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PERMANENCE STUDIES ON CONCRETE BY AGGRANDIZING WITH BIO- CEMENT ON M25 MIX

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ABSTRACT

Today, rate at which cement is utilized is a lot higher than it was fifty years prior. Major problem faced with concrete is the occurrence of micro-cracks, which affects strength and durability concrete. By avoiding micro-fissures at the initial stage of conversion of ettringite into C-S-H gel, leads to impermeable concrete. By adding Bio-cement, as additive to cement, will develop Microbiologically Induced Calcium Precipitate (MICP), fills pores formed in the concrete at the initial age itself. By the combined action of MICP and C-S-H gel, leads to dense concrete, improves solidity and sturdiness of concrete. Bio-cement was combination of Bacillus. Pasteurii (5%) and 95% nutrients (Urea and Calcium lactate). This paper was about Bio-cement as additive taken 0.5%,1%,1.5% and 2% by weight of cement for M25 mix, and concluded that 1% as optimized value after analysing compressive strength , flexural strength results. Durability studies which including Sulphate attack, Acid attack, Sorptivity and RCPT for M25concrete, at optimized 1% addition of Bio-cement. Comparative test results were presented for Weight loss, loss of compressive strength, Sorptivity coefficient and charge passed in Coulombs, to conventional concrete and Bio-concrete analysed after 28, 56 and 90 days of immersion.

Keywords: bio-cement, MICP, durability, sorptivity, RCPT, bacillus, pasteurii.

1. INTRODUCTION

The attractive Engineering attributes of solidified concrete are strength, dimensional stability and sturdiness. These are impacted by the extent, yet in addition by the properties of the concrete. This thus relies upon the micro structural underlying highlights like type, amount and dispersion of solids and voids. Impermeability of solidified concrete is a profoundly valued character since it is expected that an impermeable hydrated cement mortar would bring about an impermeable concrete. Impermeability and water snugness turns in to an essential factor in deciding durability [1].

To make impermeable concrete, Concrete structures are planned with regards to set guidelines that empower fissures make up to 0.2 mm thick. Such little fissures generally considered negligible, it doesn't straight forwardly debilitate concrete construction. Besides, little fissures patch up automatically by various assortments of concrete by an explicit crack-mending ability. Investigation has found that it is basically connected with the amount of non-reacted cement components in the concrete. On crack improvement, water entered and acts with these component leads to major fissures [2].

Wide-going cracks were seen to act naturally mended in traditional concrete, fissures recuperated if it contains microscopic organisms. Key thought of this strategy is to explain about certain classifications of microorganisms (Bacillus.Pasteurii) works to control little cracks inside the concrete prior they create in to greater and promote to oversee fissures. This bio explanation strategy includes numerous parts, to finish these undertakings [2].

