Industrial Waste Materials Silica Fume and Hypo Sludge Are Used In High Performance of M60 Grade of Concrete

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***Abstract*— Utilization of industrial waste materials products in concrete is gaining importance all around the world. Concrete is the basic engineering material used in most of the civil engineering structures. Concrete like other engineering materials needs to be designed for properties like strength, durability, workability and cohesion. Hypo sludge is such an industrial waste produced in plenty by paper mills. Concrete of M60 grade are investigated with silica fume as powder along with Hypo sludge. The test was carried out to evaluate the mechanical properties like slump test and compressive strength of 7 and 28 days and split tensile strength of 28 days. It was found from the experimental study that concrete composites with superior properties can be produced using Silica Fume and combination of Hypo Sludge.**

***Index Terms*— Cement; Silica Fume; Hypo Sludge; Slump Test; Compressive Test; Split Tensile test.**

I. INTRODUCTION

Today construction cost is very high with using routine material like cement, fine aggregate and coarse aggregate. This study includes use of different waste material as a partial replacement of cement. Industries in India produce lots of waste which may be useful in partial replacement of all the raw materials due to their different properties So hereby we studied as many useful research papers in this field and trying to improve with locally available waste material so it can be proved economical as well. Research in this field and positive results are crucial so as to continue all developments with least damage to surrounding environment and obtaining all infrastructures for services and convenience which are desired to get.

Natural resources are not unlimited therefore, they must be optimally consumed. The manufacturing of Ordinary Portland cement (OPC) which is the main ingredient of concrete but it releases a large amount of greenhouse gases specially CO_2. On the other side dumping of wastes produced from industries causes a major problem to environmental issues. This shall help not only to control degradation of environment but also the conserve them for the use of future generation. This can be achieved by the process of recycling and, making use of industrial wastes, disposal of which otherwise is a serious problem.

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. Silica fume has been recognized as a pozzolanic admixture that is effective in greatly enhancing mechanical properties. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO_2).The addition of silica fume to concrete improves the latter's durability by reducing permeability and refining pore structure, leading to a reduction in the diffusion of harmful ions and the calcium hydroxide content, resulting in greater resistance to sulfate attack.

Out of these supplementary cementitious materials, silica fume is the one of the waste materials that is being produced in tones of industrial waste per year in our country. The first testing of silica fume in Portland-cement-based concretes was carried out in 1952. The biggest drawback to exploring the properties of silica fume was a lack of material to experiment with. Early research used an expensive additive called fumed silica, an amorphous form of silica made by combustion of silicon tetrachloride in a hydrogen-oxygen flame. Silica fume on the other hand, is a very fine pozzolanic material. It is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses of silica fume is in concrete. Because of its chemical and physical properties; it is a very reactive pozzolanic material. Concrete containing silica fume has very high strength and is very durable.

Over 300 million tons of waste produced per annum in India in the form of chemical and agricultural waste. Paper making industries generally produces a large amount of solid waste. This paper mill sludge consumes a large percentage of local landfill space for each and every year.

Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. It means that the broken, low- quality paper fibers are separated out to become waste sludge. All the inks, dyes, coatings, pigments, staples and “stickiest” (tape, plastic films, etc.) are also washed off the recycled fibers to join the waste solids. The shiny finish on glossy magazine-type paper is produced using a fine kaolin clay coating, which also becomes solid waste during recycling. This paper mill sludge consumes a large percentage of local landfill space for each and every year. Worse yet, some of the wastes are land spread on cropland as a disposal technique, raising concerns about trace contaminants building up in soil or running off into area lakes and streams. Some companies burn their sludge

in incinerators, contributing to our serious air pollution problems. To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. Keeping this in view, investigations were undertaken to produce low cast concrete by blending various ratios of cement with hypo sludge.

