Analysis of M25 Grade of Self-Healing Concrete by Partial Replacement of Coarse Aggregate with E-waste

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Abstract - *Treating electronic waste is urgently needed; India generates 2 million tonnes of E-Waste, 5 percent of which is PCB (Printed Circuit Boards). Only a small percentage of this waste gets handled, and the vast rest ends up in waterways and landfills. Electronic waste disposal is an international problem, and we propose to employ the e-waste in stiff concrete pavement to cope with it. With 43,20,000 miles of highways, India offers several opportunities for repurposing e-waste in the transportation sector. This study is mostly based on use of ABS plastic in mix with concrete. Sieve analysis is performed to filter the grain sizes of ABS and concrete with the grain size of 2.36 to 10 mm. strength of block is analyzed by 3 type of tests which are compression strength test, tensile strength test and 3-point bending test. The compressive strength of the sample shows an increasing trend with the increasing composition of ABS plastic till 15% after which its starts decreasing again. It is also greater for 1% composition of calcium lactate than 0.5% of the same. The compressive strength has been found to be maximum for 15:1 composition of the ABS Plastic and the Calcium Lactate, respectively, i.e., 21.74MPa after 7 days and 33.62 MPa after 28 days.*

Key Words: ABS plastic, calcium lactate, sieve analysis, concrete.

1. INTRODUCTION

A world in perpetual flux necessitates building methods that are always changing. Concrete is one of the most often utilised building materials nowadays. In addition to the wide range of uses that it provides, its behaviour, strength, cost-effectiveness, durability, as well as flexibility all play a significant part in its popularity. As a result, construction workers rely on concrete since they know it is a safe, solid, and straightforward material. Buildings ranging from single-story residences to the multi-story office towers may benefit from this technology (bridges, roads, etc). Various load-bearing components, including as foundations, slabs, beams, and columns, are constructed using concrete.

Cement (or lime) is the binding ingredient used to combine aggregate (brick chips, sand, stone, gravel, etc.) together with water and other admixtures in particular quantities in order to make concrete, an artificial stone-like mass. When it comes to mixing, the ratios have a big role.

1.1 COMPOSITION OF BASIC CONCRETE MIX

In a concrete mix, there are four primary constituents:

- Binding materials such as cement or lime
- Aggregates or Inert Materials
  - Fine aggregate (sand)
  - Coarse aggregate (stone chips, brick chips)
- Water
- Admixture (e.g. Pozzolana)

The following is a basic breakdown of the constituent parts of concrete.

1 Binding Materials

A concrete mix's primary constituent is binding substance. Most typically, cement is utilised as a binding agent. Lime juice is another option. To form a paste, water is added to an already-mixed cement mixture. Paste solidifies into a stone-like material when it combines with the particles and hardens.

2 Aggregates

Sand is made up of a variety of different kinds of little particles. In most mixtures, the coarsest ingredient is gravel or crushed stone.

3 Water

Chemical reactions with cement need water (hydration), as does providing the concrete with the workability. The water/cement quantitative ratio refers to the amount of water in the mix relative to the amount of cement. The stronger the concrete, the lower the w/c quantitative connection. Increased tensile strength and reduced permeability.

1.2 TYPES OF CONCRETE MIX

Concrete is utilised for anything from simple home improvements to massive buildings in the research community. You may find it in pillars, basements, floors, sidewalks, and walls, among many other places. A broad range of concrete types are put to use in the building trades.

There are three main categories of concrete that may be identified by the materials and functions for which they are intended-

1. "Lime Concrete
2. Cement Concrete
3. Reinforced Cement Concretes"

According on how much work has been completed, there are four types of definite decisions to be made like as –

