FLEXURAL BEHAVIOUR OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH STEATITE POWDER AND PROBIOTIC ADDITION FOR SELF HEALING

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Abstract – *Now a Days usage of concrete is made compulsory from small house to large infrastructure construction due to its properties, availability and economical. But somehow reason, the cracks are forming in initial and final stage of hardening process. These cracks became the root cause to failure of structure, when an improper or excess loading occurs. Hence we made an attempt to form a high density concrete with ultrafine steatite powder to quarantine the formation of crack. Steatite powder is added in concrete by replacing cement in various proportions like 0%, 5%, 10%, 15% and 20% by weight. With the optimum values of steatite powder, we adding a probiotic in different proportions like 20ML, 40ML, 60ML and 80ML made the concrete adopt self-healing property i.e. filling the cracks with calcium carbonate precipitate obtained from the probiotic bacteria. For each proportion, different sets of specimens are laid to test the concrete under compressive, tensile and flexural loading conditions after 7days, 14days and 28 days of curing, as first phase of this project. In the second phase, flexural behavior of concrete is evaluated by laying a reinforced concrete beams containing steatite and flexural concrete and set for curing for 28 days. This study shows the behavior of concrete having steatite powder and probiotic by comparing with the nominal concrete results.*

Key Words: **Steatite Powder, Probiotic, Calcium Carbonate, Flexural Strength, Split tensile strength and Compressive Strength.**

1. INTRODUCTION

Concrete is a heterogeneous mix of cement. Fine aggregate, coarse aggregate and water. Concrete is most widely used construction material in world. The reason behind the enormous use of concrete in the construction sector lies in its versatile, reliable and sustainable nature, because of its strength, rigidity, durability, mould ability, efficiency and economy. To overcome the deficiencies of concrete, fibers are added to enhance the performance of concrete. In this project, cement is replaced by steatite powder in various proportions of 5%, 10%, 15% and 20% to evaluate the strengths of concrete and ability to form a high density concrete. By adding bacillus subtilis as 20ML, 40ML, 60ML and 80ML to fill the crack with calcium carbonate Precipitation

1.1 SELF HEALING CONCRETE

Self-healing is actually an old and well-known phenomenon for concrete as it possesses some natural autogenous healing properties. Due to ongoing hydration of clinker minerals or carbonation of calcium hydroxide ($Ca(OH)_2$), cracks may heal after some time. However, autogenous healing is limited to small cracks and is only effective when water is available, thus making it difficult to control. Nonetheless, concrete may be modified to build in autonomous crack healing

2. MATERIALS USED

It is proposed to test cement concrete in which cement is added by certain percentages of hybrid fibers with carbon and polypropylene fibers. Materials required for this concrete preparation are as follows:

1. Cement
2. Fine aggregate
3. Coarse aggregate
4. Steatite powder
5. Bacillus subtilis
6. Water

2.1 Cement

The purpose of cement in the concrete is to bind the materials added in fresh concrete and hardens which gives strength to the concrete. It is a finely graded powder induces the heat of hydration process when combined with water. This process produces the bogues compounds, which give rise the strength and setting time of the concrete. The cement used in this research is ordinary Portland cement of 53 grade. The physical properties obtained from the investigations are tabulated in Table 1 as per IS 4031.

Table 1: Test results of cement

S.No	Description	Values
1	Specific Gravity	3.06
2	Normal Consistency of the cement	30 %
3	Initial Setting Time	45 min
4	Final Setting Time	540 min
5	Fineness of cement	4 %

2.2 Fine Aggregate

Fine Aggregate will be clean, strong, hard and deleterious substance and free of organic impurities. It can be added with other materials which can be suitable type with strength, density, shrinkage and durability of mortar.it will have high density and good workability and it will work in position without segregation and use of high water content. The properties of the fine aggregate are tabulated in Table 2 as per IS 2386.

Table 2: Test results of Fine Aggregate

S.No	Description	Values
1	Specific Gravity	2.7
2	Grading Zone	II
3	Fineness Modulus	2.6

2.3 Coarse Aggregate

The coarse aggregates are granular materials obtained from rocks and crushed stones and retained on 4.75 mm sieve. The properties of the coarse aggregate are tabulated in Table 3 as per IS 2386.

