HIGH PERFORMANCE CONCRETE MIX DESIGN USING SILICA FUMES AND IRON FILING WITH PARTIAL REPLACEMENT OF CEMENT AND NATURAL SAND

Mohd. Shahid Khan, Research Scholar, Dept. Of Civil Engineering, IET, SAGE University, Indore(M.P.)
Dr. Basant Kumar, Professor, Dept. Of Civil Engineering, IET, SAGE University, Indore (M.P.)

Abstract
This study is focused on the manufacturing of High-Performance Concrete by adding silica fumes and iron filing along with manufactured sand. Previously all research has been made on the manufacturing of high-performance concrete using natural sand. All the specimens cast are of M-75 grade of concrete which is designed as per IS-10262:2019 and also tested under strict laboratory control. These specimens are evaluated for compressive strength, split tensile strength, and flexural strength at the age of 7 days and 28 days. Material samples are collected from the nearby industrial area of Pithampur, Indore (M.P.).From the experimental results it is concluded that as compared to conventional concrete, the replacement of 50% manufactured sand is more beneficial as the compressive strength increased by 1.36%, split tensile strength increased to 6% and flexural strength increased to 5.1%. The effect of adding silica fume and iron filing individually to the concrete enhances the compressive strength by 4.9% and 3.06%, Split tensile strength by 7.8% and 4.3 %, and flexural strength by 10.1% and 6.7% respectively as compared to conventional concrete. Study shows that silica fume and iron filing, when used in composite form increases the compressive strength, split tensile strength, and flexural strength by 2.73%, 15.7% and 10.5% respectively. The results indicate that the combination of materials together gives high strength and durability to the concrete and provides eco-friendly construction.

Keywords: Compressive Strength, Split Tensile Strength, Flexural Strength, Iron Filing, Manufactured sand, High-Performance Concrete.

1.Introduction

High-performance concrete (HPC) has been designed to be more durable and stronger than conventional concrete. High-performance concrete mixtures are composed of essentially the same materials as conventional concrete mixtures, but the proportions are decided as per the strength and durability needed for the structural and environmental requirements of the project. However, due to the high demand for concrete, there is a need for alternative materials for cement and fine aggregates in concrete production. Manufacturing of High-Performance Concrete by adding silica fumes as a cement replacement and iron filing to enhance the strength along with manufactured sand as an economic replacement for natural sand. Together with this, the problem of industrial waste disposal has been reduced which was a major concern for planners and engineers in developing countries. It is observed that the strength of high-performance concrete is improved by using silica fumes and iron filing, in different combinations along with manufactured sand. With the improved strength, the cost is reduced by the locally available materials and travel distance also reduced hence pollution & fuel consumption also reduced as a result the overall cost of transportation is also reduced. Also due to its high-performance cross-section of building elements such as beams, columns, span, and pillars are also reduced which causes eco-friendly construction.

2.Objectives

The main objectives considered in this study are here as below:

1. To find out the effect of adding silica fume and iron filing 2.5%, 5%, 7.5% and 10% and 5%, 10%, 15%, and 20% respectively on the performance of concrete as compared to conventional concrete.

2. To find out the effect on the performance of concrete by replacing natural sand by manufacturing sand by 25%, 50%, and 75%.
3. To analyze and compare the overall performance of composite concrete with conventional concrete.

3.Data Collection

For the preparation of the required grade of concrete the cement (OPC 43 Grade),coarse aggregate (black basalt rock), fine aggregate (river sand and manufactured sand), silica fume, iron filing and other admixtures are used as per the design mix.

3.1 Cement

Ordinary Portland cement (OPC) — 43grade of cement as per IS: 8112-2013 is used for the entire experimental investigation. The physical properties were tested according to standard procedure confirming to IS: 269-2013.The physical properties of the cement are given in Table 3.1.

Table 3.1 Properties of Cement as per IS:269-2013

S.No	Characteristics	Test Result	Standard Limits
1	Consistency	32%	30%
2	Initial Setting Time	45 min	Not less than 30 min
3	Final Setting time	360 min	Not more than 600 min
4	Specific Gravity	3.156	3.15
5	Fineness Modulus	6%	Not more than 10%
6	Compressive Strength	45N/mm2	Not less than 43 N/mm2

3.2 Fine Aggregates

The natural sand is used as fine aggregate as per IS 2386 (Part V) 2021 and it is collected from the nearby Narmada River. The sand has been sieved in a 4.75 mm sieve as per IS 383 - 2016 conforms to zone II. The properties of these are presented in Table 3.2 and Figure 3.1.

