An experimental study on mechanical and durable properties of self-curing concrete by using Ferro silica slag aggregate.

K Sundeep Kumar*, P V Subba Reddy*, E Arunakanthi*
*Research Scholar, Dept. of civil engineering, J.N.T.U. Ananthapur 515 002.
*Professor, Dept. of civil engineering, NBKR IST Vidyangar, 524 413.
*Professor, Dept. of civil engineering, J.N.T.U. Ananthapur 515 002.
Email : a*sundeepkumar20702246@gmail.com, b*pvsreddy1970@gmail.com, c*earunakanthi@gmail.com.

Abstract.
Construction industry concrete used heavily. The building industry relies heavily on coarse aggregate (C.A.). Due to the lack of C.A., artificial aggregate known as Ferro silica slag (F.S.S.) is the predominant alternative material. The use of F.S.S. increases concrete strength and lowers construction costs. The strength of concrete is determined by how long it is allowed to cure. Because of improper curing, the hydration of cement problem can be solved by employing a self-curing mechanism. It's possible to use paraffin wax Light and Heavy in Concrete have a variety of beneficial effects on S.C.C.'s fresh and hardened concrete qualities. The immersing curing agent is a material that retains Water and reduces evaporation; the self-curing admixture incorporates concrete after the standard setting of concrete on account of increased water retention capacity and compares to internally cured concrete. It gives inside assuaging, known explicitly as "self-curing concrete," in short, less or no external curing is required in another way if outside mitigating may cause better warmth of hydration. Light molecular weight and high molecular weight are two examples of self-curing liquids that can boost the strength and serviceability of concrete. In this investigation, the percentage of paraffin wax in M25 grade concrete was altered from 0%, 0.1%, 0.5%, and 1.0% and compared to internally cured concrete(I). The replacement of coarse aggregate with the optimum amount of F.S.S. Paraffin is then added to concrete in a liquid form, resulting in varied dosages. Based on the literature, the optimum percentage of F.S.S. 40% with paraffin wax light and heavy 1.0% improvement of compression and flexure strength of concrete. Ultrasonic pulse velocity (U.P.V.) and Rapid chloride penetration tests (RCPT) were used to determine dense microstructure and enhanced durability of concrete.

Keywords: workability properties, Mechanical properties, U.P.V. and RCPT

1. Introduction
Concrete is replaced with mineral admixtures for improved mechanical and durability due to pozzolanic and self-cementing effects in mortar mixtures and certain forms of concrete, such as light-weight concrete, reactive powder, compacted cylinders, and concrete that self-compact [1]. Examining admixtures for workability, strength, and durability is the main concern when looking at concrete mineral admixtures. As a result, concrete is the most widely utilized building material in the world. It's the ability to be moulded into the required shape most easily. A concrete mix is composed of cement, fine and coarse particles, and water. Concrete relies heavily on aggregates. Various materials are required for any building project, including concrete, cinder blocks, and steel bricks. Specifically, concrete should be designed for its properties and adaptability with relevance to the dynamic environment. It will converse resources-protected atmosphere, save money, and result in correct energy usage [2]. Unlike traditional curing, self-curing concrete removes moisture from the concrete's water evaporation, allowing it to hold more water. Polymeric glycols and paraffin wax are examples of hydrophilic materials that self-cure [3,4]. Liquid paraffin wax as a self-curing agent, this study compares it to alternative curing regimens that simulate traditional curing procedures [5]. The literature on self-curing is sparse; Madduru et al. [6]. When self-curing chemicals are used adequately, the authors found that self-compacting mortar had improved strength and
durability. The steel slag was employed for casting ordinary concrete [7–9], alkaline activated concrete [10], hydraulic concrete [11], asphalt concrete [12], compact roller concrete [13] and pavement concrete [14], pervious concrete [15]. F.S.S. has fewer applications than iron slags. Such as Basic oxygen furnace slag (B.O.F.S.), Electric arc furnace slag (E.A.F.S.), and Ladle furnace slag (L.F.S.). These slags typically contain free lime (CaO), which can cause expansion and must be handled properly to use in construction [16–22]. Ferro silica slag aggregates’ durability properties contained concrete performed superior characteristics than natural aggregate concrete [37]. F.S.S. aggregates are used as coarse aggregates to develop self-curing concrete using liquid paraffin wax. Steel slag contains active compounds that are similar to cement, such as C2S and C3S, and as a result, has cementing properties [23–25]. Steel slag powder, as a result, has the potential to be used as an active cement material and concrete admixture. The microstructure analyses show that the steel slag powder is continuously hydrated, improving the mechanical characteristics of concrete [23]. Sustainable Use of industrial slag materials used in coarse aggregates in the production of S.C.C. [26]. Engineering properties of F.S.S. aggregate as coarse aggregate on conventional concrete [27].

