. Generally, with the decrease in size of particle of LP, the morphology changes remarkably leading to increase in chemical effect. Also, PC clinker (C_3A, C4AF) and SCMs can provide alumina sources, which enhanced the chemical reaction of LP. The incorporation of LP in cement-based materials also change the morphology of C-S-H into shorter and thicker fibers of C-S-H (1) (Nehdi & Mindness, 1996). As the dilution rate phase in cement clinker is limited, the chemical effect of LP in cement-based materials is small.

The additional aluminate in SCMs could increase the chemical effect of LP. From previous literature, the results show that the chemical reaction of LP with Pc clinker results in the decrease and increase in the alkalinity of the pore solution. The bottom line is that the chemical effects of LP in PC based materials might influence alkalinity, humidity, volume stability of the matrix hence, it is imperative to clarify the chemical reaction of LP in cement-based materials.

2.2.2 Hydration process of LP on cement-based Materials.

2.2.2.1 Hydration effect

The filler effect of LP on the hydration process of cement-based materials is negligible, hence focus is on the nucleation, dilution and chemical effects.

2.2.2.1 Nucleation effect

The LP content of particle size and surface morphology are the factors that influence the hydration process of LP in cement-based materials. Studies have shown that the hydration peak of a sample LP with particle size of about 0.7 um was 15 % higher than that of the PC sample and appeared 25 % prior to that of the PC mixture. However, with increase in particle size of LP, the heat release curves become similar to that on PC. Studies have shown that the nucleation effect of finer LP could promote the precipitation of hydration products. And increase the hydration degree of PC, releasing more hydration heat.

2.2.2.2 *D*ilution effect

The amount of LP content mainly influences the dilution effect of LP on hydration process of cement- based materials especially when the LP content contains coarser particles. When about 20 um LP particles were incorporated into PC, there was no significant heat difference evolved between mixture and pure PC but when the amount of LP content was increased, the heat evolved for the mixture was lower than that for pure PC mixture.

2.2.2.3 *C*hemical effect

The particle size, synergetic effect of SCMs with LP content mainly influence the chemical effect on hydration process of cement-based materials. When particle size of LP decreases, the dissolution of Calcium carbonate increased, and the chemical reaction between Calcium carbonate and aluminate is enhanced. since the chemical effect of LP is little because of the low phase of the aluminate content, that from SCMs could boasts the chemical effect of LP content on cement -based materials.

2.2.3 Hydration products of LP in Cement-based materials.

2.2.3.1 Nucleation effect

The nucleation Effect of LP on hydration products of cement-based materials is influenced by its particle size. The non-evaporable water content (w_n) could be potentially used, as an indication to estimate the hydration degree of cement-based materials. The non-evaporable water content of mixtures at 3 and 28 days were investigated. Test results show that wn of PC – Slag- LP inter grind mixtures were higher than that of PC -Slag- and PC-Slag-LP blended mixtures for 3 days, but the incorporation of LP had little effect on the W_n of cement-based materials at 28 days. This could be due to the nucleation effect of LP that improved the hydration degree of cement-based materials at early ages.

2.2.3.2 *D*ilution effect

The LP content mainly influence the dilution effect on hydration products of cement-based materials. In the work of Johanna et al (2014), the effects of different mineral powders such as LP, Quartz, powders on the hydration products of cement-based materials were investigated. Although, the hydration degree on mixtures, containing mineral powders was higher, the CH content was slightly lower because, the cement clinker was relatively low, especially for the mixtures containing 30 % and 40 % mineral powders at one day. A higher replacement of cement notably reduced the CH content.

2.2.3.2 *C*hemical effect on hydration products of cement based-materials

This is mainly influenced by its particle size and amount, its synergic effect with SCMs. This can be better under stood from XRD data. When LP incorporated with cement-based materials reacts with PC, the aluminate phase reacts with CaCO3 to form mono and hemi-Carbonate after 7 days. Later, the peak of hemi-carbonate decreased but the peak of mono-carbonate increased. It was also found that calcium hemi-carbonate was formed at early ages in PC blends containing LP and converted into calcium mono carbonate after 21 days. However, it was reported that the hydration degree of LP was very low at early ages, and the calcium mono carbonate hydrates was detected much later after 180 days (Sua-Iam & Makul, 2013).

The hydration products of cement-based materials with LP content are influenced by the synergic effect between LP and SCMs. By determining the carbonate consumption of hemi/mono-carbonate content, the synergistic effect between LP and slag can be quantified (Damidot *et al*, 2011). With the increase of cement clinker replacement, levels, the carbonate consumption increased. With the increase of carbonate consumption, the hemi- and mono-carbonate content increased. This may be due to the effect that reactive alumina in Slag (87 %) increased the reactivity of LP. In the presence of the calcium aluminate silicate (CAS) Glasses, the chemical effect of LP also increased. From the literatures above, one can conclude that effect of LP on cement- based materials will result in Nucleation effect if proper fine LP was incorporated into cement- based materials and the hydration degree of cement would increase, thus, more C-S-H and CH will be formed at early ages. However, the nucleation effect of LP had better effect on the hydration products, at later age. It would mainly display dilution effect if superfluous fine LP or coarse LP was incorporated into cement-based materials, thus, less C-S-H and CH were formed.

2.2.4 Microstructure of Limestone powder cement- based materials.

In general, LP particles can solidify the microstructure of cement-based materials in different ways. Fine LP particle could fill the pores between hydration products. The nucleation effect of LP could improve the hydration degree of cement and generate more hydration products at early ages. The dilution effect of LP can decrease the reactive cement clinker and reduced the amount of hydration products. Thus, all the four effects influence the microstructure of cement-based materials.

2.2.4.1 Filler effect

The filler effect of LP on the microstructure of cement -based materials depends mainly on its particle size and amount. When LP was incorporated in a mixture of a cement based material, a refined pore structure was obtained compared to lain PC mortar (Liu & Yan, 2008). Incorporating proper amount of fine LP reduced the volume of large pore and increased the volume of small pores with diameter smaller than 100 um, which had little harm to the properties of cement-based materials. Lie *et al,* {2015), also, found that the Nano – limestone particles effectively filled pores of ultra- high- performance concrete and denser matrix was observed compared to that of plain specimen.

2.2.4.2 *N*ucleation effect

The hydration of PC is accelerated by the nucleation effect of LP, promoted the precipitation of C-S-H and filled the pores in the mixtures at early ages. From the SEM results of cement-based materials, observed fibrous, C-S-H appeared on the surface of C3S at 2 hours for the mix without LP, while the fibrous C-S-H appeared on the surface of CaCO3. It was also observed that a large amount of ordered materials precipitated on the surface of LP.

2.2.4.3 *D*ilution effect

The incorporation of large quantity of LP in cement-based materials makes it more porous than that of control PC mixtures. Since the particle size of LP used was closed to that of cement, the average pore size of mixtures with LP was similar to that of control PC mixture.

2.2.4.4 *C*hemical effect

The chemical effect of LP can influence the porosity of mixture containing LP. This is because LP stabilizes the ettringite and react with aluminate phase in cement and SCMs to form hemi-and mono-carbonate. Also, the chemical effect of LP can increase the solid volume of hydration products, materials. This is because ettringite decomposes into mono sulphonate in the absence of LP. But when LP was incorporated into cement-based material, the decomposition of ettringite ceased, and calcium hemi-and mono-carbonate were formed. It has been established that inclusion of LP in cement-based materials will mainly show filler effect, refine pore structure and reduce porosity of cement-based materials. It would mainly generate aluminate, stabilizes the ettringite and thus reduce the porosity of cement based materials.

2.3 Fresh Properties of SCC.

It is no doubt that SCC is a new composite material. It is defined as a concrete that is able to flow under its own weight and completely filled the formwork evenly in the presence of dense reinforcement without the need for vibration (EFNARC,2002) while maintaining homogeneity. Therefore, to be truly self-compacting, fresh SCC must possess three key physical properties at adequate levels throughout its working period. These are:

1 Flow ability: The concrete, through all openings and spaces between reinforcements, must be able to flow into and fill within the Formwork under its own weight.

2 Passing ability: The concrete must be able to flow through all openings such as the spaces between reinforcing bars and within the formwork without bleeding.

