THE STUDY ON MECHANICAL PROPERTIES OF HIGH PERFORMANCE CONCRETE BY USING METAKAOLIN, ULTRAFINE FLYASH & NANOSILICA

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Abstract: **Concrete is a blending of cement, sand, coarse aggregate and water. Concrete is broadly used and is one of the mostly utilized building materials available in the world. It is the one of the greatest used element in the world next to water, this study aims at utilization of industrial by product such as Metakaolin, Ultrafine fly ash,Nano silica etc, for value added application. In addition, the waste used can improve the properties of construction materials. The Metakaolin, Ultrafine fly ash,Nano silica has been used in this project. The above mentioned materials were tested as concrete ingredients. Cement was partially replaced by Metakaolin, Ultrafine fly ash,Nano silica with different mix proportions along varying percentage of Metakaolin, Ultrafine fly ash,Nano silica for concrete with suitable water cement ratio. The Compressive strength, Split tensile strength and Flexural strength were conducted for the above replacements. The results showed Metakaolin, Ultrafine fly ash,Nano silica improves the mechanical properties and strength of concrete. The advantages of this project are that the partial replacement of cement with Metakaolin, Ultrafine fly ash,Nano silica which are economically cheap and eco-friendly as well as a superior concrete can be produced.**

Index Terms – Met kaolin, Ultrafine fly ash, Nano silica, Nanotechnology Compressive Strength, Flexural Strength, Split Tensile Strength.

1. INTRODUCTION

Concrete is a blending of cement, sand, coarse aggregate and water. Concrete is broadly used and is one of the mostly utilized building materials available in the world. It is the one of the greatest used element in the world next to water. Concrete has high compressive strength and toughness. These properties of concrete have made it most famous construction material for all forms of civil engineering projects. The newest advances in concrete knowledge have made it possible to use it in difficult and architecturally compound structures, needing high mark of performance and Artistic look.The term High Performance Concrete is used for concrete in order to improve its strength, workability, density, modulus of elasticity, stability in volumetric changes, achieve low permeability and resistivity towards chemical attack. High performance Concrete have become increasingly popular worldwide. HPC is being made by the materials such as ultrafine fly ash, Ground granulated blast furnace, metakioline, fly ash and the suitable plasticizer in order to improve the properties of concrete such as high density, strength, impermeability and resistance to environmental exposure. Nano technology is gaining wide variety of attention and is being applied in a lot of areas to improve materials with new operational capabilities as it possesses physical and chemical properties that are unique. Nano material is well-defined as a very small particle size in a scale of 10^{-9} meter, produced from variation of atoms and molecules in order to produce larger surface area. Hardened properties of concrete showed good results when Nano particles were added to it. Further, there was reduction found in total porosity with the size of capillary pores being small. This occurred due to cement matrix mixed with Nano filler. Nano silica has advantage over other Nano material with respect to pozzolanic reaction with products of cement hydration. It attains early pozzolanic reaction due to its ultrafine particle size. With this property it enhances blending of cement with fly ash and other pozzolanic materials which promotes the hydration process.

2. OBJECTIVES

The main objectives of this project are as follows:

1. Understanding the mechanical properties of the high-volume ultrafine fly ash concrete and to understand the workability with addition of admixture and verified by slump cone test, vee-be consistometer, compaction test.
2. To study the effect of Nano-silica and Ultrafine fly ash & Metakaolin on the fresh and hardened cement concrete.
3. To find out about the excessive overall performance concrete in fresh and hardened state, by means of replacing cement with Nano silica in proportion such as 1.5%,3%, 4.5%. and Ultrafine fly ash 5%,10%,15%,Metakaolin 5%,10%,15%.

4. The reason of this find out about is to investigate the Compressive strength,Split tensile strength and Flexural strength of concrete with the aid of partial substitute of cement with Nano silica.

3.LITERATURE REVIEW

General

Literature survey:

In this paper, the works of several authors on the use of Nanomaterials, Ultra fine fly ash, Metakaolin in cement concrete has been verified. A huge number of investigators have experimented to understand the effect of nanomaterials combination with Ultra fine fly ash,Metakaolin and their outcome on the properties of concrete. Research works dealing with Nano-silica, ultra fine fly ash & Metakaolin combination in cementitious materials are discussed in the narrative below.

[1] **F. Pacheco Torgal*, Arman Shasavandi, Said Jalali:** Examined the use of Metakaolin to improve the compressive strength & durability of fly ash based concrete. After the experimental studies results shown that the replacement of 30% fly ash leads to serious decrease in early age compressive strength.15% fly ash & 15% metakaolin leads to outstanding durability improvement.

[2] **Steve W.M. Supit, Faiz U.A. Shaikh and Prabir K. Sarker:** This study investigates the effect of Nano-silica and ultrafine fly ash on compressive strength of High volume fly ash mortor. Addition of Nano silica & Ultrafine fly ash as partial replacement to cement leads to higher compressive strength at 7&28 days. The 10% ultrafine fly ash is the optimum content that exibited higher compressive strength.Nano silica being more reactive contributes to compressive strength at early ages.

