

# **Strength and Durability Properties of Fibre Reinforced Concrete by Partial Replacement of Cement with Metakaolin and Coarse Aggregate with Ferro Chrome Slag**

Shaik Arafath<sup>1</sup>, Seeram Bhanu Pravalika<sup>2</sup>

P.G Student, Department of Civil Engineering, Gudlavalleru Engineering College, Gudlavalleru,  
Andhra Pradesh, India<sup>1</sup>

Assistant Professor, Department of Civil Engineering, Gudlavalleru Engineering College, Gudlavalleru,  
Andhra Pradesh, India<sup>2</sup>

**ABSTRACT:** Concrete is the most extensively used construction material, Maintenance and repair of concrete structures is a growing problem involving significant expenditure. The demand for concrete is increasing day by day due to growing population, urbanization, transportation and industrialization. Industrial wastes can be used in concrete production for saving the environment. Ferrochrome slag is an industrial by-product emerged from the Ferrochrome alloy industry which can be used as an alternate material for coarse aggregate in concrete. The present study is to understand the behaviour and performance of the fiber reinforced concrete in partial replacement of Cement and Coarse aggregate with Metakaolin and ferrochrome slag. In this study three Mixes was prepared to carry out various tests on harden concrete Mix-1 is Partial replacement of Cement with metakaolin as 5%, 10%, 15% and 20%, and the optimum content of 15% metakaolin was added to different percentages replacement such as 25%, 50%, 75% and 100% of coarse aggregate with ferrochrome slag and this is named as MIX-2. MIX-3 is prepared by observed optimum contains of 15% metakaolin and 75% of ferrochrome slag Steel fibres and Lathe Waste are added individually at various percentages of 0.5%, 1.0% and 1.5% to the optimum Mixes obtained earlier and Comparison was made between Steel fibers mix and Lathe Waste Mix. M30 grade of concrete mix design were formulated and specimens were casted and tested for computing compressive, split tensile and durability properties at various periods of 7, 28 and 90 days.

**KEYWORDS:** Metakaolin, Ferrochrome slag, Steel fibers, Lathe waste, compressive strength, Split Tensile Strength, Durability.

## **I. INTRODUCTION**

Due to the scarcity of naturally obtainable fine and coarse aggregate required for making concrete and on other side speedy growth of industrialization contributed to different types of waste by-product which is environmentally risky. So the industrial wastes are effectively used in the concrete to save the environment.

Metakaolin grains are approximately 10 times smaller than grains of cement and therefore they are able to fill the space between larger grains and contribute to increasing the overall density of the concrete.

Ferrochrome slag is a major by-product got during the manufacturing of Ferrochrome alloy. The Ferrochrome slag has a good material property similar to Coarse aggregate, so it is used as an alternate material for coarse aggregate in concrete.

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## II. MATERIALS

### CEMENT

Cement used in the experimental work is Ordinary Portland Cement (OPC- 53 grade) and tested as per IS 12269-1987. The physical and chemical properties of the cement obtained on conducting appropriate tests as per IS 269/4831. Specific Gravity and Fineness of cement are 3.12 and 5% respectively.

### METAKAOLIN

Metakaolin is supplementary cementitious material derived from heat treatment of natural deposits of kaolin. It was a material which is used in wide range in partial replacement of cement in concrete. It is a high quality pozzolanic material. Due to pozzolanic action, it increases strength and durability properties of cement. When used in concrete it will fill the void space between cement particles resulting in a more impermeable concrete. It is obtained from ASTRA CHEMICALS CHENNAI and its specific gravity is 2.5.



Fig. 1: Metakaolin

### FERROCHROME SLAG

Ferrochrome slag is a major by-product got during the manufacturing of Ferrochrome alloy. The Ferrochrome slag has a good material property similar to Coarse aggregate, so it is used as an alternate material for coarse aggregate in concrete. It is obtained from FACOR ALLOY LIMITED GARIVIDI and its specific gravity is 3.0.



