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Effect of silpozz and LSP on fresh and hardened properties of SCC

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Abstract **: This paper presents the effect silpozz and lime stone powder (LSP) on the fresh and hardened properties of self compacting concrete (SCC). The investigation comprises of six number of concrete mix having a constant water cement ratio of 0.43 and the materials used i.e. silpozz and LSP with different percentages. Cement is replaced partially with both silpozz and LSP such as 5% LSP with 15% silpozz, 10% LSP with 10% silpozz, and 15% LSP with 5% silpozz, 20% silpozz with 0% LSP and 20% LSP with 0% silpozz. The M30 grade mix design is chosen and the mix proportion is 1:1.44:2.91. The fresh concrete properties of SCC was measured using slump flow, T_{500}, J-Ring, L-Box, V-Funnel tests and satisfied the EFNARC guidelines. The test results indicate that the use of increasing amount of silpozz decrease the workability, and to increase the workability and satisfy the EFNARC guidelines the dosages of SP increases. But LSP improves the workability. To know the hardened concrete properties, the tests were carried out such as compressive, split tensile and flexural strength. The test results indicate that LSP based concrete decreases the compressive, split tensile and flexural strength at 20% replacement as compared to control mix, whereas the use of silpozz at 20% replacement increases the strength as compared to control mix. It is also observed that the compressive, split tensile and flexural strength of specimens contain 5% LSP and 15% silpozz gives higher value as compared with other specimens.**

Keywords: Silpozz, Lime Stone Powder (LSP), Compressive strength, Flexural strength and Split tensile strength.

INTRODUCTION

Self Compacting Concrete is defined as the concrete having the ability to flow under its own weight in heavy reinforcement, without any segregation and bleeding. In 1980s, Japan encountered deficiency in skilled labour which ultimately started a new solution i.e. SCC. It reduced labour cost, increases the design flexibility, save time which enhances the rate of construction and also eliminates noise pollution. Due to its numbers of applications and high productivity raise its popularity in construction engineering day by day. It generally requires chemical admixtures such as super plasticizers/viscosity modifying admixtures and higher finer materials such as supplementary cementious materials, which increases the fresh and hardened properties of SCC. This reason is useful to differentiate SCC from conventional concrete. These supplementary cementious materials are of two types i.e. pozzolanic and non pozzolanic. Pozzolanic materials are Fly ash (FA), silica fume (SF), metakaolin, rice husk ash (RHA) where as the non pozzolanic materials are lime stone powder (LSP), marble powder (MP) and granite dust.

Partial replacements of cement with SF do not have any effect on viscosity which is based on the results of T_{500}, and V-funnel tests. It gives maximum compressive strength i.e. 14% higher than control mix [1]. Gesoglu et al. [2] concluded that using of mineral admixtures such as SF increase the T_{500} slump flow time. Yazici et al. [3] observed that increase in SF required higher amount of SP for achieving desired slump value without any segregation and bleeding problems. Strength increases at increase in water curing period. It is possible to produce SCC in addition of SF and FA with all satisfactory properties of SCC. Increase in compressive strength was observed while the replacement level of SF increased. Highest compressive strength was shown at 15% replacement at 28 days [4]. Mohamed also reported similar results [5]. Sabet et al. [6] reported that increasing compressive strength is recognized as higher pozzolanic activity of SF. According to some research, strength development is basically due to the utilization of the calcium hydroxide crystals released from the hydration process which leads to the formation of further calcium-silicate-hydrate which contributed to the interfacial bond strength between aggregate particles and matrix [7-8]. Nuruddin et al. [9] concluded that ductile self compacting concrete (DSCC) can be used as high strength ductile self compacting concrete with the appropriate w/b ratio and superplasticizer. Dehwah indicated that the use of 8% quarry dust powder (QDP) and w/c 0.38 or 8% QDP plus 5% silpozz with w/c 0.4 was better than that of specimen prepared with other proportion of QDP or FA. SCC with QDP and SF can be used successfully to the structure which exposes to chloride bearing environments [10].

