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An Innovative Concrete Pavement by using Nylon Crystal as a Partial Replacement of Cement

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Abstract: *Transportation is a major developing sector in India, and required for good quality of roads, railway and airways is high. Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. Cement is major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. In the present study an attempt been made on concrete and also an experimental investigation on the concrete using Nylon Crystal.Experimental studies were performed on plain cement concrete and replacement of cement with Nylon crystal is done. In this study the concrete mix were prepared by using Nylon crystal from 1% to soon by weight of cement were added partially to the mixes. A comparative analysis has been carried out for concrete to that of the Nylon crystal reinforced concrete in relation to their compressive strength, split tension strength and flexural strength properties. The concrete made with Nylon crystal performed well in terms of compressive strength, split tension strength and flexural strength showed higher performance at the age of 7, 28, 60 and 90 days than conventional concrete. And also Bond Strength by using cylinders and two different types of acid attack is done to determine the Bond Strength and compressive strength both on conventional concrete and Nylon crystal reinforced concrete.*

Keywords: *Acid Attack, Bond Strength, Compressive strength, Flexural strength, Nylon crystal, Split Tensile strength.*

I. Introduction

Construction industry is one of the major consumers of natural resources and produces quantities of the waste materials. Infrastructure development in the developing countries increased the utilization of aggregate from the quarries leading to depletion of the natural resources. The Coarse aggregate occupies 60-70% of the concrete volume. The rheological and mechanical properties of the aggregate play a vital role in concrete structures. Mineral properties of the aggregate determine the strength and durability properties of the concrete mix. Development of composite concretes using various admixtures increased the strength properties. The utilization of the waste materials reduces the density of the concrete. Scientific methods should be developed for the utilization the various alternate aggregates.According to Indian scenario, India is expected to grow with a huge population, which crosses china by the middle of this century. These population growth leads to two effects in which India is going to have unique advantage of having the biggest work force in the coming years and which it leads to large scale developments over the coming years. India has focused on 12th Five Year plan on the growth of infrastructural facility such as roads and highways, railways, ports, power, communication, etc., and also investment of the order US 1 trillion is envisaged for this sector during the 12th plan. As we all know that concrete is the single most material that is used in this endeavor.Concrete is defined as any solid mass made by the use of a cementing medium; the ingredients generally comprise sand, gravel, cement and water. That the mixing together of such disparate and discrete materials can result in a solid mass with well-defined properties, is a wonder in itself. Concrete has been in use as a building material for more than hundred and fifty years. Its success and popularity may be largely attributed to

(1) Durability under hostile environments
(2) Ease with which it can be cast into a variety of shapes and sizes.
(3) Its relative economy and easy availability.

The main objective of this paper is to examine the physical properties of coarse aggregate, fine aggregate and cement. Investigate the mechanical properties of concrete by adding Nylon Crystal in concrete mix then find the optimum percentage of Nylon Crystal to be added in concrete in relation to their mechanical properties and determine the special mechanical properties using acid attack and bond strength on conventional concrete and Nylon reinforced crystal. Dr. Suji D[1] determines Bituminous mixes are most commonly used all over the world in flexible pavement construction. These industrial wastes occupies large amount of space around plants throughout the country. Various percentages (0, 25, 35, 40, 50 and 75%) of Foundry sand were used, and

the proposed mix designs for bituminous concrete mix were conducted in accordance with Marshall Mix design. The experimental results revealed that the addition of Foundry sand has a significant improvement on the properties of bituminous concrete mix. Deepak R[2] observes Steel Slag is a co-product of the steel industry and can be used potentially as a sustainable construction material in bituminous mix with proper mix design. Based on Intensive laboratory testing program, the characteristic properties of steel slag were assessed to determine its suitability to be used in the bituminous mix. Four different percentages (0, 25, 50, 75 and 100%) of steel slag aggregate were used and experiment results revealed that the addition of steel slag has a significant improvement on the properties of bituminous concrete mix.