3 Resistance to segregation: the concrete must be able to fulfill items 1&2 without significant separation of material constituents and its composition remains uniform during flow as well as at rest after placing. These key properties must remain present in SCC for at least Ninety minutes, working period, after mixing to allow enough time for transportation and placing.

To achieve these properties requires a low coarse aggregate volume which reduce the amount of collisions between the aggregate particles thus providing better passing ability. And increase in consequent paste volume. In addition, low water/powder ratio and superplasticizers (SP) provide both flow ability and segregation resistance (RILEM report 23, (2000).

2.3.2 Flow ability

To achieve adequate flow ability, SCC mixes must possess much higher workability compared with normal concrete. Water content of the mixture is the main factor, affecting its work ability. Though the higher the water/cement ratio, the higher the workability of the mixture, this higher water/cement ratio tend to decrease the hardened strength of concrete. Because of its relationship between water/cement ratio and strength of concrete, it is not possible to simply increase the water content within the mix in order to increase the workability.

Aggregate characteristics and the aggregate/cement ratio of the mixture is another factor that affects the work ability of SCC. If the surface area to volume of aggregate is high, this will increase water demand and for a given work ability. Moreover, the aggregate/cement ratio affects the inter-particle friction between aggregate particles. A higher aggregate/cement ratio will result in a high degree of aggregate interlocking and a stronger inter-particle friction, hence produce a concrete with low workability. Also, angular particles of aggregates require more water for a given workability of the concrete structure. However, with the introduction of plasticizers, or superplasticizers in the mix, it is possible to produce high workability concrete with relatively low water/binder ratios without increasing the amount of water. Therefore, SCC makes use of new superplasticizer technology and provides the mix with a high degree of workability to allow it to flow into all spaces within the formwork without segregation.

2.3.3 Passing ability

The passing ability of SCC is its ability to flow through an opening freely without segregation. Depending on the size of the opening, the flow could be free or not. This is one of the important properties of fresh concrete (SCC) and it is affected by the following factors:

1.**Size and Characteristics of Aggregate.**

If the sample SCC mixture contains aggregates of small sizes and roundish, the passing ability will be better compared with a sample of large size and angular in shape.

2. **Ratio between Aggregate diameter and the clear space between reinforcing bars.**

If the ratio between Aggregates and diameter to the clear spacing between reinforcing bars is low, this will enhance the passing ability of the SCC mix compared to when the ratio is high. Also, if the clear spacing between reinforcing bars is small, this will affect the passing ability of SCC sample mix.

3. **Volume of Aggregate**

If the volume of coarse or fine aggregate in a sample is high, it leads to higher risk for aggregates to collide with each other and this increase the inter-particle fraction, increasing friction between them, thereby reducing the passing ability.

4. Properties of paste and boundary conditions

The boundary condition of an opening through which an SCC sample flows through is the condition(s) that is within the opening that inhibits the flow of SCC through that opening. In reinforced concrete structural element(s), reinforcements in form of steel rods are embedded in the concrete to resist tensile stresses. The spacing between the rods is an example of a boundary condition. The shape of an opening (curvy, steep or narrow) are examples of boundary conditions. When these boundary condition(s) is compared with the size of a fine or coarse aggregate in SCC, it becomes a factor that may or may not inhibit the flow of SCC.

The size and amount of aggregates in a sample mix should be optimal to avoid aiding blockage or poor passing ability of the sample which has to be in proportion with the clear spacing of reinforcing bars through which the concrete flows. For particles to flow through an opening, they change their flow path as they approach the opening. In this process, a lot of collisions between aggregate particles occur and they form a stable arch which then blocks the flow of the remaining concrete. This occur when the particles are large in size and the volume is high.

2.3.4 Resistance to Segregation

The even distribution of the constituent materials, especially coarse aggregates of SCC enhance the maximum performance at its arrived state, however, it requires a high degree of flowing ability. i.e. more like a liquid than conventional concrete mixes. To achieve this fluidity, the particles of the mix must have a high degree of movement among itself. This means that to have this free movement, there must be enough water within the mix. Unfortunately, the viscosity and density of cement paste changes with the water content. This means that once the amount of water increased, the viscosity and density of the mix will be reduced. In other words, this can be said tto mean a thickened paste being diluted through the introduction of water.

Segregation of fresh concrete is related to the viscosity and density of the cement paste. In other words, when the density of solid is higher than that of liquid, the solid particle tends to sink inside the liquid. The viscosity of the paste is reduced due to increase in free water in the mix. This subsequently leads to a reduction in density. Once the density of the overall paste is lower than the density of aggregates, it is unable to hold the aggregate particles, which then sink down or separate from the mix, which is referred to as segregation.

Segregation resistance of SCC as achieved primarily by increasing the amount of inert powder material in the mix; but not the cement content. These powders help to thicken the paste and provide an increase in viscosity and density. The thickened paste enables the aggregate particles to be uniformly suspended within the mortar paste and thus, offer resistance to segregation. For SCC to have a high segregation resistance, high powder content is often required. Powder content ranging from 450 to 600 Kg/m^3 of concrete and about 200 Kg/m^3 for Fillers.

To attained self- compatibility, and avoid any segregation, an SCC must have values for properties as shown in Table 1.

Table 2.1: Tests and suggested Limits

Test	Properties	Suggested Limits
Slump flow	Flow ability	Diameter greater than 650 mm-850 mm, Less than 12 seconds
	Filling ability	3 to 5 seconds preferably
	Segregation resistance	By visual assessment
L – Box	Passing ability/ Blocking ratio	Blocking ratio: 0.75 - 1.0
U – Box	Filling Ability	Filling height greater than 300 mm
	Passing Ability	Flow time: 10 - 20 seconds
V – Funnel	Passing Ability	Flow time: 2 - 10 seconds
Segregation resistance	Segregation	By visual assessment
Surface settlement	Segregation resistance	Surface settlement < 0.5 %

Penetration Test	Segregation resistance	Penetration depth < 8 mm
Segregation Test	Segregation resistance	Segregation coefficient < 7 % for 700 mm Column in hardened concrete

Source: EFNARC, 2005.

2.3. 5 Consistence and Setting times

The most important part of the concrete construction is consistency and setting times of concrete. This is because it helps in the development of different kinds of concreting operations such as transporting, placing, compacting and finishing of concrete. When concrete, after mixing is to be placed in formwork, it depends on setting time of concrete, which makes it rigid. But with the production of new generation concrete such as geopolymer concrete, SCC, High strength concrete and high-performance concrete with high engineering properties, mineral admixtures, such as Metakaolin, Rice Husk Ash (RHA), Silica Fume (SF) and others are added as partial replacement of PC for better performance of advanced concrete. Since these mineral admixtures possess different chemical and mineralogical compositions as well as different particle characteristics, they could have different effects on the properties of concrete. Inclusive of the setting characteristics; knowledge of the setting characteristics is important in the field of concrete construction. This imperative in scheduling the various stages involved in concrete construction operations such as transporting, placing, compacting and finishing of concrete. Such vital information is imperative when deciding whether or not to use a retarding admixture or an accelerator. The mixing of water and PC kick starts the hydration process. The initial and final setting times, consistency can be determined by the right behavior of the matrix. The initial setting time of concrete refers to the beginning of hardening of the mixture where the final setting time of the concrete refers to the sufficient hardness of the mixture (Naik et al, 2001). Studies have shown that certain admixture increase or decrease setting times of mixtures thereby acting either as an accelerator or a retarder. It has also been reported that RHA significantly influenced the standard consistency of the binders. The work of Babako and Apeh (2020) on the setting time and consistency of quintenary binders of PC, RHA, CCW and metakaolin (MK) showed that RHA and MK acted as accelerators while CCW was a retarder.

2.4 Properties of hardened self- compacting Concrete

2.4.1 Compressive strength of self-compacting concrete

In all SCC Mixes, compressive strengths of standard cubes specimens were comparable to those of traditional vibrated concrete made with similar water-cement ratios, if anything, strengths were larger. In-situ-strengths of SCC are similar to those of traditional vibrated concrete; indeed, somewhat higher when LP is used as a filler, probably because of a densifying mechanism and the observed lower susceptibility to imperfect curing, both attributive to this type of Filler. The in-situ strengths of both types of civil engineering concrete, SCC and traditional vibrated concrete were closer to standard cube strengths than those of the Housing cube strengths mixes again, it is typical of higher strength concrete.

