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Experimental Investigation on the Strength Properties of High Performance Concrete using M-sand and Metakaolin

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Abstract - *Concrete is the most commonly used construction material in the world. The introducing of mineral admixtures in cement has gradually increased as due to advancement in concrete industry, as due to concern of cost saving, energy saving, environmental safety and maintenance of resources. However, environmental concerns both in terms of damage by extraction of raw materials and carbon di oxide emission during cement manufacture have brought pressure to reduce the cement consumption by the use of supplementary materials. High Performance Concrete (HPC) is the latest development in the concrete. It has become more popular these days and is being used in many prestigious projects.*

Study has been carried out to assess the strength properties of HPC by replacement of cement by Metakaolin with three proportions that is 0%, 10% and 20% Natural Sand by M-Sand (Manufactured Sand) by six proportions that is 0%, 20%, 40%, 60%, 80% and 100% and with same aggregate binder ratio of 2.5 and various water binding ratios of 0.30, 0.35 and 0.40 evaluating its compressive strength, split tensile strength and flexural strength.

Metakaolin used as a partial replacement of cement which was treated as an economical and due to its pozzolonic action increases strength and durability properties of concrete. M-Sand is waste material from quarry industry not disposed properly in to the land used in the concrete replaced for the sand. The test results obtained indicates that M-Sand of marginal quantity as the partial sand replacement has beneficial effects on the mechanical properties

Key Words: Manufactured Sand, metakaolin, Super Plasticizer, Strength properties, High performance concrete.

1. INTRODUCTION

1.1 Background to the study

Concrete is the constructional material composed of cement, aggregates, sand and water. Concrete has become most versatile building material which generally used for civil engineering fields like building frames, dams, bridges, roads etc., to resist compressive forces. The addition of plasticizers, super plasticizers and some pozzolanic materials are used to reduce water binder or water/cement ratio to improve the concrete properties like workability, permeability, durability, strength resistance to the cracks etc.,

Concrete mix proportions are modified by an addition of admixtures, to improve the pozzolanic activities as well as which also improves the micro-structures of concrete. The various admixtures are available to raise strengthening property of the concrete, In this s the admixtures of Metakaolin is used as a pozzolanic material and it can replace to cement to increase the strength properties of the concrete as compare to conventional concrete.

High Performance Concrete (HPC) is most recent growth in concrete, recently it has became the most popular, because this was used in so many prestigious projects like Nuclear power projects, flyover, skyscrapers and dams etc.,

HPC is the concrete used to improve the strength and durability properties of the concrete. it can be developed by an incorporating of some high reactive mineral admixtures like silica fume, fly ash, rice husk, Metakaolin, etc., are most commonly used, since the fineness property of all this admixtures are yields strength and durability properties of HPC over than the conventional concrete.

The study has been carried out to improve strength properties of concrete by using ordinary material with nominal mixing procedure (mixing, placing and curing). Concrete mixes with different percentages of Metakaolin as a cement replacement material were investigated. The dosages of Metakaolin were 0 %,10% and 20% of the cementations materials. The compressive flexural and tensile strength of concrete obtained at 7 and 28days.

1.2 Role of M-Sand

M-Sand is manufactured sand obtained from various industrial byproduct such as quarry, granite. All over world the utilization of Natural River bed sand is very high in concrete as due to increase in development activities. In

developed countries the use natural sand is quite high; in this situation developing countries are facing a shortage in available of natural sand. Due to the excess excavation of Natural sand from rivers can causes environmental problems. Therefore construction industries are identifying alternate material to reduce the dependence on natural sand by using artificially manufactured sand.

The byproduct of Granite powder is obtained from quarry, where this material cannot be used for other application except filling of low lying areas, and this can be used as replacement of natural sand in concrete. The only some part may be useful of dumping and remaining portion causes environmental problems.

In this study replacement of river sand is made by using M-Sand to assess strength properties of concrete.