Table 3: Test results of Coarse Aggregate

S.No	Description	Values
1	Specific Gravity	2.85
2	Aggregate Size	20 mm

2.4 Steatite Powder

The steatite $Mg_3(Si_4O_{10})(OH)_2$, can be completely manufactured from natural raw materials, as the mineral base for its synthesis comprises talc and plastic clays. Steatite is a mineral which forms at the convergent boundaries of the tectonic plates. The density of steatite is very high than marble, slate, limestone and granite. Because of its tiny structure the steatite can make an impermeable concrete and not allow a liquid media permeate through surface. Due to presence of magnesite as a main compound in the steatite made the material heat resistance and an excellent choice for the fire places. It can withstand the heat for longer time even after fire put-offs. Steatite powder is chemically in active in nature so we can use in the chemical laboratories because it does not react with any compound or acids in the laboratory. The specific gravity of steatite powder is 2.72.

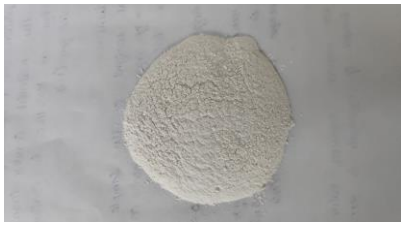


Figure 1: Steatite Powder

2.5 Bacillus Subtilis

It is also formally known as Hay bacillus or grass bacillus, is a Gram-positive, catalane-positive bacterium, found in soil and the gastrointestinal of ruminants and humans. A member of the genus Bacillus, B. subtilis is rod-shaped, and can form a tough, protective endo-spore, allowing it to tolerate extreme environmental conditions. This bacteria is extracted and grown by suppling yeast/food to extract the benefits. Here in this project we use bacillus subtilis and calcium lactate as food to the bacteria. These bacteria excrete calcium carbonate with the Microbial Induced Calcium carbonate Precipitation (MICP) method and fill the cracks fully until we supply the food and water to it.

Figure 2: Bacillus Subtillis

2.6 Water

Potable water, free from organic matter, slit, oil, chloride and acidic material as per Indian Standard was used for the entire concreting. As per IS 456, the pH value of the water mixed in concrete should be present in between 6.5 – 8.5.

3. TEST AND RESULTS

3.1 Hardened Concrete

Concrete is casted into cubes, cylinders and prisms as per IS 516 recommendations and curing should be done for 7days, 14days and 28 days. In each set 9 specimens are made i.e. 3 cubes, 3 cylinder and 3 prisms for each concrete mix of M30 grade concrete added with Steatite powder and Bacillus subtilis bacteria of different proportions. Test performed in this research are:

1. Compression Strength test
2. Split Tensile Test
3. Flexural Strength Test

The results of above test after curing period for 7days, 14days and 28 days are tabulated below

Figure 3: Casting

Figure 4: Specimens after casting

Table 4: Compression Strength of concrete added with Steatite Powder

Mix Proportions	COMPRESSION STRENGTH (N/mm²)		
	7 days	14 days	28 days
100% OPC	25.11	34.15	38.92
95% OPC + 5% SP	25.90	35.20	41.01
90% OPC + 10% SP	27.21	37.46	43.50
85% OPC + 15% SP	29.12	39.01	45.93
80% OPC + 20% SP	26.32	36.33	41.37