In another study the development of SCC using SF and hydraulic lime in various combinations shows that increase in SF and decrease in lime content increase in V-funnel time. Compressive strength increases as increase in SF and strength decreases as increase in lime content. Addition of SF and lime content increases the filling and passing ability of SCC [11]. LSP requires less water and increases slump flow. It has positive effects on workability. Increasing amount of LSP does not affect the blocking ratio of L-box due to decrease in viscosity [12]. Elyamany et al. [13] reported that the use of non-pozzolanic fillers decrease the segregation and bleeding but shows no negative effect on compressive strength as compared to pozzolanic fillers. Gesoglu et al. [14] demonstrated that 10% replacement of lime stone filler gives higher tensile strength. Lime stone filler showed lower V-funnel flow time of SCC. On the other hand higher the lime stone fines content in concrete mix minimize the initial and final setting times [15]. Silpozz is a super pozzolanic material with silica content of above 90% and can be used as a substitute material for SF in the present investigation. Aim of this study is to investigate on the effect of silpozz and LSP on the properties of SCC. To evaluate fresh concrete properties the tests were conducted such as slump flow, $T_{500,}$ J-Ring, L-Box, V-Funnel tests and hardened concrete properties were known from compressive, split tensile and flexural strength tests.

EXPERIMENTAL PROGRAM

Materials Used

The materials used in this experiment were ordinary Portland cement (OPC), silpozz and LSP. Ramco Cement, OPC 43-grade is used in the present study having specific gravity 3.15. The physical properties of cement are obtained as specified by IS 8112:1989. Silpozz was supplied by N. K. Enterprises, Singhania House, Jharsuguda, ODISHA and the specific gravity is 2.71. LSP was supplied from Gagodia lime, Rajgangpur, Sundargarh. It acts as filler materials in cement having specific gravity 2.8 and fineness 1.30%. The silpozz and LSP sample used in the experimental program is shown in Figures 1-2. The chemical properties of the materials are given in Table 1. Sand is used as natural fine aggregate (NFA) which is passing through IS 4.75 mm sieve. It is having specific gravity 2.67 and conforming to zone III, was used in the present study. Natural coarse aggregate (NCA) lies in between 10 to 20 mm size and its specific gravity is 2.86. In this project work CERA HYPERPLAST XR-W40 high end super plasticisers are used for the production of high strength and high performance SCC. The SP was supplied by Cera-Chem Private Ltd. This is conforms to ASTM C 494-03, BS 5075 and IS 9103.

Figure 1. Silpozz (Silicafume) sample

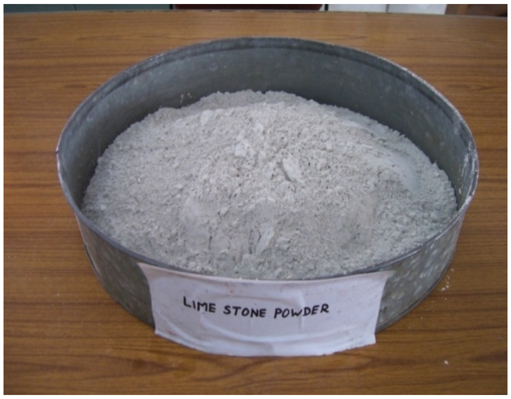

Figure 2. Lime stone powder sample

Table 1. Chemical composition of OPC, LSP and Silpozz

Oxide	OPC	LSP	Silpozz
SiO_2	20.50	10.50	88.18
Al_2O_3	5.05	0.82	1.61
Fe_2O_3	2.99	0.29	0.56
CaO	62.00	49.00	1.59
MgO	2.07	0.58	1.63
SO_3	2.40	0.10	-
LOI	3.10	38.71	-
Carbon	-	-	2.67
K_2O	-	-	1.67
Others	-	-	2.09
Moisture	-	-	0.79

Mix proportions

In this experiment, six number of concrete mix were prepared from different combinations of OPC with Silpozz and LSP. For conventional concrete, M30 grade concrete was designed as per standard specification IS: 10262-2009, to result in a mix proportion of 1: 1.44: 2.91 with W/C ratio of 0.43. For SCC, the mix design is prepared in trial basis. With 35% increase in fine aggregate and 35% decrease of coarse aggregate in CC mix with same W/C ratio and the addition of required doses of SP for different mix satisfied EFNARC guidelines of SCC mix. SCL0S0 indicate 0% LSP, 0% silpozz with 100% cement, SCL20S0 indicate

20% LSP, 0% silpozz with 80% cement, SCL15S5 indicate 15% LSP, 5% silpozz with 80% cement, SCL10S10 indicate 10% LSP, 10% silpozz with 80% cement, SCL5S15 indicate 5% LSP, 15% silpozz with 80% cement, SCL0S20 indicate 0% LSP, 20% silpozz with 80% cement. The detail mix proportions are presented in Table 2.

