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Influence of Limestone Powder and calcium Carbide Waste on the Properties of Self Compacting Concrete

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Abstract

**Concrete is a widely used material. Among its constituents, cement contributes most to its strength development. This study evaluated the influence of Limestone and Calcium carbide waster contents on the properties of the blended Mixes. Sixteen mixes with PC as control and others 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 and cylinders were cast, cured to determine compressive and splitting tensile strengths at 28 and 56 days respectively. Test results show that consistency of the blended cements slightly increased compared with control value. Similarly, the setting times were 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 2005 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 +LP20 +CCW10 attaining a compressive strength of 46.25 N/mm2 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 + LP20 +CCW10 which produced a strength of 46.25 N/mm2 yielded the most synergy between LP and CCW and can be used to attain self-compatibility of SCC.**

*Keywords: Limestone, Calcium Carbide Waste, Setting Time, Compressive strength, filling ability, passing ability;*

1. Introduction.
   1. Background of 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, 2000). 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/m3. Since it is uneconomical to use excessive cement content and also considering the environmental implications, it is imperative that replacement powders are sought for, such as Fly ash (FA), silicfume (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 (Petit and wirgun, 2010; katsion 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 SiO2 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, (2003) indicates that the use of ternary blended cements reduces the cost of PC production, thus CO2 emission and improve early and late age compressive strengths.

The work of Makaratat (2011) shows that Calcium carbide waste (CCW) is a by- product from acetylene gas (C2h2) production. It is obtained when water reacts with calcium carbide (CaC2) as shown in equation (1).

CaC2 + 2H2O (2) C2 H2 + Ca (OH)2 (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 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. The work of Jaturapitakkul and Roongreung (2003) indicate that a pozzolanic reaction could occur between CaC2 and Rice husk Ash yielding a maximum compressive strength of 15.60 MPa at 28 days. Disposal of most waste material s is one of the environmental problems, world- wide today. However, they ca be successfully and economically utilized to improve some fresh and hardened properties of SCC. Co2 emissions from concrete production accounts for around 8 % man-made CO2 (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 behaviour of binary cementitious system becomes an issue. A possible approach to improve early age - mechanical behaviour 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 (Weerdt,2011a) and produce almost zero associate CO2 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 – CaC2, 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.

**2.0 Materials and Method**

**2.1 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.

**2.1.2 Mix Proportion**

For the study, proportion mix procedure (EFNARC, 2005) was adopted. This include a water content of 150 – 200 Kg/m3, 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. Sixteen Mixes were produced accordingly {Table 1).

**Table 1: Mix Proportion**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **s/**  **no** | **Mix ID** | **Type**  **of**  **Paste** | **Total**  **Binder**  **Kg/m3** | **PC**  **Kg/m3** | **LP/**  **CCW**  **Kg/m3** | **Fine**  **Agg.**  **Kg/m3** | **Coarse**  **Agg.**  **Kg/m3** | **Water**  **Kg/m3** | **SP**  **(%)** | **W/B**  **Ratio** |
| 1 | SCC | Cont. | 400 | 400 |  | 847.84 | 740.73 | 152 | 0.75 | 0.38 |
| 2 | PC +LP5 | binary | 400 | 380 | 20 | 847.84 | 740.73 | 152 | 0.75 | 0.38 |
| 3 | PC+LP10 | binary | 400 | 360 | 40 | 847.84 | 740.73 | 152 | 0.77 | 0.38 |
| 4 | PC+LP15 | binary | 400 | 340 | 60 | 847.84 | 740.73 | 152 | 0.85 | 0.38 |
| 5 | PC+LP20 | binary | 400 | 320 | 80 | 847.84 | 740.73 | 152 | 0.85 | 0.38 |
| 6 | PC+CCR5 | binary | 400 | 380 | 20 | 847.84 | 740.73 | 152 | 0.78 | 0.38 |
| 7 | PC+CCR10 | binary | 400 | 360 | 40 | 847.84 | 740.73 | 152 | 0.80 | 0.38 |
| 8 | PC+LP5+CCR5 | ternary | 400 | 360 | 40 | 847.84 | 740.73 | 152 | 0.82 | 0.38 |
| 9 | PC+LP10+CCR10 | ternary | 400 | 320 | 80 | 847.84 | 740.73 | 152 | 0.84 | 0.38 |
| 10 | PC+LP15+CCR10 | ternary | 400 | 300 | 100 | 847.84 | 740.73 | 152 | 0.85 | 0.38 |
| 11 | PC+LP20+CCR10 | ternary | 400 | 280 | 120 | 847.84 | 740.74 | 152 | 0.86 | 0.38 |
| 12 | PC+LP25+CCR10 | ternary | 400 | 260 | 140 | 847.84 | 740.74 | 152 | 0.88 | 0.38 |
| 13 | PC+LP30+CCR7.5 | ternary | 400 | 250 | 150 | 847.84 | 740.74 | 152 | 0.88 | 0.38 |
| 14 | PC+LP25+CCR5 | ternary | 400 | 280 | 120 | 847.84 | 740.74 | 152 | 0.86 | 0.38 |
| 15 | PC+LP20+CCR5 | ternary | 400 | 300 | 100 | 847.84 | 740.74 | 152 | 0.84 | 0.38 |
| 16 | PC+LP20+CCR7.5 | ternary | 400 | 290 | 110 | 847.84 | 740.74 | 152 | 0.84 | 0.38 |