Chart 1: Compression Strength of concrete added with Steatite Powder

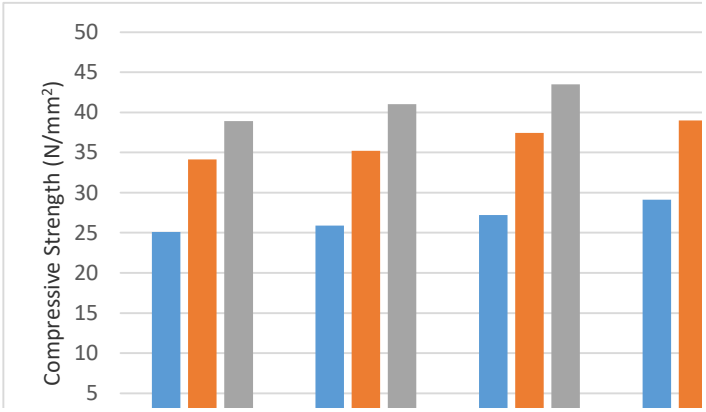


Table 5: Split Tensile Strength of concrete added with Steatite Powder

Mix Proportions	SPLIT TENSILE STRENGTH (N/mm²)		
	7 days	14 days	28 days
100% OPC	1.63	2.76	3.36
95% OPC + 5% SP	1.73	2.9	3.75
90% OPC + 10% SP	1.90	3.18	4.06
85% OPC + 15% SP	2.14	3.37	4.36
80% OPC + 20% SP	1.79s	3.04	3.67

Chart 2: Split Tensile Strength of concrete added with Steatite Powder

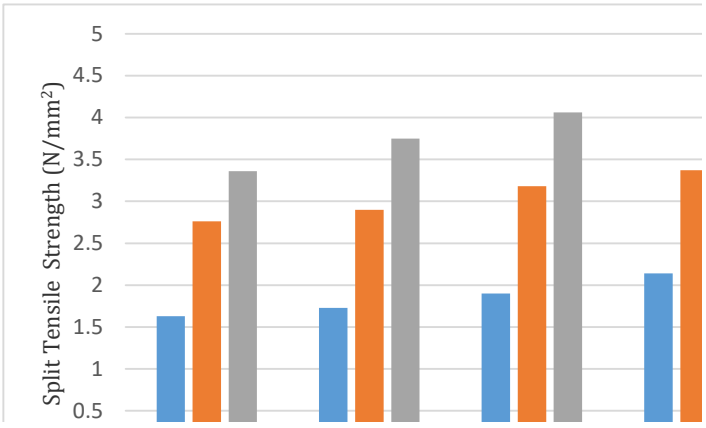


Table 6: Flexural Strength of concrete added with Steatite Powder

Mix Proportions	FLEXURAL STRENGTH (N/mm²)		
	7 days	14 days	28 days
100% OPC	3.00	3.59	3.86
95% OPC + 5% SP	3.06	3.65	4.03
90% OPC + 10% SP	3.15	3.78	4.16
85% OPC + 15% SP	3.27	3.87	4.29
80% OPC + 20% SP	3.09	3.71	4.00

Chart 3: Flexural Strength of concrete added with Steatite Powder

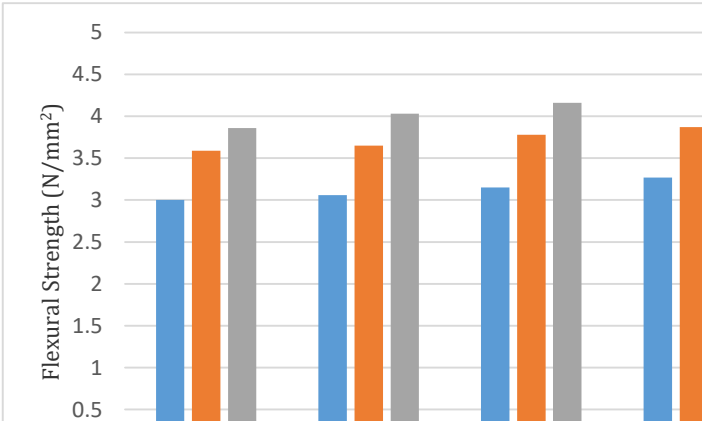


Table 7: Compression Strength of concrete by adding bacillus subtilis bacteria and steatite powder

Mix Proportions	COMPRESSION STRENGTH (N/mm²)		
	7 days	14 days	28 days
15% SP + 0 ML PB	29.12	39.01	45.93
15% SP + 20ML PB	31.09	41.07	47.21
15% SP + 40ML PB	32.92	42.72	49.62
15% SP + 60ML PB	34.71	43.95	50.37
15% SP + 80ML PB	35.07	45.19	51.91

