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MAINTENANCE OF MICROCRACKING IN RIGID PAVEMENT WITH THE AID OF BACTERIA

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Problem statement

Microcracking of rigid pavement usually occur due to the shrinkage of concrete after casting or throughout its service life due to repeated compressive, tensile, and shear stress.

Such cracking exhibit a durability problem.

Aim of the study

Self-healing techniques will be adopted with the aid of bacteria and healing agent to precipitate $CaCo_3$ on the formed micro-cracks.

A soil bacterium named Bacillus subtilis will be cultured in the laboratory, the concentration of bacteria cell of B. subtilits in normal saline (NaCl, 9 g/l) suspension was 106 cell/ml.

Impact of Healing of pre-cracked specimens with the aid of bacteria in the curing water on the strength properties of concrete will be monitored.

Methodology adopted

- Concrete specimens of various type (cube of 100x100x100 mm, cylinder of 100mm diameter and 200mm height, and beam of 100 x 100 x 500 mm) size will be prepared in the laboratory, then separated to three sets.
- The first set of specimens will be subjected to controlled compression and flexure pre-cracking, then subjected to healing and curing in a water bath which contains the prementioned bacteria at 20°C for 7 days.

The second set was the control specimens cured in water bath for 7 and 28 days at 20°C.

The third set of specimens will be subjected to healing and curing in a water bath which contains the prementioned bacteria at 20°C for 7 and 28 days and then tested for compressive, indirect tensile, and flexure properties.

Materials and testing methods

- **Ordinary Portland cement type 1.**
- **Coarse and fine aggregates.**
- **Water.**
- **Culture of Bacteria Bacillus Subtilis.**

Chemical composition of cement

Oxide	% by weight	Limit of Iraqi specification No.5/ 1984
CaO	61.28	--------
SiO2	18.372	--------
Al2O3	3.58	--------
Fe2O3	5.02	--------
MgO	1.39	< 5.0
SO3	2.02	< 2.80
C_3A	0.988	--------
Loss on ignition	2.85	≤ 4.0
Insoluble residue	1.07	< 1.5
Lime saturated Factor	1.0148	≥ 0.66 ≤ 1.02

Physical properties of cement

Physical properties	Test result	Limits of Iraqi specification
Specific surface area, Blain's method m^2/kg	394	≥ 230
Soundness, Autoclave's Method, %	0.03	< 0.8
Setting time, Vicat's method Initial setting hour: min Final setting hour: min	 2:15 3:30	 ≥ 45 min ≤ 10 hours
Compressive strength 3 days N/mm^2 7 days N/mm^2	 20.7 26.1	 ≥ 15 ≥ 23

Properties of Coarse and fine aggregates

Type of aggregate	Bulk Specific Gravity	Density(kg/ m^3)	Absorption %	SO3 %
Crushed aggregate	2.63	1646	1.167	0.034
Fine aggregate	2.5	1789	9.3	0.126

Combined aggregates gradation adopted

Sieve size mm	19	12.5	9.5	4.75	1.18	0.3	0.15
Percentage finer by weight	100	85	70	59	46.4	16	3.3

►► Preparation, Isolation and Culture of Bacteria Bacillus Subtilis

- **The isolation and culture of bacteria bacillus subtilis starts by collection of soil samples from Agricultural areas in Baghdad city and evacuation in glass bottles.**
- **The soil sample was then mixed with distilled water and shaken vigorously to ensure thorough mixing.**
- **Serial dilution was made by transfer of 1 ml of soil suspending to 9 ml of distilled water in test tube, this soil suspension is of 10^{-1} dilution.**

This process was repeated until 10^{-6} dilution is obtained.

After all these steps, petri-dishes plates with nutrient agar media according to the bacteria requirement have been prepared.

The solution of concentration 10^{-4} to 10^{-6} was spread by cotton swab on the petri-dishes plate with nutrient agar media in it and incubated in 37 °C to 24 hours in the incubator.