In vertical elements, in-situ strengths of both vibrated SCC and traditional vibrated concrete are higher at the bottom than at the top, vibration of in-situ strengths for both types of concrete is much lower in the horizontal elements. In this case, the beams. These observations are characteristic of traditional vibrated concrete. The in-situ strengths of elements (beams) cast and cured out doors in winter, whether SCC or conventional are lower than those cast in-doors at the same time; i.e the column in summary, one might conclude that the fresh SCC properties have little effect on the in-situ strengths.

2.4.2Tensile strength

Tensile strengths of SCC is assessed indirectly by the splitting test on cylinders. For SCC, both the tensile strengths themselves and the relationships between tensile and compressive strengths were of a similar order to those of traditional vibrated concrete.

2.4.3 Durability aspects

Elements of all types of concrete when cast, are left exposed to varying environmental conditions at service. This is to be able to assess its durability. The permeability of the concrete which is a recognized parameter for durability can be measured either by the extent of water absorption of test specimens of concrete or by its sorptivity. Tests results conducted and reported showed that the water absorption of its near surface conducted for both types of concrete mixes, the near surface concrete is denser and more resistant to water ingress than for the NVC specimens. In terms of conventional, tests reported in literatures indicates that the SCC and civil engineering mixes measured for one year showed no carbonation.

From the literatures reviewed and considering data elsewhere, it is likely that durability performance of SCC may be equal or better than NVC of the same mix and grade.

In terms of structural performance, for both types of concretes, column test specimens cast, cured and tested. Test results showed that both Columns from both types of concrete exceeded the calculated failure Load before actual failure, indicating that both types of concrete have showed equal structural performance. It has been reported too, that the behavior of structural element (Beam) cast from both types of concrete in terms of first cracking load, service load, Failure load, crack width and load-deflection were similar.

2.5 Blended Cements

2.5.1 Binary Cement containing limestone powder

Self-compacting concrete (SCC), being a high content powdered material requires such amount of powder so as to retain self-compatibility or compacting property. High content of cement will be costly and also will cause high heat of hydration. Hence the dire need to use supplementary cementitious materials as a partial replacement of PC. Limestone powder is one of the most commonly used SCMs due to its availability and low cost. Moreover, the grinding of LP to very fines consistency requires low energy compared with grinding of clinker force in concrete productions. As already discussed in literature, the effects of LP on concrete is mainly due to its particle size, as a Filler, nucleation site, dilution and chemical effect respectively. It has been reported that LP especially Nano limestone powder reacts with the aluminate phase of PC to give new products like calcium mono-carbo aluminate and calcium hemi-carbo aluminate instead of the calcium mono-sulpho-aluminaate which could stabilize the ettringite (d Wang et al, 2019). Otherwise, non-aluminate phase could provide C_3A and C_3AF in cement as well as from SCMs too. Studies have established that particle sizes, shape and quantity of LP influences fresh bleeding resistance (Demirhan et al, 2018). It has been reported that LP inclusion in SCC increases the yield stress and plastic viscosity of SCC paste and decreases the fluidity of mortar.

2.5.2 Binary blended cement containing calcium carbide waste.

Calcium Carbide waste (CCW) is a by-product from acetylene gas (C_2H_2) production (Makaratat *et al*,2011). When water and Calcium Carbide reacts together, Calcium hydroxide waste is obtained as shown in equation (2.1).

$$Cac_2 + 2H_2O \longrightarrow C_2H_2 + Ca\,(OH)_2 \quad (2.1)$$

Acetylene gas as fuel is used in agriculture for repining of fruits, in heating process such as Flame heating, Flame gouging, welding Flame, heating flame, hardening flame, cleaning Flame, strengthening thermal spraying and other heating applications. However, in most of the developing countries like Nigeria, acetylene gas is used in Oxy-acetylene gas welding. The residue is carelessly disposed in most cases as waste into the environment such that sooner or later, is incorporated into the soil which contaminates it, polluting the environment. A study has shown that the concentration of CCW more than 100g could drastically reduce the growth of the Okra plant (Abiya et al, 2015). Nevertheless, study conducted by Wang et al (2013) confirmed that the main chemical composition of Calcium Carbide slag are basically the same with natural Limestone. It has also been reported that a pozzolanic reaction could occur when Calcium carbide residue is mixed with rice Husk Ash in a Mortar and achieved highest compressive strength of 15.6 Mpa at 28 days.

2.6 Ternary Blended Cements

2.6.1 Ternary blended Cement containing Limestone Powder and Calcium carbide waste

It has already been established that CCW is a by-product in the acetylene gas production process and can be harmful to the environment. Combined influence of CCW and fly ash was used at a ratio of 30:70 and served as a binder for the casting of concrete. No cement was added. It was reported that the concrete produced from these binders had a compressive strength of 20.4 n/mm2 at 28 days and 33.5 N/mm^2 at 90 days. Hassan et al, (2019) examined the fresh state and mechanical behavior of self- compacting mortar incorporating sorghum husk ash (SHA) and CCW as a binder material. Various dosage of superplasticizer was adopted, ranging from 1.5 -3.75 % and 70:30 (SHA/CCW) with a water/cement ratio of 0.40. The maximum compressive strength of 14.08 N/mm^2 which comply with type N of ASTM C270 Mortar was obtained. Ugwu *et al* (2018) investigated the flow and mechanical behavior of SCC blended with pulverized fuel ash, Calcium carbide and quarry dust. The cement content was partially replaced by 5 5, 10 % 15 % and 20 %. The fresh properties including passing ability, flow ability, segregation resistance improved with the addition of these additives. The desirable improvement and compressive strength was observed at 20 % replacement level of cement by pulverized fuel ash and 15 % of quarry dust and pulverized fuel ash. However, the compressive strength decreases with 20 % CCR. Significant number of researchers investigated the use of CCR in concrete production and yielded promising results. However, its potential application in large concrete production is still unclear. Therefore, making use of CCW as a filler material, SCMs lead to concrete products characterized by hydration. Thus, improving construction practice and performance accompanied by reduction in environmental pollution. According to Aggarwal et al (2008), mineral additions in SCC plays a vital role on the mitigation of average effects from aggressive environments and obtain significant economic benefits. Furthermore, in strategy of sustainable development, it is an important element in terms of effective management of wastes, lowering energy consumption in cement production and decrease in carbon dioxide emissions. Just as in concrete production, by-products such as Fly Ash slag are used to lower adverse effect on the environment, Silica Fume is also used in Self-compacting concrete as additives or as in some cases as cement replacement materials. This is based on concrete strength and durability requirements and their presence affects rheological properties of the mixture significantly. Researchers studied the utilization of mineral additives and affirmed that the incorporation of the admixtures played vital and significant roles in the properties of SCC concrete. It is therefore critical to understand the effect of non reactive fillers (i.e. the calcium carbide residue) on the fresh and engineering properties of SCC. Therefore, this study among others explored the influence of the filler, Nucleation, dilution and chemical effects of LP and CCW as well as the synergistic effect(s) of both LP and CCW on the properties of SCC. In other words, the combined use of LP and CCW in the ternary cementitious blends requires more detailed investigations, especially the synergy between the SCMs so as to clarify its effectiveness on the fresh and hardened properties of SCC.

CHAPTER THREE

3.1 MATERIALS AND METHOD

3.1.1 Materials

Materials used in the study include Portland cement (PC), 42.5 N. River sharp sand, Limestone (LP) and Calcium carbide (CCR) and Granite crushed coarse aggregates. PC was obtained from Dangote cement Plc, Nigeria through its local dealers. Fine aggregate was obtained from Local supply while Granite crushed coarse aggregates was obtained from a local Quarry.in Minna, Niger state, Nigeria. CCR was obtained from local panel beaters in Minna, Niger state. Preliminary tests for their suitability was conducted to ensure they conform to all relevant standards for each of the materials Maximum size of coarse aggregates used is 20mm.The physical and chemical properties of constituent materials were determined. Sieve analysis test, particle size distribution (PSD) of SCMs, PC, and chemical compositions were conducted.

3.2 Mix proportion procedure

For the study, proportion mix procedure (EFNARC, 2005) was adopted. This include water content of 150 – 200 Kg/m^3, w/c was between 0.4 – 0.55 by mass. Coarse aggregate content is 28 -35 % by volume while fine aggregate content balanced the volume of the rest constituents. Detailed mix proportion is shown in Table 3.1

.