Chart 4: Compression Strength of concrete by adding bacillus subtilis bacteria and steatite powder

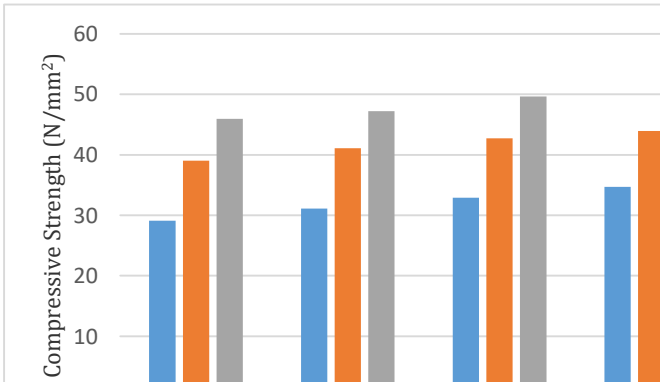


Table 8: Split Tensile Strength of concrete by adding bacillus subtilis bacteria and steatite powder

Mix Proportions	SPLIT TENSILE STRENGTH (N/mm²)		
	7 days	14 days	28 days
15% SP + 0 ML PB	2.14	3.37	4.36
15% SP + 20ML PB	2.63	3.76	4.36
15% SP + 40ML PB	2.73	3.90	4.75
15% SP + 60ML PB	2.90	4.18	5.06
15% SP + 80ML PB	3.14	4.37	5.36

Chart 5: Split Tensile Strength of concrete by adding bacillus subtilis bacteria and steatite powder

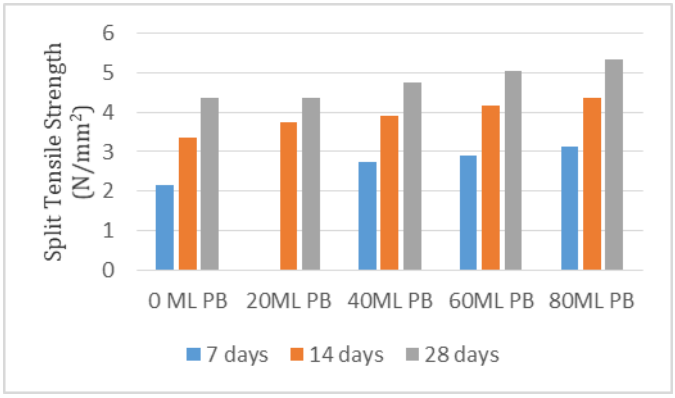
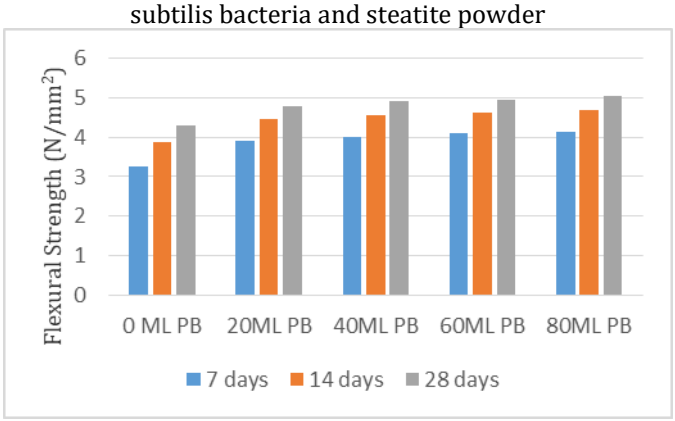


Table 9: Flexural Strength of concrete by adding bacillus subtilis bacteria and steatite powder

Mix Proportions	FLEXURAL STRENGTH (N/mm²)		
	7 days	14 days	28 days
15% SP + 0 ML PB	3.27	3.87	4.29
15% SP + 20ML PB	3.90	4.48	4.80
15% SP + 40ML PB	4.01	4.57	4.93
15% SP + 60ML PB	4.12	4.64	4.96
15% SP + 80ML PB	4.14	4.70	5.04

