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Quantify the Physical Properties of Concrete by Partial Replacement of River Sand by M- Sand Using Fly Ash as Mineral Admixture

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Abstract: Sand and cement, which go into making concrete, is in great demand because it is a crucial building material. Due to this demand, environmental degradation is rising during the production of cement and river basins are running out of sand. Concrete is being updated with suitable substitutes without sacrificing its durability and strength. Fly ash and M sand are used in this study as alternatives to cement and fine aggregates, respectively. Fly ash is by product of combustion process; hence utilizing this product in concrete can be advantageous to both the environment and cost considerations. Whereas M sand is obtained by crushing aggregates into desirable sizes which can benefit workability of concrete .The percentage of these alternatives for which partial replacement results in higher test values is indicated in this study. Super plasticizer was used in testing on newly laid concrete. M 45 grade concrete mix design as per IS 10262:2019 is calculated. Testing was done on M45 grade fresh concrete for workability: slump cone test, compaction factor test, vee bee consist-meter test, as well as hardened concrete for compression strength, tensile strength, and flexural strength. The tests were conducted for variable percentages of fly ash and M sand by weight of cement and natural sand replacement. In this study natural sand is replaced with M sand in 0, 10, 20, 30, 40 & 50% for every 0%, 10% & 15% replacement of fly ash with cement. Satisfying results were found for 10% fly ash and 40% M sand mix for both workability tests and strength tests conducted in the specimen.

I. INTRODUCTION

Concrete is an essential building material that you can use to enhance the strength of your building.The major raw material for concrete production is limestone & natural sand which are coming with cost to both environmentally & financially. Due to rapid urbanization of developing nations and the upkeep of structures in developed nations, there is a high demand for high-quality concrete at the same time. Therefore, the production of concrete can be made more sustainable by substituting some concrete constituents with industrial waste, since these substitutes are already produced but still disposed. On the other hand, the addition of discussed industrial wastes has been shown to improve the properties of concrete: strength and workability. Sand is currently very expensive. Large-scale market introductions of materials like artificial sand have significantly lessened the cost burden of river sand on concrete. It makes sense for the world to use industrial wastes, such as slag, fly ash, etc., to partially replace fine aggregates.

II. FLY ASH

When lignite or pulverised coal is burned, a significant amount of by- product is formed in thermal power plants, due to the high burning temperature of the coal, the fragmented particles that become molten and then solidify are generally spherical particles known as Fly ash. Fly ash is fine spherical silt sized (10-100 μ) solid residual, which could be transported easily by flue gases and deposited at electro- filters. About 80% of the ash residue produced is carried by flue gases and subsequently collected by electrostatic precipitators that are installed in chimneys to decrease air pollution. The remaining 20% of the residual is at the bottom forming bottom ash. Fly ash, hopper ash, or chimney ash are all terms used to describe the ash that is collected at the top of the chimney. Fly ash is made up of organic components like unborn carbon and inorganic substances like silica and alumina. The fly ash's mineral makeup and particle sizes have a big impact on its pozzolonic properties.

A. Properties of Fly ash

1) Improved workability: The shape of particles is spherical hence they act as small ball bearings in concrete as lubricants.
2) Lowered water demand: Fly ash, which accounts for around 20% of the cementitious material, reduces water demand by about 10%.

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3) Reduced heat of hydration: Concrete's hydration heat can be reduced by using fly ash.
4) Improved ultimate strength: Fly ash concrete gains strength over time as a result of growing binder resulted by the interaction of the fly ash with available lime.
5) Reduced permeability: Because of the improved binder produced by the interaction between the fly ash and easily accessible lime, fly ash concrete gets stronger over time.
6) Improved resistance to corrosion: The corrosion resistance is increased by the decrease in permeability.

III. MANUFACTURED SAND

M Sand is manufactured sand used in cement or concrete construction that is made by crushing rocks or granite. Natural sources for sand such as river sand, stream sand, pit sand, sea sand and other sands, for use as aggregate in construction are becoming scarce and exhausted as a result of environmental deterioration. M Sand was developed in response to a rising need in the building sector for alternative aggregates. Another argument in favour of its utilisation is the active availability of M sand, which cuts down on pollutants and transit times. M Sand is a better option than river sand since it is manufactured by machines in the correct ratios of particle size.

