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Research Paper

An Experimental Study on Real Time Behaviour of Microbial & Sustainable Self Repairing Concrete (SRC)

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ABSTRACT: *One of the most popular building materials is concrete, yet it is not without flawsthat it is subjected to cracking during various external and internal actions. As a result, Micro – Crack in concrete occurs, which leads to a significant reduction in concrete service life, time consuming, and high repairing cost. Therefore, the objective of this work has been intact by means of Self Repairing Concrete (SRC). This overcomes the problem by repairing Micro – Cracks on the concrete surface by itself, the Self Repairing Concrete (SRC) is a Microbial Organism (Bacillus Subtilis) which is in liquid form and is mixed with nominal concrete with different percentages having 2%, 5%, 10%, 12%, 15%, 20% of Micro Organism out of these percentages 10% has given the optimum level of Micro Organism which gives Autonomous Crack Repairing i.e., the crack got repaired in 3 Days to 4 Days. The Self Repairing Concrete (SRC) is eco–friendly, sustainable, durable, and reduces cracks by reacting with constituents of concrete.*

KEYWORDS: *Microbial Organism, Sustainability, Macrobiotic, Bacillus Subtilis, AutonomousCrack Repairing, Impermeable nature of concrete, Durability.*

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I. INTRODUCTION

Self-repairing concrete (SRC) represents one of the most significant advances in concrete technology where the cracks produced on the structure are repaired by itself. In various reviews lot of investigation has been done on repairing agents, Micro Cracks are inherently present in concrete. This causes the degradation of concrete leading to the ingress of deleterious substances into concrete, resulting in the deterioration of substances. To surmount these situations self-repairing techniques are adopted. The addition of urease-engendering bacteria along with calcium source results in calcite precipitation in concrete. The urease bacteria which include Pasterurii can engender with the calcium source to seal the freshly composed micro cracks. From the various urease bacteria, we have come out with a natural Microbial Organism (Bacillus Subtilis) in liquid form into the nominal concrete with different percentages having 2%, 5%,10%, 15%, 20% of Micro Organism out of percentages 10% has given the optimum level of Micro Organism which gives Autonomous Crack Repairing i.e., the crack got repaired in 3 Days to 4 Days. When the Microbial Organism in the construction reacts with atmospheric agents it produces Lime Sediment and repairs all the cracks in the structure without any external activities. The Self Repairing Concrete (SRC) is eco–friendly, sustainable, durable and reduces the cracks by reacting with constituents of concrete

ADVANTAGES OF SELF REPAIRING CONCRETE (SRC):

It has proved beneficial economically because of several factors as noted below:

- Maintenance cost is reduced
- Reduction in site manpower
- Improves durability
- The Concrete is Eco – Friendly
- The life span of the structure is increased
- Repairs the internal and external cracks that were produced in the concrete structure

MICROBIAL ORGANISM:

BACILLUS SUBTILIS: Bacillus Subtilis is a natural Microbial Organism mixed in concrete that produces Calcium Carbonate (Lime Sediment) when exposed to atmospheric agents like Air, Water, etc., Bacillus Subtilis is a rod-shaped cureolytic type bacterium. The microorganism can be mixed in nominal concrete in the number of percentages2%, 5%, 10%, 12%, 15%, and 20%. From the physical work, we have learned that 10% of microorganisms is the optimum level.

II. MIX DESIGN

Mix design is a selection of the proportion of materials that need to be used to get a fresh, hardened state of concrete depending upon the soil parameters, and climatic conditions of the area. For normal regions with an average temperature of +/- 27 degrees Celsius. M25 grade of concrete with mix proportion of 1:1:2 with 20mm coarse aggregate, zone II river sand which has passed from Indian standard sieve 2.36mm and ordinary Portland cement of 53grade and a water cement ratio ranging from 0.4 - 0.55.