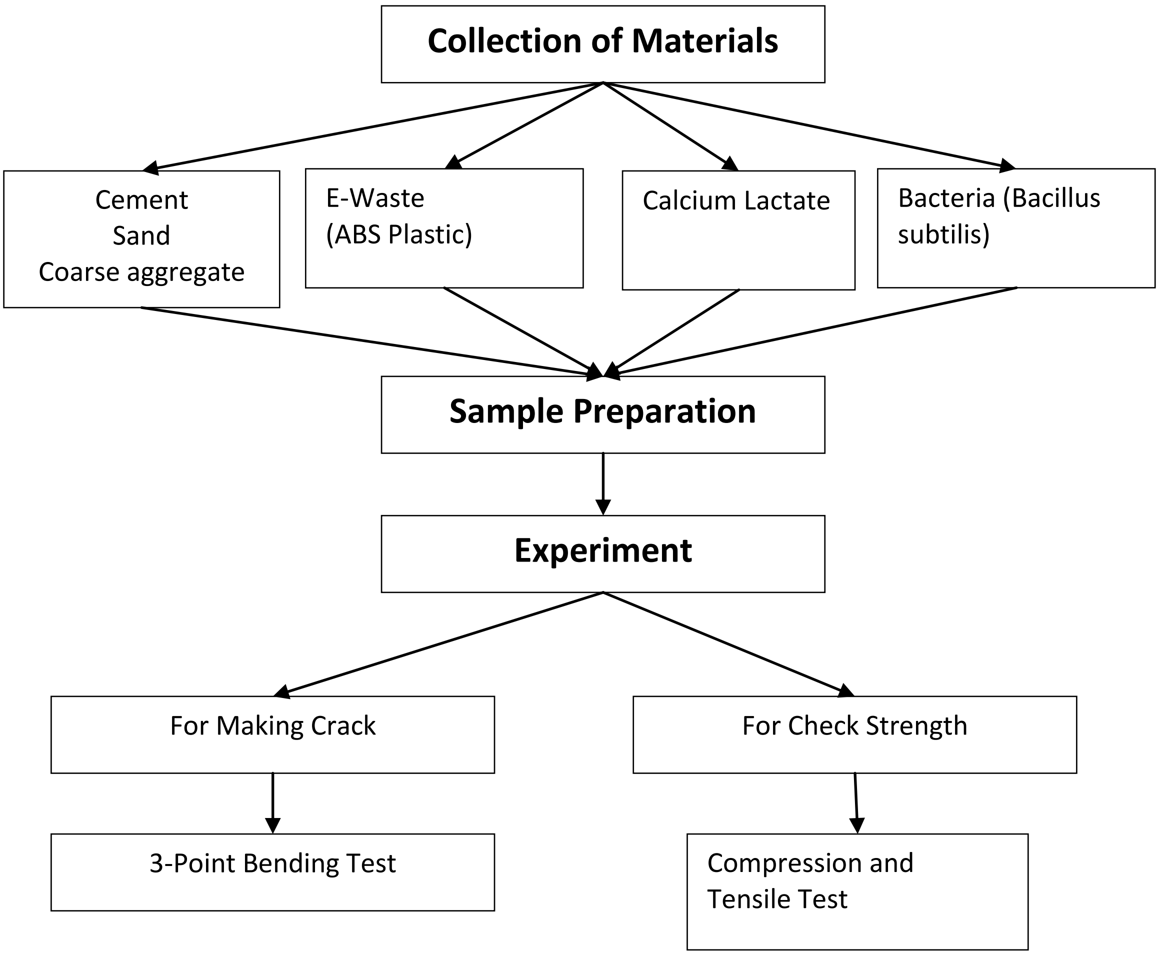
1. "Dry Ready Mix
2. Ready Mix
3. Bulk Dry Materials
4. Transit Mix"

By varying the amounts of the primary constituents, new varieties of concrete may be produced for a variety of purposes like:

- "Regular Concrete
- High-strength Concrete
- Stamped Concrete
- High-Performance Concrete
- Self-consolidating Concretes
- Vacuum Concrete
- Shotcrete
- Roller-Compacted concrete
- Glass Concrete
- Asphalt Concrete
- Rapid Strength Concrete
- Polymer Concrete
- Limecrete
- Light-weight Concrete
- Self-healing concrete"

2. METHODOLOGY

The purpose of this study is to examine the impacts of using varying percentages of E-Waste in lieu of Natural Coarse Aggregate in the concrete and to quantify the latter's capacity for self-healing. This might be useful for figuring out how much of Natural Coarse Aggregate could be substituted with the bacteria-containing E-waste without significantly altering the mechanical characteristics of a concrete and giving it the capacity to cure itself.