[3] **SATYAJIT PARIDA:** studied the Effect of Nano Silica on the Compressive Strength of Concrete, on addition of nano silica there is subsatantial increase in early age compressive strength compared to 28 days strength.Quality of concrete will be slightly affected but overall quality will be retained.

[4] **A. Narender Reddy*, Prof T. Meena:** studied the overview of performance of Nano silica concrete,with 5% usage of nano silica there is increase of 20% & 17% compressive strength of 7 & 28 days respectively.1% - 1.5% is the optimum replacement level of the nano silica willshow the optimum results. Addition of 0.5%-4% of NS leads to the reduction of water demand without use of superplasticizers.

[5] **G.QUERCA & H.J.H BROUWERS:** The results of this investigation shows that use of NS leads to the financially attractive concrete & reduces the Co2 footprint of produced concrete products.

[6] **Hasan Biricika, Nihal Sarierb:** Made an Comparative Study of the Characteristics of Nano Silica,Silica Fume and Fly Ash Incorporated Cement Mortars,The results showed that increase in the amount of NS 5%-10% leads to increase in compressive strength.

[7] **Renu Tiwar, Neha Gupta:** In this paper we study the effects of Nano silica,it is observed that the application of nano silica enhances the mechanical properties of the concrete.How ever the optimum content of the NS is still a question mark for the scientists and there are few challenges in nano technology such as proper dispersion and compitability of nano silica in concrete.

[8] **Dr. D. V. Prasada Rao, S. Venkata Maruthi:** here in this paper experimental investigation was carried out on use of nano silica and metakaolin in the concrete both the materials are used as partial replacement for the cement in the concrete.The higher surface area of metakaolin yielded the higher strengtyh and fastest strength gain rate.The combined replacement of NS and Metakaolin exibited strength increase than that of only metakaolin.

4.WORKABILITY TEST ON FRESH CONCRETE

General

The following table shows the slump values which are observed or obtained from our project work. The slump test is conducted on a different water binder ratio with different mix proportions of Nano-silica and Ultrafine fly ash & Metakaolin.

Fig 4.1 Slump Test

Fig 4.2 For 0.3 w/b ratio

Fig 4.3 For 0.325 w/b ratio

Fig 4.4 For 0.350 w/b ratio

Table 4.1 Slump results for Mix with 1.5% NS

W/B Ratio	Slump Value(mm)
0.3	159
0.325	154
0.35	148

Table 4.2 Slump results for Mix with 3% NS

W/B Ratio	Slump Value(mm)
0.3	148
0.325	142
0.35	140

Table 4.3 Slump results for Mx with 4.5% NS

W/B Ratio	Slump Value(mm)
0.3	152
0.325	145
0.35	137

- From the table 4.1, 4.2 and 4.3, 4.4 it is observed that the workability has been increased along with increasing w/b ratio.

5. RESULTS AND DISCUSSION

5.1 Compressive strength:-

Fig 5.1.1 Compression test of HPC

Fig 5.1.2 Compression failure of HPC

Table 5.1.1 Compressive strength results for 7 days for different W/B ratio

MATERIALS USED(%)			W/C RATIO		
NS	UFFA(%)	METAKAOLIN(%)	0.3	0.325	0.35
0%	**0%**	**0%**	**45.67**	**44.32**	**43.90**
1.5%	5%	5%	72.32	69.72	69.42
	10%	10%	58.65	55.46	54.59
	15%	15%	53.97	48.96	47.78
3%	5%	5%	74.68	71.09	69.97
	10%	10%	59.6	57.97	55.97
	15%	15%	57.93	56.64	55.38
4.5%	5%	5%	75.90	73.69	72.39
	10%	10%	64.39	62.92	63.10
	15%	15%	58.45	56.76	55.11

Table 5.1.2 Compressive strength results for 28 days for different W/B ratio

MATERIALS USED(%)			W/C RATIO		
NS	UFFA(%)	METAKAOLIN(%)	0.3	0.325	0.35
0%	**0%**	**0%**	**60.33**	**58.25**	**55.92**
1.5%	5%	5%	88.56	85.37	83.70
	10%	10%	71.39	70.04	68.76
	15%	15%	66.24	63.92	62.06
3%	5%	5%	90.12	88.37	86.40
	10%	10%	73.64	71.06	69.83
	15%	15%	68.46	66.76	64.63
4.5%	5%	5%	91.09	89.62	87.76
	10%	10%	73.47	71.62	68.77
	15%	15%	69.76	68.64	67.16

