Experimental Investigation on the Strength and Behaviour of Mild Steel Powder Reinforced Concrete

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Abstract*: Steel rods are mostly used as reinforcement for concrete because of its desired properties. But maintenance and handling of steel rods are time consuming and uneconomical parameters because of skilled labour requirement for particular project. In order to avoid these problems in construction field, reinforcement in finer form holds the better replacement over steel rod for reinforcing the concrete. Using of finer reinforcing materials also helps in pore modification of concrete and also it has other important advantages over steel rod. Mild Steel Powder is the type of metal powder which has desired strength and durability properties for reinforcement because of its origin. Mild Steel Powder is the finer powder form of Mild Steel with good ductile property which is needed for reinforcement. Mild Steel Powder of different ranges of sizes is available in the market with economic price. This study deals with experimental investigation of strength and durability of Mild Steel Powder reinforced concrete with various ratios of Mild Steel Powder to Cement. Totally 10 ratios are adopted for this study and the Mild Steel Powder is Reinforced integrally to the M 20 grade concrete with W/C of 0.6. Compressive strength test, Cylindrical Splitting Tension test, Flexural strength test are the various types of tests investigated which determines the strength. Rapid Chloride Penetration Test, Water Absorption tests are also investigated for durability study for Mild Steel powder reinforced Cement concrete.

Index Terms*: Durability, Finer reinforcing materials, Mechanical strength, Mild Steel Powder.

I. INTRODUCTION

Cement Paste is a type of binding material which is weak in tension and strong in compression and cement composites like Cement mortar and Plain Cement Concrete (PCC) are also weak in tension and strong in compression. In order to increase the tensile property of cement composites, reinforcement are used and this matrices is called Reinforced Cement Concrete (RCC). In 1853, Francois Coignet built the first iron reinforced concrete structure. So far, Steel is more generally used as a reinforcing material for construction of buildings and other structures. While using steel rod as a reinforcing material in cement concrete, the matrices create macro cracks in that composite under flexural load and Steel rod needs pre-work like cutting, bending, binding and there is a need of skilled labours for pre work and also maintenance of steel rod is uneconomical. In order to overcome these problems, now the study and practice is going on with using micro fibres as a reinforcing material in cement paste composite which is in micrometre scale (i.e.) the dimensions of micro fibres are referred in micrometre. This is called Fibre Reinforced Concrete (FRC). Fibres have higher aspect ratio, lesser density and higher tensile strength when compared with steel rod [1]. Research has established that addition of fibres improves the static flexural strength, fatigue, ductility and fracture toughness of cementitious composites. Earlier, improvement on the properties of cementitious composites were obtained with the application of various types of macro fibres and micro fibres such as steel, glass, carbon and synthetic materials like acrylic, asbestos, cotton, nylon, polyester, polyethylene, polypropylene, rayon, rock wool [5]. These fibres are short, discrete, randomly oriented and uniformly distributed. Long fibres are also used; however, they are not discretely distributed. While using micro fibres as reinforcement in cement composite, it creates micro cracks under flexural load and this micro cracks leads to macro cracks [2]. But this study deals with mild steel powder as reinforcement in cement composite to arrest the micro cracks. Using of finer materials as reinforcement is the best way to avoid the micro cracks because of its size. Certain Steel Crystal Bonding Powder also has good binding property [4]. The topic of research on application of Mild Steel Powder as a reinforcing material in cementitious composites is one among in the field of innovative researches. Using of materials in powder form is going to drastically change the construction industry in the years to come [3]. Metals like Aluminium, Chromium, Cobalt, Copper, Gold, Iron, Molybdenum, Nickel, Silver, Stainless Steel, Mild Steel, Tin, Zinc, etc. and non- metals like Carbon, Diamond, Graphite, etc.…are available in powder form in the market. The advantages of finer particles are high surface area, they can fill pores more efficiently to enhance the overall strength and durability, impart higher strength and faster chemical reactions, it can accelerate cement hydration due to their high activity, use of materials in powder form gives the best gradation for the mixes of cement composites, extra reinforcement like nominal shear reinforcement, hanger bars is neglected, economic construction, it reduces the time and also skilled labour requirements for the construction work,

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finer reinforcing materials helps in pore modification within concrete
matrices, cost for manufacturing of powder is economical and also the process of manufacturing of metal powders and its maintenance are simple. 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, and 0.1 are the 10 ratios of MSP to cement are adopted for this research work.
The reason for the selection of lower ratios is that the Mild Steel powder has high surface area.

