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Some studies on strength properties of tetra blended concrete with partial replacement of cement by various pozzolanic materials and micro Al_2O_3

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Abstract - *Sustainable development in construction field shall meet the needs of the present situation without compromising ability of future generation to meet their own needs. It also shows that development that going to be made to sustain the planetary resources by using them effectively without making unnecessary wastage. The usage Slag, Silica fume and Quartz powder to replace the cement is because the production of the cement emits carbon dioxide gas to atmosphere. The emission of carbon dioxide will increase the effect of global warming due to the emission greenhouse gases. Among the greenhouse gases, carbon dioxide contributes about 65% of global warming. Many researchers have studied the properties of ordinary Portland cement with different mineral admixture like silica fume, slag, fly ash, rice husk ash as cement replacement materials. The conventional mix has been designed for M20 grade concrete. In the present study, effect of pozzolanic materials with addition of micro Al_2O_3 is studied through compressive, split tensile and flexural strength in concrete. Slag, Pulverized 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 based on cube compressive strength and an attempt is made for ternary blended concrete with16% of these three pozzolanic materials (slag + pulverized Quartz powder + silica fume) by three equal parts and tetra blended concrete with addition of 0.5-2.5% micro Al2O3 powder on 84% weight of cement. From the test results, it was found that tetra blended concrete mix with 16% pozzolanic materials and 1% of Al2O3 yielded higher compressive strength.*

Key words - Pulverized Quartz Powder, Slag, Silica Fume, Micro Al2O3, Binary, ternary, and Tetra blended

1.INTRODUCTION

Concrete is one of the most extensively using construction materials in the world, with about two billion tons of utilization worldwide each year. It is attractive in many applications because it offers considerable strength at a relatively low cost. Concrete can generally be produced of locally available constituents, can be cast in to wide variety of structural configurations, and requires minimal maintenance during service. However, environmental concerns, stemming from high-energy expense and CO_2 emission associated with cement manufacture, have brought pressures to reduce consumption through the use of supplementary materials. Both natural and artificial (man-made) materials show pozzolanic activity and are used as supplementary cementitious materials.

In this experimental work a comparative study is done to find the optimum replacement of cement by Pulverized quartz powder, slag and Silica fume at 4, 8, 12, 16 and 20% of weight of cement by Compressive strength of M20 Binary blended mix . An attempt is made to find the optimum replacement of the above three pozzolanic materials combinedly at 16% weight of cement in equal parts along with 0.5% to 2.5% micro Al2O3 on 84% weight of cement to find the strength properties of Tetra blended concrete mix like Cube and Cylinder compressive strength, Split tensile strength, flexural strength. The used W/B ratio for the current investigation was 0.4.

1.1 Literature Review

Naresh Kumar (2014) Investigated on Compressive and Flexural strength of binary blended concrete. Metakaolin and silica fume area 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. The optimal replacement of silica fume and metakaolin is achieved at 10%.

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 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 with constant o.4 w/c ratio. They reported that the addition of 6% SF to different FA replacements has a high compressive strength than 10% SF. ternary system had high compressive strength than all other mixes. The optimum and high strength concrete can be obtained with 6% SF and 30% FA.

D.Audinarayana et all Compressive Strength of Ternary Blended Concrete at the ages of 28, 90, 180 days for various combinations of Fly Ash and Micro Silica mixes were investigated. 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.

Deepa A Sinha (2012) This experimental investigation is to study the effect of ternary blends on the strength and workability and strength characteristics. 30% of cement is replaced by ternary blend combinations such as (FA+SF), (FA+GGBFS) and FA+MK). The proportions of (FA+SF) or (FA+GGBFS) or (FA+MK) are (0+0), (30+0), (25+5), (20+10), (15+15), (10+20), (5+25) and (0+30) with constant water binder ratio of 0.45. from the experimental work Up to 30% (10% fly-ash and 20% silica fume & 10% fly-ash and 20% GGBS) replacement of cement with supplementary cementitious material can give higher strength than normal concrete at 28 & 90 days. Out of all pozzolanic material Silica fume gives highest strength in flexure after 28 and 90 days.