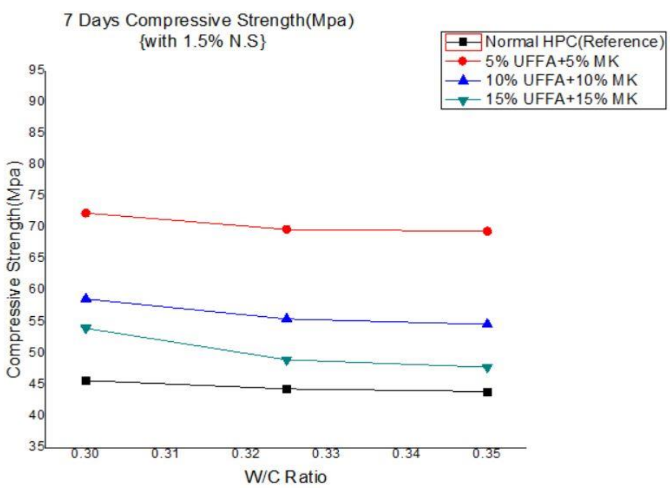

Fig 5.1.3 Graph showing compressive strength with 1.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

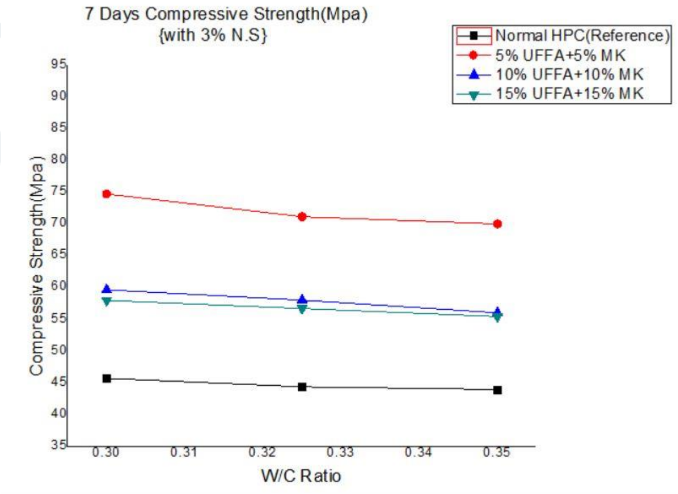

Fig 5.1.4 Graph showing compressive strength with 3% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

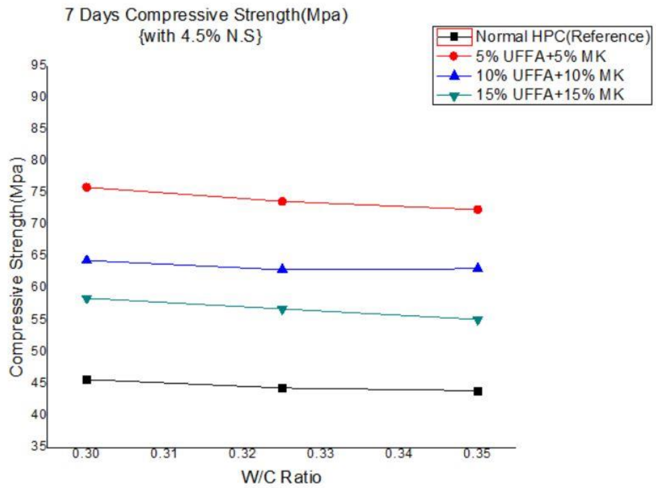

Fig 5.1.5 Graph showing compressive strength with 4.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

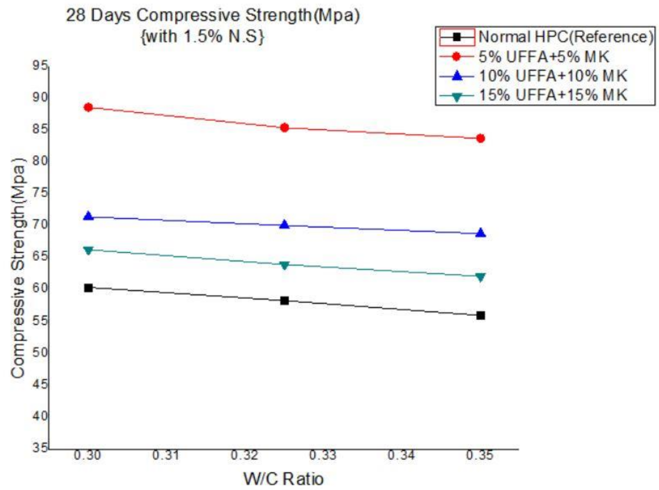

Fig 5.1.6 Graph showing compressive strength with 1.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

