STUDY OF CEMENT CONCRETE BY REPLACEMENT OF CEMENT WITH VARIOUS POZZOLANIC MATERIALS & MICRO FE_2O_3 (PENTA BLENDED MIX)

S. Ramesh Reddy[1], N.Supraja[2], Dr V. Bhaskar Desai[3]

[1]*Professor, Dept. of civil Engineering, Brindavan Institute of Technology & Science, AP, India.*
[2]*M Tech Student, Dept.of civil Engineering, Brindavan Institute of Technology & Science, AP, India.*
[3]*Professor, Department of Civil Engineering, J.N.T.University, Anantapuramu, AP, india.*

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Abstract - *Concrete is a versatile material extensively used in construction applications throughout the world. It is a mixture of cement, sand, coarse aggregate and water. The production of cement results in emission of many green house gases into atmosphere, which are responsible for global warming. In the present study, effect of pozzolanic (slag, silica fume, pulverized Quartz powder and) materials with addition of micro Fe2O3 is studied through compressive, split tensile and flexural strength in cement concrete. Slag, Quartz powder and silica fume are used as cement replacement materials at 4%, 8%, 12%, 16% and 20% individually, finding the optimum replacement of cement individually based on cube compressive strength and an attempt is made for quaternary blended concrete with16% of these three pozzolanic materials (slag + silica fume + pulverized Quartz powder) in three equal parts and penta blended concrete with addition of 0.5-2.5% of micro Fe2O3 powder with 16% in equal parts by weight of cement. The results were observed after 7&28 days of water curing for M20 grade of concrete. From the test results, it was found that concrete mix with 16% of quaternary blended cement and 2% of Fe2O3 yielded higher compressive strength. This experimental work proves that these pozzolanic materials can be used effectively as partial replacement materials for cement in the concrete and makes the concrete more economical and eco-friendly.*

Key words - Silica Fume(SF), Slag(SL), pulverized Quartz Powder(QP), Micro Fe2O3, Binary, Quaternary(T16), and Penta blended(T17-T21).

1.INTRODUCTION

Concrete is widely used construction material for various types of structures due to its structural stability and strength. The relative quantities of cement, aggregate and water control the properties of concrete in wet state as well as hardened state. It is no doubt that with the improvement of human civilization, concrete will continue to be a governing construction material in the future. It is probably the most widely used construction material in the world and it is only second to water as the most profoundly consumed substance with about six billion tons being produced every year, which is reducing the natural sources and also increasing the CO_2 emissions causing green house effect on environment causing gobal warming.ion. The industrial by products or supplementary cementations materials such as slag, silica fume, fly ash, rice husk ash are waste products, which may be used as partial replacement of cement in concrete due to its inherent pozzolanic properties. Using these waste materials as replacement in cement can replace the production of cement substantially on one hand, on the other hand it shows went for disposal and these industrial wastes as otherwise used as land fill and due to its micro structure they acts as micro filler materials there by increasing the durability of concrete.

In this research a comparative study is conducted to calculate and compare the compressive, split tensile and flexural strength with silica fume, slag and pulverized Quartz Powder which are used individually and optimum replacement is found. Partial replacement of cement was also done by taking silica fume, slag, and pulverized Quartz Powder i.e 5.33% each (Combindly 16%) along with 0.5% to 2.5% micro Fe2O3 to make quaternary and Penta blended concrete. The compressive, Split Tensile and flexural strengths were calculated. Compressive and Flexural strength testing was done according to IS: 516-1959. Then a comparative result is shown with a table and the variation of the compressive, Split Tensile and flexural strength comparatively according to the replacement of cement with mineral admixtures is also shown graphically.

The objective of this study is to investigate the strength properties of concrete containing partial replacement of cement by slag, silica fume, silicon powder and micro iron oxide. Our task is to enhance the strength, durability and reduce the cost than the conventional concrete.

1.1 Literature Review

D.Audinarayana (2013): An attempt has been made to study the strength properties of ternary blended concrete for various w/b ratios of 0.55, 0.45 and 0.35 for 28, 90 and 180 days. They concluded that the combination of micro silica and fly ash leads to increase in compressive strength split tensile, flexural strength as compared to control mix irrespective of water to binder ratios.