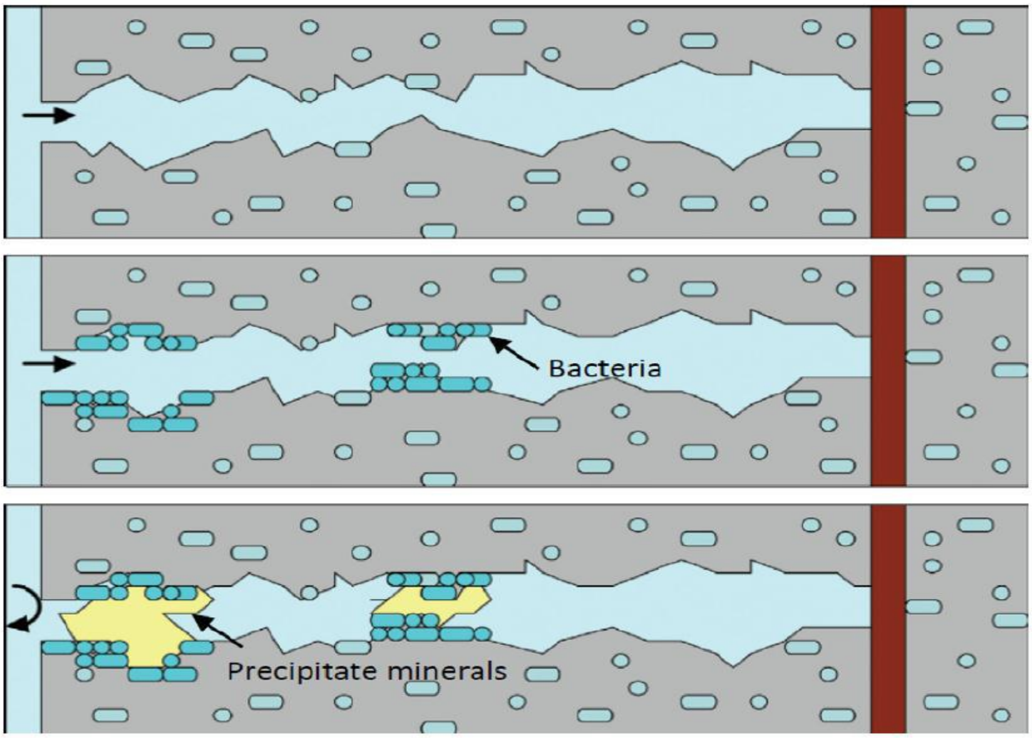

Figure-1. Crack-healing processes through bacteria in concrete.

Water exists in the hydrated cement paste in various states, similar to capillary water, adsorbed water and interlayer water. By the formation Micro biologically induced Calcium precipitate in addition to C-S-H gel will fill the pores formed. Which increase ability of hydrated cement paste to form dense concrete. Since impermeable and dense nature of concrete has good strength, stability and durability. With the addition of Bio- cement in small percentage to cement form MICP at the early age of concrete, which enhances strength by filling voids in concrete. If voids are there in concrete leads to micro cracks upon loading. Micro cracks propagate with time and effects durability and finally life cycle of concrete [3].
Bio-cement which is combination of Bacillus. Pasteurii (5%) and the remaining percentage has filled with (95%) nutrients Urea and Calcium lactate. Bio-cement formation results from MICP and this process known as bio cementation. Bio-cement refers to a $CaCO_3$ deposit formed in the calcium ion-rich system due to micro - organism activity. Bacillus. Pasteurii is the microorganism, which is intensively used, based on its ability to produce Calcium Carbonate formed as bio-mineral. If sufficient Calcium ions present in the nutrient medium Bacillus. Pasteurii also with stand high pH values required to Bio mineralization. [3].

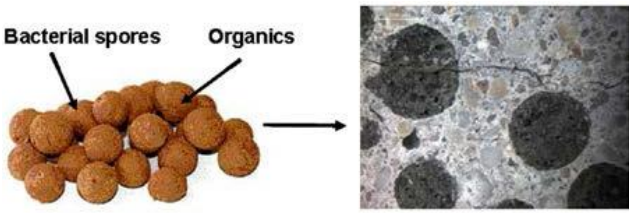

Figure-2. Bacterial spores (left), bacterial spores embedded in concrete mix (right).

Microbial Urease enzyme catalyses the hydrolysis of Urea in to Ammonium and Carbonate. MICP contains a progression of complex bio- compound responses. As a piece of digestion a few microscopic organisms species produce Urease, which catalyses Urea to create CO_2 and Ammonia, coming about expansion in the encompassing where particles ca^{+2} and co_3^{-2} accelerates as $CaCO_3$, at the cell surface that gives a nucleation site summed up as follows [3].

$$Ca^{+2} + Cell \rightarrow Cell - Ca^{+2} \quad - (1)$$

$$Cl^- + HCO_3^- + NH_3 \rightarrow NH_4Cl + CO_3^{-2} \quad - (2)$$

$$Cell\text{-}Ca^{+2} + CO_3^{-2} \rightarrow Cell\text{-}CaCO_3 \quad - (3)$$

As a microbial sealant, $CaCO_3$ displayed its positive potential to specifically solidify simulated fractures and surface crevices. By the development of MICP, gel pores framed during the time spent change of ettringite to C-S-H gel were filled with MICP. Because of the decrease of volume of enormous hair like voids in the

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paste network will lessen the porousness. This will be conceivable by the effective blend of MICP and C-S-H gel. With the progressive loss of free water from concrete, because of the development of hydration products, surface adsorption of somewhat crystalline products, ettringite to MICP, C-S-H gel, causes the paste to harden and finally to shape dense concrete, which have magnificent strength and solidness.

In this paper, the Bio- cement is utilized as added substance 0.5% to 2% and, optimized to 1% by noticing after effects of compressive strength and flexural strength. At stream lined addition of Bio-cement considered weight reduction, loss of compressive strength determined in Sulphate attack and Acid attack tests. The nature of concrete was observed by Sorptivity and Rapid chloride permeability tests, by contrasting estimations of sorptivity coefficient and Charge passed in Coulombs at enhanced 1% addition of Bio-cement. Every one of these outcomes are contrasted with conventional concrete [4, 5].

2. MATERIALS AND TESTING STRATEGIES

2.1 Cement

OPC of 53 grade utilized in exploratory work. As per IS 4031-199 6 [13] guidelines, test results considered were appeared in Table-1. From the underneath Table properties of cement decided such as fineness, specific gravity, normal consistency, initial and final setting time and compressive strength of cement by adding 1% Bio-cement.