Table 2. Details of mix quantity per m^3 of concrete

Mix Identity	Cementitious material per m^3 of concrete			NFA (kg)	NCA (kg)	SP (kg)	Water (kg)
	OPC (kg)	LSP (kg)	Silpozz (kg)				
SCL0S0	434.32	0	0	843.43	822.23	1.52	186.76
SCL20S0	347.46	86.86	0	843.43	822.23	1.52	186.76
SCL15S5	347.46	65.15	21.72	843.43	822.23	1.73	186.76
SCL10S10	347.46	43.43	43.43	843.43	822.23	2.17	186.76
SCL5S15	347.46	21.72	65.15	843.43	822.23	2.60	186.76
SCL0S20	347.46	0	86.86	843.43	822.23	2.82	186.76

Test Procedure

The cementious materials such as OPC, LSP and silpozz with NCA, NFA were weighed and placed in the concrete mixer in dry conditions with required amount of water was added during mixing. SP is added to bring the concrete into proper workability condition. The dosage of SP changed due to different replacement level of LSP and silpozz. For SCC, the flow ability, passing ability and filling ability was measured from five experiments such as slump flow test, T_{500} test, J-Ring test, V-Funnel test and L-Box test. The test specimens were cast in steel mould and demolded after 24 hours. The test samples were cured for 7 and 28 days under tap water. A set of three concrete cubes, cylinders and prisms were cast as per mix design to know the hardened concrete properties of SCC. 150×150×150 mm cube specimens were cast to test compressive strength for 7 and 28 days. Cylindrical specimens of 100×200 mm were cast to know split tensile strength and flexural strength was measured from 500×100×100 mm prismatic specimen.

In slump flow test, place the base plate on level stable ground and the slump cone placed centrally on the base plate and hold down firmly. Then base plate and inside slump cone is moisten properly and filled in slump cone with concrete as shown in Figure 3. Make the top surface level and then lift the slump cone and measure the flow diameter of concrete. In T_{500} test, set the stopwatch, then lift the slump cone straightly in a stroke, allow the concrete to flow freely to a diameter of 500 mm is measured as shown in Figure 3. After completion of flow stop the stopwatch and note the time. Slump flow test and T_{500} test were done according to the procedure of EFNARC (2005) guidelines.

Figure 3. T_{500} test of SCC


Figure 4. L-box test of SCC

Figure 5. V-funnel test of SCC

In J-Ring test moisten the base plate and inside of slump cone and place the J-Ring centrally on the base plate. Fill the cone and remove any excess concrete from around the base of the cone. Raise the cone vertically and allow the concrete to flow out freely. Measure the difference in height between the concrete just inside the bars and that just outside the bars at four locations (in mm) as shown in Figure 7. J-Ring test were done according to EFNARC (2002) guidelines. To determine the filling ability of the SCC, V-funnel test were done. Fill the V-Funnel completely with concrete without compacting and open the trap door within 10 sec after filling the concrete and allow the concrete to flow out under gravity. Start the stopwatch when the trap door is opened, and record the time for the discharge to complete (the flow time) into a bucket. V-funnel test and L-box test were done according to EFNARC (2005) guidelines as shown in Figures 4-5. In L-box test, the vertical section is filled with concrete and then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section. The horizontal section of the box can be marked at 200 mm and 400 mm from the gate and the times taken to reach these points measured. These are known as the T_{200} and T_{400} times and are an indication for the filling ability of SCC.

TEST RESULTS AND DISCUSSIONS

Fresh Concrete Results

The test results of slump flow, T_{500} test and J-ring test are presented in Table 3 and shown in Figures 6-7 for control mix (SCL0S0). The lower flow time indicates that the high flowability nature of concrete. All the replacement of LSP and silpozz belongs to slump flow classes SF1 which lies in between 550-650 of EFNARC (2005) guidelines. But SCL0S20 belongs to SF2 which lies in between 660-750 of EFNARC (2005) guidelines. Addition of 20% of LSP increases the slump flow. The mixture containing mineral admixtures such as LSP provide better workability with less need of water [11]. But the increase in addition of silpozz decreases the slump flow. So to get proper workability and satisfy EFNARC guidelines silpozz needs to increase the dosage of SP. The increase in SP demand may be due to the specific gravity of silpozz is lower than the OPC [3]. But LSP need less amount of SP as compared to the silpozz. The T_{500} test is used to assess the horizontal free flow of SCC in the absence of obstructions. T_{500} is classified into two classes in EFNARC (2005) guidelines i.e. VS1 and VS2. For VS1 classes the result is ≤ 2 and for VS2 class the result is > 2. From the Table 3, all the test results come under VS2 classes. SCL20S0 achieve higher flowability of SCC. The J-Ring test is used for evaluation of the passing ability of the concrete. According to EFNARC (2002) guidelines, J-ring test results should lies in between 0-10 mm. From Table 3, it is shown that all the test results comes under the EFNARC (2002) guidelines criteria and lies in between 0-10 mm except SCL0S0.