Naresh Kumar(2014): Investigated on Compressive and Flexural strength of binary blended concrete. Metakaolin and silica fume are used as cement replacement materials at 5%, 10% and 15% by mass keeping water–cement ratio as 0.42. He concluded that Replacement of Metakaolin increase the Compressive Strength at all ages of curing.

10% is the optimal replacement for silica fume and metakaolin.

Hariharan A R , Santhi A S , Mohan Ganesh G (2011) Investigated on the effect of ternary cementitious system on compressive strength of concrete. The concrete containing ternary blends of Portland cement, silica fume (SF) and wide range of fly ash (FA) Class C fly ash is used in this study in various proportions (i.e.) 30%, 40% and 50% and that of silica fume by 6% and 10% by weight of cement. The mix proportions of concrete had constant water binder ratios of 0.4 and super plasticizer was added based on the required degree of workability.

D.Audinarayana, P.sarika, Dr.Seshadri Sekhar.T An attempt has been carried out on the optimization of a Ternary Blended Cementitious system based on Ordinary Portland Cement (OPC)/ Fly Ash / Micro Silica for the development of high- performance concrete. Fly Ash was replaced by 0%, 15% and 20% along with Micro Silica of 0%, 5%, and 10%. The percentage increase in Compressive Strength of Ternary Blended Concrete (5% Micro Silica + 15% Fly Ash) for various W/B ratios compared with Ordinary Concrete is observed to be 15% to 32%.finally they concluded that The combination of Micro Silica and Fly Ash is complimentary.

Murthi et.al (2009) Their experimental study intended, to identify the relationship of Compressive Strength and splitting tensile strength of Ternary Blended Concrete. Two kinds of binary blended concrete systems were considered in this study using the optimum replacement of cement by ASTM class Fly Ash (FA) and rice husk ash (RHA). The replacement of cement in the binary system by Micro Silica was suggested as 4%, 8% and 12% of total powder content by weight.

2.EXPERIMENTAL STUDY:

The constituents used in the present investigation are

2.1 Cement: OPC (53 Grade) manufactured by ultra-tech company was used in the present experimental work. The cement is tested for its various properties as per Indian Standard Code(12269- 1987).

Table 1: Properties of Cement

S. No.	Properties	Results	Requirements
1	Specific gravity	3.2	-
2	Fineness	4 %	10 %
3	Normal consistency	34 %	30 – 35 %
4	Initial setting time	49 min	>30 min
5	Final setting time	450 min	< 600min
6	Soundness	5 mm	-
7	Compressive strength at 28 days	52.35 N/mm^2	53 N/mm^2

2.2 Silica Fume (SF): It is an ultra fine powder collected as a by-product of the silicon metal & Ferro silicon alloy production and it was brought from ASTRRA chemicals, and 100% material was passed through 90 micron sieve.

Table 2: physical properties of silica fume

Sl. No.	Properties	Results
1	Color	White
2	Specific gravity	2.30

2.3 Slag (SL): It is used in this project as replacement of cement and it is produced from the steel plant. Slag is a by-product from the blast furnaces used to make iron, obtained from JSW, Bellary, and 100% material was passed through 90 micron sieve.

Table 3: Physical Properties of Slag

S. No.	Properties	Results
1	Color	Off- white
2	Specific gravity	2.45

2.4 Pulverized quartz powder(QP): It is obtained from Rayalaseema industries,Kurnool where less than 90 microns is disposed off as waste material. It has white in color, specific gravity of 2.32 and 100% material was passed through 90 micron sieve.

2.5 Micro Powder (Fe2O3): This compound is inorganic, red-brown in color and odorless. It was brought from Bottom Up Technologies Corporation, Jharkhand, and 100% material was passed through 90 micron sieve.