1.3 Importance of HPC over Conventional Concrete

- Easy in Mixing and placing
- To withstand with segregation
- Initial strength is high
- Durability
- To withstand with all atmospheric conditions
- Resist chemical attack
- Resist and withstand to the all deterioration process
- Toughness
- Volume stability
- Strengthens the concrete properties
- Improvement in mechanical properties

1.4 Objectives

The main objective of the study to know strength properties of the concrete by an incorporation of mineral admixtures and M-Sand with constant aggregate binder ratio i.e. 2.5. Following are the particular objectives are to be achieved

- To know the strength properties of different water binding ratio of plain HPC with different percentage of M-Sand.
- To measure the strength properties of HPC for different percentage of mineral admixture and M-Sand.
- To measure strength properties for different water binding ratio of HPC (i.e. 0.3 0.35 0.4).
- To reduce the water binding ratio by an addition of super plasticizer.
- Comparison of strength properties for conventional and mineral admixture concrete.

2.0 MATERIALS

2.1 Material used and their properties

- Cement (OPC- 43 Grade) Ultratech
- Fine Aggregate
- Manufacture Sand or M-Sand
- Coarse Aggregate
- Water
- Super Plasticizer
- Mineral Admixture- metakaolin (0%, 10% & 20%)

2.1.1Mineral admixture

- Carefully fired (calcinated) refined kaolin clay, under controlled condition, which creates amorphous allumino silicate, reactive to cement is called Metakaolin. 25% of hydrated Portland cement which is accounted as calcium hydroxide, which does not prove to contribute strength or durability, combines with metakaolin and produces additional cementing compounds responsible stronger concrete.
- Metakaolin is neither industrial by-product nor a natural available material. Mk has great advantage as ASCM since it can increase many properties of concrete and also reduces cementing consumption. Usage of metakaolin can be more advantageous for preparing stronger and more durable concrete mixes. The performance of concrete improved by addition of Metakaolin. Chemical formula of Metakaolin is **$al_2o_3 \cdot 2sio_2 \cdot 2h_2o$.** The Specific gravity of Metakaolin is = 2.5. Table 5: Indicates the chemical composition of Metakaolin.

Table 2.1: Chemical composition of Metakaolin.

Chemicals	Percentage (%)
Sio2	62.62
Al2o3	28.63
Fe2o3	1.07
Mgo	0.15
Cao	0.06
Na2o	1.57
K2o	3.46
Tio2	0.36
Li2o	2

2.1.2Manufactured sand

This manufactured sand is used to replacement of Natural sand. The size of the aggregates is less than 4.75mm. Bellow Table shows the physical properties of M-sand.

Table 2.2: Properties of M-Sand

S.No	properties
1	Specific gravity = 2.5
2	Bulk density = 1752 kg/m^3
3	Water absorption = 1.0%

3.0 MIX DESIGN DATA

Mix design can be calculated for three various W /B ratio, that are 0.30, 0.35 and 0.40 and kept aggregate binding ratio2.5 as constant for all W /B ratio and hence bellow tables are indicates material per cubic meter of concrete in Kg's.

Table 3.1: W/B = 0.30 and Metakaolin = 0%

M-sand	0%	20%	40%	60%	80%	100%
Cement	719.88	754.65	792.95	835.34	882.52	935.35
MTK	0	0	0	0	0	0
Water	215.96	226.39	237.88	250.6	264.76	280.6
C.A	863.86	905.58	951.54	1002.4	1059	1122.4
F.A	575.9	482.98	380.61	267.31	141.2	0
M-sand	0	120.74	253.74	400.96	564.81	598.62

Table 3.2: W/B = 0.30 and Metakaolin = 10%

M-sand	0%	20%	40%	60%	80%	100%
Cement	644.4	675.35	709.41	747.1	789.02	835.93
MTK	71.6	75.038	78.824	83.012	87.669	92.881
Water	214.8	225.12	236.47	249.04	263.01	278.64
C.A	859.2	900.46	945.89	996.14	1052	1114.6
F.A	572.8	480.25	378.35	265.64	140.27	0
M-sand	0	120.06	252.24	398.46	561.08	743.04