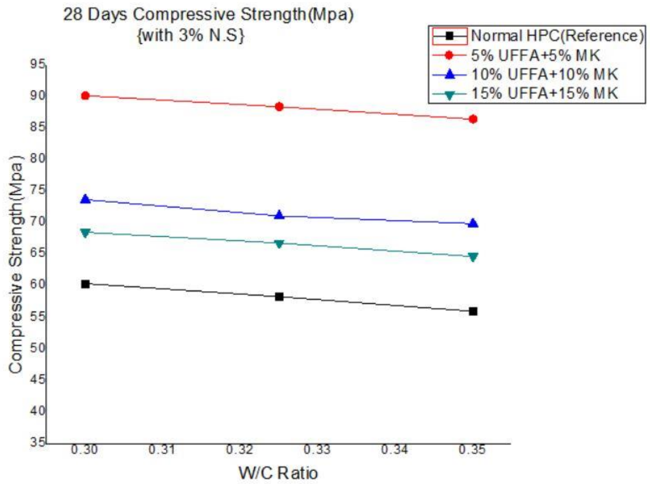

Fig 5.1.7 Graph showing compressive strength with 3% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

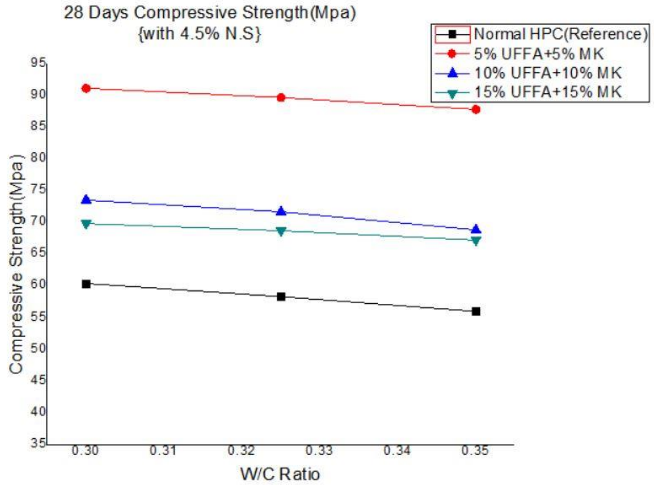

Fig 5.1.8 Graph showing compressive strength with 4.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

5.2 Split tensile strength:-

Fig 5.2.1 Split tensile test of HPC

Fig 5.2.2 Split tensile tensile failure of HPC

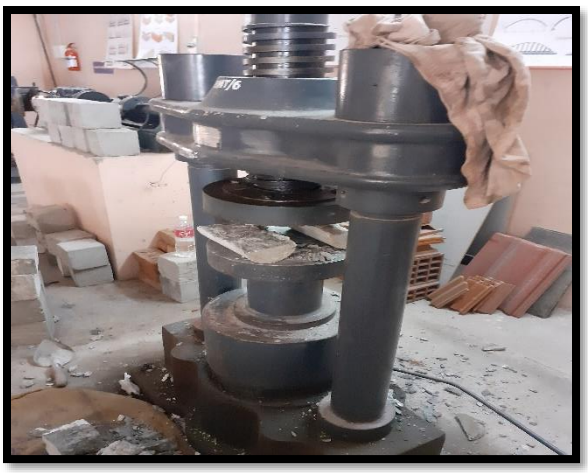

Table 5.2.1 Split tensile strength results for 7 days for different W/B ratio

MATERIALS USED(%)			W/C RATIO		
NS	**UFFA(%)**	**METAKAOLIN(%)**	**0.3**	**0.325**	**0.35**
0%	**0%**	**0%**	**4.27**	**4.01**	**3.85**
1.5%	5%	5%	6.25	6.11	5.72
	10%	10%	5.62	5.54	4.99
	15%	15%	5.48	4.62	4.23
3%	5%	5%	7.23	6.42	6.23
	10%	10%	5.82	5.62	5.12
	15%	15%	5.62	5.21	4.96
4.5%	5%	5%	7.92	7.84	6.82
	10%	10%	5.92	5.82	5.53
	15%	15%	5.68	5.53	5.28

Table 5.2.2 Split tensile strength results for 28 days for different W/B ratio

MATERIALS USED(%)			W/C RATIO		
NS	**UFFA(%)**	**METAKAOLIN(%)**	**0.3**	**0.325**	**0.35**
0%	**0%**	**0%**	**5.33**	**5.01**	**4.55**
1.5%	5%	5%	7.58	6.86	6.74
	10%	10%	6.92	6.46	5.92
	15%	15%	6.54	5.72	5.46
3%	5%	5%	8.12	7.88	7.22
	10%	10%	7.36	6.92	6.24
	15%	15%	6.74	6.24	5.72
4.5%	5%	5%	8.12	8.04	7.82
	10%	10%	7.8	7.24	6.56
	15%	15%	7.56	6.93	6.25