The manufactured sand is also used as fine aggregate and it is collected from Pithampur, Indore. The sand has been sieved in a 4.75 mm sieve as per IS 383 - 2016 conforms to zone II. The properties are presented in Table 3.2 and Figure 3.1.

The physical properties of fine aggregates are given in Table 3.4.

Table 3.2 Gradation of Fine Aggregates

Is Sieves	Percentage passing		Specification Limit (IS:383-2016, Table-9)			
Size	Natural sand	M-Sand	Zone I	Zone II	Zone III	Zone IV
10 mm	100	100	100	100	100	100
4.75 mm	93.85	91.78	90-100	90-100	90-100	95-100
2.36 mm	78.37	84.34	60-95	75-100	85-100	95-100
1.18 mm	62.50	64.68	30-70	55-90	75-100	90-100
600 mic	42.66	38.63	15-34	35-59	60-79	80-100
300 mic	11.33	14.42	5-20	8-30	12-40	15-50
150 mic	1.86	2.66	0-10	0-10	0-10	0-15

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 4, October : 2023

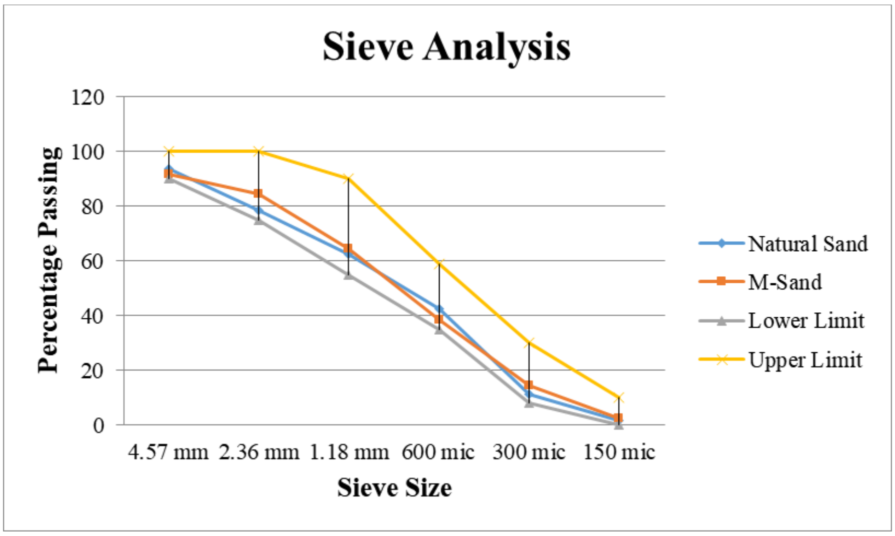


Figure 3.1 Gradation Curve of Fine Aggregates.

Manufactured Sand Natural Sand

Figure 3.2 Fine aggregates used

Table 3.3 Properties of Fine Aggregates

Property	M-Sand	Natural Sand	Test Method
Specific Gravity	2.72	2.60	IS2386(Part-III)2021
Bulk density(Kg/m^3)	1720-1810	1460	IS2386(Part-III)2021
Absorption (%)	1.20 — 1.50	Nil	IS2386(Part-III)2021
Moisture Content (%)	Nil	1.5	IS2386(Part-III)2021
Fine particles less than 0.075 mm (%)	12-15	6	IS2386(Part-III)2021
Sieve analysis	Zone-II	Zone-II	IS-383-2016
Silt Content	3.6	7.2	IS2386(Part-II)2021

3.3 Coarse Aggregates

Black Basalt coarse aggregate obtained from, Agarwal crusher Pithampur, Indore is used as per IS 383:2016. The coarse aggregate is chosen as angular in shape as per IS 2386 (Part I) 2002, surface texture characteristics of aggregate is classified as in IS 383 - 2016. The following properties of coarse aggregates were determined and tabulated in Table3.4.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 4, October : 2023

Table 3.4 Properties of Coarse Aggregates

S.No	Characteristics	Test Result	IS Code
1	Specific Gravity	2.7	IS 2386 (Part I) 2021
2	Absorption %	1.05	IS 2386 (Part I) 2021
3	Bulk Density (Kg/m^3)	1560	IS 2386 (Part I) 2021
4	Fineness Modulus	2.99	IS 2386 (Part I) 2021

3.4 Silica Fumes and Iron Filing

Silica fume used is extremely small particle finer than 1µm grayish black powder and it is obtained from industries in Pithampur, Indore. Its specific gravity is 2.22 and its bulk density is $430kg/m^3$ IS:15388-2003.