A. *Properties of M-Sand*

1) Greater Durability: M Sand can withstand challenging environmental conditions and has balanced physical and chemical characteristics.
2) Higher Strength: M Sand doesn't contain any elongated or flaky particles and has a smooth surface texture thanks to the usage of a VSI shaping machine.
3) Greater Workability: Mortar has outstanding workability due to its cubical shape and correct gradation, which calls for particles to range in size from 150 microns to 4.75 mm.
4) Economy: Waste is nonexistent because M Sand doesn't have any contaminants like river sand does. Given that it is easily accessible, the cost of transportation also decreases.

IV. OBJECTIVE OF THE WORK

The goal is to determine the strength parameters to efficiently utilize fly ash and M sand in the mix as it decreases the environmental effect and also can be made cost effective as well as not compromising with the durability and strength parameters. In this study natural sand is replaced with M sand in 0, 10, 20, 30, 40 & 50% for every 0%, 10% & 15% replacement of fly ash with cement. Tests such as compressive strength test, split tensile test & flexural strength test are conducted. Workability tests such as vee bee consist-meter test, compaction factor test and slump cone test are as well conducted on fresh concrete. Both fly ash & M sand have been studied as potential partial replacements in concrete. In the current study, the behaviour of concrete is made by swapping out traditional components for the right proportion of these alternates is examined. Tests for workability and strength are used to see the impact of the fly ash and M sand.

V. MATERIALS FOR CONCRETE MIX

1) *Cement:* OPC 43 grade cement was used with the properties listed below

TABLE -1: Properties of Cement

Material Properties	Results
Specific Gravity	3.15
Fineness	4%
Normal Consistency	34%
Initial setting time	45 min
Final setting time	5 hrs 50 min

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2) Fly Ash: Class F dry fly ash with properties below

TABLE -2: Properties of Fly ash

Seive size(μ)	Weight retained (gms)	% passing
90	95	92%
75	122	83%
45	704	62%
Specific Gravity	2.2	

3) Fine Aggregates

TABLE -3: Properties of Fine aggregates

Sieve size(μ)	Cumulative % passing	Specifications of zone II (IS:383-1970)
4.75mm	100	90-100
2.36mm	98	75-100
1.18mm	83	55-90
600	55	35-59
300	16	8-30
150	2	0-10
Pan	0	0
Specific Gravity	2.65	
Bulk Density	1765 Kg/m^3	
Water Absorption	1.0%	

4) Coarse Aggregates

TABLE -4: Properties of Coarse aggregates

<table>
<tr><th rowspan="3">IS Sieve Size in mm</th><th colspan="2">% passing of CA</th><th colspan="3">% passing of different fractions</th><th colspan="3">Specifications as per IS: 383-1970</th></tr>
<tr><th rowspan="2">I (20mm)</th><th rowspan="2">II (12.5mm)</th><th rowspan="2">I 60%</th><th rowspan="2">II 40%</th><th rowspan="2">Combined 100%</th><th rowspan="2">graded</th><th colspan="2">Single sized</th></tr>
<tr><th>I</th><th>II</th></tr>
<tr><td>20</td><td>100</td><td>100</td><td>60</td><td>40</td><td>100</td><td>95-100</td><td>85-100</td><td>-</td></tr>
<tr><td>12.5</td><td>0</td><td>98.50</td><td>0</td><td>0</td><td>0</td><td>-</td><td>-</td><td>85-100</td></tr>
<tr><td>10</td><td>0</td><td>32.20</td><td>0</td><td>29.50</td><td>29.50</td><td>25-55</td><td>0-20</td><td>0-45</td></tr>
<tr><td>4.75</td><td>0</td><td>8.40</td><td>0</td><td>4.10</td><td>4.10</td><td>0-10</td><td>0-5</td><td>0-10</td></tr>
<tr><td colspan="9">Specific Gravity = 2.74</td></tr>
<tr><td colspan="9">Bulk Density = 1732 Kg/m³</td></tr>
<tr><td colspan="9">Water Absorption = 0.5%</td></tr>
</table>

VI. MIX DESIGN

A. M45 grade concrete mix design (As per IS: 10262 – 2019)

1) Target mean strength :

$f'_{ck} = f_{ck} + 1.65 \times s = 45 + 1.65 \times 5 \Rightarrow f'_{ck} = 53.25\ N/mm^2$.