Benefits of Hypo Sludge

- Hypo sludge improves the properties of fresh and hardens concrete.
- Hypo sludge reduces degradation and bleeding.
- Hypo sludge improves the durability of concrete.
- Hypo sludge improves the setting of concrete due to presence of silica and magnesium.
- Environmental friendly.
- Hypo sludge is the cheaper substitute to Ordinary Portland Cement.

Limitations of Hypo Sludge

- Availability.
- Handling problem.

Chemical reactions involved in partially replaced in concrete

1. Primary Hydration

$$\text{Cement} + \text{Water} \rightarrow \text{C-S-H (gel)} + Ca(OH)_2$$

2. Secondary Hydration

Here Silica Fume and Hypo Sludge act as a pozzolana.

$$Ca(OH)_2 + \text{Pozzolana} \rightarrow \text{C-S-H (gel)}$$

Increase in amount of C-S-H gel increase the compressive strength but only up to a certain extent.

II. LITERTURE REVIEW

R.Srinivasan, K.Sathiya & M. Palanisamy reported on "Experimental investigations in developing low cost concrete from paper industry waste". Over 300 million tons of industrial wastes are being produced per annum by chemical and agricultural process in India. These materials pose problems of disposal and health hazards. The wastes like phosphor gypsum and red mud contain obnoxious impurities which adversely affect the strength and other properties of building materials based on them.

A Balwaik & SP Raut reported on "Utilization of waste paper pulp by partial replacement of cement in concrete". The use of paper-mill pulp in concrete formulations was investigated as an alternative to landfill disposal. The cement has been replaced by waste paper sludge accordingly in the range of 5% to 20% by weight for M-20 and M-30 mix. By using adequate amount of the waste paper pulp and water, concrete mixtures were produced and compared in terms of slump and strength with the conventional concrete.

Verma ajay etal have studied the effect of micro silica and the strength of concrete with ordinary Portland cement. They observed that silica fume increases the strength of concrete and reduces capillary pores.

Dilip Kumar Singha Roy has investigated on the strength parameters of concrete made with partial replacement of cement by Silica Fume.

T.Shanmugapriya studied the influence of silica fume on M60 concrete and found that 7.5% of silica fume replacement increases the maximum compressive strength, split tensile strength and flexural strength.

H. Katkhuda, B. Hanayneh & N. Shatarat reported on "The effects of silica fume on compressive strengths on high strength lightweight concrete". They carried out by replacing cement with different percentages of silica fume at different constant water-binder ratio keeping other mix design variables constant. The silica fume was replaced by 0%, and 8% for a waterbinder ratios ranging from 0.26 to 0.42. For all mixes, compressive strength was determined at 7& 28 days. The results showed that the compressive strengths increased with silica fume incorporation but the optimum replacement percentage is not constant because it depends on the water cementitious material (w/c) ratio of the mix. Based on the results, a relationship between compressive strengths of silica fume concrete was developed using statistical methods.