Table 3.3: W/B = 0.30 and Metakaolin = 20%

M-sand	0%	20%	40%	60%	80%	100%
Cement	569.73	596.93	626.87	659.97	696.75	737.88
MTK	142.43	149.23	156.72	164.99	174.19	184.47
Water	213.65	223.85	235.08	247.49	261.28	276.71
C.A	854.59	895.4	940.3	989.95	1045.1	1106.8
F.A	569.73	477.55	376.12	263.99	139.35	0
M-sand	0	119.39	250.75	395.98	557.4	737.88

Table 3.4: W/B = 0.35 & Metakaolin =0%

M-sand	0%	20%	40%	60%	80%	100%
Cement	694.87	727.21	762.7	801.85	845.22	893.56
MTK	0	0	0	0	0	0
Water	243.2	254.52	266.95	280.65	295.82	312.75
C.A	833.84	872.65	915.25	962.22	1014.3	1072.3
F.A	555.86	465.41	366.1	256.59	135.24	0
M-sand	0	116.35	244.07	384.89	540.94	571.88

Table 3.5: W/B =0.35 & Metakaolin =10%

M-sand	0%	20%	40%	60%	80%	100%
Cement	622.12	650.92	682.51	717.33	755.88	798.82
MTK	69.12	72.32	75.83	79.7	83.98	88.75
Water	241.93	253.13	265.42	278.96	293.95	310.65
C.A	829.5	867.9	910.02	956.44	1007.9	1065.1
F.A	553	462.88	364	255.05	134.38	0
M-sand	0	115.72	242.67	382.57	536.77	710.07

Table 3.6: W/B =0.35 & Metakaolin =20%

M-sand	0%	20%	40%	60%	80%	100%
Cement	550.13	575.46	603.23	633.82	667.67	705.35
MTK	137.53	143.86	150.8	158.45	166.91	176.33
Water	240.68	251.76	263.91	277.29	291.1	308.6
C.A	825.2	863.2	904.85	950.73	1001.5	1058
F.A	550.13	460.37	361.94	253.52	133.53	0
M-sand	0	115.08	241.29	380.3	534.14	705.35

Table 3.7: W/B =0.40 & Metakaolin =0%

M-sand	0%	20%	40%	60%	80%	100%
Cement	671.54	701.7	734.69	770.94	810.95	855.34
MTK	0	0	0	0	0	0
Water	268.62	280.68	293.88	308.38	324.38	342.14
C.A	805.85	842.03	881.63	925.13	973.14	1026.4
F.A	537.23	449.09	352.65	246.7	129.75	0
M-sand	0	112.27	235.1	370.05	519.01	547.42
S.P (0.4)	2.69	2.81	2.94	3.08	3.24	3.42

Table 3.8: W/B =0.40 & Metakaolin =10%

M-sand	0%	20%	40%	60%	80%	100%
Cement	601.34	628.21	657.58	689.84	725.42	764.88
MTK	66.82	69.8	73.06	76.65	80.6	84.99
Water	267.26	279.2	292.26	306.6	322.41	339.95
C.A	801.79	837.61	876.77	919.79	967.23	1019.8
F.A	534.53	446.72	350.71	245.28	128.96	0
M-sand	0	111.68	233.81	367.91	515.86	679.9

Table 3.9: W/B = 0.40 & Metakaolin =20%

M-sand	0%	20%	40%	60%	80%	100%
Cement	531.85	555.48	581.32	609.67	640.93	675.57
MTK	132.96	138.87	145.33	152.42	160.23	168.89
Water	265.92	277.74	290.66	304.84	320.47	337.79
C.A	797.77	833.23	871.98	914.51	961.4	1013.4
F.A	531.85	444.39	348.79	243.87	128.19	0
M-sand	0	111.1	232.53	365.8	512.74	675.57

4.0 RESULTS AND DISCUSSION

The test on concrete was done in two stages:

- Fresh concrete
- Hardened concrete

4.1 Slump Cone Test

The slump is maintained in between 70 to 90 mm for better workability.

