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Study on the Mechanical Properties of Ultra High Strength Concrete with Water Soluble Polymer on Partial Replacement of Quarry Dust as Fine Aggregate

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***Abstract:** This project presents the effects of water soluble polymer, p- Phenylene Diamine with partial replacement of Quarry dust as fine aggregate on the mechanical properties of ultra-high strength concrete. The concrete cubes having 28 days more than 100MPa will be termed as ultra-high strength concrete. The inclusion of polymer in the ultra-high strength concrete, modifies the properties of resulting concrete mixes. The replacement of quarry dust with natural sand also favours economic without altering its properties. In this study concrete mixes are proportioned by ACI method of mix design. The concrete mix was prepared by replacing cement with silica fume, natural sand with quarry dust and super plasticizer to increase workability. The concrete cubes are casted with varying percentages of quarry dust with replacing natural sand. Water soluble polymer, p-Phenylene Diamine of 5% by weight of cement and super plasticizer of 2% by the weight of cement were added during the mixing of concrete. The concrete cubes are casted and test on 7 and 28 days to compute the compressive strength. Split tensile strength of this concrete mixes also tested at its respective ages. It is found that the increase in compressive and split tensile strength is achieved with the increase in the percentage of quarry dust and then the value decreases towards higher values of replacement.*

Keywords: *Ultra high strength concrete, p- Phenylene Diamine, Quarry dust, Compressive strength, Split tensile strength*

I. INTRODUCTION

A. Ultra High Strength Concrete

In the past several years, improvements have been occurring in concrete technology. Sustainable use of supplementary materials and revolutionary developments in super plasticizing admixtures has facilitated improvements in the mechanical properties and durability of concrete. For example, researchers are using silica fume and high range water reducing admixtures to produce high density concrete. In addition to the use of mineral and chemical admixtures, applying pre-setting pressure and using post setting heat treatment can also be used to produce dense microstructure. In addition to high strength, the concrete should exhibit greater durability characteristics. This means that the concrete should be high strength and high performance. One of the materials developed in recent years is ultra high strength concrete (UHSC) also known as reactive powder concrete (RPC). This material possesses a compressive strength greater than 21,750 psi (150 MPa). The concept of RPC was first 2010 Concrete Sustainability Conference 2 © National Ready Mixed Concrete Association developed by Richard and Cheyrezy (1994) and was first produced in the early 1990s by researchers at Bouygues' laboratory in France (Dili and Santhanam 2004). This new material is usually produced with cement, fine quartz sand, silica fume, steel fibres and high range water reducing admixture (HRWRA). Very low water-to-cementitious materials ratios are used to produce this kind of concrete. This material differs from conventional concrete not only in terms of strength, but also in terms of durability. UHSC is more durable because the low water-to-cementitious materials ratio results in very low porosity. The possibility of achieving high strength, durability, and improved ductility with the use of ultra high strength concrete encourages researchers and engineers to use this modern material in many practical applications like nuclear waste containment structures, high rise structures, long span bridges, and walkways. In the present research, an attempt has been made to develop UHSC mixtures with locally available materials. The materials used in this work included Type I/II Portland cement, silica fume, fine sand (passing ASTM No. 30 sieve), coarse aggregates, polymers and HRWRA. Mixtures with and without polymers were prepared and tested to study the effects of polymers on compressive strength and tensile strength.

B. Polymers In Concrete

Polymer concrete is a composite material in which the aggregate is bound together in a matrix with a polymer binder. The composites do not contain a hydrated cement phase, although Portland cement can be used as an aggregate or filler.Polymer concrete may be used for new construction or repairing of old concrete. The adhesive properties of polymer concrete allow repair of both polymer and conventional cement-based concretes. The low permeability and corrosive resistance of polymer concrete allows it to be used in swimming pools, sewer structure applications, drainage channels, electrolytic cells for base metal recovery, and other structures that contain liquids or corrosive chemicals. It is especially suited to the construction and rehabilitation of manholes due to their ability to withstand toxic and corrosive sewer gases and bacteria commonly found in sewer systems. Unlike traditional concrete structures, polymer concrete requires no coating or welding of PVC-protected seams. It can also be used as a bonded wearing course for asphalt pavement, for higher durability and higher strength upon a concrete substrate. Polymer concrete has historically not been widely adopted due to the high costs and difficulty associated with traditional manufacturing techniques. However, recent progress has led to significant reductions in cost, meaning that the use of polymer concrete is gradually becoming more widespread.