Table 4: Physical properties of (Fe2O3):

Sl. No.	Properties	Results
1	Color	Red
2	Specific gravity	5.2

3	Particle Size	40-100 µ
4	Physical Form	Light Powder

2.6 Aggregates: These are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy.

2.6.1 Coarse Aggregate: The fractions from 20mm to 4.75mm are used as coarse aggregate. The coarse aggregate from crushed Granite rock with nominal maximum size of 20mm procured from Tadakanapalli, peddatekur (confirming to IS: 383-1970) has been used. The C.A is also tested for its various properties.

Table 5: Physical Properties of Coarse Aggregate

S. No	Property	Result
1	Fineness modulus	7.75
2	Specific gravity	2.8
3	Bulk density(fully compacted) (loosely compacted)	1600 kg/m^3 1490 kg/m^3
5	Impact value	16.6 %
6	Crushing value	9.95 %
7	Elongation index	22.98 %
8	Flakiness index	10.55 %
9	Water absorption	0.33 %

2.6.2 Fine aggregate: Those fractions from 4.75mm to 150µ are termed as fine aggregates. The locally available river sand confirming to zone1 has been used as F.A in the present investigation. The sand is tested for various properties like sp.gr, bulk density etc., and accordance with Indian standard 383(1970).

Table 6: Properties of Fine Aggregates

S. No	Property	Result
1	Fineness modulus	3.15
2	Specific gravity	2.6
3	Fully compacted density	1772 kg/m^3
4	Partially compacted density	1500 kg/m^3

2.7 Super plasticizer: To maintain required workability Plaxem was used as Super plasticizer. It improves workability and cohesiveness of mix. It reduces W/C ratio and thereby increase compressive strength. It increases durability of concrete. It eliminates Bleeding, Segregation and is highly economical. Dosage: 20ml-50ml per bag of 50kg cement was used. A high level of fluidity can be maintained in spite of the low water content by the use of only small amounts of Super plasticizers.

3. EXPERIMENTAL PROCEDURE

3.1. General: An experimental study is conducted to find out the cube compressive, cylinder compressive, split tensile and beam flexural strength of concrete at 7 days and 28 days. Slag/ Silica fume/ Quartz powder is used in concrete for the production of binary blended concrete. It has been used in percentages i.e. 4%, 8%, 12%, 16% and 20% to the weight of cement to study the 7 days and 28 days strength. Optimum % replacement of cement was found to be 16% for each individual. An attempt is made to blend all these three admixtures @ 5.33% (combindly 16%) and with increments of 0.5% micro Fe2O3 (T_{16} to T_{21}). Cubes, cylinders and beams were casted and tested to analyze the change in strength properties.

3.2 Concrete Mix: M20 grade of concrete is designed according to IS: 10262-2009. The mix proportion that adopted was 1:1.8:3.5 with constant w/c ratio 0.4.

3.3 Work plan: The present experimental program includes casting and testing of specimens for cube and cylinder compressive strength, cylinder split tensile strength, and beam flexural strength. Specimens are prepared for M_{20} grade concrete. Total of 258 specimens with various percentages of slag, silica fume, pulverized Quartz powder, micro iron oxide are casted.

3.4 PREPERATION OF TEST SPECIMENS:

3.4.1 Mixing & Casting of specimens: Mixing of ingredients is done by hand mixing. The cementations materials are thoroughly blended with hand and then the aggregate is added to this and mixed. Water is weighed exactly and added to the dry mix and entire mix is thoroughly mixed till uniform color and consistency are achieved which is then ready for casting. The standard cast iron moulds are cleaned of dust particles and applied with mineral oil on all sides, before concrete is poured in to the moulds. The well mixed concrete is filled into the moulds by vibration with table vibrator. For casting the cube, standard cast iron metal cube moulds of size 150x150x150mm, standard cylinders and beams of size 300x150mm and 100x100x500 mm were used to determine the compressive strength, split tensile strength, and flexural strength of concrete.

3.4.2 Curing & testing of specimens: After casting the moulded specimens are undisturbed at room temperature for 24 hours. The specimens are then removed from the moulds and immediately transferred to the curing tank containing clean and fresh water. The curing water is renewed after every 5 days. The specimens are cured for 7 & 28 days in present work. A time schedule for testing of specimens is maintained to ensure their proper testing on the due date and time.