4.2 Compressive strength

The compressive strength of the concrete for mix proportion were tested for 7 and 28th days of curing. The specimen was tested under compressive testing machine.

0% Admixture		7days strength (Mpa)			28day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	M.Sand						
100%	0%	44.72	43.52	441.9	53.92	52.82	50.88
80%	20%	45.84	43.94	42.72	56.77	53.94	52.77
60%	40%	47.55	45.72	43.66	58.84	56.62	54.55
40%	60%	50.83	47.44	45.24	59.96	58.73	56.44
20%	80%	47.66	45.58	43.82	57.77	56.88	54.82
0%	100%	45.55	43.92	42.67	54.24	53.66	52.55

10%		7days strength (Mpa)			28day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	M.Sand						
100%	0%	54.83	53.11	50.46	64.68	61.92	60.44
80%	20%	56.77	54.22	52.88	67.31	65.26	61.33
60%	40%	59.55	56.11	53.55	69.54	66.12	64.52
40%	60%	62.11	58.92	55.42	72.88	68.88	66.44
20%	80%	58.92	55.17	52.37	68.22	65.03	62.15
0%	100%	55.14	53.41	50.08	65.11	62.77	59.82

20% Admixture		7days strength (Mpa)			28day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	M.Sand						
100%	0%	43.26	41.36	39.46	52.33	50.27	49.02
80%	20%	44.47	42.77	40.72	54.62	51.82	50.13
60%	40%	46.22	44.55	42.11	57.16	53.11	51.77
40%	60%	48.77	46.11	44.33	58.44	56.93	53.03
20%	80%	46.33	44.07	41.77	56.11	53.55	51.08
0%	100%	43.55	41.62	41.11	53.07	50.72	49.55