II. MATERIALS USED

A. Cement

The Bureau of Indian Standards (BIS) has classified OPC in three different grades. The classification is mainly based on the compressive strength of cement–sand mortar cubes of face area 50 cm2 composed of 1 part of cement to 3 parts of standard sand by weight with a water-cement ratio arrived at by a specified procedure. There are 33 grade, 43 grade, 53 grade, the grade number indicates the minimum compressive strength of cement sand mortar in N/mm2 at 28 days. As per IS 4031-1988 the different laboratory tests were conducted on cement to determine the standard consistency, initial and final setting time and compressive strength. In this project Ordinary Portland Cement of 53 grade is used.

B. fine aggregate

Aggregate which is passed through 4.75 mm IS sieve and retained on 75 micron (0.075 mm) IS sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. Ordinary river sand conforming IS 383-1970 was used in this project.

C. Quarry Dust

For our construction field sand is an important one. River sand is most commonly used for making concrete. Nowadays, because of growing construction field, the sand becomes demand. This results in sand scarcity. So we forced to find substitution for sand. At the same time the dust form crushes dump the crushed stone dust in ground. According to crushers, crushed stone dust is waste materials.The dumping of crushed material's disposal makes ground pollutions and also environmental problems. Not only for demand of sand but also have had we taken sand from river bed. It is excess sand mining resulting in depletion of ground water, creating environmental problems. If we can use this crushed stone dust, is making by either in partly or in fully replacement of natural river sand, then this will not only save the cost of construction but also the problem of disposal of quarry dust.

D. Coarse Aggregate

The coarse aggregate for the works should be river gravel or crushed stone. Angular shape aggregate of size is 25 mm and below. The aggregate which passes through 75 mm sieve and retain on 4.75 mm sieve are known as coarse aggregate. It should be hard, strong, dense, durable, clean, dry and free from clay or loamy admixtures or quarry refuse or vegetable matter. Aggregate should be properly screened and if necessary washed clean before use. Coarse aggregate containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregate should be as per specifications of IS 383-1970. In this project, coarse aggregate of 25 mm was used as the normal maximum size.

E. Silica Fume

Silica fume also known as micro silica is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine material with spherical particles less than 1 µm in diameter which is approximately 100 times less than the average cement particle. Because of its extreme fineness and high silica content, it is added to concrete to improve its properties, in particular its compressive strength, bond strength, abrasion resistance and durability. It also reduce bleeding and permeability. So that it protects the reinforcing steel of concrete from

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corrosion.

F. Water

The water should fit for mixing. The water should not have high concentration of sodium and potassium and there is a danger of alkali-aggregate reaction. Natural water that are slightly acidic or harmless, but water containing organic acids may adversely affect the hardening of concrete. Such water as well as highly alkaline water should be tested. The water should conform to IS 456-2000 standards. Generally, water satisfactory for mixing is also suitable for curing purposes. However, it is essential that curing water should be free from substances that attack hardened concrete like free CO_2 etc.

G. Super Plasticizer

Super plasticizers are technically called as High Range water Reducer. The super plasticizers can reduce the water content of about 15%-40% without reduction in the workability of the concrete. Some of the super plasticizers sulphonated napththalene formaldehyde, Acrylic polymer based, Poly carboxylate ester, Poly carboxylate Ether (PC) and so on. In this project, Poly carboxylate Ether is used as the Super Plasticizer.

H. P-Phenylene Diamine Polymer

p-Phenylene diamine polymer is an organic compound with formula C6H4(NH2)¬2. This derivative aniline is a white solid, but samples can darken due to air oxidation. It is mainly used as a component of engineering polymers and composites. The p-Phenlyene diamine polymer gives a better strength, corrosive resistance, fast curing, etc., for concrete. Because of these it can be used in new or repair construction.

I. Preparation Of Polymer

1) Chemicals Needed

a) p-Phenyl diamine

b) Concentrated HCl

c) P-toluene sulphuric acid

d) Ammonium per sulphate

e) Sodium chloride

f) Solution preparation

g) p-phenylene diamine solution:

162g of p-phenylene diamine salt is taken and is mixed with 200 ml of distilled water and 2 ml of HCl. This mixture is stirred well until a clear solution is obtained.

2) p-toluene sulphuric acid: .804g of p-toluene sulphuric acid salt is mixed with 200 ml distilled water. This mixture is stirred well until a clear solution is obtained.

3) *Ammonium per sulphate solution:*4.562g of ammonium per sulphate is taken and mixed with 200 ml of distilled water.

