Strength Characteristics of Normal Weight Aggregate Concrete with Diatomite Powder as an Admixture

V. Giridhar Kumar, V. Pradeep

Abstract- Diatomite is a naturally available mineral resource material which contains large amounts of amorphous silica and cristabolite. It is available at a low cost in many areas. It provides a viable alternative admixture to cement in concrete. Investigations on concrete with diatomite as partial replacement of cement are presented in this paper. Results show that 28 - day compressive strength of mix with diatomite is 43.5 MPa at 10 percent partial replacement of cement. The mix shows similar trends for the development of split tensile strength as well as flexural strength. The investigations show that diatomite has a good potential as fine aggregate in concrete construction. It not only reduces the cost of construction but also helps to consume natural mineral resource material for few concrete applications .It is also used as a prime filter material for water treatment processes.

Keywords: Diatomite, Pozzolanas, Natural mineral material, Cement replacement, Mechanical properties of concrete.

I. INTRODUCTION

The strength characteristics of concrete greatly influence the structural behavior of members as well as to achieve economy in civil engineering construction. Both compressive and tensile strength characteristics are named as mechanical properties of concrete. The improvement of mechanical properties as well as reduction in the cost of construction can be achieved by partially replacing cement with alternative materials like Fly ash, Silica fume, Metakaolin and Diatomite powder. Few investigations are carried out with Diatomite powder as partial replacement of cement. Diatomite is a sedimentary rock of biogenic origin. It has high natural silica content in amorphous state (Opal - A). The name of amorphous silica is mainly in the form of diatom frustules. It is in the form of sponge spicules, silicone - flagellate skeletons and/or radiolarian cells. Diatomite powder is characterized as natural pozzolana which has high percent of active silica content. The strength development in concrete is due to the formation of calcium - silicate - hydrates (C-S-H). C-S-H gel is formed by the reaction of SiO_2 with $Ca(OH)_2$ which is formed by the chemical reaction between cementitious compounds and water, called as *hydration* when they mixed with water. Diatomite powder is produced by grinding diatomite rocks and has high surface area similar to cement because of its eased grindability and high siliceous but low calcareous content . The effects of diatomite as an admixture to cement in concretes have been studied in recent years.

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Addition of large quantities of natural pozzolanas decreases the compressive strength of concrete; therefore the optimum quantity is necessary to achieve the maximum compressive strength. Use of diatomite stones increases the compressive strength and makes concrete as light weight, as it has low density.In this study, the effect of use of diatomite powder on the mechanical properties of NWA concrete are examined The aim of this study is to optimize the required amount of diatomite for replacement of cement in the production of concrete with lower water content due to economic and environmental reasons.

Fragoulis ***et al*** had conducted investigations on compressive strength of cement mortar cubes with diatomite powder for partial replacement of cement and concluded that the presence of diatomite in mortars and concrete made high water demand without significant changes in strength characteristics [1]. **Unal** ***et al*** had studied the effects of granulometries of different mineral aggregates along with different cement contents in the production of diatomite - concrete blocks [2].

Stamatakis ***et al*** had demonstrated the use of diatomite as admixture requires high water demand. The cement produced with diatomite exhibits high compressive strength values than referred Portland cement without diatomite [3]

Aruntas has studied the effect of addition of diatomite powder in cement and reported that the addition of diatomite increases the fineness of cement. Diatomite bricks can be used for thermal and acoustic insulation as Diatomite has low thermal conductivity and good insulation properties. [4].

Unal ***et al*** had studied the physical and mechanical properties of lightweight concrete produced with diatomite as Lightweight aggregate. These test results has indicated that lightweight concrete with diatomite reduces the dead load in civil engineering constructions [5].The investigations on the use of diatomite in concrete as an alternative additive for partial replacement of cement for NWA concrete are presented in this paper. Standard concrete cubes (150 x 150 x150 mm), cylinders (150 x 300 mm) and prisms (100x 100 x 500 mm) were tested in the laboratory. The chemical composition of diatomite is also included in ***Table 1*** .