Table 2.1. Mix Design for M25 grade Concrete

S No	Materials	Proportion	Properties
1	Cement	1	Ordinary Portland cement (OPC) 53 grade
2	Fine Aggregate	1	Zone II River Sand 2.36mm IS Sieve
3	Coarse Aggregate	2	20mm Size Aggregate
4	Microbial Organism	2%,5%,10%,15%,20%	Bacillus Subtilis

III. RESULTS AND DISCUSSION

3.1. COMPRESSIVE STRENGTH:

Table 3.1.1. Average Compression Strength of Specimens at age of 7, 14 & 28 days of the curing period

S No	Percentage of Micro Organism	Compression Strength in MPa			Average Compression Strength in MPa		
		7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
1	0%	17.6	22.8	26.5	17.4	22.8	26.3
		16.8	23.1	25.6			
		17.9	22.5	26.8			
2	2%	24.4	29.5	32.8	24.1	28.8	32.2
		23.8	28.1	32.2			
		24.2	28.9	31.8			
3	5%	25.6	29.8	34.9	25.1	29.3	34.7
		24.7	28.9	35.3			
		25.2	29.3	34.1			
4	10%	29.6	30.2	34.1	29.3	30.5	33.8
		27.9	29.1	33.5			
		30.44	32.2	33.9			
5	15%	26.3	28.7	33.4	25.8	28.7	33.9
		25.4	29.3	34.3			
		25.8	28.1	34.1			
6	20%	25.7	29.6	33.3	25.2	29.2	32.8
		24.8	28.7	32.9			
		25.3	29.4	32.4			

The table represents the average Compressive Strength of the specimens in (MPa) for the specimens that were kept in the curing tank for the duration of 7 days, 14 days, and 28 days and observed that the strength of the specimens after the addition of Micro Organism is same as the target strength.

3.2.1. COMPRESSION STRENGTH 7 DAYS OF CURING PERIOD

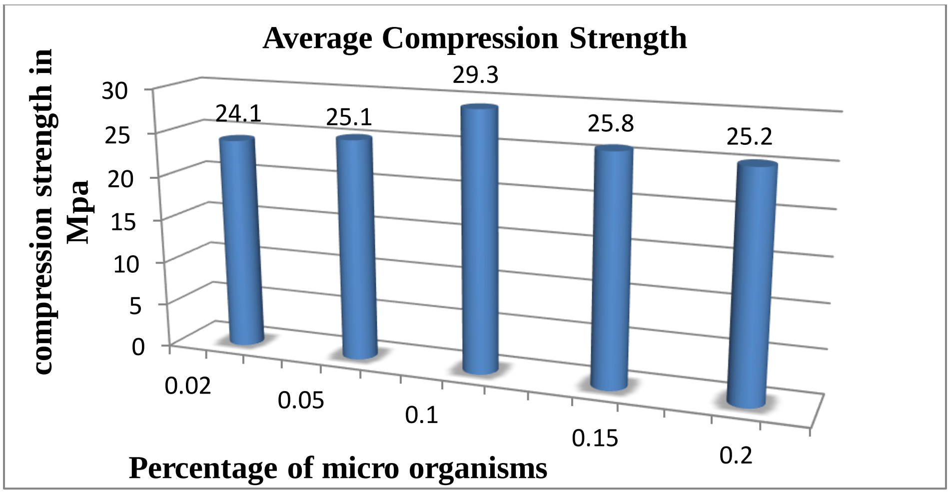


Fig 3.2.1. Average Compression Strength of Specimens for 7 days of Curing Period

The Graphical representation of the average Compressive Strength of the Microbial Organism used specimens in (MPa) which were kept in the curing tank for 7 days. The amount of micro-organisms used has been represented in the X-axis and the average compression strength of the specimens was represented in the Y-axis. It is observed that the Microbial Organism used in the specimen did not affect the compression strength of the specimens. By this, we understand that the compression strength of concrete is not reduced by using microorganisms. We cast the M25 grade of concrete for this grade of concrete the target strength is 31.6Mpa. The target strength is attained after the curing for 7 days.