Table 3.1: Mix Proportion

s/ no	Mix ID	Type of Paste	Total Binder Kg/m^3	PC Kg/m^3	LP/ CCW Kg/m^3	Fine Agg. Kg/m^3	Coarse Agg. Kg/m^3	Water Kg/m^3	SP (%)	W/B Ratio
1	SCC	Cont.	400	400		847.84	740.73	152	0.75	0.38
2	PC +LP_5	binary	400	380	20	847.84	740.73	152	0.75	0.38
3	PC+LP_{10}	binary	400	360	40	847.84	740.73	152	0.77	0.38
4	PC+LP_{15}	binary	400	340	60	847.84	740.73	152	0.85	0.38
5	PC+LP_{20}	binary	400	320	80	847.84	740.73	152	0.85	0.38
6	PC+CCR_5	binary	400	380	20	847.84	740.73	152	0.78	0.38
7	PC+CCR_{10}	binary	400	360	40	847.84	740.73	152	0.80	0.38
8	PC+LP_5+CCR_5	ternary	400	360	40	847.84	740.73	152	0.82	0.38
9	PC+LP_{10}+CCR_{10}	ternary	400	320	80	847.84	740.73	152	0.84	0.38
10	PC+LP_{15}+CCR_{10}	ternary	400	300	100	847.84	740.73	152	0.85	0.38
11	PC+LP_{20}+CCR_{10}	ternary	400	280	120	847.84	740.74	152	0.86	0.38
12	PC+LP_{25}+CCR_{10}	ternary	400	260	140	847.84	740.74	152	0.88	0.38
13	PC+LP_{30}+$CCR_{7.5}$	ternary	400	250	150	847.84	740.74	152	0.88	0.38
14	PC+LP_{25}+CCR5	ternary	400	280	120	847.84	740.74	152	0.86	0.38
15	PC+LP20+CCR_5	ternary	400	300	100	847.84	740.74	152	0.84	0.38
16	PC+LP_{20}+$CCR_{7.5}$	ternary	400	290	110	847.84	740.74	152	0.84	0.38

3.3. Method

3.3.1 Cement pastes

Sixteen paste mixtures were tested. PC paste as control and Fifteen PC blended pastes (PC – CCR, PC- LP, PC + CCW + LP). The blended (PC-SCMs) pastes were obtained by replacing PC with LP, CCW at binary and ternary at 0, 2.5, 5, 7.5, 10, 12.5, 15, 20, 25 and 30 % respectively (Table 3.1). The pastes mixtures were tested for fresh and hardened properties in terms of consistency, setting times, flow ability, passing ability, segregation, compressive and splitting tensile strengths respectively.

3,3.2 Consistency and Setting Times

The consistence of a material is the percentage amount of water required to produce a Mix with a penetration of 33 – 35 mm with the needle of the Vicat apparatus. Each of the Mixes was tested for consistence and setting times, in accordance with BS EN196. Each mixes sample was thoroughly mixed on a glass sheet. The sample was scooped into the Vicat apparatus Mould and obtained a standard consistence after a penetration between 33 – 35 mm. The standard consistence of a material is the percentage amount of water required to produce a mix with a penetration between 33 – 35 mm with the needle of the Vicat apparatus. The standard consistence of the mix is given by the relation:

$$Mw / Mm \quad X\ 100 \qquad (3.1)$$

Where, Mw = Mass of water, Mm = Mass of Mix. This was repeated for all the mixes.

Then, the setting times (initial and final) were determined for all the Mixes. Setting time of a Mix is the period required for a Mix to start setting until it just begins to harden or the period required for the stiffening. In other words, setting time is the time required foe stiffening a cement paste to a defined consistency. After the determination of consistence of the mixes, their setting times (initial and final) were determined too. A fresh Mix was prepared and filled into the Vicat apparatus Mould and then allowed to set. The period when the Vicat Needle was on the Mix surface to when it stiffened to a defined consistency was recorded as the initial setting time of the mix. Similarly, the final setting time was taken as the period when the Needle just touched the mix to the point when the needle makes no impression on the surface of the Mix. This was recorded for each mix in the study.

Figure 3.1: Slump cone

3.3. 3 Flow- ability

The flow ability of each Mix was tested using the Slump Cone (Figure 3.1) in accordance with EFNARC 2005 provisions. The slump Cone was filled with freshly Mix sample and allowed to stand for 30 to 60 seconds. The Cone was then lifted vertically. The Mix flowed horizontally until it stops on its accord. The diameter of the flow spread was measured twice perpendicular to each other. The average value was recorded as the spread flow for the Mix. Each Mix was tested twice and a mean value was recorded as the spread flow. Acceptable spread flow values are 550 mm – 850 mm (EFNARC, 2005).

3.3.4 Passing Ability

The Passing ability of a Mix is its ability to flow through a congested reinforcement in a structural element, curved surfaces, complex areas without segregation and maintenance of homogeneity. It is measured using the L- box, J-ring and the U- Box apparatus respectively.

The L-Box apparatus (Figure 4.4) was used for the Test. Six Liters of fresh Mix for each of the Mixes was prepared and poured into the vertical portion of the L-Box with the trap closed and then allowed to stand for 30 – 60 seconds. The Trap was slid open and the concrete flowed from the vertical portion to the horizontal portion until it stops on its own accord. The ratio of height of concrete at the horizontal (H_2) to that at the vertical (H_1) is a measure of the passing ability or the blocking ratio, as shown in the relation, named equation (3.2):

$$H_2/H_1 \qquad (3.2)$$

Where H_1 = height of concrete at the vertical portion of the L box,

H_2 = height of concrete at the horizontal portion of the L Box.

For SCC Mix to have an acceptable passing ability, the blocking ratio, H_2/H_1 should be between 0.80 to 1.0 (EFNARC, 2005). When the blocking ratio is within EFNARC specifications, it is an indication that sufficient concrete has flowed from vertical portion, to the horizontal portion, through the trap/reinforcement bars with little or no hindrance and still maintains its homogeneity. The test was repeated for all classes of mixes and results recorded.

3.3.5 Segregation Resistance

Segregation is separation of the solid phase of SCC (aggregate) from the Liquid phase (paste). This occurs when the density of the solid phase (aggregate) is higher than that of the Liquid phase; the aggregate tends to sink into the liquid phase instead of being uniformly suspended in the liquid phase. A segregation Test was conducted to investigate the segregation resistance of all the mixes. A ten Litre mix freshly prepared poured into a bucket to under-go static segregation for 15 minutes. Then the top layer of the sample (4.8kg) was poured into a 5 mm sieve. Some mortar then passes through the sieve. The ratio of amount of mortar that passes the 5 mm sieve to that of the total mass sieved (top layer removed, 4.8kg), if less than 15 % (indicates stability) segregation index and if greater than 95 % indicates higher segregation resistance (EFNARC, 2005; EN 12350 -11 (EN 2010). Stability index is given by the relation:

$$ŧ = {}^{Mcs}/_{Mc} \text{ x } 100 \quad (3.3)$$

Where, Mcs = mass of concrete collected through the 5 mm sieve opening size.

Mc = initial mass of top layer concrete (4.8kg).

3.3.6 Hardened Properties of the Samples

Compressive strength of all the mixes used in the study were tested by casting three, each (100 x 100 x 100 mm) cubes, cured them and tested at 28, 56 and 90 days respectively and the average of each test is recorded herein. Test was conducted by means of a 3000 kN capacity testing Machine. Similarly, splitting tensile strength of the SCCs was determined. Cylinder (ɵ150 mm x 300 mm) specimens were cast, cured and also tested for same curing ages and the result of the average of three Cylinder specimen results is reported herein. The tests were conducted in accordance with ASTM C 39 and ASTM C 496 (1999).

.

CHAPTER FOUR

4.1 RESULTS AND DISCUSSION

4..1.1 Preliminary Test Results

Preliminary test results on constituent Materials such as physical and mechanical properties were conducted. Table 2.0 show the physical and chemical properties of the constituent Materials. The specific gravities of LP and CCW are 2.68 g/cm^3 and 2.19 g/cm^{3}much less than that of PC, 3.13 g/cm^3 indicating that more LP and CCW will be required in mass to replace PC quantity. Also, LP and CCW can readily serve as filler materials in between PC particles to further densify the paste Mortar thus enhancing its viscosity. Also, LP and CCW particles could act as nucleation point to enhance precipitation of hydration products. It should be noted that the LOI of CCW and LP are high (31.70 and 42.86) which are indications of content of unburnt carbon (degree of impurity) which is likely to influence reactions with other elements. Figure 4.1 show the particles size distribution (PSD) for PC, LP and CCW.