Due to a lack of research on steel slags, increased properties and applications are needed to fill this gap. When it comes to cementitious materials, slags play an essential role. In this investigation, E.F.N.A.R.C. standards [30] were used. Self-compacting concrete’s workability, according to E.F.N.A.R.C., can be enhanced by filling capability, appropriate viscosity defined by flow rate, the ability to pass through a short section, and separation resistance [29,30]. For S.C.C., it is typical to limit the amount of coarse material. As the title suggests, the primary purpose of this work is to examine the effects of different cure circumstances such as water cure (W.C), internal cure (I), and Liquid Paraffin Wax curing (L.P.W.C.), and age of curing (3, 7, 28, 56, and 90 days) on S.C.C.’s mechanical properties.

2 Experimental program
To identify an appropriate curing admixture with the optimal dosage for the durability of S.C.C. The experimental program, designed to determine resistance and durability properties, is a self-compaction concrete of M25 grade of concrete. According to Indian standards, testing was conducted with cubes 150 X 150 X 150mm and cylinders 50 mm high and 100 mm diameter for RCPT testing. The NDT tests are used in this study because the structure will not disturb to check its serviceability of concrete. Due to that reason, U.P.V. and RCPT are to give quick and accurate results.

2.1 Nomenclature of specimens
According to this study, the S.S.C. specimens of paraffin wax light and heavy are marked as ‘F’ and ‘M.’ Internal curing (I) and water curing (W), respectively. The percentage of dosage is denoted as 0, 0.1, 0.5, and 1.0. Typically specimens named SBF 0.1% represent Mix-B specimen containing curing compound of light paraffin wax with a dosage of 0.1%.

2.2 Materials used for concrete
2.2.1 Cement
O.P.C. 53 conforming to IS 12269 BIS, 1987 [35] was used in this study. The Sp.gr is 3.14, the S.S.A. was 225 m²/g. 42 min is initial, 552 min is the final setting time.

2.2.2 Fine aggregate
In this experimental work, locally accessible natural sand was employed according to IS 383 1970[36]. The sand in Zone II was 0.80% water absorption, the fineness module was 2.79, and the sp. gravity was 2.6, as indicated in IS 383.

2.2.3 Coarse aggregate
As coarse aggregates, crushed granite stones are used with a dia. of 16 mm and 12.5 mm. The coarse compound has 0.3% water absorption in oven-dry conditions and a bulk sp. gravity of 2.6.

2.2.4 Ferro silica slag aggregate
Slag obtained in lumps form. It is wrecked into pieces using a hammer, then crushed and sieved by a crushing machine to obtain two coarse aggregate fractions following BIS 383:1970 [36]. The first fraction ranged from 16 mm to 12.5 mm, whereas the second ranged from 12.5 to 4.75 mm, as shown in Figure 1.
2.2.5 Fly ash
Fly ash is collected from a power plant named Sri Damodaram Sanjeevaiah at Nelatur Village, near Krishnapatnam, about 23 km from Nellore city in Andhra Pradesh (India). Table 1 shows the chemical properties of fly ash.

Table 1: Physical and chemical properties of materials

| Contents     | Cement | FSS  | Fly ash |
|--------------|--------|------|---------|
| SiO₂         | 20.9   | 30.53| 63.2    |
| CaO          | 62.55  | 18.8 | 2.01    |
| Fe₂O₃        | 4.9    | 5.24 | 3       |
| Al₂O₃        | 5      | 3.9  | 26.5    |
| SO₃          | 2.82   | 0.9  | 0.19    |
| Mgo          | 1.08   | 4.86 | 1       |
| Loss on ignition | 1.58 | 1.65 | 1.23    |
| Sp. gravity  | 3.15   | 2.82 | 2.11    |
| Fineness(m²/kg) | 345 | -    | 360     |

2.2.6 Water
Potable Water is used mixing and curing S.C.C. specimens.

2.2.7 Super-plasticizer
A new generation super-plasticizer improves the flow and workability properties, with decreased water-cement ratio, a high-end water reduction.