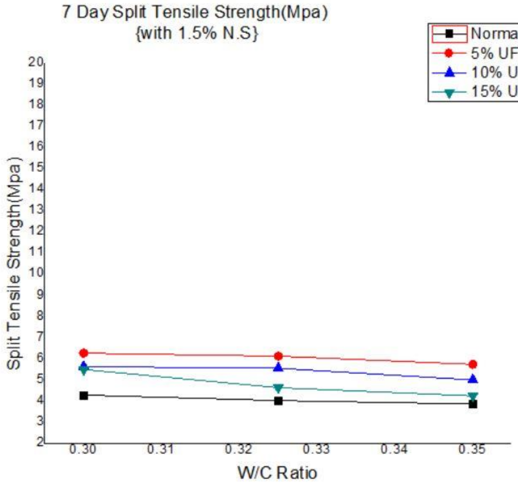

Fig 5.2.3 Graph showing Split tensile strength with 1.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

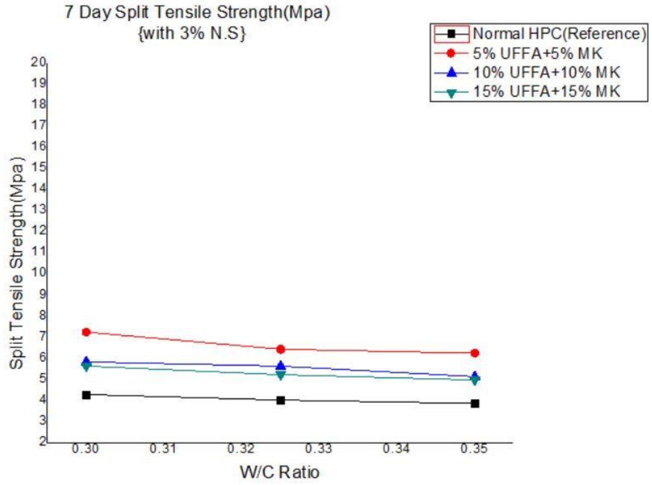

Fig 5.2.4 Graph showing Split tensile strength with 3% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

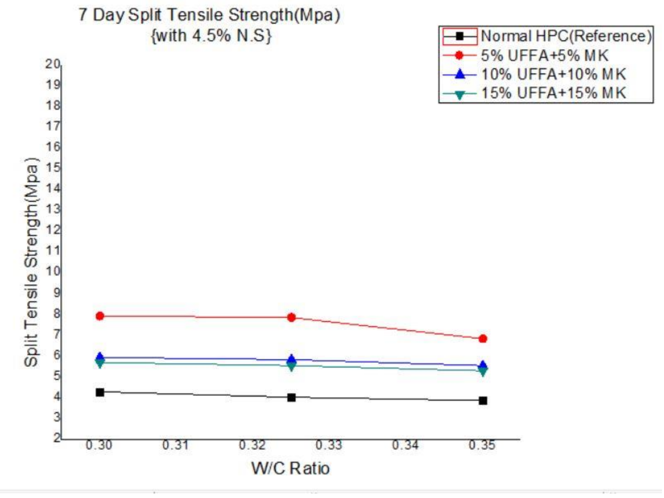

Fig 5.2.5 Graph showing Split tensile strength with 4.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

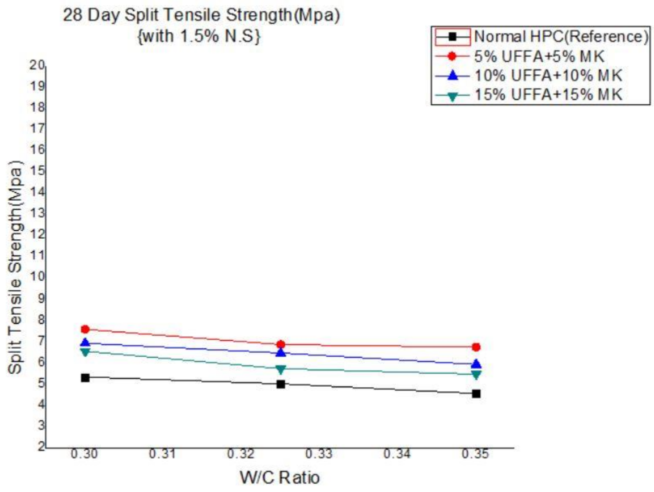

Fig 5.2.6 Graph showing Split tensile strength with 1.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

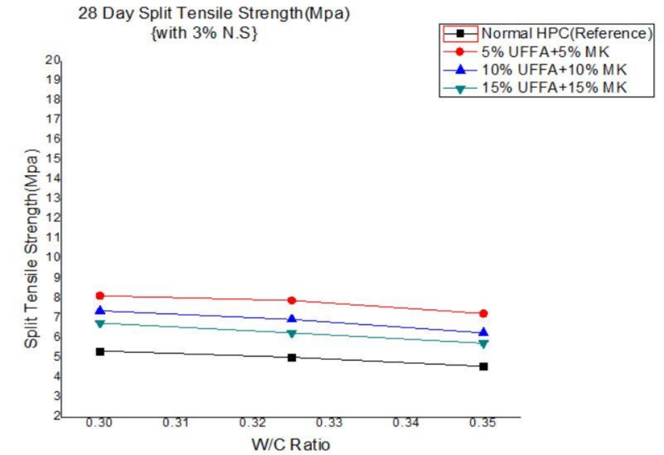

Fig 5.2.7 Graph showing Split tensile strength with 3% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