II. Experimental Study

2.1 Material Used

1) Cement

- Specific gravity of cement used is 3.16.
- Fineness of cement is 92.3%.
- The initial setting time of the cement used is 51 minutes. > 30 minutes
- The final setting time of cement is 5hours 20 minutes.< 10 hours

2) Fine Aggregate

This material which passes through BIS test sieve number 4 (4.75mm) is called as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates.

- Specific gravity of fine aggregate is 2.74
- Sieve Analysis was conducted to the fine aggregate which shows the sand belong to zone III as per IS: 383-1917.

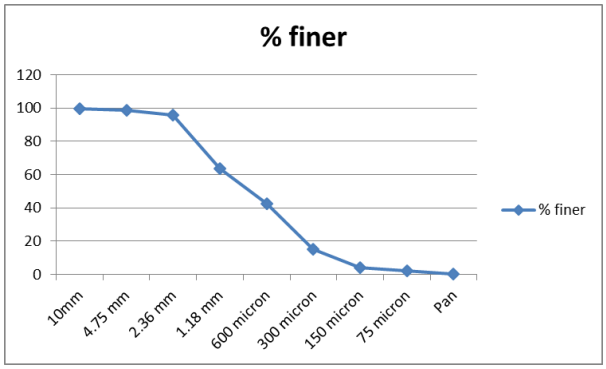

Fig 1. Sieve analysis graph for fine aggregate

3) Coarse Aggregate

The material which is retained on BIS test sieve number greater than 4.75mm size of aggregate is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20mm was used.

Table 1 specific Gravity Of Aggregates

Size	Specific gravity
20mm	2.64
10mm	2.57

- Average impact value of aggregate sample = 21.43%
- Average abrasion value of aggregate sample =15.82%
- Average crushing value of aggregate sample = 19.81%.

4) Nylon Crystal

Properties of Nylon Crystal:

- Strength – Good tenacity, strongest textile fiber, excellent abrasion resistance.
- Elasticity – Good elasticity, high elongation and excellent recovery.
- Resilience – Retains smooth appearance and wrinkles from daily activities.
- Drapability – Excellent draping qualities. Light weight sheer nylon has high draping quality. Medium weight can drape very nicely.

- Structure – Normal cross section is circular.
- Density – 1.14 g/cc (light weight)
- Effect of sunlight - Fair resistance to sunlight

Fig 2. Nylon Crystal

2.2 Mix Design

All the concrete mixes in the project are prepared as per IS: 10262-2009.This standard was first prepared in the year 1982 and later revised in the year 2009.This Indian standard was adopted by the Bureau of Indian standards, after the draft finalized by the cement and the concrete sectional committee has been approved by the civil engineering division council.

haracteristic Comp. Strength required in the field at 28 days is 50Mpa

Max. size of aggregate=20mm

Type of exposure is Mild.

III. Test And Results

3.1 Experimental Test

3.1.1 Compressive strength

The compressive strength of a material is that value of uni-axial compressive stress reached when the material fails completely. The cubes are then tested between the loading surfaces of the compressive testing machine of capacity 2000KN in such a way that the smooth surface directly receives the load and it is applies until the failure of the load. The compressive strength is determined by the ratio of failure load to the cross sectional area of the specimen.

$$f_c = \frac{failure\ load}{cross\ sectioal\ area}$$

Fig.3 Testing of Cube Specimens

3.1.2 Split tensile strength

The resistance of a material to a force tending to tear it apart, measured as the maximum tension the material can withstand without tearing. Tested by keeping the cylindrical specimen in the compressive testing machine and is continued until failure of the specimen occurs.

Splitting Tensile Strength shall be calculated by using the formula:

$$f_{ct} = \frac{2P}{\pi ld}$$

P = maximum load in Newtons applied to the specimen,

L = length of the specimen in mm,

D = cross sectional dimension of the specimen in mm.