Table 1: Chemical Composition of Portland Cement and Diatomite

Chemical Compound	Portland Cement	Diatomite
SiO_2	24	61.75
Al_2O_3	8	30.30
Fe_2O_3	5	0.90
$CaCO_3$	64	4.80

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$MgCO_3$	0.87	2.02

The strength in direct compression at 7 days and at 28 days and that in split tension and flexure were compared at 7 days and 28 days respectively. The procedure for mixture proportions in accordance with IS 10262: 2009 and SP 23: 1982 using 20 mm aggregate was adopted in the investigations.

II. PHYSICAL PROPERTIES

Tests on physical properties like bulk density, specific gravity, water absorption, fineness modulus, grading were conducted to develop suitable mixture proportioning for the investigations. Sand procured from River Handri and granite stone metal procured from a local granite quarry near Kurnool A.P was used for making concrete. The physical properties of the fine and coarse aggregates used are indicated in Tables 2 and 3 respectively. Sand is falling in Zone I (IS 383: 1970) as per the particle size distribution. The properties should be ascertained to proportion the mix for the concrete quality required. Ordinary Portland cement (OPC) of 53grade, conforming to IS 12269: 1987 were used in the test specimens. Super plasticizer (CONPLAST SP 430) was used as workability agent to get required flowability to the mixes D_O to $D_{2O.}$ The physical properties of fine and coarse aggregates are presented in ***Table 2*** and ***Table 3*** respectively.

Table 2: Properties of Fine Aggregate

Property	**River sand**
Bulk density, kg /m^3	157.0
Specific gravity	2.65
Fineness modulus	3.06
Free surface moisture	0.1 percent
Water absorption	1.0 percent

Table 3: Properties of the Coarse Aggregate

Property	***Value***
Maximum nominal size, mm	20
Bulk density kg / m^3, mm	
Loose state	1450
Compacted state	1530
Specific gravity	2.78
Fineness modulus	6.85
Voids, percent	
Loose state	41
Compacted state	47
Free surface moisture, percent	0.6
Water absorption, percent	0.5

III. CONCRETE MIXTURE PROPORTIONING

Concrete designated as Mixes D_o (control mix) , D_5, D_{10}, D_{15}, D_{20} with river sand as fine aggregate and Diatomite powder as partial replacement of cement at 0 , 5, 10, 15, 20 percentages by weight of cement were used in the investigations and presented in the ***Table 4*** . D_0 represents the concrete mix for control specimens with zero percent diatomite. Normal weight aggregates of 20 mm size were used for all mixes. The mix proportions were based on IS 10262: 1982 and SP 23: 1982 for M 20 grade concrete with a target strength of 26.6 MPa. The values of workability of fresh concrete by slump were comparable(13mm) for all mixes from D_5, D_{10}, D_{15}, D_{20} , so also were the values of compacting factors (0.95) respectively. The ingredients of concrete were thoroughly mixed mechanically by pan mixer till uniform consistency was achieved.

Table 4: Concrete Mix Proportions

Material	Mix Designation (1 : 2.5 : 3.2)				
	D_O (control Mix)	D_5	D_{10}	D_{15}	D_{20}
Cement, kg / m^3	350	350	350	350	350
Diatomite, kg / m^3	0	17.5	35	52.5	70
River Sand, kg / m^3	866	866	866	866	866
Coarse aggregate kg / m^3	1136	1136	1136	1136	1136
Water Cement ratio	0.4	0.4	0.4	0.4	0.4
Slump mm,	10	12	10	15	18
Compaction factor	0.95	0.955	0.94	0.96	0.96

IV. RESULTS AND DISCUSSION

Standard cubes, cylinders and prisms were tested for compressive and tensile strength properties respectively. The specimens were tested after 7 - days and 28 - days of curing and the mean strength values of three specimens were compared.The results of the tests on 150 mm – cubes are indicated in ***Table 5.*** The 28 – day compressive strength was 43.5 MPa for mix D10 (mix with 10 percent diatomite) and the strength of this mix was about 16.6 percent higher than that of control mix D0. The 7 - day strengths have shown similar trends. The results of the compressive strength tests are shown in the F**igure 1.**

