International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 03 - Issue 02(S) || PP.66-71

Beneficial Utilization of Waste foundry sand and Copper slag in Self Compacting Concrete

Vijay Anand K.[1*], Vennila A.[2*], Dr. Sreevidya V.[3*]
[1]*Student, Department of Structural Engineering, Sri Krishna College of Technology, India.*
[2]*Faculty, Department of Civil Engineering, Sri Krishna College of Technology, India.*
[3] *Faculty, Department of Civil Engineering, Sri Krishna College of Technology, India.*

Abstract: Self- compacting concrete is a type of concrete which flows under the influence of gravity without segregation is used in heavily reinforced structural members. It avoids the need of vibration equipment. In the present scenario, waste materials from various industries are added to the mix. Over 400 million tons of waste materials are being produced by various industries every year. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as Foundry sand. Foundry sand production is nearly 6 to 10 million tons annually. Copper slag is one of the waste materials which can have a hopeful expectation in construction industry as partial or full alternative of fine aggregates. There is a possibility of substituting natural fine aggregate with waste foundry sand and copper slag which offers technical, economic and environmental advantages which are of great use in the construction sector. This project explores the strength studies of self- compacting concrete using waste foundry sand and copper slag as partial replacement for fine aggregate to enhance the mechanical properties. Various tests are to be carried out to determine the properties of fresh and hardened concrete such as workability test, compressive test, flexure and tensile test. The percentage replacement of foundry sand with sand includes 20% & 30% and copper slag with sand includes 10% & 20%. The mix design for SCC was arrived as per the guidelines of EFNARC.
Keywords: Copper slag, Compressive strength, Eco-friendly, Foundry sand, Industrial waste, SCC.

1. Introduction

Self-compacting concrete (SCC) represents one of the most significant advances in concrete technology for decades. Inadequate homogeneity of the cast concrete due to poor compaction or segregation may drastically lower the performance of mature concrete in-situ. SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas. SCC was developed first in Japan in the late 1980s to be mainly used for highly congested reinforced structures in seismic regions. As the durability of concrete structures became an important issue in Japan, an adequate compaction by skilled labours was required to obtain durable concrete structures. This requirement led to the development of SCC and its development was first reported in 1989. SCC can be described as a high performance material which flows under its own weight without requiring vibrators to achieve consolidation by complete filling of formworks even when access is hindered by narrow gaps between reinforcement bars. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete, such as underwater concreting, cast in-situ pile foundations, machine bases and columns or walls with congested reinforcement. The high flow ability of SCC makes it possible to fill the framework without vibration. Since its inception, it has been widely used in large construction in Japan. Recently, this concrete has gained wide use in many countries for different applications and structural configurations. In the present scenario, waste materials from various industries are added to the mix. Over 400 million tons of waste materials are being produced by various industries every year. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as Foundry sand. Foundry sand production is nearly 6 to 10 million tons annually. Copper slag is one of the waste materials which can have a hopeful expectation in construction industry as partial or full alternative of fine aggregates. There is a possibility of substituting natural fine aggregate with waste foundry sand and copper slag which offers technical, economic and environmental advantages which are of great use in the construction sector. The construction industry is now slowly becoming aware of the environmental issues and other sustainable development issues for cement and concrete industries. It is looking for the ways and means to develop building products, which will increase the life span and quality.

2. Materials

2.1 Cement

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. Ordinary Portland cement of 53 grade conforming to Indian Standard IS 12269-1987 was used in the experiment. The typical fineness of cement ranges from 350 to 500 m^2/kg respectively. More than 500 kg/m^3 cement can be dangerous and increase the shrinkage. Less than 350 kg/m^3 may only be suitable with the inclusion of other fine filler, such as fly ash, pozzolona. The composition of Portland cement is shown in the table 1. The properties of cement is shown in the table 2.

Table 1. Composition of Portland cement

Ingredients	**Percentage Content**
CaO (Lime)	60-70
SiO_2 (Silica)	17-25
Al_2O_3 (Alumina)	3-8
Fe_2O_3 (Iron Oxide)	0.5-6
MgO (Magnesia)	0.1-4
Alkalies	0.4-1.3
Sulphur	1-3

2.2 Fine Aggregate

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size being finer than gravel and coarse than silt. Fine aggregate (sand) used for this investigation is river sand conforming to zone-II of IS 383- 1970 and it was well graded, passing through 4.75mm sieve. The sand was air dried and sieved to remove any foreign material, prior to mixing. The properties of fine aggregate is shown in the table 3.

2.3 Coarse Aggregate

The coarse aggregate chosen for SCC is typically round in shape, is well graded, and smaller in maximum size than that used for conventional concrete. As with conventional concrete construction, the maximum size of the coarse aggregate for SCC depends upon the type of construction. Typically, the maximum size of coarse aggregate used in SCC ranges from approximately 10 mm to 20 mm. The coarse aggregate should have a maximum of 12mm. It is to be confirmed as per the BIS specifications. Using lesser size aggregates improves the flow ability of concrete. The properties of coarse aggregate is shown in the table 4.