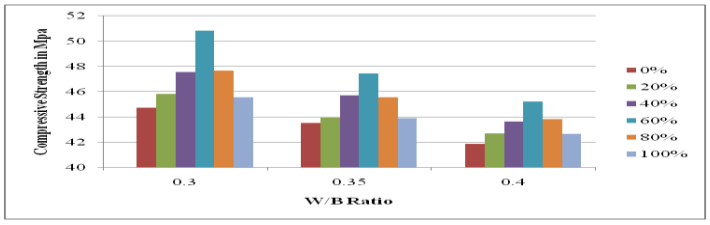

Chart -1: 0% Mineral admixture for 7days

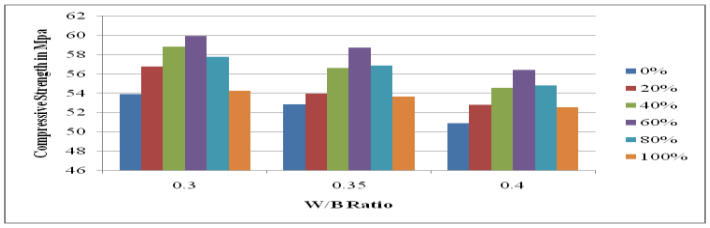

Chart -2: 0% Mineral admixture for 28days

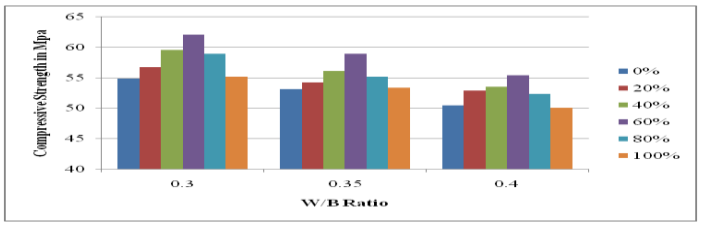

Chart -3: 10% Mineral admixture for 7days

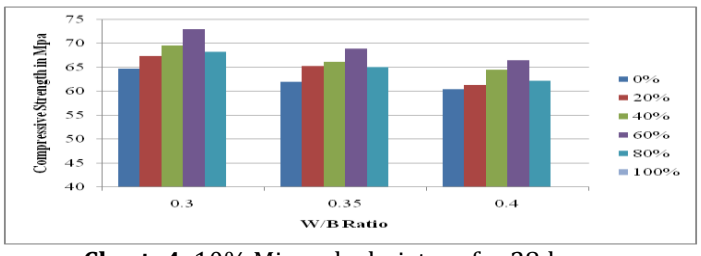

Chart -4: 10% Mineral admixture for 28days

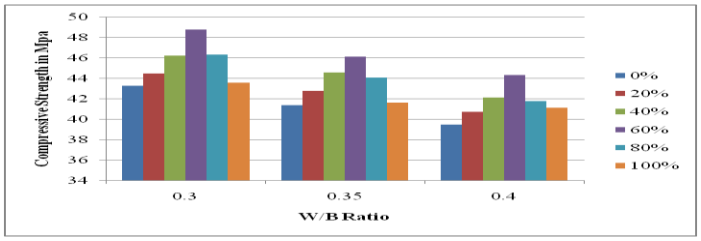

Chart -5: 20% Mineral admixture for 7days

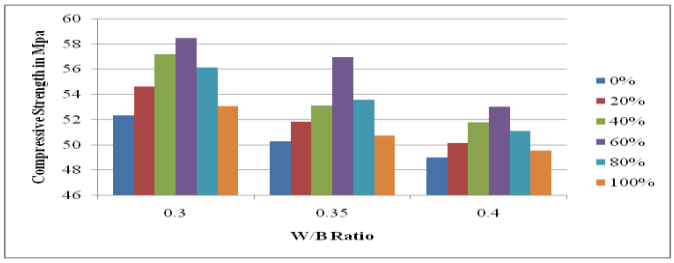

Chart -6: 20% Mineral admixture for 28days

4.3 Split Tensile Strength

The cylinder was kept horizontally in between the two plates of the compressive testing machine and the load is applied. The load at which the specimen ultimately fails is noted and split tensile strength is calculated.

0% Admixture		7 days strength (Mpa)			28 day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	MS and						
100%	0%	4.16	4.02	3.84	4.84	4.55	4.44
80%	20%	4.26	4.11	3.96	5.03	4.78	4.52
60%	40%	4.48	4.34	4.07	5.25	4.96	4.74
40%	60%	4.67	4.42	4.22	5.33	5.21	4.92
20%	80%	4.44	4.26	4.11	5.24	4.92	4.71
0%	100%	4.11	4.08	3.92	4.92	4.64	4.55

10% Admixture		7 days strength (Mpa)			28 day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	MS and						
100%	0%	4.82	4.46	4.22	5.66	5.42	5.11
80%	20%	4.94	4.66	4.37	5.92	5.66	5.33
60%	40%	5.06	4.82	4.55	6.14	5.88	5.58
40%	60%	5.33	5.04	4.82	6.44	6.04	5.72
20%	80%	4.88	4.72	4.51	5.96	5.62	5.41
0%	100%	4.77	4.66	4.24	5.68	5.44	5.16

20% Admixture		7 days strength (Mpa)			28 day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	MS and						
100%	0%	4.02	3.92	3.88	4.55	4.42	4.19
80%	20%	4.11	4.03	3.91	4.68	4.48	4.36
60%	40%	4.22	4.11	3.96	4.82	4.74	4.66
40%	60%	4.36	4.23	4.15	5.04	4.91	4.82
20%	80%	4.24	4.16	4.04	4.92	4.72	4.57
0%	100%	4.03	4.05	3.86	4.62	4.44	4.24