Sundar.J Manivel.S (2015) The concrete mix M30 grade is prepared as per the procedure given in the IS: 10262: 2009 and proportion of mix were 1:1.52:2.48. They discussed the strength of multi component cement concrete containing slag, metakaolin, silica fume and fly ash with the addition of different percentages by weight of cement. The maximum increase in compressive strength of concrete observed at 50% cement+ 10% fly ash + 10% metakaolin + 10% silica fume + 10% slag and Addition of GGBS will reduce early strength of concrete.

S. Vijaya Bhaskar Reddy, Dr. P. Srinivasa Rao (2016) They studied the compressive Strength of Ternary Blended Concrete at the ages of 7, 28, 60, 90 days for various combinations of Micro Silica and GGBS mixes were investigated. Micro Silica of 0%, 5%, and 10% and15% along with GGBS was replaced by 20%, 30% 40% and 50%. All the mixes were studied at water cement ratio of 0.55. Based on their test results the optimum percentage of Micro Silica was 10% and GGBS was 30%. At which we can get better results in workability and compressive strength comparatively with reference to ordinary concrete.

N. K. Amudhavalli, Jeena Mathew (2012) reported that Compressive strength, split tensile strength, flexural strength of M35 grade of concrete with partial replacement of cement by silica fume by 0, 5, 10,15and by 20%. The optimum 7 and 28-day compressive strength and flexural strength have been obtained in the range of **10-15 %** silica fume replacement level.

Ali Nazari*, Shadi Riahi, Shirin Riahi, Seyedeh Fatemeh Shamekhi and A. Khademno(2010) The compressive strength and workability of concrete by partial replacement of cement with nano-phase Al2O3 particles. Al2O3 nanoparticles with the average diameter of 15 nm were used with four different contents of 0.5%, 0.1%, 1.5% and 2.0% by weight. The results showed that the use of nano-Al2O3 particles up to maximum replacement level of 2.0% produces concrete with improved strength. However, the ultimate strength of concrete was gained at 1.0 wt% of cement replacement. The workability of fresh concrete was decreased by increasing the content of Al2O3 nanoparticles.

M. R. Arefi 1,*, M. R. Javeri 1, E. Mollaahmadi1 -2011 In this work, research has been done on the compressive, tensile and flexural strength of cement mortar containing Al2O3 nanoparticles in the amounts of 1, 3 and 5 percent by weight of cement. The results show that the mechanical properties of samples containing 1 and 3 percent Al2O3 nanoparticles are desirable than the ordinary cement mortar. But by increasing Al2O3 nanoparticles to 5 percent, the mechanical properties reduce severely.

2.EXPERIMENTAL STUDY

2.1 CEMENT: It is a binding material. The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. Ordinary Portland cement of Ultra-tech 53 grade confirming to ISI standards IS:12269-1987 has been used for casting all specimens. Tests on cement are conducted according to IS: 4031-1988.

Specific gravity	=	3.10
Initial testing time	=	48 min
Final testing time	=	450 min
Fineness modulus	=	4%
Normal consistency	=	34%
Soundness	=	5 mm

2.2 FINE AGGREGATE: The aggregates which passes through a IS sieve of size 4.75mm is known as fine aggregates. Sand is used as a filler material in concrete and it gives strength to the concrete. In this investigation locally available clean and dry Hundri river sand was used. In this test zone II grade sand has been used. The physical properties of fine aggregate are tested in accordance with IS: 2386-1963.

Specific gravity = 2.60

Fully compacted density = 1766 (Kg/m3)

Partially compacted density= 1500 (Kg/m3)

Fineness modulus = 3.15

2.3 COARSE AGGREGATE: The crushed aggregate of 20mm maximum size has been obtained from the local crushing plant Kurnool is used in the present study and it was free from clay, weeds, and other organic matters. The physical properties of coarse aggregate are tested in accordance with IS: 2386-1963.

Bulk density (compacted state) = 1600 kg/m^3

Bulk density (Loosest state) = 1440 kg/m^3

Fineness modulus = 4.13

Specific gravity (Granite) = 2.80

2.4 WATER: This is the least expensive but most important ingredient in concrete. The water which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid etc., in general the water which is fit for drinking should be used for making concrete.