J. Polymer preparation

1) A 2litre beaker is taken and is kept in freezing mixture(sodium chloride + ice cubes)

2) The solutions p-phenylene diamine and p-toluene sulphuric acid solutions are added to beaker and it is stirred for 10 minutes Then the solution ammonium per sulphate solution is added to mixture and it is stirred for about two hours. After that polymer named “poly para phenylene diamine” is obtained. It is water soluble and has concentration of 3605 ppm.

3) From the obtained above solution 100 ml is taken and is mixed with 600 ml of distilled water. The resulting polymer solution has a concentration of about 500 ppm The optimum amount of polymer has 5% to be added to the concrete by replacement of water. Figure 1 shows the preparation of polymer.

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Fig.1. Polymer Preperation

III.MIX DESIGN

A. Mix Methodology

The Indian code has provided the mix design procedure for up to the grade of M55. Hence, the mix proportioning is done based on American Concrete Institute (ACI 211.1-91) recommendations. The high performance concrete (M100) is achieved by having low water-cement ratio.The mix ratio is shown in table 1.

TABLE 1 MIX RATIO

WATER Kg/m^3	CEMENT Kg/m^3	FINE AGGREGATE Kg/m^3	COARSE AGGREGATE Kg/m^3
193	772	482.3	923.4
0.25	1	0.63	1.19

B. Compressive Strength Test

One of the most important properties of the hardened concrete is its strength which represents the ability if concrete to resist forces. If the nature of the force is to produce compression the strength is termed as compressive strength. Cubes of size 150 mm were casted and shown in figure 2.The compressive strength test for cubes was conducted in compression testing machine as per IS 516:1964. The automatic Compression Testing machine is shown in figure 3. The cubes were tested in compressive testing machine(Fig.4) at the rate of 140 Kg/cm^2/min and the ultimate loads were recorded. The bearing surface of machine was wiped off clean and the surface of the specimen was cleaned. The specimen was placed in machine in such a manner, load was applied to opposite sides of the cubes such that casted side of specimen was top and bottom. The axis of the specimen was carefully aligned at the centre of loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and longer can be sustained. Maximum load applied on specimen was recorded. Compressive strength of cubes at 7 days and 28 days.

Compressive Strength = (Compressive load)/(Contact area)

The tested cubes are shown in fig.5

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Fig.2. Casting of cubes

Fig.3. Automatic Compression Testing Machine

Fig.4. Testing of Cubes

Fig.5 Tested cube Specimen

C. Split Tensile Test

It is the standard test, to determine the tensile strength of concrete of concrete in an indirect way. This test could be performed in accordance with IS: 5816-1970.A standard test cylinder of concrete specimen (300mm x 150mm diameter) is placed between the loading surfaces of Compression Test Machine (Figure.6). The Compression load is applies diametrically and uniformly along the length of cylinder until the failure of the cylinder along the vertical diameter. To allow the uniform distribution of this applied load and to reduce the magnitude of the high compressive stresses near the points of application of this load, strips of plywood are placed between the specimen and loading platens of the testing machine. Concrete cylinders split into two halves along this vertical plane due to indirect tensile stress generated by Poisson's effect.Due to this compressive loading, an element lying along the vertical diameter of the cylinder is subjected to a vertical compressive stress and a horizontal stress. The loading condition produces a high compressive stress immediately below the loading points. But the larger portion of the cylinder, corresponding to its depth is subjected to uniform tensile stress acting horizontally. It is estimated that the compressive stress is acting for about 1/6 depth and the remaining 5/6 depth is subjected to tension due to Poisson's effect. Assuming concrete specimen behaves as an elastic body, a uniform lateral tensile stress of ft acting along the vertical plane causes the failure of the specimen, which can be calculated the formula as,

$$f_t = 2P/\pi DL$$

Where,

P = Compressive load at failure

L = Length of the cylinder

D = Diameter of cylinder

The tested specimens are shown in fig.7.

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Fig.6. Testing of Cylinder for split tensile strength


Fig.7. Tested specimen

IV. RESULT AND DISCUSSION

The compressive strength of the concrete mixes increases gradually from 0% to the 40% replacements of Quarry dust with the River Sand, which yields the higher strength of 110.81 MPa and the compressive strength value gradually decreases towards 100% replacement. The 100% replacement of Quarry dust results in poorer strength when compared to concrete with 100% river sand at 28 days strength value. Table 2 and 3 shows the compressive strength of concrete at 7 days and 28 days respectively. Figures 8 and 9 shows the graph plotted compressive strength versus percentage of quarry dust at 7 days and 28 days respectively. Fig.10 shows the comparison of 7 days and 28 days compressive strength of concrete.