W/C = 0.45< 0.60(Fig. 1 of IS 10262:2019)

2) Determination of water content :

=186 + [8.4/100*186] =201.62kg(120mm slump)

Water content = 201.62 x 0.77 = 155.25 Kg (Super plasticizer is used)

3) Determination of cement content:

Cement = $\frac{\text{Water content}}{\text{W/C}} = \frac{155}{0.45}$ => Cement content =345 Kg/m³

Cemenetitious material content = 345 x 1.10 = 379 Kg/m³

W/C = $\frac{155}{379}$ = 0.41

Total cementitious material content = 379 x 30% = 113.85 Kg/m³(Fly ash @ 30%)

Cement = 379 – 113.85 = 265.65 Kg/m³

∴ Cement content = 379 Kg/m³> 240 Kg/m³(T-5 IS 456-2000)

4) Quantity of Coarse & fine aggregates:

for W/C =0.41,

= 0.62 + 0.019 (correction applied)

coarse aggregate corrected volume = 0.639 m³

for fine aggregate = 1.00 – 0.639

fine aggregate corrected volume = 0.361 m³

B. Mix Design Calculations per Unit Volume

1) Concrete volume = 1.00 m³

2) Wet concrete entrapped air volume = 0.01 m³

3) Cement volume = $\frac{\text{mass of cement}}{\text{specific gravity of cement}} \times \frac{1}{1000} = \frac{265.65}{3.15} \times \frac{1}{1000} = \mathbf{0.08\ m^3}$

4) Volume of fly ash = $\frac{\text{mass of fly ash}}{\text{specific gravity of fly ash}} \times \frac{1}{1000} = \frac{113.85}{2.2} \times \frac{1}{1000} = \mathbf{0.052\ m^3}$

5) Volume of water = $\frac{\text{mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000} = \frac{155}{1} \times \frac{1}{1000} = \mathbf{0.155\ m^3}$

6) Chemical admixture volume = $\frac{\text{mass of chemical admixture}}{\text{specific gravity of admixture}} \times \frac{1}{1000} = \frac{3.79}{1.145} \times \frac{1}{1000} = \mathbf{0.003\ m^3}$

7) Volume of all in aggregate = [(1-0.01)– (0.08+0.052+0.155+0.003 = ***0.70 m³***

8) Mass of CA = **g****CA corrected volume*** ***Sp gty of CA* 1000** = 0.70× 0.639×2.74× 1000 = ***1217.47 Kg***

9) Mass of FA = **g****FA corrected volume*** ***Sp gty of FA* 1000** = 0.70 × 0.361×2.65× 1000 = ***665.21 Kg***

TABLE-5 Mix proportion

Cement (Kg/m³)	Fine aggregate (Kg/m³)	Coarse aggregate (Kg/m³)	Water (Kg/m³)	Fly ash (Kg/m³)	Chemical admixture (Kg/m³)
265.65	665.21	1217.7	155.25	113.85	3.79

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VII. EXPERIMENTAL INVESTIGATIONS & RESULTS

A. *Workability Tests*

TABLE -6: Variation of Slump values

Sl No.	% replacement of Fly Ash with OPC	% replacement of natural sand with M sand	Slump values(mm)
M1	0	0	70.00
M2	0	10	71.00
M3	0	20	72.00
M4	0	30	74.00
M5	0	40	74.00
M6	0	50	72.00
M7	10	0	73.00
M8	10	10	74.50
M9	10	20	75.00
M10	10	30	75.50
M11	10	40	76.00
M12	10	50	74.50
M13	15	0	72.00
M14	15	10	73.00
M15	15	20	73.50
M16	15	30	74.00
M17	15	40	74.50
M18	15	50	73.00