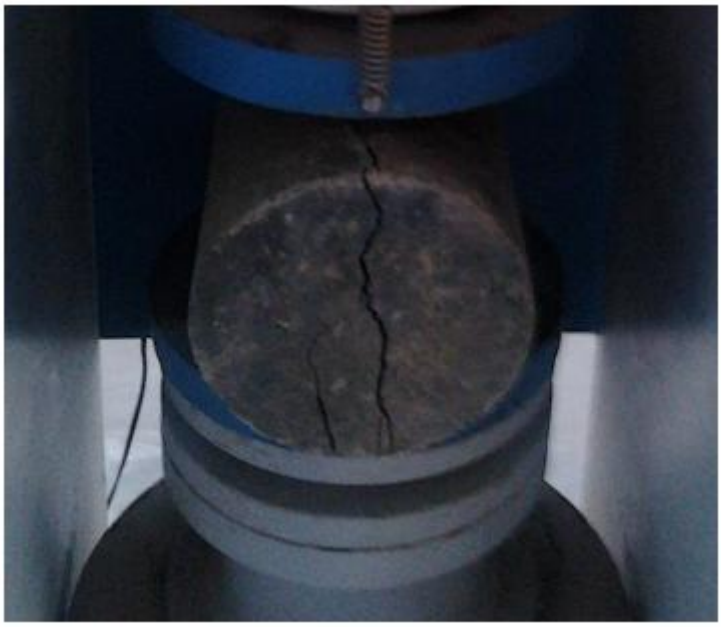

Fig 4 Testing of Cylindrical Specimens

3.1.3 Flexural Strength

The flexural strength may be expressed as the modulus of rupture f_b, which, if "a" equals the distance between the line of fracture and the nearer support, measured on the centre line of tensile side of the specimen, shall be calculated to the nearest 0.5kg/sq.cm as follows:

Where
b=measured width in cm of the specimen
d=measured depth in cm of the specimen.
l= length in cm of the span in which the specimen was supported and
p=maximum load in kg applied to the specimen.

Fig 5 Testing of Prism Specimens

3.1.4 Durability Tests

- Acid Exposure

Hydrochloric acid (HCL) of 1% concentration was considered to be representative of aggressive sewer environments and 1% Hydrochloric acid (HCL) solution has been used in many laboratory tests to investigate the acid resistance of concretes for sewer structures. Concrete cube 15 × 15 × 15 cm samples were immersed in 1% Hydrochloric acid solution over 28, 60 and 90 days and the samples were regularly investigated by visual inspection of surface deterioration, measuring mass change and testing load bearing capacity in compression.

Fig 6 Specimens of Acid Exposure

- Sulphate Exposure

In this study, Sodium sulphate,Na_2SO_4 1% by mass of water solution is prepared .The compressive strength of cube specimens with dimensions of 15 × 15 × 15 cm which were prepared by the substitution of quartzite by coarse aggregate by weight were determined after the specimens were kept in 1% Na_2SO_4 Sulphate solution. Then, the specimens were placed into sulphate solution and kept there for 28, 60 and 90 days. The specimens were removed from sulphate solution after 28, 60 and 90 days, and then, the compressive strength and mass losses of the specimens were determined.

Fig 7 Specimens of Sulphate Exposure

3.1.5 Bond strength

- A hollow hydraulic machine with maximum loading capacity of 30 ton was needed to perform cement bond tests
- The load was applied with a rate of 2KN/sec and distributed on the specimen surface by a square plate with size of 20cm and a hole at the centre.
- Bond stress is calculated as average stress between the reinforcing bar and the surrounding concrete along the embedded length of the bar.
- For uniform bond ,the bond stress S can be expressed as:

$$S= P_{max}/(\Pi *L*D)$$

Where P_{max} = Maximum load applied
L = length of the specimen
D= diameter of the specimen

Fig 8 Bond strength Testing Machine

Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength, Split tensile strength, flexural strength requirements, Durability Test and Bond strength. The different tests were conducted in the laboratories as shown in below.

