# Evaluation of the Fresh and Hardened Properties of Self Compacting Self Cured Concrete using Waste Materials Micro Particles As A Cement Replacement Materials

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***Abstract*— In industries such as glass and ceramic, about 5-10% of production goes as waste in various manufacturing processes. This dumped in vacant spaces or landfilling causes environmental pollution hazardous for human health and agricultural lands. Therefore, using glass (GWP) and ceramic (CWP) waste powder in self-compacting self-cured concrete (SCSCC) as a cement replacement material (CRM) would benefit in protecting the environment. Thus, GWP and CWP can be converted into powder form with fine particle size passing through a Sieve of 90 microns. Their chemical composition consists of $Al_2O_3$ and $SiO_2$, making them accepted materials for CRM partially in SCSCC and, consequently, reducing the amount of waste. This paper aims to produce SCSCC by using CWP and GWP as partial CRM with percentages from 0 to 50% by the binder contain of SCSCC. Evaluating the results of the fresh and mechanical properties tests are introduced. Results show that Increasing CWP percent led to a decrease in flowability and passability of SCSCC but using GWP increases it. The optimum value of CWP was 10% and 20%for GWP. Using GWP as a CRM gives higher strengths than using CWP.**

***Keywords—Self-compacted; self-curing; ceramic waste powder; glass waste powder; properties.***

## I. INTRODUCTION

### A. *Self-Compacting Self-Cured Concrete*

This SCC was originally introduced in Japan in the late twentieth century, and it has been regarded as important advancement in the building business. Since the early 1970s, Europe has been employing concrete that has been laid without the requirement for vibration or minor compaction. The Swedish transport network was Europe's first SCC project in civil works in the mid-1990s. SCC has been hailed as "the most significant advance in concrete building in recent periods." Created to solve an increasing shortage of skilled workers, it has proven economical due to a variety of factors such as rapid construction, reduced site manpower, excellent surface finishes, simpler placement, improved durability, and a safe and secure construction site [1]. SCC has been hailed as "the most significant advance in concrete building in recent periods." Created to solve an increasing shortage of skilled workers, it has proven economical due to a variety of factors such as rapid construction, reduced site man - power, excellent surface finishes, simpler placement, improved durability, and a safe and secure construction site [2-4].

To achieve good flowability, maintain stability and sufficient cohesion, high powder content in this type of concrete is required. Increasing the amount of cement will cause cracking and will increase the cost of concrete. Thus, cement content cannot be increased to meet the demand of high powder content. Fillers or mineral admixtures are used with large quantities in SCC to reduce the occurrence of impact between particles and hereafter improve the flowability [2]. Because of the benefits of SCC, many researchers have investigated the use of various types of fillers, both reactive and inert, such as limestone powder, fly ash, and marble stone dust. For example, (Pansesar and Aqel 2014) [5] studied the effect of replacing cement with limestone powder that led to higher compressive strength. A study on marble powder (Alyamac and Ince, 2009) [6] found that it had a minor influence on flowability but could result in higher compressive strength at a given w/c ratio than traditional concrete. Ceramic and glass Waste Powder have fine particle size, and their chemical composition consists of $Al_2O_3$ and

$SiO_2$, mainly making them accepted materials for replacement of cement.

Curing concrete is necessary for the formation of concrete microstructures, which increases the performance and durability of the material. To obtain outstanding concrete structural behavior and long-lasting concrete, enough curing is required. As a consequence, it's one of the most important aspects to think about while looking for the greatest concrete performance. A usual healing regimen demands a lot of water, especially if you live in a hot climate. The usage of large amounts of fresh water in concrete casting and curing is a main source of concern in the building industry today. In many large cities, the desired quality and quantity of water are not accessible at a fair price, and some municipal corporations have set restrictions on the use of fresh water for development. As a result, natural resources such as ponds and tube wells have been exploited. According to literature dating back to the early twentieth century, curing is the foundation for the development of all hydrated concrete qualities. Internal curing, a developing topic in concrete technology that has piqued the interest of many researchers across the world, has demonstrated improvements in concrete durability and performance due to improved hydration.

Self-curing concrete has shown to be a feasible alternative in high-rise and enormous buildings, as well as in difficult-to-cure locations. The curing processes and duration of concrete have a significant impact on its efficiency. The two most frequent forms of concrete curing methods are water adding techniques and water retraining techniques. The self-curing technique is a sort of water retraining or preservation that occurs from within. Self-curing concrete may save a lot of water, especially in developed nations [7]. According to the ACI-308 rule [8-13], "internal curing refers to the process by which the hydration of cement occurs due to the availability of extra internal water that is not part of the mixed water." Traditionally, curing concrete entails creating circumstances in which water does not evaporate from the surface of the concrete. Curing is thought to occur "from the outside in." In contrast, "internal curing (IC)", also known as "self-curing (SC)", allows for curing from the inside to the outside via internal reservoirs.

### *B. Waste Materials Problem*

Because byproducts and trash from industry are increasing on a daily basis, the entire globe is challenged with the difficulty of disposing of them. Both the growth in the number of trash and the challenge of disposing of them are compelling researchers to use them in a sustainable manner. Conversely, the concrete industry has a higher carbon impact on the environment since it consumes a large amount of traditional materials such as cement and sand. As cement substitute in concrete production, additional materials having cementitious capabilities have been employed[16].

#### *1) Ceramic Waste Powder*

Alternative materials such as FA, SF, and rice husk have been used in recent decades. These materials have been shown to suit the concrete criteria of construction [17, 18]. Ceramic trash pollutes the environment and constitutes a health danger to humans when it is left in abandoned sites or disposed of in landfills. Currently, no form of this waste can be recycled. As a consequence, these ceramic wastes may be pulverised and utilised as cement filler materials in SCC, therefore reducing the quantity of ceramic waste in landfills.

The chemical examination of ceramic waste powder revealed that silica ($SiO_2$) accounts for about 69.4 percent of the material. Alumina is also a substantial component of ceramic waste powder, accounting for around 18.2 percent of the total. In ceramic waste powder, the combined mix of silica and alumina oxides reaches 80% of the total material weight. 3.19 percent $Na_2O$, 3.53 percent MgO, 0.306 percent Cl, 1.89 percent $K_2O$, 1.24 percent CaO, 0.617 $TiO_2$, 0.83 percent $Fe_2O_3$, and 0.266 percent $ZrO_2$ were among the other components. Ceramic waste powder has a specific surface area (SSA) of 555 $m^2/kg$ when measured using the Blaine fineness technique [19].

Daniel and Anna [20], Agil.R and Kumar.A [21] studied concrete made with CWP and discovered that the compressive, tensile, and flexural strength of the concrete rose by up to 15% when cement was replaced with CWP. Rani.S (2016) [22], discovered that CWP may be used as a 10% replacement material for cement, and that larger replacement of cement with CWP diminishes compressive strength.

Manogna. P, SriLakshmi. M. (2015) [23], GANESH. V, et al., (2018) [24], and Karthika.V, et al., (2015) [25] concluded that when cement is replaced with CWP, the compression, split tensile, and flexural strength of concrete increases by up to 30%, and further replacement of cement with CWP decreases the strength consistently. Concrete's durability has improved as a result of CWP.

#### *2) Glass Waste Powder*

Glass waste comes in a variety of forms, including flat glass like windows, container glass, cathode ray tube glass, and bulb glass. On general, glass garbage does not disintegrate in the land and hence does not affect the environment; nevertheless, if disposed of incorrectly, it may cause harm to both people and animals. Glass, on the other hand, may be recycled with high performance and distinct aesthetic characteristics, making it appropriate for a wide range of applications.

GWP can be used as a partial replacement for cement in concrete. Using GWP as a pozzolan in concrete, on the other hand, significantly improves building sustainability. On the one hand, the mechanical properties of the concrete, including GWP, must be provided; on the other hand, the impact of GWP on specific mechanical properties of concrete must be investigated.