Table 3. Fresh concrete properties of SCC

Mix Identity	Slump Flow (mm)		T_{500} Test (SECONDS)		J-ring Test		
	Test Result (mm)	EFNARC (2005) Criteria	Test Result	EFNARC (2005) Criteria	Step Height Result (mm)	Total Flow Result (Sec)	EFNARC (2002) Criteria
SCL0S0	560	550-650	15	>2	12	21	0-10
SCL20S0	645	550-650	4	>2	05	7	0-10
SCL15S5	618	550-650	9	>2	04	10	0-10
SCL10S10	622	550-650	7	>2	05	11	0-10
SCL5S15	626	550-650	6	>2	06	13	0-10
SCL0S20	672	660-750	5	>2	05	9	0-10

LSP - 0% and SF - 0%

Figure 6. Slump flow test of SCC

LSP - 0% and SF - 0%

Figure 7. J-ring test of SCC

The test results of V-funnel and L-box test are presented in Table 4. V-funnel test determines the filling ability of SCC. According to EFNARC (2005) guidelines, the V-Funnel test results ≤ 10s, it comes under VF1 classes and the test results in between 7-27s come under VF2 classes. The present test results come under VF2 classes which satisfy the EFNARC (2005) guidelines. 20% replacement of LSP shows lower flow time as compared to others mixtures [14]. According to EFNARC guidelines the L-box test results ≥ 0.75 comes under PA1 classes with 2 rebars and the test results ≥ 0.75 comes under PA2 classes with 3 rebars. In present study, the L-box test results comes under PA2 classes with 3 rebars which satisfy the EFNARC

(2005) guidelines. SF improves the passing ability as compared to control mix [1]. Increasing LSP does not affect the blocking ratio of L-box [11].

Table 4. Fresh concrete properties of SCC

Mix Identity	V- Funnel (SECONDS)		L-Box (Passing Ability)			
	Test Result	EFNARC (2005) Criteria	Test Result H_2/H_1	T_{20} Sec	T_{40} Sec	EFNARC (2005) Criteria
SCL0S0	20	7-27	0.76	5	16	≥ 0.75
SCL20S0	9	7-27	0.93	3	09	≥ 0.75
SCL15S5	18	7-27	0.82	3	15	≥ 0.75
SCL10S10	19	7-27	0.81	4	13	≥ 0.75
SCL5S15	20	7-27	0.78	6	16	≥ 0.75
SCL0S20	14	7-27	0.85	3	23	≥ 0.75

HARDENED CONCRETE RESULTS

Compressive Strength

The compressive strength versus age of SCC for 7 and 28 days is represented in Figure 8. The concrete mix SCL20S0 shows decrease in compressive strength as compared to SCL0S0 concrete mix. LSP performs as an inert mineral admixture which reduces the compressive strength of LSP based concrete [11]. The compressive strength of SCL5S15 after 7, 28 days gives better result as compared to other mixes. The compressive strength of SCL5S15 increases 13.73% and 22.28% as compared to SCL0S0 concrete mix in 7 and 28 days respectively. Silpozz increases the compressive strength which can be useful for the production of SCC which develops mechanical properties [3]. Increase in water curing duration increases the strength [4]. The compressive strength results of different SCC mixes for curing period 7 and 28 days are presented in Figure 9.