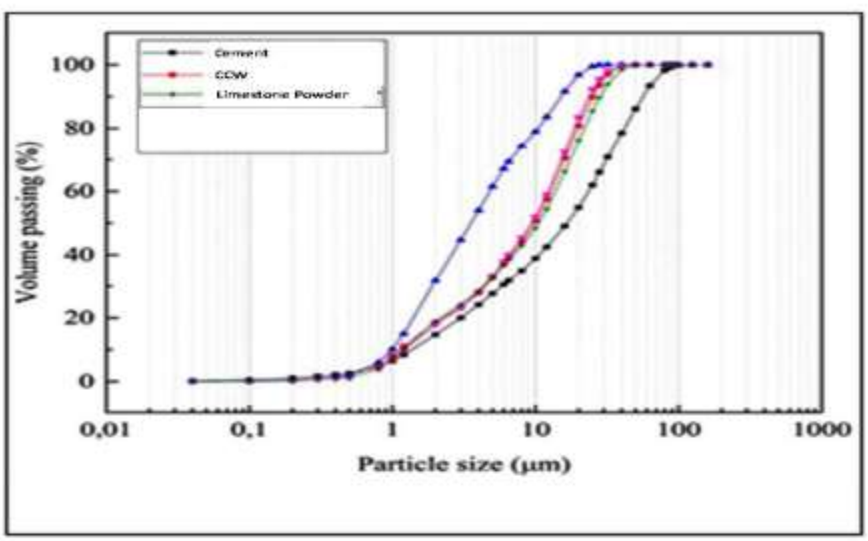

FIGURE 4.1: Particle size distribution of PC and LP.

Although the Materials show a PSD between 0 and slightly above 100 um. PC has a PSD coarser than LP and CCW respectively. This agrees with the values of their specific gravities. Table 4.1 show the Oxide compositions of the constituent Materials. The materials apparently complement each other in their oxide compositions. Both LP and CCW are not pozzolanic Materials since their SAF Oxide contents does not amount to 70 %, however, the CaO content are high enough (55.07 and 95.69 %) to readily provide Ca++ ions, ensuring that Ca/Si ratio is maintained (kept at not less than PH 12, for reactions to continue.

Table 4.1; Physical and chemical properties of constituent materials

OXIDE	PC	CCR	LP
SIO2	**19.49**	**2.10**	**0.22**
Al_2O_3	**4.52**	**0.50**	
Fe_2O_3	**3.38**	**0.54**	**0.44**
CaO	**63.60**	**95.69**	**55.07**
MgO	**8.63**		**0.34**
K_2O	**2.84**	**0.47**	
Na2O	**0.13**		
SO_3	**0.38**	**0.31**	**0.11**
TiO		**0.09**	
LoI	**2.99**	**31.70**	**42.86**
Specific gravity	**3.13**	**2.19**	**2.68**
Blaine Fineness	**2387**		**4001**

4.1.2. Consistency and setting times of mixes

Sixteen Mixes, control Mix (PC – CCW) only, six binary and nine Ternary Mixes were prepared for consideration. For consistency and setting times, this is to observe changes (if any) in the water requirements of the pastes due to the addition of admixtures. Test results shows that control pastes (100 % PC- CCW) has a normal consistence of 29 % (Table 4.2). For the binary pastes containing LP / (PC + LP), consistence increased with increase in LP content. This is due to the fact that LP increases the plasticity of cement paste. It plays a vital role in PC hydration by acting as nucleation sites for precipitation of C-S-H, thereby enhancing the rate of hydration. Another factor is the Blaine fineness of LP which also influences hydration which requires less water than that of ettringite (Newman & Choo, 2005). For the Binary pastes containing CCW contents, results showed increase in consistence with increase in CCW content due to the low reactivity index of CCW. For the Ternary blended cement pastes containing both LP and CCW, there is slight increase in consistence when compared with binary cement pastes. The consistence ranged from 29 % to 31 % which is close to control value of 29 %. The reason being not far fetch. The CCW does not require much water and due to its low reactivity while for the LP content, it is inert and its requirement for water is because of its nucleation action which aids hydration and the formation of mono carbo aluminate in pozzolanic reaction later which requires less water in formation.

In the work of Babako and Apeh (2020), the consistence of the Ternary blends (PC-CCW-MK) was appreciable compared with its control value. However, this could be attributed to MK content which is highly reactive. Also, from the quaternary Mix, from the same study

(Babako and Apeh, 2020), the Mix show high consistency which can be attributed to MK and RHA contents which are both highly reactive and requires more water. For the ternary blended mixes containing LP and CCW, there is slight increase in consistency when compared with that of the binary values. This is probably due to the synergy between LP and CCW. The CCW that will require much water is shared by the LP which needs little water. Consistency ranged from 29 % to 31 % which is close to the control value of 29 %.This could also be due to the low reactivity of CCW and the inert of LP and its low requirement for water. However, LP acting as nucleation sites give rise for the need for more water as it aids hydration and formation of mono carbo aluminate, though, which requires less water in formulation. By and large, the increase in consistency of the ternary cement paste is fruitful as it facilitates more reactions between constituents and the primary hydrate of PC.

4.1.3 setting Time

For the setting times, two periods were used to assess the setting times (initial and final) respectively. The setting times are shown in Table 4.2. The control mix has an IS and FS of 110 and 165 minutes. It can be observed that the setting times of the binary pastes containing CCW increased with increase in CCW content. At 5 % CCW content, IS increased by 8.33 %, FS increased by 6.78 5 of control values respectively. At 10 % CCW content, IS increased by 12 %, FS increased by 9.34 %. This can be attributed to the low reactivity of CCW. For binary mixes containing LP, IS and FS also increased with increase in LP content. For the binary mixes containing 5 -30 % LP, increase in IS ranged from 4.35 % to 15.38 % and FS increased from 6.25 % to 13.16 % of control values respectively. For the ternary mixtures compared to reference value, IS increased by 14.40 % and FS is 12.70 % for PC +LP_5+CCW_5 and for PC +LP_{30} +$CCW_{7.5}$ IS increased by 15.38 % and FS by 14.51 % respectively. It is important to note that among the ternary mixes, **PC+LP$_{20}$ +CCW$_{10}$** has the lowest increase of **9.84 %** for IS and **10.08 %** for FS and then Mix **PC+LP$_{20}$ +CCW$_{7.5}$** which has an IS of **11.29 %** and FS of **10.81%.** When the ternary mixes are further compared to values of the binary mixes, IS and FS values improved over that of binary mixes. This is not unconnected to the influence of CCW content, though a low reactivity SCM, is able to boost the nucleation and filling effect of LP with its own pozzolanic reaction with the by- product of PC, Calcium Hydroxide for more reactive process which improved both the IS and FS respectively.

Table 4.2: consistency and setting time

Mix ID	Consistency (%)	Setting Time	
		initial (mins)	Final (Mins)
PC- SCC	29	110	165
PC- CCW$_5$	30	120	177
PC- CCW$_{10}$	31	125	182
PC – LP$_5$	28	118	180
PC - LP$_{10}$	25.5	121	183
PC - LP$_{15}$	25.75	123	185
PC - LP$_{20}$	25.25	126	187
PC - LP$_{25}$	26	130	190
PC - LP$_{30}$	26.75	128.5	189
PC +LP5 +CCW5	25.85	127.25	188
PC +LP$_{10}$ +CCW$_{10}$	29	125	186.5
PC +LP15+CCW$_{10}$	28.5	124	185
PC +LP$_{20}$ +CCW$_{10}$	29	122	183.5
PC +LP$_{25}$ +CCW$_{10}$	30	128	190
PC +LP30 +CCW$_{7.5}$	31	130	193
PC +LP20 +CCW$_5$	29.25	124	185

4.1.4 Flowing Ability

To assess the flow ability of SCC, the slump flow test was used. This was achieved by measuring the diameter of a flowing concrete for the mixes (Figure 4.1). Acceptable slump flow diameters ranged from 550 mm to 800 mm (Table 4.4, EFNARC 2005). Slump flow test for the SCC mixes were conducted for varying percentage replacement of PC with LP and CCW respectively. Test results are shown in figure 4.2.