When GWP is used in the production of concrete, it causes two forms of adversarial action: the pozzolanic reaction, which helps concrete qualities, and the alkaline-silica reaction, which harms concrete [26].

The alkali-silica reaction is often linked with coarse particles containing amorphous silica, in which the silica network is destroyed to free silica, which subsequently combines with calcium and alkali to form CSH gel, causing concrete expansion [25,26]. While pozzolanic activity is frequently linked with tiny particles, silica is freed when hydroxide ions destroy the silica network and combine with Portlandite calcium to form CSH, which enhances concrete properties [29,30]. As a result, the fineness of the glass powder is a

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crucial parameter in the production of glass pozzolans in order to increase their performance [31].

According to Bhat and Bhavanishankar Rao (2014), Raju and Kumar (2014) [4,32] state that the results revealed that increasing the amount of glass powder by up to 20% enhances the strength, but beyond that, it lowers. Anwar (2016), on the other hand, stated that the compressive, tensile, and flexural strength of concrete increases up to 15% when cement is replaced with glass waste powder, and that increasing the percentage of waste glass powder leads to a decrease in compressive strength and an increase in concrete density due to the filling of powder in voids [33].

## II. RESEARCH SIGNIFICANCE

The study aimed to study two main points. The first is producing SCSCC using PEG400 by percentages of (0.5, 1, 1.5, 2) % of the cement weight and selecting the optimum dosage of PEG400 according to its effect on the SCSC concrete fresh and hardened properties. The second is to evaluate the effect of incorporating CWP and GWP as solid waste from the industry for possible use as an alternative ingredient to partially CRM in SCSCC. The concrete mixtures incorporating CWP and GWP by percentages of (0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50% by mass) on the fresh properties of SCSCC (flowability and passing-ability) and hardened properties of SCSCC (compressive strength, indirect tensile strength, and flexural strength).

## III. EXPERIMENTAL PROGRAM

### *A. Materials*

**Cement**: Cement: OPC was implemented. It was supplied by Beni Suef Cement Company BSCC (Beni Suef city, Egypt) within the standards (ASTM C150/C150M) [34] the chemical composition of cement is as follows in Table I.

Due to the European Guidelines for SCC, published in May 2005, "The usual cement content is 350-450 $Kg/m^3$. Moreover 500 $Kg/m^3$ cement might be hazardous and promote shrinkage. Less than 350 $Kg/m^3$ may only be appropriate with the addition of other fine filler, such as fly ash, pozzolan, " and so on (SCCEPG, 2005) [41]

**Silica fume:** SF is a noncombustible amorphous silica ($SiO_2$) waste byproduct of the silicon and silicon alloys industry. Egyptian Ferro Alloys Corporation created the utilized silica fume (EFACO). The silica fume utilized had a density of 2210 kg/m3 and a fineness of 23.52 $m^2$/gm. The silica fume utilized satisfied the primary criteria of ASTM C 1240 [35].

**Ceramic and glass Wastes Powder**: Ceramic and glass waste is generally created as a byproduct of ceramic processing. This waste is the primary source of contamination in the land, air, and water. During the grinding operation of ceramic tiles, a large amount of CWP is produced. In the Los Angeles Abrasion testing equipment, CWP and GWP was collected from various industries and converted to micro-sized powdered. CWP and GWP was employed, which was sieved using a 90-micron sieve. The chemical composition of CWP and GWP was tested in strength and testing of materials laboratory at the faculty of engineering Assuite university using X-ray fluorescence test (XRF) as shown in Table I. The average particle size for waste materials was 0.4 µm and 2 µm for CWP and GWP, respectively as shown in figure 1.

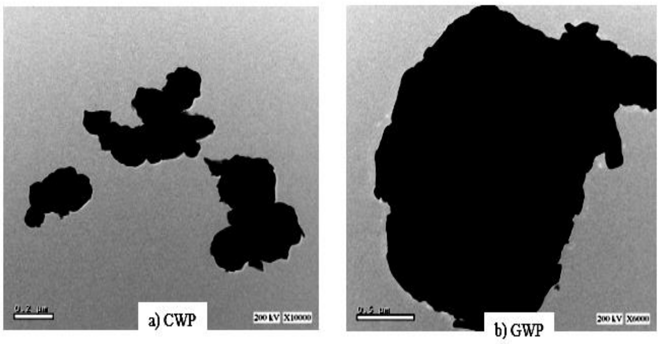


Fig. 1. TEM images of ceramic and glass waste powder

The chemical examination of CWP revealed that silica ($SiO_2$) accounts for about 58.98 percent of the material. Alumina is also a substantial component of ceramic waste powder, accounting for around 16.65 percent of the total. In ceramic waste powder, the combined mix of silica and alumina oxides reaches 75% of the total material weight. 0.36 percent $Na_2O$, 0.43 percent MgO, 0.01 percent Cl, 1.87 percent $K_2O$, 12.49 percent CaO, 0.94 $TiO_2$, and 7.58 percent $Fe_2O_3$ were among the other components.

The chemical examination of glass waste powder revealed that silica ($SiO_2$) accounts for about 76.47 percent of the material. Alumina is also a substantial component of ceramic waste powder, accounting for around 1.00 percent of the total. In ceramic waste powder, the combined mix of silica and alumina oxides reaches 77% of the total material weight. 0.81 percent $Na_2O$, 2.48 percent MgO, 0.02 percent Cl, 16.01 percent CaO, 0.11 $TiO_2$, and 1.48 percent $Fe_2O_3$ were among the other components.

Table I: CHEMICAL COMPOSITION OF PORTLAND CEMENT, GLASS POWDER AND CERAMIC POWDER.

| Composition (% by mass)/ property | Cement | Glass powder | Ceramic powder |
|---|---|---|---|
| Silica ($SiO_2$) | 21.1 | 76.47 | 58.98 |
| Alumina ($Al_2O_3$) | 5.50 | 1.00 | 16.65 |
| Iron oxide ($Fe_2O_3$) | 3.20 | 1.48 | 7.58 |
| Calcium oxide (CaO) | 63.5 | 16.01 | 12.49 |
| Magnesium oxide (MgO) | 0.71 | 2.48 | 0.43 |
| Sodium oxide ($Na_2O$) | 0.10 | 0.81 | 0.36 |
| Potassium oxide ($K_2O$) | 0.5 | - | 1.87 |
| Sulphur trioxide ($SO_3$) | 2.4 | 0.16 | 0.02 |
| Unit weight, $Kg/m^3$ | 3150 | 2579 | 2330 |
| Specific gravity | 3.15 | 2.58 | 2.33 |

**Water**: As per the Egyptian code of practice, clear, drinkable, new, and impurity-free tap water was utilised for mixing and curing the examined samples [36].

**Super-plasticizer:** Sika Viscocrete 3425 is the utilised SP; it is a polycarboxylate-based SP offered by Sika Egypt for construction chemicals firm; it is a 3th group SP for concrete and mortar that fulfils the standards of ASTMC494, kinds G and F(ASTM C494, 2003) [37]. The used SP has 1.08 Kg/lit density, 4.0 pH value, and 40% solid content (by weight) as stated by the supplier.

**Polyethelene glycol (PEG):** PEG 400 is used in concrete curing (see Table II). The use of PEG lowers water losing from the surface of concrete and aids in water retaining. They were used at ratio 0.5, 1, 1.5 and 2 wt. % of cement. it was from El-Gomhorya Company Table 2. shows properties of PEG.

Table II: CHARACTERISTICS OF POLYETHYLENE-GLYCOL

| Type | Molecular weight | Viscosity range | Physical state | Solubility in water |
|---|---|---|---|---|
| Synthetic | 400 | 6.8-8.0 | Liquid | ∞ |

**Fine aggregate**: Naturally quartz sand was employed as the fine aggregate throughout this experimental program in the concrete mix with characteristics that satisfies the Egyptian Standard Specification for aggregate [38]. It was clean and nearly free from impurities with a specific gravity 2.5 t/m $^3$ and a fineness modulus of 2.73 The grain size distribution for used sand are shown in Table III.