Concrete cylinders were tested and Split tensile strength of these concrete mixes are found to increases with increase in the replacement percentage upto 40% at attains maximum value of 7.09Mpa and shows same trend as in the compressive strength results. There is 22.14% increase in split tensile strength was achieved when compared to conventional concrete. Table 4 and figure 11 shows the split tensile strength of concrete for varying proportion of quarry dust replacement.

Table 2. COMPRESSIVE STRENGTH OF CONCRETE CUBES (N/mm^2) – 7 DAYS

% of Quarry Dust	Sample ID	Compressive load (KN)	Average Compressive load (KN)	Compressive Strength (N/mm^2)
0	C-1	1150	1323.33	58.81
	C-2	1270		
	C-3	1550		
10	C-1	1380	1453.33	64.59
	C-2	1500		
	C-3	1480		
20	C-1	1450	1500	66.67
	C-2	1550		
	C-3	1500		
30	C-1	1550	1533.33	68.15
	C-2	1570		
	C-3	1480		
40	C-1	1640	1620	72.00

	C-2	1600		
	C-3	1620		
50	C-1	1600	1503.33	66.81
	C-2	1490		
	C-3	1420		
60	C-1	1380	1430	63.56
	C-2	1420		
	C-3	1490		
70	C-1	1300	1360	60.94
	C-2	1380		
	C-3	1420		
80	C-1	1210	1320	58.67
	C-2	1400		
	C-3	1350		
90	C-1	1280	1243.33	55.30
	C-2	1150		
	C-3	1300		
100	C-1	1280	1196.67	53.19
	C-2	1250		
	C-3	1060		

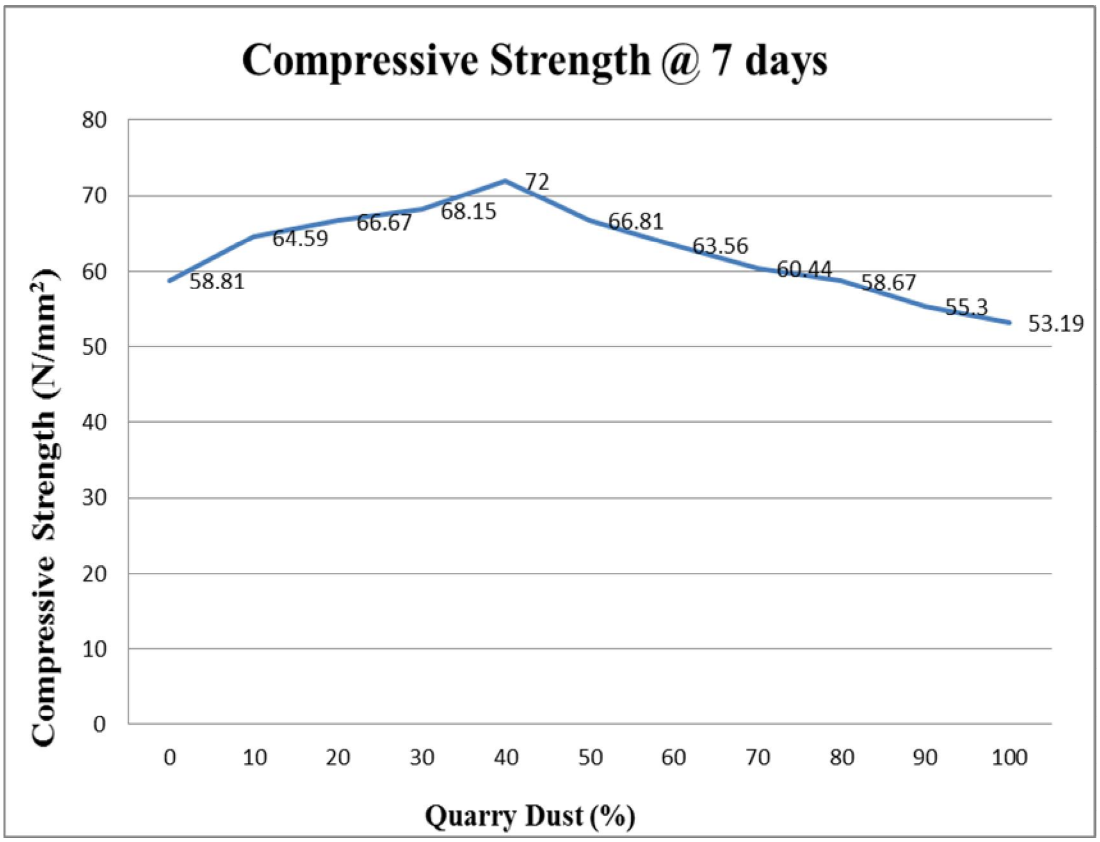

Fig. 8. Compressive strength at 7 days

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Table 3.COMPRESSIVE STRENGTH OF CONCRETE CUBES (N/mm^2) – 28 DAYS