Figure 4.2: Slump flow values measured practically for Mixes tested.

For a concrete to be self- compactible, its filling, passing and segregation requirements must be fulfilled in accordance with EFNARC, 2005, ACI 237) provisions. This will provide ease

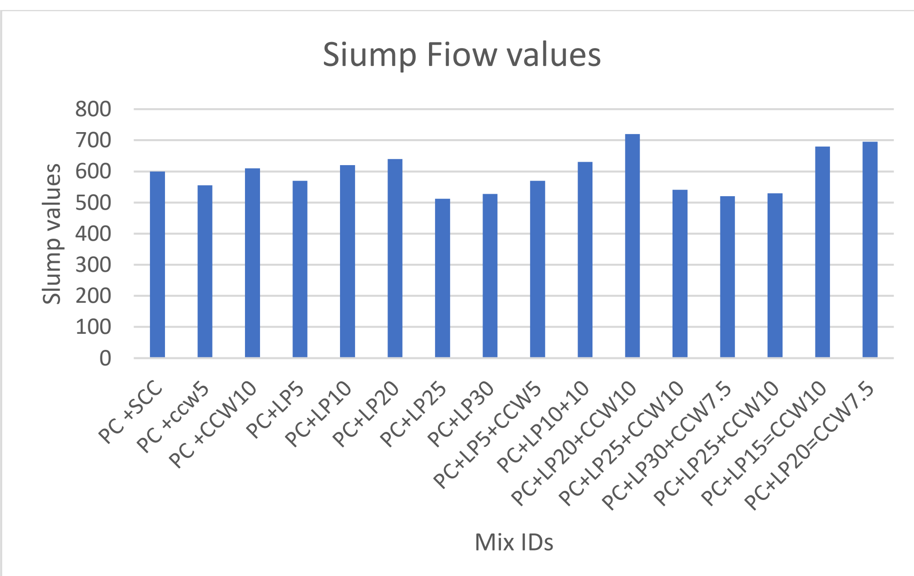

Figure 4.3: Slump values for various mixes tested.

of flow when unconfined by formwork and reinforcement and an ability to remain homogeneous in fresh state. It has been suggested that the filling ability and stability of SCC for the fresh state can be defined by four key characteristics namely: flow ability, viscosity, passing ability and segregation resistance (Table 4.4, EFNARC, 2005). Hence, the fresh properties of the mixes were measured in accordance with EFNARC provisions.

Figure 4.2 show various mixes and their slump values. It can be observed that mixes with high content of LP has slump values that does not meet EFNARC specifications (Table 4.1). For example, mix PC + LP_{30} +CCW_{10} has a slump spread flow of 530 mm, PC + LP_{25}+ $CCW_{7.5}$ has a slump flow of 530 mm, PC + LP_{25} +CCW_{10} has a slump flow of 512 and PC + LP_{30} + CCW_{10} has a slump flow of 518 mm. because of the size of LP particles with a specific gravity of 2.68, much less than that of PC, readily fills the voids between PC particles, increasing the plastic viscosity of the paste, thereby increasing its viscosity which affects its flow lowering the slump flow value. Also, as percentage LP content exceeds 20 %, the mixes becomes densified, less self -compacting (Beera and Gunakaile, 2013). Figure 4.3 show that mix PC + LP_{25} + $CCW_{10,}$ PC + LP_{30}, PC + LP_{30} +$CCW_{7.5}$, PC + LP_{25}, PC + LP_{30} slump values fell short of EFNARC, 2005 provisions, which is due to high viscosity of the mixes as a result of high content of LP.

Mixes in SF1 class include PC – SCC, all binary mixes with LP content not exceeding 20 % and that of CCW. Test results further indicates that binary mixes with high content of LP show low slump values due to the high viscosity of these mixes resulting from filling of the voids between the PC particles by LP particles.

4.1.5 Passing Ability

Figure 4.3 show the L Box used to measure the passing ability of the mixes tested. It is called the L Box because it consists of a vertical and horizontal sections. As aforementioned, concrete is filled in the vertical section and after 30 – 60 seconds, is allowed to flow from the vertical section unto the horizontal section until it stops.

Figure 4.4: The L Box used to measure the passing ability of the mixes tested

Table 4.3 show the passing abilities of mixes tested. Five mixes (PC +LP_{25}, PC + LP_{30}, PC +LP_{25} +CCW_{10}, PC + LP_{25} +CCW_5, PC + LP_{30} +CCW_5) did not meet EFNARC, 2005; ACI 237-07) specification of 0.80 – 1.0 passing ability while the passing abilities of11mixes met the requirements of both codes. It can be observed that mixes with high content of LP has low PA. This is because of the high viscosity of the mixes. A considerable quantity of LP, with a specific gravity of 2.68 fills the voids between the more coarse PC particles densifying the mix thus increasing its viscosity leading to low PA. Out of the eight binary mixes, two failed EFNARC/ ACI 237-07 provisions, (those with high LP contents greater than 20 %) while for the ternary mixes, three fell short of the provisions of the aforementioned codes, with PA less than 0.80. by and large, 11 mixes have PA greater than 0.80 while five have PA less than 0.80. this implies that 11 mixes will have no issue in terms of segregation during transportation and placing, passing ability through reinforcements and curved surfaces of formworks while five of the mixes will be susceptible to segregation resistance during transportation, placing and filling of formworks.

Table 4.3: Passing Ability of Mixes tested (H_2/H_1)

s/no	Mix ID	H1(mm)	H2 (mm)	H_2/H_1 ==PA
1	PC - SCC	107	86.00	0.800
2	PC + CCW5	106	86.50	0.816
3	PC + CCW10	106	87.00	0.821
4	PC + LP5	108	84.50	0.782
5	PC + LP10	105.5	86.50	0.812
6	PC + LP 20	107	89.00	0.832
7	PC + LP25	112	79.00	0.705
8	PC + LP30	114	70.00	0.614
9	PC + LP5 +CCW5	108	86.00	0.796
10	PC + LP10 + CCW10	107	88.50	0.883
11	PC + LP15 +CCW10	104	92.00	0.846
12	PC + LP20 + CCW10	104	92.00	0.883
13	PC + LP25 + CCW10	112	72.00	0.643
14	PC + LP30 + CCW10	113	70.00	0.619
15	PC + LP25 + CCW5	112	72.50	0.647
16	PC + LP20 + CCW7.5	103	88.00	0.854

Table 4.4: slump flow, Passing ability and viscosity classes (EFNARC, 2005; ACI 237R-07)

Slump flow class	Slump flow diameter (mm)	Passing Ability class	H_2/h_1	Viscosity class T_{500} (s)
SF 1	550 – 650	PA 1	≥ 0.80 with 2 rebars	Vs1/VF 1 ≤ 2
SF 2	660 – 750	PA 2	≥ 0.80 with 3 rebars	Vs 2/VF 2 ≥ 2
SF 3	760 – 850			V-funnel time (s) Vs1/Vf 1 ≤ 8 Vs 2/Vf 2 9 -25

4.2 Hardened Properties

4.2.1 Compressive strength

The results of the compressive strength tests conducted on the cube specimens is in figure . it can be observed that for both binary mixtures containing LP and CCW, the compressive strengths are less than control values at 28 days. This is due to the replacement of PC with LP and CCW contents which reduce the PC clinker. The LP and CCW, depending on their degree of reactivity need to wait for CH, which is a by- product of PC hydration to react with in order to produce C-S-H, C-A-S-H. The same trend can be seen with the ternary blended mixes when compared with control pastes. The improvement is more outstanding with the ternary blended mixes. It can be observed that for the ternary mixes, the improvement ranged from 2.60 % - 13.71 % for ternary mixes with LP content up to 20 % and decreased from 7.34 % - 10.74 % for mixes with LP content greater than 20 %. This shows that compressive strength decreased when LP content exceeds 20 %. This can be seen in both binary and ternary mixes. Optimum compressive strength values of 46,25 n/mm^2 and 42.29 N/mm^2 were obtained at 20 % LP, 10% CCW contents respectively. This implies that the synergy was most at this combination compared with other mixes.