3.2 Mechanical Characteristics of Nylon Crystal in Concrete

3.2.1 Compressive Strength of Nylon Crystal in Cube Specimens

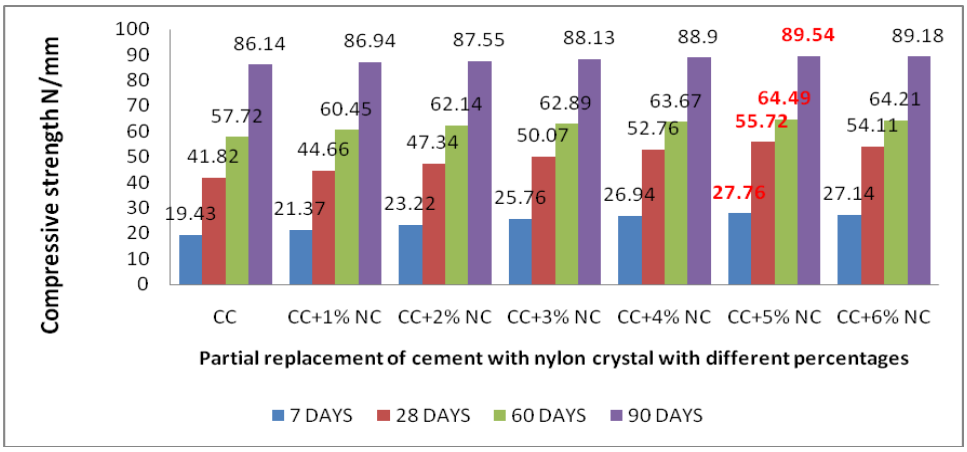

Fig 9 Compressive strength values of C.C and Nylon Crystal at 7, 28, 60 and 90 Days

3.2.2 Split Tensile Strength of Nylon Crystal in Cylinder Specimens:

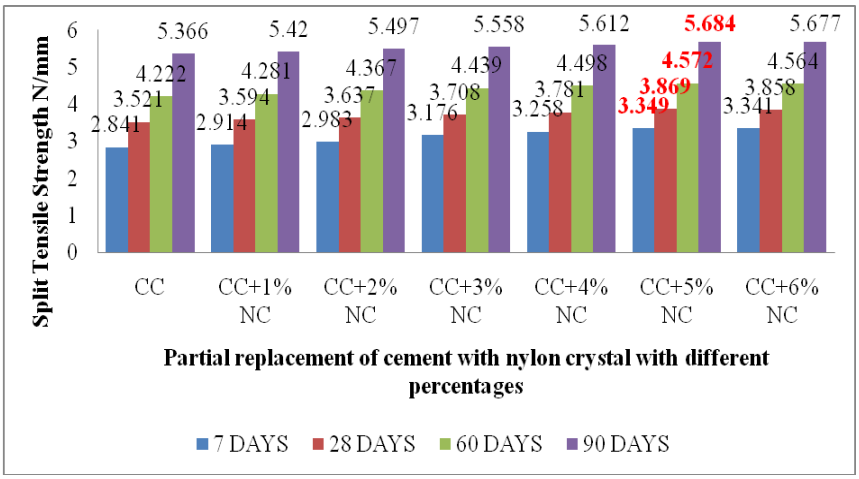

Fig 10 Split tensile strength values of C.C and Nylon Crystal at 7, 28, 60 and 90 Days