**Coarse aggregate:** Dolomite has been used as an ingredient. It was used during "saturated surface dry" (SSD). It has a specific gravity of 2.65, a maximum nominal size of 12.5 mm, and meets Egyptian Standard Specification for aggregate [38]. Table IV illustrates the sieve analysis of utilised dolomite.

Table III: GRADING OF THE USED SAND.

| Sieve size (mm) | Grading % Passing | Specification limits (ASTM C33) % passing |
|---|---|---|
| 4.75 | 100 | 95-100 |
| 2.36 | 97.4 | 80-100 |
| 1.18 | 83.9 | 50-85 |
| 0.61 | 54.08 | 25-60 |
| 0.31 | 22.18 | 5-30 |
| 0.16 | 1.7 | 0-10 |

Table IV: GRADING OF THE USED DOLOMITE.

| Sieve size (mm) | Grading % Passing | Specification limits (ASTM C33) % passing |
|---|---|---|
| 12.5 | 100 | 90-100 |
| 9.51 | 67 | 40-70 |
| 4.75 | 5.3 | 0.0-15 |
| 2.36 | 0.0 | 0.0-5 |

## B. Mix Proportions

Choosing the self-compacted concrete mix proportions was conducted firstly based on previous research conducted by Etman, 2006 [39]. Mix proportions used in this test program are summarized in Table V.

## C. Testing Procedures and Equipment

The fresh concrete tests are essential to evaluate the effect of adding PEG400, ceramic and glass waste powders to the self-compacted concrete fresh properties. The flowability and passing- ability properties were evaluated using the slump flow and J-Ring tests, respectively. Figure 2-a and 2-b show slump flow and J-Ring tests that were done according to the British standard [40] and the Egyptian code [36]. For the slump flow test, the acceptable range of the time for self-compacted concrete that is needed to reach 500 mm diameter ($T_{50}$) ranges between 2 and 5 seconds. Also, the average diameter ($D_{av}$) acceptable range of the slump flow ranges between 600 and 800 mm. The J-ring test ($T_{50}$) is accepted if it did not exceed 5.5 seconds. Also, the average diameter ($D_{av}$) is measured and compared with that of the slump flow and the difference between the two-average diameter of the two tests must not exceed 25 mm due to EFNARC-2005[41].

The compressive, indirect tensile and flexural strength are the investigated hardened concrete properties for the studied twenty-seven concrete mixes. The previous tests are recommended by ASTM C39 [36] to be studied. Cubes of dimensions 100x100x100 mm as shown in Figure 2-c were used to determine the concrete compressive strength. The indirect tension test (splitting method) was performed using cylinders with 100 mm diameter and 200 mm height dimensions, as shown in Figure 2-d. Flexural strength test was done using prism specimens of dimensions 100 x 100 mm cross-sectional area and 500 mm length (460 mm span), as shown in Figure 2-e.

All specimens were tested at the Concrete and Strength of Material Laboratory of Civil Engineering Department in the faculty of engineering, El Nahda University, Beni suef.

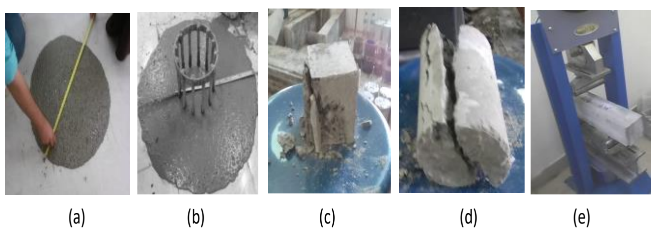


*Fig. 2. Fresh and Hardened testes*

## D. Specimens Nomenclature

The mixes were divided into three main groups. For the first group (self compacted concrete): The first part (SCSC) refers to self-compacting self-cured concrete and the second part of the name (0, 0.5, 1, 1.5, 2) % refers to polyethylene glycol 400 percent of the total binder content. The second group (self-compacting self-cured concrete produced by ceramic waste powder: The part of (CWP) refers to self-compacting self-cured concrete with the addition of ceramic waste powder (0, 5, 10, 15, 20, 25, 30) % as a cement replacement. For the third group (self-compacting self-

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cured concrete produced by glass waste powder): The part of (GWP) refers to self-compacting self-cured concrete with addition of glass waste powder (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50) % as a cement replacement.

## IV. RESULTS AND DISCUSSION

Test results of fresh and hardened concrete are investigated to study the effect of using CWP and GWP as CRM on the properties of fresh and hardened SCSCC.

### A. *Fresh Concrete Tests Results*

Slump flow and J-Ring tests were carried out on fresh concrete to investigate the flowability and passing-ability of SCSCC mixtures. Results of the average diameter and the 500mm diameter’s time were recorded and shown in Table VI.

**For using PEG400**, It could be observed that using PEG400 affects the flowability of the control mix (SCSC0), but it remains acceptable as a SCC according to EFNARC-2005[41]. It could be observed that increasing self-curing agent dosage (PEG400) increases the flowability and passability of SCSCC, it is noticed that the value for the four mixes gets increased by different percentage with maximum value for 2%, but the optimum value was 1% based on their main mechanical properties, as shown in Table VI and fig3.

**For using CWP as a CRM**, it is observed that increasing CWP percent led to decrease in the flowability and passability of SCSCC it is noticed that the value for the six mixes (CWP5, CWP10, CWP15, CWP20, CWP25, CWP30) are satisfied the acceptance criteria for SCC. But the four mixes (CWP35, CWP40, CWP45, CWP50) are not accepted because of did not achieve acceptance criteria for SCC as shown in Table VI and fig 4.

The increasing the quantity of CWP in the mixes affects flowability while being within the range suggested by EFNARC-2005[41]. This might be attached to the increased water requirement caused by the particles' increased Specific surface area CWP particles reduces the capacity of the mixture to expand, resulting in smaller slump flow widths. Also, using the ceramic waste powder in self-compacting self-cured concrete absorbing more water, which results in the reduction of concrete segregation. Thus, the strength of SCC also improved.

**For using GWP as a CRM**, when using GWP as a CRM, it was discovered that increasing the percentage of GWP resulted in an improvement in the flowability of SCSCC. All of the mixtures passed the self-compacting concrete approval criterion. This might be attributable to an increase in the free water content and filling ability of GWP concrete mixtures, as indicated in Table VI and fig5.

Table V: The mixture proportions

| Group | Mix | C ($Kg/m^3$) | W/B ($Kg/m^3$) | C.A ($Kg/m^3$) | F.A ($Kg/m^3$) | SF/C ($Kg/m^3$) | SP/B ($Kg/m^3$) | Polyethylene glycol 400 (%) | Waste material | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | CWP% | GWP% |
| 1 | SCSC0 | 425 | | | | | | 0 | | |
| | SCSC0.5 | | | | | | | 0.5 | | |
| | SCSC1 | | | | | | | 1 | | |
| | SCSC1.5 | | | | | | | 1.5 | | |
| | SCSC2 | | | | | | | 2 | | |
| 2 | CWP 0 | 425 | | | | | | | 0 | |
| | CWP 5 | 403.75 | | | | | | | 5 | |
| | CWP 10 | 382.5 | | | | | | | 10 | |
| | CWP 15 | 361.25 | | | | | | | 15 | |
| | CWP 20 | 340 | | | | | | | 20 | |
| | CWP 25 | 318,75 | | | | | | | 25 | |
| | CWP 30 | 297.5 | | | | | | | 30 | |
| | CWP 35 | 276.25 | 163.6 (35%) | 730 | 994 | 42.5 (10%) | 9.35 (2%) | Optimum (1%) | 35 | |
| | CWP 40 | 255 | | | | | | | 40 | |
| | CWP 45 | 233.75 | | | | | | | 45 | |
| | CWP 50 | 212.5 | | | | | | | 50 | |
| 3 | GWP 0 | 425 | | | | | | | | 0 |
| | GWP 5 | 403.75 | | | | | | | | 5 |
| | GWP 10 | 382.5 | | | | | | | | 10 |
| | GWP 15 | 361.25 | | | | | | | | 15 |
| | GWP 20 | 340 | | | | | | | | 20 |
| | GWP 25 | 318,75 | | | | | | | | 25 |
| | GWP 30 | 297.5 | | | | | | | | 30 |
| | GWP 35 | 276.25 | | | | | | | | 35 |
| | GWP 40 | 255 | | | | | | | | 40 |
| | GWP 45 | 233.75 | | | | | | | | 45 |
| | GWP 50 | 212.5 | | | | | | | | 50 |

denotes cement, SF denotes silica fume, C.A denotes coarse aggregate dolomite, F.A denotes fine aggregate sand, W denotes water, SP denotes super plasticizer, CWP denotes ceramic waste and GWP denotes glass waste powder.