2.2.8 Self-curing agent
As self-curing agents, light paraffin wax is known as L.M.W. (F), and heavy is known as H.M.W. (M) is used; their physical properties are shown in Table 2. Before adding to the concrete, they were thoroughly mixed with Water.
Table-2: Properties L.M.W., H.M.W. paraffin

| Form                  | Light LMW (F) | Heavy HMW (M) |
|-----------------------|---------------|---------------|
| Sp. gr at 25°C        | 0·760–0·810   | 0·830–0·860   |
| Appearance            | Clear colourless liquid | Clear colourless liquid |
| Dynamic viscosity at 20°C: mPa.s | 30–95   | 120–240   |

3. Mix proportions

S.C.C. mixtures developed in this investigation. Several trial mixtures were initially carried out to change the amount of the control concrete to fresh qualities that satisfy the standards laid down at the European Federation of National Association of Special Building Products of Concrete Producers and Applications E.F.N.A.R.C., 2005 Table-3[30]. S.C.C. mixes 0% paraffin 40% of steel slag from several samples, was tested on pilot study and literature [31], and represented as S.B.W. Table-4 shows mix proportion of S.C.C.

Table-3 EFNARC specifications

| S.No | Test          | Property     | Class | Range          |
|------|---------------|--------------|-------|----------------|
| 1    | Slump flow    | Filling ability | SF1   | 550-650 mm     |
|      | test          |              | SF2   | 660-750 mm     |
|      |               |              | SF3   | 760-860 mm     |
| 2    | T500          | Viscosity    | VS1   | ⩽ 2 S          |
|      |               |              | VS2   | >2 S           |
| 3    | V funnel test | Viscosity    | VF1   | ⩽ 8 S          |
|      |               |              | VF2   | 9-25 sec       |
| 4    | L - box test  | Passing ability | PA2   | ⩾ 0.80         |

Table-4 Mix proportion of S.C.C. with slag aggregate

| Ingredients(Kg/m³) | SCC with Slag |
|--------------------|---------------|
| Cement             | 370           |
| Fine aggregate     | 850           |
| Granite (16 mm)    | 0             |
| Granite (12.5 mm)  | 0             |
| Slag (16 mm)       | 453           |
| Slag (12.5 mm)     | 302           |
| Water              | 195           |
| Fly ash            | 190           |
| Superplasticiser   | 3.7           |

4. Workability properties

S.C.C. workability tests of filling ability, viscosity, and passing ability tests of concrete mix. Table -5 exhibits Slump flow used to assess concrete filling ability, while T500, V-funnel, and L-box tests evaluated viscosity and passing ability.
Table 5 Workable properties of S.C.C. with slag aggregate

| Property | Efnarc range | SBW | SBF 0.1 | SBF 0.5 | SBF 1.0 | SBM 0.1 | SBM 0.5 | SBM 1.0 |
|----------|--------------|-----|---------|---------|---------|---------|---------|---------|
| H-flow: mm | 650–850 | 725 | 715 | 735 | 745 | 755 | 730 | 760 |
| T50: s | 2–5 | 2.6 | 2.75 | 3.23 | 3.15 | 3.15 | 3.42 | 2.37 |
| V 5 min: s | 9–15 | 9.65 | 11.45 | 1.86 | 13.25 | 11.55 | 11.89 | 12 |
| J-ring: mm | 0–10 | 8 | 8 | 9 | 7 | 7 | 8 | 6 |
| L-box | 0.8–1.0 | 0.92 | 0.87 | 0.9 | 0.9 | 0.84 | 0.82 | 0.83 |
| V-funnel: s | 6–12 | 9.45 | 9.25 | 8.25 | 9.55 | 7.75 | 7.55 | 8.25 |

The workable properties of fresh concrete when mixing into curing admixtures shows better flow properties. All mixes followed E.F.N.A.R.C. [30] guidelines. Figure-2 shows filling ability is more on S.C.C. of mix SBM 0.1, SBM 1.0.

Fig-2 Slump flow values L.M.W. and H.M.W. concrete.

5. Results & discussions

5.1 Compressive strength

To determine the compressive strength of cube specimens at the age of 7, 28, 56, and 90 days of curing. All mixes show significant improvement compared with internally cured concrete (S.B.I.) for 7, 28, 56, and 90 days. When the water-curing period increased, the compressive strength of S.C.C. at 28 days had more growth. According to Fig. 3, for SBF 1.0, SBM 1.0, the highest strength value is related to all mixes. But as the age increases, the results of combinations SBF 1.0 and SBM 1.0 [39] get closer Water cured (S.B.W.) mixes also show the best strength at different ages. The self-cured and Water cured specimens are attained nearer values of the different curing ages. Still, internally cured specimens do not show much strength variation with varying curing ages after 56 and 90 days.
5.2 Flexural strength test
Figure-4 shows the flexural strength values of Mix-B concrete when light and heavy paraffin curing chemicals are used. The S.B.W. mixes have higher flexural values than the typical aggregates, i.e., 3.85, 3.96 Mpa for 28, 56 days [40]. Because slag particles have a higher angularity, all Mix-B mixes with slag aggregates achieve higher flexural strength values than Mix-A concrete. The increased flexural strength is most likely due to the more significant structure improving the gel structure's bond [32]. Fig -4 indicates that light and heavy paraffin wax have values closer to water-cured samples than internally cured samples.
5.3 Rapid chloride penetration test (RCPT)