3.2.2. COMPRESSION STRENGTH 14 DAYS OF CURING PERIOD

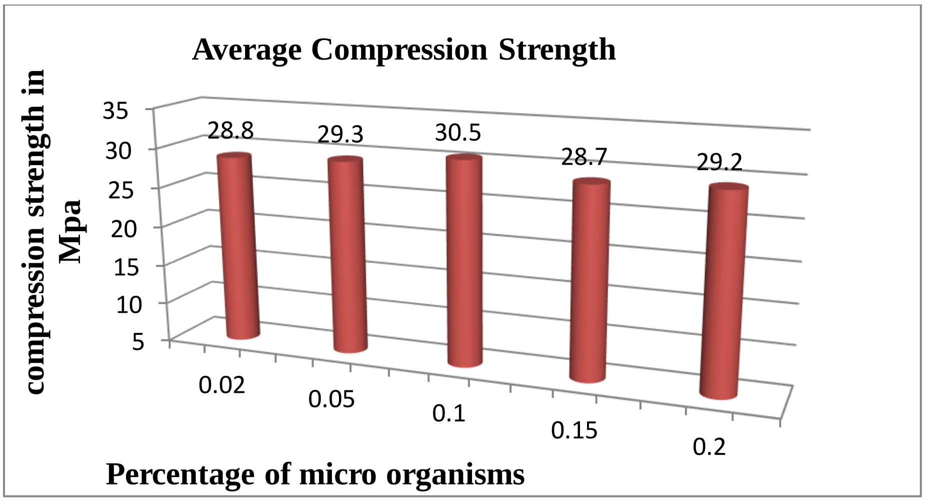


Fig 3.2.2. Average Compression Strength of Specimens for 14 days of Curing Period

The Graphical representation of the average Compressive Strength of the Microbial Organism used specimens in (MPa) which were kept in the curing tank for 14 days. The amount of micro-organisms used has been represented in the X-axis and the average compression strength of the specimens was represented in the Y-axis. It is observed that the Microbial Organism used in the specimen did not affect the compression strength of the specimens. By this, we understand that the compression strength of concrete is not reduced by using microorganisms. We cast the M25 grade of concrete for this grade of concrete the target strength is 31.6Mpa. The target strength is attained after the curing for 14 days.

3.2.3. COMPRESSION STRENGTH 28 DAYS OF CURING PERIOD

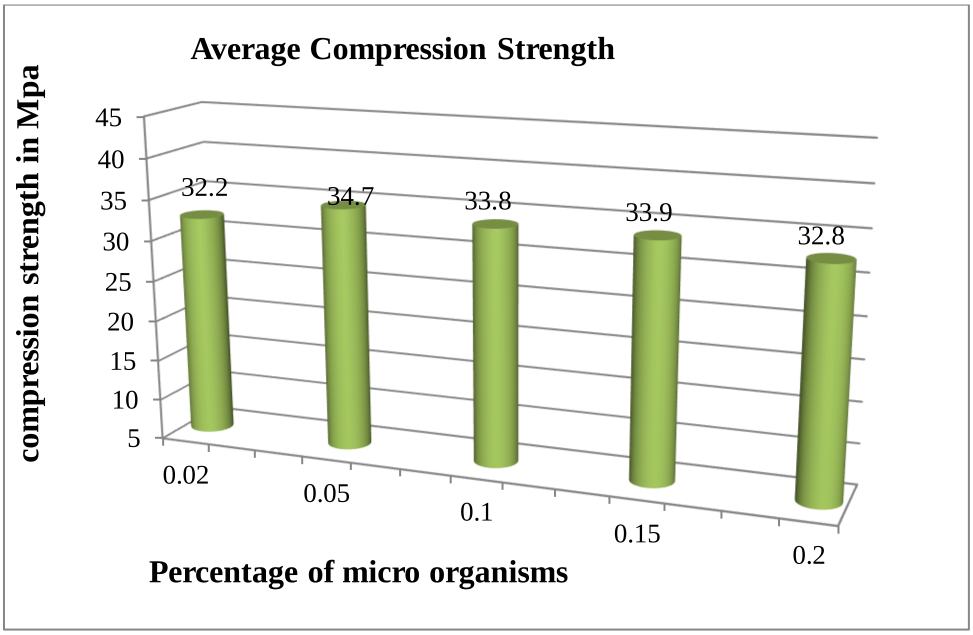


Fig 3.2.3. Average Compression Strength of Specimens for 28 days of Curing Period

The Graphical representation of the average Compressive Strength of the Microbial Organism used specimens in (MPa) which were kept in the curing tank for 28 days. The amount of micro-organisms used has been represented in the X-axis and the average compression strength of the specimens was represented in the Y-axis. It is observed that the Microbial Organism used in the specimen did not affect the compression strength of the specimens. By this, we understand that the compression strength of concrete is not reduced by using microorganisms. We cast the M25 grade of concrete for this grade of concrete the target strength is 31.6Mpa. The target strength is attained after the curing for 28 days.