A. Scope and Objectives

The Main aim of this work is to experimentally investigate the mechanical properties and durability properties of Mild Steel Powder (MSP) reinforced concrete with various ratios of MSP and cement.

The objectives of this study are as follows:

i. To study the mechanical properties like compressive strength, cylindrical splitting tensile strength, flexural strength of Mild Steel Powder reinforced concrete by experimental analysis when Mild Steel Powder is mixed integrally with concrete.

ii. To investigate the durability of Mild Steel Powder reinforced concrete experimentally by using Rapid Chloride Penetration test and Water Absorption test

II. EXPERIMENTAL INVESTIGATION

A. Materials

Ordinary Portland cement of 53 grade (OPC 53) confirming to IS 12269: 2013 was used. The fine aggregate of Standard sand confirming to IS 650: 1991 with specific gravity of 2.64, Crushed angular shaped coarse aggregate of 20 mm size confirming to IS 383: 1970 with specific gravity of 2.72 and Potable water confirming to IS 456: 2000 were used as the constituent materials for control specimen. And Mild Steel Powder (MSP) obtained from Shiva Traders at Ennore was additionally reinforced with control specimen with various ratios to cement and it is referred as Test specimens. The various properties of Mild Steel powder given by the supplier are shown in Table 1 and Fig 1 shows the Mild Steel Powder (MSP).

Table 1 Properties of Mild Steel Powder (MSP)

S.NO.	PROPERTIES	TEST RESULT
1.	Purity	99.9%
2.	Approximate particle size	25-50 μm
3.	Form	Powder
4.	Solubility	Insoluble in water
5.	Melting point	1400°C
6.	Boiling point	2862°C
7.	Density	7.8 g/cc
8.	Colour	Black

Fig 1 Mild Steel Powder (MSP)

B. Preparation of Specimens

Nominal mix proportion of M 20 grade concrete was chosen as 1:1.5:3. W/C ratio of 0.6 was adopted for both control and Mild Steel Powder reinforced concrete specimens. Cube specimens of size 150 mm were prepared with the guidance of IS 516: 1959 for compressive strength test. Cylindrical specimens of size 150 mm diameter and 300 mm height were prepared as per ASTM C - 496 - 90: 1990 [1] for cylindrical splitting tension test. Prismatic specimens of size 100 mm x 100 mm x 500 mm were prepared as per IS 516: 1959 for flexural strength test. Cylindrical specimens of size 100 mm diameter and 50 mm height were prepared as per ASTM C - 1202: 1997 for Rapid chloride penetration test. Cube specimens of size 150 mm were prepared for water absorption test. MSP/Cement ratios of 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09 and 0.1 were adopted for Test specimens. 3 numbers of each ratio were prepared and also 3 numbers of control specimens were prepared. All the specimens were cured for 28 days in water as per Indian Standard requirements.

C. Testing of Specimens

Compressive strength test was conducted on both control and test specimens with 2000 KN capacity of hydraulic compression testing machine as per Indian standard requirements. The compressive strength of cube was calculated by using the following equation with the help of failure load and cross section of the specimen

$$\text{Compressive strength (MPa)} = \frac{\text{Ultimate compressive load in N}}{\text{C/s area of specimen in Sq.mm}}$$

Where,

C/s area of cube specimen = 150 *150 = 22500 mm^2

Cylindrical splitting tension test was conducted on both control and test specimens with 2000 KN capacity of hydraulic compression testing machine as per Indian standard requirements. Cylindrical splitting tensile strength was calculated by using the following equation with the help of experimental observations

$$\text{Split tensile strength (MPa)} = \frac{2 * \text{Ultimate compressive load in N}}{(\pi * \text{Diameter} * \text{Length}) \text{ in Sq.mm}}$$

Where,

Diameter = 150 mm and Length = 300 mm

Flexural strength of the specimens were carried out using two point loading arrangement as shown in Figure 2. And the specimens were tested in a 100 tonne capacity Universal Testing Machine as per Indian Standard requirements.

