Studies on influence of mineral admixture on mechanical properties of CC and SCC

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Abstract. Now a day's research is more concern on the successful utilization of different mineral admixture so as to cut down the environmental pollution caused by cement industries throughout cement production. Self-Compacting Concrete (SCC) is a new generation concrete has been developed without compromising the strength characteristics with minimum time and labour cost. So to make more economic and environmental friendly concrete, two mineral admixtures (waste products of the industries) i.e. Silpozz and Lime Stone Powder (LSP) were used during this experimental work. The aim of this study is to evaluate the fresh and hardened properties of the conventional concrete (CC) and Self Compacting Concrete (SCC) containing mineral admixtures. Cement is partially replaced with Silpozz and LSP as 0%, 10% and 20% for both CC and SCC. Total ten numbers of concrete mixes have prepared for M30 grade of concrete. Fresh concrete properties of CC have evaluated by slump test and for SCC, slump flow, T500, V-funnel and J-ring test were conducted. Hardened concrete properties were evaluated after 7 and 28 days for compressive, split tensile and flexural strength test. The desired amount of superplasticizer (SP) is used in SCC to make the concrete workable. The test results indicate that the 20% replacement of Silpozz influences the mechanical properties of concrete as compared to LSP replacement.

1. Introduction
Japan introduced Self-Compacting Concrete (SCC) in 1988 due to deficiency in skilled workers [1]. SCC is gaining popularity due to its nature of compact itself in congested stirrups and rebar without any vibration. It decrease the labour cost, reduces noise level and pouring the concrete time get reduced during construction [2]. The key features of SCC are increase in segregation resistance, high flowability and high passing ability which make it advantages over other concrete in presence of superplasticizer and other additives [3]. The higher cost of superplasticizer reduces its application [4]. This problem can be solved by utilizing mineral admixtures as partial replacement of cement as reported by Kannan [5].

Due to industrialization the waste product generated from the industries created the disposal problem which also pollute soil, water and air [6]. Researches were using these mineral admixtures as partial substitution for cement to mitigate the problem [7]. Mineral admixtures help to enhance the strength and overall performance of concrete. An agro-industrial waste is Rice Husk Ash (RHA) which is generated by the combustion of rice husk in a control temperature to form husk [8]. This husk has
beneficial effects such as improve strength and durability, reduce heat of hydration and reduces the cement consumption when utilizing it as partial cement substitute [6]. The production of rice husk is about 148 million tons in 2015 in worldwide. The final product of RHA contain about more than 90% of amorphous silica[4]. In SCC, RHA with urea improve the flowability in mass concrete and the concrete temperature is get reduced [9]. RHA provides denser microstructures based on chemical interaction among calcium hydroxide and water and form C-S-H gel in SCC [10]. Inclusion of RHA in conventional concrete (CC) shows better performance as compared to control specimen [11]. Silpozz addition enhances the Compressive, split tensile and flexural strength at all ages of curing [12]. He et al. [13] reported that the waste Lime Stone Powder (LSP) was generated during the quarrying process of crushing and grinding Lime Stone which is a non pozzolanic material. The mineral composition of LSP is present in various forms such as calcite, aragonite, amorphous calcium carbonate and vaterite etc. Crystalline, clastic, massive or granular are some of the form of LSP based on the formation[14]. It generally used in cement production due to its filler effect. LSP is very fine and caused the environmental pollution as well as health hazards. It increases the workability, total shrinkage but reduces the setting time as compared to control specimen [1]. Cement paste containing high LSP has come across different stages of hydration such as dissolution, acceleration, dynamic balance and hardened stage [13]. It induces high early strength by increasing the hydration [15]. LSP can be used as low cost ultra-high performance concrete and reduces the carbon dioxide emission [16] without compromising the strength characteristics [17] and improves the sulphate resistance in CC [18]. Using wood fiber waste with limestone powder waste help to produce light weight concrete [19]. In cement paste, the CaCO3 consumption increases due to the formation of carboaluminate when the lime stone powder increases. LSP has low cost and wider availability make it more popular to use in concrete [20]. RHA and LSP substitution decreases the unit weight of concrete [1]. The combine effect of slag and pulverized LSP helps to reduce the slump loss by providing better workability and reduces depth of carbonation, drying shrinkage for better durability properties [16]. Matsagar [21] concluded that the porosity of transition zone among both cement paste and aggregate can be reduced through substitution of Silpozz with 10% FA. FA and Silpozz replacement in concrete up to certain limit improve the resistance against deterioration [22]. The combine effect 10-30% FA and 10-20% of Silpozz affect the fresh and hardened characteristics of concrete [23]. It is evident that the past studies are showing good performance by the utilization of mineral admixtures. Here the effort has been done to investigate of mineral admixtures such as Silpozz and LSP utilization in CC and SCC as partial cement replacement to minimise the contamination generated by the manufacture of cement and the efficient use of waste industrial byproducts, which creates the disposal problem. In order to achieve this aim, various experiments on fresh and hardened concrete have been carried out to determine the effect of raw materials on the finished products.