1 Material Selection

- Cement

Regular cement is utilised in this investigation. It has passed all of the tests required by the Indian standards.

- Sand

The research sand was purchased. The grains range from very fine to medium. After doing a sieve examination of a sand per ASTM C136, we again checked that the sand's gradation fell within the ranges set out in ASTM C33.

- Coarse Aggregate

Coarse aggregate consists of crushed stone with a specific gravity of 2.84 and the maximum size of 20 mm.

Fig. 1 Impact Test on the Coarse aggregates

- ABS Plastic

ABS may be easily altered by changing the proportions of its three monomers, butadiene, acrylonitrile, and styrene. Non-reinforced and reinforced grades alike are using heat stabilisers, hydrolysis stabilisers, lubricants, UV stabilisers, etc. to improve upon a variety of already present material qualities.

- Calcium lactate

The white powder that contains calcium lactate ($C_6H_{10}CaO_6$), also known as calcium salt pentahydrate, has an efflorescent odour. Lactic acid reacts with the calcium hydroxide or the calcium carbonate to produce this powder.

2 Sample Preparation

Apparatus: Vicat's apparatus with mould, Plunger, Balance, Measuring cylinder, Non-porous plate.

The equipment includes a Vicat mould, a balance, a plunger, a cylinder for measuring, and a nonporous plate.

Fig. 2 Sample Preparation

Make a paste using the same amount of water as cement, as measured by weight (during not less than 3 minutes and even no longer than 5 minutes). In order to determine how much time will pass until the mould is filled, remember to start timing as soon as water is added to dry cement. Put some paste in the Vicat's mould and work your way all the way down to the very end of the jar gently. Set the mould and test block on the nonporous plate and position the plunger in the centre of the plate. Carefully bring the plunger down until it just touches the test block, then rapidly let go to let it fall into the paste.

To find out how much water is required to get the Vicat's plunger to penetrate 5mm to 7mm from a bottom, make trial pastes with varying% of water and conduct testing as described above.

Concrete Mix Design

- "Characteristic Compressive Strength – M25
- Nominal maximum size of coarse aggregates – 20mm
- Shape of Coarse aggregates – angular

- Degree of workability required at the site – 100-120 mm slump
- Degree of quality control – As per IS:456
- Exposure site – Moderate (IS:456)
- Minimum cement content : 300 kg/m^3 (IS 456:2000)
- Maximum water-cement ratio : 0.50 (IS 456:2000)
- Specific gravity of cement – 3.15
- Specific gravity of coarse aggregates – 2.84
- Specific gravity of mild aggregate (sand) – 2.64"
- Water absorption:

1) "Coarse aggregate : 0.5 %
2) Fine aggregate (M.sand) : 2.5 %"

- Free (surface) moisture:

1) "Coarse aggregate : Nil (Absorbed Moisture also Nil)
2) Fine aggregate : Nil"

Material Testing Process

Different type of test has been performed to check the strength of sample

1. Compression Strength and
2. Tensile Strength
3. 3-Ponit Bending test

Compression Strength Test

The SCCs were compressed during a curing time of at least 28 days that was in accordance with ASTM C39. After being subjected to both room temperature & high temperatures, the "200 x 100 mm SCC specimens" were compressed at speeds of 1 mm/min and 0.5 mm/min, respectively Two linear variable differential transducers (LVDTs) were placed on the specimens in a symmetrical fashion on opposing sides to measure axial deformation of the concretes in a testing instrument. The stated value of shortening was calculated by taking the mean of the two LVDT readings. The axial stress-strain plots of the SCCs were calculated using the deformation as well as load data collected during the compression test. The compressive characteristics of the SCCs were derived using these graphs. In addition, each specimen had thin wooden sheets affixed to both ends in order to get the uniform distribution of a compressive force throughout the whole end surfaces and prevent stress concentration caused by the surface roughness.