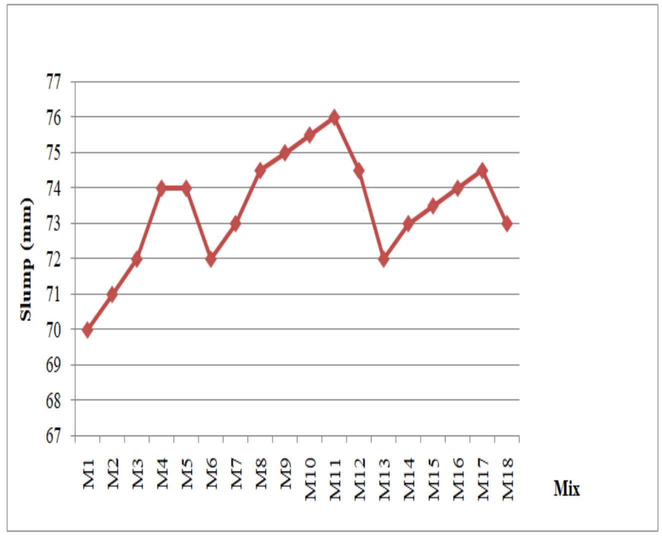

CHART -1: Variation of Slump values

TABLE -7: Variation of Compaction factor values

Sl No.	% replacement of Fly Ash with OPC	% replacement of natural sand with M sand	Compaction Factor (CF)
M1	0	0	0.860
M2	0	10	0.865
M3	0	20	0.868
M4	0	30	0.870
M5	0	40	0.872
M6	0	50	0.875
M7	10	0	0.876
M8	10	10	0.878
M9	10	20	0.880
M10	10	30	0.882
M11	10	40	0.911
M12	10	50	0.902
M13	15	0	0.910
M14	15	10	0.913
M15	15	20	0.915
M16	15	30	0.917
M17	15	40	0.920
M18	15	50	0.910

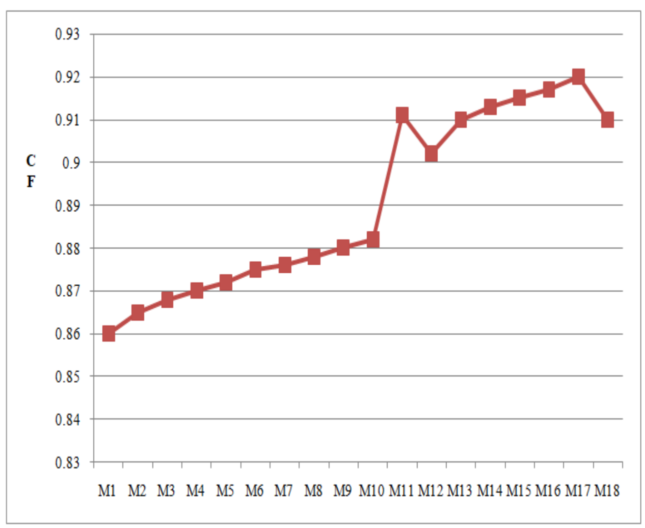

CHART -2: Variation of CF values

TABLE -8: Variation of Vee Bee time

Sl No.	% replacement of Fly Ash with OPC	% replacement of natural sand with M sand	Vee – Bee time (sec)
M1	0	0	15
M2	0	10	12
M3	0	20	10
M4	0	30	10
M5	0	40	8
M6	0	50	10
M7	10	0	9
M8	10	10	8
M9	10	20	8
M10	10	30	7
M11	10	40	5
M12	10	50	7
M13	15	0	8
M14	15	10	10
M15	15	20	12
M16	15	30	14
M17	15	40	14
M18	15	50	15