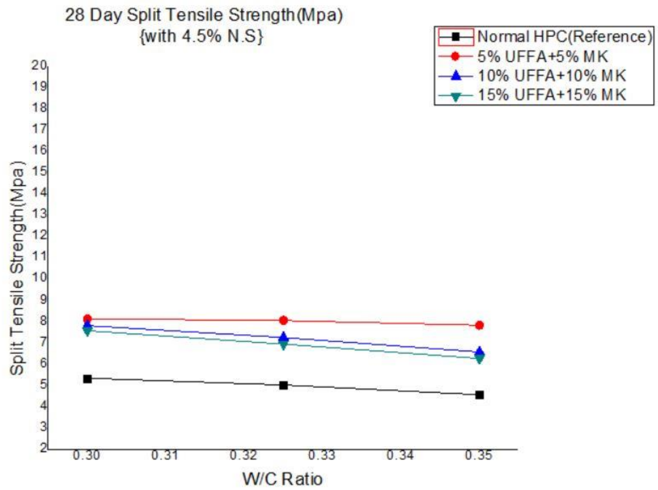

Fig 5.2.8 Graph showing Split tensile strength with 4.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

5.3 Flexural strength:-

Fig 5.3.1 Flexural strength test of HPC

Fig 5.3.2 Flexural strength failure of HPC

Table 5.3.1 Flexural strength results for 7 days for different W/B ratio

MATERIALS USED(%)			W/C RATIO		
NS	UFFA(%)	METAKAOLIN(%)	0.3	0.325	0.35
0%	**0%**	**0%**	**7.35**	**6.85**	**6.52**
1.5%	5%	5%	10.28	9.62	8.38
	10%	10%	8.76	8.16	7.96
	15%	15%	8.56	7.99	7.89
3%	5%	5%	11.56	11.04	10.12
	10%	10%	9.56	8.76	8.99
	15%	15%	9.24	8.96	8.99
4.5%	5%	5%	12.1	11.92	9.98
	10%	10%	9.56	9.16	9.02
	15%	15%	9.28	8.56	8.16

Table 5.3.2 Flexural strength results for 28 days for different W/B ratio

MATERIALS USED(%)			W/C RATIO		
NS	UFFA(%)	METAKAOLIN(%)	0.3	0.325	0.35
0%	**0%**	**0%**	**13.02**	**12.53**	**12.09**
1.5%	5%	5%	17.12	15.21	15.28
	10%	10%	14.16	13.28	12.50
	15%	15%	13.16	13.76	12.80
3%	5%	5%	17.81	16.2	15.94
	10%	10%	16.72	15.16	14.28
	15%	15%	14.88	14.31	13.98
4.5%	5%	5%	19.1	18.72	17.68
	10%	10%	16.48	15.82	14.98
	15%	15%	15.28	14.96	14.55

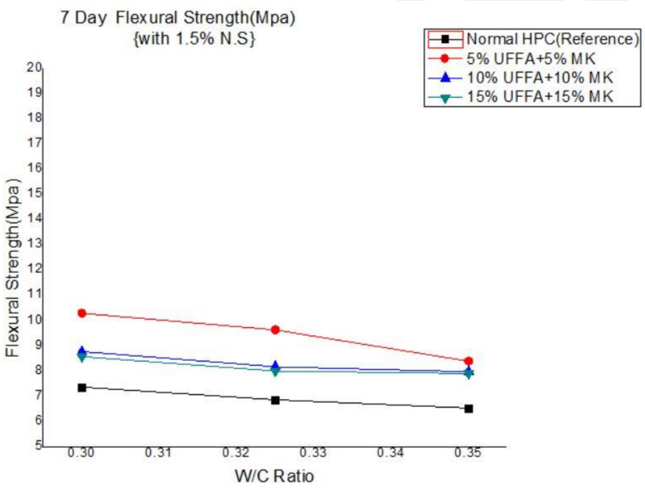

Fig 5.3.3 Graph showing Flexural strength with 1.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

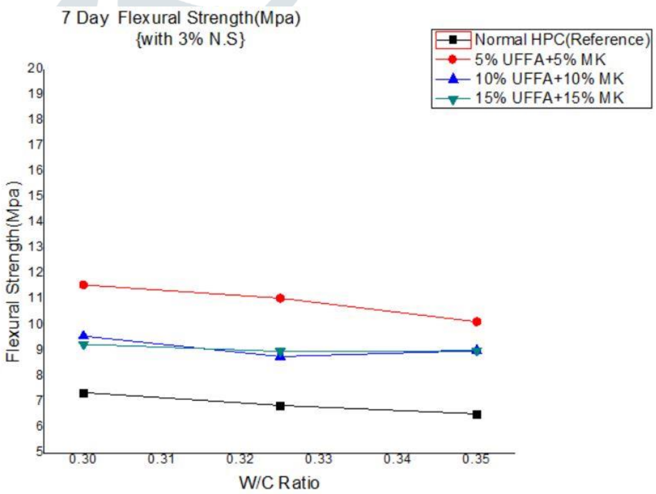

Fig 5.3.4 Graph showing Flexural strength with 3% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