4 TESTS ON HARDENED CONCRETE

4.1 Compressive strength test: Compression test is done as per IS: 516-1959. In this test the cube specimen was placed at right angles to that as cast in the compression testing machine. According to the standard specification the load on the cube was applied at standard constant rate up to the failure of the specimen and the ultimate load was noted. Cube compressive strength was tested and the results were tabulated. Variations of compressive strength with various percentage replacements of mineral admixtures with and without Replacement of cement by Micro Fe2O3 in concrete for 7 days 28 days curing has been calculated and variations are recorded in tables and graphs.

Compressive strength $\mathbf{F_C=P/A}$

P = Compressive load causing failure
A = Cross sectional area in mm^2

4.2 Split tensile strength test: This test is carried out by using the cylindrical specimens as per IS: 5816-1959. The test was conducted on the compression testing machine.
split tensile strength = $\mathbf{2P/\pi DL}$
D = diameter of the cylinder.
L = Length of the cylinder in mm.

4.3 Flexural strength: This test was conducted on the Universal Testing machine. The load was applied at the central point of the effective span of the flexural beam. Flexural strength is calculated by the following formula

$$f_b = PL/ bd^2$$

b ,d & L = measured width, depth & length in cm of the specimen.

4.4. Tables & Graphs

Table 7: Cube Compressive strength of Binary Concrete.

Cement Replacement (%)	Cube compressive strength N/mm2					
	7 days			28 days		
	Quartz powder	Silica Fume	Slag	Quartz powder	Silica Fume	slag
CM0	21.63			29.67		
4	27.58	24.84	26.60	35.55	31.26	33.48
8	29.76	27.46	28.81	37.55	33.33	34.81
12	32.10	29.34	31.33	38.36	35.39	38.55
16	**33.4**	**33.1**	**33.8**	**40.8**	**41.3**	**43.55**
20	28.82	31.08	30.22	36.88	37.45	35.33

Table 8: % Variation of Cube Compressive strength of Binary blended Concrete over controlled mix.

Cement Replacement(%)	Variation over controlled mix (%)					
	7 days			28 days		
	QP	SF	SL	QP	SF	SL
4	27.36	14.38	22.97	19.85	5.40	12.87
8	37.63	26.49	33.20	26.60	12.37	17.36
12	47.94	35.18	35.56	29.33	19.32	19.86
16	**54.1**	**52.7**	**54.2**	**37.8**	**39.14**	**46.83**
20	30.46	43.13	39.71	24.34	26.26	19.11

Table 9: Mix proportions of Quaternary & Penta Blended concrete (SL+SF+QP+Fe2O3)

Mix ID	Cement %	% of (SL+SF+QP)	Fe_2O_3 %	Fe2O3 by wt of cement(84%)
T16	84.00	16	0	---
T17	83.58	16	0.5	0.42
T18	83.16	16	1.0	0.84
T19	82.74	16	1.5	1.26
T20	82.32	16	2.0	1.64
T21	81.90	16	2.5	2.10

Table 10: % Variation of Cube Compressive strength of Penta blended concrete at 7 days

Mix name	Strength N/mm^2	% increase over control mix	% increase over T-16 mix
T16	32.66	50.99	-----
T17	27.55	27.36	-15.50
T18	29.10	34.53	-10.73
T19	31.11	43.83	-4.57
T20	35.55	55.10	9.05
T21	29.33	35.60	-10.13

Table 11: % Variation of Cube Compressive strength of Penta blended at 28 days

Mix name	strength	% increase over control mix	% increase over **T-16** mix
T16	39.33	32.60	-----
T17	28.81	4.86	-26.77
T18	30.08	8.14	-23.74
T19	36.13	21.81	-08.14
T20	**40.78**	**37.45**	**03.66**
T21	31.85	07.38	-19.03

Table 12: % Variation of Cylinder Compressive strength of Penta blended concrete at 7 days