% of Quarry Dust	Sample ID	Compressive load (KN)	Average Compressive load (KN)	Compressive Strength (N/mm^2)
0	C-1	1640	1643.33	73.04
	C-2	1450		
	C-3	1840		
10	C-1	1800	1816.67	80.74
	C-2	1750		
	C-3	1900		
20	C-1	1940	1933.33	85.93
	C-2	1900		
	C-3	1960		
30	C-1	2260	2130	94.67
	C-2	1980		
	C-3	2150		
40	C-1	2470	2493.33	110.81
	C-2	2590		
	C-3	2420		
50	C-1	2040	2160	96
	C-2	2280		
	C-3	2160		
60	C-1	1950	1963.33	87.26
	C-2	1890		
	C-3	2050		
70	C-1	1750	1753.33	77.93
	C-2	1680		
	C-3	1830		
80	C-1	1740	1673.33	74.37
	C-2	1690		
	C-3	1590		
90	C-1	1760	1570	69.78
	C-2	1450		
	C-3	1500		
100	C-1	1550	1440	64
	C-2	1400		
	C-3	1370		

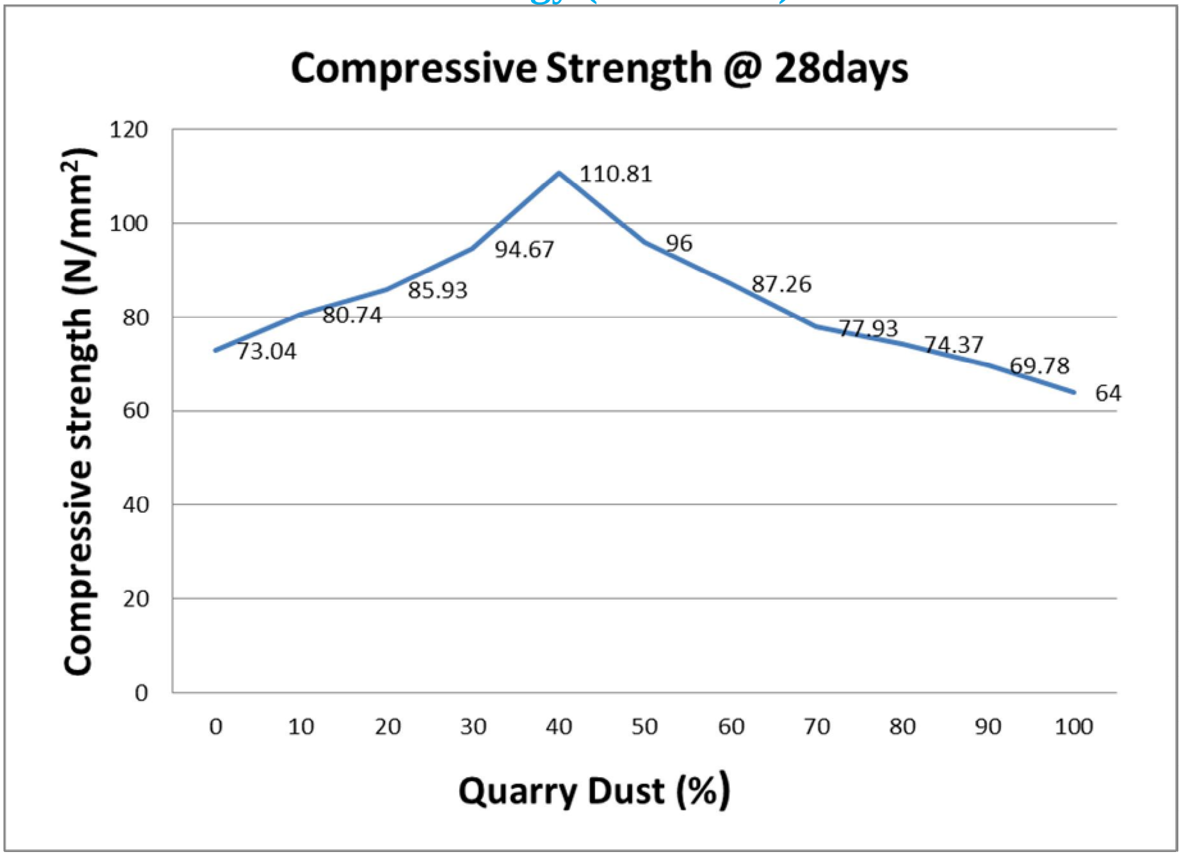

Fig. 9. Compressive strength at 28 days