2.5 CHEMICAL ADMIXTURE:

The super plasticizer is used in concrete mix makes it highly workable for more time with much lesser water quantity. It is observed that with the use of large quantities of finer materials like cement, slag, silica fume etc., the concrete is much stiff and requires more water for required workability hence, in the present study PLAXEM is used as water reducing admixture.

2.6MINERAL ADMIXTURES

2.6.1 SLAG:

Slag is by-product from the blast furnaces used to make iron. In this project the slag was brought from JSW plant, Gadivemula, Kurnool. It is off white in colour, specific gravity is 2.4 and 100% material was passed through 90 micron sieve.

2.6.2 SILICA FUME:

Silica fume is a by-product resulting from the reduction of high quantity quartz with coal in electric arc in the manufacture of silicon or Ferro silicon alloy. It was brought from ASTRRA Chemicals, white in color, specific gravity of 2.30 and 100% material was passed through 90 micron sieve.

2.6.3 PULVERIZED QUARTZ POWDER:

It is obtained from Rayalaseema industries, Kurnool where less than 90 microns is disposed off as waste material. It is white in colour; specific gravity of 2.32 and 100% material was passed through 90 micron sieve.

2.7 MICRO POWDER (Al2O3):

This compound is inorganic, white in colour and odorless. It was brought from Bottom Up Technologies Corporation, Jharkhand, and 100% material was passed through 90 micron sieve.

Physical properties of (Al2O3):

Specific gravity = 3.6

Particle size = 40 to 100 microns

Appearance = white powder

Physical state = solid granular

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, pulverized quartz powder and micro Al2O3 powders are used in concrete for the production of binary, ternary, tetra blended concrete. Slag, pulverized quartz powder and silica fume are used as partial cement replacement materials i.e. from 4-20% with multiples of 4 individually to find the optimum replacement of cement. Based on cube compressive strength and an attempt is made for ternary blended concrete with16% of these three pozzolanic materials (slag + pulverized Quartz powder + silica fume) by three equal parts. Micro Al2O3 has been used in various percentages i.e. 0.5%, 1%, 1.5%, 2% and 2.5% to the weight of cement (84%) to make tetra blended mix.

3.2. Tables & Graphs

Concrete Mix: The M20 grade of concrete is designed according to IS: 10262-2009.

Table1: M20 grade concrete mix proportions & their quantities

Cement (Kg/m³)	FA (Kg/m³)	CA (Kg/m³)	Water (L)
375	682	1305	150
1	1.81	3.5	0.4

TABLE:2 Quantities of materials required per 1m ^{3} of binary blended concrete at different percentage of Slag/SF/QP.

Cement replace ment (%)	SL/SF/ QP Kg/m3	Cement Kg/m3	FA Kg/m3	CA Kg/m3	Water Litres
0%	0	375	681.41	1304.57	150
4%	15	360	681.41	1304.57	150
8%	30	345	681.41	1304.57	150
12%	45	330	681.41	1304.57	150
16%	60	315	681.41	1304.57	150
20%	75	300	681.41	1304.57	150

Table:3 Cube Compressive strength of Binary blended (cement+ slag) concrete

Mix ID	Cube Compressive Strength N/mm²		% Increase in Strength Over Control Mix	
	7 Days	28 days	7 days	28 days
CM	20.83	28.76	---	----
SL-4	25.50	32.48	22.42	12.93
SL-8	27.83	33.51	33.61	16.52
SL-12	28.33	34.45	36.01	19.78
SL-16	**32.43**	**42.65**	**55.69**	**48.30**
SL-20	29.43	34.36	41.29	19.47

Table:4 Cube Compressive strength of Binary blended (cement+ silica fume) concrete

Mix ID	Compressive Strength N/Mm²		% Increase In Strength Over Control Mix	
	7days	28day	7days	28day
CM	20.83	28.76	----	------
SF-4	23.73	30.23	13.92	5.11
SF-8	26.33	32.33	26.40	12.41
SF-12	28.34	34.49	36.05	19.92
SF-16	**32.13**	**40.37**	**54.25**	**40.37**
SF-20	29.96	36.55	43.83	27.09

Table:5 Cube Compressive strength of Binary blended (cement+ pulverized quartz powder) concrete

Mix ID	Cube Compressive Strength N/Mm²		% Increase in Strength Over Control Mix	
	7days	28day	7days	28day
CM	20.83	28.76	------	------
QP-4	26.45	34.35	26.98	19.44
QP-8	28.57	36.15	37.16	25.70
QP-12	31.50	37.76	51.22	31.29
QP-16	**32.73**	**39.83**	**57.13**	**38.49**
QP-20	27.72	35.38	33.08	23.02

Table6: Various mixes and their ingredients details.