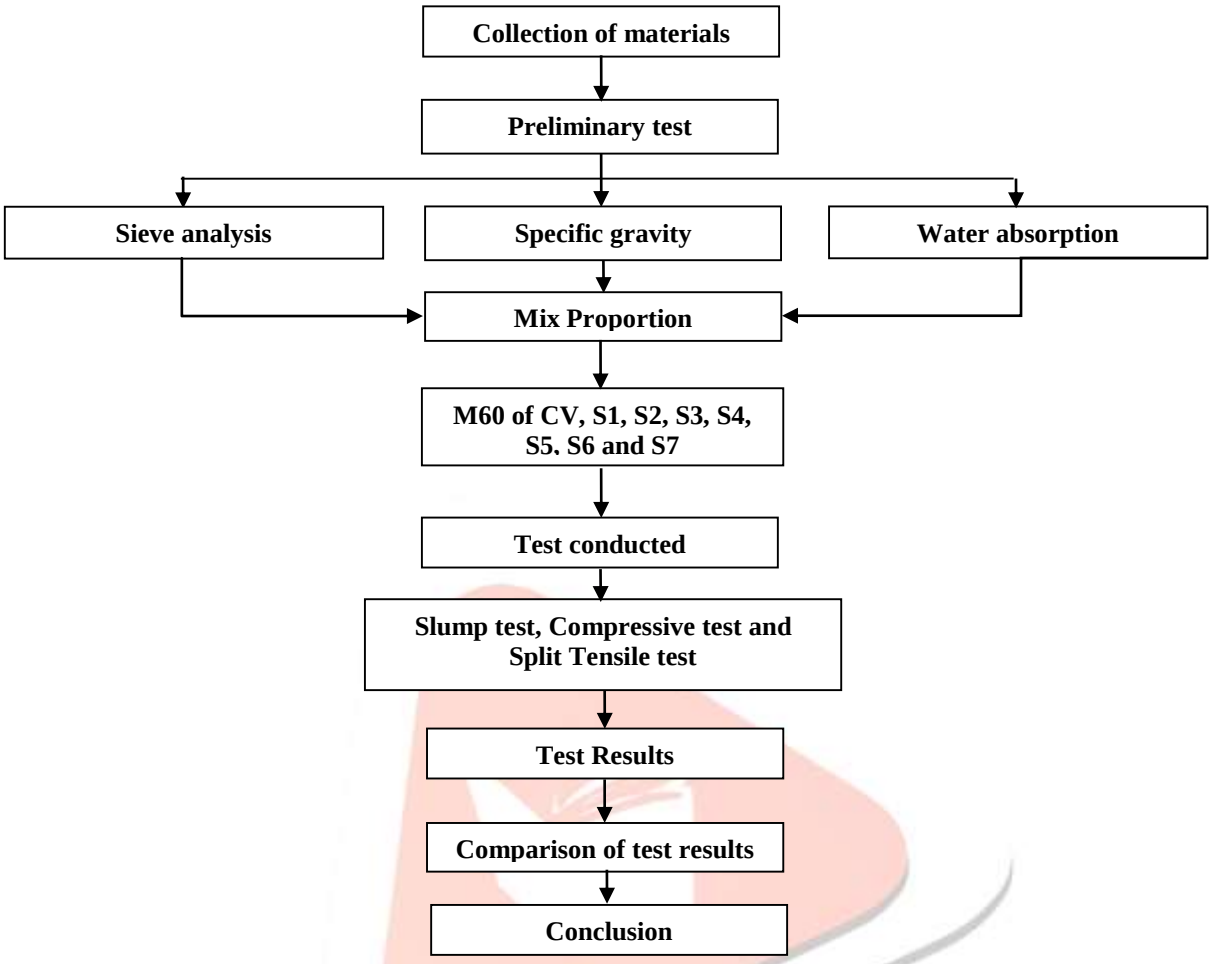
III. SIGNIFICANCES OF THE WORK

The cost cement is more expensive and is not eco-friendly. One ton of cement producing one ton of Greenhouse gases. Replacement with supplementary materials will address two problems by reducing Greenhouse gases and cost effective. By recycling the waste materials with cement we can decrease optimum amount of waste. In some cases the concrete will allows water from one surface to another. The waste materials produced by industry like hypo sludge, rice husk ash, fly ash, silica fume, etc., can be replaced with cement with suitable proportions. Hypo sludge is easily adopted in field. It minimizes the maximum degradation in environmental due to cement and safeguard the ozone layer from Greenhouse gases. For every construction projects workability plays an important role for that particular problem silica fume will increases the workability.

IV. METHODOLOGY AND MATERIALS

4.1 Methodology

The methodology of the work is given in flow



4.2 Materials

4.2.1 Cement: Ordinary Portland cement of 53 grade, with Specific gravity 3.15 .

4.2.2 Water: Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

4.2.3 Fine Aggregate: Locally available natural river sand confirming to grading zone-II (IS 388-1970) with specific gravity 2.65 was used as fine Aggregate.