**2.2 Method**

**2.2.1 Consistency, initial and final setting Times**

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 2.0). 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 in accordance with EFNARC, 2005; ACI 237-07, BS EN 196- 3.

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 Mix 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/Mn X 100 (2)

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.

**3.3. 3 Flow- ability**

The flow ability of each Mix was tested using the Slump Cone 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 twi ce 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 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 (H2) to that at the vertical (H1) is a measure of the passing ability or the blocking ratio, as shown in the relation, named equation (2):

**2.3 Compressive strength**

Fourty-eight cube specimens of sizes, 150 x 150 x 150 mm cast, cured 28 and 56 days and tested for compressive strength in accordance with BS EN 12390 -3. At each curing age, the cubes were crushed using a universal testing machine and peak or crushing force was used to compute the compressive strength using equation (3).

F = F/A (3)

where f = compressive strength (N/mm2), F = peak or crushing force, A = area of cross section of cube (mm).

**2.4 Splitting tensile strength**

Splitting tensile strength test was conducted on SCC using 100 x 200 mm cylindrical specimens. Force obtained at failure was used to calculate the splitting tensile strength using equation (4) in accordance with ASTM C 496-11.

l D (4)

Where F = tensile strength (N/mm2), P = compressive load, l = length of cylindrical specimen, diameter of cylindrical specimen.

**3.0 Test Results**

**3.1 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/cm3 and 2.19 g/cm3much less than that of PC, 3.13 g/cm3 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 1.0 show the particles size distribution (PSD) for PC, LP and CCW.

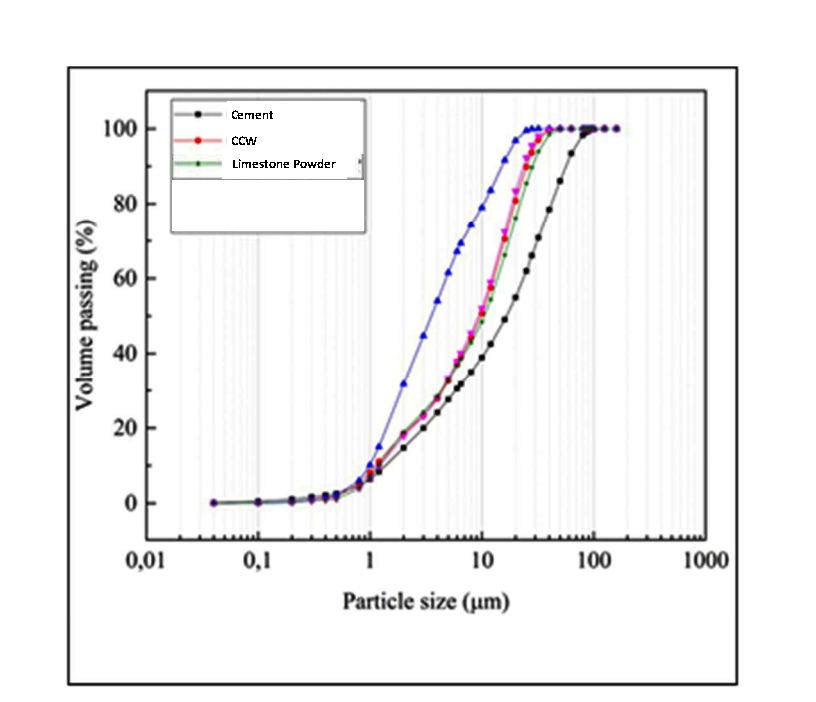


FIGURE 1: Particle size distribution (PSD) for PC, LP and CCW

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 2.0 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 2.0; physical and chemical properties of constituent materials

|  |  |  |  |
| --- | --- | --- | --- |
| **OXIDE** | **PC** | **CCR** | **LP** |
| **SIO2** | **19.49** | **2.10** | **0.22** |
| **Al2O3** | **4.52** | **0.50** |  |
| **Fe2O3** | **3.38** | **0.54** | **0.44** |
| **CaO** | **63.60** | **95.69** | **55.07** |
| **MgO** | **8.63** |  | **0.34** |
| **K2O** | **2.84** | **0.47** |  |
| **Na2O** | **0.13** |  |  |
| **SO3** | **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**

**3.2 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 showed that control pastes (100 % PC- CCW) has a normal consistence of 29 %. 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.