SCSC0: control mix cured in water -All mixes that contain self-curing agents were air cured

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TABLE VI: SLUMP FLOW AND J-RING TEST RESULTS FOR SCSCC MIXES

| Group | Code | Slump Flow test | | J-ring test | | Acceptance |
|---|---|---|---|---|---|---|
| | | D (mm) | T50(sec) | D (mm) | T50(sec) | |
| 1 | SCSC0 | 730 | 3.38 | 720 | 3.41 | A |
| | SCSC0.5 | 710 | 3.18 | 630 | 3.22 | A |
| | SCSC1 | 715 | 3.45 | 665 | 3.01 | A |
| | SCSC1.5 | 695 | 3.2 | 677 | 3.21 | A |
| | SCSC2 | 650 | 2.88 | 690 | 3.00 | A |
| 2 | CWP 0 | 715 | 3.45 | 665 | 3 | A |
| | CWP 5 | 670 | 3.35 | 661 | 3.4 | A |
| | CWP 10 | 655 | 3.41 | 651 | 3.43 | A |
| | CWP 15 | 630 | 3.48 | 610 | 4.1 | A |
| | CWP 20 | 617 | 3.86 | 608 | 4.11 | A |
| | CWP 25 | 610 | 3.9 | 606 | 4.19 | A |
| | CWP 30 | 608 | 4.12 | 601 | 4.23 | A |
| | CWP 35 | 583 | 5.1 | 588 | 5.21 | N |
| | CWP 40 | 576 | 5.08 | 568 | 5.17 | N |
| | CWP 45 | 555 | 5.13 | 550 | 5.3 | N |
| | CWP 50 | 540 | 5.2 | 530 | 5.34 | N |
| 3 | GWP 0 | 715 | 3.45 | 665 | 3 | A |
| | GWP 5 | 685 | 3.09 | 672 | 2.97 | A |
| | GWP 10 | 694 | 3.02 | 688 | 2.89 | A |
| | GWP 15 | 700 | 2.92 | 690 | 2.75 | A |
| | GWP 20 | 710 | 2.89 | 701 | 2.71 | A |
| | GWP 25 | 716 | 2.79 | 705 | 2.7 | A |
| | GWP 30 | 730 | 2.65 | 722 | 2.62 | A |
| | GWP 35 | 738 | 2.61 | 729 | 2.57 | A |
| | GWP 40 | 745 | 2.53 | 736 | 2.51 | A |
| | GWP 45 | 765 | 2.46 | 754 | 2.39 | A |
| | GWP 50 | 778 | 2.39 | 764 | 2.3 | A |

* A: means accepted as a self-compacted concrete
* N: means not accepted as a self-compacted concrete
* CWP 0, GWP 0: means mix with optimum value of PEG400(SCSC1)
* Optimum value based on their main mechanical properties.

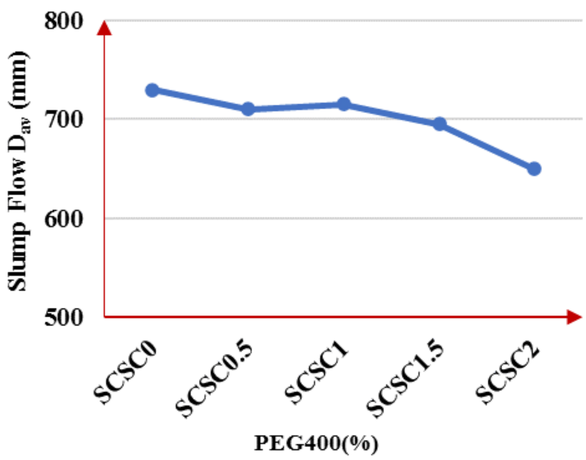


Fig. 3. Effect of Using PEG400 on slump flow diameter of SCC

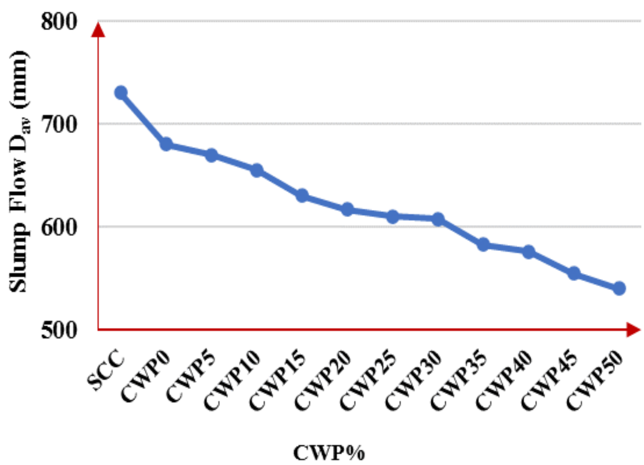


Fig. 4. Effect of Using CWP on slump flow diameter of SCSCC Concrete

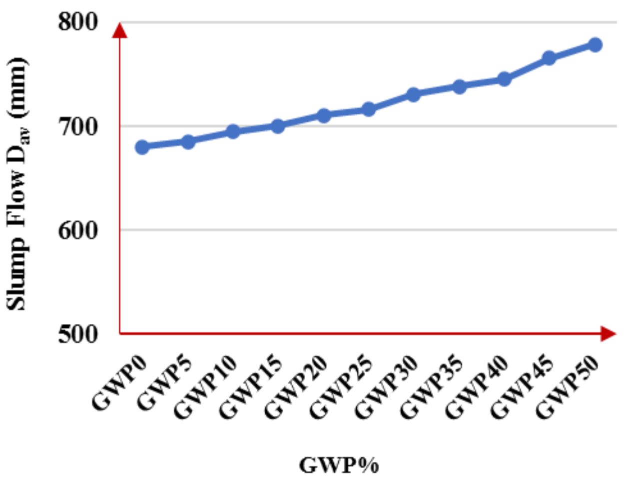


Fig. 5. Effect of Using GWP on slump flow diameter of SCSCC

*B. Hardened Concrete Strengths Tests Results*

The hardened properties of the tested concrete mixes, which were taken into consideration, were the compressive strength at 7, 28, 56- and 90-days age, the indirect tensile strength and the flexural strength at 7- and 28-days age.

*1) Compressive Strength Test Results*

The compressive strength of the tested self-compacted self-curing concrete mixes at 7, 28, 56, and 90 days is shown in TABLE VII.

**For using PEG400**, the effect of applying PEG400 in percentages of (0, 0.5, 1, 1.5, 2) on the compressive strength of the tested self-compacted self-curing concrete mixes is shown in TABLE VII and Fig 6. It can be seen from the test results in the table that, when compared to the control mix (SCSC0), applying PEG400 increased compressive strength. And it is determined that adding PEG at a high dose of over 1% cement would not give the required strength and will not be practical.