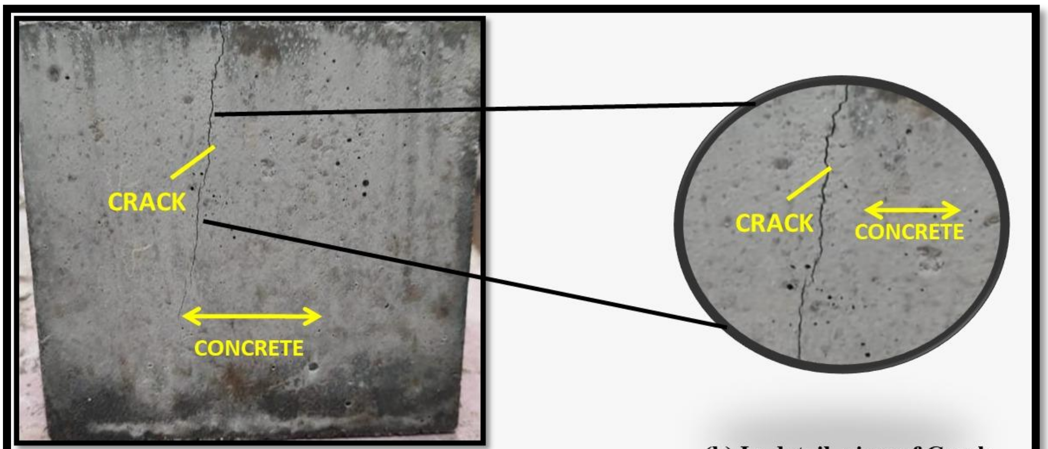
3.3. OBSERVATION OF CRACK REPAIRDNESS:

Two cross sections of the specimens namely "CUBES**"** and **"**CYLINDERS" were casted after the curing period for 7 days, 14 days, 28 days cracks were initiated to the specimens and measured by using a universal portable crack measuring device named **"**Crack Measuring Card" (CMC), the measurement of the cracks obtained for CUBES at a percentage of 2%, 5%, 10%, 15%, 20% are 1mm, 0.8mm, 1mm, 1.3mm,1.1mm, the measurement of cracks obtained for CYLINDERS are 1.5mm 2mm 2.2mm 2.1mm 1.7mm, these specimen were kept in curing tank for the repairing process, for every 2 hours of interval crack investigation was done, for every 2 days interval the propagation of the crack mentioned in the table by using a universal portable crack measuring device named **"**Crack Measuring Card" (CMC), it was found that the optimum rate of repairing of the crack was obtained at 10% Micro Organism, at 10% Micro Organism the crack propagated was 1.6mm for cubes and 2.2mm for cylinders, the cracks has been repaired in a period of less than 4 days.

