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Potential Utilization of Micro Silica as a Limited Substitution with Addition of Glass and Polypropylene Fiber for M40 Concrete

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Abstract: Nowadays there is an increase in environmental knowledge and its effects on the environment, the disposal of waste products from industries are being big deal to manage. Such waste materials cannot be dumped on any lands, due to this reason it is difficult to manage waste materials. After so many investigations finally conclude that waste material can be utilized in the construction as additives, such materials can reduce the cost of construction and gives more strength compared to conventional concrete. These products can be utilized to partial replacement of cement. In this investigation, we are using Silica fume/ Micro silica as a partial replacement of cement. From this combination, we can improve the strength, workability and resist cracks in concrete. To reduce water content PAR PLAST SPL super plasticizer is used. The present investigation is to determine the strength behavior of Silica fume/Micro silica and fibres in Rigid pavement. The concrete mix design is as per IRC 44 2009, and it is proportioned to set target mean strength as 40 Mpa. The water-cement ratio as per mix design is 0.38. Specimens was casted and cured for various percentages that are 0%, 2.5%, 5%, 7.5% and 10%. With this constant percentage of fibres was added that is 1% Polypropylene fibre and 0.5% Glass fibre. This specimen tested for 3, 7, 28 days for cubes and 7, 28 days for beams and cylinders. From this investigation, Cement can be replaced with Micro silica to improve strength properties like bending and tensile strength. The Silica fume/ micro silica found at 7.5% optimum dosage, up to this percentage cement can be replaced.

Keywords: Glass Fibre, PAR PLAST SPL, Polypropylene Fibre, Silica fume/ Micro silica, Stone Crusher Sand.

I. INTRODUCTION

Roads in India are bituminous roads. However, National Highway consists of a few concrete roads too. In 1990s concrete roads were not popular in some location, because of less availability of cement [2]. But nowadays cement is available in all location thus concrete roads once again increased its popularity.

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Concrete roads require less maintenance and weatherproof as compared bituminous based roads [8]. The National Highways are the pillar of the highway infrastructure and concrete roads in India. They convey most of India's goods and passenger traffic [10]. Major district roads and State highways represent the secondary roads in India. The major roads in India are under huge pressure and in significant require of modernization to grasp the increased need of the Indian economy with low-priced environment-friendly roads [10]. In addition to existing road maintenance, the growth of the interconnecting network and existing roads widening is becoming most important. This would then permit the roads to hold vehicular traffic and also enable for a consistent increase in the average vehicle movement speed on India's roads.

The rigid pavement is a highway structure, this is constructed from cement concrete laid on underlying superimposed courses, generally a base course and a subgrade [16]. Various advantages are attached to follow rigid pavements against flexible pavements [4]. Especially, a rigid pavement provides a comfortable, efficient, cost-effective and high-performance when it is dealing with high traffic loads [16]. Certainly, due to its mechanical resistance and high flexural rigidity, a concrete road layer permits to transmit the vehicular weights to the underlying courses, prevent stress and load in the subgrade, deflection and subsidence of the concrete pavement structure. Further, marking and roughening methods [5], generally based on suitable floor grinders, macro and micro-surface and skid resistance and friction of the rigid pavement surface may be accurately arranged which is a key matter in validating suitable safety standards.

II. MATERIALS USED AND METHODS

A. Cement:

Cement is the binding agent or binding powder to the Concrete to become a strong bond when water added to cement with proper ratio. Cement used is 53 grade OPC of Supreme Company as confirming IS 12269:1987 [14], The basic properties of the cement are tested in the laboratory.

Figure 1: OPC 53 Grade Cement

Table 1: Physical Properties of Cement

Properties	Result	Permissible limits as per IS 12269-1987
Fineness	2.22%	Not more than 10%
Standard Consistency	33%	-
Initial Setting Time	30 min	Should not be < 30min
Final Setting Time	180 min	Should not be > 600min
Specific Gravity	3.10	-

B. Silica Fume/ Micro Silica:

Supreme (Silica fume/ Micro silica) is a concrete additive, it has produced in powder form based on silica fume technology confirming IS 15388, ASTM C1240. It is used effectively in high-performance concrete [1].