Maximum deflection at breaking load was also calculated by using longitudinal extensometer with the least count of 1 division is equal to 0.01 mm. In this experiment, the distance between line of fracture and the nearest support is greater than 133 mm for all specimens. So, the following equation was adopted for calculating the flexural strength of prismatic specimens.

$$\text{Flexural strength (MPa)} = \frac{\text{Breaking load} * L_{span}}{bt^2}$$

Where,

t = 100 mm, b = 100 mm, L_{span} = 400 mm

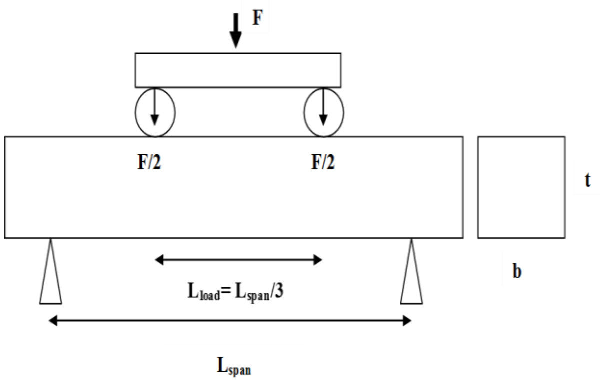

Fig. 2 Loading arrangement for flexural strength test

(Two Point Loading)

Cylindrical specimens for Rapid Chloride Penetration test were investigated as per American Standard requirements. Automatic data processing equipment was used to find charge passed through the specimens directly in Coulombs. Cube specimens of size 150 mm were completely immersed in clean water at room temperature for 24 hours. The specimens were removed from the water bath and allowed to drain for one minute by placing them carefully on a wire mesh. Outer surface of the specimens were wiped-off and weighed as Wet weight. After, the specimens were dried in an oven at 100°C for 24 hours. Then the Dry weight of the specimens was noted. Water absorption was calculated using the formula shown in equation.

$$\text{Water Absorption in \%} = \frac{(\text{Wet wt} - \text{Dry wt}) * 100}{\text{Dry wt}} \%$$

III. RESULTS AND DISCUSSIONS

A. Mechanical Properties

The recorded and calculated values of Compressive strength test, Cylindrical splitting tension test and Flexural strength test after 28 days curing were tabulated in Table 2, Table 3 and Table 4 respectively.

Table 2 Compressive Strength (28 days curing)

MSP / Cement Ratio	Load in N x 10^3	Compressive strength in N/mm2	Average Compressive strength in N/mm^2
0 (Control)	545	24.22	24.21
	544	24.18	
	545	24.22	
0.01	549	24.40	24.44
	551	24.49	
	550	24.44	
0.02	553	24.58	24.59
	554	24.62	
	553	24.58	
0.03	559	24.84	24.92
	562	24.98	
	561	24.93	
0.04	566	25.16	25.20
	567	25.20	
	568	25.24	
0.05	576	25.60	25.60
	578	25.69	
	574	25.51	
0.06	583	25.91	25.85
	582	25.87	
	580	25.78	
0.07	591	26.27	26.34
	592	26.31	
	595	26.44	
0.08	603	26.80	26.80
	604	26.84	
	602	26.76	
0.09	619	27.51	27.50
	617	27.42	
	620	27.56	
0.1	633	28.13	28.16
	635	28.22	
	633	28.13	

Table 3 Split Tensile Strength (28 days curing)