Table 3.3.1. Observation of Repairdness of cracks in Cubes and Cylinders

Specimen Type	Percentage Of Micro Organisms	Curing Period	Propagation Of Crack (mm)	Reparing Process of the crack (mm)													
				2 Days	4Days	6Days	8 Days	10Days	12 Days	14Days	16Days	18Days	20Days	22Days	24Days	26Days	28Days
Cubes	2%	7Days	1.1	0.1	0.15	0.2	0.3	0.3	0.3	0.4	0.5	0.6	0.7	0.75	0.75	0.8	0.8
		14Days	1.3	0.1	0.2	0.25	0.3	0.3	0.4	0.4	0.45	0.6	0.65	0.65	0.7	0.7	0.8
		28Days	1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7
	5%	7Days	1	0.1	0.25	0.35	0.4	0.6	0.7	0.8	1	–	–	–	–	–	–
		14Days	0.9	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	–	–	–	–	–	–
		28Days	0.8	0.1	0.1	0.2	0.3	0.4	0.65	0.75	0.8	–	–	–	–	–	–
	10%	7Days	1.4	0.9	1.4	–	–	–	–	–	–	–	–	–	–	–	–
		14Days	1.5	1	1.5	–	–	–	–	–	–	–	–	–	–	–	–
		28Days	1.6	1	1.6	–	–	–	–	–	–	–	–	–	–	–	–
	15%	7Days	1.1	0.3	0.4	0.6	0.8	1	1.1	–	–	–	–	–	–	–	–
		14Days	1.4	0.4	0.6	0.8	1	1.2	1.4	–	–	–	–	–	–	–	–
		28Days	1.3	0.5	0.8	1.1	1.2	1.3	–	–	–	–	–	–	–	–	–
	20%	7Days	1.2	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	0.7	0.8	0.85
		14Days	1.3	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.8	0.9
		28Days	1.1	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.5	0.65	0.7	0.75	0.8	0.9
Cylinder	2%	7Days	1.6	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2	1.3
		14Days	2	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2	1.4
		28Days	1.5	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.9	1	1.3
	5%	7Days	1.9	0.2	0.6	0.9	1.2	1.4	1.7	1.9	–	–	–	–	–	–	–
		14Days	2.1	0.3	0.5	0.8	1.3	1.5	1.8	2.1	–	–	–	–	–	–	–
		28Days	2	0.3	0.5	0.9	1.1	1.6	1.65	1.8	–	–	–	–	–	–	–
	10%	7Days	2.1	1.1	2.1	–	–	–	–	–	–	–	–	–	–	–	–
		14Days	2	1	2	–	–	–	–	–	–	–	–	–	–	–	–
		28Days	2.2	1.3	2.2	–	–	–	–	–	–	–	–	–	–	–	–
	15%	7Days	2	0.5	0.6	0.8	1.2	1.8	2	–	–	–	–	–	–	–	–
		14Days	1.8	0.3	0.5	0.8	1.2	1.5	1.8	–	–	–	–	–	–	–	–
		28Days	2.1	0.7	0.9	1.4	1.7	2	2.1	–	–	–	–	–	–	–	–
	20%	7Days	1.9	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1	1.2	1.4	1.5
		14Days	2	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	1	1.2	1.3	1.4	1.5	1.6
		28Days	1.7	0.2	0.3	0.5	0.6	0.7	0.8	0.9	0.9	1	1.2	1.3	1.4	1.5	1.5

3.4. Observation of cracks in cubes



(a) Before Repairing of Crack

(b) In detail view of Crack

Fig 3.4.1. (a, b) Observation of crack before repairing in "CUBES":

After the initiation of the crack to the cubes, a micro-level observation of the crack is done for the cement concrete specimens with the optimum level which is 10% of the Microbial Organism named Bacillus Subtilis. The micro-level observation of the crack was done which consists of a width of 1.6mm which is measured by using a universal portable crack measuring device named " Crack Measuring Card". The specimen is kept in a curing tank for the repair process