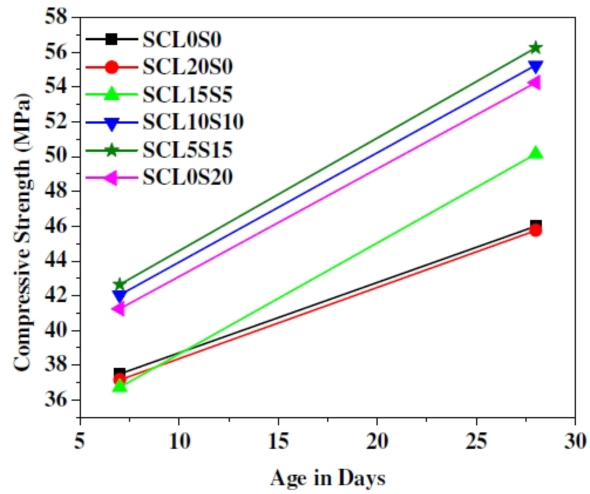

Figure 8. Compressive strength versus age in Days

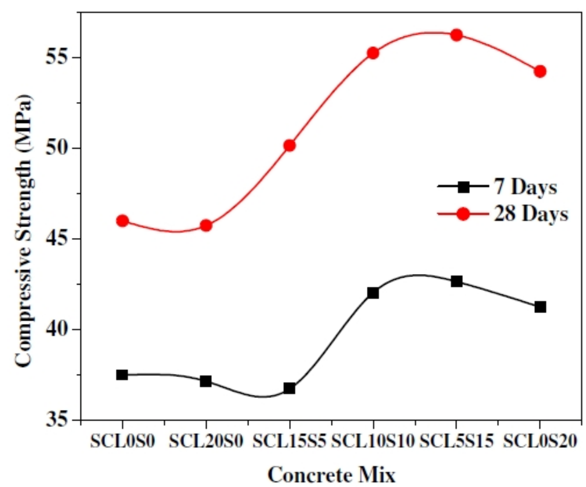

Figure 9. Compressive strength of different SCC mix

Flexural Strength

The test result of flexural strength determined at different age is shown in Figure 10. In LSP-silpozz based concrete, increase in silpozz and decrease in LSP quantity enhance the flexural strength and gives better performance at all age. It was observed that SCL5S15 and SCL10S10 indicate higher flexural strength, whereas decrease in flexural strength observed in SCL20S0 concrete mix as compared to other concrete mix. The flexural strength of SCL5S15 increases 31.50% and 19.49% as compared to SCL0S0 concrete mix in 7 and 28 days respectively. The flexural strength results of different SCC mixes for curing period 7 and 28 days are presented in Figure 11.