Mix name	strength	% increase over control mix	% increase over **T-16** mix
T16	21.3	26.86	----
T17	18.10	7.80	-15.02
T18	19.42	15.66	-8.83
T19	20.47	23.52	-3.89
T20	**23.93**	**42.52**	**12.34**
T21	19.99	19.05	-6.57

Table 13:% Variation of Cylinder Compressive strength of Penta blended concrete at 28 days

Mix name	Strength	% increase over control mix	% increase over **T-16** mix
T16	25.60	38.45	----
T17	23.26	25.79	-9.14
T18	25.34	37.047	-1.02
T19	28.62	54.78	11.79
T20	**31.12**	**68.30**	**21.56**
T21	28.43	53.75	11.05

Table 14:% Variation of Cylinder Split tensile strength of Penta blended concrete at 7 days

Mix name	strength	% increase over control mix	% increase over **T-16** mix
T16	3.20	13.07	-----
T17	3.16	11.63	-1.25
T18	3.34	18.02	4.37
T19	3.58	26.50	11.87
T20	**3.67**	**29.68**	**14.68**
T21	3.53	24.74	10.31

Table 15:% Variation of Cylinder Split tensile strength of Penta blended concrete at 28 days

Mix name	strength	% increase over control mix	% increase over **T-16** mix

T16	3.89	16.12	-----
T17	3.62	8.06	-6.94
T18	3.87	13.50	-0.51
T19	4.03	20.29	3.60
T20	**4.24**	**26.56**	**8.99**
T21	3.96	18.21	1.80

Table 16:% Variation of beam flexural strength of Penta blended concrete at 7 days

Mix name	strength	% increase over control mix	% increase over **T-16** mix
T16	4.30	53.57	-----
T17	4.21	50.35	-2.09
T18	4.50	60.71	4.65
T19	4.65	66.07	8.14
T20	**4.80**	**71.42**	**11.63**
T21	4.53	61.78	5.35

Table 17:% Variation of beam flexural strength of Penta blended concrete at 28 days

Mix name	Strength	% increase over control mix	% increase over **T-16** mix
T16	4.59	45.25	-----
T17	4.43	40.19	-3.48
T18	4.65	47.15	1.30
T19	4.91	55.38	6.97
T20	**5.20**	**64.55**	**13.29**
T21	4.80	51.89	4.57

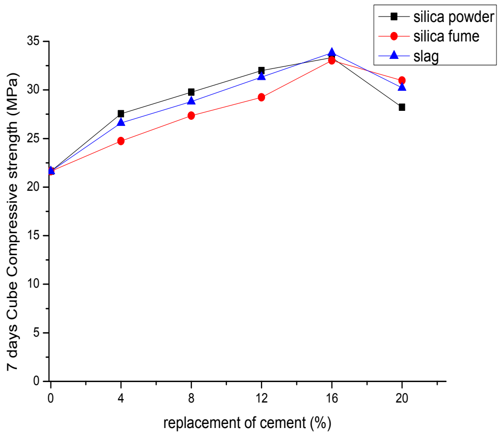

Fig 1: Cube Compressive strength at 7 days with different % of Quartz powder, Slag & Silica fume.

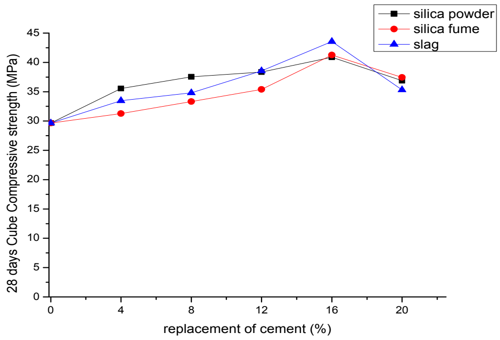

Fig 2: Cube Compressive strength at 28 days v/s different% of Quartz powder, Slag & Silica fume.

