EXPERIMENTAL STUDY ON SELF-HEALING OF RIGID PAVEMENTS

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Abstract - This paper majorly focuses on the application of Self-healing of Rigid pavements and its sustainability. It is built using ultra high strength concrete and special fibers, it is not only cost-effective, but has greater longevity. Unlike the typical Rigid Pavement in which cement is a key component, in self-repairing road it uses 80% Cement And 20% Fly-Ash and 5 % Activated Carbon & 2.5 % of Fibers. These materials on constituent with cement and Activated Carbon makes a normal grade concrete as High Strength and High Performance Concrete. The main content that self heals the Pavement is fibers. The Fibers being used in constructing self- repairing Pavement, should have a epoxy resin and un hydrated cement attracts water in the event of rains. The water then becomes a key component in healing cracks. When a crack appears, this water gives hydration capability to the un- hydrated cement, and produces more silicates, which actually close the crack before they grow larger. The total number of cubes were casted for this project for Compressive Strength for 7, 14, 28 days are 12 cubes, In which 3 are Conventional concrete, 3 cubes were made with 5% of Activated Carbon, 3 cubes were 2.5% of Fibers, 3 cubes were made with 5 % of Activated Carbon & 2.5% of Fiber. The total number of cylinder were casted for this project for Split Tensile Strength for 7, 14, 28 days are 12 Cylinders , In which 3 are Conventional concrete, 3 Cylinders were made with 5% of Activated Carbon,3 Cylinders were 2.5% of Fibers, 3 Cylinders were made with 5 % of Activated Carbon & 2.5% of Fiber. Additionally 3 moulds with 100 mm thickness with 5% of Activated Carbon& 2.5% of Fibers & 5% of Epoxy Resin were prepared for Generation of crack and Healing of Crack at 7, 14, 28 days. The road is about 100mm thick, which makes it 50 % to 60% less thick than the standard Indian road. This makes the first-time cost of laying out such a road about 20% to 30% cheaper.

Key Words: Rigid pavement, Cement, Concrete, Fibers, Fly-Ash, Activated Carbon, Water, Rain, Epoxy Resin, Self-Healing, Compressive Strength, Split Tensile Strength.

1. INTRODUCTION

Self-healing technology is a new field within material technology. It represents a revolution in materials engineering and is changing the way that materials behave. Incorporating self-healing technology into the road design process has the potential to transform road construction and maintenance processes by increasing the lifespan of roads and eliminating the need for road maintenance. By decreasing the unnecessary premature ageing of rigid pavements, self-healing asphalt can reduce the amount of natural resources used to maintain road networks, decrease the traffic disruption caused by road maintenance processes, decrease CO2 emissions during the road maintenance process and increase road safety. In addition to environmental savings, self-healing materials have the potential to deliver significant cost savings for road network maintenance .

Concrete structures often suffer from cracking that leads to much earlier deterioration than designed service life.To prevent such deterioration, regular inspection of cracks in concrete structures and their repair are usually carried out by means of some kind of human intervention.

The roads will require less servicing, increasing productivity while decreasing cost. Self-healing roads far outperform conventional roadways, self-healing Rigid Pavement can improve traffic flow, reduce maintenance activity, and can easily extend the life of a road up to 40 years. Durability is experiencing a shift from the idea of minimizing damage to the new era of self-healing capabilities.

OBJECTIVE

• To test and lay high strength concrete road 5% of activated carbon, 20% fly ash and cement content 80%. The presence of Activated carbon & Fibers in concrete increases the strength of the road to 15-30% compared to conventional concrete.

• To give secondary reinforcement for the high strength concrete road with Steel and coir fibers.

• To induce the concept of self-repair when crack are formed with polar substances natural and Synthetic Fibers.

• To increase the life span of the road and durability when compared to normal asphalt and cement roads.