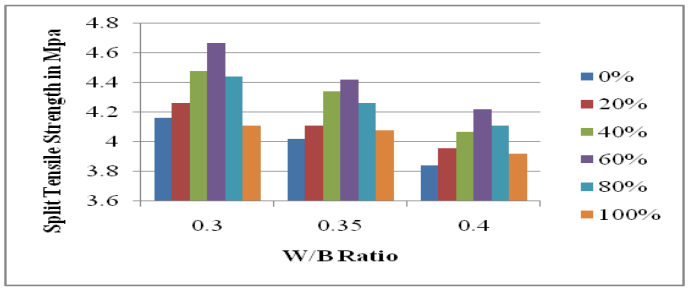

Chart -7: 0% Mineral admixture for 7days

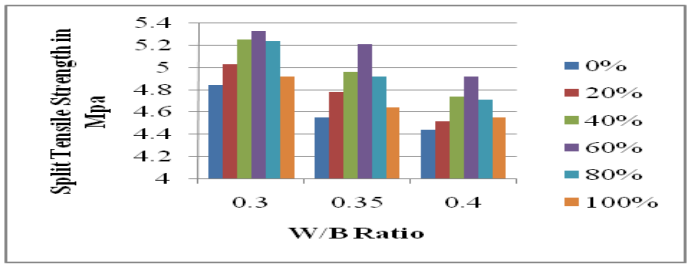

Chart -8: 0% Mineral admixture for 28days

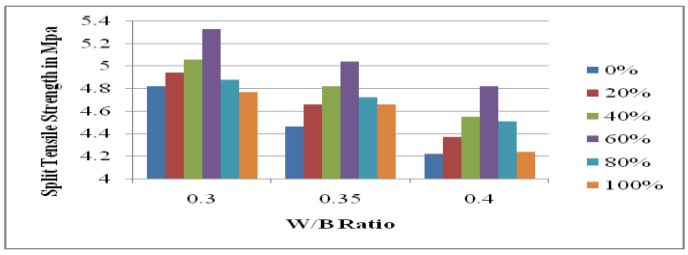

Chart -9: 10% Mineral admixture for 7days

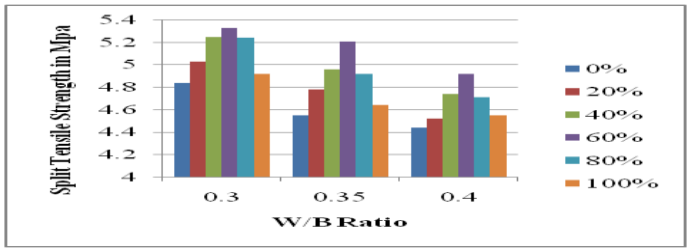

Chart -10: 10% Mineral admixture for 28days

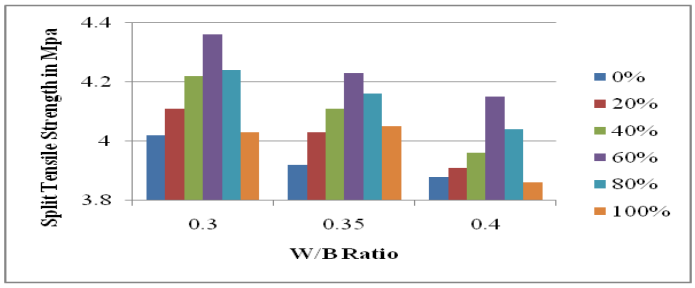

Chart -11: 20% Mineral admixture for 7days

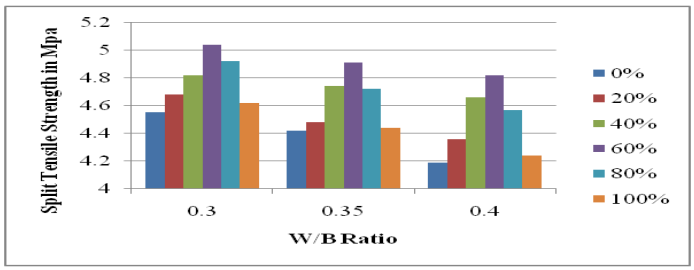

Chart -12: 20% Mineral admixture for 28days

4.4 Flexural Strength

The prism was tested after 7 and 28 days to know the flexural properties of concrete. The test has been conducted in universal testing machine of about 60T capacity. Casted

beam(100x100x500mm) has been placed under two point loading to know the flexural strength of concrete.