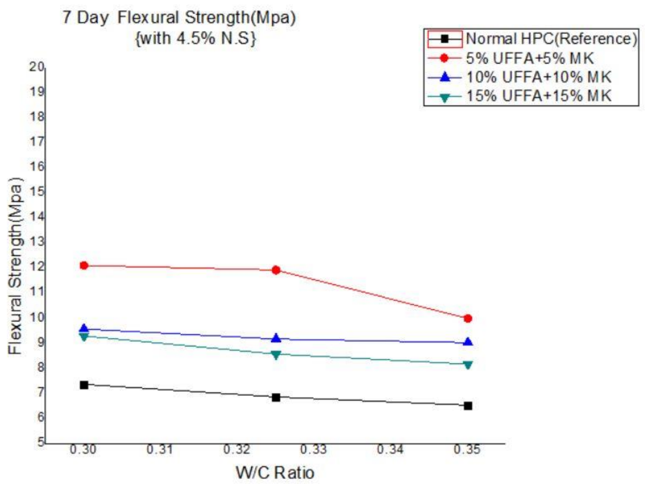

Fig 5.3.5 Graph showing Flexural strength with 4.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 7 days

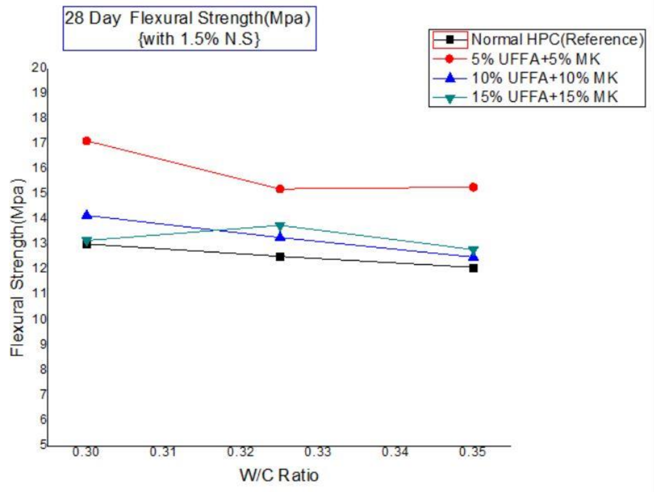

Fig 5.3.6 Graph showing Flexural strength with 1.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

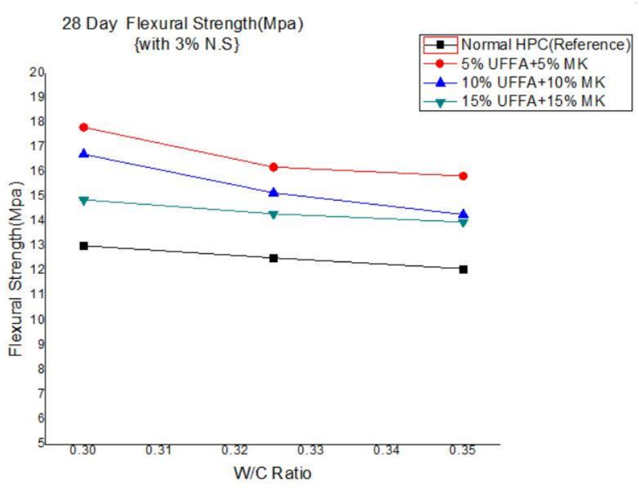

Fig 5.3.7 Graph showing Flexural strength with 3% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

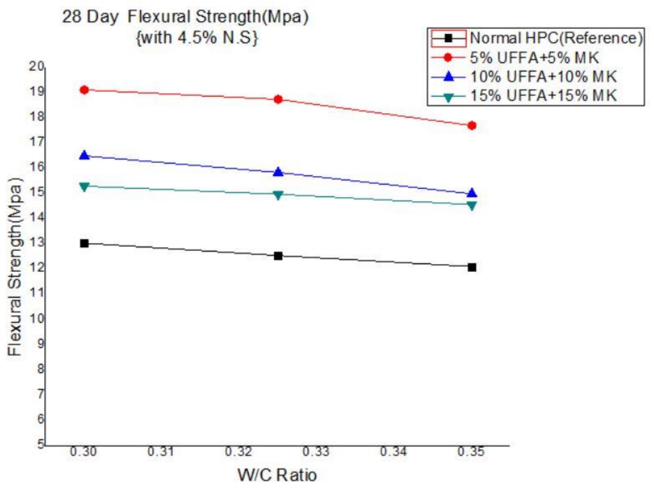

Fig 5.3.8 Graph showing Flexural strength with 4.5% NS Vs Diff Mix for 0.30,0.325 and 0.35 w/b ratio for 28 days