Mix ID	% of (S+SF +QP)	Micro Al_2O_3 %	Micro Al_2O_3 in wt of cement (84)%	Cement %	FA %	CA %
CM	0	0	0	100	100	100
TB	16	0	0	84.00	100	100

TBA1	16	0.5	0.42	83.58	100	100
TBA2	16	1.0	0.84	83.16	100	100
TBA3	16	1.5	1.26	82.74	100	100
TBA4	16	2.0	1.68	82.32	100	100
TBA5	16	2.5	2.10	81.90	100	100

Table7: Tetra blended concrete cube compressive strength

Mix ID	Cube Compressive Strength N/mm²		% Variation In Strength Over Control Mix	
	7 days	28 days	7 days	28 days
CM	20.83	28.76	-----	-----
TB	32.66	39.33	56.79	36.75
TBA1	34.03	38.27	63.37	33.07
TBA2	**36.44**	**41.98**	**74.94**	**45.97**
TBA3	31.77	37.77	52.52	31.33
TBA4	30.37	35.11	45.80	22.08
TBA5	29.03	32.73	39.37	13.80

Table8: Tetra blended concrete cylinder compressive strength .

Mix ID	Cylinder Compressive Strength N/mm²		% Variation In Strength Over Control Mix	
	7 days	28 days	7 days	28 days
CM	17.10	20.39	----	----
TB	20.30	25.6	14.11	32.03
TBA1	21.50	27.13	20.85	39.92
TBA2	**22.20**	**28.29**	**24.79**	**45.90**
TBA3	20.83	26.59	17.09	37.13
TBA4	19.93	25.03	12.03	29.09
TBA5	18.83	24.33	5.85	25.48

Table9: Tetra blended concrete cylinder split tensile strength.

Mix ID	Cylinder Split tensile Strength N/mm²		% Variation In Strength Over Control Mix	
	7 days	28 days	7 days	28 days
CM	2.83	3.35	----	----
TB	3.11	3.74	13.07	16.12
TBA1	3.20	3.89	9.89	11.64
TBA2	**3.39**	**3.96**	**19.78**	**18.20**
TBA3	3.25	3.85	14.84	14.92
TBA4	2.97	3.49	4.94	4.18
TBA5	2.68	3.28	-5.30	-2.08

Table10: Tetra blended concrete beam flexural strength

Mix ID	Flexural Strength N/mm²		% Variation In Strength Over Control Mix	
	7 days	28 days	7 days	28 days
CM	2.95	3.65	---	---
TB	4.30	4.59	53.57	45.25
TBA1	4.40	4.78	57.14	51.26
TBA2	**4.65**	**4.90**	**66.07**	**55.06**
TBA3	4.55	4.67	62.5	47.78
TBA4	4.20	4.45	50.0	40.82
TBA5	3.90	4.29	39.28	35.76