0% Admixture		7days strength (Mpa)			28day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	M.Sand						
100%	0%	6.82	6.55	6.06	12.11	11.88	11.44
80%	20%	6.94	6.77	6.33	12.55	12.06	11.77
60%	40%	7.33	6.88	6.66	13.04	12.44	12.03
40%	60%	7.77	7.22	6.82	13.33	12.92	12.52
20%	80%	7.22	6.77	6.42	12.72	12.55	12.11
0%	100%	6.92	6.33	6.18	12.33	12.03	11.66

10% Admixture		7days strength (Mpa)			28day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	M.Sand						
100%	0%	8.11	7.72	7.33	14.62	14.11	13.68
80%	20%	8.55	8.02	7.64	14.91	14.45	13.92
60%	40%	8.72	8.36	7.88	15.24	14.72	14.22
40%	60%	9.06	8.62	8.24	15.66	15.06	14.77
20%	80%	7.88	7.52	7.33	15.18	15.32	14.92
0%	100%	7.52	7.22	6.88	14.52	14.24	13.88

20% Admixture		7days strength (Mpa)			28day strength (Mpa)		
W/C		0.3	0.35	0.4	0.3	0.35	0.4
Sand	M.Sand						
100%	0%	6.52	6.23	5.92	11.88	11.62	11.22
80%	20%	6.68	6.44	6.11	12.04	11.85	11.55
60%	40%	6.92	6.63	6.33	12.33	11.92	11.77
40%	60%	7.12	6.82	6.55	12.62	12.11	12.02
20%	80%	6.72	6.55	6.22	11.92	11.77	11.66
0%	100%	6.55	6.27	6.02	11.68	11.52	11.11