It could be found that using PEG400 with percentages (0.5, 1, 1.5) the compressive strength increased by (10.26%, 20.69%, 5.42%) respectively at the age of 28 days but using PEG400 with percent of 2% led to decrease in the compressive strength by 5.68%. The preceding observation demonstrates that the inclusion of self-curing chemicals improves the durability of cement hydration even at later ages (up to 90 days). This may be related to improved water retention, which allows the cement hydration process to continue, resulting in fewer voids and pores and an increase in the bonding strength between cement paste and aggregates. This enhancement could also be attributed to the conversion of calcium hydroxide to CSH.

**For using CWP as a CRM**, TABLE VII and fig 7 shows the effect of using CWP with the percentages of (0, 5, 10, 15, 20, 25, 30) on the compressive strength of the tested SCSCC mixes. According to the test results shown in the table it could be observed that, compared to the control mix (CWP0), using the CWP affects the compressive strength positively. Also, it is noticed that the compressive strength of SCSCC produced by using CWP get increased up to 10% of CWP and then decreased. Hence, the optimum value of CWP was 10%.

It could be found that using waste ceramic powder CWP with the percentages of (5, 10, 15) the compressive strength increased by (3.90%, 9.95%, 6.46%) respectively at the age of 28 days but using waste ceramic powder CWP with percentages of (20, 25, 30) led to decrease in the compressive strength by (7.45%, 10.76%, 23.01%) respectively. Also, using the CWP minimizes the void ratio, hence lowering the water-cement ratio, which results in the reduction of concrete segregation. CWP has tiny particle size and a chemical composition that mostly comprises of $SiO_2$ and $Al_2O_3$, making it an excellent cement substitute material. The drop over CWP 20%, on the other hand, might be owing to the micro-filling effect of CWP not being capable to compensate for the fall in cement content.

It might be a viable alternative approach for the safe disposal of CWP. We can tackle challenges like the trash disposal crisis by implementing such approaches. For a 10% cement substitution with CWP, the cost of Portland cement in concrete is reduced. The cost of cement accounts for over 45 percent of the total cost of concrete. As a result, the overall amount of concrete required will be significantly decreased. As a result, using CWP as a partial replacement for cement in concrete is cost effective.

**For using GWP as a CRM,** TABLE VII and figure 8 shows the effect of employing waste glass powder GWP with percentages of (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50) on the compressive strength of the evaluated SCSCC mixtures when used as a cement replacement material. According to the test findings given in the table, utilising the GWP has a beneficial effect on compressive strength when compared to the control mix (GWP0). It has also been observed that the compressive strength of SCSCC generated by applying GWP increases up to 20% of GWP and subsequently decreases. As a result, the ideal GWP value was at 20% replacing percent.

It could be found that using GWP with the percentages of (5, 10, 15, 20, 25) the compressive strength increased by (5.51% , 10.90% , 11.60%, 18.71%, 10.09%) respectively at the age of 28 days, but using GWP with percentages of (30, 35, 40, 45, 50) led to decrease in the compressive strength by ( 13.59% , 18.70% , 29.74%, 37.55%, 50.17%) respectively. This outcome may be attributable to the accomplishment of adequate concrete workability, which leads to increased compaction levels and improved compressive strength. The filler impact of GWP microparticles grains is the second component that may produce an increase in compressive strength. This might be because the amount of silica in 20% MWG is just enough to exhaust the lime created during hydration. Also, using GWP showed relatively dense microstructure with fewer and smaller pores because of the for GWP may be 20 % as a partial cement replacement material. pozzolanic activity is frequently linked with tiny particles, silica is freed when hydroxide ions destroy the silica network and combine with Portlandite calcium to form CSH, which enhances concrete properties [29,30]. As a result, the fineness of the glass powder is a crucial parameter in the production of glass pozzolans in order to increase their performance.

TABLE VII: COMPRESSIVE STRENGTH TEST RESULTS FOR SCSCC MIXES

| Group | Code | 7 Days Compressive strength (MPa) | 28 Days Compressive strength (MPa) | 56 Days Compressive strength (MPa) | 90 Days Compressive strength (MPa) |
|---|---|---|---|---|---|
| 1 | SCSC0 | 25.55 | 30.78 | 35.23 | 38.6 |
| | SCSC0.5 | 29.95 | 33.94 | 38.88 | 39.97 |
| | **SCSC1** | **31.44** | **37.15** | **40.07** | **42.97** |
| | SCSC1.5 | 28.12 | 32.45 | 37.11 | 38.92 |
| | SCSC2 | 26.16 | 29.03 | 32.18 | 35.15 |
| 2 | CWP 0 | 31.44 | 37.15 | 40.07 | 42.97 |
| | CWP 5 | 31.9 | 38.6 | 42.65 | 46.7 |
| | **CWP 10** | **34.17** | **40.85** | **44.78** | **47.6** |
| | CWP 15 | 33 | 39.55 | 43.83 | 47.22 |
| | CWP 20 | 29.25 | 34.38 | 37.43 | 40.73 |
| | CWP 25 | 24.34 | 33.15 | 35.93 | 40.51 |
| | CWP 30 | 21.66 | 28.6 | 33.67 | 38.29 |
| 3 | GWP 0 | 31.44 | 37.15 | 40.07 | 42.97 |
| | GWP 5 | 32.42 | 39.2 | 44.4 | 46.8 |
| | GWP 10 | 35.2 | 41.2 | 45.15 | 47.47 |
| | GWP 15 | 35.76 | 41.46 | 45.78 | 47.91 |
| | **GWP 20** | **38.3** | **44.1** | **47.19** | **48.47** |
| | GWP 25 | 32.2 | 40.9 | 41.8 | 44.5 |
| | GWP 30 | 26.6 | 32.1 | 40.27 | 43.66 |
| | GWP 35 | 23.3 | 30.2 | 36.34 | 40.48 |
| | GWP 40 | 21.6 | 26.1 | 35.51 | 38.11 |
| | GWP 45 | 18.7 | 23.2 | 30.68 | 34.29 |
| | GWP 50 | 17.6 | 18.51 | 26.62 | 30.36 |