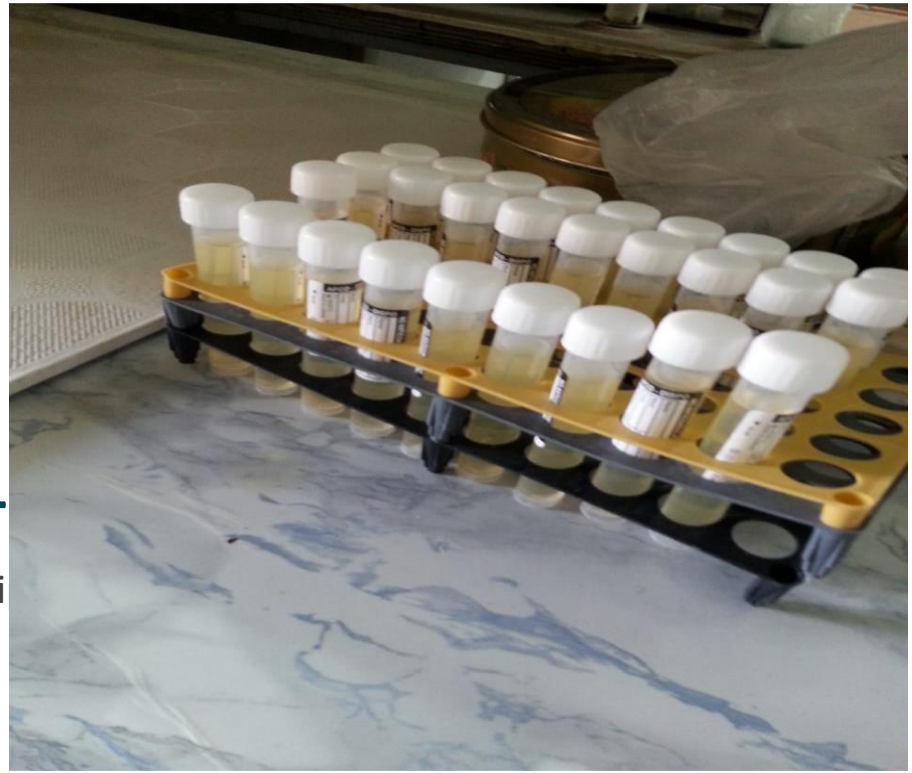
- **After this, the different type of colonies on different plates were observed and the growth after 24 hours incubation was checked.**
- **Afterword, Preparation of the concentration 10^{6} of bacterial cell (bacillus subtilis) starts by Transfer of loop full of single colonies of bacillus subtilis that form urease enzyme from nutrient agar to brain heart broth media and incubation at 37 °C on shaker at 150 rpm for 24 hours.**

The harvest of bacterial cell was done by centrifuge the 24 hour's old grown culture (5000 rpm, 5 minutes).

The sediments (bacterial cell) was form after centrifuge and were re-suspended in normal saline (NaCl, 9 g/l).

The concentration of bacteria cell of bacillus subtilits in suspension was 10^6 cell/ml.

Isolation of the bacteria.



Culture and dilution of the bacteria

Preparation of Concrete Mixture

Control concrete mixture was designed as per ACI 211.1-91 method, such mixture is usually used for rigid pavement construction.

The mix proportion is (1:1.5:3.75) with 0.45 water cement ratio.

Cube, beam and cylinder specimens have been prepared, covered with polythene sheets to retain the mixing water for curing for 24 hours. Specimens were immersed in water with bacterial concentration of 10^6 cell/ml of water.

Calcium lactate of 5% by weight of cement were added to the bacterial water.