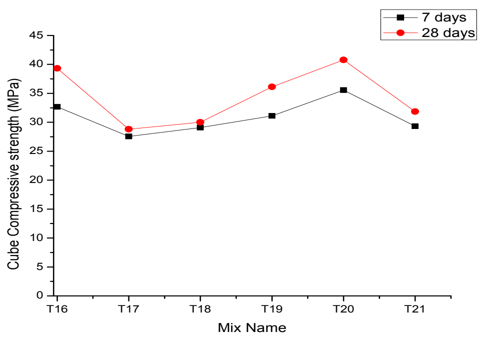

Fig 3: Cube Compressive strength at 7 & 28 days of Penta blended concrete.

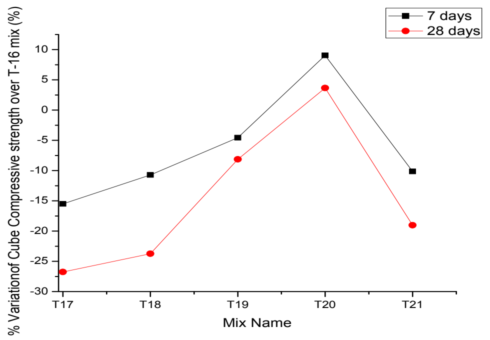

Fig 4: % Variation of Cube Compressive strength of Penta blended concrete over T-16 mix at 7 & 28 days

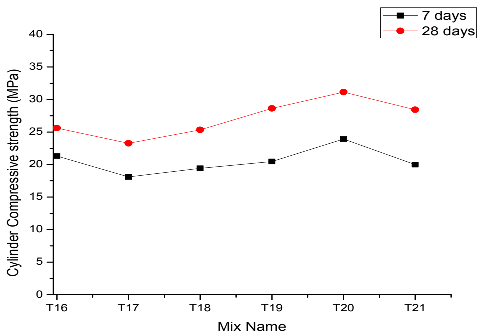

Fig 5: Cylinder Compressive strength at 7 & 28 days of Penta blended concrete.

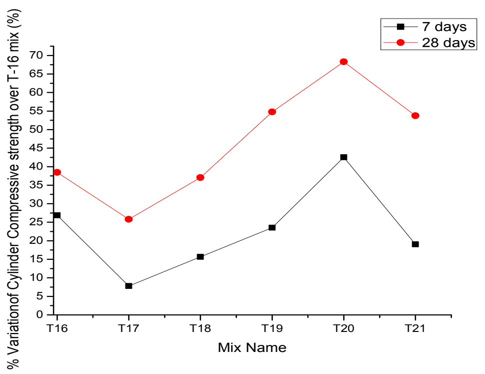

Fig 6: % Variation of Cylinder Compressive strength of Penta blended concrete over control mix at 7 & 28 days

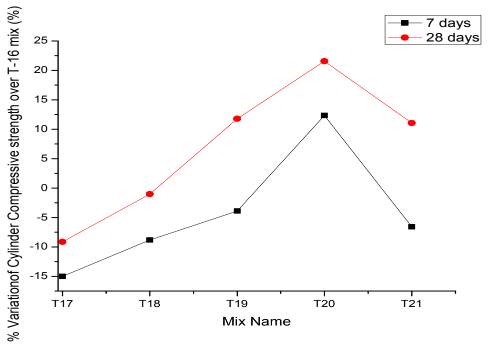

Fig 7: % Variation of Cylinder Compressive strength of Penta blended concrete over T-16 mix at 7 & 28 days

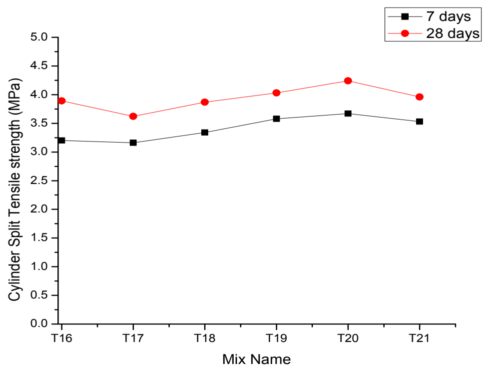

Fig 8: Cylinder Split tensile strength of penta blended concrete at 7 & 28 days.