Figure 2: Silica Fume/ Micro Silica

Table 2: Physical Properties of Micro silica

Properties	Results
Size	0.15μm
Bulk density	500 kg/m^3
Specific gravity	2.2
Moisture content	3%
Surface area	15 m^2 /gm

C. Fine Aggregate (Stone Crusher Sand):

Aggregate is an important part of concrete. They provide the body with concrete, and their durability also reduces the economics of contraction and effort [7]. The aggregate occupies the more than 60 to 70 % by volume of concrete. The basic properties of Stone crusher sand vary from place to place. In this project work, we used fine aggregate from Stone Crusher Sand which is available in Raichur dist Deodurga Taluk.

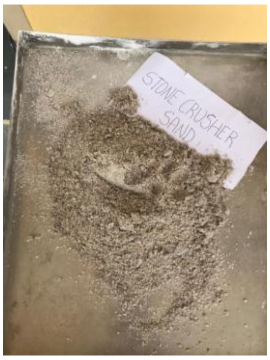

Figure 3: Stone Crusher Sand

Table 3: Fine Aggregate Results

Test	Results
Fineness Modulus	3.69 (Zone II)
Specific Gravity	2.53
Water Absorption	1.41%

D. COARSE AGGREGATE:

In this project work, 20 mm down sized coarse aggregates are used [11], aggregate is obtained from the local available crusher machine at Deodurga. The basic properties of coarse aggregate are tested at GPT college Deodurga laboratory.

Figure 4: Coarse Aggregate

Table 4: Coarse Aggregate Results

TEST	TEST RESULTS
Fineness modulus	4.27
Specific Gravity	2.742
Water Absorption	1%
Impact value	26.87%

E. Polypropylene Fibre:

RIPSTAR FIBRE is a high-performance monofilament polypropylene fibre developed as a crack controlling additive for concrete and mortar [5]. This material is manufactured by SP CONCARE PVT LTD an ISO 9001-2008 company.

Figure 5: Polypropylene Fibre

Table 5: Properties of Polypropylene Fibre

PROPERTIES	VALUES
Relative density	0.91
Material	Polymerised Polypropylene
Diameter of fibre	18 µ
Length of Fibre	12 mm
Area of surface	230 m^2/kg min
Elastic Modulus	3500-3900Mpa
Tensile strength	320-400Mpa
Melting Point	160^0 C
Aspect ratio	666

F. Glass Fibre:

Anti-Crak® HD fibres is an engineered AR-glass chopped strand designed for mixing in concrete and all hydraulic mortars [4]. This product was manufactured by OWENS CORNING COMPANY from China.

These fibres are manufactured with Zicronium content in compliance with ASTM C1666/C 1666/M-07.

Figure 6: Glass Fibre

Table 6: Properties of Glass Fibre

PROPERTIES	VALUES
Specific Gravity	2.68
Material	Alkali Resistant Glass
Fibre diameter	14 µ
Fibre length	12 mm
Elastic modulus	72 Mpa
Tensile strength	1700 MPa
Softening point	860° C.
Loss of Ignition	0.60 %
Aspect ratio	857

G. Super Plastisizer:

PAR PLAST SPL is a highly effective, water-reducing liquid admixture with no added chloride. It provides a significant improvement in workability without any bleeding segregation. PAR PLAST SPL is confirming by IS 1903-1999 and ASTM-C-494-86, type A & F.

Figure 7: PAR PLAST SPL

Table 7: Properties of PAR PLAST SPL

PROPERTIES	VALUES
Specific gravity	1.19
Colour	Dark Brown
Base	Sulfonated Naphthalene Formaldehyde
Dose	Up to 750 ml/50kg bags of cement

H. Water:

Potable water is used for preparing concrete.

III. MIX DESIGN

Mix design is calculated as per IRC 44-2009 code recommendation. The mix design was carried out for M40 grade of concrete. Mix proportion obtained for M40 grade concrete is given in the Table below.

CEMENT	FINE AGGREGATE	COARSE AGGREGATE	WATER
1	1.67	3.22	0.38
392 kg/m^3	655 kg/m^3	1263 kg/m^3	149 kg/m^3

IV. DETAILS OF PRESENT INVESTIGATION

The present investigation consists of a total number of cubes cast for compressive strength is 45 no's for mixed concrete, 30 no's of beams for flexural test and 30 no's of a cylinder for split tensile test. These test results give the conclusion of the present investigation of the project for M40 concrete.