Fig. 2: Ferrochrome Slag

### COARSE AGGREGATE

Crushed stone metal with maximum size of 20 mm from a local source having the specific gravity of 2.78 conforming to IS 383-1970 was used.

### FINE AGGREGATE

Locally available river sand passing through 4.75mm IS sieve conforming to grading Zone-II of IS 383-1970 was used. The specific gravity of fine aggregate was 2.60.

### WATER

Potable tap water was used for the preparation and curing of all concrete specimens. Its pH value should be lies in between 6-8.

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### LATHE WASTE FIBRE

Lathe waste fibre is collected from nearby foundry used as fibres in concrete. Lathe waste fibre of 0.75 mm thickness has been used in this investigation. The average length of 40 mm and of aspect ratio about 53.33 has been used in this experimental work.



Fig. 3: Lathe Waste fibre

### STEEL FIBRE

The steel fibre of 0.65 mm diameter, 35 mm length and aspect ratio 53.80 has been used in this experimental work.



Fig. 4: Steel fiber

### III. EXPERIMENTAL PROGRAMME

The present work explores that the partial replacement of cement with metakaolin and coarse aggregate with ferrochrome slag in M30 grade concrete. The mix proportion was done as per IS: 10262-2009. The target mean strength was 38.25 MPa. Water binder ratio of 0.42 was taken in the present investigation. The compressive strength and split tensile test were found for 7 and 28 days and 90 days.

MIX-1 was planned and conducted in order to determine the optimum METAKAOLIN replaced with weight of cement as 5%, 10%, 15% and 20%.

MIX-2 was planned and conducted in order to determine the optimum FERROCHROME SLAG replaced with weight of coarse aggregate as 25%, 50%, 75% and 100%.

MIX-3 was designed and carried out by adding steel fibres and Lathe waste in percentages by weight of optimum METAKAOLIN replaced cement and optimum FERROCHROME SLAG replaced coarse aggregate concrete in 0.5%, 1.0% and 1.5%

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## IV. RESULTS AND DISCUSSIONS

### Optimum Content of METAKAOLIN

Strength tests were conducted on concrete in which cement is partially replaced with METAKAOLIN in percentages of 5%, 10%, 15% and 20% by weight of cement. The results of compressive strength were conducted on specimens cured for different curing periods are presented in Table.1

Table. 1: Variation of Compressive strength with % of METAKAOLIN replacement

MIX-1	Percentage replacement in cement		Compressive Strength N/mm <sup>2</sup>	
	CEMENT	METAKAOLIN	7 days	28 days
1	100%	0%	21.92	39.10
2	95%	5%	22.30	39.72
3	90%	10%	25.86	43.92
4	85%	15%	26.31	45.63
5	80%	20%	24.90	42.26

All test results showed there is a remarkable improvement in strength characteristics up to 15% partial replacement of METAKAOLIN in cement. The amount of cement replacement up to 15% with METAKKAOLIN, strength gain increases, and beyond this level of METAKAOLIN addition the strength gain decreases. From the Table 1 it is noticed that the optimum percentage replacement of METAKAOLIN was found to be 15% from the viewpoint of strength characteristics.

### Optimum Content of FERROCHROME SLAG

Strength tests were conducted on concrete in which cement is partially replacement of cement with metakaolin and various percentages of ferrochrome slag replaced in coarse aggregate in Table.2

Table. 2: Variation of Compressive strength Partial replacement of Cement with Metakaolin and various percentages of ferrochrome slag

MIX-2	Percentage replacement in cement		Percentage replacement In coarse aggregate		Compressive Strength N/mm <sup>2</sup>	
	Cement	Metakaolin	Coarse aggregate	Ferro chrome slag	7 days	28 days
1	100%	0	100	0	21.92	39.10
2	85%	15%	75%	25%	25.27	45.82
3	85%	15%	50%	50%	26.04	47.32
4	85%	15%	25%	75%	28.63	49.26
5	8%	15%	0%	100%	25.06	44.40

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All test results showed there is a remarkable improvement in strength characteristics up to 75% partial replacement of FERROCHROME SLAG in coarse aggregate. The amount of coarse aggregate replacement up to 75% with FERROCHROME SLAG strength gain increases, and beyond this level of FERROCHROME SLAG addition the strength gain decreases. From the Table 2, it is noticed that the optimum percentage replacement of FERROCHROME SLAG was found to be 75% from the viewpoint of strength characteristics.