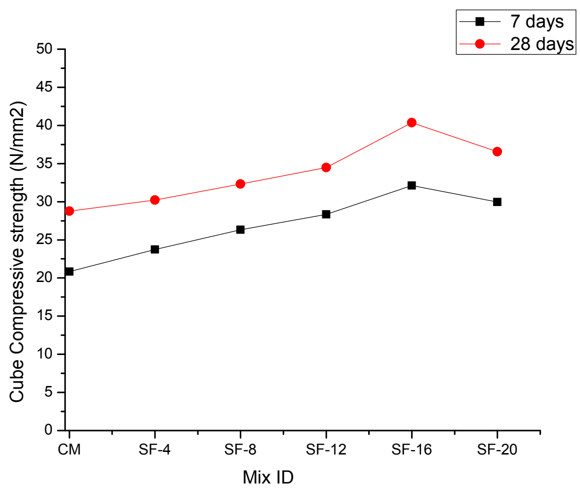

Fig 1: Compressive Strength V/S Different % Of Slag

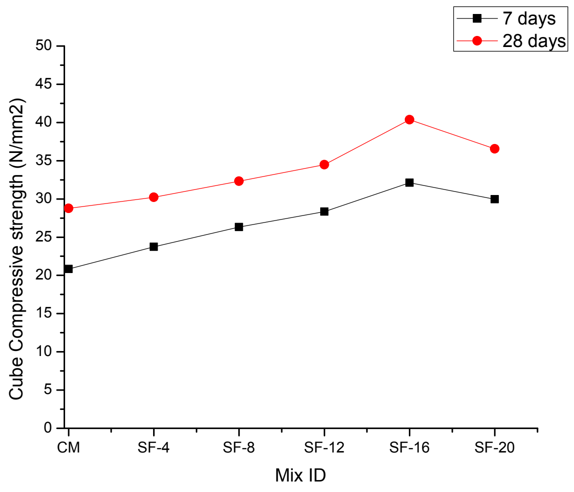

Fig 2: Compressive Strength V/S Different % Of Silica Fume

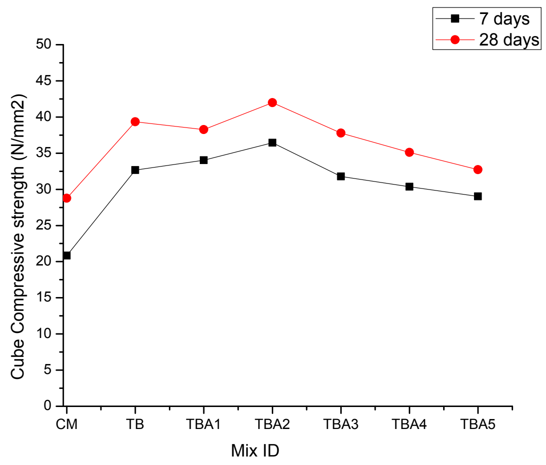

Fig4: Compressive Strength Of Cube At Various % Of Micro Powder Al_2O_3 At 7days & 28 Days.

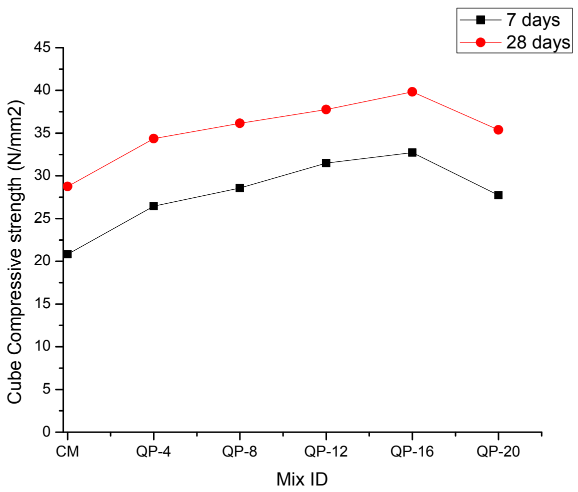

Fig 3: Compressive Strength V/S Different % Of Pulverized Quartz Powder

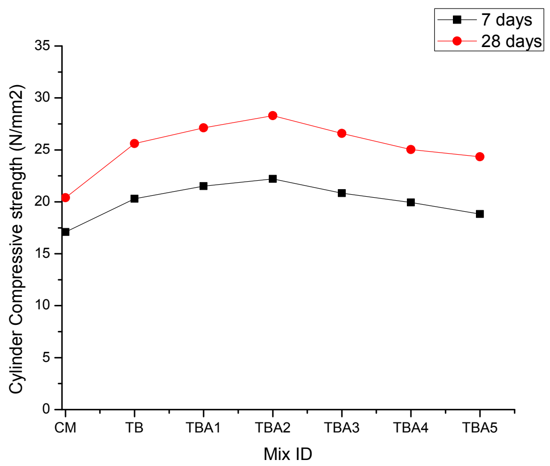

Fig5: Compressive Strength Of Cylinders At Various % Of Micro Powder Al_2O_3 At 7days & 28 Days