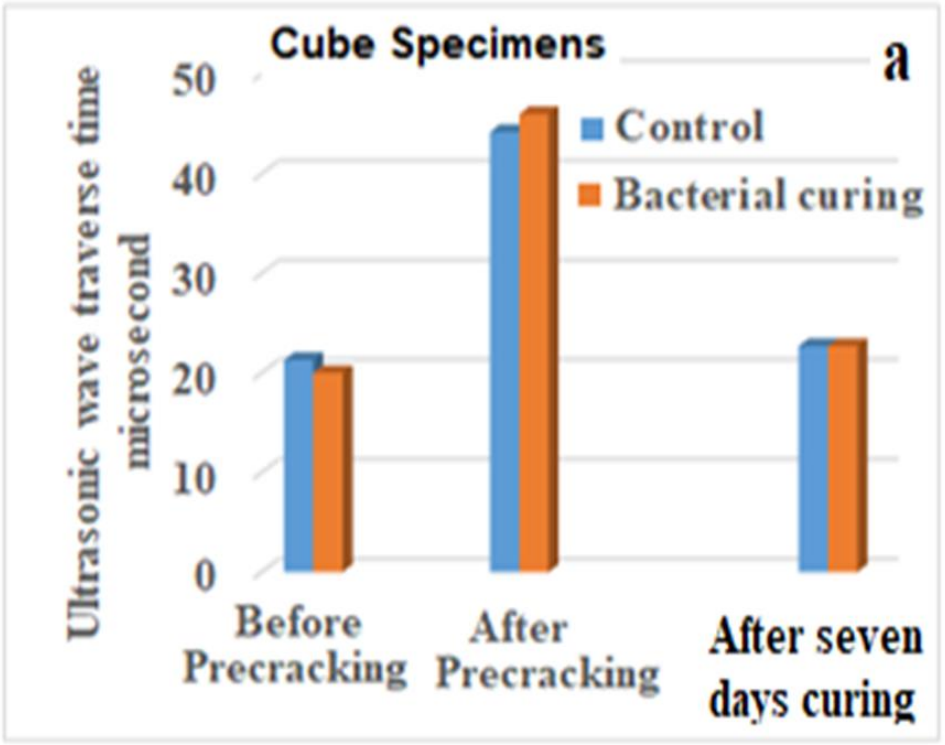
Specimens were tested after seven and 28 days to assess the impact of curing in bacterial water on the physical properties.