### Optimum Lathe Waste

The replacement of cement partially with METAKAOLIN and coarse aggregate with FERROCHROME SLAG gives the desired strength but it is not very significant. Addition of fibres may help to enhance strength properties of concrete. Strength tests were conducted on partial replacement of cement with METAKAOLIN and coarse aggregate with FERROCHROME SLAG concrete added with lathe waste fibres in percentages of 0.5%, 1.0% and 1.5% by weight of cement. Compressive strength and splitting tensile strength results of specimens cured for different curing periods are presented in Table 3 and 4 respectively.

Table 3: Compressive strength by using Lathe Waste for MIX-3

MIX-3	Metakaolin %	Ferrochrome slag %	% of Lathe Waste	Compressive Strength (MPa)		
				7 days	28 days	90 days
1	0	0	0	22.38	39.10	42.93
2	15	75	0.5	27.36	50.32	52.08
3	15	75	1.0	30.84	51.86	54.17
4	15	75	1.5	28.62	48.92	50.73

Table 4: split tensile strength by using Lathe Waste for MIX-3

MIX-3	Metakaolin%	Ferrochrome slag %	% of Lathe waste	Split Tensile Strength (Mpa)		
				7 days	28 days	90 days
1	0	0	0	2.98	3.29	3.42
2	15	75	0.5	3.57	3.61	3.76
3	15	75	1.0	3.78	3.95	4.13
4	15	75	1.5	3.47	3.38	3.51

From the strength test results shown in Table 3 and 4, the optimum percentage of adding lathe waste is found to be 1.0%. Addition of lathe waste fibres enhances the compressive strength and splitting tensile strength in percentages of 20.74% and respectively for 28 days.

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## Optimum Steel Fibre

Strength tests were conducted on partial replacement of cement with metakaolin and coarse aggregate with FERROCHROME SLAG concrete with steel fibres in percentages of 0.5%, 1.0% and 1.5% by weight of cement. Test results are shown in Table 5 and 6 respectively.

Table 5: Compressive strength by adding steel fibers

MIX-3	Metakaolin %	Ferrochrome slag %	% of Steel Fiber	Compressive Strength (MPa)		
				7 days	28 days	90 days
1	0	0	0	22.38	39.10	42.93
2	15	75	0.5	29.56	51.10	54.13
3	15	75	1	32.56	53.92	56.29
4	15	75	1.5	30.42	50.63	52.42

Table 6 Split tensile strength by adding steel fibers

MIX-3	Metakaolin%	Ferrochrome Slag %	% of steel fibers	Split Tensile Strength(Mpa)		
				7 days	28 days	90 days
1	0	0	0	2.98	3.29	3.42
2	15	75	0.5	3.70	3.79	3.91
3	15	75	1.0	3.92	4.03	4.31
4	15	75	1.5	3.57	3.68	3.79

From the test results shown Table. 5 and 6 the optimum percentage of adding steel fibres is found to be 1.0% from the viewpoint of strength characteristics.

From the strength test results shown in Table 5 and 6, the optimum percentage of adding steel fibres is found to be 1.0%. Addition of lathe waste fibres enhances the compressive strength and splitting tensile strength in percentages of 20.74% and respectively for 28 days.

## DURABILITY TEST

To study durability characteristics, the specimens are subjected to 2% solution of H<sub>2</sub>SO<sub>4</sub> and HCL for 28 days. In this investigation, the concrete cube specimens of various concrete mixtures of size 150 mm x 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. After 28 days of curing, 2% of HCL and H<sub>2</sub>SO<sub>4</sub> solution is taken weight of water was added to water in which the concrete cubes were stored. The p<sup>H</sup> was maintained throughout the period of 90 days. After 90 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of

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concrete to acid attack was found by the % loss of compressive strength and % of weight loss on immersing concrete cubes in acidwater.