Table 5: Compressive Strength of 150 mm Cubes (average of 3 Cubes)

Mix	*Compressive Strength, N / mm^2*		*Percentage increase(+) indicates the percentage increase(-) indicates the percentage decrease.*	
	7 days	28 days	7 days	28 days
D_O	27.2	37.33	-	-
D_5	29.77	41.33	9.44	10.71
D_{10}	31.55	43.55	15.99	16.6

D_{15}	26.6	40.88	- 2.20	9.50
D_{20}	24.4	36.44	-10.29	-2.38

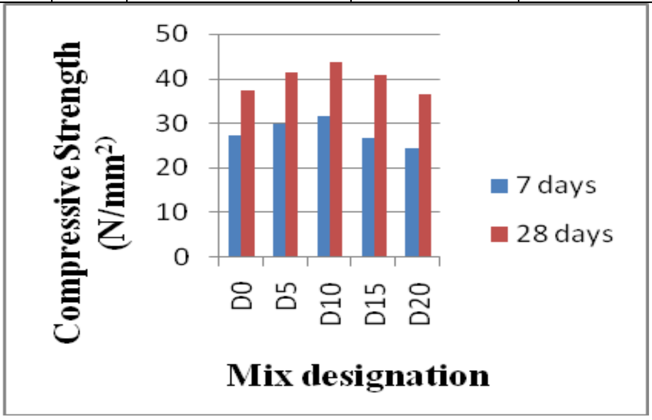

Figure 1: Cube Compressive Strength Tests

Table 6 indicates the results of split tensile strength tests on 150 mm x 300 mm cylinders . Mix D0 showed a 28 – day mean strength of 3.7 MPa while mix D10 developed a mean strength of 4.4 MPa , an increase of 18.9 percent . The 7 – day strength for split tension will also show similar trends in rate of increase of strength. The results of the split tensile strength tests are shown in the **Figure 2.**

Table 6: Split Tensile Strength of 150 x 300 mm Cylinders (Average of 3 Cylinders)

Mix	*Split tensile Strength, N / mm^2*		*Percentage increase(+)indicates percentage increase(-) indicates the percentage decrease.*	
	7 days	28 days	7 days	28 days
D_O	2.405	3.74	-	-
D_5	2.97	3.89	23.49	4.01
D_{10}	3.04	4.45	26.40	18.98
D_{15}	2.75	3.96	14.34	5.88
D_{20}	2.61	3.6	8.52	-3.74

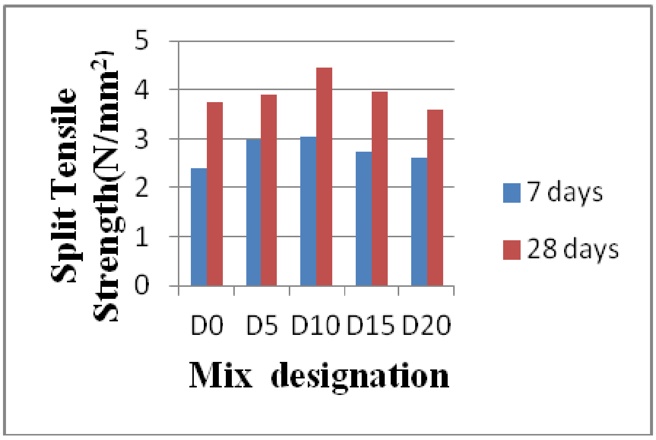

Figure 2: Split Tensile Strength Tests on Cylinders

The flexural strength tests results on prisms 100 x100 x 500 mm prisms for (modulus of rupture) are shown in the ***Table 7*** . The flexural strength of D10 mix was found to be 7.4 MPa with a rate of increase of 34 percent when compared to the control specimens with a flexural strength of 5.5 MPa.