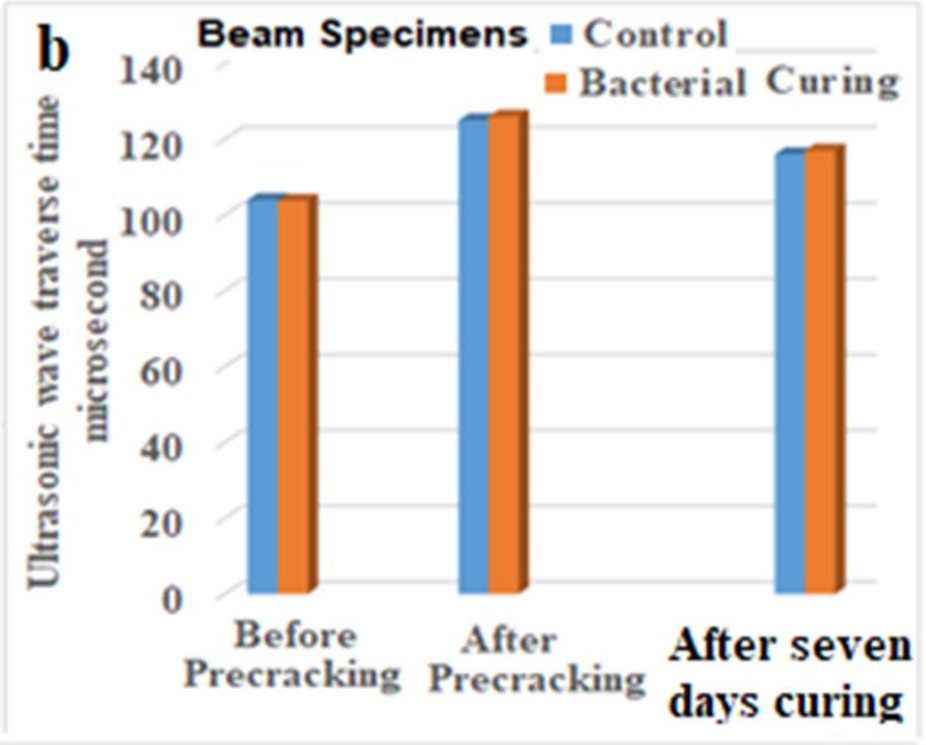
►► Pre-cracking of specimens

- Cube specimens were subjected to pre-cracking after 24 hours of curing, a load of 260 kN was applied for one minute then released.
- Cube specimens were subjected to ultrasonic wave traverse with the aid of pundit to determine the time required for the sound to traverse the specimen before and after the pre-cracking process.

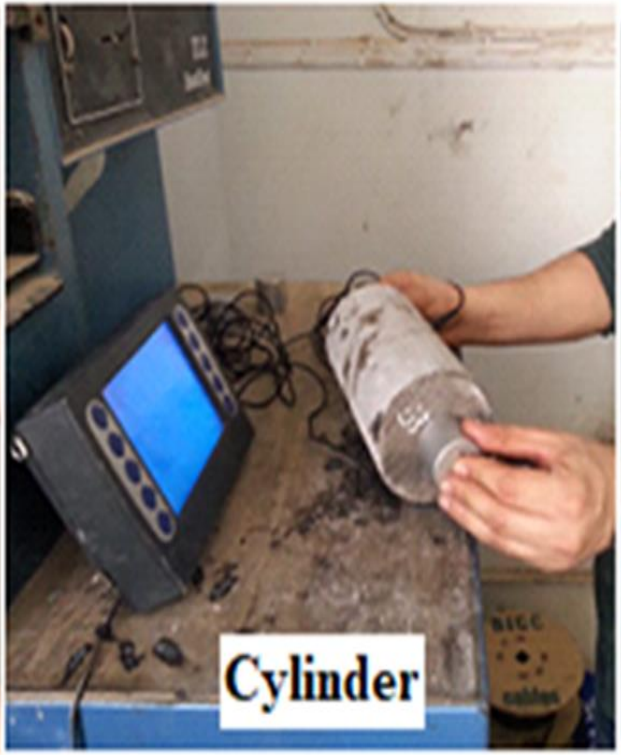
- For beam specimens, the pre-cracking was conducted using a flexure load of 5kN, while the ultrasonic wave traverse along the length of the beam.
- The time required for the sound to traverse the specimen before and after the pre-cracking process was recorded.