MSP / Cement Ratio	Load in N x 10^3	Cylindrical splitting Tensile strength in N/mm2	Average Cylindrical splitting Tensile strength in N/mm2
0 (Control)	221	3.13	3.11
	219	3.10	
	220	3.11	
0.01	222	3.14	3.15
	222	3.14	
	224	3.17	
0.02	223	3.15	3.17
	225	3.18	
	224	3.17	
0.03	224	3.17	3.17
	224	3.17	
	224	3.17	
0.04	226	3.20	3.20
	226	3.20	
	227	3.21	
0.05	229	3.24	3.24
	230	3.25	
	228	3.23	
0.06	232	3.28	3.28
	232	3.28	
	231	3.27	
0.07	233	3.30	3.28
	233	3.30	
	230	3.25	
0.08	234	3.31	3.30
	232	3.28	
	233	3.30	
0.09	236	3.34	3.34
	236	3.34	
	236	3.34	
0.1	237	3.35	3.36
	237	3.35	
	238	3.37	

Table 4 Flexural Strength (28 days curing)

MSP / Cement Ratio	Load in N x 10^3	Flexural strength in N/mm2	Avg Flexural strength in N/mm^2	Deflection in mm	
				Div	mm
0 (Control)	8.62	3.448	3.46	5	0.05
	8.69	3.476		5	0.05
	8.63	3.452		5	0.05
0.01	8.95	3.58	3.57	5	0.05
	8.92	3.568		5	0.05
	8.94	3.576		5	0.05
0.02	9.14	3.656	3.64	5	0.05
	9.11	3.644		5	0.05
	9.08	3.632		5	0.05
0.03	9.41	3.764	3.82	5	0.05
	9.59	3.836		5	0.05
	9.62	3.848		5	0.05
0.04	9.82	3.928	3.94	5	0.05
	9.86	3.944		5	0.05
	9.89	3.956		5	0.05
0.05	10.07	4.028	4.03	5	0.05
	10.08	4.032		5	0.05
	10.11	4.044		5	0.05
0.06	10.58	4.232	4.23	5	0.05
	10.56	4.224		5	0.05
	10.59	4.236		5	0.05
0.07	10.88	4.352	4.36	5	0.05
	10.91	4.364		5	0.05
	10.9	4.36		5	0.05
0.08	11.32	4.528	4.53	6	0.06
	11.34	4.536		6	0.06
	11.31	4.524		6	0.06
0.09	11.71	4.684	4.69	6	0.06
	11.74	4.696		6	0.06
	11.72	4.688		6	0.06
0.1	12.02	4.808	4.81	6	0.06
	12.06	4.824		6	0.06
	12.03	4.812		6	0.06

From Table 2, Table 3 and Table 4 it is seen that the compressive strength, Cylindrical splitting tensile strength and Flexural strength of integrally mixed Mild Steel Powder with cement concrete specimen is increases with the increase of MSP / Cement ratio. For this experimental investigation MSP / Cement ratio of 0.1 shows the highest increase in its compressive strength (16.32%), cylindrical splitting tensile strength (8.03%) and flexural strength (39.01%) when compared with control specimen with the W/C ratio of 0.6. It may further increase with the higher MSP / Cement ratio until certain level of MSP / Cement ratio.

The reasons behind that the increase of compressive strength, cylindrical splitting tensile strength and flexural strength are that the Mild Steel Powder reduces the porosity and increases the ductility of concrete because of its fineness and its good ductile property.

B. Durability Properties

The results of Rapid Chloride Penetration test and Water absorption test after 28 days curing were tabulated in Table 5 and Table 6 respectively.