Table-1. Cement possessions.

Property	Fineness	Specific gravity	Normal consistency	Initial setting time	Final setting time	Specific gravity	Compressive strength
Test value	7%	3.15	31%	53 min	245 min	3.15	MPa

2.2 Fine Aggregate

The local accessible river sand from River Krishna is utilized for the trial examination affirming to IS-383:1970 [14]. The acquired values of the sand are as appeared in Table-2 underneath:

Table-2. Fine aggregate possessions.

Property	Specific gravity	Water absorption	Fineness modulus
Test value	2.6	1.65%	2.5

2.3 Coarse Aggregate

In order to withstand the design loads and impacts of weathering, aggregates should be superior than the solidified cement confirming to IS-383:1970 [14]. The values of the aggregates were arranged in Table-3 beneath.

Table-3. Coarse aggregate possessions.

Property	Specific gravity	Water absorption	Bulk density	AIV	ACV
Test value	2.7	1.4%	1490 kg/m^3	19.1%	10.23%

2.4 Water

Locally accessible, consumable drinking water utilized in the experimental work for all blends.

2.5 Bio-Cement

In this examination, Bacillus. Pasteurii microscopic organisms utilized which is refined and nutrients are blended in extent of 5% and 95% at DVS Bio life Pvt. Ltd. Research facility, Hyderabad, India.

2.6 Compressive Strength Test

Compressive strength test on concrete cubes of size150mm x150mmx 150 mm according to IS: 516-1959 specifications [15]. Cubes prepared, cured and tried after 7 and 28 days according to IS: 456-2000 [17] guidelines. The test information was presented in Table-4.

Table-4. Outcomes of compressive strength test – Mpa.

Curing Time	Conventional concrete	Bio - concrete			
		0.5%	1%	1.5%	2%
7 days	21.66	23.85	25.81	23.68	21.28
28 days	30.96	33.91	35.71	33.34	30.43

2.7 Flexural Strength Test

Flexural strength test on concrete prisms of size 100mm x100mmx 500 mm as per IS: 516-1959 specifications [15]. Prisms tested after 7 and 28 days of curing as per IS: 456-2000 [17] standards. The test data was presented in Table-5 below.

Table-5. Outcomes of flexural strength test - Mpa.

Curing Time	Conventional concrete	Bio – concrete			
		0.5%	1%	1.5%	2%
7 days	2.86	3.28	3.69	3.18	2.61
28 days	4.13	4.77	5.42	4.68	4.02

2.8 Sulphate Attack Test

Sulphate attack test was carried out on cubes of size 150x 150 x 150mm. Compressive strength of cubes estimated after 28 days curing in water, and then 28, 56 and 90 days of immersion in 5% H_2SO_4 solution according to ASTM C1012-09 [7, 18]. Results of weight reduction, loss in compressive strength were appeared in Table-6 beneath.

Table-6. Outcomes of sulphate attack test.

MIX	% of Bio- cement	No of days of immersion	Weight loss in %	Loss of compressive strength in %
M25	0%	28	0.42	0.0125
	1%		0.173	0.012
	0%	56	1.681	4.12
	1%		0.924	2.15
	0%	90	3.57	13.68
	1%		2.461	5.93

2.9 Acid Attack Test

Acid attack test was carried out on 150 x 150 x 150mm cubes. Weight loss was calculated as distinction between initial weight and final weight, before and after immersion in solution. Compressive strength of specimens was measured after 28 days of water curing, and then 28, 56 and 90 days of submersion in 5% HCl solution as per ASTM C1012-09 [7, 18]. Outcomes of reduction in weight, change in compressive strength were appeared in Table-7 below.

Table-7. Results of acid attack test.

MIX	% of Bio- cement	No of days of immersion	Weight loss in %	Loss of compressive strength in %
M25	0%	28	0.38	0.0118
	1%		0.153	0.0104
	0%	56	1.52	5.45
	1%		0.832	1.98
	0%	90	3.31	11.76
	1%		2.238	3.87

2.10 Sorptivity Test

For sorptivity test three prisms of size 50mm heightx100mm diameter for each blend were cast. Prisms were in water curing, and tested after 28, 56 and 90 days of curing. All the prisms are tested after drying the surface of the specimen. This test was conducted for conventional concrete and Bio- concrete with1% Bio-cement has added as added substance. Prisms at testing were shown in Figure-3. Results of water ingestion at cumulative time spans are shown in Table-8, Table-9, Table-10 and Table-11 underneath.

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Figure-3. Sorptivity test specimens.