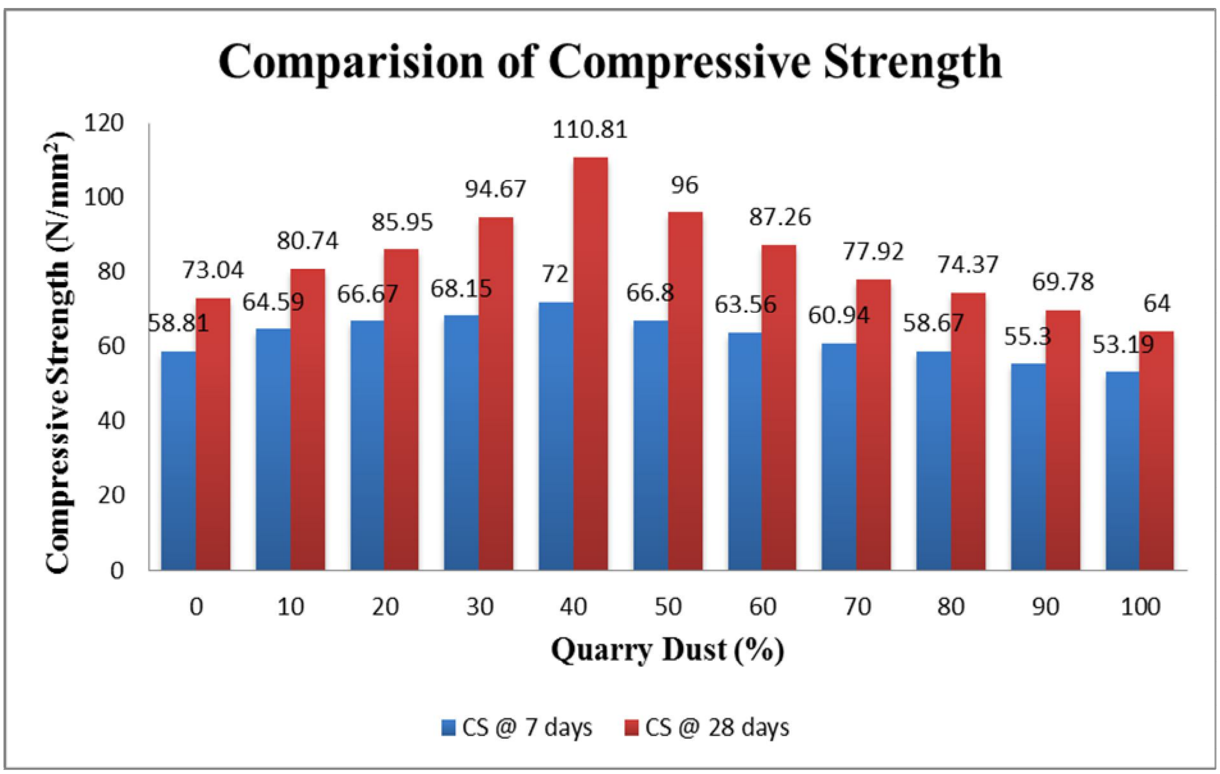

Fig. 10. Compressive strength at 7 days and 28 days

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TABLE 4. SPLIT TENSILE STRENGTH AT 28 DAYS

% of Quarry Dust	Sample ID	Tensile load (KN)	Average Tensile load (KN)	Tensile Strength (N/mm^2)
0	C-1	396	390	5.52
	C-2	390		
	C-3	384		
10	C-1	410	420	5.94
	C-2	430		
	C-3	420		
20	C-1	428	450.33	6.37
	C-2	458		
	C-3	465		
30	C-1	488	478.67	6.77
	C-2	478		
	C-3	470		
40	C-1	562	501.33	7.09
	C-2	492		
	C-3	510		
50	C-1	456	469	6.63
	C-2	485		
	C-3	466		
60	C-1	405	421.67	5.96
	C-2	420		
	C-3	440		
70	C-1	406	402.33	5.69
	C-2	415		
	C-3	416		
80	C-1	388	378	5.35
	C-2	375		
	C-3	371		
90	C-1	358	366	5.18
	C-2	372		
	C-3	368		
100	C-1	359	353	4.99
	C-2	348		
	C-3	352		