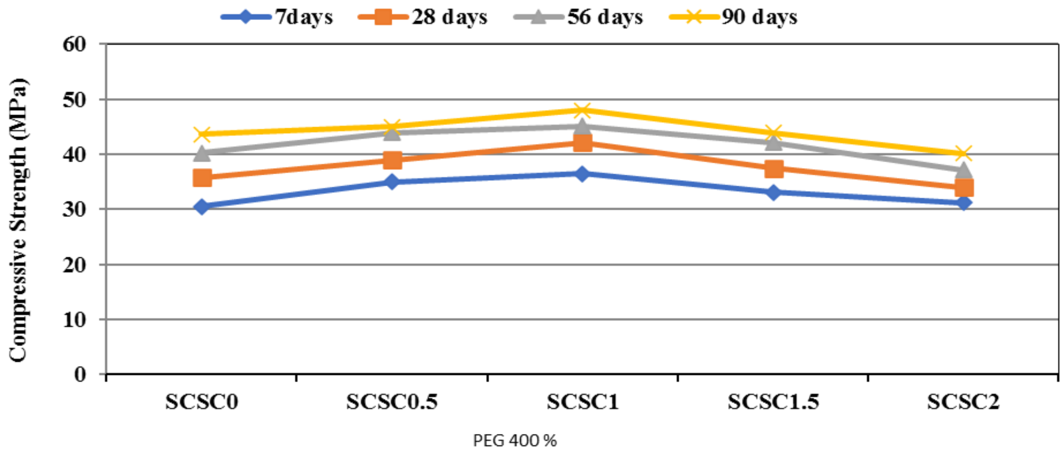


Fig. 6. Effect of Using PEG 400 on Compressive Strength for SCC

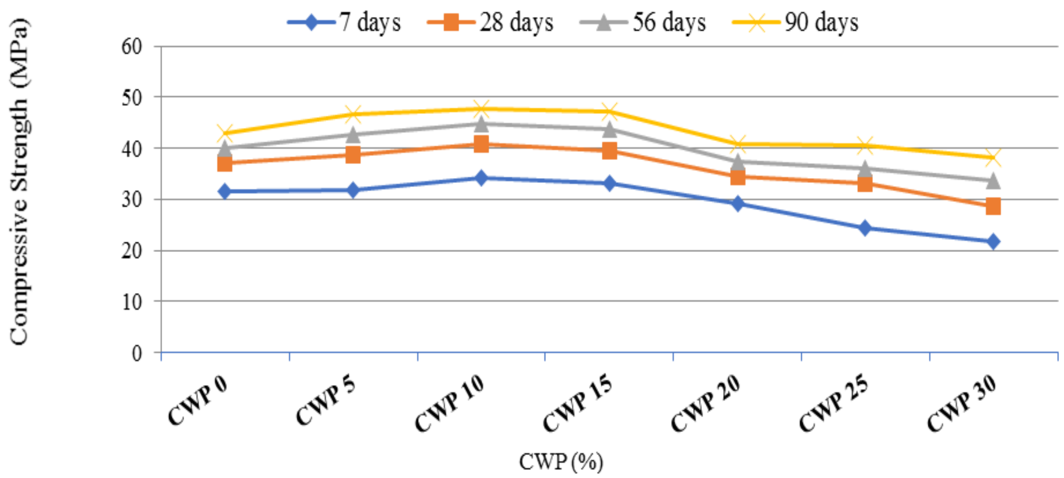


Fig. 7. Effect of Using CWP on compressive strength of SCSCC

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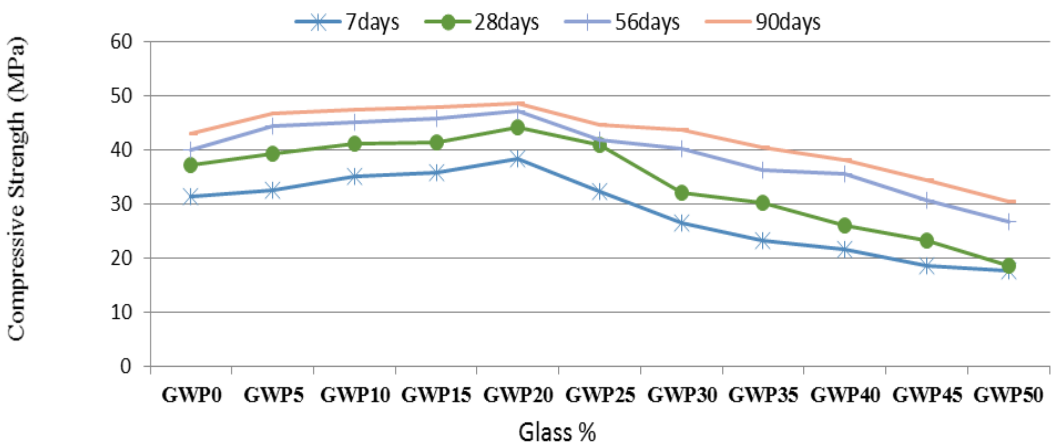


*Fig. 8. Effect of Using GWP on compressive strength of SCSCC*

*1) Indirect Tensile Strength Test Results*

**For using PEG400**, Fig 9 depicts the influence of PEG400 on the indirect tensile strength of the SCSCC mixes that were tested. According to the test results, adding self-curing agents increased tensile strength when compared to the control mix (SCSC0). and the recommended dosage of peg400 was 1% of the cement content.

It could be found that using PEG400 with percentages (0.5, 1 , 1.5) the tensile strength increased by ( 13.71% , 17.14% , 7.13%) respectively at the age of 28 days but using PEG400 with percent of 2% led to decrease in the tensile strength by 11.71%. From the previous observation proves that the addition of self-curing agents has a positive impact on continuing the cement hydration process. This can be ascribed to better water retention and the continuance of the cement paste's hydration process, which results in fewer voids and pores and a stronger binding between the cement paste and aggregates.

**For using CWP as a CRM,** Fig 10 shows the effect of CWP as a cement substitution on the indirect tensile strength of the tested self-compacted self-curing concrete mixtures. It can be seen that utilizing CWP has a beneficial impact on indirect tensile strength.

It could be found that using CWP with the percentages of (5, 10, 15, 20) the tensile strength increased by (6.58%, 14.87% , 8.04%, 2.92%) respectively at the age of 28 days but CWP with percentages of ( 25, 30) led to decrease in the tensile strength by ( 3.17% , 17.07%) respectively. CWP has fine particle size, and its chemical composition mainly consists of $SiO_2$ and $Al_2O_3$ making it a good material for replacement of cement. On the other hand, the reduction beyond 20% might be due to the micro filling effect of CWP was not able to offset the reduction in the cement content.

**For using GWP as a CRM,** fig 11 shows the effect of using GWP on the indirect tensile strength of the tested self-compacted self-curing concrete mixes. According to the test results shown in the table it could be observed that, the indirect tensile strength of self-compacting self-cured concrete produced by using GWP gets increased up to 20% of GWP and then decreased.

It could be found that using GWP with the percentages of (5, 10, 15, 20, 25) the tensile strength increased by (0.73% , 4.14% , 10.24%, 17.80%, 13.65%) respectively at the age of 28 days but using GWP with percentages of (30, 35, 40, 45, 50) led to decrease in the tensile strength by ( 3.17% , 29.02%, 29.26%, 56.09%, 63.17%) respectively. This result may be attributed to the amount of silica present in 20% GWP is just adequate to exhaust the lime produced during hydration. Also, using GWP showed a relatively dense microstructure with fewer and smaller pores because of the formation of secondary CS-H gel by the pozzolanic reaction.