Compression strength is carried out to find out strength and quality of concrete. In this test, cubes are prepared of 150mm x 150mm x 150 mm cubes size and cubes are cured for 03, 07 and 28 days. Cubes casted for 0%, 2.5%, 5%, 7.5% and 10% silica fume replaces with cement and 1% polypropylene fibre and 0.5% glass fibre is maintained constant throughout the compressive strength test.

Flexural test is carried out to find bending strength of the concrete. In this test, we prepare a prism of size 100mm x 100mm x 500mm. and cured the prisms up to 07 and 28 days for testing of the bending strength of concrete. Beams casted and tested for 0%, 2.5%, 5%, 7.5% and 10% silica fume replaces with cement and 1% polypropylene fibre and 0.5% glass fibre is maintained constant throughout the Flexural test. The Split tensile strength is used to determine the tensile strength of the concrete. In this test, cylinders are used to cast concrete for 07 and 28 days. In this test, the size of the cylinders is height 300mm X 150mm. Cylinders casted and tested for 0%, 2.5%, 5%, 7.5% and 10% silica fume replaces with cement and 1% polypropylene fibre and 0.5% glass fibre is maintained constant throughout the Split tensile test.

V. RESULTS AND DISCUSSION

A. SLUMP CONE TEST

Slump cone is used to determine the workable concrete as per IS 7320: 1974 recommendation [13]. This test was conducted in GPT college Deodurga.

Figure 8: Slump Cone Test

Table 8: Shows the Result of Slump Cone Value

Description	Slump Results (mm)
S 0%	24
S 2.5%	21
S 5%	18
S 7.5%	17
S 10%	15

B. COMPACTION FACTOR TEST

The compaction factor test is carried out to determines the workable of fresh concrete [13]. The test was conducted at Navodaya Institute of Technology Raichur as per IS 5515: 1996 recommendation.

Figure 9: Compaction Factor Test

Table 9: Shows the Result of Compaction Factor Value

Description	Compaction factor
S 0%	0.864
S 2.5%	0.856
S 5%	0.852
S 7.5%	0.846
S 10%	0.846

C. COMPRESSION TEST:

In this test, specimen 150 mm x150 mm x 150 mm was casted and cured for 3days, 7days, and 28days. After curing with respected days we test specimen in a CTM as per IS 516-1959 code recommendation [13]. It is calculated by using below given formula

$$F_{ck} = \frac{P}{A} \quad (1)$$

Where F_{ck} = Compression strength of cube N/mm^2
P = Specimen failure load
A = Cross-sectional area in mm^2

Figure 10: Cubes Casting and Testing

Table 10: Compressive Strength at 3 Days

MIX	Load (kn)	Compression value (N/mm^2)	Mean Compression value (N/mm^2)
S 0%	325	14.41	14.52
	340	15.15	
	315	14.03	
S 2.5%	350	15.59	15.03
	335	14.82	
	330	14.68	
S 5%	345	15.33	15.48
	360	16.05	
	340	15.13	
S 7.5%	375	16.61	15.99
	355	15.77	
	350	15.58	
S 10%	355	15.79	15.25
	345	15.35	
	330	14.62	

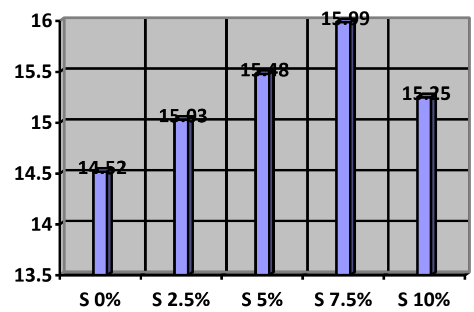

Figure 1: Compressive Strength at 3 days

Table 11: Compressive Strength at 7 Days

MIX	Load (Kn)	Compression value (N/mm²)	Mean Compression value (N/mm²)
S 0%	660	29.36	28.45
	645	28.63	
	650	28.89	
S 2.5%	670	29.72	29.84
	685	30.29	
	665	29.53	
S 5%	695	30.87	30.4
	685	30.49	
	670	29.74	
S 7.5%	700	31.15	31.7
	725	32.29	
	715	31.72	
S 10%	710	31.56	30.62
	680	30.27	
	700	31.10	