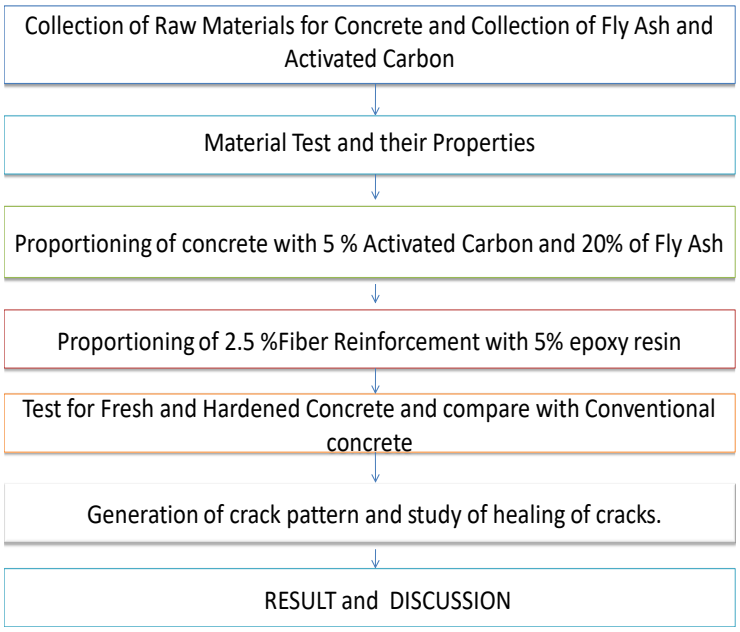
• To increase the Compressive strength and Split Tensile of the rigid pavement by adding Activated Carbon and Fibers which will increase the strength by 15-30% compared to conventional concrete.

MECHANISM

- The Activated Carbon in the Concrete will increase the compressive strength evidently and reduce the pores in the rigid pavement. This will significantly resist the road from cracks.

- The Coir Fiber with Hydrophilic coating have natural tendency to self-repair when cracks areformed.
- When a crack appears, this water gives hydration capability to the un-hydrated cement, and react with hydrophilic substance and produce silicates, which close the crack before they grow larger.
- Continued Hydration of anhydrous cement particles with come in contact with water and precipitation of Cement crystals.

METHODOLOGY



MATERIALS COLLECTED

Cement (OPC 53 grade), Fine aggregate, Coarse aggregate(40 mm), Flyash, Epoxy resin, Activated carbon, Steel & Coir fiber.

Figure 1 : Materials Collected

MIX DESIGN

Grade of concrete	: M30
Cement	: OPC 53
Size of aggregate	: 40 mm
Exposure	: Severe
Workability	: 25 -50 mm Slump
Degree of site control	: Good
Specific gravity of Fine Aggregate	: 2.74
Specific gravity of Coarse Aggregate	: 2.56
Specific gravity of Cement	: 3.15
Fine Aggregate zone	: I

TARGET STRENGTH FOR MIX PROPORTIONING

$f'_{ck} = f_{ck} + 1.65\ s$

Where

f'_{ck} -- target average compressive strength at 28 days,

f_{ck} -- characteristic compressive strength at 28 days, and

s = standard deviation.

From Table 1, standard deviation, s -- 5 N/mm^2.

Therefore, target strength = 30 + 1.65 x 5 = 38.25 N/mm^2.

SELECTION OF WATER-CEMENT RATIO

From Table 5 of IS 456, maximum water-cement ratio = 0.45. Based on experience, adopt water-cement ratio as 0.40.

0.40 < 0.45, hence O.K.

SELECTION OF WATER CONTENT

From Table 2, maximum water content = 165 litre (for 25 to 50 mm slump range) for 40 mm aggregate

Estimated water content for 50 mm slump = 165 litre

CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.40

Cement content = 165/0.40

= 413 kg/m^3

From Table 5 of IS 456, minimum cement content for 'severe' exposure condition = 320 kg/m^3

413 kg/m^3 > 320 kg/m^3, hence, O.K.

Now, to proportion a mix containing fly ash the following steps are suggested:

a) Decide the percentage fly ash to be used based on project requirement and quality of material.
b) In certain situations increase in cementitious material content may be warranted. The decision on increase in cementitious material content and its percentage may br based on experience and trial.

Increase of 10 percent cementitious material content.

Cementitious material content =413 x 1.10 = 455 kg/m^3

Water Content =165 kg/m^3

So, water-cement ratio =140 / 455=0.308

Fly ash 20% of total cementitious material content =455 x 20% = 91 kg/m^3

Cement (OPC) =455 - 91 = 364 kg/m^3

Saving of cement while using fly ash =413 – 91 = 322 kg/m^3 and

Fly ash being utilized = 91 kg/m^3

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 3, volume of coarse aggregate corresponding to 40 mm size aggregate and fine aggregate (Zone 1) for water-cement ratio of 0.50 = 0.69.

In the present case water-cement ratio is 0.40. Therefore, volume of coarse aggregate is required lo be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10, the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every +or- 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.71

Therefore,

Volume of coarse aggregate = 0.71.

Volume of fine aggregate content = 1 - 0.71 = 0.29.

MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows

a)Volume of concrete = 1m^3

b)Volume of cement = (Mass of cement / specific gravity of cement) (1/1000)

=(364/3.15)/(1/1000)

=0.1156m^3

c) Volume of fly ash = (Mass of fly ash / specific gravity of fly ash) (1/1000)

= (91/2.2)(1/1000)

= 0.0455

d) Volume of water = (Mass of water / specific gravity of water) (1/1000)

= (165/1)(1/1000)

= 0.165

e) Volume of all in aggregate = (a - (b + c + d))=(1-(0.1156+0.0455+0.165))

= 0.6739

f) Mass of coarse aggregate = e*volume of coarse aggregate*specific gravity of coarse aggregate *1000

= 0.6739*0.71*2.56*1000

= 1225 kg/m^3

g) Mass of fine aggregate = e*volume of fine aggregate*specific gravity of fine aggregate *1000

= 0.6739*0.29*2.74*1000

= 536 kg/m^3

Activate carbon (5% of cement) =18.2 kg/m^3

Steel and Coir fiber (2.5% of fine aggregate) =10.72 kg/m^3

MIX PROPORTION

M30 Design mix

CEMENT (kg)	FINE AGGREGATE (kg)	COARSE AGGREGATE (kg)	WATER CEMENT RATIO
364	536	1225	0.308
1	1.5	3.5	0.308

- Fiber reinforcement with Epoxy Resin are added with 2.5 %.
- Activated Carbon are added as 5% as volume of Cement.
- Cement as been replaced by 20% of Fly Ash.

Figure 2: Preparation Of Moulds

COMPRESSIVE STRENGTH TEST

Table -1: Compressive strength Test for Hardened Conventional Concrete

SL NO	SPECIMEN	7 DAYS (N/mm^2)	14 DAYS (N/mm^2)	28 DAYS (N/mm^2)
1	Compressive strength for conventional hardened concrete	**19.40**	**27.84**	**32.33**

Table - 2 : Compression Test of Hardened Concrete with Fiber Reinforcement, Activated Carbon.

SL NO	SPECIMEN	7 DAYS (N/mm^2)	14 DAYS (N/mm^2)	28 DAYS (N/mm^2)
1	Compressive test for hardened concrete with **5% of ACTIVATED CARBON**	**22.4**	**28.9**	**35.82**
2	Compressive test for hardened concrete with **2.5 % of FIBER REINFORCEMENT.**	**24.26**	**30.22**	**37.32**
3	Compressive test for hardened concrete with **5% of ACTIVATED CARBON & 2.5 % of FIBER REINFORCEMENT.**	**29.78**	**39.56**	**46.26**

Figure 3 : Compressive Strength

SPLIT TENSILE STRENGTH TEST

Table - 3 : Split Tensile Strength of Hardened Conventional Concrete.

SL NO	SPECIMEN	7 DAYS (N/mm^2)	14 DAYS (N/mm^2)	28 DAYS (N/mm^2)
1	Split Tensile strength for conventional hardened concrete	**2.12**	**2.54**	**2.83**

Table – 4 : Split Tensile Strength of Hardened Concrete with with Fiber Reinforcement, Activated Carbon.

SL NO	SPECIMEN	7 DAYS (N/mm^2)	14 DAYS (N/mm^2)	28 DAYS (N/mm^2)
1	Split Tensile test for hardened concrete with **5% of ACTIVATED CARBON**	**2.26**	**2.82**	**2.97**
2	Split Tensile test for hardened concrete with **2.5 % of FIBER REINFORCEMENT.**	**2.40**	**3.11**	**3.53**

3	Split tensile test for hardened concrete with **5% of ACTIVATED CARBON & 2.5 % of FIBER REINFORCEMENT.**	**2.55**	**3.40**	**3.68**