Fig. 3 Compression Testing

The compressive strength is calculated by

$$Compressive\ strength = \frac{P}{A}$$

where P = Load in N
A= Area in mm^2

Tensile Strength Test

The ASTM C496 compliant cylindrical 200 x 100 mm SCCs were subjected to the compression test using the testing instrument. Compression loading was applied along the cylinder, and a rate of loading of 0:3 mm/min was used for the tension test. To further disperse the compressive force, two thin hardwood fiberboards were installed at the loading site.

Fig.4 Tensile Strength Testing

3-Point bending test

There was the three-point bending test conducted on concrete with textile reinforcement (Figure 4 8). The flexural tests were performed in the clear span of 150 mm using the Instron 5965 testing machine. At a steady pace of 1mm/min, the specimens were loaded.

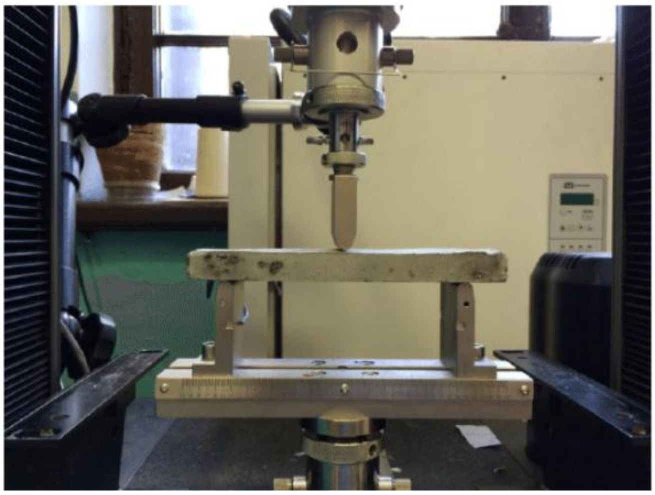


Fig. 5 Three-point bending test of concrete

The bending strength was calculated from the test data as the greatest bending moment divided by an axial section modulus in the bending.

$$\sigma = \frac{M}{W}$$

where
M - maximum bending moment, kN-m;
W – moment of inertia, m^3 .

3. Result and DIscussion

After 7 days curing duration

The compressive strength of the samples prepared have been tested after 7 days of curing duration which have been mentioned in the table 5.1 below.

Table 1 Result of 7 days Compressive Strength

Sample	ABS Plastic (%)	Calcium Lactate (%)	Compressive Strength (MPa)
1.a	5	0.5	16.63
1.b	10	0.5	17.21
1.c	15	0.5	18.74
1.d	20	0.5	17.12
1.e	25	0.5	16.13
2.a	5	1.0	18.89
2.b	10	1.0	19.88
2.c	15	1.0	21.74
2.d	20	1.0	19.10
2.e	25	1.0	18.32

The compressive strength of the sample shows an increasing trend with the increasing composition of ABS plastic till 15% after which its starts decreasing again. It also increases with higher percentage of Calcium Lactate composition, as the compressive strengths of the respective samples with same percentage of ABS plastic has been observed to be higher for 1% Calcium lactate composition than 0.5% of it. However, the compressive strength has been found to be maximum for 15:1 composition of the ABS Plastic and the Calcium Lactate, respectively, i.e.21.74 MPa.

The graph below in the figure 5-1 demonstrates the same comparison of the compressive strengths which is maximum for the 15:1 ratio of the compositions.