Table 5 Chloride Permeability (28 days curing)

MSP / Cement Ratio	Charge Passed in Coulomb	Average Charge Passed in Columb	Chloride Permeability
0 (Control)	4050	4030	HIGH
	4040		
	4000		
0.01	3900	3867	MODERATE
	3850		
	3850		
0.02	3700	3725	MODERATE
	3750		
	3725		
0.03	3800	3733	MODERATE
	3750		
	3650		
0.04	3775	3750	MODERATE
	3750		
	3725		
0.05	3475	3517	MODERATE
	3500		
	3575		
0.06	3400	3450	MODERATE
	3450		
	3500		
0.07	3650	3658	MODERATE
	3650		
	3675		
0.08	3750	3742	MODERATE
	3725		
	3750		
0.09	3500	3558	MODERATE
	3575		
	3600		
0.1	3575	3550	MODERATE
	3525		

	3550		

Table 6 Water Absorption (28 days curing)

MSP / Cement Ratio	Wet weight in kg	Dry weight in Kg	Water Absorption in %	Average Water Absorption in %
0 (Control)	8.808	8.552	2.99	2.99
	8.810	8.555	2.98	
	8.807	8.551	2.99	
0.01	8.823	8.567	2.99	2.99
	8.819	8.564	2.98	
	8.824	8.567	3.00	
0.02	8.836	8.580	2.98	2.98
	8.838	8.582	2.98	
	8.838	8.582	2.98	
0.03	8.850	8.595	2.97	2.96
	8.849	8.594	2.97	
	8.850	8.596	2.95	
0.04	8.867	8.612	2.96	2.96
	8.869	8.613	2.97	
	8.865	8.612	2.94	
0.05	8.883	8.628	2.96	2.96
	8.885	8.629	2.97	
	8.886	8.630	2.97	
0.06	8.897	8.642	2.95	2.96
	8.897	8.641	2.96	
	8.899	8.643	2.96	
0.07	8.914	8.659	2.94	2.95
	8.916	8.661	2.94	
	8.920	8.663	2.97	
0.08	8.930	8.675	2.94	2.94
	8.928	8.673	2.94	
	8.932	8.677	2.94	
0.09	8.947	8.691	2.95	2.94
	8.945	8.690	2.93	
	8.946	8.690	2.95	
0.1	8.957	8.705	2.89	2.92
	8.959	8.705	2.92	
	8.958	8.702	2.94	

From Table 5, it is seen that the Chloride permeability of integrally mixed MSP with cement concrete specimen shows the variation with the increase of MSP / Cement ratio.

It can be seen that the effect of addition of MSP improves pore structure by the reduction of porosity and permeability; thereby specimens with MSP should exhibit moderate chloride ion permeability. But it was seen that addition of conductors (MSP) have shown moderate chloride ion permeability. This may be due to higher conductivity imparted to concrete by addition of MSP. This can be observed by the fact that the amount of current passed increased with increased quantity of MSP added. From Table 6, it is seen that the Water Absorption of integrally mixed Mild Steel Powder with cement concrete specimen is decreases with the increase of MSP / Cement ratio. For this experimental investigation MSP / Cement ratio of 0.1 shows the highest decrease in its Water Absorption (2.39%) when compared with control specimen with the W/C ratio of 0.6. It may further decrease with the higher MSP / Cement ratio until certain level of MSP / Cement ratio. The reason for the decrease of Water Absorption with addition of Mild Steel Power is the reduction in porosity of concrete.

IV. CONCLUSION

Experimental investigations were conducted to determine the strength and durability of Mild Steel Powder reinforced M 20 grade concrete mix. Various tests like Compressive strength test, Cylindrical splitting Tension test, Flexural strength test, Rapid chloride penetration test, Water absorption test were conducted to compare the Mild Steel Powder reinforced concrete specimen with Control specimen for M 20 mix with 28 days curing. Pore modification (reduction of pores) in concrete is one of the best techniques to increase the strength and durability of concrete which is possible by using finer constituent material to prepare concrete gives the effective and economical result. In this investigation finer reinforcing material (MSP) and finer binding material (OPC 53 grade cement) were used for reduction of pores in concrete. Using of finer constituent materials for preparing concrete reduces the duration of making any concrete structures. Mild Steel Powder has high tensile strength. So, the flexural strength was increased with various ratios with binding material. Compressive strength and cylindrical splitting tensile strength of Mild Steel Powder reinforced concrete are also increase because of reduction in pores of concrete with the use of finer reinforcing material. Durability of Mild Steel Powder reinforced concrete was also good which was observed from RCPT and Water absorption test results.

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