3.2.3 Flexural Strength of Nylon Crystal in Prism Specimens:

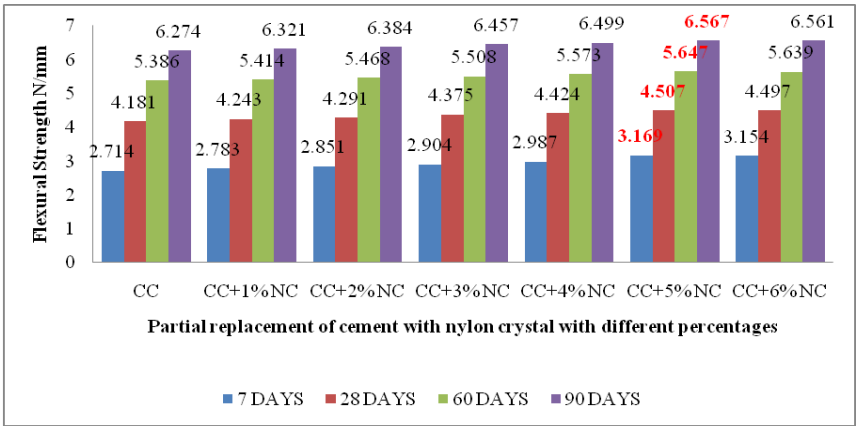

Fig 11 Flexural strength values of C.C and Nylon Crystal at 7, 28, 60 and 90 Days