▸▸Ultrasonic wave traverse time for pre-cracked specimens



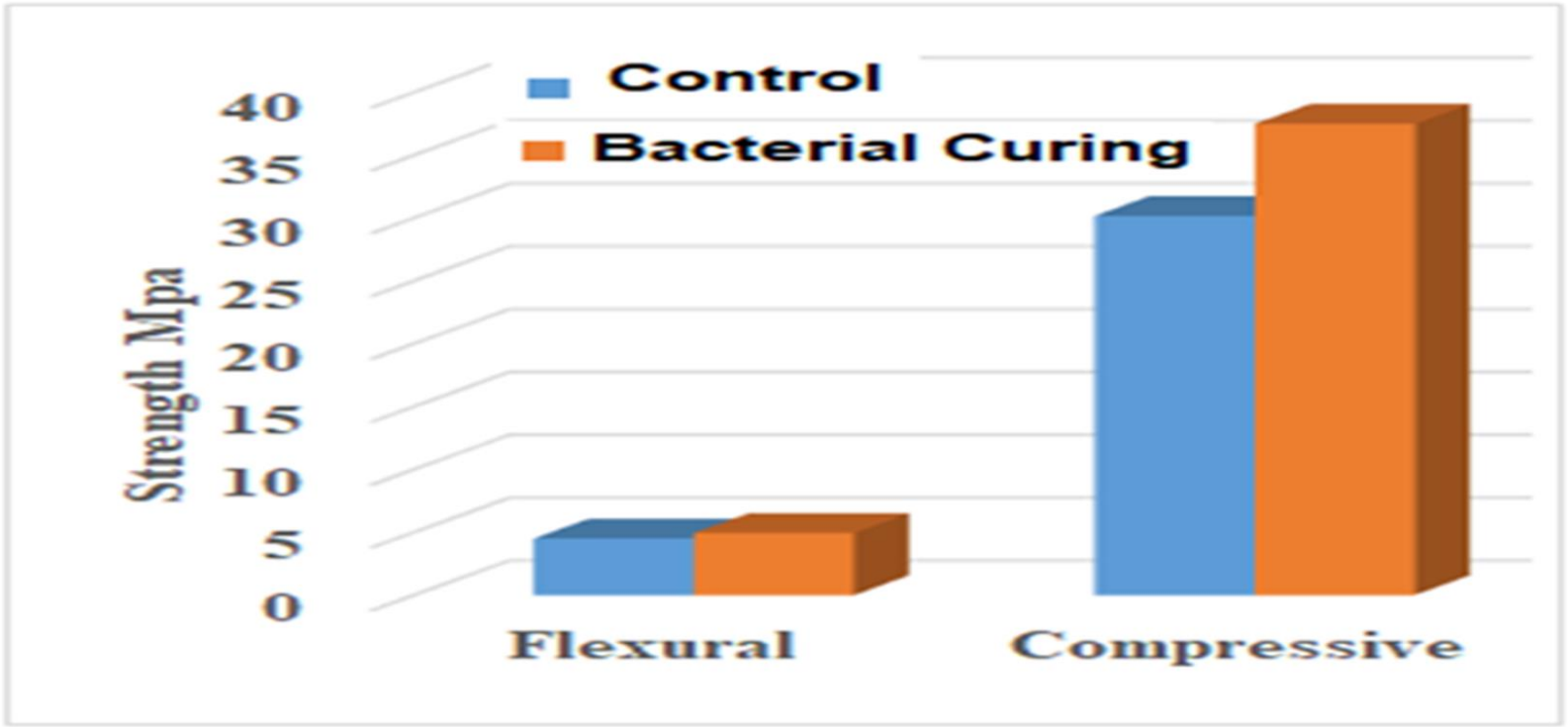


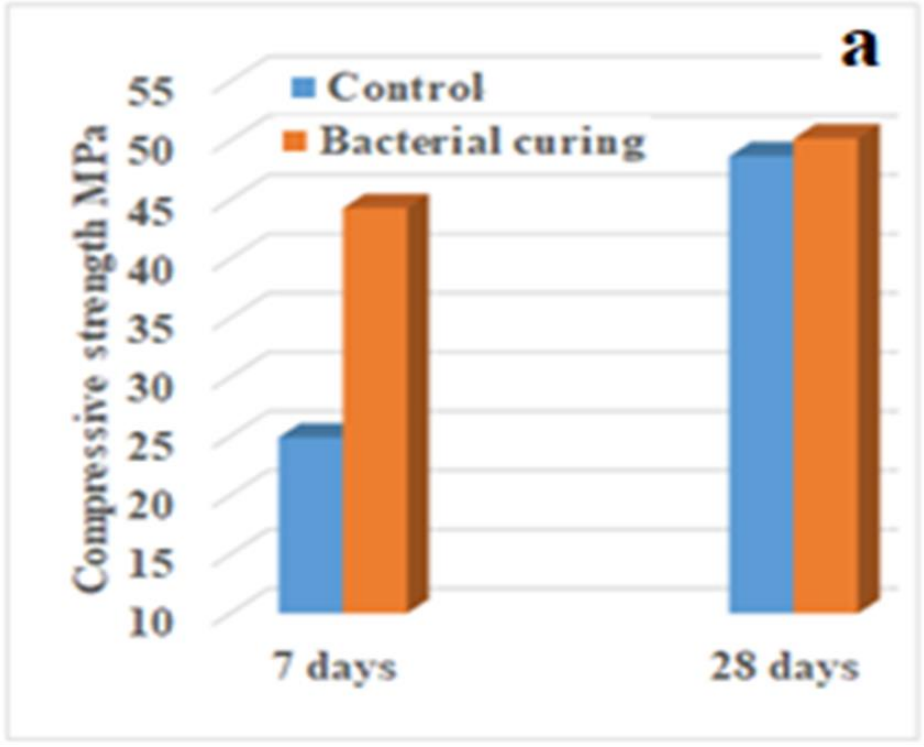

Cube

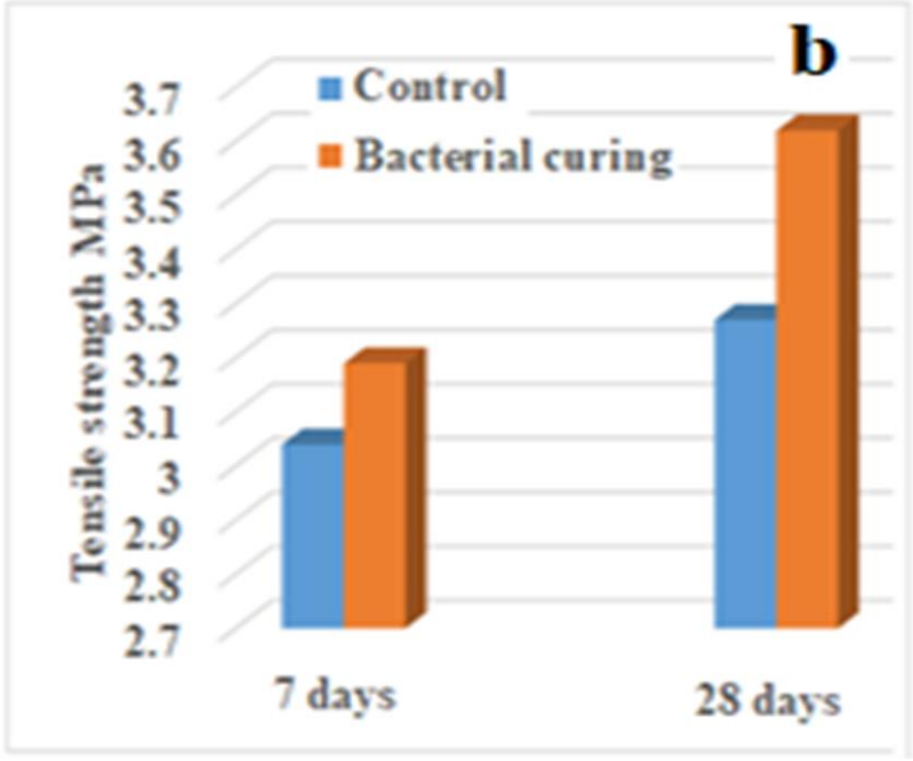

Cylinder

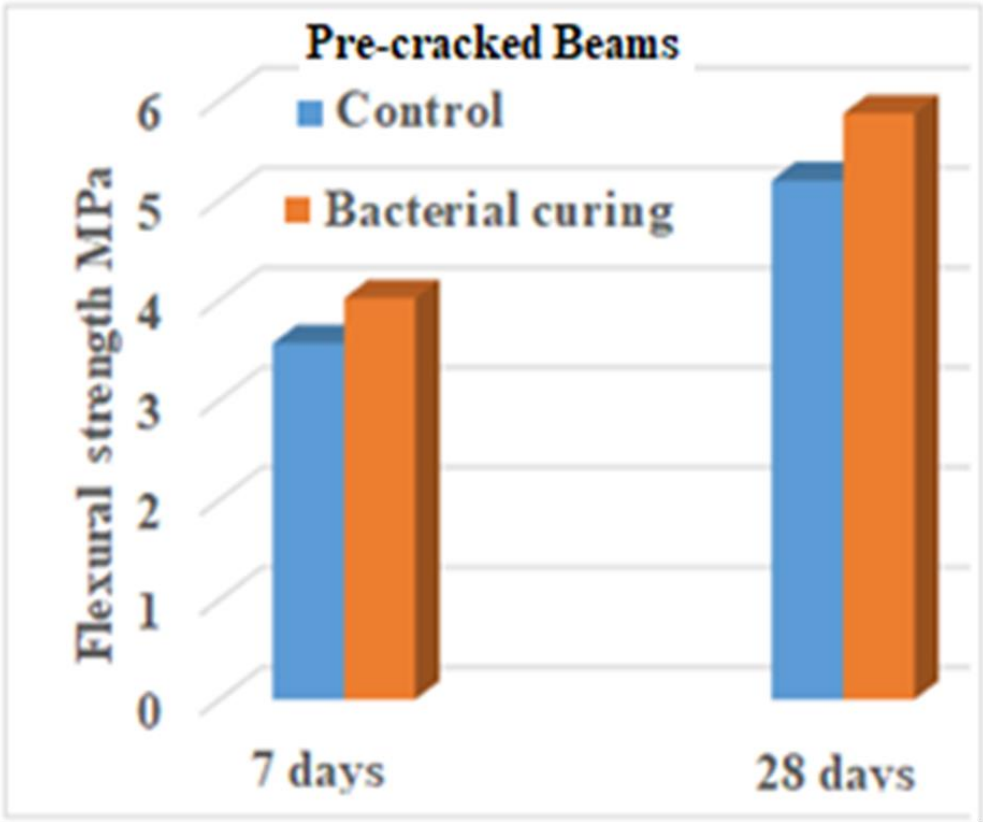

Prisim

- **Strength properties after pre-cracking and curing for seven days**




a
Control
Bacterial curing
Compressive strength MPa
55
50
45
40
35
30
25
20
15
10
7 days
28 days


b
Control
Bacterial curing
Tensile strength MPa
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
7 days
28 days


Pre-cracked Beams
Control
Bacterial curing
Flexural strength MPa
0
1
2
3
4
5
6
7 days
28 days

CONCLUSIONS

Implementation of bacteria (Bacillus subtilis) in the curing water exhibit a positive influence on the strength properties as well as crack healing of concrete.

Bacterial cured concrete exhibit high compressive strength of (107 and 23) % after 7 and 28 days of curing respectively when compared to that of control concrete. The increment in compressive strength after 28 days of curing was (95.5 and 18.4) % for control and bacterial Concrete respectively.

Bacterial cured concrete exhibit high tensile strength of (5 and 10.7) % after 7 and 28 days of curing respectively when compared to that of control concrete. The increment in tensile strength after 28 days of curing was (8.3 and 14.2) % for control and bacterial concrete respectively.

Bacterial cured concrete exhibit high flexural strength of (22.5 and 16) % after 7 and 28 days of curing respectively when compared to that of control concrete. The increment in flexural strength after 28 days of curing was (38 and 48.7) % for control and bacterial concrete respectively.

Specimens subjected to controlled pre-cracking exhibit improvement in strength properties after the healing process provided by the bacteria by (28 and 33) % for compressive and flexure strength respectively as compared to those of control mixture after 7 days of curing in bacterial water.

Recommendation

- It is recommended to implement bacterial water for curing of rigid pavement to assess the crack healing process.

Thank you