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EXPERIMENTAL STUDY ON STRENGTH AND DURABILITY PARAMETERS OF FAL-G CONCRETE

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***Abstract*--**The experimental studies aims at the maximal utilization of industrial wastes like flyash and foundry waste sand in concrete production. Moreover, to determine the optimum proportion of using industrial wastes like flyash and foundry waste sand in concreting, without compromising the quality of concrete. Production of cement leads to more pollutants and so the use of cement is proposed to be reduced in the making of concrete

The experimental investigation on the strength of FaL-G concrete and on the durability parameters was performed. Replacing cement by flyash in different mix proportions and comparing the same with conventional concrete was carried out. The replacement of M-sand by foundry waste sand has been carried out to make concrete more eco-friendly and economical. The optimum ratio of flyash replacement which can be effectively used can be arrived from the experimental analysis.

It is understood that FaL-G concrete can be used for construction projects. The strength gain is obvious and the durability parameters also verified. The strength variation while using foundry sand is also researched.

Index Terms - Corrosion, durability, Electron dispersion Spectroscopy, Electron beam, Electron Microscopes, FaL-G concrete, Fly ash, Foundry waste sand, M-sand, Super plasticizers, Scanning Permeability.

Nomenclature

FaL-G is the product name given to a cementitious mixture in composed of fly ash (Fa), lime (L) and gypsum (G).Fal-G technology, it is based on two principles namely, that the fly ash-lime pozzolanic reaction does not need external heat under tropical temperature condition and that the strength of flyash-lime mixture can be greatly augment in the presence of gypsum. This has dispensed the need for heavy duty press and auto clave and also made the process energy efficient, bringing the activity within the reach of tiny sector entrepreneurs.

I Introduction

Due to the ever increasing quantities of waste materials and industrial by products, solid waste management is the prime concern in the world. Scarcity of land filling space and because of its ever increasing cost, recycling and utilization of industrial by-products and waste materials has become an attractive proposition to disposal. The utilization of such materials in concrete not only makes it economical but also helps in reducing disposal concerns. One such waste product is foundry waste sand. It is a by-product of ferrous and nonferrous metal casting industries. 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 termed as foundry waste sand.

Disposal of foundry waste sand has become a major environmental problem due to the scarcity of landfills and ever increasing cost of land. When the foundry waste sand is dumped in low lying areas, it may affect the ground water resources polluting them by leaching heavy metals especially during wet seasons. So, utilization of foundry waste sand in concrete production is a better way for reusing it. Ultimately the cost of concrete reduces to a larger extent.

II MATERIALS USED

OPC is a common component used for concrete, mortars and other common construction essentials that require cement in the mixture.

Flyash in FaL-G concrete contributes the properties of the hardened concrete through hydraulic or pozzolanic activity or both. The properties of the aggregate are decisive for the compressive strength and modulus of elasticity of concrete. In normal strength concrete (NSC), the aggregate has a higher strength and stiffness than the cement paste.

FaL-G concrete typically contains high contents of fine cementitious materials such that the grading of the FA used is relatively important. Hence Class C fly ash is used. However, it is sometimes helpful to increase the fineness modulus (FM) as the lower FM of Fine aggregate (FA) can give the concrete a sticky consistency and less workable fresh concrete with a greater water demand. Therefore, sand with a FM of about 3.0 is usually preferred.

Table 1: Test Results on the Materials

S.No	Description	Test Results	IS Code	Range as per IS Code
1	CEMENT Fineness modulus Specific gravity of cement Consistency	 2.2% 3.15 30%	IS 8112:2013 IS 4031 (part4): 1988	Residue should not exceed 10% 25-30%
2	FINE AGGREGATE Specific gravity Fineness modulus	 2.57 3.06	IS 2386 (part3): 1963 IS 2386 (Part1): 1963	 2.4-3.0 2.0 - 3.5
3	COARSE AGGREGATE Specific Gravity Flakiness Index Elongation Index	 2.60 4 9.7	IS 2386 (part3): 1963 IS 2386 (Part1): 1963 IS 2386 (Part1): 1963	 2.5-3.0 Should be less than 15% Should be less than 15%
4	FLY ASH- PAI Specific Gravity	85% 2.2	ASTM C618	75% - 100%.