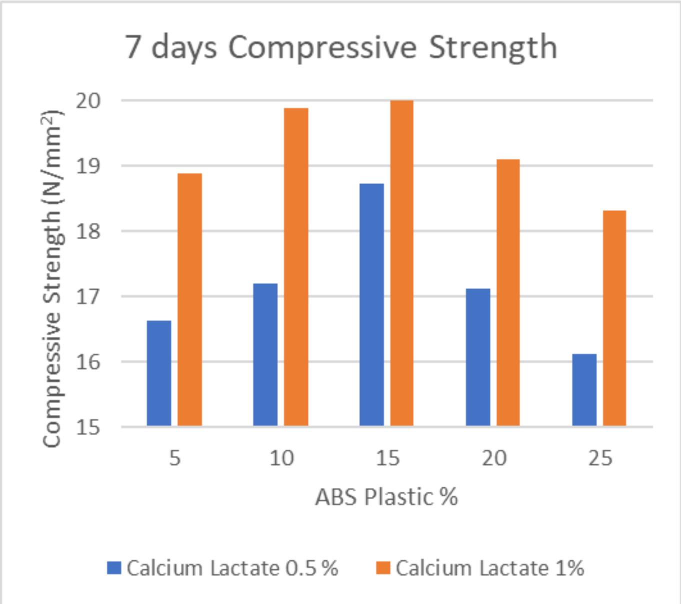


Fig.6 Strengths of the samples after 7 days

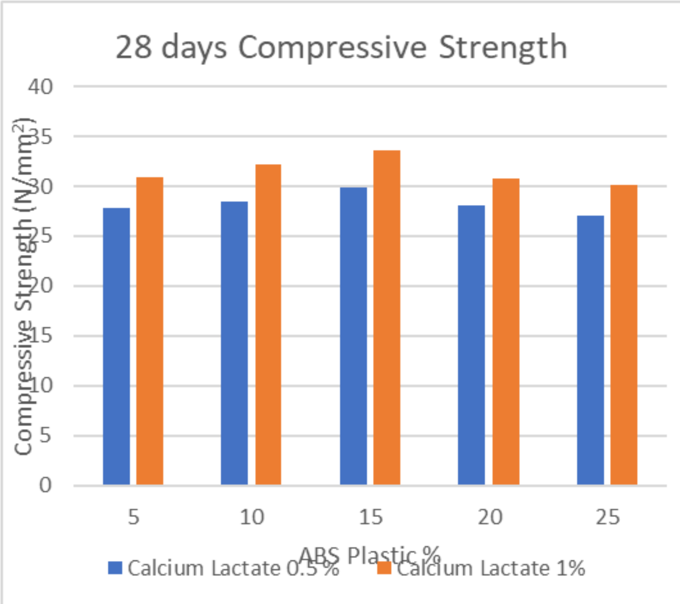


Fig.7 Compressive Strengths of the samples after 28 days

After 28 days curing duration

The compressive strength of the samples prepared have been tested after 7 days of curing duration which have been mentioned in the table 5.2 below.

Table 2 Result of 28 days Compressive Strength

Sample	ABS Plastic (%)	Calcium Lactate (%)	Compressive Strength (MPa)
1.a	5	0.5	27.81
1.b	10	0.5	28.43
1.c	15	0.5	29.88
1.d	20	0.5	28.12
1.e	25	0.5	27.02
2.a	5	1.0	30.88
2.b	10	1.0	32.12
2.c	15	1.0	33.62
2.d	20	1.0	30.74
2.e	25	1.0	30.12

The compressive strength of the samples show again show a similar trend after 28 days of curing duration, i.e. it increases with the increasing composition of ABS plastic till 15% after which its starts decreasing again as can be seen in the table and the graph above. It also increases with higher percentage of Calcium Lactate composition, as the compressive strengths of the respective samples with same percentage of ABS plastic has been observed to be higher for 1% Calcium lactate composition than 0.5% of it. However, the compressive strength has been found to be maximum for 15:1 composition of the ABS Plastic and the Calcium Lactate, respectively, i.e. 33.62 MPa.

Tensile Strength Test

The compressive strength of the samples prepared have been tested after 7 days of curing duration which have been mentioned in the table 5.3 below.

Table 3 Result of 28 days Tensile Strength

Sample	ABS Plastic (%)	Calcium Lactate (%)	Tensile Strength (MPa)
1.a	5	0.5	2.12
1.b	10	0.5	2.64
1.c	15	0.5	3.26
1.d	20	0.5	2.40
1.e	25	0.5	2.10
2.a	5	1.0	3.68
2.b	10	1.0	4.18
2.c	15	1.0	4.88
2.d	20	1.0	4.11
2.e	25	1.0	3.58

The tensile strength of the samples show again show a similar trend as that of the compressive strength, i.e. it increases with the increasing composition of ABS plastic till 15% after which its starts decreasing again as can be seen in the table and the graph above. It also increases with higher percentage of Calcium Lactate composition, as the tensile strengths of the respective samples with same percentage of ABS plastic has been observed to be higher for 1% Calcium lactate composition than 0.5% of it. However, the tensile strength has been found to be maximum for 15:1 composition of the ABS Plastic and the Calcium Lactate, respectively, i.e. 4.88 MPa. This has also been demonstrated in the graph given in the figure 5-3 below.