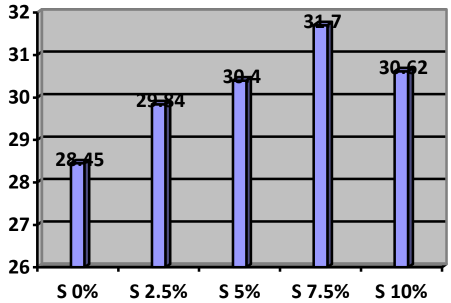

Figure 2: Compressive Strength at 7 days

Table 12: Compressive Strength at 28 Days

MIX	Load (kn)	Compression value (N/mm²)	Mean Compression value (N/mm²)
S 0%	1080	48.04	48.29
	1095	48.69	
	1085	48.25	
S 2.5%	1110	49.57	49.32
	1120	49.79	
	1095	48.65	
S 5%	1145	50.84	50.36
	1125	50.07	
	1130	50.28	
S 7.5%	1160	51.53	51.47
	1170	52.06	
	1145	50.84	
S 10%	1150	51.17	50.73
	1135	50.41	
	1140	50.63	

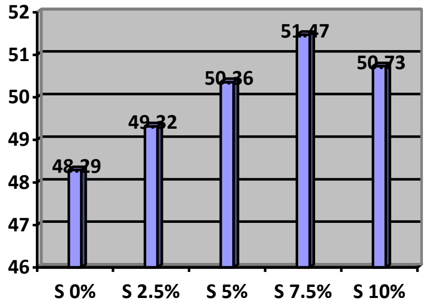

Figure 3: Compressive Strength at 28 Days

D. FLEXURAL TEST:

The Specimen of size 100mm X 100mm X 500mm were cast and cured for 7 and 28 days. Modulus of rupture is calculated by using below given formula [13]

$$F_{cr} = \frac{(P\times L)}{(b\times d^2)} \quad (2)$$

Where F_{cr} = Modulus of Rupture (N/mm²)
P = Applied load (N)
L = Beam length (mm)
b = Beam width (mm)
d = Beam depth (mm)

Figure 11: Beams Casting and Testing

Table 13: Flexural Strength at 7 Days

MIX	Load (Kn)	Modulus of rupture (N/mm²)	Mean Flexural (N/mm²)
S 0%	5.84	2.92	3.02
	6.22	3.11	
	6.04	3.02	
S 2.5%	6.28	3.17	3.16
	6.09	3.044	
	6.52	3.26	
S 5%	6.58	3.29	3.26
	6.76	3.38	
	6.24	3.12	
S 7.5%	7.06	3.53	3.74
	7.44	3.72	
	7.94	3.97	
S 10%	6.82	3.41	3.60
	7.32	3.61	
	7.58	3.74	

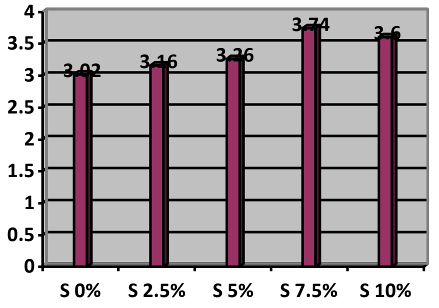

Figure 4: Flexural Strength at 7 days

Table 14: Flexural Strength at 28 Days

MIX	Load (Kn)	Modulus of rupture (N/mm^2)	Mean Modulus of rupture (N/mm^2)
S 0%	8.92	4.35	4.46
	9.16	4.58	
	9.04	4.15	
S 2.5%	9.96	4.98	4.84
	9.43	4.72	
	9.69	4.83	
S 5%	10.51	5.25	5.26
	10.37	5.17	
	10.75	5.38	
S 7.5%	11.42	5.71	5.71
	11.18	5.59	
	11.67	5.83	
S 10%	10.49	5.22	5.29
	10.71	5.37	
	10.57	5.29	