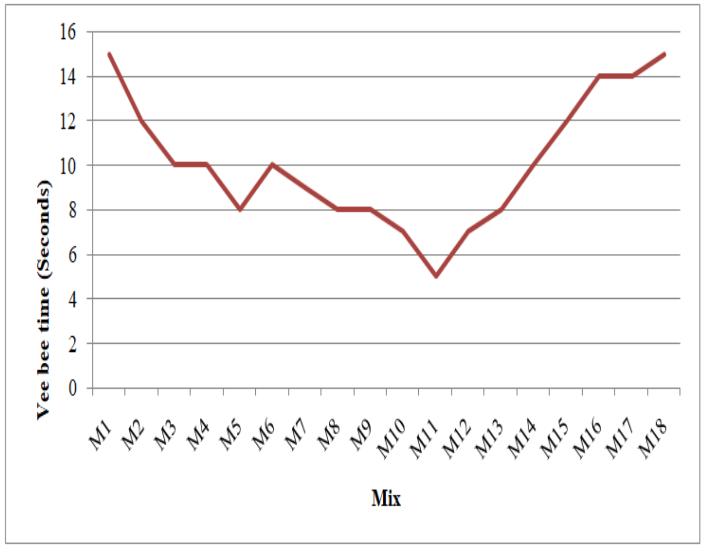

CHART -3: Variation of Vee Bee time

B. Results Of Tests On Hardened Concrete

TABLE -9: Variation of Compressive strength at 7 days

Sl. No.	Specimen	Failure load (kN)	Compressive strength (MPa)
1.	F 0% – M 0%(RM)	698	31.00
2.	F 0% – M 10%	743	33.00
3.	F 0% – M 20%	754	33.50
4.	F 0% – M 30%	765	34.00
5	F 0% – M 40%	788	35.00
6.	F 0% – M 50%	743	33.00
7.	F 10% – M 0%	802	35.65
8.	F 10% – M 10%	854	37.95
9.	F 10% – M 20%	867	38.525
10.	F 10% – M 30%	880	39.10
11.	F 10% – M 40%	906	40.25
12.	F 10% – M 50%	854	37.95
13.	F 15% – M 0%	729	31.372
14.	F 15% – M 10%	752	33.396
15.	F 15% – M 20%	763	33.902
16.	F 15% – M 30%	775	34.408
17.	F 15% – M 40%	797	35.42
18.	F 15% – M 50%	752	33.396

CHART-4: Variation of Compressive strength at 7 days

TABLE -10: Variation of Compressive strength at 28 days

Sl. No.	Specimen	Failure load(kN)	Compressive strength (MPa)
1.	F 0% – M0%(RM)	872	38.75
2.	F 0% – M 10%	929	41.25
3.	F 0% – M 20%	943	41.875
4.	F 0% – M 30%	957	42.51
5.	F 0% – M 40%	985	43.75
6.	F 0% – M 50%	929	41.25
7.	F 10% – M 0%	1003	44.56
8.	F 10% – M 10%	1067	47.43
9.	F 10% – M 20%	1083	48.15
10.	F 10% – M 30%	1100	48.87
11.	F 10% – M 40%	1132	50.31
12.	F 10% – M 50%	1067	47.43
13.	F 15% – M 0%	882	39.21
14.	F 15% – M 10%	940	41.74
15.	F 15% – M 20%	954	42.37
16.	F 15% – M 30%	968	43.01
17.	F 15% – M 40%	996	44.27
18.	F 15% – M 50%	940	41.74

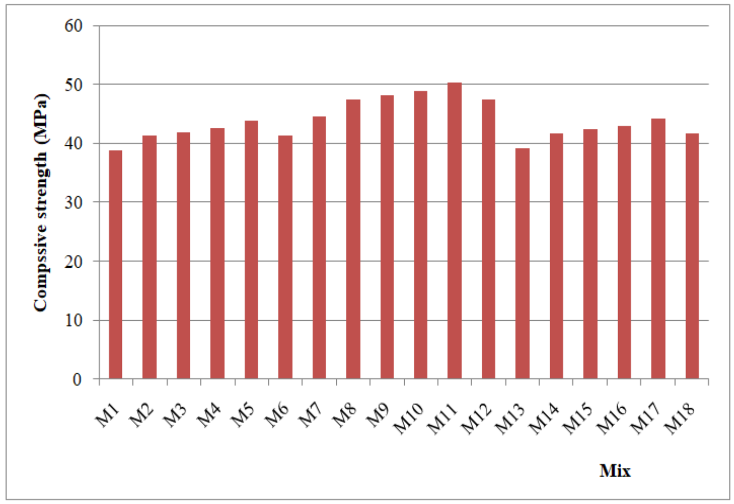

CHART-5:Variation of Compressive strength at 28 days

TABLE -11: Variation of Split tensile strength

Sl. No.	Specimen	Failure load (kN)	Split tensile strength (MPa)
1.	F 0% – M 0%(RM)	174	2.45
2.	F 0% – M 10%	213	3.01
3.	F 0% – M 20%	218	3.08
4.	F 0% – M 30%	223	3.15
5.	F 0% – M 40%	227	3.20
6.	F 0% – M 50%	229	3.24
7.	F 10% – M 0%	220	3.10
8.	F 10% – M 10%	229	3.24
9.	F10% – M 20%	237	3.35
10.	F 10% – M 30%	255	3.60
11.	F 10% – M 40%	284	4.01
12.	F 10% – M 50%	276	3.90
13.	F 15% – M 0%	241	3.40
14.	F 15% – M 10%	227	3.21
15.	F 15% – M 20%	215	3.03
16.	F 15% – M 30%	213	3.00
17.	F 15% – M 40%	213	3.01
18.	F 15% – M 50%	211	2.98