Table 7: Percentage of strength Loss of concrete cube when cured with 2% of HCL solution in addition to water for a period of 90 days

MIX-3	% of Lathe waste added	Average strength of cube immersed in water(N/mm <sup>2</sup> )	Average strength of cube immersed in HCl solution(N/mm <sup>2</sup> )	Percentage strength loss
1	0	51.87	41.87	19.27
2	0.50	52.08	43.25	17
3	1.0	54.17	46.87	13.5
4	1.5	50.73	41.68	17.8

Table8: Percentage of strength Loss of concrete cube when cured with 2% of H<sub>2</sub>SO<sub>4</sub> solution in addition to water for a period of 90 days

MIX-3	% of Lathe waste added	Average strength of cube immersed in water(N/mm <sup>2</sup> )	Average strength of cube immersed in H <sub>2</sub> SO <sub>4</sub> solution(N/mm <sup>2</sup> )	Percentage strength loss
1	0	51.87	41.04	20.5
2	0.50	52.08	42.86	17.71
3	1.0	54.17	46.02	15.05
4	1.5	50.73	40.54	20.09

Table9: Percentage of strength Loss of concrete cube when cured with 2% of HCL solution in addition to water for a period of 90 days

MIX-3	% of Steel fibers added	Average strength of cube immersed in water(N/mm <sup>2</sup> )	Average strength of cube immersed in HCl solution(N/mm <sup>2</sup> )	Percentage strength loss
1	0	51.87	42.96	17.20
2	0.50	54.13	45.89	15.23
3	1.0	56.29	48.51	14
4	1.5	52.42	43.28	17.44



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Table10: Percentage of strength Loss of concrete cube when cured with 2% of H<sub>2</sub>SO<sub>4</sub> solution in addition to water for a period of 90 days

MIX-3	% of Steel fibers added	Average strength of cube immersed in water(N/mm <sup>2</sup> )	Average strength of cube immersed in H <sub>2</sub> SO <sub>4</sub> solution(N/mm <sup>2</sup> )	Percentage strength loss
1	0	51.87	41.87	20.3
2	0.50	54.13	45.04	16.80
3	1.0	56.29	48.12	14.52
4	1.5	52.42	42.87	18.22

Table11: Percentage of weight Loss of concrete cube when cured with 2% of HCL solution in addition to water for a period of 90 days

MIX-3	% of Steel Fibers added	Average weight of cube before immersed in HCl solution (Kg)	Average weight of cube after immerse in HCl solution (Kg)	Percentage of weight loss
1	0	8.88	8.68	2.26
2	0.50	9.05	8.76	3.21
3	1.0	9.12	8.88	2.64
4	1.5	9.07	8.71	3.76

Table12: Percentage of weight Loss of concrete cube when cured with 2% of H<sub>2</sub>SO<sub>4</sub> solution in addition to water for a period of 90 days

MIX-3	% of Lathe waste added	Average weight of cube before immerse in HCl solution(Kg)	Average weight of cube after immersed in HCl solution(Kg)	Percentage of weight loss
1	0	8.80	8.51	3.30
2	0.50	8.98	8.57	4.60
3	1.0	9.13	8.75	4.17
4	1.5	9.03	8.61	4.36



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Table13: Percentage of weight Loss of concrete cube when cured with 2% of HCL solution in addition to water for a period of 90 days

MIX-3	% of Lathe Waste added	Average weight of cube before immersed in H <sub>2</sub> SO <sub>4</sub> solution (Kg)	Average weight of cube after immersed in H <sub>2</sub> SO <sub>4</sub> solution (Kg)	Percentage of weight loss
1	0	8.98	8.67	3.46
2	0.50	9.0	8.58	4.67
3	1.0	9.17	8.81	4.00
4	1.5	9.05	8.65	4.42

Table14: Percentage of weight Loss of concrete cube when cured with 2% of H<sub>2</sub> SO<sub>4</sub> solution in addition to water for a period of 90 days