4.2.4 Coarse Aggregate: Crushed granite confirming to IS: 383-1970, consisting of 20 mm maximum size of aggregates and with specific gravity 2.67, was obtained from the local quarry.

Table 1: Physical properties of Aggregates

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.65	2.6
Fineness modules	28	-
Water absorption (percent)	1.9	0.6
Maximum size (mm)	4.75	20 and 10
Bulk density (kg/m^3)	1520	1575
Sand equivalent (percent)	83	-

4.2.5 Hypo Sludge: Hypo sludge is also known as paper industry waste. It is the by-product of the paper waste. This hypo sludge contains low calcium and minimum amount of silica. Hypo sludge behaves like cement because of silica and magnesium properties. Hypo sludge may be used as part replacement of cement. It is usually used in proportion of percent of cement content of the mix.

Table 2: Chemical properties of Hypo Sludge

Ingredients	% in Hypo Sludge
Moisture	54.9
CaO	48.2
MgO	3.4
SiO_2	8.8
R_2O_3	3.8
Igneous	28

4.2.6 Silica Fume: Silica fume particles are extremely small; with more than 95% of the particles being less than 1 µm. particle size is extremely important for both the physical and chemical properties of silica fume of concrete.

Table 3: Chemical properties of silica fume

Ingredient	% in Silica Fume
SiO_2	90
Al_2O_3	2.18
Fe_2O_3	2.2
CaO	1.52
MgO	0.9
SO_3	1.2
Alkalies (K_2O, Na_2O)	2

V. MIX DESIGN FOR M-60 GRADE OF CONCRETE

The experimental program was designed to compare the mechanical properties i.e. compressive strength, and split tensile strength of high strength concrete with M60 grade of concrete and with different replacement levels of ordinary Portland cement (ultra tech cement 53 grade) with silica fume (5%) and Hypo Sludge (5%, 10%, 15%, 20%, 25% and 30%).

5.1 Mix Proportion: The concrete mixes were designed to a compressive strength of M60 grades with water cement ratio of 0.30 as per IS code 10262-2009.

Table 4: Mix proportion of concrete

S.No	Materials	Quantity
1.	Cement	450 kg/m^3
2.	Water	137 kg/m^3
3.	Fine Aggregate	604 kg/m^3
4.	Coarse Aggregate 20 mm	546 kg/m^3
5.	Coarse Aggregate 10 mm	444 kg/m^3
6.	Water Cement ratio	0.30

Table 5: Percentage replacements materials

S.No	Type of mix	Silica Fume (%)	Hypo Sludge (%)	Cement (%)
1.	CV	-	-	100
2.	S1	5	-	95
3.	S2	5	5	90
4.	S3	5	10	85
5.	S4	5	15	80
6.	S5	5	20	75
7.	S6	5	25	70
8.	S7	5	30	65

VI. RESULTS AND DISCUSSION

6.1 Test on fresh concrete: The concrete slump test will measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete. The design slump value was 152 mm M60 grade of concrete and the maximum slump value found was 166 mm. Many variations have been seen while checking for slump of different concrete mixes is presented in table 6.

6.2 Compressive Strength: As we know that concrete is a compressive (brittle) material. The strength of the concrete increase with the age. At the age of 1, 3, 7, 14, 21 and 28 days the percentage of compressive strength is 16%, 40%, 65%, 90%, 95% and 99% respectively. The compressive strength M60 grade concrete at the age of 28 days is presented in table 7. Compressive strength of concrete at the 28 days age, with replacement of silica fume was increased gradually up to an optimum replacement level of 5% and then gradually decreased by adding Hypo sludge. At 20% and 25% replacement of cement (silica fume of 5% and Hypo sludge 15%) the compressive strength is 62.1 MPa and 60.3 MPa respectively is approximately same.