2.4 Waste Foundry Sand

Foundry sand is high quality silica sand that is a by-product from the production of both ferrous and nonferrous metal castings. The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. It can be reused several times in foundries but, after a certain period, cannot be used further and becomes waste material, referred to as used or spent foundry sand. The properties of waste foundry sand is shown in the table 5.

2.4 Copper Slag

Copper slag is a by-product obtained during matte smelting and refining of copper. The slag is a black glassy particle and granular in nature and has a similar particle size range like sand. It has good pozzalonic properties. At present, about 2600 tons of Copper slag is manufactured every day. Generally 2.2 to 3.0 tons of copper slag is produced while manufacturing every ton of copper metal. The properties of copper slag is shown in the table 6.

2.5 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. The water used in concrete plays an important part in the mixing, laying, compaction, setting and hardening of concrete. The strength of concrete directly depends on the quantity and quality of water used in the mix. Ordinary potable water of pH 7 is normally used for mixing and curing the concrete specimen.

2.6 Admixture

Conplast SP430 DSI (Sulphonated Naphthalene Formaldehyde based super plasticizer) was used. The Dosage is about 1% of cementations material. The product is suitable for tropical and hot climatic conditions. It is a light brownish colour liquid. Conplast is especially suitable for the production of concrete mixes which require high early strength development, powerful water reduction and excellent flow ability. Conplast SP430 (NE) is used where a high degree of workability and its retention are required, where delays in transportation or placing are likely or when high ambient temperatures cause rapid slump loss. It facilitates production of high quality concrete. The chemical admixture (Conplast) obtained from market are shown in Fig.1 The properties of chemical admixture is shown in the table 7.

Figure 1. chemical admixture (Conplast) obtained from market

3. Properties of Materials used

Table 2. Properties of cement

S.No	Properties	Values
1.	Specific Gravity	3.15
2.	Bulk Density	1440 kg/m^3
3.	Surface area	225 m^2/kg
4.	Initial setting time	30 min
5.	Final setting time	600 min

Table 3. Properties of fine aggregate

S.No	Properties	Values
1.	Specific Gravity	2.63
2.	Bulk Density	1318.18 kg/m^3

Table 4. Properties of coarse aggregate

S.No	Properties	Values
1.	Specific Gravity	2.7
2.	Bulk Density	1404.2 kg/m^3
3.	Size	10 mm

Table 5. Properties of waste foundry sand

S.No	Properties	Values
1.	Specific Gravity	2.4
2.	Colour	Black

Table 6. Properties of copper slag

S.No	Properties	Values
1.	Specific Gravity	3.4
2.	Colour	Black and glassy

Table 7. Properties of Chemical admixture

S.No	Properties	Values
1.	Specific Gravity	1.145
2.	Colour	Light brown

4. Results and Discussion

4.1 Fresh properties

Workability of self-compacting concrete can be characterized by three parameters- filling ability, passing ability and resistance to segregation. The fresh properties of concrete are assessed by doing the following experiments such as slump flow test, L-box test, U-box test and V-funnel test. The Fresh concrete test results are shown in the table 8.

Table 8. Fresh concrete test results

S.NO	COMBINATIONS	SLUMP FLOW (sec)	V-FUNNE (sec)	L-BOX	U-BOX (cm)
1	SCC	4	5	0.8	30
2	MIX 1	6	6	0.8	31.5
3	MIX 2	9	7	0.77	32.3
4	MIX 3	11	9	0.73	33.6
5	MIX 4	13	11	0.7	35

As per guidelines of EFNARC, for slump flow, the typical range of value is 650-800 mm, for T50cm, range is 2 to 5 sec and for V-funnel, range is 6-12 sec, for L-box, the range is 0.82 to 1, for U-box, the range is 0 to 30 mm. But the mix almost satisfies the range specified by EFNARC guidelines.

4.2 Hardened properties

4.2.1 Compressive strength test

Compressive strength tests are carried out on cubes of size 150 mm x 150 mm x150 mm. The specimens are tested after keeping it for curing at the age of 7 and 28 days. The results obtained are compared with the results of a control mix specimens. The Compressive strength results are shown in table 9. The fig.2 graph showing compressive strength results.

S.No	Combination	Compressive strength test			
		7 day strength		28 day strength	
		Cube		Cube	
		1	2	1	2
		(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)
1	SCC	24.33	23.37	37.49	36.02
		23.85		36.75	
2	MIX 1	24.76	23.78	38.13	36.63
		24.27		37.38	
3	MIX 2	25.07	24.09	38.68	37.16
		24.58		37.92	
4	MIX 3	26.41	25.37	40.64	39.04
		25.89		39.84	
5	MIX 4	26.76	25.72	41.23	39.61
		26.24		40.42	