Figure 4 : Split Tensile Strength

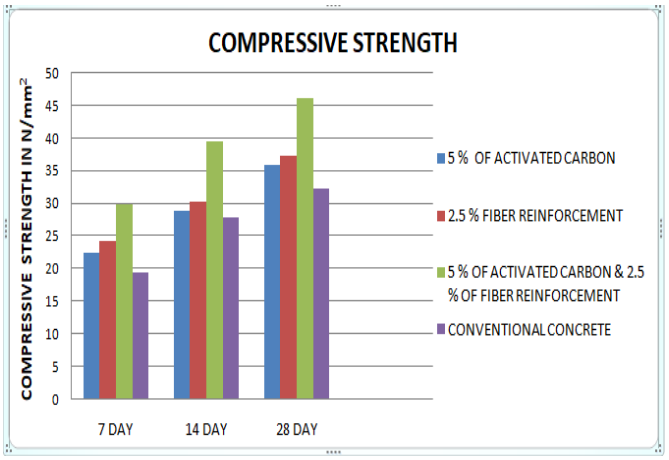


Chart – 1 : Compressive Strength

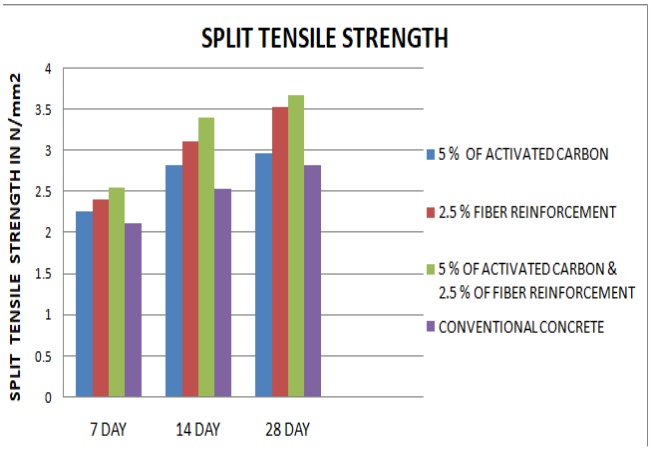


Chart – 2 : Split Tensile Strength

GENERATION OF CRACK AND SELF HEALING OF CRACK

The Fibers being used in constructing self- repairing road, should have a epoxy resin and un hydrated cement attracts water in the event of rains. The water then becomes a key component in healing cracks. When a crack appears, this water gives hydration capability to the un- hydrated cement, and produces more silicates, which actually close the crack before they grow larger.

Figure 5 : Preparation of Mould

GENERATION OF CRACK

Figure 6: Generation of Crack

Figure 7: Generated Cracks

SELF HEALING OF CRACK

2.5 % of Natural Fibers (Coir) with addition of Epoxy Resin with 5% will induce the self repairing property.

The Fibers being used in constructing self- repairing road, should have a epoxy resin and un hydrated cement attracts water in the event of rains. The water then becomes a key component in healing cracks. When a crack appears, this water gives hydration capability to the un- hydrated cement, and produces more silicates, which actually close the crack before they grow larger.

Figure 8 : Self Healing of Cracks

CONCLUSION

This project mainly interests the design of rigid pavement as demand for road maintenance increases Pavement road contractors and highway engineers need to look widely for ways to improve and maintain the roads. So we hereby concludes that roads with self healing property reduces the cost of maintenance and it believes that with certain natural and synthetic fibers we could done it. On the other hand these Pavement has been laid with high strength concrete containing activated carbon as a main strength improving agent.

From the Compressive strength test results it was clear that OPC mix gave a compressive strength value of 32.33 N/mm^2, whereas 5% of Activated carbon mixes gave value of 35.82 N/mm^2, 2.5% of Fibers reinforcement mixes gave value of 37.22 N/mm^2, & 5% of Activated carbon and 2.5 % of Fiber Reinforcement gave value of 46.26 N/mm^2 respectively. The admixture replaced mixes due to good particle packing effect gave good Compressive strength values as nominal mix. In specific 5% of Activated carbon and 2.5 % of Fiber Reinforcement replaced mixes gave higher compressive strength 15% than nominal Conventional Concrete.

From the Split tensile strength test results it was clear that OPC mix gave a Split tensile strength value of 2.83 N/mm^2, whereas 5% of Activated carbon mixes gave value of 2.97 N/mm^2, 2.5% of Fibers reinforcement mixes gave value of 3.53 N/mm^2, & 5% of Activated carbon and 2.5 % of Fiber Reinforcement gave value of 3.68 N/mm^2 respectively. The admixture replaced mixes due to good particle packing effect gave good Split tensile strength values as nominal mix. In specific 5% of Activated carbon and 2.5 % of Fiber Reinforcement replaced mixes gave higher Split tensile strength values than nominal mix. Therefore, without compromising on tensile strength aspects, the admixtures like Fibers can be used practically for providing good tensile strength properties to concrete

Self repairing using natural and synthetic fibers coated with hydrophilic nano coating which has a impaired quality to repair the minute holes and hair pin line cracks which may be a width of about 0.01-2mm,and particularly it is well suited for street roads rather than country roads on increasing its durability to double the span of conventional road.

From this project we have gained practical knowledge towards our project field and the major need of the road maintenance and its solutions which can be given by civil engineers.

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