Table 4.5: Compressive strength of Mixes (N/mm^2)

s/no	Mix ID	28 Days	56 Days
1	PC – SCC	38.25	40.05
2	PC + CCW5	30.15	35.12
3	PC + CCW10	32.25	36.22
4	PC + LP5	34.72	37.05
5	PC + LP10	32.85	38.25
6	PC + LP 20	30.65	40.22
7	PC + LP25	26.65	32.15
8	PC + LP30	24.95	28.85
9	PC + LP5 +CCW5	32.15	42.32
10	PC + LP10 + CCW10	31.85	43.12
11	PC + LP15 +CCW10	31.00	44.75
12	PC + LP20 + CCW10	31.45	46.25
13	PC + LP25 + CCW10	28.25	36.33
14	PC + LP30 + CCW10	26.35	35.75
15	PC + LP25 + CCW5	24.75	37.12
16	PC + LP20 + CCW7.5	27.32	42.25

4.2.2 Splitting Tensile Strength

Splitting tensile strength test was conducted in accordance with ASTM C 496-90. Results are shown on Table 7. It can be observed that the variation in splitting tensile strength show the same trend as observed in compressive strength. Increase in splitting tensile strength of 3.76 n/mm2 and 4.56 n/mm2 at 28 and 56 days in mixes PC + LP20 +CCW10 and PC +LP20 +CCW7.5 when compared with control values amount to 7.0 % at 56 days. It is worthy to note that pozzolanic reaction continues and improved values are obtained at later curing ages when compared with control value.

Table 4.6: Splitting Tensile strength of Mixes (N/mm^2)

s/no	Mix ID	28 Days	56 Days
1	PC – SCC	4.14	4.24
2	PC + CCW5	3.68	3.86
3	PC + CCW10	3.80	4.03
4	PC + LP5	3.94	4.08
5	PC + LP10	3.85	4.15
6	PC + LP 20	3.72	4.25
7	PC + LP25	3.47	3.60
8	PC + LP30	3.35	3.80
9	PC + LP5 +CCW5	3.80	4.36
10	PC + LP10 + CCW10	3.85	4.25
11	PC + LP15 +CCW10	3.73	4.40
12	PC + LP20 + CCW10	3.56	4.56
13	PC + LP25 + CCW10	3.25	3.60
14	PC + LP30 + CCW10	3.05	3.55
15	PC + LP25 + CCW5	24.75	37.12
16	PC + LP20 + CCW7.5	27.32	42.25

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Summary of Results

Influence of LP and CCW contents on the properties of SCC was studied. The suitability of constituent materials for the study was achieved through preliminary tests conducted on the materials. This was followed by preparing sixteen mixes with varying contents of LP and CCW. They were tested and the effects of the varying contents on the properties of SCC were evaluated Results were analyzed and discussed and values compared with that available in relevant codes. Summary of findings are as follows:

1 Limestone powder with a specific gravity of 2.68 and Blaine fineness of 4003 cm2/g, calcium carbide waste with a specific gravity of 2.19 g/cm3 influence the properties of SCC.

2 The consistency of SCC containing LP and CCW blends increased slightly compared with control values and the blended mixes are retarders since the setting times increased when compared with control values.

3 The workability of SCC blended with LP and CCW contents in terms of flow ability, passing ability were improved. The flow ability of SCC containing LP and CCW up to 20 % and 10 % contents met EFNARC provisions of 550 – 800 mm. the passing ability of SCC containing up to 20 %LP and 10 % CCW met PA1 and PA2 requirements of 0.80 minimum as blocking ratio. Beyond 20 and 10 % contents of LP and CCW, the mix is susceptible to segregation.

4 The hardened properties of SCC incorporated with LP and CCW contents were improved when compared with reference values. Both binary and ternary mixtures improved in compressive strength up to 13.71 % compared with control values but decreased when LP content exceeded 20 %.

5 The splitting tensile strength of SCC blended mixtures has the same trend as that of the compressive strength.

5.2 Conclusion

From the test results, analysis and discussion of the results, summary of findings, the following conclusion is drawn:

1 self- compatibility of Concrete can be achieved when PC is replaced with LP and CCW up to 20 % and 10 % respectively at a constant w/b ratio of 0.38 by weight of binder and a slightly varying content of SP from 0.75 – 0.88.

2 The optimum content of LP and CCW in blended SCC IS 20 % LP and 10 % CCW at 0.38 w/b ratio and 0.75 – 0.88 % of SP which yielded the most synergy between LP and CCW with a compressive strength of 46.25 N/mm^2 after 56 days, an increase in strength of 13.71 % over reference value.

5.3 Recommendation

The following recommendations are suggested:

1 Utilization of higher specific surface area for LP contents could improve the 20 % replacement level of PC.

2 Durability properties of SCC incorporating LP and CCW such as sorptivity, porosity to improve its transportation ability should be investigated.

5.4 Contribution to body of knowledge

Self-compatibility of concrete containing LP and CCW is attained at 20 % and 10 % contents at a w/b ratio of 0.38, an SP content of 0.75 – 0.88 % yielding utmost synergy between LP and CCW with a compressive strength of 46.25 N/mm^2 after 56 days of curing.

This implies that the use of SCC blended with LP and CCW helps to reduce these waste materials thus making SCC blended with LP and CCW a low – impact environmental material.

References

ACI committee 318 (2005). 'Building codes requirements for structural concrete'' (ACI 318-05). American concrete institute, Farmington Hills, MI.

ACI Technical committee 237. (2017) Self – consolidating concrete. American concrete institute, pp 1- 30.

Abiya, SE, Odiyi BO, Salau I. Effect of calcium carbide waste on the growth and, Biomass of Okra (Abelmoschus esebicentusimoench). IOSR J. environ Sci. Toxicol Food Technology, 2015), 9(1), 68 – 71.

ASTM C 191 (2008): Standard method for normal consistency and setting of hydraulic cement. Annual Book of ASTM standards, pp 172 – 174.

Babako, M. and Apeh, J.A. (2020). Setting time and standard consistency of Portland cement binder blended with rice Husk ash, calcium carbide and Metakaolin admixtures. IOP Publishing. IOP Conf. series. Materials science 7 engineering, 805 (2020) 012031 pg 1 -13.

Bessey, S.E. (1938): Proced. Symp; Chem. Cements, Stockholm, 1938, pp 186.

Bouzouba N, Lachemi, M. (2001): Self- compacting concrete, incorporating high volumes of class F fly ash. Preliminary results. Cem. Concr. Res. 31; 413 – 420.

Chai Jaturapitakul, Iboonmarkkoon. Greeing cementing materials from calcium carbide residue – Rice husk ash. J. mater. Civ. Eng. 2003. 15 470 – 475.

Chockalingam, M. (2012). Experimental investigation on self-compacting concrete using marble powder and silica fume. International Journal and magazine of engineering. Pg 212 – 235.

Craeye, B; schutter, G.D., Desmet, B; Vantomme. J. Heiriman, G., Vande Walls, L. & Kadir, O. Effect of Mineral filler type on autogenous shrinkage of self-compacting concrete. Cem. Concr. Res. 2010, 40(6), 908 – 913.

Damido, D; Lothenbach, B. Herfort, d; & Glasser, F.I. Thermodynamics and cement science. Cem. Conc. Res. 2011, 4(7). 679 – 695.

Domone, P.I. (2006): Self-compaceing concrete: An analysis of 11 years of case studies. Cement and concrete composites, 28(2), 197 – 208.

Daniels, A.B, (Stokholm), 33(1) 1 – 14 (1948), Abstract J. AM concr. Inst. 1949, 2193} 232.

Deweerdt, K. Ben. H.M., Lie; S.G. Kjellien, K.O.; Justnes, H; and Lothenbach, B. (2011): Hydration mechanisms of ternary Portland cements containing Limestone powder and Fly ash. Cem. Concr. Res., 2011, 41(3): 279 – 291.

Demirhan, S. Turk, K; &Wugerge, K. Fresh and hardened properties of self- consolidating Portland Limestone cement Mortars: effects of high volume Limestone powder replacing PC. Constn. Build. Mater. Vol. 196, pp 115 – 125, 2019.

EFNARC 2005.EFNARC specification and guidelines for self-compacting concrete in: European Federation for specialists' construction chemicals & concrete systems, may, 2005.