Table 9. Compressive strength test results

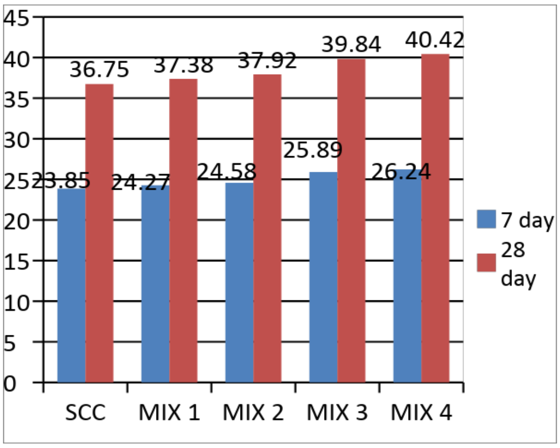

Fig 2. Graph showing compressive strength results

4.2.2 SPLIT TENSILE STRENGTH TEST

For the determination of split tensile strength of concrete, cylinder specimens of diameter 150 mm and height 300 mm were casted. The cylinders were casted for partial replacement of WFS and CS. The tests were conducted on cylinders at an age of 7 and 28 days. The Split tensile strength results are shown in table 10. The fig.3 graph showing split tensile strength results.

S.No	Combination	Split tensile strength test			
		7 day strength		28 day strength	
		Cylinder		Cylinder	
		1	2	1	2
		(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)
1	SCC	2.60	2.50	3.09	2.97
		2.55		3.03	
2	MIX 1	2.64	2.54	3.22	3.10
		2.59		3.16	
3	MIX 2	2.73	2.63	3.25	3.13
		2.68		3.19	
4	MIX 3	2.77	2.67	3.42	3.28
		2.72		3.35	
5	MIX 4	2.81	2.70	3.53	3.39
		2.75		3.46	

Table 10. Split tensile strength results

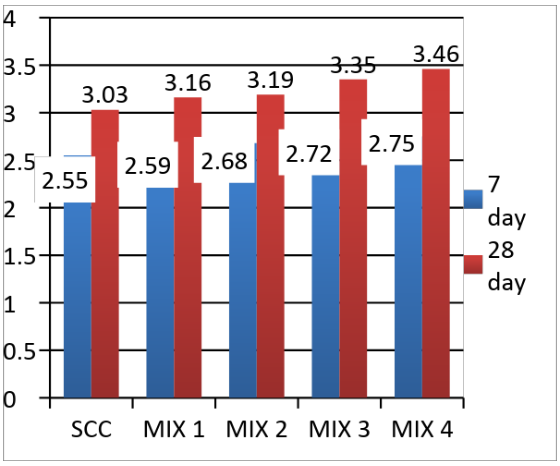

Fig 3. Graph showing split tensile strength results

4.2.3 FLEXURAL STRENGTH TEST

Flexural strength test is carried out on prism specimens of dimensions 100 mm x 100 mm x 500 mm. The test is carried out by applying two point loading on the prism at the age of 7 and 28 days. The tests are carried out for partial replacement of WFS and CS. The Flexure strength results are shown in table 11. The fig.4 graph showing flexural strength results.

S.No	Combination	Flexural strength test			
		7 day strength		28 day strength	
		Prism		Prism	
		1	2	1	2
		(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)
1	SCC	3.29	3.16	4.06	3.90
		3.22		3.98	
2	MIX 1	3.35	3.22	4.14	3.98
		3.29		4.06	
3	MIX 2	3.41	3.28	4.21	4.05
		3.35		4.13	
4	MIX 3	3.48	3.34	4.29	4.13
		3.41		4.21	
5	MIX 4	3.54	3.40	4.37	4.19
		3.47		4.28	

Table 11. Flexural strength test results

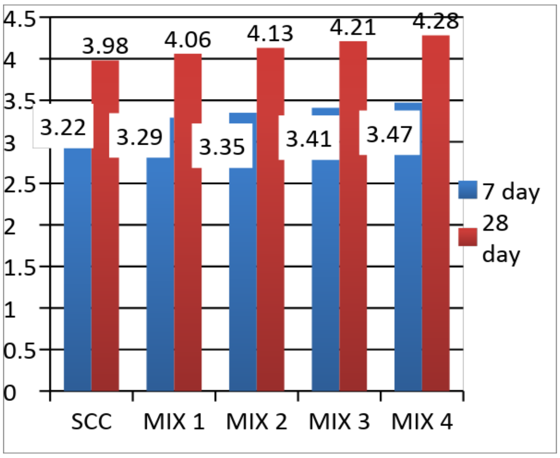

Fig 4. Graph showing flexural strength results

5. Conclusion

Based on the above study the following observations are made regarding the properties and behavior of concrete on the partial replacement of fine aggregate by waste foundry sand and copper slag.

1. Use of WFS and CS in concrete improves strength properties.
2. The replacement % of 30 & 20 of WFS and CS self-compacting concrete has exhibited a maximum compressive strength of 40.41 MPa at 28 days.
2. The compressive strength, the split tensile strength and the flexural strength increase with increase in the percentage of replacement % of 30 & 20 of WFS & CS percentage increase in strength is 10-14% over normal SCC.
3. Satisfactory workability was maintained with increasing WFS and CS by using super plasticizer.
4. The main aspect followed in this project is to reduce the waste disposal and save the earth from environmental hazards.

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