6.3 Split Tensile Strength: The Split tensile strength M60 grade concrete at the age of 28 days is presented in table 8. Split tensile strength of concrete at the 28 days age, with replacement of silica fume was increased gradually up to an optimum replacement level of 5% and then gradually decreased by adding Hypo sludge. At 20% replacement of cement (silica fume of 5% and Hypo sludge 15%) the split tensile strength is 3.87 MPa is approximately same.

Table 6: Workability of concrete

S.No	Type of Mix	Slump (mm)
1.	CV	158
2.	S1	166
3.	S2	158
4.	S3	147
5.	S4	145
6.	S5	140
7.	S6	138
8.	S7	125

Table 7: Compressive strength of Concrete

Sl.No	Type of Mix's	Compressive Strength (MPa)		
		3 Days	7 Days	28 Days
1.	CV	35.22	52.3	60.6
2.	S1	38.54	54.8	67.2
3.	S2	39.53	54.2	65.3
4.	S3	36.24	53.3	63.5
5.	S4	34.56	51.4	62.1
6.	S5	32.24	50.2	60.3
7.	S6	28.26	48.2	58.4
8.	S7	24.16	45.3	55.3

Table 8: Split Tensile Strength of Concrete

Sl.No	Type of Mix's	Split Tensile Strength at 28 days (MPa)
1.	CV	3.83
2.	S1	4.34
3.	S2	4.06
4.	S3	3.96
5.	S4	3.87
6.	S5	3.78
7.	S6	3.42
8.	S7	2.98

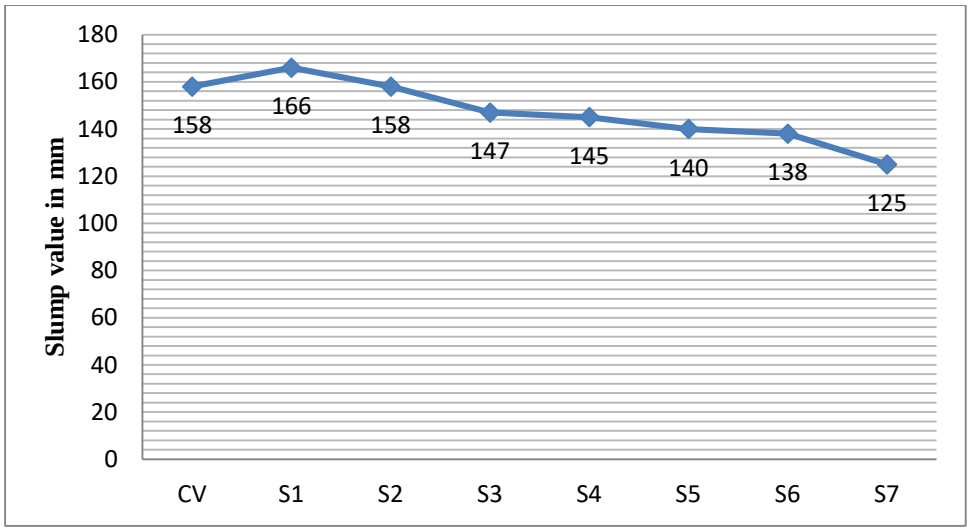


Figure 1: Slump test of concrete.