As per IS 2386, The fineness modulus of fine and coarse aggregate (CA), flakiness index of aggregates, elongation index of aggregate and as per ASTM C311, the Pozzolanic Activity Index (PAI) of fly ash is calculated.

Many studies have shown that crushed stone produces higher strengths than rounded gravel. The most likely reason for this is the greater mechanical bond, which can develop with angular particles. However, accentuated angularity is to be avoided because of the attendant high water requirement and reduced workability. The ideal CA should be clean, cubical, and angular, 100% crushed aggregate with a minimum of flat and elongated particles (ACI 363R, 1992).Usually, water for concrete is specified to be of potable quality (ACI 363R, 1992).

The Super plasticizers, also polymers are used as dispersants to avoid particle segregation and to improve the flow characteristics. Their addition to concrete or mortar allows the reduction of water to cement ratio without affecting the workability of the mixture and enables the production of self- consolidating and high performance concrete.

Foundry waste sand is a by-product of ferrous and nonferrous metal casting industries. 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 termed as foundry waste sand.

Methodology

It mainly focuses on replacement of cement by fly ash and M-sand by foundry waste sand .Thus, the maximization of industrial wastes like fly ash and foundry waste sand in concreting is done, which is good for the environment and the use of cement is reduced, which makes the concrete more economical. These two changes are brought in the best way without compromising the quality. Experiments are carried out

- To do a comparative study between conventional concrete and FaL-G concrete.
- Maximal utilization of industrial wastes like fly ash and foundry waste sand in concrete.
- To determine the optimum proportion of using industrial wastes without compromising the quality.
- Finding the optimized results in terms of strength which can be used in real time.
- Durability parameters of Fal-G concrete.

III EXPERIMENTAL PROGRAMME

The aim of this research is to find an optimum proportion of fly ash to cement ratio that can be used to make concrete in the civil engineering industry. It mainly focuses on replacement of cement by fly ash and M-sand by foundry waste sand .Thus, the maximization of industrial wastes like fly ash and foundry waste sand in concreting is done, which is good for the environment and the use of cement is reduced, which makes the concrete more economical. These two changes are brought in the best way without compromising the quality.

The durability parameters like corrosion resistance and permeability of Fal-G concrete is studied.By comparing it with that of conventional concrete using standard methods given in the code books.

It is important to know the material characteristics before carrying out an experimental work. The material properties are investigated carefully as per the Indian Standard codal provisions. The results obtained are used for the mix design of M20 concrete.

The main experimental work for strength test is done by casting of cubes of size 150*150*150 mm. The cubes are then kept in the curing tank and they are tested in the Compression Testing Machine (CTM).

Conventional concrete and FaL-G concrete with optimum replacement of cement by flyash and msand by foundry waste sand with three different ratios of fly ash and foundry waste sand combination is done.

In this work, two main durability parameters are tested, the corrosion resistance and the permeability. The methods are RCPT, SEM analysis and EDS. The permeability test is carried out with standard permeability testing apparatus. All these tests are done for FaL-G concrete and Conventional concrete of the same grade for which the strength tests were done. The comparison of the results of FaL-G concrete and conventional concrete gives the idea whether the FaL-G concrete is durable.

Design Mix

Concrete grade M20 was proportioned by adopting I.S method of mix design. The mix proportion arrived was 1: 1.8: 3 with water cement ratio 0.5. The mixing of cement and aggregate was done by manually.

Table 2: Proportion of the constituents from mix design

Cement (kg/m^3)	Water (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Admixture (kg/m^3)
372	186	679	1122	1.86

Experimental result of various percentage replacement of foundry waste sand fly ash in a fixed ratio already determined from experimentation is used to make FaL-G concrete and was compared with that of conventional concrete of the same design mix.

When comparing the experimental results of three different ratio of foundry waste sand, the second mix ratio with 5% replacement of foundry waste sand is found to give optimum results after testing. The testing of durability parameters can carried out for the above mentioned mix ratio for M20 grade of concrete.

Table 3: Comparison of experimental results of various percentage of flyash with conventional concrete.