Felekoglu, B. Baradan, B. Utilization of Limestone powder in self-levelling binders in: KK Dhir, M.D. Newlands, J.E. Newlands editors, proceedings of the international symposium of advances in waste management and retying. Thomas Telford ltd, London, 2003, pp 476-484.

Ferraris, S.F., Buwer, I, Daczko, J., Ozyildircem, C. (2000). Workability of self -compacting concrete, in: proceedings: the economical solution for durable Bridges and transportation structures. International conference production methods and workability of concrete. EFFN spon. London, 1999 pp 1 – 24.

Gumeyisi, E. (2010). Fresh properties of self-compacting rubberized concrete incorporated with fly ash. Mater. Struct. 2010, 43: 1037 – 1048.

Goaszewski, J & Szwabowski, (2004): J. Influence of Superplastizers on Rheological behavior of fresh cement Mortars. Cement and concrete Research 34, 235 -248.

Hognestad, E.(1954): j. Amer. Concr. Inst. 195425 (9). 801 – 803.

Joudi, B.I. Lecomtecb, A, Onezdoua, M.B.; and Achoure, T (2012): Use of Limestone sands and Fillers in concrete without superplasticizer. Cem. Concr. Compos. 34(6); 771 – 780.

Kamine, V.F.S.F, Alireza, N. (2014). Studying the strength of self-compacting concrete. According to the ratio of plasticizers and slump flow using experimental methods. Life science Journal. Pp 104 – 125;

Karen, L.S. (2012) Impact of Microstructure on the durability of concrete. 'second international conference on microstructural -related durability of cementitious composites, 11 – 13 April 2012, Amsterdam, The Netherlands .

Katsaori, M; Gkamis D. Pipilikaki, P. Sakeraruni, A; Papathannasioni, A; Teas, CH. (2009): Study of the substitution of Limestone filler with pozzolanic additives in Mortars. Construction Build. Mater. 23, 1960 – 1965.

Lachemi, M. Hossain, K.A., Lambros, V., Nkinamubansi, PC, Bouzouba (2004). Performance of New viscosity modifying admixtures in enhancing the rheological properties of cement paste. Cem. Concr. Res. 2004; 34; 185 – 193.

Lie, W.G. Huanng, Z.Y. Cao, F.C. Sun, Z.H. & SHA, S.P. (2015): Effects of Nano – silica and Nano- Limestone on flow ability and mechanical properties of ultra – high performance concrete matrix. Constn build. Mater. 95, 366 – 314,

Li, W.G.; Huang, Li, Y, Zu, T.Y.; Shu, C.J.; Duan, W.H.; & Shan, S.P. (2016): Influence of Nano limestone on the hydration, mechanical strength, and autogenous shrinkage of Ultra High Performance concrete. J. Mater. Mcivileng. 28(1), 04615068.

Liu, S.H. & Yan, P.Y. (2008): Influence of limestone Powder on filling effect of cement paste and pore structure of sand grout. J. Chin.ceram. SOC. 1, 3691), 210 -213.

Lothenbach, B; Serevener, K.C. & Hooton, R.D. (2011): Supplementary cementitious Materials,,cem. Concr. Res. 41(12); 1244 – 1256.

Makaratat, N. Jaturapitakul C, Namaik, C, Sata, V. (2011): Effects of binder and CaC2 contents on the strength of calcium carbide residue-fly ash concrete. Cem. Conc. Compos. 33(3),436 – 443.

Makaratat, N; Jaturapitakul, C; Nabrak, C, Sata, V. (2011): Effects of binder and calcium carbide contents on the strength of calcium carbide residue – Fly ash concrete. Cem. Concr. compos. 33(3); 430 – 442.

Malhotra, V.M. &Carede, G.G. (1985): Performance of Limestone cement Mortar. In: concrete incorporating Limestone dust as partial replacement for sand. ACI Materials, J. 82(3), 363 – 371.

Martin, C. Phillippe, L; & Erick, R. {2006): Efficiency of Mineral admixtures in Mortar. Quantification of the physical and chemical effects of the admixtures in relation with compressive strength. Cem. Concr. Res., , 36; 264 – 277.

Menedez, G; Ronnaveti, V. Irasser, EF. (2003}. Strength development OF Ternary cement with limestone Filler and blast furnace Slag; Cem.Concr. comp. 25 – 61.

Naik, T.R, & Kraus, R.N, (2001): Temperature effects on high performance concrete. Proceedings of 6th international symposium on the utilization of high strength/high performance concrete, Vol, 2. Leipzig, June 2001, pp 1209 – 1222.

Nehdi, M & Mindness, G. (1996): Optimization of high strength Limestone filler cement Mortars. Cem. Concr. Res. 26, 6: 883 –891.

PCI (2003). Interim guidelines for the use of self-consolidating concrete in precast/prestressed concrete institute member plants. (TR-6-03); Chicago, H. Precast/prestressed concrete mixture.

Petity and Wirquim, E. (2010). Effect of Limestone Filler content and superplasticizer dosage on rheological parameters of highly flowable Mortar under light pressure conditions. Cem. Conc. Res. 2010. 40; 235 – 241.

Roder S. Oyabur, R.L., Kobayashi, k; Yamada, H. & Kunle, A. (2009): True atomic - resolution inaging of calcite in aqueous solution by frequency modulation atomic force microscopy. Langinar, 23, 2830 – 2833.

Rilem's report, 23 (2000)- Self-compacting concrete- state of the Art report of rilem Technical committee 174 SCC, 2000.

Sellenoid, I.J.; Bager, D.H; Jensen, E.K. & Knudsen, T. (1982): Silica Fume cement Pastes. Hydration and pore structure condensed Silica Fume in concrete. Institute for By grings material laere, Norges Tekniske Hogskole, Norway, BML 82, 610.

Soroka, I & Setter, N.(1977): The effect of fillers on strength of cement mortars. Cem. Concr. Res. 1977, 7(4), 449 – 456.

Sua- Iam, G. Makul, N. Utilization of Limestone powder to improve the properties of Self-compacting concrete incorporating high volume of untreated rice husk Ashas fine aggregate. Constn Build Mater 38(156); 455 – 464.

Sun, H, Li,Z, bai J, Memon, SA, Dona, B. Fang V.Xu W, Xing, F.(2015): Properties of chemically combusted calcium carbide residue and its influence on cement properties. Materials, 8(2); 638-651.

Sun, H., Li, Z; Bar, J; Memou, SA, Deng, B; Fang, Y; Xu, W, Xing, F. (2015): Properties of chemically combusted Calcium Carbide residue and its influence on cements properties. Materials Feb. 13; 8(2): 638 – 651.

Tattersall, G.H. &Banfill, P. F.G. (2016). The rheology of fresh concrete. PAMAN, 356p.

Ugwu, O.O, Nwoji, C.U. Onyia, M.I. Gber, A, Tarzomon, T.T. (2018): Development of self-compacting concrete using Industrial Wastes as Mineral and chemical additives. ISOR Journal of mechanical and civil engineering, Vol 15, 5(3), pp 45 – 48..

Vikan, H. Justness, H. &Winefeld, F. (2005). The importance of cement type on flow resistance of cement paste. Second North American conference on the design and use of self-compacting concrete, Chicago, IC ; ACBM.

Wang YL, Dong SI, Liu, LL,Cut SP (2013). Using Calcium carbide slag as one of calcium containing Raw materials to produce cement clinker. Mater. Science Forum; 2013, 743 – 744, 771 – 774.

Wang, D.(2019): A quantitative study on physical and chemical effects of Limestone powder on properties of cement pastes. Constn Build Mater. Vol. 204, no 10, April, pp 58 – 69.

Wang, D; wang, Q; Xue. J (2010) reuse of hazardous electrolytic Manganese residue. Detailed leaching characterization and novel application as a cementitious material. Resour, conserve. Recy. 2020, 154. 104645.

Wang, Y.L., Dong, S.L., Liu, L.L., Cue, S.P. (2013): Using calcium carbide slag as one of calcium- containing raw materials to produce cement clinker. Mater. Sci. Forum. 743 – 744, 171 – 174.

Xie T, Mohammed Ali, M.S.; EcchalakanipuVisintui, P. (2021): Modelling fresh and hardened properties of self- compacting concrete containing supplementary cementitious materials using reactive moduli constn Build. Mater. 272, 121954.