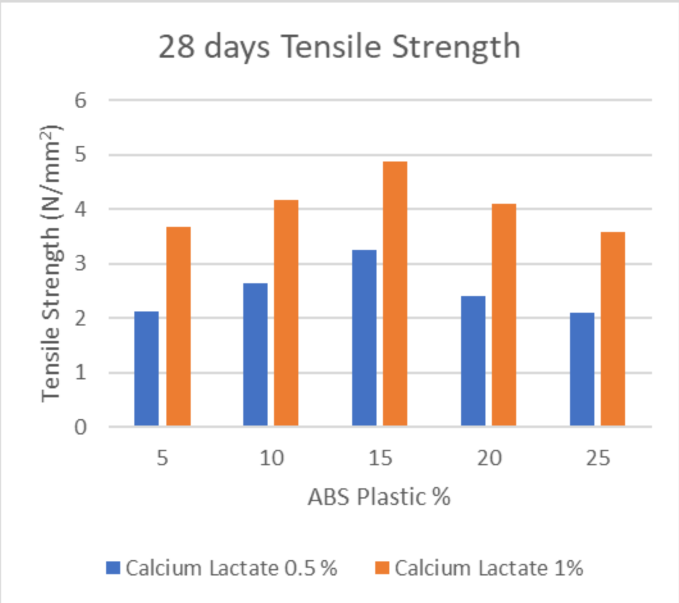


Fig.8 Tensile Strengths of the samples after 28 days

Crack Healing
7 days healing age

The table 5.4 below shows the widths of the crack that has been healed effectively after 7 days for the 15:0.5 as well 15:1 compositions of ABS plastic and Calcium Lactate, respectively, with 0.3% and 0.5% of bacteria.

Table 4 Healing Age 7 Days

Sample	ABS Plastic (%)	Calcium Lactate (%)	Bacteria (%)	Crack Width (mm)
	15	0.5	0.3	0.16
	15	0.5	0.5	0.65
	15	1.0	0.3	0.48
	15	1.0	0.5	0.68

Similar observations has been illustrated in the graph given in the figure 5.4 below, more the composition of calcium lactate and bacteria, the greater is the width of the crack healed. The crack width healed has been found maximum for 1% of calcium lactate and 0.5% of bacteria, i.e. 0.68mm.

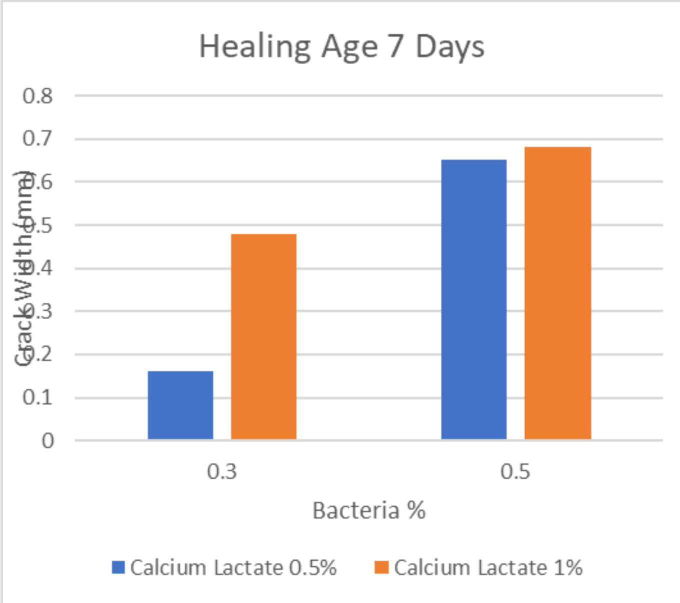


Fig.9 Healing Age 28 Days

28 days healing age

The table 5.5 below shows the widths of the crack that has been healed effectively after 7 days for the 15:0.5 as well 15:1 compositions of ABS plastic and Calcium Lactate, respectively, with 0.3% and 0.5% of bacteria.