Table 7: Flexural Tensile Strength of 100 x 100 x 500 Prisms (Average of 3 Prisms)

Mix	*Tensile Strength, N / mm^2*		*Percentage increase(+) indicates the percentage increase (-) indicates the percentage decrease*	
	7 days	28 days	7 days	28 days
D_O	3.92	5.52	-	-
D_5	5.12	6.8	30.61	23.18
D_{10}	6.8	7.4	73.46	34.05
D_{15}	5.68	6.36	44.89	15.21
D_{20}	5.12	5.36	30.61	-2.89

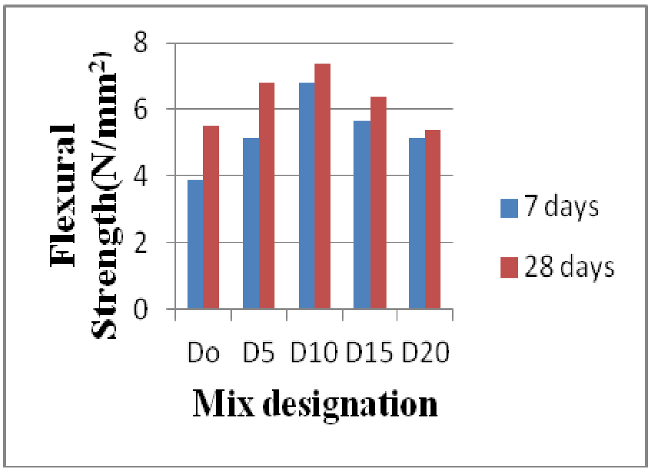

Figure 3: Flexural Tensile Strength Tests on Prisms

It can be seen that Mix D10 with 10 percent diatomite replacement had shown comparatively consistent higher strengths in direct compression, split tension and flexure than control mix without diatomite. Mixes with higher percents of diatomite replacement had shown lower strengths which indicates that 10 percent diatomite replacement to cement is the optimum percent for consistent higher strength .

V. EFFECTS OF DIATOMITE REPLACEMENT

Chemical composition of diatomite were compared with those of Portland cement in ***Table1.*** Both Portland cement and diatomite mainly composed of calcia and silica respectively. The compressive strength of mixes increased with age. The compressive strength development of concrete with diatomite percent is related to the cement replacement level and curing age. It was observed that the replacement of Portland cement with 10% diatomite powder significantly increased the compressive strength of concrete.. The rate of strength increase depends on the combination of clinker hydration and the pozzolanic activity of diatomite. The filler effect Pozzolanic reaction of diatomite with C-H and super plasticizer percent are the prime factors which may contribute for the strength development of mixes.The fineness and the amount of diatomite may improve the initial porosity of the mix by filling the voids, which is called as filler effect. The pozzolanic reaction between the amorphous silica of diatomite and the calcium hydroxide will make the concrete homogenous and dense. The concrete mix with diatomite percent has demanded more water than that of control mix. The high water absorption is mainly due to the high surface area and low density of diatomite. Use of super plasticizers may decrease the water demand in the production of concrete and contribute for further strength development in mix.

VI. CONCLUSIONS

In this project work, the possibility of Diatomite as an admixture to cement has been investigated. The following conclusions are drawn from the investigations.

1. Concrete mix with 10 percent diatomite as partial replacement to cement exhibit high compressive strength among all mixes. Microfossils in diatomite are the primary source of reactive silica which is responsible for strength development in concrete mixes.
2. Diatomite provides considerable energy saving in the milling operations of production of cement. The addition of Diatomite to cement increases SiO_2 and reduces Na_2O and K_2O which may likely produce more durable concretes.
3. Lower specific gravity of diatomite (1.90) compared to that of Portland cement enables for the production of light weight structural concrete components using diatomite.
4. Use of high percent of pozzolans reduces compressive strength but the pozzolanic reaction accelerated as the curing time increases.
5. There is an optimum amount of diatomite to be used to get an optimum productivity and efficiency for maximum strength.

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