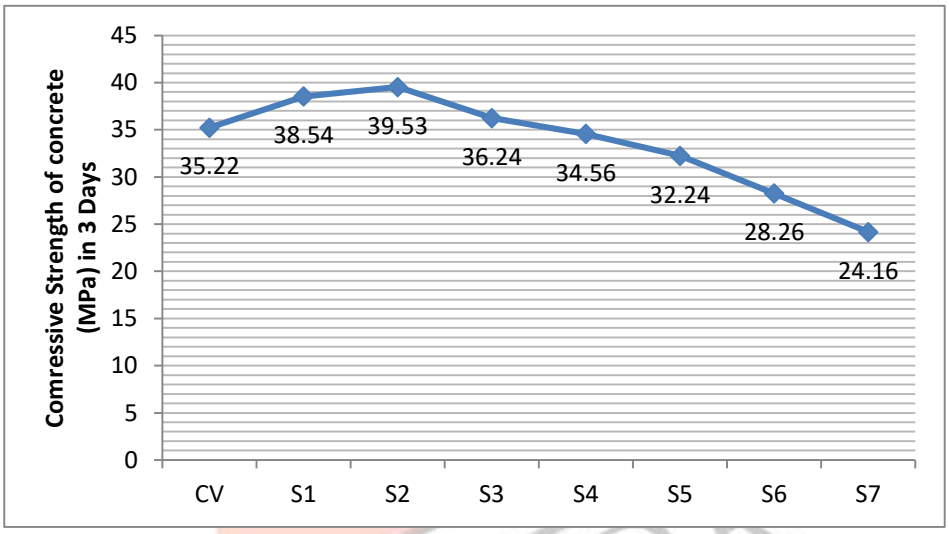


Figure 2: Compressive strength of concrete (MPa) in 3 days.

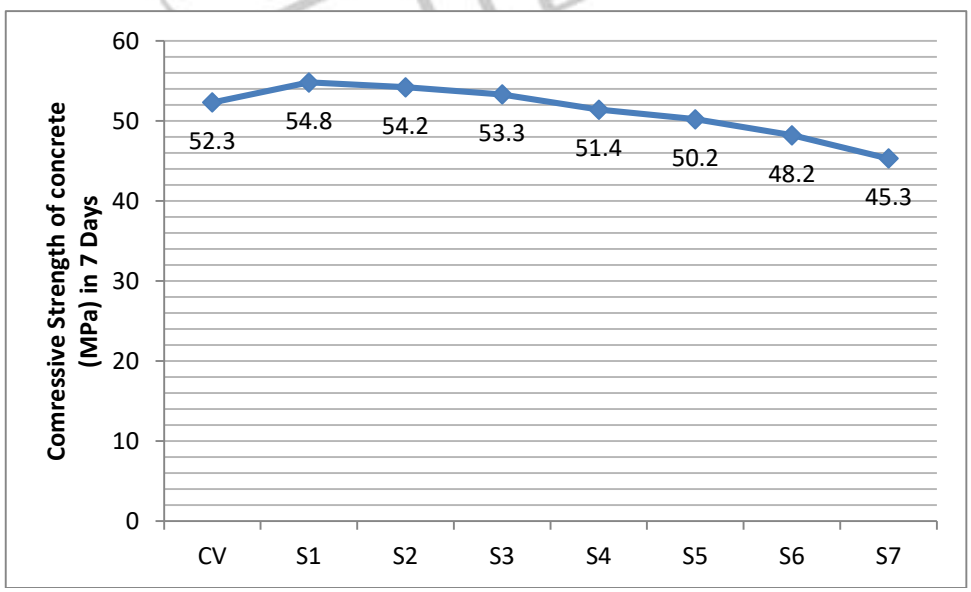


Figure 3: Compressive strength of concrete (MPa) in 7 days.