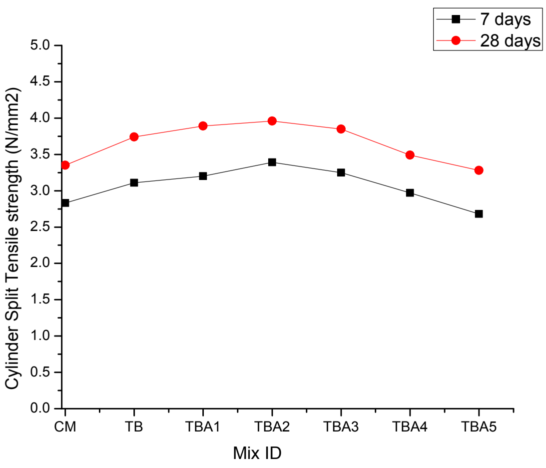

Fig6: Split tensile Strength of Cylinders at Various % Of Micro Powder Al_2O_3 At 7days & 28 Days.

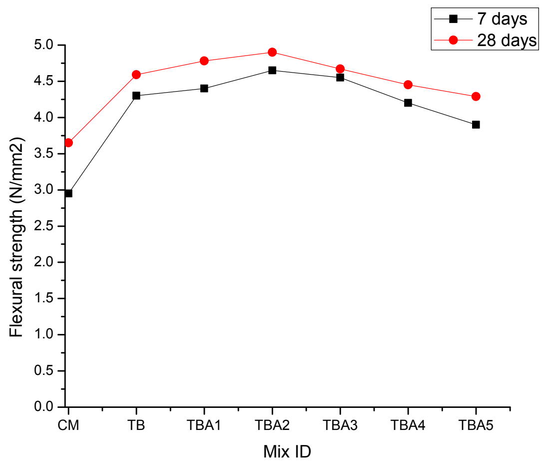

Fig7: flexural Strength Of beams At Various % Of Micro Powder Al_2O_3 At 7days & 28 Days.

RESULT

1. The cube compressive strength, cylinder compressive strength, split tensile strength and flexural strength at the age of 28 days of curing for the conventional mix are 28.76N/mm², 19.39N/mm², 3.35N/mm² and 3.16N/mm².
2. The Maximum Cube compressive strength of binary blended concrete with the replacement of cement by 16% slag & silica fume and pulverized quartz powder are 42.65N/mm², 40.37N/mm², 39.83N/mm².
3. It was observed that as the replacement level increases there is an increase in compressive strength of concrete up to 16% replacement level of cement by Slag/silica fume/Silica powder and beyond that level there is a decrease in strength.
4. The cube compressive strength, cylinder compressive strength, split tensile strength and beam flexural strength of Ternary mix (TB) are 39.33 N/mm², 25.6 N/mm², 3.74 N/mm² and 4.59 N/mm²
5. The cube compressive strength of tetra blended concrete containing constant 16% of (S+SF+SP) and varying amounts of micro Al2O3 powder i.e. 0.5%- 2.5%, the maximum strength 41.98 N/mm² is achieved at 1% replacement level (TBA2).
6. The Maximum cylinder compressive strength and split tensile strength of tetra blended alumina concrete are 28.29 N/mm² and 3.96 N/mm² at 1% replacement of micro Al2O3 powder.
7. The Maximum Flexural strength of tetra blended alumina concrete is 4.90 N/mm² at 1% replacement of micro Al2O3 powder.

CONCLUSION

1. From the experimental study it may be concluded that the cube compressive strength of binary blended concrete was increased continuously with the increase in percentages of slag/Silica fume/pulverized quartz powder i.e., from 0 to 16% replacement.
2. It was observed that cube compressive strength, beam flexural strength, cylinder split tensile strength of tetra blended alumina concrete have increased continuously with the increase in percentages of 0.5 to 1.0 of micro Al2O3 and further increments of Al2O3 there is decrease in strength . Maximum strength value is achieved at 1% replacement of cement by Al2O3.

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