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Micromechanical properties of concrete with partial replacement of cement with Diatomaceous earth

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ABSTRACT: -In the present work suitability of diatomaceous earth asa partial replacement to cement in the concrete is studied by analysing strength and durability properties.Cementpartially replaced with diatomaceous earth (DE) in incremental proportions of 0%, 5%, 10%, 15%, 20% and 25%and the mechanical properties like compressive strength for 7 and 28 days and spilt tensile strength studied. Concrete with 15%DE shows maximum compressive strength compared with reference mix and microstructural analysis of concrete by conducting SEM, SEM WITH EDS and XRD ascertain the same.

KEYWORDS: Diatomaceous earth, pozzolanic material,Mechanical properties, compressive strength, split tensile strength.

1. INTRODUCTION

Concrete is the most extensively used composite construction material in the world, which is made primarily from cement, fine aggregate, coarse aggregate and water. Ordinary Portland cement (OPC) is generally expensive, and carbon dioxide gas will bereleasedduringthe production of cement.Cement utilisation will reduce by using different alternative materials.

Natural material which exhibits pozzolanic activity when reacts with cement can be used as an alternative to cement. Pozzolana materials like zeolite, diatomaceous earth, metakaolin and by-products such as fly ash, silica fume and slag can be used as alternative materials.

This paper involves in the utilisation of diatomaceous earth collected from bethamcherla town in Kurnool district. DE obtained from crushing sedimentary rocks of biogenic origin formed from the accumulation of algae shell fossilised due to the silica deposit on its structure. Its origin is usually associated with quartz, iron oxide and clay composing than the name diatomaceous earth. When DE has reacted with cement paste products like calcium silicates hydrates (CSH), and calcium alumina silicate hydrates (CASH) areformed and are responsible for the development of strength.

2. OBJECTIVE

The objective of the present study is to utilise DE as a partial replacement to cement. The work is carried out by replacing cement by weight with different percentages of DE, i.e., 0%, 5%, 10%, 15%, 20% and 25%. The mechanical properties of concrete like compressive strength at the age of 7 and 28 days and spilt tensile strength at aperiod of 28 days will be studied.

3. MATERIAL USED

Cement:In this work, BIRLA cement of 53 grade used for all concrete mixes. The cement was uniform in colour and free from lumps. The various tests conducted on cement are initial and final setting time, specific gravity, and fineness. Testing of cement done as per IS 12269–1987.Various tests results conducted on the cement reported in Table 1

Table 1: Properties of cement

Property	Results obtained
Fineness of cement	3.51%
Specific gravity	3.10
Standard consistency	30%
Initial setting time	40 min
Final setting time	280 min

Fineaggregate: Natural sand procured from Handry rever in Kurnool and which passes through 4.75mm IS sieve and conforms to grading Zone-II of IS 383:1970used. Various tests conducted on the fine aggregate and results reportedin Table 2

Table 2: Properties of fineaggregates

Property	Results obtained
Fineness modulus	2.83
Bulk density kg/m^3	1574
Specific gravity	2.65
Water absorption %	2.0

Coarse aggregate: Crushed stone granite aggregate of maximum size 20mm confirming IS383-1970 obtained from the local quarry in Kurnool.Various tests conducted on the coarse aggregate and resultsreported in Table 3.

Table 3: Properties of coarse aggregates

Property	Results obtained
Maximum nominal size, mm	20
Fineness modulus	4.23
Specific gravity	2.76
Bulk density kg/m^3	1430
Impact value (%)	11.3
Crushing strength value (%)	11.23

Diatomaceous material: Diatomaceous earth procured from Bethamcherla town near Kurnool. Table 4 and Table 5 presentsthe physical and chemical properties of diatomaceous earth.

Table 4: Physical properties of diatomaceous earth

Property	Results obtained
Specific gravity	2.2
Colour	Light brown

Table 5: Chemical composition of Cement and Diatomaceous Earth

Chemical structure (%)	Cement	Diatomaceous earth
Sio_2	21.73	87.6
$Al_2 o_3$	3.83	2.14
Cao	61.98	0.18
Fe_2o_3	2.71	3.86
Na_2o	0.12	3.86
Mgo	3.92	0.31
L.O.I.	1.44	7.74

Water: Waterused for the domestic purpose used in this experimental program for mixing concrete and curing specimens which is free from organic substance and acids, conforming to IS 3025-1986.