Iron filing used is sourced from nearby workshops in Pithampur, Indore. The iron filings used in this research have water absorption of 1.5%, specific gravity of 3.95 and fineness modulus 2.24 IS:1612-2003.

Samples used in this research for silica fume and iron filing are shown in Figure 3.3.

Figure 3.3 Iron filing and Silica fumes

3.5 Concrete Mix Design for M-75

For the M-75 grade of concrete mix design is done by using IS method of design given following:

1. Characteristic compressive strength required at 28 days = 75 N/mm^2
2. Type of cement used = OPC (Ultratech) 43 grade
3. Degree of Workability = 100mm Slump
4. Degree of quality control = Good
5. Degree of exposure = Moderate
6. Method of concrete placing = By hand
7. Chemical Admixture = Master Glanium
8. Specific gravity of cement = 3.15
9. Specific gravity of fine aggregate = 2.75
10. Specific gravity of coarse aggregate = 2.75
11. Coarse aggregate type = Nominal size (IS 383, Table 2)
12. Fine aggregate = Grading zone-II (IS 383, Table 4)
13. Water absorption :
    a) Coarse aggregate = 0.42%

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 4, October : 2023

b) Fine aggregate = 15% (Moisture content)
14. Standard deviation (s) = 5
15. Tolerance factor (t) = 1.65
16. Target mean strength = 83.25 N/mm^2
17. Selection of water content = 165 L/m^3 (IS 10262, Table 5)
18. Sand content as a percentage of total aggregate by absolute volume = 35% (As sand in zone II no adjustments are required)
19. Determination of cement content
Water cement ratio = 0.33
Water = 165 Lit
Therefore, Cement = 500 kg/m^3
20. Super plasticizer required0.75% of cement content = 3.9 kg/m^3
21. Correction for aggregate = decrease the volume of sand by 1%.
22. Volume of fresh concrete
Maximum size of aggregate 20 mm, amount of entrapped air in the wet concrete is 2%
Fa = 636kg
Hence, Coarse aggregate Ca = 1212 kg/m^3
23. Adding 5% of silica fume = 25 kg
24. Adding 10% of iron filing = 50 kg

Ingredients	**Cement kg/m^3**	**Sand kg/m^3**	**Aggregate kg/m^3**	**Water Lit/m^3**	**Admixture kg/m^3**
Quantity	500	636	1212	165	3.9
Ratio	1.00	1.27	2.42	0.33	0.008

4.Methodology and Analysis of Data

4.1 Compressive Strength Test

To determine the compressive strength, six cubes (150mm x 150mm x 150mm) are cast for each trial mix of M75 concrete for each mix and three samples are tested after 7 days and the next three samples are tested after28 days of curing. 7 and 28-day cube compressive strength test is conducted. Compressive strength tests are carried out using a 2000-capacity compression testing machine.