3.3 Acid Attack on Concrete

3.3.1 Compressive Strength of Nylon Crystal in Cube Specimens with HCL

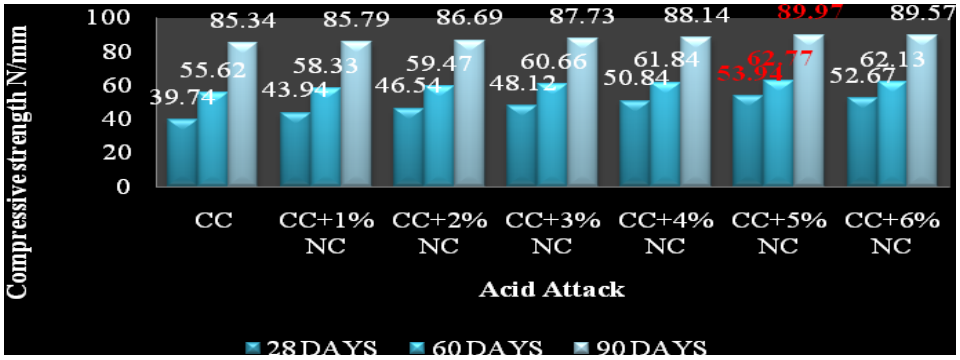

Fig 12 Compressive strengths of Nylon Crystal cube specimens with HCL

3.3.2. Compressive Strength of Nylon Crystal in Cube Specimens with Na_2SO_4

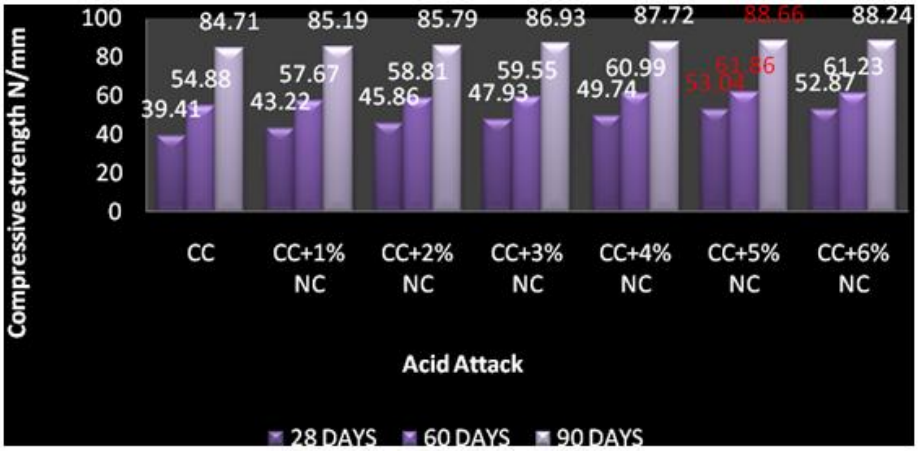

Fig 13 Compressive strengths of Nylon Crystal cube specimens with Na_2SO_4

3.4 Bond Strength on Concrete

3.4.1 Split Tensile strength of Nylon Crystal in Cylinder Specimens

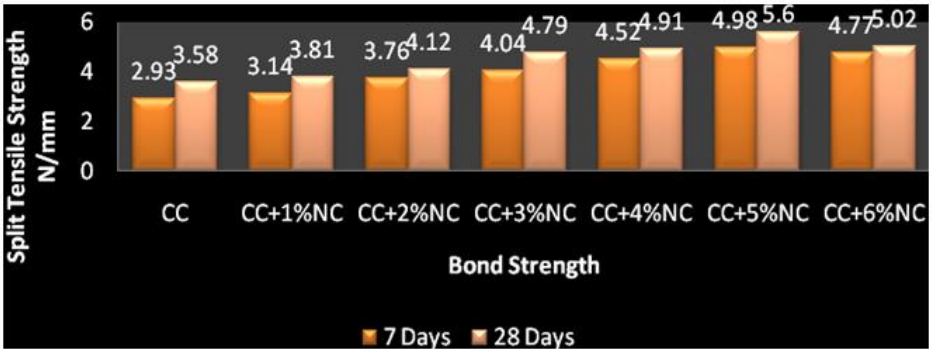

Fig 14 Bond strength of Nylon Crystal Cylinder Specimens

IV. Conclusion

1. It is observed that the concrete slump values are decreasing with the increasing Nylon Crystal percentage. The reduction in slump with the increase in the Crystal will be attributed to presence of Crystal which causes obstruction to the free flow of concrete.
2. It is observed that the optimum dosage of Nylon Crystal is 5%.
3. It is observed that the compressive strength of the concrete increases to 6.79%, 13.19%, 19.72%, 26.15%

and 33.23% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 28 days.

4. It is observed that the compressive strength of the concrete increases to 0.92%, 1.63%, 2.31%, 3.20% and 3.94% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 90 days.
5. It is observed that split tensile strength of the concrete increases to 2.07%, 3.29%, 5.31%, 7.38% and 9.88% when % of Nylon crystal increases from 1%, 2%, 3%, 4% and 5% for NCRC when it is compared with conventional concrete at 28 days.
6. It is observed that the Split tensile strength of the concrete increases to 1.11%, 2.42%, 3.54%, 4.58% and 5.97% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 90 days.
7. It is observed that flexural strength of the concrete increases to 1.43%, 2.63%, 4.54%, 5.74% and 7.65% when % of Nylon crystal increases from 1%, 2%, 3%, 4% and 5% for NCRC when it is compared with conventional concrete at 28days.
8. It is observed that the flexural strength of the concrete increases to 0.79%, 1.75%, 2.87%, 3.50% and 4.62% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 90 days.
9. During HCL acid attack on concrete it is observed that the compressive strength of the concrete increases to 4.87%, 6.92%, 8.95%, 9.06% and 12.85% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 60 days.
10. During HCL acid attack on concrete it is observed that the compressive strength of the concrete increases to 0.52%, 1.58%, 2.80%, 3.28% and 5.42% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 90 days.
11. During Na_2SO_4 acid attack on concrete it is observed that the compressive strength of the concrete increases to 5.08%, 7.16%, 8.50%, 11.13% and 12.71% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 60 days.
12. During Na_2SO_4 acid attack on concrete it is observed that the compressive strength of the concrete increases to 0.56%, 1.27%, 2.62%, 3.55% and 4.66% when % of Nylon crystal increases from 1%,2%,3%,4% and 5% for NCRC when it is compared with conventional concrete at 90 days.
13. It is observed that the Bond Strength of Split Tensile strength of Nylon Crystal in Cylinder Specimens of the concrete increases to 3.58%, 3.81%, 4.12%, 4.79%, 4.91%, 5.6%, 5.02% when % of Nylon crystal increases from 1%, 2%, 3%, 4%, 5% for NCRC when compared with conventional concrete at 28 days.
14. It is observed that bond strength of the concrete increases to 0.06%, 0.15%, 0.33%, 0.37% and 0.44% when % of Nylon crystal increases from 1%, 2%, 3%, 4% and 5% for NCRC when it is compared with conventional concrete at 28 days.

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