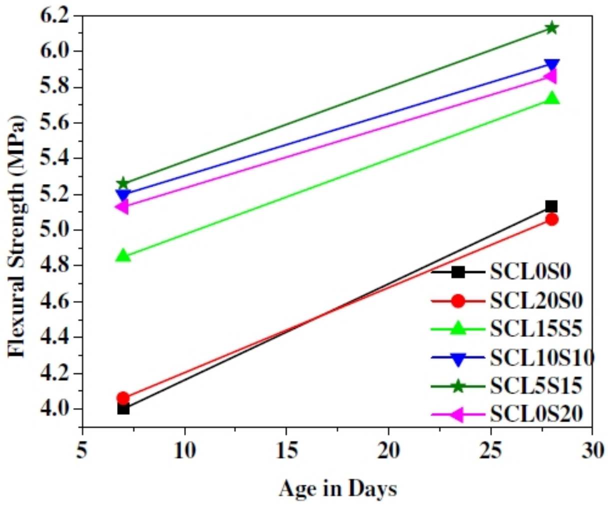

Figure 10. Flexural strength versus age in Days

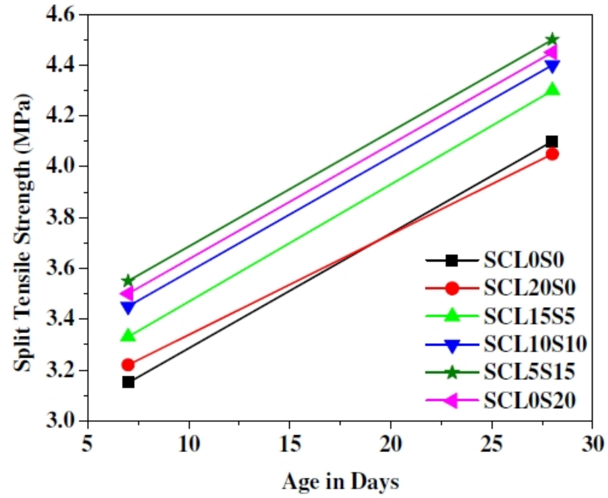

Figure 12. Split Tensile strength versus age in Days

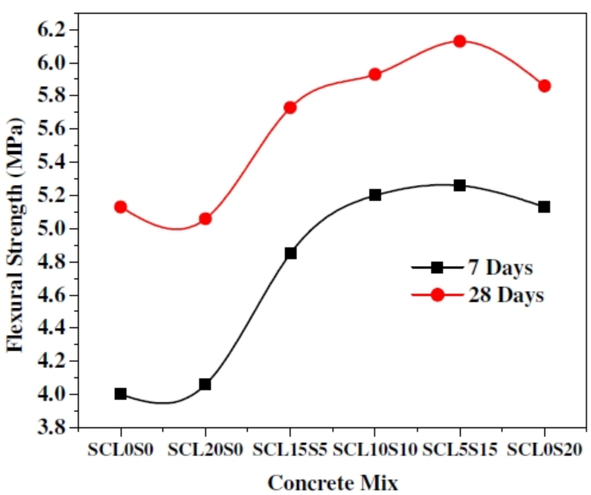

Figure 11. Flexural strength of different SCC mix

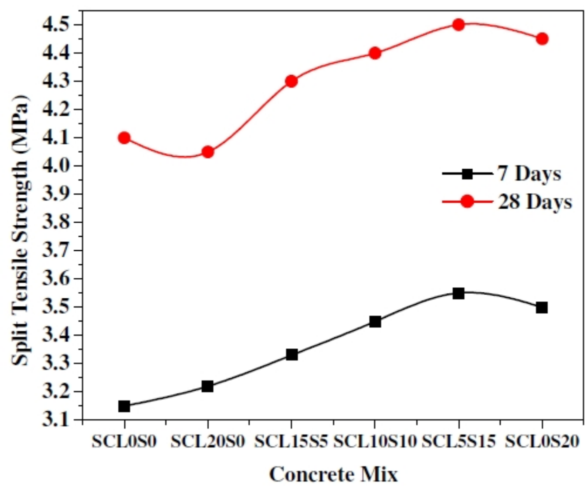

Figure 13. Split Tensile strength of different SCC mix

Split Tensile Strength

The split tensile strength of SCC specimen versus age in days is shown in Figure 12 and the split tensile strength results of different SCC mixes for different curing period i.e. 7 and 28 days is presented in Figure 13. The maximum split tensile strength was observed for 5% replacement of LSP and 15% replacement of silpozz i.e. SCL5S15 at all age as compared to other concrete mix. 20% replacement of LSP increases the split tensile strength as 2.22% and decreases the strength as 1.22% as compared to control mix (SCL0S0) at 7 and 28 days respectively. SCL0S20 increases split tensile strength as compared to SCL0S0. The percentage increase in split tensile strength with respect to control specimen is 11.11% and 8.53% at 7 and 28 days respectively.

CONCLUSIONS

This paper represents the experimental program to describe the effect of silpozz and LSP on fresh and hardened properties of SCC with different percentage of silpozz and LSP replacement of cement. Based on the above results the following conclusions can be drawn:

- For all the concrete mixture in SCC provide satisfactory results in fresh state. Partial replacement of LSP enhanced workability in addition of smaller amount of SP as compared to silpozz replacement.
- The increase in silpozz replacement decreases the slump flow in addition of constant amount of SP. But to satisfy EFNARC (2005) guidelines the dosage of SP was needed to be increased.
- 20% replacements of LSP decrease the T_{500} flow time (i.e. 4 sec) and V-funnel time (i.e. 9 sec) in addition of 0.35% of SP which belongs to VS2 classes and VF2

classes respectively and satisfy the EFNARC (2005) guidelines.

- For L-box test results all the concrete mix satisfies the EFNARC (2005) guidelines and come under PA2 classes with 3 rebars in addition of required amount of SP.
- The test results indicate that the strength of SCC increases, as curing period increases from 7 days to 28 days.
- The compressive strength decreases at 20% replacement of LSP where as 5% LSP and 15% silpozz shows higher compressive strength as compared to other mix.
- The highest flexural and split tensile strength was obtained from the specimen containing 5% LSP with 15% silpozz as compared to control mix.
- Using 20% replacement of LSP decreases the flexural strength as compared to control mix at all age.
- Increase in silpozz increases the strength due to its higher pozzolanic effect. But the best performance for SCC was obtained from 5% LSP with 15% silpozz replacement in cement.

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