2. Experimental Program

| Oxide | SiO2 | Al2O3 | Fe2O3 | CaO | MgO | SO3 | LOI | Carbon | K2O | Others | Moisture |
|-------|------|-------|-------|-----|-----|-----|-----|--------|-----|--------|----------|
| OPC   | 20.50| 5.05  | 2.99  | 62.00| 2.07| 2.40| 3.10| -      | -   | -      | -        |
| Silpozz | 88.18| 1.61  | 0.56  | 1.59 | 1.63| -   | -   | 2.67   | 1.67| 2.09   | 0.79     |
| LSP   | 10.50| 0.82  | 0.29  | 49.00| 0.58| 0.10| 38.71| -      | -   | -      | -        |

2.1. Materials

Ordinary Portland Cement (OPC) 43 grade is used and it’s specific gravity is 3.15. Silpozz is the trade name for RHA which is an agricultural byproducts which contain more than 85% of silica. Its particle size of Silpozz is 25 microns and specific gravity is 2.71 [24]. LSP is a non pozzolanic material which can act as filler materials and it has specific gravity 2.8. The chemical compositions of OPC, Silpozz and LSP are presented in Table 1.
River sand is used as fine aggregate passing through 4.75 mm sieve conform to zone III is used having water absorption 0.40, specific gravity 2.67. Coarse aggregate has specific gravity 2.86 and water absorption 0.20. CERA HYPERPLAST XR W-40 superplasticizer is used in SCC to obtain good workability [24]. This conforming to IS 9103, ASTM C 494-03 and BS 5075.

2.2. Mix proportions and test procedure
For M30 grade concrete with w/c ratio 0.43 with mixing proportions of 1:1.44:2.91 as per IS: 10262-2009, the mix design was prepared. By varying the Silpozz and LSP content in OPC, five concrete mixes for CC is prepared. Variations of fine and coarse aggregate, variation of Silpozz and LSP replacement in cement along with the addition of superplasticizer (SP) is used to prepare five SCC mixes as represented in Table 2. Fresh concrete workability was assessed immediately after completion of the mixing. For CC, slump test is conducted to determine the fresh concrete properties. For SCC the fresh concrete is accessed by Slump test for filling ability, T500 test and V-Funnel test for flow ability by following EFNARC 2005 guidelines and J-Ring test measure the passing ability by following EFNARC 2002 guidelines. The mechanical characterization of hardened concrete was evaluated by compressive strength test in a cube of size 150 × 150 × 150 mm, split tensile strength test in a cylinder of size 100 × 200 mm and flexural strength in the prism of size 100 × 100 × 500 mm for both CC and SCC after the curing period of 7 and 28 days. Three specimens were cast and examined for each day of testing. The average value is taken as final value for the specific test conducted.

