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An experimental study on mechanical properties of fiber reinforced self-healing concrete

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ABSTRACT

Concrete is most commonly used construction material which is strong in compression and weak in tension. The major drawback of concrete is formation of cracks, which affects the serviceability of concrete. When the applied load exceeds the limit, cracks develops on the structure through which water, salts and other foreign matters enters into the concrete and leads to the failure of the structure. Bacterially induced Calcium carbonate precipitation has been proposed as an environmental friendly technique which can remediate cracks in concrete. Metabolic activities of bacteria in concrete can improve overall performance of concrete. Micro cracks developing the material during its manufacture due to inherent volumetric and micro structural changes. Hence it is necessary to impart tensile resistance properties to concrete structural members to use it as a load bearing material. The tensile strength of the concrete can be improved by adding fibres in the concrete. Addition of fibres would act as crack resistor and would substantially improve static and dynamic properties. For the improvement of pore structure in concrete the Bacillus Pasteurii bacteria of concentrations 10^6 is used. Bacillus species are aerobic spore forming gram positive bacteria with specialized thick walled dormant cells, viable for more than 200 years under dry condition. Incorporation of calcite precipitating bacteria to concrete in certain concentrations so that the bacteria will precipitate calcium carbonate when it comes in contact with water and this precipitate will heal the cracks. To improve tensile strength Polyester fibers are used. Polyester is environmental friendly and non hazardous. It easily disperses and separates in the mix. It prevents the micro shrinkage cracks developed during hydration, making the structure inherently stronger. In this project an experimental investigation is carried out to study the properties of polyester fiber reinforced bacillus pasteurii bacterial concrete.

INTRODUCTION

Self-healing concrete is a result of biological reaction of non-reacted limestone and a calcium based nutrient with the help of bacteria to heal the cracks appeared on the building. Special type of bacteria's known as Bacillus is used along with calcium nutrient known as Calcium Lactate. While preparation of concrete, this products are added in the wet concrete when the mixing is done. These bacteria's can be in dormant stage for around 200 years. When the cracks appear in the concrete, the water seeps in the cracks. The spores of the bacteria germinate and starts feeding on the calcium lactate consuming oxygen. The soluble calcium lactate is converted to insoluble limestone. The insoluble limestone starts to harden. Thus filling the crack, automatically without any external aids. The other advantage of this process is, as the oxygen is consumed by the bacteria to

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convert calcium into limestone, it helps in the prevention of corrosion of steel due to cracks. This improves the durability of steel reinforced concrete construction.

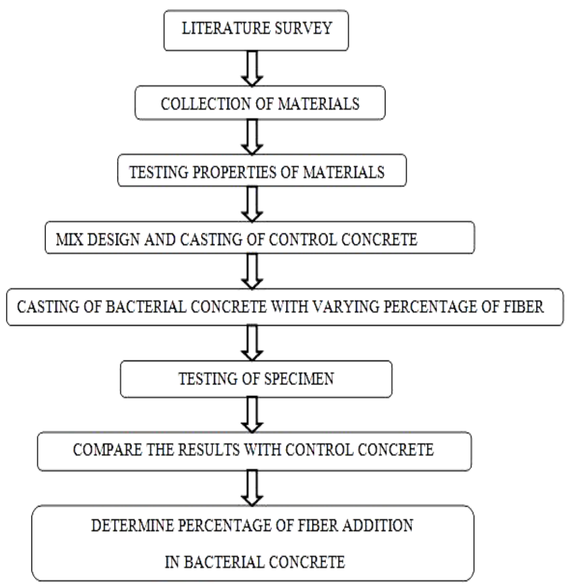
AIMS AND OBJECTIVES

The main aim of the study is to find the properties of Polyester fiber reinforced bacterial concrete using bacillus pateurii bacteria. The study is carried out in M25 concrete. The strength of the Polyester reinforced bacterial concrete is compared with plain cement concrete.

- To experimentally investigate the characteristics of Polyester reinforced bacterial concrete.
- To determine the optimum percentage of addition of Polyester fibre in bacterial concret.
- To compare the strength of conventional concrete with Polyester reinforced bacterial concrete.