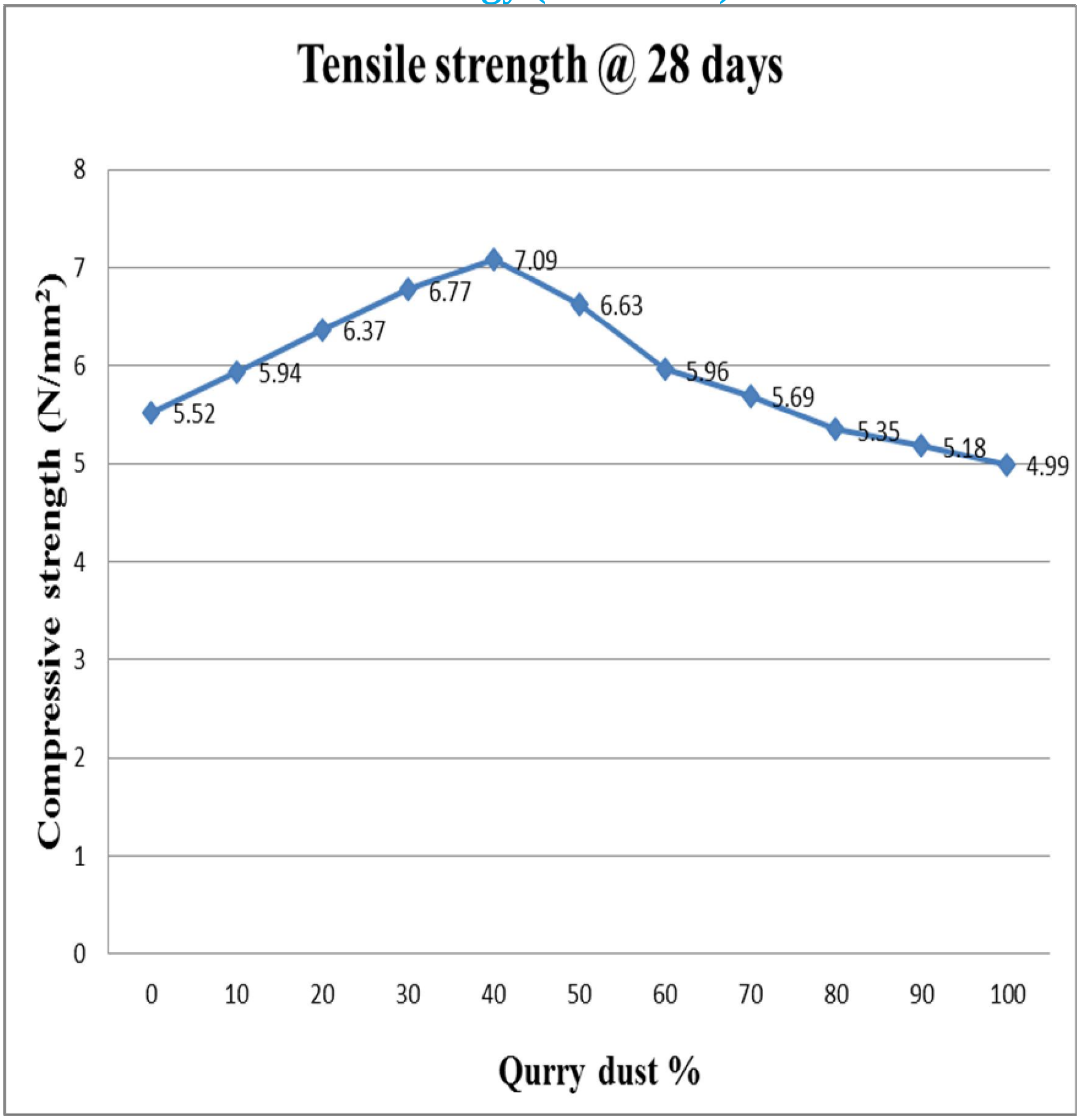

Fig. 11. Split tensile strength at 28 days

V. CONCLUSIONS

The following are the conclusions made from this experiment.

It is found that there is a gradual increase in compressive strength of High Strength Concrete with water soluble polymer is achieved with the increase in Quarry dust percentage up to 40% replacement with river sand.

There is a 34.09% increase in the compressive strength is achieved when compared to the conventional concrete, which is 0% Quarry dust. The trend in increase in the compressive as well as split tensile strength was steep at the same time the decreasing trend of this strength was flatter. It shows that increase in the quarry dust content in the river sand may have little effect in decreasing the strength values.