Table 2. Concrete Mix proportions of CC and SCC

| Mix Identity | Concrete Mix Proportion       |
|--------------|--------------------------------|
| CL0S0        | OPC 100%                       |
| CL10S0       | OPC 90%+ LSP 10%               |
| CL20S0       | OPC 80%+ LSP 20%               |
| CL0S10       | OPC 90%+ Silpozz 10%           |
| CL0S20       | OPC 80%+ Silpozz 20%           |
| SCL0S0       | OPC 100%+ SP 0.35%             |
| SCL10S0      | OPC 90%+ LSP 10% + SP 0.35%    |
| SCL20S0      | OPC 80%+ LSP 20% + SP 0.35%    |
| SCL0S10      | OPC 90%+ Silpozz 10% + SP 0.45%|
| SCL0S20      | OPC 80% + Silpozz 20% + SP 0.65%|

Figure 1. Slump test results of CC
3. Results and Discussion

3.1. Fresh Concrete Test Results

Slump test is performed to evaluate the fresh concrete properties of CC. Figure 1 represents the slump test results of CC. The use of LSP in concrete has been found to improve workability in concrete. Concrete containing 10% LSP shows good workability as comparison to other CC mixes. This is related to the changes occurs in morphology in presence of finer particles of LSP which reduce water bleeding and segregation [16]. But Silpozz addition decrease the workability of CC due to higher surface area of Silpozz [11]. In absence of superplasticizer addition, the more will be the Silpozz content in concrete the lesser will be the workability [25].

| Mix Identity | SP (%) | Slump Flow Result (mm) | T<sub>500</sub> Test EFNARC(2005) Result (sec) | EFNARC(2005) |
|--------------|--------|------------------------|---------------------------------------------|---------------|
| SCL0S0       | 0.35   | 560                    | 550-650                                     | 15            | >2            |
| SCL10S0      | 0.35   | 573                    | 550-650                                     | 12            | >2            |
| SCL20S0      | 0.35   | 645                    | 550-650                                     | 4             | >2            |
| SCL0S10      | 0.45   | 580                    | 550-650                                     | 9             | >2            |
| SCL0S20      | 0.65   | 672                    | 660-750                                     | 5             | >2            |

In the case of SCC, the results of workability by slump flow, T<sub>500</sub> test is represented in Table 3 and J-Ring Test, V-Funnel test results is represented in Table 4. Constant amount of superplasticizer i.e. 0.35% required in control specimen and 10%, 20% of LSP addition and it shows higher slump flow[26]. Increasing the Silpozz content in SCC tends to decreases the workability and required more superplasticizer for better workability [8] due to higher viscosity is caused by increase in particle friction [2]. T<sub>500</sub> test results satisfy EFNARC (2005) guidelines and come under VS2 category which provides good flowability in SCC. Finer the Silpozz particle the more will be the water requirement [7].

| Mix Identity | J-ring Test Height(mm) | Flow(sec) | EFNARC(2002) 0 – 10 | Result | EFNARC(2005) 7 – 27 |
|--------------|------------------------|----------|----------------------|--------|----------------------|
| SCL0S0       | 12                     | 21       | 0 – 10               | 20     | 7 – 27               |
| SCL10S0      | 07                     | 15       | 0 – 10               | 14     | 7 – 27               |
| SCL20S0      | 05                     | 7        | 0 – 10               | 9      | 7 – 27               |
| SCL0S10      | 07                     | 8        | 0 – 10               | 12     | 7 – 27               |
| SCL0S20      | 05                     | 9        | 0 – 10               | 14     | 7 – 27               |

Passing ability of SCC is measured through J-Ring and all concrete mix fulfills EFNARC (2000) criteria except the control specimen. Increase in porosity of Silpozz due to 20% replacement in cement increases the water requirement and required more superplasticizer [9]. Flowability of SCC measured by V-Funnel test fall under EFNARC (2005) criteria VF2 [4]. All SCC mixes shows acceptable flow ability as specified by EFNARC criteria. Addition of 20% LSP shows better performance as compared to other mixes in SCC by incorporation of higher amount of superplasticizer.