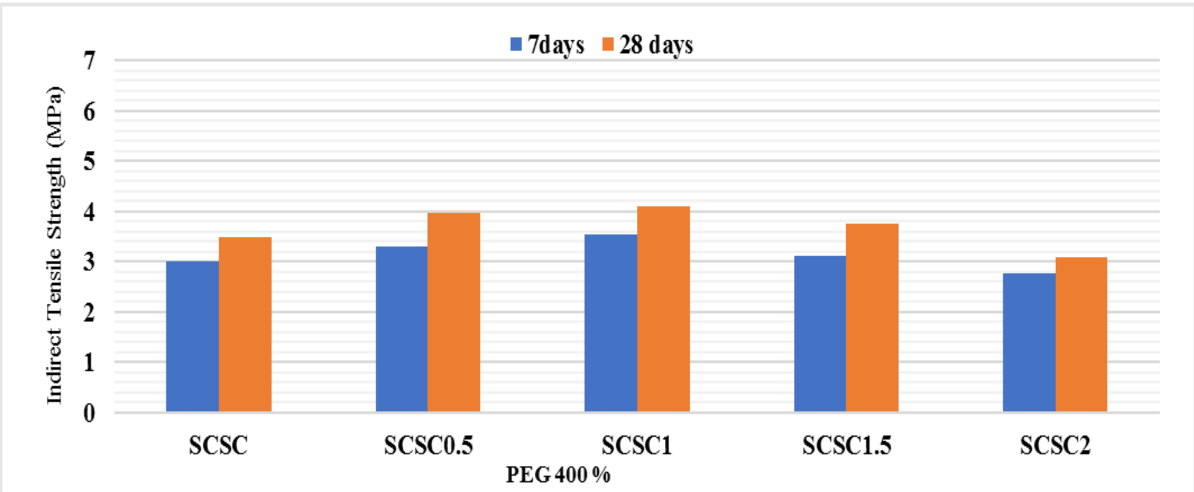


Fig. 9. Effect of Using PEG 400 on Indirect Tensile Strength for SCC

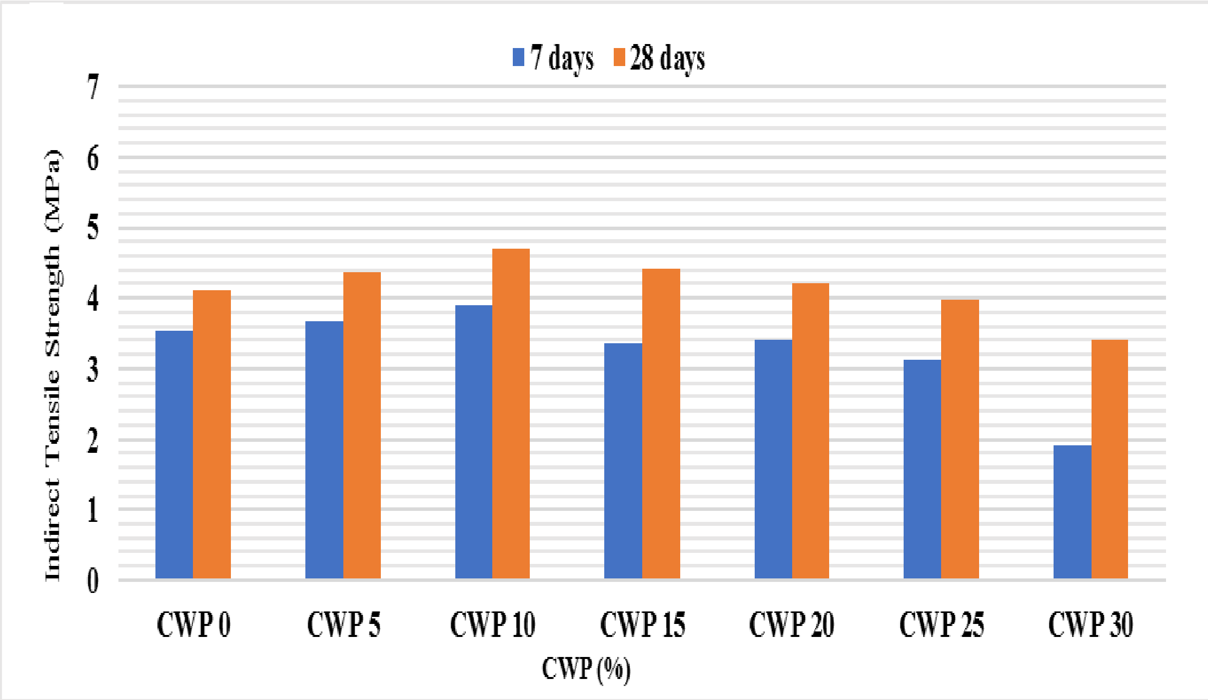


Fig. 10. Effect of Using CWP on Indirect Tensile strength of SCSCC

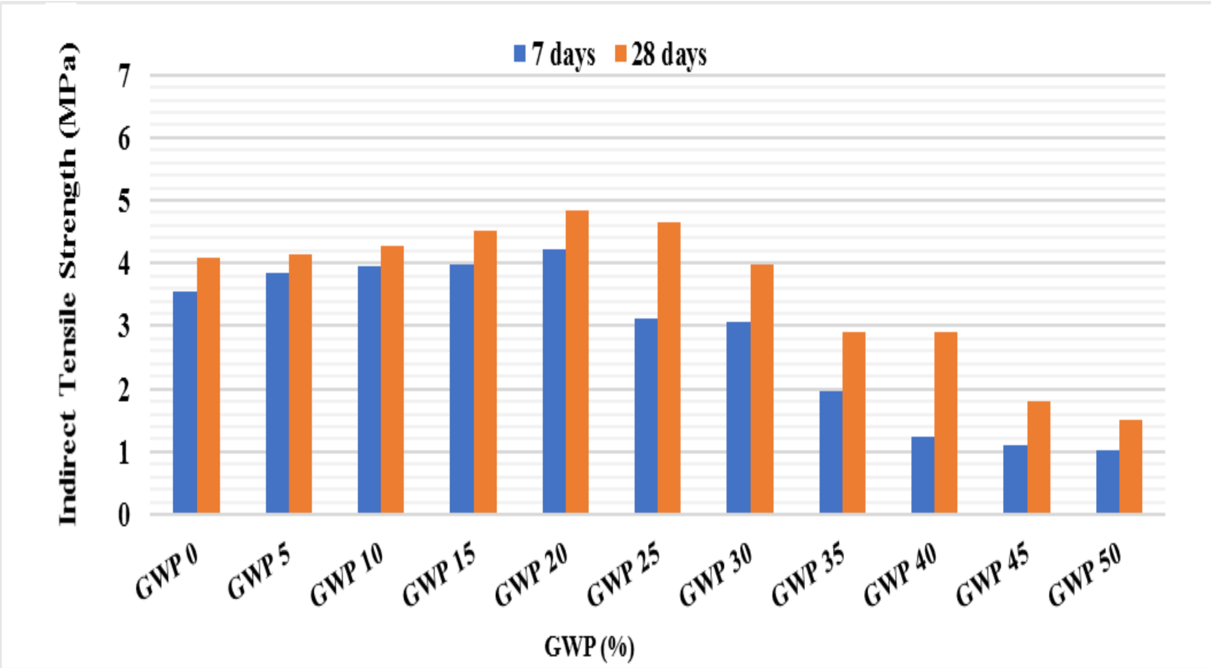


Fig. 11. Effect of Using GWP on Indirect Tensile Strength of SCSCC

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*1) Flexural Strength Test Results*

**For using PEG400**, Fig 12 depicts the influence of PEG400 on the flexural strength of the tested self-compacted self-curing concrete mixtures. It has been shown that the flexural strength of self-compacted concrete increases up to 1% PEG400 and thereafter decreases.

It could be found that using PEG400 with percentages (0.5 , 1 , 1.5) the flexural strength increased by ( 1.5% , 7.95% , 1.92%) respectively at the age of 28 days but using PEG400 with percent of 2% led to decrease in the flexural strength by 17.04%. The above observation demonstrates that the addition of self-curing chemicals has a good effect on the cement hydration process. This can be due to better water retention, which permits the hydration process of cement paste to continue, resulting in fewer voids, pores, and a stronger binding between the cement paste and aggregate.

**For using CWP as a CRM**, fig 13 shows the effect of using CWP on the flexural strength of the tested self-compacted self-curing concrete mixes.

According to the test results shown in the table, it is noticed that the flexural strength of self-compacting self-cured concrete produced by using CWP get increased up to 10% of CWP and then decreased.

It could be found that using CWP with the percentages of (5, 10, 15, 20) the flexural strength increased by (3.57%, 7.29%, 5.73%, 3.72%) respectively at the age of 28 days but using waste ceramic powder CWP with percentages of (25, 30) led to decrease in the flexural strength by (0.74% , 7.14%) respectively.

**For using GWP as a CRM**, fig14 show the effect of using GWP on the flexural strength of the tested self-compacted self-curing concrete mixes. Comparing with the control mix GWP0, the use of GWP by 20% leads to an increase in the flexural strength of self-compacting self-cured concrete, and if the replacement ratio is more than 20%, the strengths will decrease.

It is observed that using GWP with the percentages of (5, 10, 15, 20) the flexural strength increased by (3.27%, 3.64%, 4.91%, 13.99%) respectively at the age of 28 days but using GWP with percentages of (25, 30, 35, 40, 45, 50) led to decrease in the flexural strength by (2.97%, 7.89%, 10.87%, 17.49%, 19.13%, 22.48%) respectively.