5. EXPERIMENTAL WORK

The experimental work is carried out by partial replacement of cement with DE in various percentages like 0%, 5%, 10%, 15%, 20% and 25% by weight. M30 grade of concrete designed as per IS code; the quantities obtained from mix design thoroughly mixed to achieve uniform consistency. Compressive strength of concrete evaluated by casting 150mmX150mmX150mm cubes,cured for 7 and 28 days,and split tensile strength of concrete by casting 150mmx 300mm cylinder,cured for 28 days. Table 6presents the mix proportions of concrete.

Table 6: Mix proportions of concrete.

Mix	Mix designation	Diatomaceous earth		Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (lt/m^3)
		In %	In (Kg/m^3)				
M1	M30	-----	------	413.33	668.90	1228.90	186
M2	5DE	5	20.66	392.66	668.90	1228.90	186
M3	10DE	10	41.33	371.99	668.90	1228.90	186
M4	15DE	15	61.99	351.33	668.90	1228.90	186
M5	20DE	20	82.66	330.66	668.90	1228.90	186
M6	25DE	25	103.33	310.00	668.90	1228.90	186

6. RESULTS AND DISCUSSIONS

Thecompressive strength of the mix M1 (reference mix) is 31.85MPa and 39.25MPa for 7 and 28 days, and the compressive strength of the mix M4 (15%DE) is 36.30MPa and 46.96MPa which are 13.9% and 19.6% morefor 7 and 28 days when compared to reference mix.The split tensile strength of the mix M1 (reference mix) is 3.32MPa for 28 days and the split tensile strength of mix M4 (15%DE) is 3.84 MPa which is 15.6% more for 28 days when compared to reference mix.Increase in strengthis due to the formation of kaolin and CSH gel in the concrete. With an increase in the percentage of DE, the compressive strength gets decreased. The test results of the various mixes shown in table 7 and table 8. Graphical representation of compressive strength and split tensile strength shown in fig 1and 2.

Table 7: Compressive strength

MIX	Compressive strength at 7 days (Mpa)	Compressive strength at 28 days (Mpa)
M1	31.85	39.25
M2	33.33	43.55
M3	35.11	44.29
M4	36.30	46.96
M5	35.25	43.55
M6	28.88	39.70

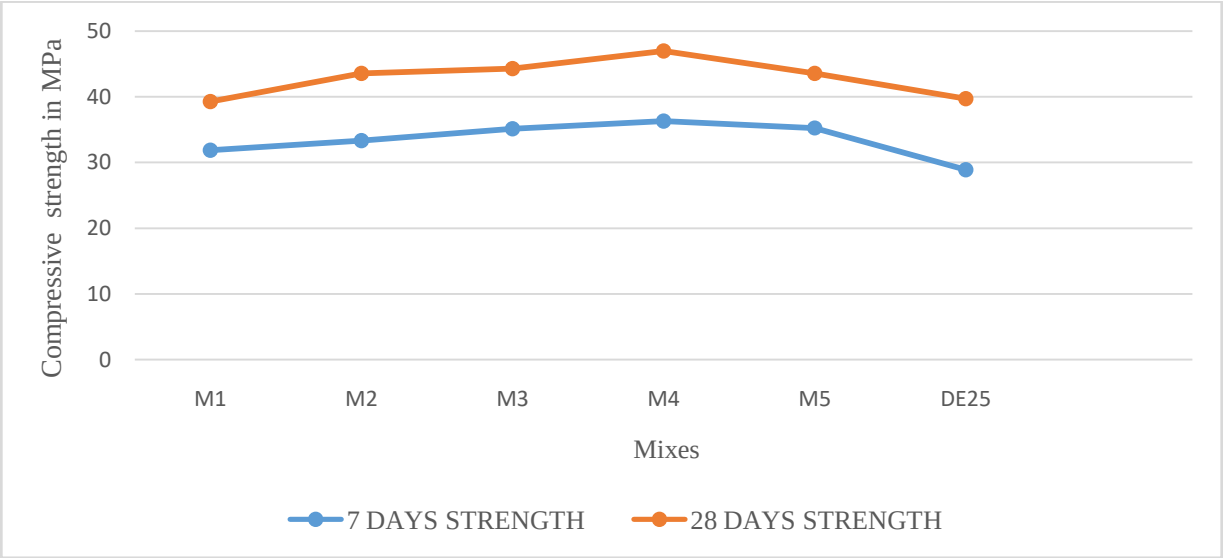


Fig 1.Compressive strength of concrete with various percentage of DE

Table 8: Spilt tensile strength

Mix	Spilt tensile strength at 28days (Mpa)
M1	3.32
M2	3.42
M3	3.75
M4	3.84
M5	3.72
M6	3.46