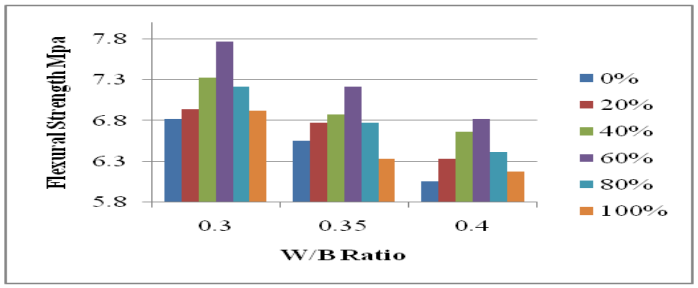

Chart -13: 0% Mineral admixture for 7days

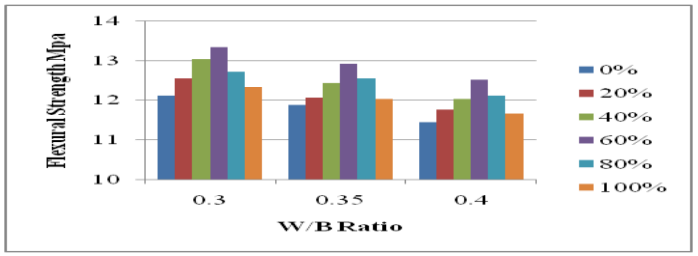

Chart - 14: 0% Mineral admixture for 28days

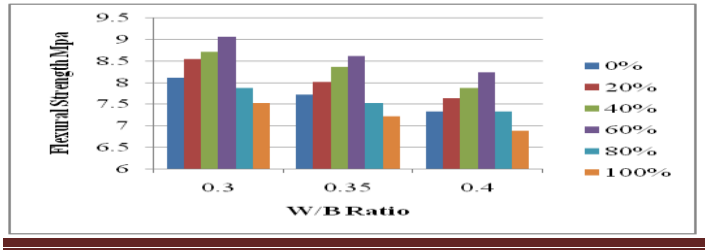

Chart - 15: 10% Mineral admixture for 7days

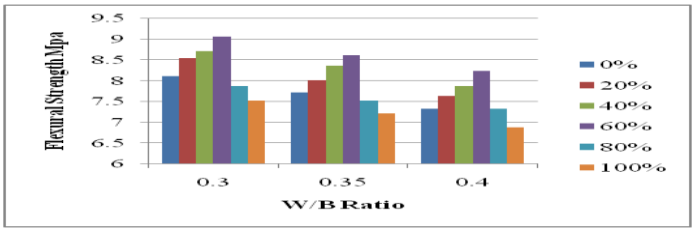

Chart - 16: 10% Mineral admixture for 28days

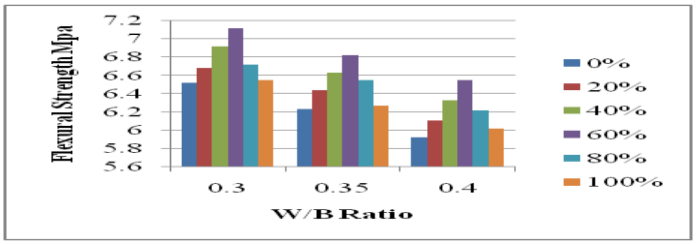

Chart - 17: 20% Mineral admixture for 7days

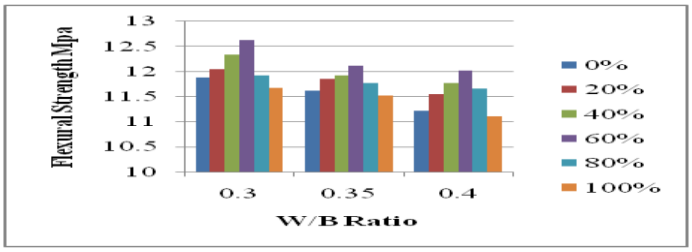

Chart - 18: 20% Mineral admixture for 28days

3. CONCLUSIONS

The main aim of this study is to assess strength properties of the concrete, and to achieve this strength, the addition of admixture and replacement of River sand by using M-Sand were accomplished. The following conclusion were made from the study.

- The replacement of sand by M-sand increases the strength properties of HPC up to 60% replacement.
- The addition of Metakaolin by replacement of cement increases the compressive strength of concrete as compare with plain HPC.
- The 7 and 28 days compressive strength of concrete for 0% admixture with 60% replacement of M-Sand is 50.83MPA and 59.96 MPA respectively. The 7 and 28 days compressive strength of concrete for 10% of admixture with 60% replacement of M-Sand is 62.11 MPA and 72.88 MPA respectively. Hence the result of replacement of cement with Metakaolin and use of M-Sand gives 22.19% (7 days) and 21.54% (28 days) increase in strength of concrete. Therefore the replacement of Metakaolin by 10% of cement was found more effective.
- The increase in W/B ratio decreases the strength of HPC.

- The increase in split tensile strength for 7and 28 days at 0.3 W/B ratio, 10% of Metakaolin and 60% of M-sand was obtained 14.13 and 20.82% respectively.
- The result of replacement of cement with Metakaolin by 10% and use of 60% M-Sand gives 16.60% (7 days) and 17.48% (28 days) increase in flexural strength of concrete at 0.30% W/B ratio.
- Therefore by replacing of admixture Metakaolin and M-Sand was found to be more effective in reducing the cement and sand quantity. The increases in mechanical properties were found on concrete by the addition of Metakaolin admixture and M-Sand by River sand.

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