METHODOLODY

In this study the properties of Polyester fiber reinforced concrete are compared with the plain concrete. As per IS 10262: 2009 the mix proportions for M25 grade concrete was worked out. Bacillus pasteurii were used as bacteria to cast bacterial concrete. Polyester fibers were added to the bacterial concrete at percentages of 0-1.5%. Slump test is conducted to determine workability of concrete. The strength tests conducted include compression test, tensile strength tests and flexural strength test. The durability tests include water absorption test and acid attack test. Tests on columns and beams were carried out.



DESIGN

- Design stipulations
- Characteristic compressive strength required at the field in 28 days = 25MPa
- Maximum size of the aggregate = 20 mm
- Test data for materials
- Specific gravity of cement = 2.92
- Specific gravity of coarse aggregate = 2.67
- Specific gravity of fine aggregate = 2.65
- Target mean strength of concrete

$fck' = fck + 1.65\ S$
$fck' = 25 + (1.65 \times 4)$
$= 31.6$ MPa

Water cement ratio

Maximum value of severe exposure = 0.50
Thus adopted a W/C ratio of 0.40

Sand and water

For 20mm aggregate size, sand of zone II, minimum

water content per m^3
=186 Kg
Adopted water content =195kg/m^3
Sand content as percentage of
total aggregate by absolute volume = 35%

Determination of cement content

W/C =0.40
Cement content = 488 Kg/ m^3

From IS 456 for severe condition of exposure, cement content should be greater than 320Kg/m^3
488 Kg/ m^3 > 320 Kg/ m^3, hence ok

Determination of coarse and fine aggregate contents

For 20mm sized aggregate, Amount of entrapped air = 2 %

Table I: Proportions obtained

Cement	Fine aggregate	Coarse aggregate	Water
488Kg/m^3	573 Kg/ m^3	1072 Kg/ m^3	0.40 lit/ m^3

Table II: Mix proportions obtained

Cement	Fine aggregate	Coarse aggregate	Water
1	1.17	2.1	0.40

DESIGN OF RCC COLUMN

Size : 100X100mm
Length : 600mm
Fck = 25 MPa
Fy = 415 Mpa
Design of longitudinal reinforcement:
Pu = 0.4fckAs+0.6fyAsc
(From clause 39.3 IS 456-2000)
Asc = 2% of gross area of column
Asc = 0.02 X Ag
Ag = 100X100
=10000mm2
Asc (required) = 0.02 X 10000
=200mm2
Provide minimum numbers of 4 rods.
Asc (provided) =4 X 3.14 X 12 X (12/4)
=452.16mm2
Ac = 0.98 X Ag
= 0.98 X 10000
= 9800mm2
Pu = (0.4 X 25 X 9800)+(0.67 X415 X452.16)
= 223.72KN
Provide 4 numbers of 12mm diameter rods as the longitudinal reinforcement.

Design of Ties

(From clause 26.5.3.2 of IS 456-2000) Diameter of ties >0.25 X Diameter of main rod
= 0.25 X 12
= 3mm
Provide minimum diameter of 8mm rods.
Spacing between ties can be taken from the least values of following:

Spacing = 48 X diameter of rods

= 48X8
= 384mm
Spacing = 16 X diameter of longitudinal reinforcement
= 16X12 =192mm
Spacing = least lateral dimensions =100mm
Spacing = 300mm
Provide 8mm diameter bars at 100mm center to center spacing.

DESIGN OF RCC BEAM

Size : 150X200mm
Breadth: 150mm
Depth : 200mm

Length : 1000mm
Loading condition: Two point load
End condition : Simply supported
Fck = 25 MPa
Fy = 415 MPa
Assuming cover of 30mm,
Effective depth, d = 200-30
=170mm
Minimum reinforcement:
Area of minimum reinforcement,
Ast min = (0.87 bd)/fy
= 62mm2
Check of Maximum reinforcement: (As per IS 456: 2000 clause 26.5.1) Maximum reinforcement = 0.04 bd
= 0.04 x150 x 200 =1200mm2
Provide 4 numbers of 12mm diameter bars
Mu,lim =0.138fckbd2
= 0.138x 25x 150x2002
= 24.84 kNm
Mu < Mu,lim
So section is under reinforced
Load Carrying Capacity
M = wL/6
W = 125kNm
Factored load = total load x factor of safety
Factor of safety =1.5
= 1.5 x 125
= 187.5
sv = 0.75 d
sv = 300mm

Provide 8mm diameter two legged stirrups at 100mm spacing

CASTING OF SPECIMENS

The quantity of ingredients was measured properly. The proper mixing of concrete was carried out manually. The mixed concrete is placed in the mould in such a way that there are no chances of segregation. Proper compaction was provided using tamping rods. After placing the concrete the surface of specimen was leveled with a trowel. After 24 hours the mould was removed and specimen was allowed to cure for 28 days in curing tank. After 28 days the specimen was tested.