Grade of concrete	Mix ratio(%by weight)			W/C ratio	admixture (% of cement)	Test results (N/mm^2)		
	(kg/m^3)	Fly ash	FWS			7th day	14th day	28th day
M20	55	45	-	0.5	0.5	10.8	16.14	21.24
M20	55	45	5	0.5	0.5	9.53	15.89	20.68
M20	55	45	10	0.5	0.5	8.42	14.58	19.70
M20	55	45	15	0.5	0.5	8.21	13.36	18.9

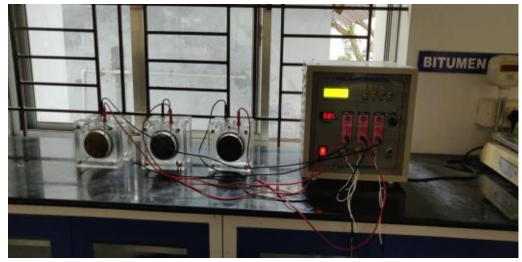

Fig.1. Running of RCPT apparatus

Table 4: Readings of acrylic diffuser 1 for conventional concrete

Time	Volts	Current (mA)	Temperature (^{0} C)
10.30	60	131.9	31.5
11.00	58.9	148.2	31.7
11.30	58.7	156.3	31.8
12.00	58.5	160.4	31.9
12.30	59.2	164.8	32.1
01.00	59.2	167.9	32.2
01.30	59.3	172.6	32.4
02.00	59.3	176.9	32.4
02.30	59	180.2	32.6
03.00	59.3	184.9	32.6
03.30	58.8	187.4	32.6
04.00	58.8	192.3	32.5

I = (900 X 2 X1877.1) / 1000 = 3378.78 Coulombs (Normal)

Table 5: Readings of acrylic diffuser 2for conventional concrete

Time	Volts	Current (mA)	Temperature (^{0} C)
10.30	60	130.9	32.2
11.00	58.9	144.6	32.3
11.30	58.7	150.7	32.4
12.00	58.5	156.5	32.5
12.30	59.2	162.6	32.8
01.00	59.2	166.6	32.8
01.30	59.3	172.7	33.1
02.00	59.3	176.9	33.0
02.30	59	176.6	33.0
03.00	59.3	183.2	33.2
03.30	58.8	181.7	33.2
04.00	58.8	181.7	33.1

I = (900 X 2 X1651.8) / 1000 = 2973.24 Coulombs (Normal)

Table 6: Readings of acrylic diffuser 3for conventional concrete

Time	Volts	Current(mA)	Temperature (^{0} C)
10.30	60	131.5	31.5

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11.00	58.9	147.0	31.7
11.30	58.7	156.3	31.5
12.00	58.5	160.8	32.0
12.30	59.2	162.3	32.1
01.00	59.3	165.9	32.3
01.30	59.3	173.1	32.4
02.00	59	177.3	31.0
02.30	59.3	180.5	32.4
03.00	58.8	185.1	32.5
03.30	58.7	185.7	32.6
04.00	59	195.1	32.2

I = (900 X 2 X1857.3) / 1000 = 3343.14 Coulombs (Normal)

Table 7: Readings of acrylic diffuser 1for FaL-G concrete

Time	Volts	Current (mA)	Temperature (^{0} C)
10.30	59.6	54.8	31.5
11.00	59.7	59.2	31.9
11.30	59.6	62.9	32.0
12.00	59.7	68.0	32.2
12.30	59.5	73.0	32.3
01.00	59.6	78.4	32.4
01.30	60.4	85.7	33.0
02.00	60.0	92.7	33.1
02.30	59.6	97.8	32.6
03.00	59.9	106.8	32.6
03.30	59.9	112.3	32.6
04.00	59.8	117.2	32.5

I = (900 X 2 X810.5) / 1000 = 1458.9 Coulombs (Normal)

Table 8: Readings of acrylic diffuser cell 2 for FaL-G concrete

Time	Volts	Current (mA)	Temperature (^{0} C)
10.30	59.6	58.0	32.1
11.00	59.7	60.0	32.5
11.30	59.6	68.5	32.7
12.00	59.7	74.4	32.9
12.30	59.5	81.0	33.0
01.00	59.6	86.7	33.1
01.30	60.4	92.7	33.6
02.00	60.0	99.4	33.2
02.30	59.8	106.0	33.3
03.00	59.9	112.3	33.2
03.30	59.9	122.0	33.2
04.00	59.8	127.1	33.2

I = (900 X 2 X1122.65) / 1000 = 2020.77 Coulombs (Normal)