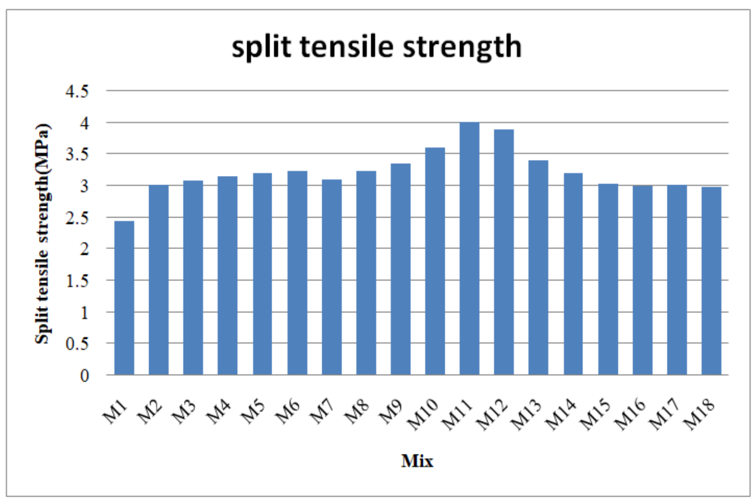

CHART-6: Variation of Split tensile strength of concrete

TABLE -12: Variation of flexural strength

Sl. No.	Specimen	Failure load (kN)	Flexural strength (MPa)
1.	F 0% – M 0%(RM)	14.50	5.8
2.	F 0% – M 10%	15.25	6.1
3.	F 0% – M 20%	16.25	6.5
4.	F 0% – M 30%	17.00	6.8
5.	F 0% – M 40%	18.75	7.5
6.	F 0% – M 50%	18.25	7.3
7.	F 10% – M 0%	16.00	6.4
8.	F 10% – M 10%	17.00	6.8
9.	F 10% – M 20%	17.50	7.0
10.	F 10% – M 30%	18.25	7.3
11.	F 10% – M 40%	19.25	7.7
12.	F 10% – M 50%	18.75	7.5
13.	F 15% – M 0%	17.50	7.0
14.	F 15% – M 10%	16.75	6.7
15.	F 15% – M 20%	16.50	6.6
16.	F 15% – M 30%	15.75	6.3
17.	F 15% – M 40%	15.00	6.0
18.	F 15% – M 50%	14.75	5.9

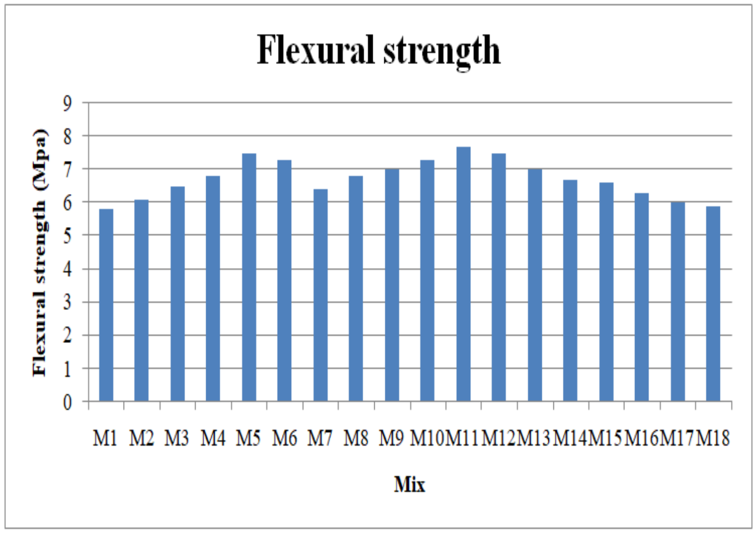

CHART-7: Variation of flexural strength of concrete

Fig -1: Vee bee consistometer test

Fig -2: compression test

Fig -3: Split tensile test

Fig 4: Flexural test

VIII. CONCLUSIONS

A. Workability goes on increasing up to 40% replacement of natural sand by M sand & 10% replacement of OPC by fly ash. Beyond this replacement level workability reduces.

B. Workability of concrete produced by replacing natural sand by M sand & OPC by fly ash is higher as compared to reference concrete.

C. Higher compressive strength can be obtained when the 40% replacement of natural sand by M sand & 10% replacement of OPC by fly ash.