6.CONCLUSION

Based on the current experimental investigation the following conclusions are made:

1. Strength of the HPC is observed to be increased in appended with Metakaolin, UFFA and Nano-silica at 0.3 W/C Ratio.

2. The strength of HPC decreases with increases in water cement ratio.

3. The compressive strength of HPC increases with increases in percentage of Nano- silica .It is observed that at 7 days the increase in strength is 58.3%,63.5% and 66.19% at 1.5%,3% and 4.5% of Nano-silica(With 5%MK+5%UFFA). For 28 days the increase in strength is 46.7%,49.3% and 50.9% at 1.5%,3% and 4.5% of Nano-silica(With 5%MK+5%UFFA) respectively.

4. The compressive strength of HPC increases with increases in percentages of Metakaolin & UFFA admixture up to 10% and further increased in Metakaolin & UFFA decreases the strength.

5. At 10% Metakaolin & UFFA the 28 days compressive strength observed is 91.09N/mm2 at 4.5% of Nano-silica .At 20% of Metakaolin & UFFA the strength decreases to 73.47N/mm2.

6. The increase in percentages of Compressive strength at 1.5%.3% and 4.5% of Nano-silica with 10% Metakaolin & UFFA is 46.7%, 49.3% and 50.9% respectively at 0.3 W/C Ratio.

7. The Split tensile strength of HPC increases with increases in percentages of Nano- silica. It is observed that 7 days the increases in strength is 46.37%, 69.3% and 85.4% at 1.5%, 3%.4.5% of Nano-silica(With 5%MK+5%UFFA). For 28 days the increases in strength is 42.21%,52.34% and 52.34% at 1.5%, 3% and 4.5% of Nano-silica(With 5%MK+5%UFFA) respectively.

8. The Split tensile strength of HPC increases with increase in addition of Metakaolin & UFFA by an amount of 10%.Further increases in Metakaolin decreases the strength.

9. At 10% Metakaolin & UFFA the 28 days strength observed is 8.12 N/mm2 at 4.5% of Nano- silica .At 20% of Metakaolin & UFFA the strength decreases and it is 7.8 N/mm2.

10. The increase in Split tensile strength of HPC at 1.5%, 3% and 4.5% of Nano- silica With 10% Metakaolin & UFFA is 42.21%,52.34% and 52.43% respectively at 0.3 W/C Ratio. .

11. The Flexural strength of HPC increases with increase in percentages of Nano-silica.It is witnessed that 7 days the increases in strength is 39.8%,57.27% and 64.6% at 1.5%,3% and 4,5% of Nano-silica(With 5%MK+5%UFFA) .For 28 days the increases in strength is 31.4%,36.7% and 46.6% at 1.5%,3% and 4.5% of Nano-silica(With 5%MK+5%UFFA) respectively.

12. The Flexural strength of HPC increases with increase in percentages of admixture Metakaolin & UFFA up to 10%.Further increase in Metakaolin decrease the strength.

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9. SATYAJIT PARIDA: studied the Effect of Nano Silica on the Compressive Strength of Concrete, on addition of nano silica there is subsatantial increase in early age compressive strength compared to 28 days strength.Quality of concrete will be slightly affected but overall quality will be retained.
10. A. Narender Reddy*, Prof T. Meena: studied the overview of performance of Nano silica concrete,with 5% usage of nano silica there is increase of 20% & 17% compressive strength of 7 & 28 days respectively.1% - 1.5% is the optimum replacement level of the nano silica willshow the optimum results. Addition of 0.5%-4% of NS leads to the reduction of water demand without use of superplasticizers.
11. G.QUERCA & H.J.H BROUWERS: The results of this investigation shows that use of NS leads to the financially attractive concrete & reduces the Co2 footprint of produced concrete products.
12. Hasan Biricika, Nihal Sarierb: Made an Comparative Study of the Characteristics of Nano Silica,Silica Fume and Fly Ash Incorporated Cement Mortars,The results showed that increase in the amount of NS 5%-10% leads to increase in compressive strength.
13. Renu Tiwar, Neha Gupta: In this paper we study the effects of Nano silica,it is observed that the application of nano silica enhances the mechanical properties of the concrete.How ever the optimum content of the NS is still a question mark for the scientists and there are few challenges in nano technology such as proper dispersion and compitability of nano silica in concrete.
14. Dr. D. V. Prasada Rao, S. Venkata Maruthi: here in this paper experimental investigation was carried out on use of nano silica and metakaolin in the concrete both the materials are used as partial replacement for the cement in the concrete.The higher surface area of metakaolin yielded the higher strengtyh and fastest strength gain rate.The combined replacement of NS and Metakaolin exibited strength increase than that of only metakaolin.