Table 9: Readings of acrylic diffuser cell 3 for FaL-G concrete

Time	Volts	Current (mA)	Temperature (^{0} C)
10.30	59.6	57.0	32.5
11.00	59.7	67.4	32.0
11.30	59.6	74.5	32.1
12.00	59.7	77.0	32.3
12.30	59.5	82.2	32.4
01.00	59.6	87.1	32.5
01.30	60.4	92.8	33.1
02.00	60.0	98.3	33.2
02.30	59.8	102.3	32.7
03.00	59.9	108.7	32.6
03.30	59.9	111.7	32.7
04.00	59.8	114.2	32.6

I = (900 X 2 X987.6) / 1000 = 1777 Coulombs (Normal)

INTERPOLATION OF RESULT

Table 10. Chloride permeability

Charge passed (Coulombs)	Chloride permeability
> 4,000	High
1,000 - 4,000	Normal
< 1,000	low

Table 11 Test result of RCPT

S.No.	Acrylic diffuser cell	Charge passed (Coulombs)	Chloride permeability
1	Cell 1 (conventional)	3378.78	Normal
2	Cell 2 (conventional)	2973.24	Normal
3	Cell 3 (conventional)	3343.14	Normal
4	Cell 1 (FaL-G)	1458.90	Normal
5	Cell 2 (FaL-G)	2020.77	Normal
6	Cell 3 (FaL-G)	1777.00	Normal

SEM ANALYSIS

A Scanning Electron Microscope (SEM) is a powerful magnification tool that utilizes focused beams of electrons to obtain a magnified image of a sample. The electron beam is scanned in a regular pattern across the surface of the sample and the electrons that come out are used to create the image.

The high resolution, three-dimensional images produced by SEMs provide topographical, morphological and compositional information, makes them invaluable in a variety of science and industry applications.

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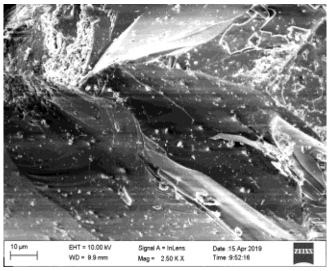


Fig 3 SEM-Conventional concrete (10μm)

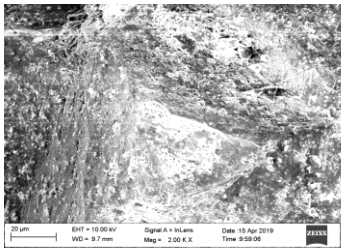


Fig 4 SEM-FaL-G concrete (10μm)

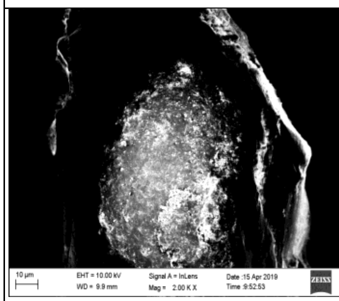


Fig 5 SEM-Conventional concrete (10μm)

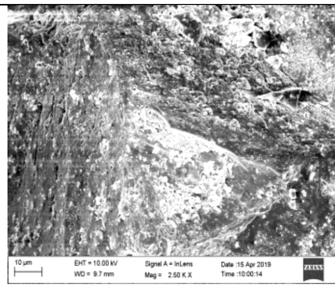


Fig 6 SEM-FaL-G concrete (10μm)

Fig 2 Scanning Electron Microscopes (SEMs)

COMPARISION OF FAL-G AND CONVENTIONAL CONCRETE

It is evident from the pore structure that the FaL-G concrete has less denser configuration when compared with that of conventional concrete, it means that the pozzolanic reaction has started taking place which will show the complete effect over a long period of time.

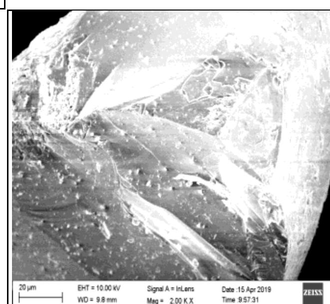


Fig 9 SEM-Conventional concrete (20μm)

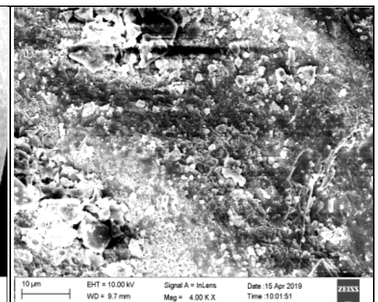


Fig10 SEM-FaL-G concrete (20μm)