The same trend of gradual increase in split tensile was noticed when the replacement of Quarry dust approaches to 40% increase in split tensile strength was achieved when compared to the control concrete. This may be due to the Quarry dust particles are irregular shape and high rough surface compared to the River Sand which favours better bonding between the concrete particles.

From this study, it is evident that the Quarry dust may be used as effective replacement over the natural River Sand for the production for ultra high strength concrete with polymer up to 40% replacement and it may extended to 100% replacement with River Sand with little comprise in the reduction of compressive strength.

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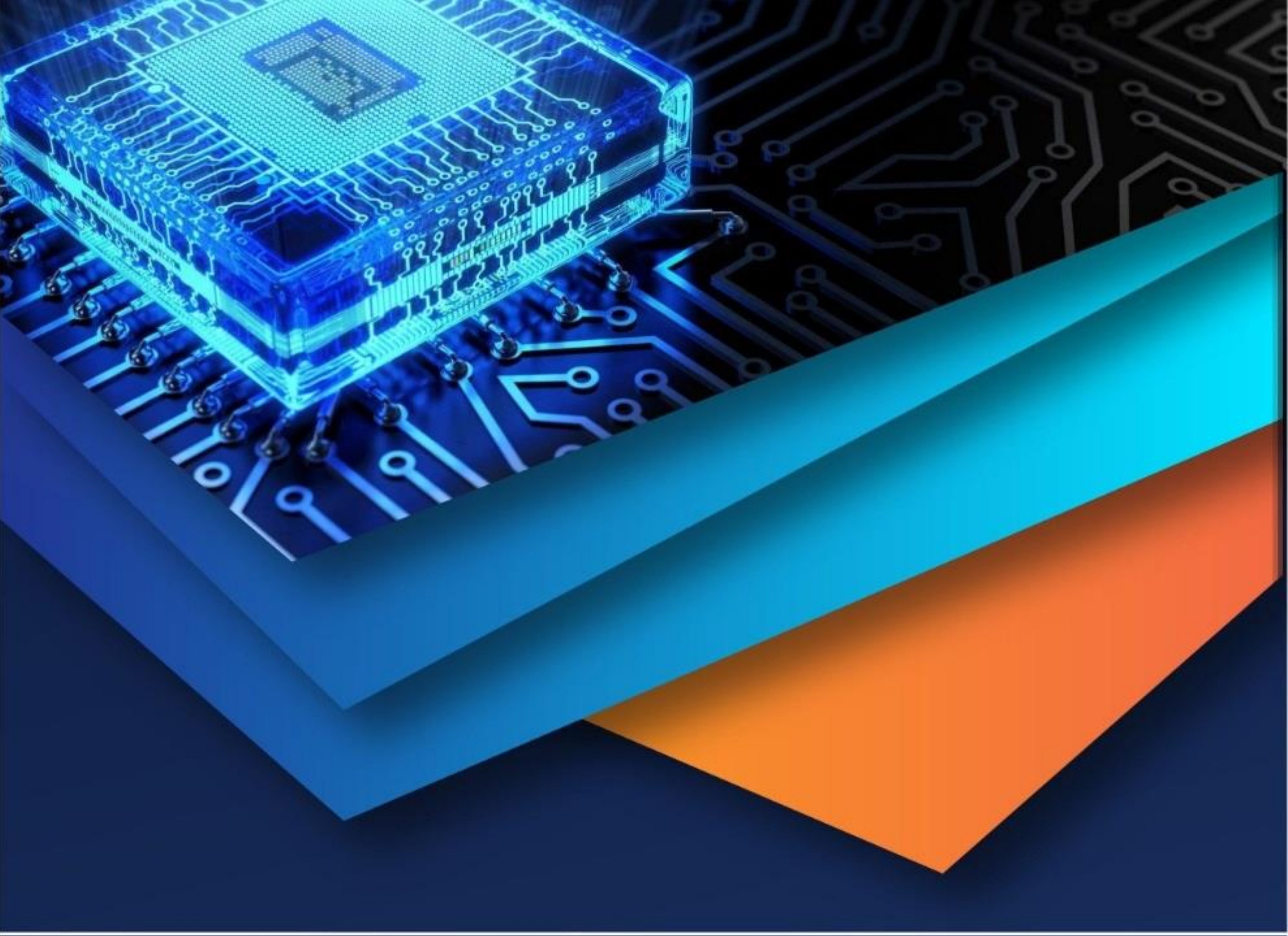

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