Figure 4.1 Testing of specimen

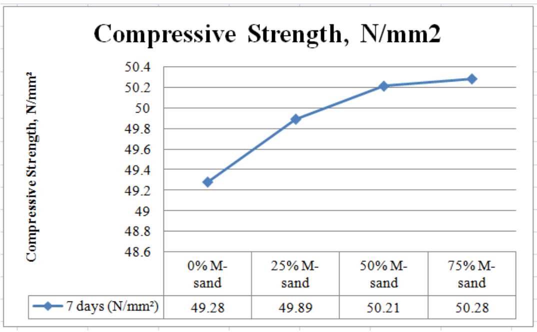


Figure 4.2 Effect of Manufactured Sand 7 days

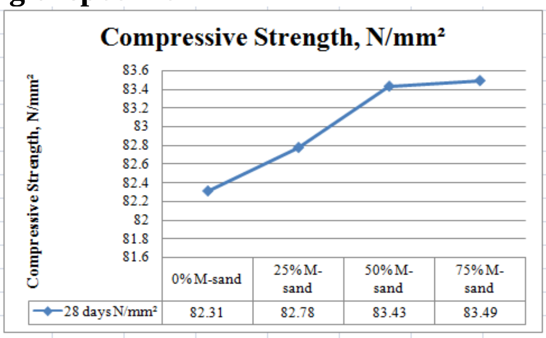


Figure 4.3 Effect of Manufactured Sand 28 days

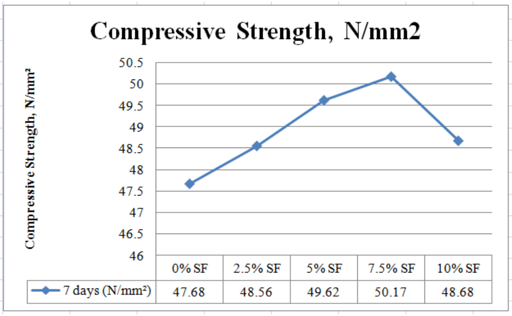


Figure 4.4 Effect of Silica Fumes 7 days

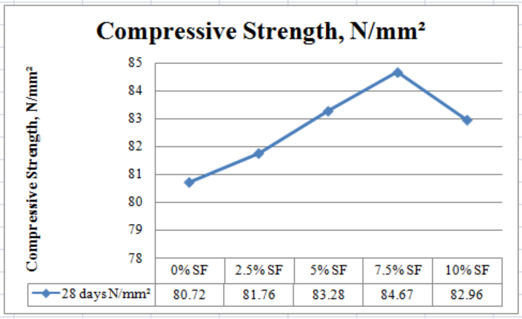


Figure 4.5 Effect of Silica Fumes 28 days

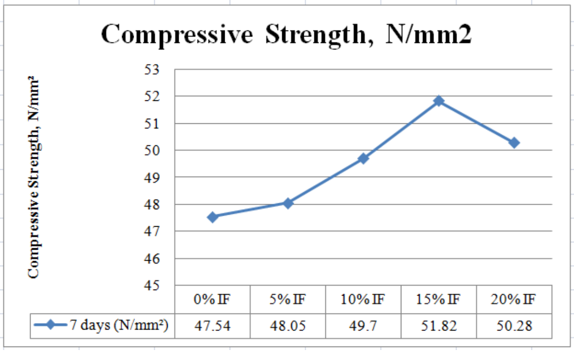


Figure 4.6 Effect of Iron Filing 7 days

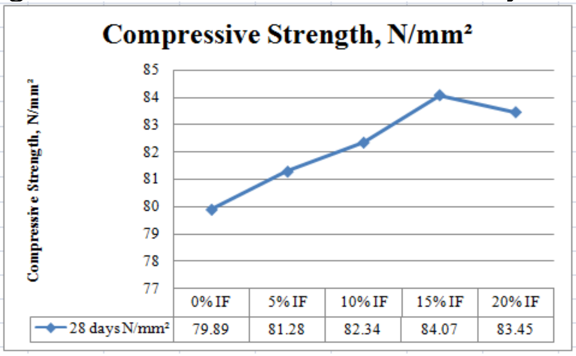


Figure 4.7 Effect of Iron Filing 28 days

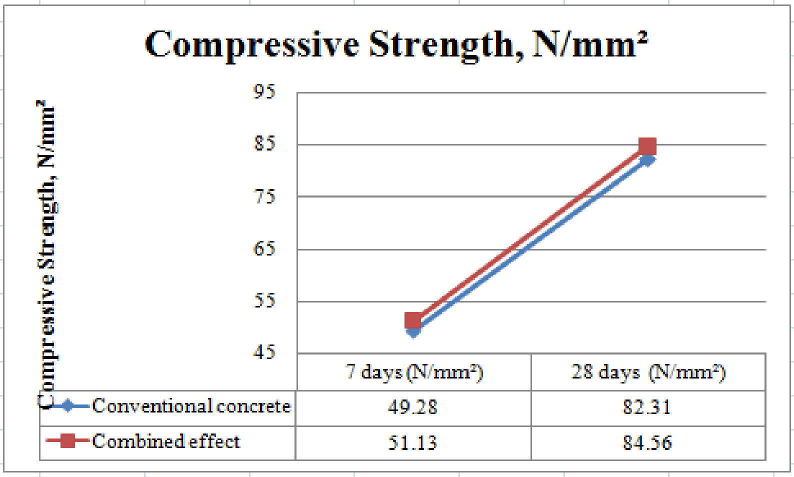


Figure 4.8 Effect of Combination all Altogether

From the above observations, it is observed that in conventional concrete compressive strength achieved at the age of 28 days is 82.31 N/mm^2 whereas the manufactured sand increased at 25% and 50% strength obtained is 82.78 N/mm^2 and 83.43 N/mm^2 respectively, but if manufactured sand is increased more, there is a slight difference to 83.49 N/mm^2. Hence it can be concluded that the partial replacement of natural sand to 50% manufactured sand is quite beneficial to increase strength. Also the effect of adding silica fume and iron filing in different quantities compressive strength increases from 80.72 N/mm^2 to 84.67 N/mm^2 and 79.89 N/mm^2 to 84.07 N/mm^2 respectively. But suddenly decreases at 10% silica fume and 20% iron filing. Also it can be observed that when silica fume and iron filing is used in composite increases compressive strength from 82.31 N/mm^2 to 84.56 N/mm^2.

4.2 Split Tensile Strength Test

The split tensile strength test is conducted as per IS 5816:2018. For the split tensile strength test, cylindrical specimens of dimension 100 mm diameter and 300 mm length are cast. In each mix, three cylinders were cast and tested and their average value was taken. The split tension test is conducted by using a digital compression machine having 2000 KN capacity.