3.5. Observation of Crack Repairing in “CUBES”:

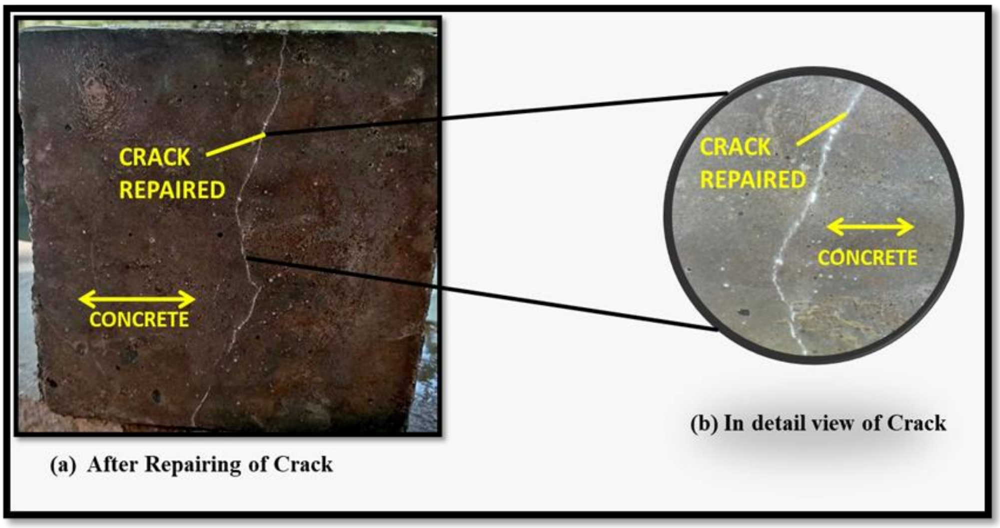


Fig 3.5.1(a, b) Observation of crack after repairing in “CUBES”

After placing the cubes in the curing tank for the repairing process the crack started, and observation of the crack specimen was done at 2-hour intervals. The figure represents the autonomous crack repair in which the crack was been measured for every 2-day interval by using a universal portable crack measuring device namely "**Crack Measuring Card**". During the observation it has come to know that 10% microbial organism is suitable for autonomous crack repairing in which the initial crack propagated was 1.6mm for 2 days intervals the measurement of crack repaired is 1mm, in 4 days the measurement of crack repaired is 1.6mm, the crack has been completely repaired.

3.6. Observation of Crack in “CYLINDERS”:

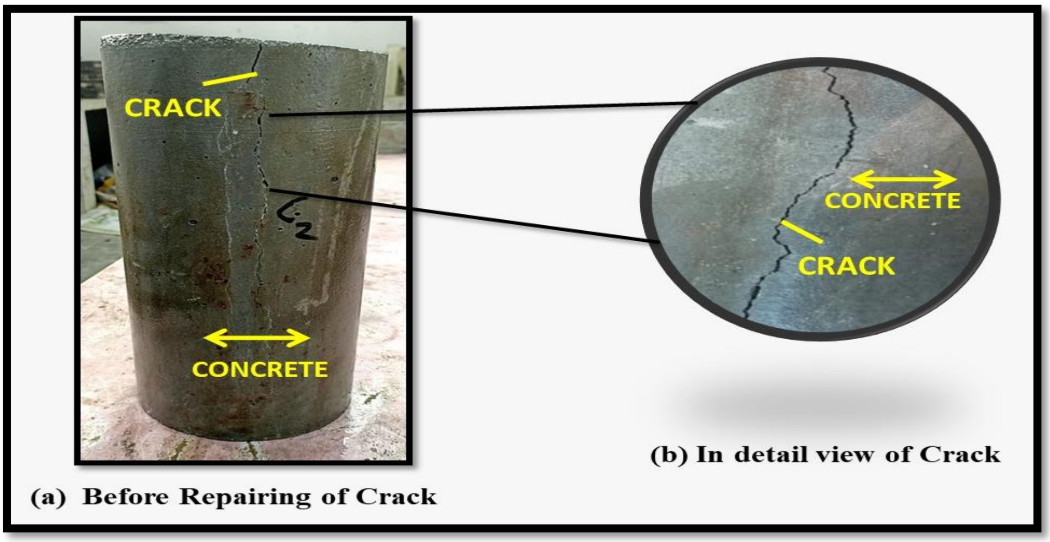
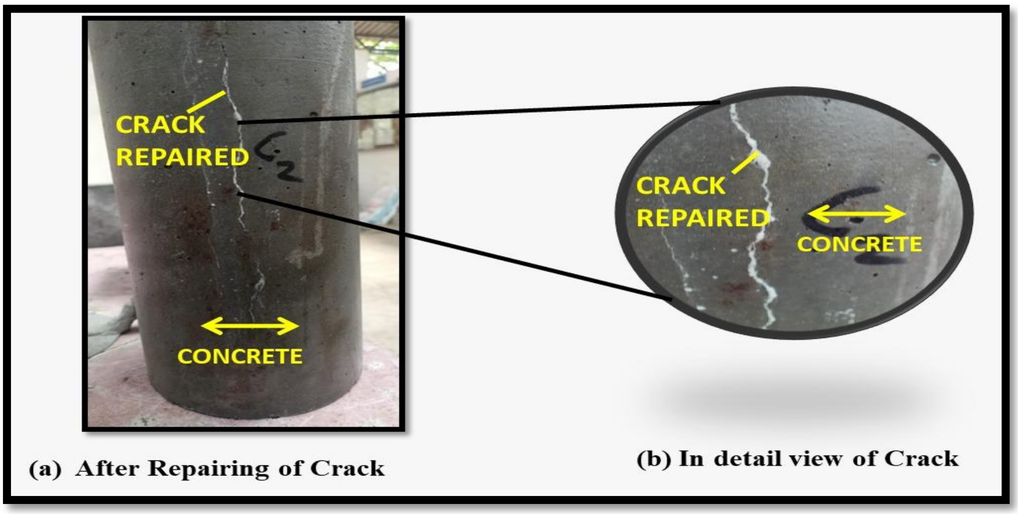