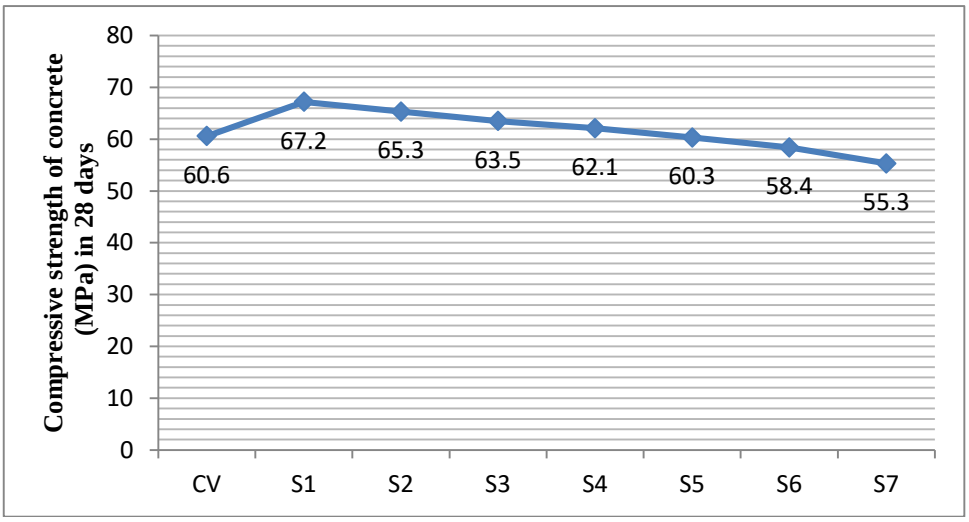


Figure 4: Compressive strength of concrete (MPa) in 28 days.

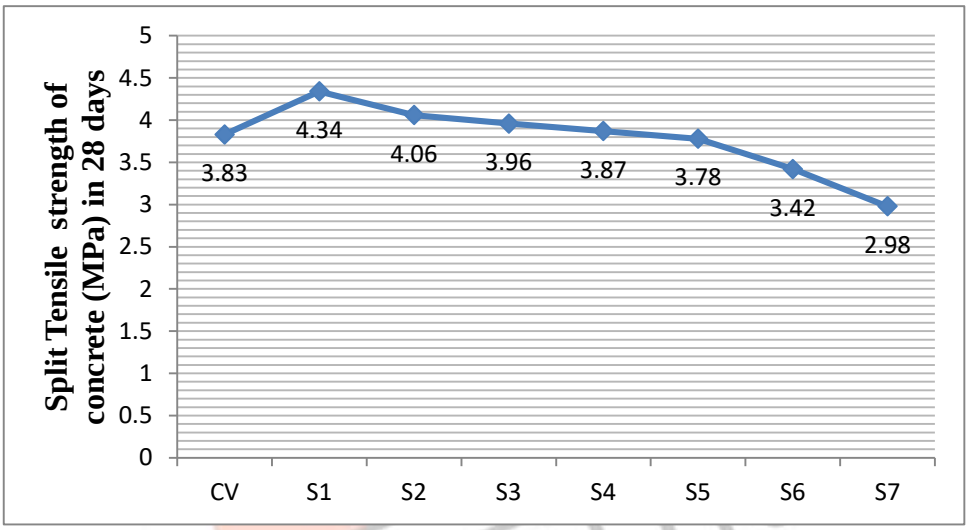


Figure 5: Split Tensile strength of concrete (MPa) in 28 days.

VII. CONCLUSION

The industrial waste material like Silica fume and Hypo sludge are used in high strength performances concrete of M60 grade with the experimental studies conducted on the following conclusions can be drawn:

- In development of high strength concrete, the aggregate of smaller size play very important role. In the present mix design, the aggregate of 20 mm and 10 mm size is being used.
- Cement replacement with Silica fume and Hypo sludge in S4 and S5 i.e., 20% (5% Silica Fume and 15% Hypo Sludge) and 25% (5% Silica Fume and 25% Hypo Sludge) compressive strength is increased in this investigation grade.
- Beyond 30% there is a decrease in compressive strength for 28 days curing have period.
- Cement replacement with Silica fume and Hypo sludge in S4 i.e., 20% (5% Silica Fume and 15% Hypo Sludge) split tensile strength is increased in this investigation grade.
- There is a decrease in any way as the replacement level increases, and hence water Consumption will be more for higher replacements.
- Use of silica fume gives significant result on properties of concrete as compared to conventional concrete.
- Slump value is depended on amount of hypo sludge.

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