Table 6: Rapid Chloride permeability test (RCPT) of S.C.C. concrete

| Mix-B | 28 days | 90 days | Chloride permeability |
|-------|---------|---------|----------------------|
| SBW   | 1958    | 875     | Very Low             |
| SBI   | 2346    | 2856    | Moderate             |
| SBF 0.1 | 2325    | 1598    | Low                  |
| SBF 0.5 | 2198    | 1354    | Low                  |
| SBF 1.0 | 2278    | 1423    | Low                  |
| SBM 0.1 | 2178    | 1672    | Low                  |
| SBM 0.5 | 2365    | 1762    | Low                  |
| SBM 1.0 | 1985    | 1381    | Low                  |

The RCPT test is used to find out harsh environment deteriorates gradually and leads to failure of concrete at initial days and serviceability based on criteria selected as 28 and 90 days of curing. This test is used to evaluate the durability of S.C.C. The total current passed through specimens is determined. The charge passed permeability of chloride ion of concrete is maximum at internally cured specimens and minimum for water cured specimens. According to ASTM C 1202 [33], for Water cured samples, low chloride permeability and moderate for internally cured specimens. The chloride permeability of self-cured specimens is lower than that of uncured specimens. Light paraffin SBF 0.5 and heavy paraffin SBM 1.0 [40] mixes allow less chloride penetration into concrete than internally cured specimens (S.B.I.). Table 6 shows the chloride permeability for various curing regimes. Fig. 5 shows the different curing percentages shows the influence of chloride passed on concrete. The properties of the self-curing agent influence the efficacy and optimal dosage of self-curing S.C.C.

![Fig-5 RCPT of L.M.W., H.M.W. concrete](image-url)

5.4 Ultrasonic pulse velocity test (U.P.V.)

U.P.V. test is a non-destructive test that is used for analyzing the homogeneity of the concrete. The presence of cracks, voids, and other imperfections by detecting internal flaws like inadequate compaction, voids or cracks, and segregation in concrete so that initial and later on behavior is observed on this study, i.e., 28 and 90 days of curing. Mix-B noticed an improvement of pulse 15.04 % to 15.68 % for SBF 1.0, for 28 days, and 90 days 23.28% to 23.90
% for SBM-1.0. For mix, (4789 m/s) has the highest pulse velocity, 20.12 % higher than the internal curing specimens. Table-7 shows the age of concrete increases pulse velocity also increases. The velocity range for evaluating substantial-quality was provided by BIS 13,311 (Part 1)-1992[34]. In the current study, all concrete mixes are good quality, and SAF 1.0, SBF 1.0, and SBM 1.0 at 90 days are of excellent quality, as shown in Fig.6.

| S.No | % replacement | Ultra sonic pulse velocity m/ sec |
|------|---------------|----------------------------------|
|      | Mix-B 28 days | 91 days                          |
| 1    | SBW           | 4652                             | 4952 |
| 2    | SBI           | 3952                             | 3825 |
| 3    | SBF 0.1       | 4232                             | 4456 |
| 4    | SBF 0.5       | 4512                             | 4712 |
| 5    | SBF 1.0       | 4652                             | 4823 |
| 6    | SBM 0.1       | 4189                             | 4278 |
| 7    | SBM 0.5       | 4345                             | 4478 |
| 8    | SBM 1.0       | 4687                             | 4789 |

6. Conclusions
The present study aimed to evaluate the workability, mechanical, and durability of S.C.C. containing paraffin wax as a self-curing agent and Ferro silica slag as coarse aggregate. Following conclusions from this experimental investigation.

- Liquid paraffin wax with F.S.S. contained mixes shows better workability properties.
- The slump flow value of slag-containing concrete with an optimum dose of curing admixture performed better flow than considerably higher than those of control mix.
- Self-cured concrete specimens attained relative values of the Water cured samples with all curing ages. SBF 1.0%, SBM 1.0% mixes gained maximum compressive strength values of all ages compared to internally cured concrete.
- F.S.S. has more angularity number because of that reason; it requires more curing admixture.
- The flexural strength values are superior compared to the no cured specimens.
- In durable studies, RCPT values are higher for internal curing specimens (S.B.I.), indicating moderate chloride permeability. Whereas Water cured and self-cured specimens with optimum dosages have achieved low susceptibility to chlorine penetration.
• U.P.V. concrete values are nearer values of Water cured specimens, and internally cured specimens attained fewer values.

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