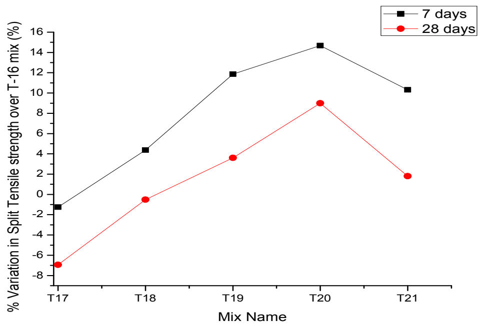

Fig 9: % Variation of Cylinder split tensile strength of Penta blended concrete over T-16 mix at 7 & 28 days.

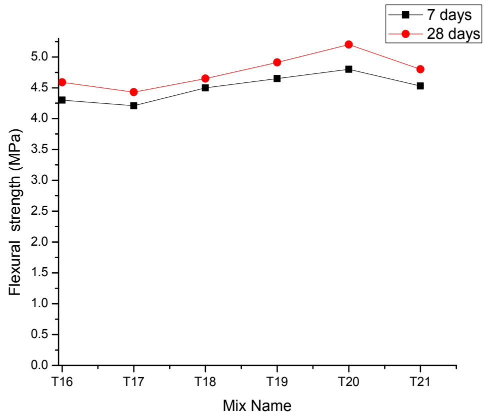

Fig 10: Beam Flexural strength at 7 & 28 days of Penta blended concrete.

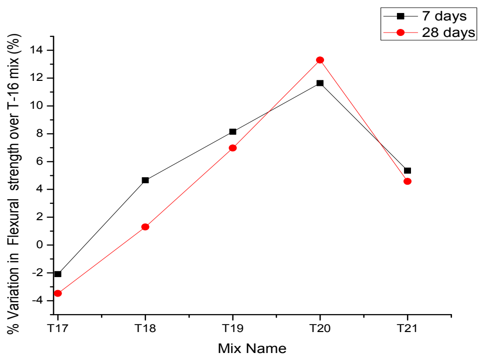

Fig 11: % Variation of Beam Flexural strength of Penta blended concrete over T-16 mix at 7 & 28 days

5. RESULT

1. At the age of 28 days curing the cube, cylinder compressive strength, split tensile strength and beam flexural strength for the control mix is 29.66MPa, 18.49Mpa, 3.35Mpa and 3.16Mpa.
2. The binary blended cement concrete cube compressive strength is compared with the design mix. The maximum cube compressive strength achieved as 40.88Mpa, 41.28Mpa and 43.55Mpa at 16% replacement of pulverized quartz powder, silica fume and slag individually.
3. The cube compressive strength of quaternary blended concrete is 32.66MPa & 39.33MPa and it is increased by 50.99% & 32.60% for 7 & 28 days than controlled mix.
4. The cube compressive strength cylinder compressive strength, split tensile strength and beam flexural strength of quaternary blended concrete is 39.33MPa ,25.60MPa, 3.89MPa and 4.59MPa .
5. The cube compressive strength, cylinder compressive strength, split tensile strength and flexural strength for the penta blended concrete containing constant 16% of (S+SF+QP) and varying amounts of micro Fe_2O_3 powder, the maximum strength value is achieved at 2% replacement of micro Fe_2O_3 i.e. 40.77Mpa, 31.12Mpa, 26.56Mpa and 64.55Mpa.

6. 6. Conclusion:

From the experimental study, the following conclusions can be arrived;

1. In binary blended concrete, the optimum 7 days & 28 days strength have been obtained in the range of 16% slag, silica fume and pulverized quartz powder by individual replacement to cement and there is a systematic increase in compressive strength.
2. The increase in strength may be due to the high content of silicon dioxide and fineness of pozzolanic admixtures.
3. The strength of the quaternary blended concrete was equal to or lower than binary blended concrete mixes.
4. The maximum strength of penta blended concrete was achieved at 2% of micro Fe2O3 replacement level and it is more than the strength of quaternary blended concrete.

77. References

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