Fig 3.6.1(a, b) Observation of crack before repairing in “CYLINDERS”

After the initiation of the crack to the cylinders, a micro-level observation of the crack is done for the cement concrete specimens with the optimum level of 10% of the Microbial Organism named Bacillus Subtilis. The observation of the crack was done consisting of a width of 2.2mm which was measured by using a universal portable crack measuring device named **“Crack Measuring Card".** The specimen is kept in a curing tank for the repairing process.

3.7. Observation of Crack Repairing in "CYLINDERS":



(a) After Repairing of Crack
(b) In detail view of Crack

Fig 3.7.1(a, b) Observation of crack after repairing in "CYLINDERS"

After placing the cylinders in the curing tank for the repairing process the crack started, and observation of the crack specimen was done at every 2 hours of interval. The figure represents the autonomous crack repair in which the crack was been measured for every 2-day interval by using a universal portable crack measuring device namely "**Crack Measuring Card**". During the observation it has come to know that 10% microbial organism is suitable for autonomous crack repairing in which the initial crack propagated was 2.2mm for 2 days intervals the measurement of the crack repaired is 1.3mm, in 4 days the measurement of the crack repaired is 2.2mm, the crack has been completely repaired.

3.8. Measuring of Crack on the Specimen:

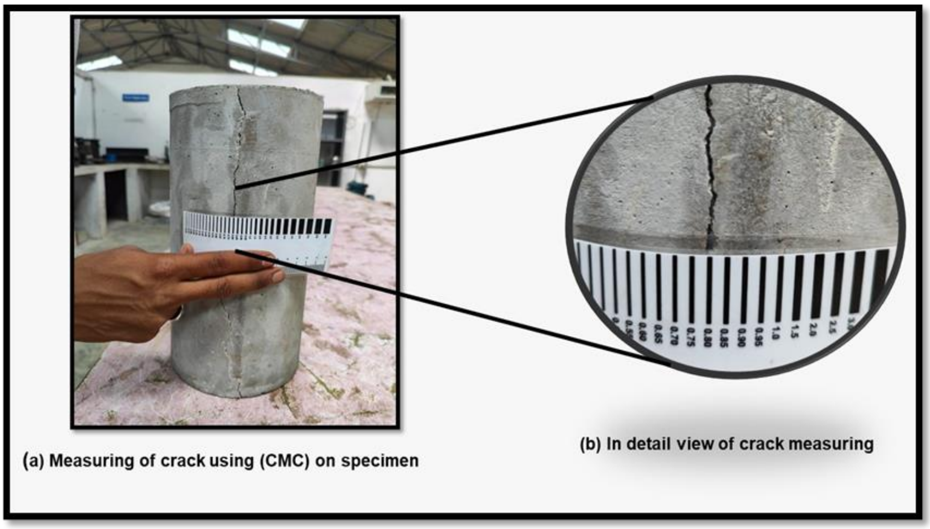

(a) Measuring of crack using (CMC) on specimen
(b) In detail view of crack measuring

Fig 3.8.1(a, b) Measuring of Crack on the Specimen using "Crack Measuring Card" (CMC)

Crack Measuring Card (CMC) is a device that is used to measure the length and thickness of the concrete used in roads, pavements, bridges, and other structures. It can monitor crack width from 0.1mm to 7mm. The Crack Measuring Card is a handy, field reference tool. It is manufactured by **Gilson's company**. The scale is highly used for measuring crack width in concrete. Before repairing the crack, it needs to be measured by using a device named a Crack Measuring Card (CMC).