Chart 6: Flexural Strength of concrete by adding bacillus subtilis bacteria and steatite powder



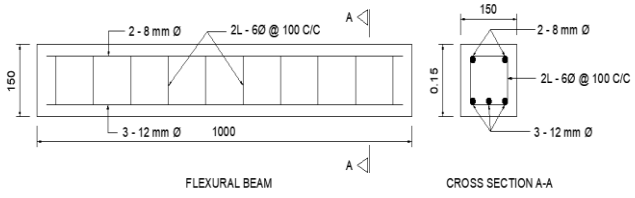


Figure 5: Beam Details

Three beams are casted with optimum values of strength results obtained from above tables and the deflections of each beam are evaluated using the universal testing machine and those values are represented in below tables and charts

Figure 5: Testing of beam

Figure 6: After testing of beam

Table 10: Load Vs Deflection casted With Nominal Concrete

S.No	Load (kgf)	Deflection (mm)	Remarks
1	0	0	
2	5	0.05	
3	10	0.14	
4	15	0.20	
5	20	0.35	
6	25	0.69	
7	30	0.93	
8	31.87	0.94	First crack load
9	35	1.22	
10	40	1.55	
11	45	1.85	
12	50	2.20	
13	55	2.39	
14	60	2.59	
15	61.78	2.63	Ultimate crack load

Chart 7: Load Vs Deflection casted With Nominal Concrete

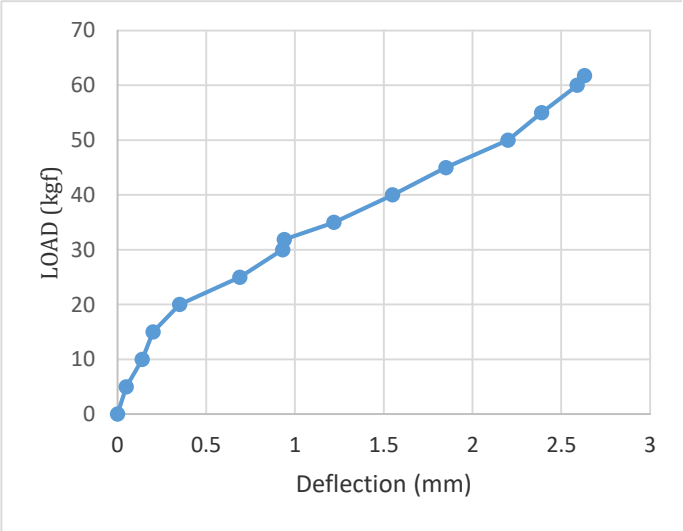


Table 11 Load Vs Beam casted with Steatite based Concrete

S.No	Load (kgf)	Deflection (mm)	Remarks
1	0	0	
2	5	0	
3	10	0.05	
4	15	0.09	
5	20	0.13	
6	25	0.26	
7	30	0.29	
8	35	0.32	
9	40	0.55	
10	45	0.69	
11	50	0.99	
12	51.97	1.02	First crack load
13	55	1.16	
14	60	1.67	
15	65	2.1	
16	70	2.30	
17	75	2.45	
18	80	2.56	
19	85	2.68	
20	90	2.73	
21	90.22	2.82	Ultimate crack load