Table-8. Cumulative percentage of water Absorption in % wt. at 28 days.

Mix	% of Bio-cement	Time in minutes						
		5	10	20	30	60	120	180
M25	0%	0.98	0.983	0.985	0.988	0.993	0.993	0.993
	1%	0.94	0.943	0.946	0..956	0.956	0.956	0.956

Table-9. Cumulative percentage of water Absorption in % wt. at 56 days.

Mix	% of Bio-cement	Time in minutes						
		5	10	20	30	60	120	180
M25	0%	0.933	0.937	0.940	0.943	0.957	0.959	0.959
	1%	0.930	0.933	0.935	0.937	0.940	0.943	0.943

Table-10. Cumulative percentage of water Absorption in % wt. at 90 days.

Mix	% of Bio-cement	Time in minutes						
		5	10	20	30	60	120	180
M25	0%	0.925	0.929	0.931	0.94	0.948	0.95	0.95
	1%	0.915	0.922	0.93	0..934	0.937	0.937	0.937

Table-11. Results of Sorptivity test for conventional and Bio concrete.

Mix	No of days of curing	Conventional concrete			1% Bio-cement		
		Dry density Kg/mt^3	Wet density Kg/mt^3	Sorptivity coefficient	Dry density Kg/mt^3	Wet density Kg/mt^3	Sorptivity coefficient
M25	28	0.96	0.993	0.0313	0.928	0.956	0.0265
	56	0.92	0.959	0.0371	0.9125	0.943	0.0289
	90	0.908	0.95	0.0398	0.906	0.937	0.0294

2.11 Rapid Chloride Permeability Test

For test three prisms of size 50mm height x100mm diameter for each blend were cast. Prisms were in water curing, and tested after 28, 56 and 90 days of curing. This test was conducted for conventional concrete and Bio- concrete with 1% Bio-cement has added as additive. The advanced LED Display shows the voltage accessible across the concrete specimen under test. The current readings are noted down automatically by the microcontroller. Test procedure according to ASTM C-

1202 [4, 20] appeared in Figure-4 underneath. Test outcomes charge passed in Coulombs, Recommendations were appeared in Table-12, Table-13 below.

Figure-4. RCPT test.

Table-12. RCPT Results of M25 mix specimens in mA.

Initial time	Final Time	Time difference (Min)	Time duration (Min)	28 days		56 days		90 days	
				0%	1%	0%	1%	0%	1%
2.41pm	2.41pm	0	0	100.8	89.5	94.6	82.3	91.2	80.2
2.41 pm	3.11 pm	30	30	119.5	101.9	111.4	95.6	108.3	92.5
3.11 pm	3.41 pm	30	60	130.4	109.1	122.2	105.6	118.6	102.4
3.41 pm	4.11 pm	30	90	139.9	115.8	131.5	113.7	128.5	108.2
4.11 pm	4.41 pm	30	120	147.8	121.5	139.7	119.4	134.2	115.3
4.41 pm	5.11 pm	30	150	154.3	126.4	147.3	123.6	145.7	121.5
5.11 pm	5.41 pm	30	180	158.0	129.2	152.5	125.2	148.2	122.9
5.41 pm	6.11 pm	30	210	162.5	131.8	158.5	129.8	153.6	124.2
6.11 pm	6.41 pm	30	240	165.2	134.2	163.2	133.2	158.4	129.6
6.41 pm	7.11 pm	30	270	169.6	137.3	166.6	135.4	161.7	132.4
7.11 pm	7.41 pm	30	300	171.3	138.2	168.3	136.8	163.8	134.2
7.41 pm	8.11 pm	30	330	173.7	139.1	169.7	138.2	164.7	135.1
8.11 pm	8.41 pm	30	360	175.0	140.6	170.3	139.6	165.1	135.8
				3294180	2699190	3174030	2641410	3084930	2570040
Charge Passed coulombs				3294.18	2699.19	3174.03	2641.41	3084.93	2570.04

Table-13. Recommendations of tested samples as per ASTM 1202.

MIX	No of days	% of Bio-cement	Charge passed in Coulombs	Recommendations
M25	28	0%	3294.18	Moderate
		1%	2699.19	Moderate
	56	0%	3174.03	Moderate
		1%	2641.41	Moderate
	90	0%	3084.93	Moderate
		1%	2570.04	Moderate

3. DISCUSSIONS OF TEST OUTCOMES

3.1 Outcomes of Bio-cement on Compressive and Flexural Strength

Experimental investigations shown in Table-4 and Table-5 the compressive and flexural strength esteems increments with rate increment in Bio- cement an incentive up to 1% by weight of cement. After 1% strength esteems diminishes. Fall in compressive strength with increment in Bio- cement concentration was because of overabundance arrangement of MICP and with increment in Nitrogen content in concrete, disturbs bonding and formation of C-S-H gel.