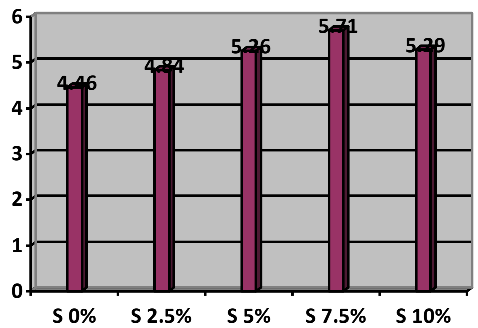

Figure 5: Flexural Strength at 28 days

E. SPLIT TENSILE STRENGTH TEST

Tensile strength test for a various mix at 07 and 28 day tested as per IS 5816-1970 [13]. The specimen tested on the CTM. It can be calculated by using given below formula

$$\sigma = \frac{2P}{\pi DH} \quad (3)$$

Where σ = Tensile strength (N/mm^2)
P = Load
L = Cylinder height (mm)
D = Cylinder diameter (mm)

Figure 12: Split Tensile Casting and Testing

Table 15: Split tensile Strength at 7 Days

MIX	Load (Kn)	Tensile value (N/mm^2)	Mean Tensile (N/mm^2)
S 0%	245	3.46	3.27
	230	3.25	
	220	3.11	
S 2.5%	250	3.53	3.56
	265	3.75	
	240	3.43	
S 5%	275	3.91	3.72
	260	3.67	
	255	3.60	
S 7.5%	270	3.82	3.96
	280	3.96	
	290	4.17	
S 10%	265	3.75	3.59
	240	3.46	
	255	3.62	

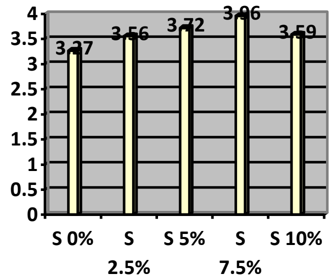

Figure 6:Tensile strength at 7 days

Table 16: Split tensile Strength at 28 Days

MIX	Load (Kn)	Tensile (N/mm2)	Mean Tensile (N/mm2)
S 0%	305	4.24	4.16
	290	4.13	
	280	3.96	
S 2.5%	325	4.59	4.57
	335	4.74	
	310	4.38	

S 5%	370	5.23	5.20
	380	5.37	
	355	5.02	
S 7.5%	405	5.73	5.75
	395	5.58	
	425	5.94	
S 10%	400	5.62	5.47
	390	5.51	
	375	5.30	

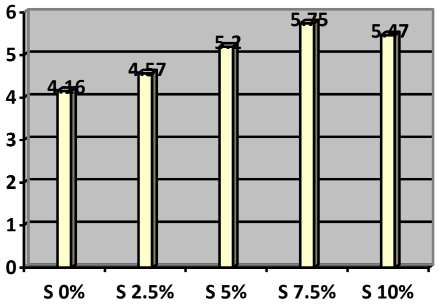

Figure 7: Tensile strength at 28 days

VI. CONCLUSION

From in this experiment workability of concrete, Compression strength, Modulus of Rupture and split tensile on M40 concrete mix with Silica fume 0%, 2.5%, 5% 7.5% and 10% partial replacement for cement and constant 1% of Polypropylene fibre and 0.5% of Glass fiber is considered for the present project investigation, following are the conclusions are obtained from this experiment mentioned below

1. Here the slump cone value decreases with the increase of Silica fume and getting medium workable slump value to easy workability of concrete.
2. The compression strength increases with the replacement of Micro silica by cement up to2.5% to 7.5% and gradually decreases the strength replacement of 10% the optimum strength getting at 7.5% replacement of Silica fume with respect normal concrete.
3. The tensile strength increases with the replacement of 5% and 7.5% with the addition of polypropylene fibre and Glass fibre and decreases strength when increases of Silica fume10% compared with normal concrete, normal concrete gives good strength compare to the replacement of Silica fume.
4. Flexural strength decreases the strength with the increase of Silica fume by 5 % its start decreases the strength compared with the Normal concrete.
5. Finally, we conclude that the replacement of Silica fume for M40 grade concrete 7.5% of Silica fume gives the good strength for Non- structural concrete work and it is helpful for road works and pavers.
6. In this experiment gives the utilisation of Silica fume up to 7.5% is no problem but increase the Micro silica decreases the strength of the concrete.

7. 7.5% replacement will helpful to the decreases the cement usage by 7.5% and solve the little bit environmental disposal of Silica fume.

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