**3.3 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 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 +LP5+CCW5 and for PC +LP30 +CCW7.5IS increased by 15.38 % and FS by 14.51 % respectively. It is important to note that among the ternary mixes, **PC+LP20 +CCW10**has the lowest increase of **9.84 %** for IS and **10.08 %** for FS and then Mix **PC+LP20 +CCW7.5** 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, CH for more reactive process which improved both the IS and FS respectively.

**Table 3.0 Consistency and setting times of Mixes**

|  |  |  |
| --- | --- | --- |
| **Mix ID** | **Consistency (%)** | **Setting Time initial (mins) Final (Mins)** |
| PC- SCC | 29 | 110 165 |
| PC- CCW5 | 30 | 120 177 |
| PC- CCW10 | 31 | 125 182 |
| PC – LP5 | 28 | 118 180 |
| PC - LP10 | 25.5 | 121 183 |
| PC - LP15 | 25.75 | 123 185 |
| PC - LP20 | 25.25 | 126 187 |
| PC - LP25 | 26 | 130 190 |
| PC - LP30 | 26.75 | 128.5 189 |
| PC +LP5 +CCW5 | 25.85 | 127.25 188 |
| PC +LP10 +CCW10  PC +LP15+CCW10  PC +LP20 +CCW10  PC +LP25 +CCW10  PC +LP30 +CCW7.5  PC +LP20 +CCW5 | 29  28.5  29  30  31  29.25 | 125 186.5  124 185  122 183.5  128 190  130 193  124 185 |

**3.4 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. Acceptable slump flow diameters ranged from 550 mm to 800 mm (EFNARC 2005). Slump flow test for the SCC mixes were conducted for varying percentage replacement of PC with LP and CCW respectively. Specimen Test results is shown in figure 2.

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 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 (EFNARC, 2005). Hence, the fresh properties of the mixes were measured in accordance with EFNARC provisions.



Figure 2: Slump flow spread as measured using the Slump Cone

Figures 2 and 3 show test Specimen result and results of 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). For example, mix PC + LP30 +CCW10 has a slump spread flow of 530 mm, PC + LP25+ CCW7.5 has a slump flow of 530 mm, PC + LP25 +CCW10 has a slump flow of 512 and PC + LP30 + CCW10 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 exceeds20 %, the mixes becomes densified, less self -compacting (Beera and Gunakaile, 2013). Figure show that mix PC + LP25 + CCW10, PC + LP30, PC + LP30 +CCW7.5, PC + LP25, PC + LP30 slump values fell short of EFNARC, 2005 provisions.

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.

Figure 3: Slump flow values of mixes tested.

**3.5 Passing Ability**

Table 4 show the passing abilities of mixes tested. Five mixes (PC +LP25, PC + LP30, PC +LP25 +CCW10, PC + LP25 +CCW5, PC + LP30 +CCW5) 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.

**3.5 Passing Ability**

Table 4 show the passing abilities of mixes tested. Five mixes (PC +LP25, PC + LP30, PC +LP25 +CCW10, PC + LP25 +CCW5, PC + LP30 +CCW5) 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: Passing Ability of Mixes tested (H2/H1)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **s/no** | **Mix ID** | **H1(mm)** | **H2 (mm)** | **H2/H1 ==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 5:: slump flow, Passing ability and viscosity classes (EFNARC, 2005; ACI 237R-07)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Slump flow class** | **Slump flow diameter (mm)** | **Passing Ability class** | **H2/h1** | **Viscosity class T500 (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 |
|  |  |  |  |  |

**3.6 Hardened Properties**

**3.6.1 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/mm2 and 42.29 N/mm2 were obtained at 20 % LP, 10% CCW contents respectively. This implies that the synergy was most at this combination compared with other mixes.

**3.6.2 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 7: Splitting Tensile strength of Mixes (N/mm2)

|  |  |  |  |
| --- | --- | --- | --- |
| **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 |

**4.1 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 contents of LP exceeded 20 %.
5. The splitting tensile strength of SCC blended mixtures has the same trend as that of the compressive strength.
   1. **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/mm2 after 56 days, an increase in strength of 13.71 % over reference value.

**4.3 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.

**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/mm2 after 56 days.

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