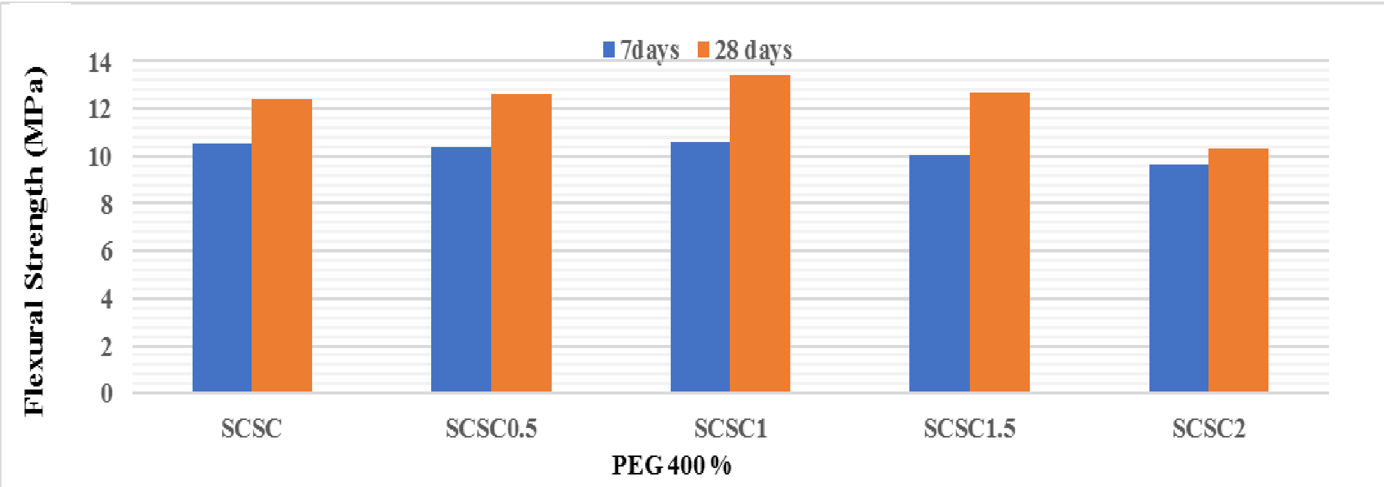


Fig. 12. Effect of Using PEG 400 on Flexural Strength for SCC

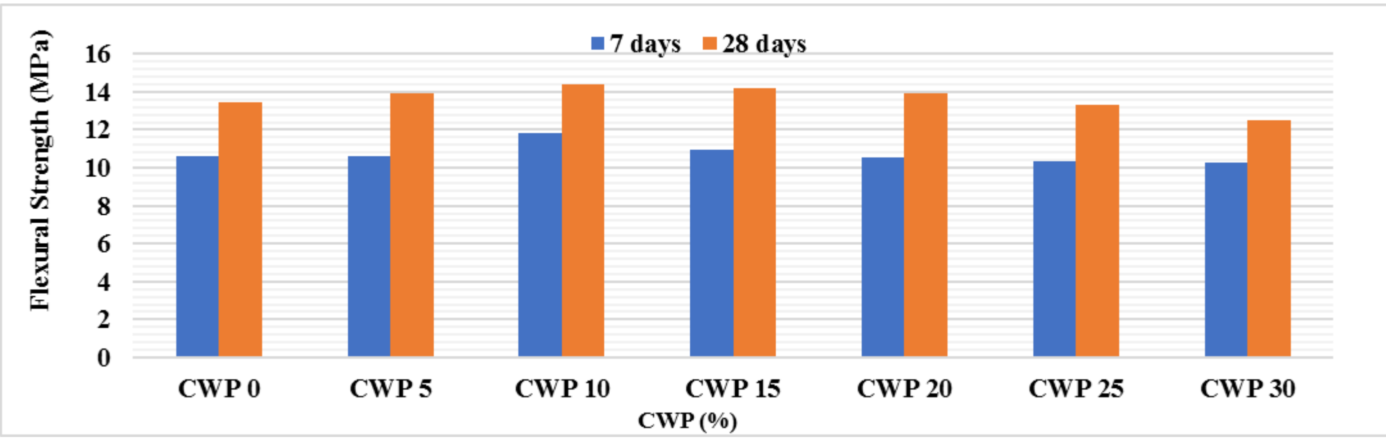


Fig. 13. Effect of Using CWP on Flexural strength of SCSCC

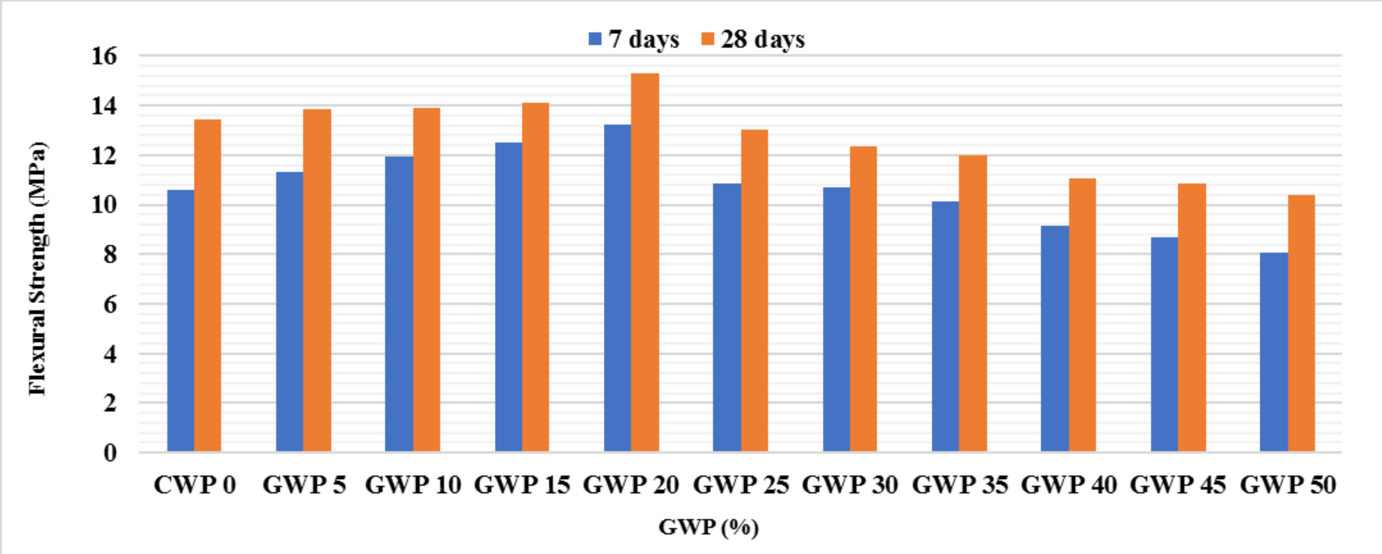


Fig. 14. Effect of Using GWP on Flexural Strength of SCSCC

## V. Conclusions

Based on the findings of the current study, the following conclusions can be made:

- The addition of the self-curing agent PEG400 to concrete mixes improves the mechanical properties of SCC under air curing conditions.
- The optimum dosage of peg400 was 1% of the used cement content.
- The use of ceramic waste powder as a partial replacement for cement in various ratios caused a reduction in the flowability and passability of SCSCC.
- The flowability and passability of the six mixes (CWP5, CWP10, CWP15, CWP20, CWP25, CWP30) are accepted and satisfied the acceptance criteria for SCC. But the four mixes (CWP35, CWP40, CWP45, CWP50) are not accepted because of did not achieves acceptance criteria for SCC.
- Comparing with the control mix CWP0, the use of CWP by 10% leads to an increase in the compressive, tensile, and flexural strengths of SCSCC, and if the replacement ratio is more than 10%, the strengths will decrease.
- Increasing glass waste powder GWP percent led to increase in the flowability of SCSCC. All the mixes satisfied the acceptance criteria for SCC.
- Comparing with the control mix GWP0, the use of GWP by 20% leads to an increase in the compressive, tensile, and flexural strengths of self-compacting self-cured concrete, and if the replacement ratio is more than 20%, the strengths will decrease.
- The compressive strength of the SCSCC produced by using GWP as a CRM gives higher results than that produced by using CWP.

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