Figure 4.9 Testing of specimen

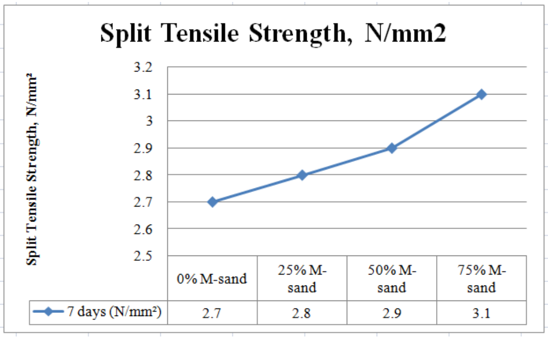


Figure 4.10 Effect of Manufactured Sand 7 days

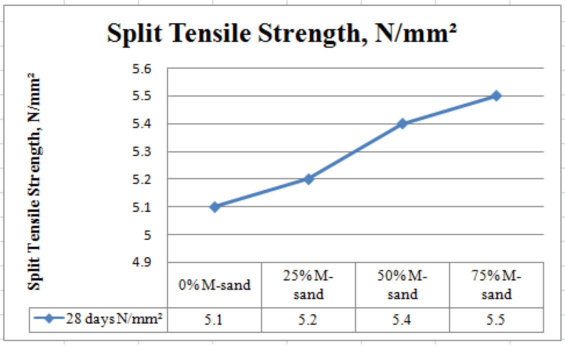


Figure 4.11 Effect of Manufactured Sand 28 days

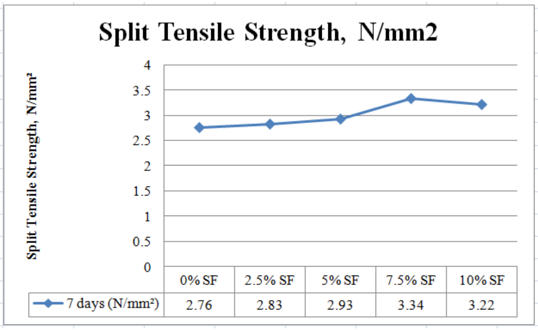


Figure 4.12 Effect of Silica Fumes 7 days

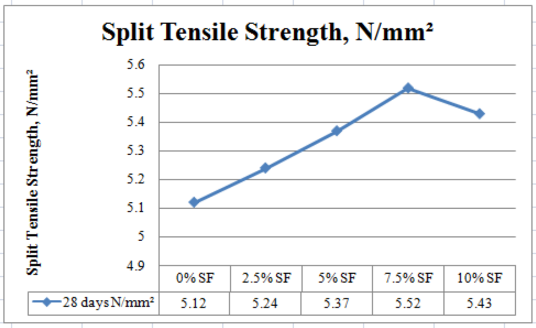


Figure 4.13 Effect of Silica Fumes 28 days

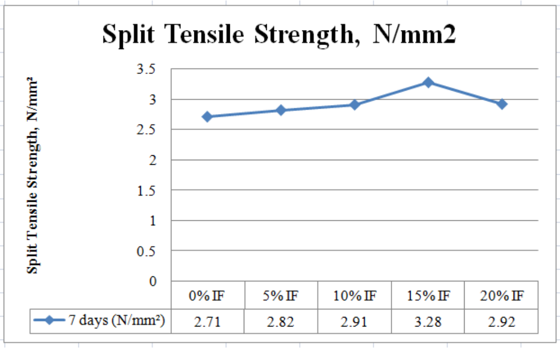


Figure 4.14 Effect of Iron Filing 7 days

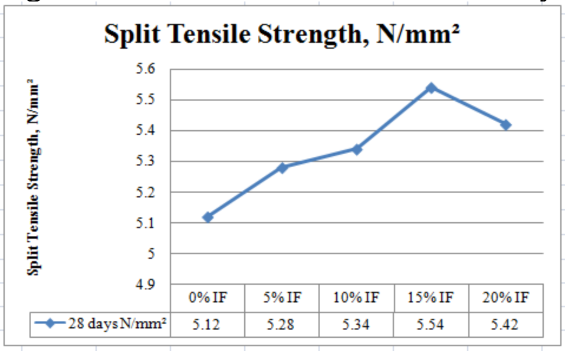


Figure 4.15 Effect of Iron Filing 28 days

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 4, October : 2023

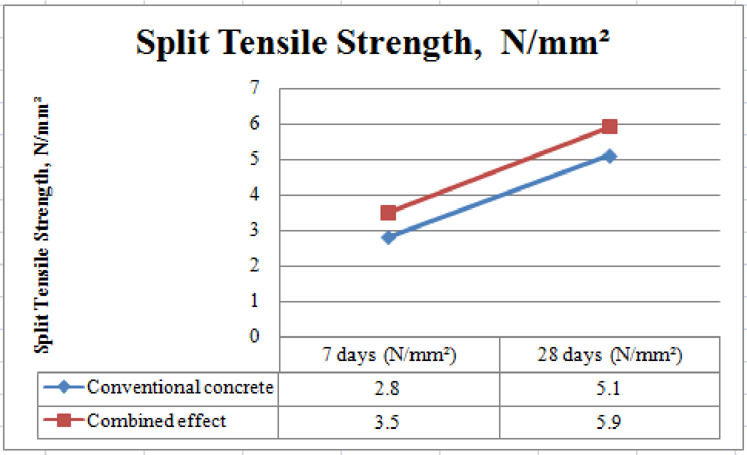


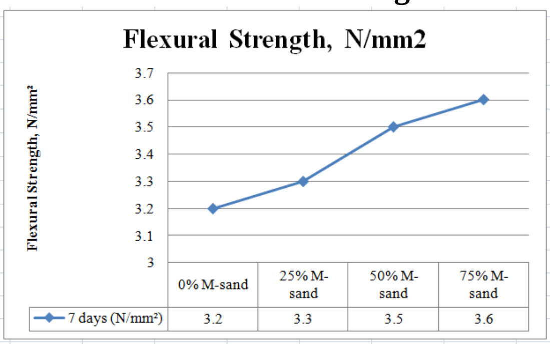
Figure 4.16 Effect of Combination all together

From the above observations, it is observed that in conventional concrete split tensile strength achieved at the age of 28 days is 5.1 N/mm^2 whereas the manufactured sand increased at 25% and 50% strength obtained is 5.2 N/mm^2 and 5.4 N/mm^2 respectively but if manufactured sand is increased more, there is a slight difference to 5.5 N/mm^2. Hence it can be concluded that the partial replacement of natural sand to 50% manufactured sand is quite beneficial to increase strength. Also the effect of adding silica fume and iron filing in different quantities split tensile strength increases from 5.12 N/mm^2 to 5.52 N/mm^2 and 5.12 N/mm^2 to 5.54 N/mm^2 respectively. But suddenly decreases at 10% silica fume and 20% iron filing. Also it can be observed that when silica fume and iron filing is used in composite increases split tensile strength from 5.1 N/mm^2 to 5.9 N/mm^2.

4.3 Flexural Strength Test

For Flexural strength test, prism specimen of 100mm X 100 mm X 500 mm is casted. For conventional and optimum mix, three prisms are casted and tested with two point load is applied and their average value is reported. A beam specimen is placed in the ultimate testing machine of 2000 KN capacity for testing.