D. Higher split tensile strength can be obtained when the 40% replacement of natural sand by M sand & 10% replacement of OPC by fly ash.

E. Concrete produced by replacing natural sand by M sand & OPC by fly ash exhibit higher split tensile strength as compared to reference concrete.

F. Higher flexural strength can be obtained when the 40% replacement of natural sand by M sand & 10% replacement of OPC by fly ash.

G. Concrete produced by replacing natural sand by M sand & OPC by fly ash exhibit higher flexural strength as compared to reference concrete.

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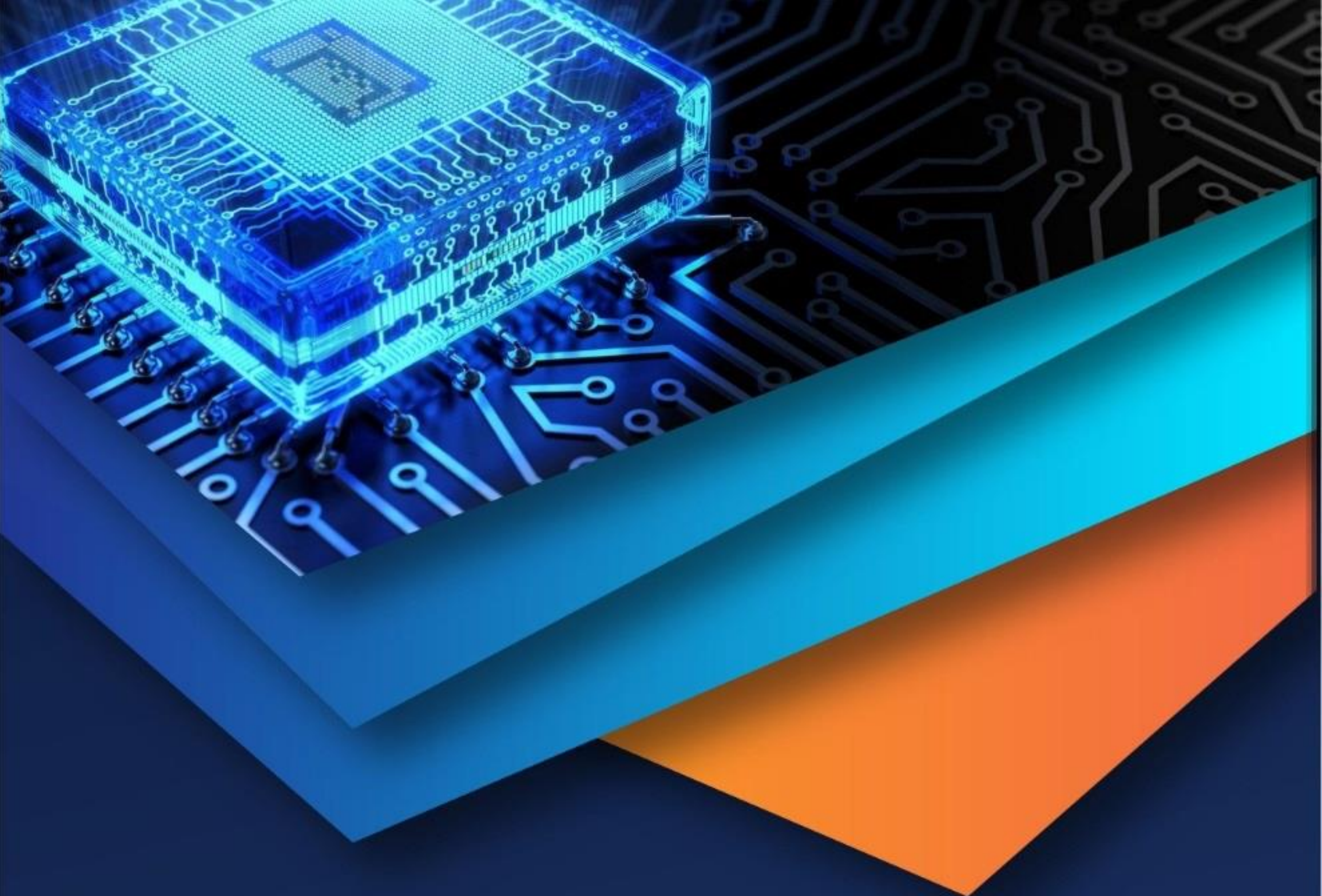

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