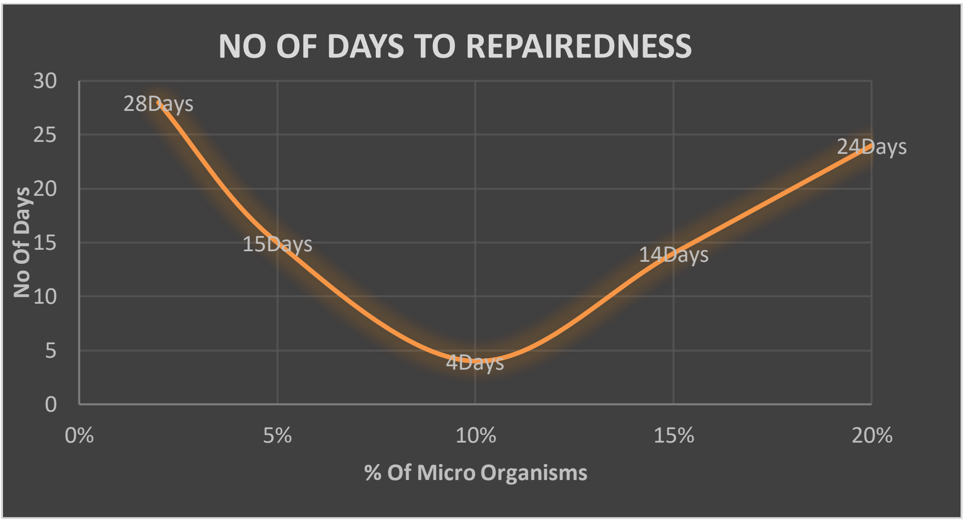


Fig 3.8.2 The percentage of Microorganism required for repairing the cracks in no. of days.

In this graphical representation, we show the period for repairdness.In the x-axis % of microorganisms and the y-axis, The days and the line graph show the period for repairdness. The rate of the repairing process was been increasing gradually by increasing the % of microorganisms in concrete. From 2% to 10% the rate of repairing increased gradually but at the 15% of microorganisms the rate of repair was found to be decreased gradually, at 20% Microorganism the rate of repair was found to be completely decreased at that point from this study we identify that for 2% of microorganisms time taken to repair the crack more than 28days and 5% of microorganisms time taken to repair the crack is more than 15 days and 10% of microorganisms time taken to repair the crack less than 5 days by this we get the optimum level of repairdness in concrete. From this study, we finalized that 10% is the optimum level of repairdness in concrete. Our main aim is for the rate of repairing is more in less period.

IV. CONCLUSIONS

According to the research work developed in the above stages of work, the following conclusions can be drawn:

- A biological-based sustainable concrete of grade M25 has been obtained with the range of data analysis using various percentages ranging from 2%, 5%, 10%, 15% & 20%.
- Based on the results obtained, it was observed that at 10% of Micro Organism composition, the optimum nature of repairing the crack has been identified & considered for optimizing results to perform further projects.
- Self Repairedness of Concrete has been found obtained in both internal and external cracks which were produced in the concrete structure on performance with the proportionate of 10% micro-organism with respect to the age of curing period convective at 4 days i.e., 96 hours by virtue of its behavior.
- From the Investigation of this work, it was obtained that the compressive strength of M25 Self-Repaired Concrete (SRC) has achieved better performance than that of the conventional type having 29.3 Mpa, 30.5 Mpa, and 33.8 Mpa for SRC & 17.4 Mpa, 22.8 Mpa, and 26.3 Mpa for conventional type at an age of 7, 14 & 28 days curing period respectively.
- Based on the results of the research on the performance of SRC-M25 maturity which obtained at 10% of micro-organisms, it shows that the project developed using this technology can have favorable economic profit and serviceability over its lifetime.

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