Figure 4.17 Testing of specimen



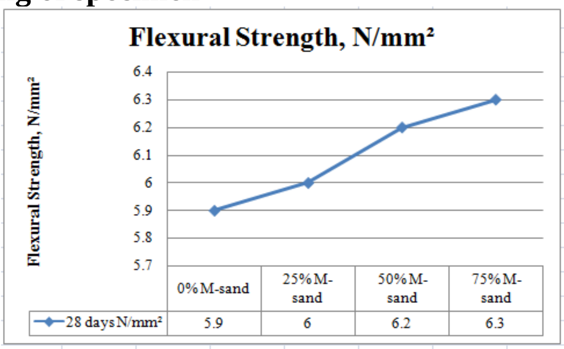


Figure 4.18 Effect of Manufactured Sand 7 days Figure 4.19 Effect of Manufactured Sand 28 days

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 4, October : 2023

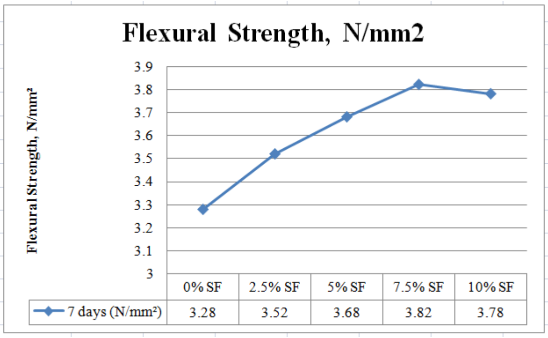


Figure 4.20 Effect of Silica Fumes 7 days

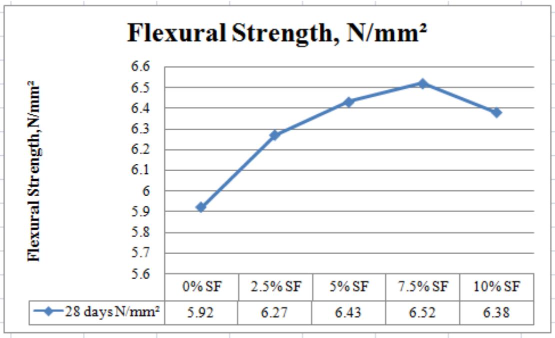


Figure 4.21 Effect of Silica Fumes 28 days

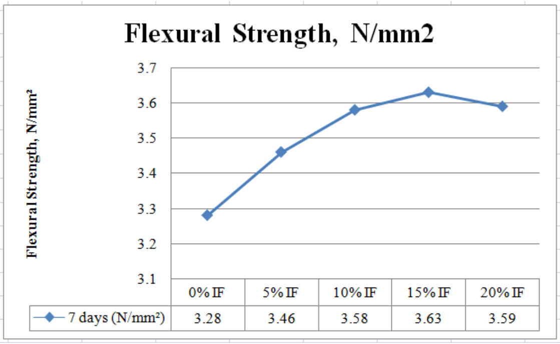


Figure 4.22 Effect of Iron Filing 7 days

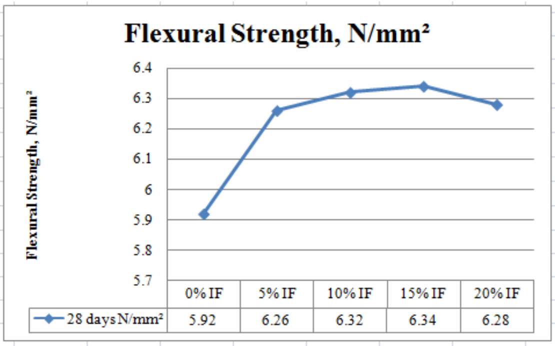


Figure 4.23 Effect of Iron Filing 28 days

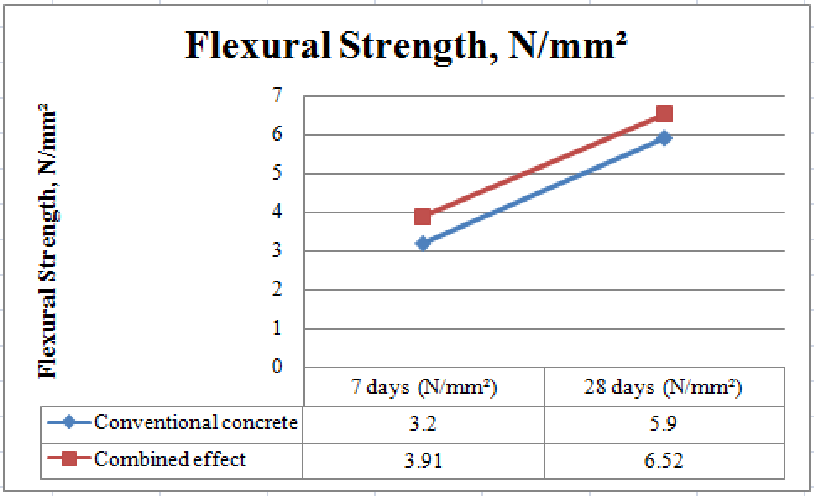


Figure 4.24 Effect of Combination all together

From the above observations, it is observed that in conventional concrete split tensile strength achieved at the age of 28 days is 5.9 N/mm^2 whereas the manufactured sand increased at 25% and 50% strength obtained is 6.0 N/mm^2 and 6.2 N/mm^2 respectively but if manufactured sand is increased more, there is a slight difference to 6.3 N/mm^2. Hence it can be concluded that the partial replacement of natural sand to 50% manufactured sand is quite beneficial to increase strength. Also the effect of adding silica fume and iron filing in different quantities split tensile strength increases from 5.92 N/mm^2 to 6.52 N/mm^2 and 5.92 N/mm^2 to 6.34 N/mm^2 respectively. But suddenly decreases at 10% silica fume and 20% iron filing. Also it can be observed that when silica fume and iron filing is used in composite increases split tensile strength from 5.9 N/mm^2 to 6.52 N/mm^2.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 4, October : 2023

Conclusion

Within the scope of present work following conclusions are drawn:

1. It is concluded from the results that as compared to conventional concrete, the replacement of 50% manufactured sand is more beneficial as the compressive strength increases to 1.36%, split tensile strength increases to 6% and flexural strength increases to 5.1%.