Chart 11 Load Vs Deflection casted With Steatite based Concrete

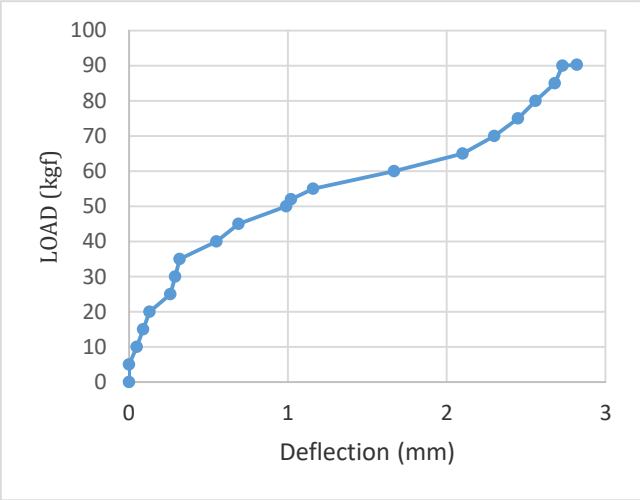


Chart 12 Load Vs Deflection casted With Steatite based Bio-Concrete

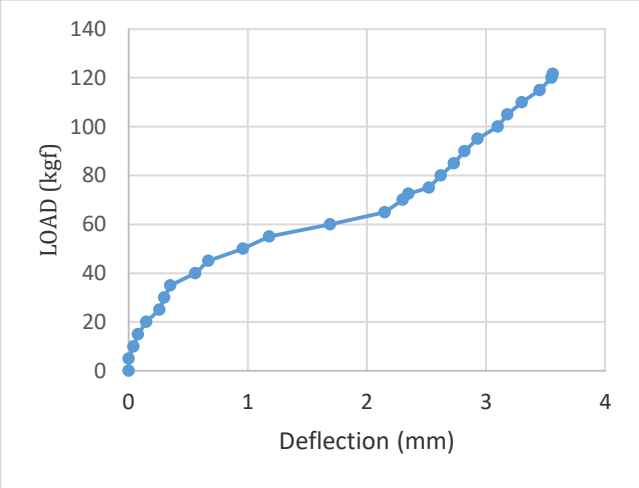


Table 12 Load Vs Beam casted with Steatite based Bio-Concrete

S.No	Load (kgf)	Deflection (mm)	Remarks
1	0	0	
2	5	0	
3	10	0.04	
4	15	0.08	
5	20	0.15	
6	25	0.26	
7	30	0.30	
8	35	0.35	
9	40	0.56	
10	45	0.67	
11	50	0.96	
12	55	1.18	
13	60	1.69	
14	65	2.15	
15	70	2.30	
16	72.56	2.35	First crack load
17	75	2.52	
18	80	2.62	
19	85	2.73	
20	90	2.82	
21	95	2.93	
22	100	3.1	
23	105	3.18	
24	110	3.30	
25	115	3.45	
26	120	3.55	
27	121.60	3.56	Ultimate crack load

As per IS 456, the maximum deflection of the beam should be less than the length of beam/250 i.e., 1000/250 = 4mm.

5. CONCLUSIONS

Based on the experimental investigations carried out in the phase I and phase II, the conclusions obtained on the concrete partially replacing cement with steatite and probiotic bacteria bacillus subtilis addition for self-healing are drawn as following:

- The steatite powder is easily compatible with the cement and can be used as construction material for high density concrete.
- For M30 grade concrete, steatite powder gives the optimum values of strength at 15% replacing of cement by weight is observed and beyond that it shows a fall.
- When compared to nominal concrete, compressive strength increased by 10.48 % for 28 days on the 15% replacement of cement with steatite.
- When compared with nominal concrete, Split tensile strength increased by 14.08 % for 28 days on the 15% replacement of cement with steatite.
- Similarly, when compared with nominal concrete, Flexural strength increased by 6.01 % for 28 days on the 15% replacement of cement with steatite.
- The Strength of the concrete increases with increases amount of bacteria added to concrete with 15% of cement with steatite powder.
- Compressive strength increased by 25.02 % for 28 days on the steatite based concrete with mixing of 80ML of bacteria added.
- Split tensile strength increased by 39.78 % for 28 days on the steatite based concrete with mixing of 80ML of bacteria added.
- Similarly, Split tensile strength increased 23.32 % for 28 days on the steatite based concrete with mixing of 80ML of bacteria added.

- The first crack load resistance of steatite based concrete beam and steatite based bio concrete has increased by 6.06% and 59.56% respectively, when compared to nominal concrete beam.
- The ultimate crack load resistance of steatite based concrete beam and steatite based bio concrete has increased by 8.15% and 27.04% respectively, when compared to nominal concrete beam.
- The deflection of the all the beams casted above is less than the maximum deflection of the beam as per IS 456.

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