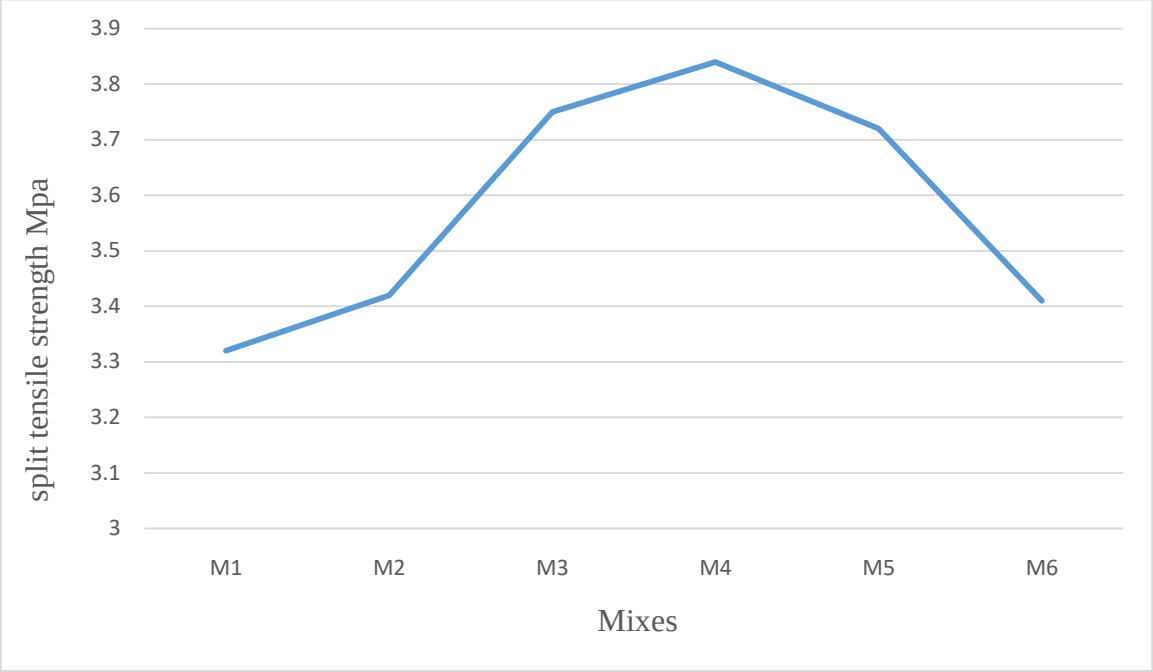


Fig 2. Spilt tensile strength of concrete with various percentage of DE

5. MICRO-STRUCTURAL ANALYSIS

Materials assessed by scanning electronic microscopy with energy dispersive spectroscopy. The operating conditions for obtaining SEM images were high vacuum: high voltage-15kv and a secondary electron detector. Fig 3shows SEM and EDS testing equipment and sampler. Fig 4 and Fig 5 show microstructural images of mix M1 and M4 for 28 days curing sample. In fig 4, the microstructural image showsa sharp needle, cylindrical and spherical structure, etc. Fig 5 shows the presence of a particle with multiple layers and bulk structure pronounced texture that appears to be a cluster of kaolin plates, identified by EDS with silicon and aluminium etc.