2. The effect of adding silica fume and iron filing individually to the concrete enhances the compressive strength by 4.9% and 3.06%, Split tensile strength by 7.8% and 4.3 %, and flexural strength by 10.1%, 6.7% respectively as compared to conventional concrete.
3. Also as the silica fume and iron filing, when used in composite form increases the compressive strength, split tensile strength and flexural strength by 2.73%, 15.7%, and 10.5% respectively.

References

[1] **Abdullah Jabar Hussain, Zainab S. Al-Khafaji** (2021) "Experimental investigation on applying waste iron filings in the engineering fields for protection the environment from contamination", Materials Today, Elsevier, https://doi.org/10.1016/j.matpr.2021.09.039.

[2] **Abhinav Shyam, Abdullah Anwar, Syed Aqeel Ahmad,**(2017) "A Literature Review on Study of Silica fume as Partial Replacement of Cement in Concrete", IJAEMS, Vol. 3, Issue 3, ISSN: 2454-1311, pp. 250-253.

[3] **Aishwarya Devi S. Jangam, Santosh S. Mohite, Bajirao V. Mane,** (2020) "Design of High Performance Concrete upto 120 MPa", IJESRT, Vol. 5, Issue 9, ISSN: 2277-9655, pp. 259-270.

[4] **Changlong Wang, Gaofei Zhao, Yongchao Zheng, Kaifan Zhang, Pengfei Ye, Xiaowei Cui,** (2019) "Study on the Preparation of High Performance Concrete using Steel Slag and Iron Ore Tailings", IIETA, Vol. 22, Issue 4, pp. 217-223.

[5] **Dhruva Narayana Katpady, Hirotaka Hazehara, Masashi Soeda, Takashi Kubota, Satoshi Murakami,** (2018) "Durability Assessment of Blended Concrete by Air Permeability", IJCSM, ISSN: 2234-1315.

[6] **J.Vengadesh Marshall Raman, R.Rajesh, P.SabariVelswaran,** (2019) "Study on Strength of High Performance Concrete by Partial Replacement of Fine Aggregate by Copper Slag", IJAER, Vol. 14, Issue 19, ISSN: 0973-4562, pp. 2795-2798.

[7] **Priyanka lohiya, Dr. SuprakashBiswas,** 2020 "A Literature Review On Study Of Silica FumeAs APartial Replacement Material Of Cement In Concrete", JXUAT, Vol. 12, Issue 6, ISSN: 1006-7930, pp. 109-113.

[8] **Sunidhi Rajhans, Ajay Kumar Singh,** (2022) "Study on Partial Replacement of Coarse Aggregatewith Steel Slag", IJRASET, Vol. 10, Issue II, ISSN: 2321-9653, pp. 1203-1209.