ANALYSIS AND RESULTS

PE fibers were added to the bacterial concrete (Bacillus pasteurii were used as bacteria) At percentages of 0-1.5%. The workability test values and strength test values are compared with the control mix.

WORKABILITY TEST

Slump test

Concrete slump test was done to determine the workability or consistency of concrete mix.

Table III: Slump Values

Mix	Slump (mm)
Control mix	120
Bacteria +0% PE	103
Bacteria +0.25% PE	95
Bacteria +0.5% PE	91
Bacteria +0.75% PE	86
Bacteria +1% PE	78
Bacteria +1.5% PE	74

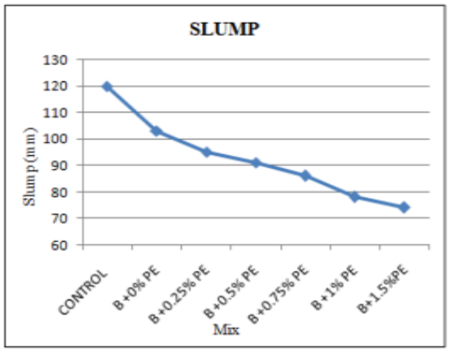


Figure I: Slump Values

Strength test

Compression test

Compression test was conducted to determine the compressive strength. The test was conducted on the cubes of size 150mm X 150mm X 150mm using compression testing machine

Table V: Compression Strength Results

MIX	COMPRESSIVE TEST RESULTS (MPa)		
	7 day	14 day	28 day
CONTROL	19.90	20.75	26.53
B +0% PE	21.07	21.88	27.73
B +0.25% PE	22.47	23.04	28.45
B +0.5% PE	23.77	24.05	28.64
B +0.75% PE	22.29	22.52	28.15
B +1% PE	22.16	22.32	28.05
B+1.5%PE	22.14	22.20	28.03

Split tensile test

Split tensile test was conducted to determine the tensile strength of the concrete. The test was conducted on cylinders of diameter 150mm and 300mm length in compression testing machine. The test was conducted as per IS: 516-1959

Table VI: Split Tensile Strength Results

MIX	SPLIT TENSILE TEST RESULTS (MPa)		
	7 day	14 day	28 day
CONTROL	2.01	2.17	2.61
B +0% PE	2.01	2.17	2.62
B +0.25% PE	2.10	2.22	2.68
B +0.5% PE	2.21	2.27	2.73
B +0.75% PE	2.12	2.22	2.68
B +1% PE	2.04	2.20	2.65
B+1.5%PE	2.02	2.17	2.62

Flexural test

Flexural test was conducted to determine the flexural strength. The test was conducted on prisms of size 100mmX100mmX500mm. Flexural strength is measured using universal testing machine. The test was conducted as per IS 516-1959.

Table VII: Flexural Strength Results

MIX	FLEXURAL TEST RESULTS (MPa)		
	7 day	14 day	28 day
CONTROL	2.46	2.72	3.24
B +0% PE	2.52	2.78	3.31
B +0.25% PE	2.54	2.81	3.34
B +0.5% PE	2.61	2.88	3.35
B +0.75% PE	2.53	2.82	3.33
B +1% PE	2.50	2.79	3.32
B+1.5%PE	2.48	2.75	3.31

CONCLUSION

The findings obtained from the experimental investigations are:

- The workability was found to decrease as the fiber content increase in the bacterial concrete in slump test.
- Up to 0.5% of fiber addition, the compressive strength was found to increase on bacterial concrete made with Bacillus Pasteurii bacteria. The compressive strength in bacterial concrete obtained with fiber content 0.5% was higher than plain cement concrete and bacterial concrete without fiber.
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- The percentage of increase in Compression strength, Split tensile strength and flexural strength is 7.95, 4.59 and 3.39 respectively.
- The optimum percentage of PE fiber addition in bacterial concrete was found to 0.5%.
- The compressive strength of concrete tends to increases and it gives better bond strength.

  The addition of 0.5% of polyester fiber in bacillus Pasteurii based self-healing concrete increases the mechanical properties than the control mix.

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