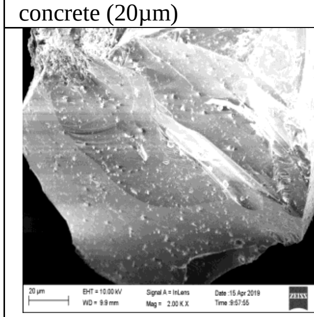


Fig 11 SEM-Conventional concrete (20μm)

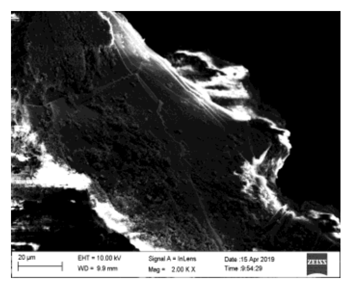


Fig 12 SEM-FaL-G concrete (20μm)

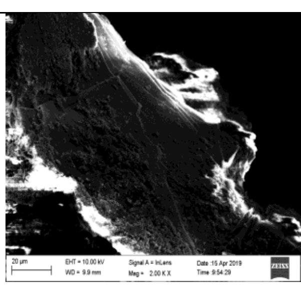


Fig 7 SEM-Conventional concrete (20μm)

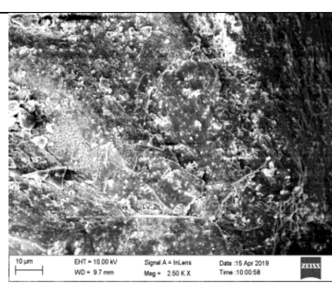
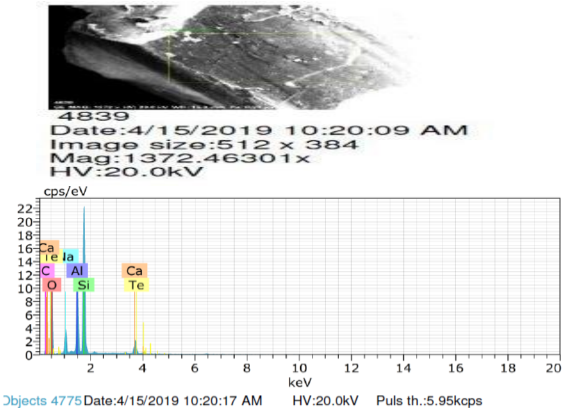


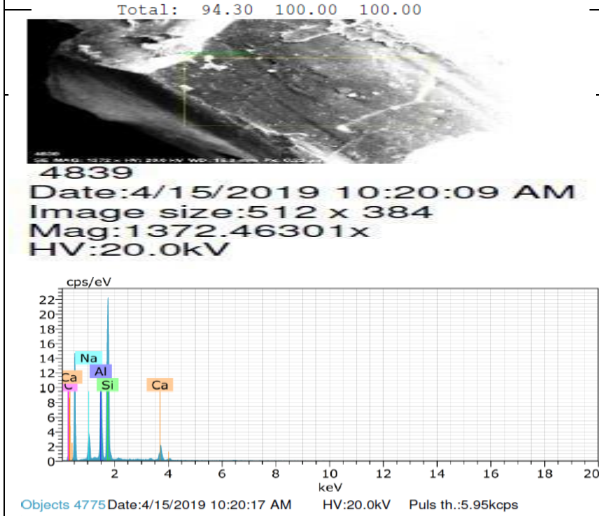
Fig 8 SEM-FaL-G concrete (20μm)

The electron dispersion spectroscopy is an imaging done using Scanning Electron Microscope. The study of the constituent elements can be done by this analysis.