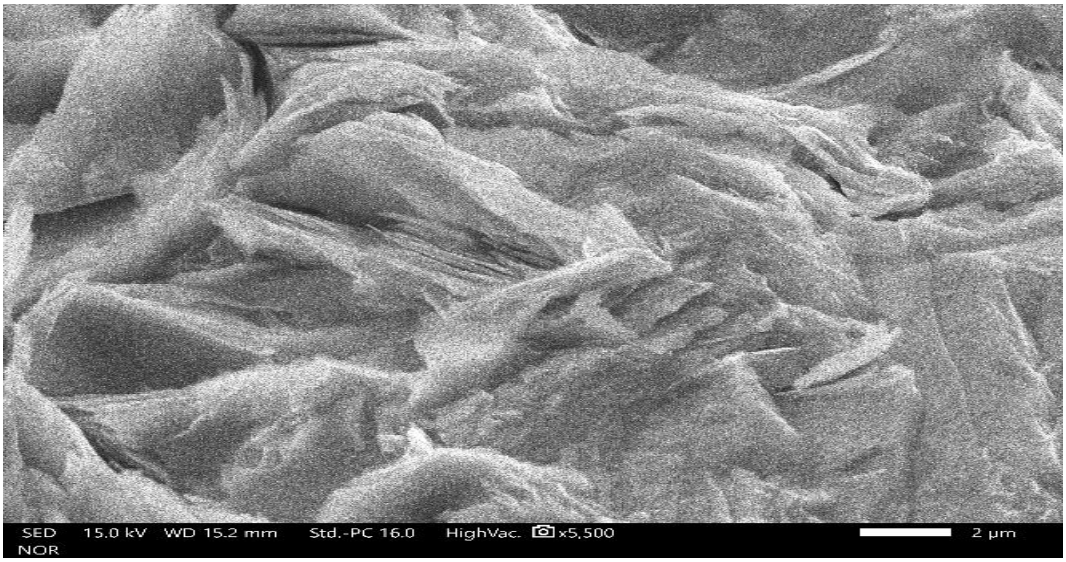


Fig.4 SEM image of reference mix (M1)

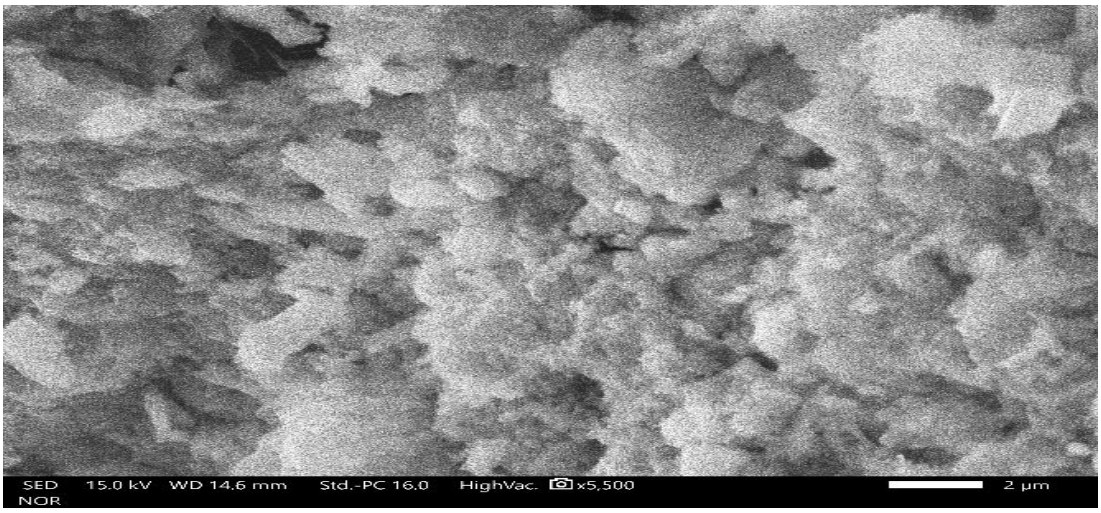
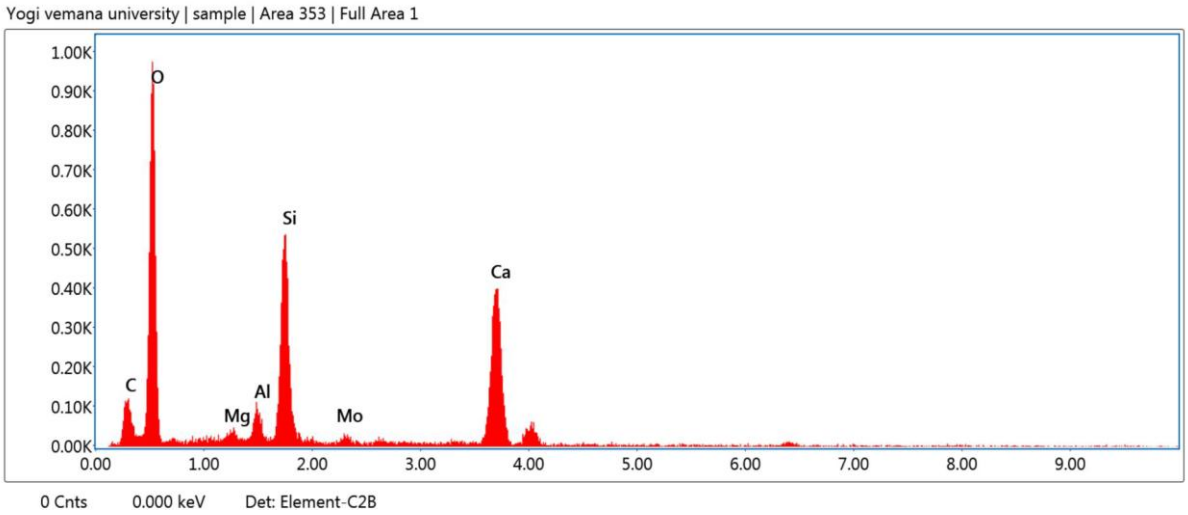