3.2. Compressive Strength Test Results

The compressive strength results of CC and SCC is represented in Figure 2. The results shows that the increase in compressive strength of CC and SCC in case of 10% LSP addition and more the addition
shows decrease in strength as comparison with Silpozz addition [1]. Adding LSP has both positive and negative effect on compressive strength [26]. LSP had detrimental impact on ultra-high performance concrete at 20% replacement [17]. It also reduces the hydration and increase concrete porosity [27]. Due to the nucleation and filling effect, LSP affects compressive strength at an early stage [16]. The strength decrease in LSP based concrete may be due to the dilution effect of LSP [20]. Author reported that the use of LSP in CC shows good strength as compared to control specimen [19]. Inclusion of Silpozz has beneficial effect on both CC and SCC [2]. After 28 days of curing time, pozzolanic reaction start to proceed in addition of RHA in CC improve the densification by decreasing the amount of CH as reported by the researcher [11]. In SCC, 10% of Silpozz has higher strength than control specimen and 20% of Silpozz shows small reduction in strength. More the addition of Silpozz in concrete more will be the compressive strength [7]. The strength increment caused by the micro filling effect of RHA that enhances the microstructure and provide denser matrix phase [1, 4]. The strength is also get influenced by increasing the curing time from 7 days to 28 days [12]. CC prepared with 25% RHA shows highest strength than other as reported by the researchers [19].
3.3. Split Tensile Strength Test Results
The results of split tensile strength results for all mixes of CC and SCC are shown in Figure 3. Better results are observed by the substitution of Silpozz in both CC and SCC as compared to LSP addition at 7 and 28 days of curing. The improvement of strength may be related to the higher pozzolanic impact of Silpozz addition. Lesser amount of Silpozz addition in SCC increases the split tensile strength as reported by Gill and Siddique [8]. Increasing in concrete age increases the process of hydration which help to improve the split tensile strength. At all curing period inclusion of 10% Silpozz significantly increases the split tensile strength as comparison with reference sample [12]. More than 10% of LSP addition shows decrement in split tensile strength due to lesser hydration product with lower bonding and weak ITZ determined by Demirhan et al. [26]. Pradhan and Panda [28] reported that the utilization of 20% LSP shows lower split tensile strength as compared to 20% of Silpozz addition in SCC.

3.4. Flexural Strength Test Results
Flexural strength test results of CC and SCC concrete mixes are represented in Figure 4. SCC shows comparatively better performance as compared to CC. LSP addition of 20% has least strength value as compared to all other concrete mixes. Similar results were obtained by Pradhan and Panda [28]. The calcium carbonate in LSP has a very little reaction with cement hydrates create the filler effect in concrete [1]. Silpozz replacement shows better performance as compared to control mix in SCC and this leads to resistant against microcracks propagation with lower porosity [4]. Highest flexural strength is observed by 20% Silpozz addition in both CC and SCC.

![Figure 4. Flexural Strength Results of CC and SCC](image)

4. Conclusions
Performance of mineral admixtures significantly influences the fresh and hardened concrete properties of CC and SCC. Silpozz and LSP help to produce green concrete by reducing cement consumption and solve disposal problem. The following conclusion can draw from this experimental assessment:

- Incorporation of superplasticizer in concrete plays a critical role in workability of SCC.
- When Silpozz is used in CC it absorbs water and decreases the workability. In SCC, the addition of a superplasticizer facilitates to get desired workability.
- Adding LSP in CC enhances the slump flow and a fixed amount of superplasticizer shows remarkable results.
- Compressive strength test result the higher strength is achieved by CC as compared to SCC.
- Compressive strength test, the replacement of 10% LSP shows better performance than 20% LSP and control specimen for both CC and SCC.
Increasing the substitution of Silpozz in cements as partial replacement shows an increment in compressive strength in both CC and SCC.

SCC improves the split tensile and flexural strength test results as compared to CC. It also shows that both 7 and 28 days of curing have a similar pattern of strength gain.

Among all concrete mixes, split tensile and flexural strength test results show LSP as 10% replacement and Silpozz as 20% replacement shows good performance in both CC and SCC.

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