MIX-3	% of Steel Fibers added	Average weight of cube before immersed in H <sub>2</sub> SO <sub>4</sub> solution (Kg)	Average weight of cube after immersed in H <sub>2</sub> SO <sub>4</sub> solution (Kg)	Percentage of weight loss
1	0	8.91	8.79	3.37
2	0.50	9.05	8.89	3.87
3	1	9.24	8.98	3.25
4	1.5	9.18	9.05	4.04

### V. CONCLUSION

By the comparison of conventional mix, the percentage increase in compressive strength for partial replacement of cement with 15% of Metakaolin was 14.31% for 28 days. By the comparison of conventional mix, the percentage increase in compressive strength for partial replacement of coarse aggregate with 75% of Ferrochrome slag and 15% of Metakaolin was 20.62% for 28 days. By the comparison of conventional mix, the percentage increase in compressive strength and split tensile strength for extension of steel fibers are 23.73% and 20.60% for 90 days respectively. By the comparison of conventional mix, the percentage increase in compressive strength and split tensile strength for extension of Lathe waste are 20.74% and 17.19% for 90 days respectively. The optimum quantity for partial replacement of cement with Metakaolin is obtained at 15%. By making the 15% of Metakaolin constant, the optimum quantity for partial replacement of coarse aggregate with Ferrochrome slag obtained at 75%. The optimum extension of steel fibers and Lathe waste is obtained at 1%. The durability results show that steel fibers is more effective than Lathe waste. In durability the strength loss is higher in H<sub>2</sub>SO<sub>4</sub> than HCL.

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## REFERENCES

- [1] Satyendra Dubey, Rajiv Chandak R.K. Yadav (June 2015) "Experimental Study of Concrete with Metakaolin as Partial Replacement of OPC". International Journal of Advanced Engineering Research and Science (IJAERS) vol-2 issue 6.
- [2] M. Narmatha, Dr. T. Felixkala (2016) "Meta kaolin – The Best Material for Replacement of Cement in Concrete". Journal of Mechanical and Civil Engineering, PP 66-77.
- [3] Milind V. Mohod (2012) "Performance of Steel Fiber Reinforced Concrete". International Journal of Engineering and Science ISSN: 2278-4721, Vol. 1, PP 01-04.
- [4] Bindu Biju, Imran H (2016) "Partial Replacement of Cement with Metakaolin in High Performance Concrete". International Journal of Innovative Research in Science, Engineering and Technology.
- [5] Vasudev R, Dr. B G Vishnuram (2013) "Studies on Steel Fibre Reinforced Concrete – A Sustainable Approach". International Journal of Scientific & Engineering Research Volume 4, 1941 ISSN 2229-5518.
- [6] CH Jyothi Nikhila and J D Chaitanya Kumar (2015). "Partial replacement of cement with metakaolin in high strength concrete". International Journal of Engineering Research and Science & Technology Vol. 4.
- [7] Zenisek Michal, Vlach Tomas Laiblova Lenka (2016) "Dosage of Metakaolin in High Performance Concrete".
- [8] Avinash Joshi, Pradeep reddy, and Pramod hatker Punith kumar "Experimental Work on Steel Fibre Reinforced Concrete". International Journal of Scientific & Engineering Research Volume 7 971-982.
- [9] Abdul Ghaffar, Amit S. Chavhan, Dr. R. S. Tatwawadi (2014). "Steel Fibre Reinforced Concrete". International Journal of Engineering Trends and Technology (IJETT) – Volume 9.
- [10] Sathwik S R, Sanjith J, Sudhakar (December 2016) "Development of High Strength Concrete Using Ferrochrome Slag Aggregate as Replacement to Coarse Aggregate".
- [11] Poorva Haldkar, Ashwini Salunke "Analysis of Effect of Addition of Lathe Scrap on the Mechanical Properties of Concrete". International Journal of Science and Research (IJSR)
- [12] IS 10262:2009, Concrete Mix proportion Guidelines.
- [13] IS 456-2000, Indian standard plain and reinforced concrete structures