Fig.5 SEM image of mix 15%DE (M4)

Software Esprit was used to analyse EDS results of concrete with the addition of diatomaceous earth. The images in fig 6 show diatomaceous earth covered with kaolin plates which indicate silica and aluminium.



Element	Weight %	Atomic %	Error %
C K	4.27	7.35	16.77
O K	51.66	66.69	10.13
Mg K	1.04	0.88	15.49
Al K	2.17	1.66	10.38
Si K	12.38	9.10	4.83
Mo L	1.23	0.26	36.92
Ca K	27.25	14.04	3.61

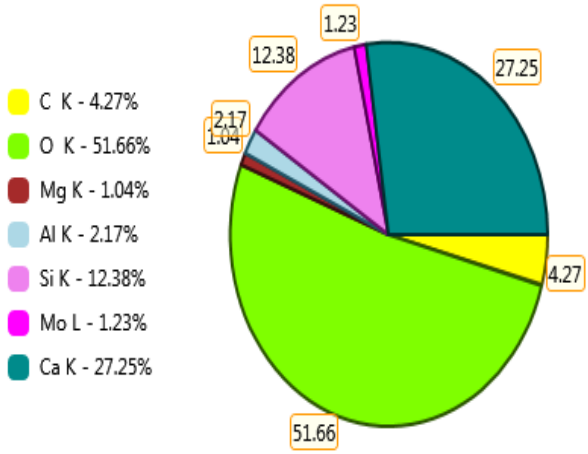
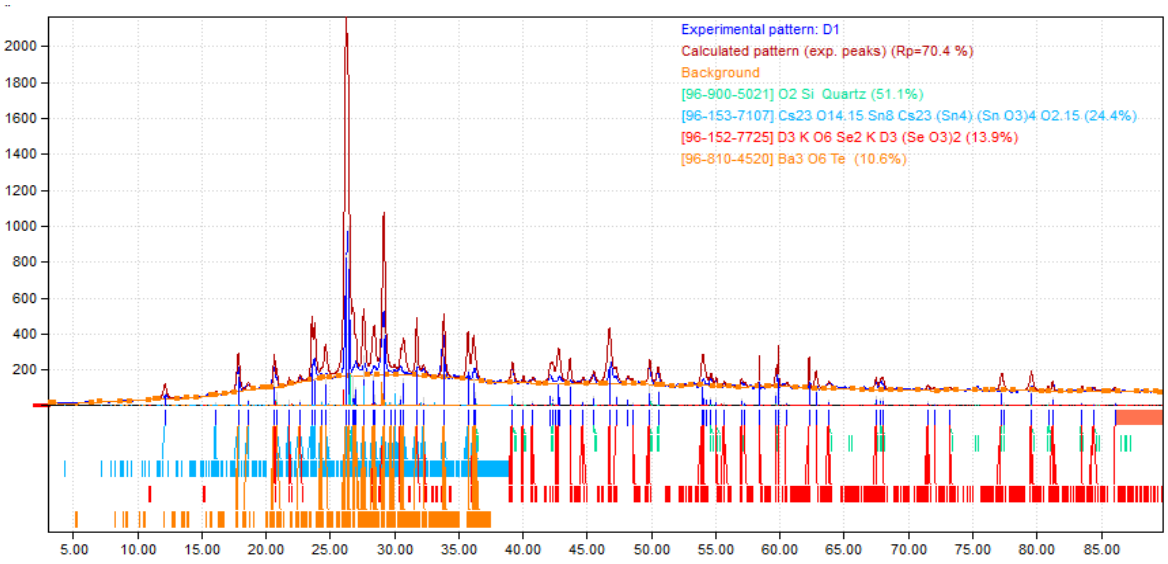