Percent expansion in compressive strength for Bio-cement when contrasted with conventional concrete for 0.5%, 1% and 1.5% was 9.52%, 15.34% &7.68% following 28 days of curing. After 2% addition of Bio-cement Compressive strength diminishes quickly to bring down than conventional concrete. Similarly, the percent increase in flexural strength for Bio-cement when compared to conventional concrete for 0.5%, 1% and 1.5% was 14.06%, 15.17% & 14.03% following 28 days of curing. After 2% addition of Bio-cement flexural strength likewise diminishes quickly to bring down an incentive than conventional concrete. From the above outcomes it was seen that the expansion in compressive strength at 1% of Bio- cement addition is higher than the compressive strength of conventional concrete, and then decreases because of contribution of MICP in concrete.

3.2 Effect of Bio-Cement on Sulphate and Acid Attack

Test results on the outcome of microorganisms arrangement on loss of compressive strength was appeared in

Table-6 and Table-7 for conventional and 1% Bio-cement blends of M25 grade concrete. From these results, it came to notice that the strength of 1% Bio-cement is higher in correlation with all ages of conventional mixes, as a result of Impermeability of Bio-concrete due to the formation of MICP in pores, assists in accomplishing more strength than conventional concrete mixes.

Percentage decline in loss of compressive strength in Sulphate attack for Bio-cement when compared to conventional concrete 4, 47.81and 56.65 % respectively after 28 ,56 and 90days of immersion, which is very excellent when assess to control mix concrete. Similarly, the percentage decline in compressive strength in Acid attack for Bio-cement when compared to conventional concrete 1.86, 63.66 and 67.09% respectively after 28.56 and 90 days of inundation. From the above it was perceive that the reduction in loss of compressive strength at 90 days is higher than the compressive strength at 28 days because of contribution of Bacillus.Pasteurii bacteria along with calcium lactate and Ammonia for conventional concrete mixes and Bio-cement concrete mixes.

3.3 Variation of Sorptivity Coefficient with Bio-Cement

The results of Sorptivity coefficient variation on conversional concrete and Bio-concrete was shown in Table-11. The decrease in Sorptivity coefficient value of Bio- concrete ,comparison with conventional concrete at 28, 56 and 90 days are 15.33, 22.1and 26.13 %.This is because of filling of pores formed by capillary water, adsorbed water, and interlayer waters with MICP. As concrete becomes impermeable, water absorption characteristics will decreases. Which was observed in outcomes of Sorptivity test.

3.4 Changes in RCPT Value due to Bio-Cement

Test results of Charge passed in Coulombs in conventional concrete and Bio-cement concrete were shown in Table-13.

Decrease in Charge passed value of Bio-concrete, compared to conventional concrete at 28, 56 and 90 days are 18.06, 16.78 and 16.69 %. Which happens because of decrease in pore size, then only chloride permeability value falls down in Bio-cement concrete compared to conventional concrete .It obviously shows as porosity diminishes, pickup in strength and micro fissures also healed due to MICP development.

3.5 Connection between Flexural Strength and Compressive Strength for Concrete Blends

The empirical connection proposed beneath.

Flexural strength = 0.152 f_{ck} for Bio- concrete

= 0.135 f_{ck} for conventional concrete

f_{ck} = Compressive strength of concrete

4. CONCLUSIONS

a) Strength of Bio-cement concrete indicates higher values than conventional concrete at all ages up to 1.5% addition of Bio-cement and then diminishes, with extreme increase in value at 1% addition of Bio-cement.

b) In Bio-cement concrete with Bacillus.Pasteurii, the compressive strength and flexural strength esteems are improving with enhance in Bio-cement up to 1%, after this dosage the outcomes are not ideal because of the way that expansion in Nitrogen content affects hydration cycle and development of C-S-H gel.

c) Sulphate and acid attack analysis revealed that the MICP development in all Bio-cement concrete mixes which is helpful to fill the pores, which reflects in deficiency of weight and loss of compressive strength esteems.

d) The Sorptivity test shows the water absorption capacity diminished in Bio- cement concrete, shows Bio concrete becomes impermeable straight forwardly influences strength of concrete.

e) The RCPT test represents Bio- cement concrete gets dense than conventional concrete, represented as fall in charge passed value, Chloride ion permeability values for Bio-cement concrete.

Affirmations

The Research Work has been completed using the computational laboratory set up at KITS, Guntur, AP, India.

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