Table 5 Healing Age 28 Days

Sample	ABS Plastic (%)	Calcium Lactate (%)	Bacteria (%)	Crack Width (mm)
1	15	0.5	0.3	0.23
2	15	0.5	0.5	0.86
3	15	1.0	0.3	0.73
4	15	1.0	0.5	0.92

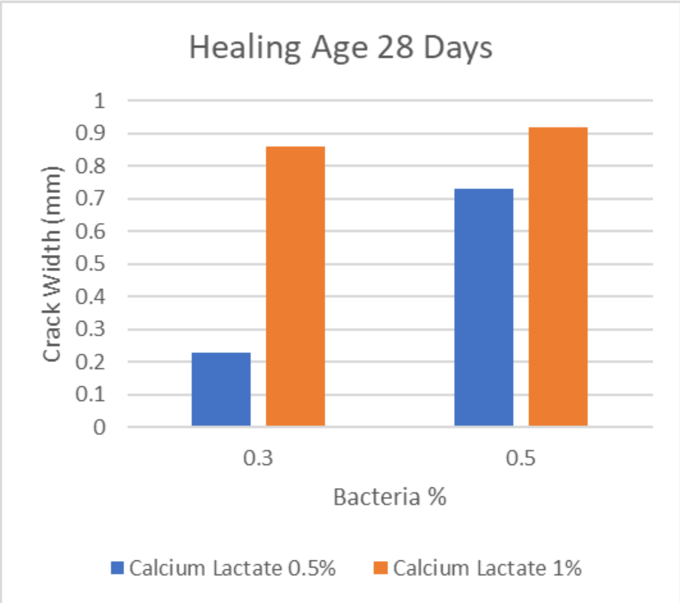


Figure** Error! No text of specified style in document.-**1** **Healing Age 28 Day

Similar observations has been illustrated in the graph given in the figure 5.5 below, more the composition of calcium lactate and bacteria, the greater is the width of the crack healed. The crack width healed has been found maximum for 1% of calcium lactate and 0.5% of bacteria, i.e. 0.92mm.

3. CONCLUSIONS

Compressive and tensile strengths of M25 grade concrete mixes with different amounts of the ABS plastic E-waste and the calcium lactate were measured after 7 & 28 days of the curing. The healing effects of various fracture widths are next investigated by combining these samples with either 0.3% or 0.5% of bacteria. These findings have been described below:

- Compressive strengths are higher after 28 days of curing than after 7 days, indicating that curing time has a positive effect on the tensile and compressive strength.
- The sample's compressive strength increases until the ABS plastic content reaches 15%, after which it begins to decrease again. Calcium lactate at 1% concentration is also superior to calcium lactate at 0.5% concentration. Results show that a 15:1 ratio of ABS plastic to calcium lactate provides the highest compressive strength, peaking at 21.74 MPa after 7 days and 33.62 MPa after 28 days.
- The tensile strength of the samples follows the same pattern as the compressive strength: it rises as the ABS plastic content rises up to 15%, and then it begins to fall. After 28 days of curing, the ABS plastic/Calcium Lactate 15:1 mixture reaches its maximum strength of 4.88 MPa.
- More calcium lactate and bacteria are present, the wider the fracture that can be mended. Maximum crack healing was seen with 1% calcium lactate and 0.5 % bacteria, with a width of 0.68 mm after 7 days and 0.92 mm after 28 days, respectively.
- Addition of calcium lactate and bacteria together by 1% and 0.5% give increase in compressive strength up to 2.34%.
- In case of coarse aggregate replacement with E-waste, the strength increases up to 15% replacement, Further on increasing the replacement percentage strength starts decreasing.
- Optimum strength seen at 15% replacement of the coarse aggregate with E- plastic waste and addition of 1% calcium lactate and 0.5% bacteria.
- By replacement of the coarse aggregate with E-waste plastic the cost of construction decrese up to 3% to 3.5%.

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