Fig.6 shows SEM with EDS spectrum

MINERALOGICAL ANALYSIS: In theXRDdiagrams of the control mix (M1) of the concrete, as shown in fig 7, the following are observed in the sample tested shown in table 9

.Table 9: XRD Results

Formula	Matched phase	Quantity(%)
O_2si	Quartz	75.1
$D_3ko_6se_2$	paraelectric	13.6
C $caco_3$	calcite	11.3



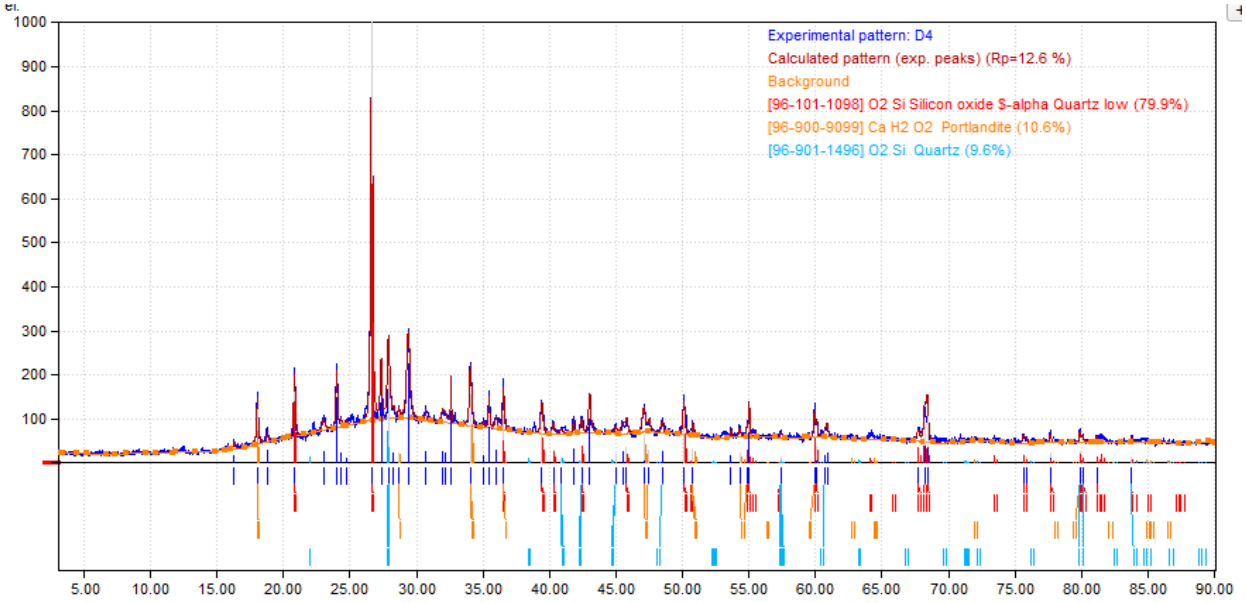
Theta-2θ vs **I (counts)**

Fig.7XRD Patterns of the mix (M1)

In theXRDdiagrams of the mix (M4) shown in fig 8.the following are observed shown table 10.**T**

Table 10: XRD Results

Formula	Matched phase	Quantity (%)
O_2si	Silicon oxide $-alpha Quartz low	79.9
CaH_2O_2	portandite	10.6
O_2si	Quartz	9.5



Theta-2θ vs **I (counts)**

Fig.8XRD Patterns of the mix (M4)

8. CONCLUSIONS

In this study, micromechanical properties of concrete areinvestigated and the following conclusionsare drawn.

- The compressive strength of mix M4 (15% DE) is 36.30MPa and 46.96MPa,which is 13.9% and 19.6% more for 7 and 28 days when compared to the reference mix.
- The split tensile strength of mix M4 (15% DE) is 3.84MPa which is 15.6% more for28 days when compared to the reference mix.
- The increase of strength is mainly due to the formation of kaolin and denseformation of CSH gel when DE used in optimum percentages in concrete.
- The binder intensity was higher for cement with diatomaceous earth, an indicator that relates the binder efficiency and use of material.
- When XRD results of both samples compared mix M4 (15%DE) gives maximum strength because silica reacts with $Ca(OH)_2$ and forms the calcium aluminium silicate.
- With the increase in the percentage of DE, there is an adverse effect on the mechanical properties of concrete.
- Use of DE in the production of concretereduces the emission of $CO_2$and makes concrete eco-friendly and cost-effective.

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