As per ASTM E1508, Scanning electron microscopes (SEMs) employ electron beams in order to get information from a sample at the nanoscale. The main type of signals that are detected are the backscattered (BSE) and secondary electrons (SE), which generate a grayscale image of the sample at very high magnifications. However, there are many other signals which can be a product of the electron-



El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
O	8	K-series	42.88	45.47	57.17	5.54
Si	14	K-series	21.22	22.50	16.12	0.94
Al	13	K-series	11.45	12.15	9.05	0.58
C	6	K-series	5.84	6.19	10.36	1.47
Na	11	K-series	5.03	5.34	4.67	0.37
Te	52	L-series	4.27	4.53	0.71	0.17
Ca	20	K-series	3.60	3.82	1.92	0.15
		Total:	94.30	100.00	100.00	

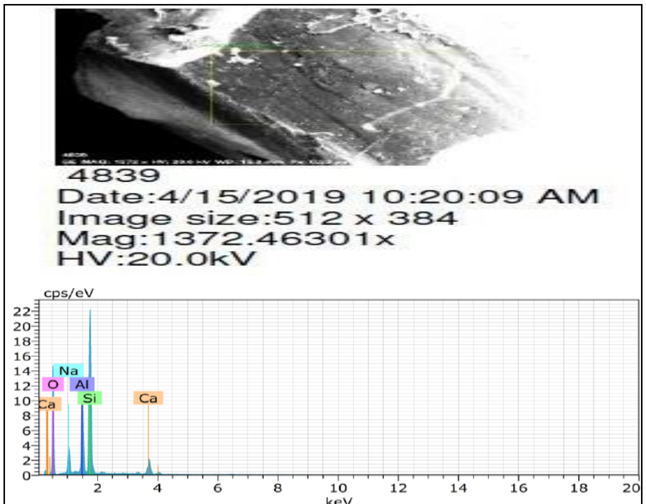


El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Si	14	K-series	24.63	41.92	32.89	1.09
Al	13	K-series	12.39	21.09	17.22	0.63
C	6	K-series	11.88	20.22	37.09	2.93
Na	11	K-series	5.16	8.79	8.42	0.38
Ca	20	K-series	4.69	7.98	4.39	0.18
		Total:	58.76	100.00	100.00	

Fig 14 EDS report of conventional concrete (part 2)

matter interaction, and these can provide additional information about the electron – matter interaction.

The electron beam-matter interaction generates a variety of signals that carry different information about the sample. For example, backscattered electrons produce images with contrast that carries information on the differences in atomic number secondary electrons give topographic information cathodoluminescence can give information on the electronic structure and the chemical composition of materials and transmitted electrons can describe the sample's inner structure and crystallography.



El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
O	8	K-series	40.84	50.51	64.07	5.28
Si	14	K-series	20.28	25.08	18.12	0.90
Al	13	K-series	10.78	13.33	10.02	0.55
Na	11	K-series	4.69	5.80	5.12	0.35
Ca	20	K-series	4.28	5.29	2.68	0.17
		Total:	80.86	100.00	100.00	

Fig 13 EDS report of conventional concrete (part1)

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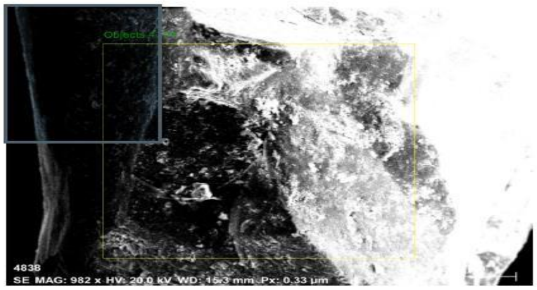


Spectrum: Objects 4774

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
O	8	K-series	41.15	47.85	56.45	6.17
Si	14	K-series	16.83	19.57	13.15	0.77
C	6	K-series	9.67	11.24	17.67	2.78
Al	13	K-series	8.42	9.79	6.85	0.46
Na	11	K-series	4.16	4.84	3.97	0.34
Te	52	L-series	3.32	3.86	0.57	0.19
Ca	20	K-series	2.45	2.85	1.34	0.14
		Total:	86.00	100.00	100.00	

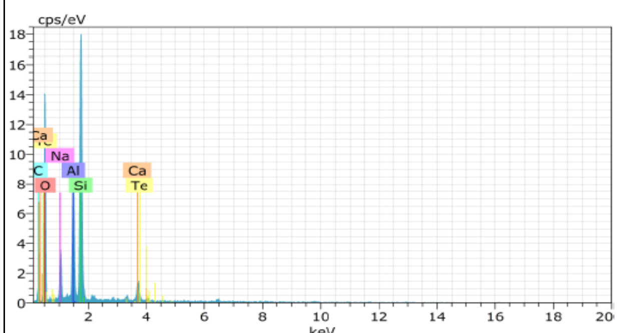
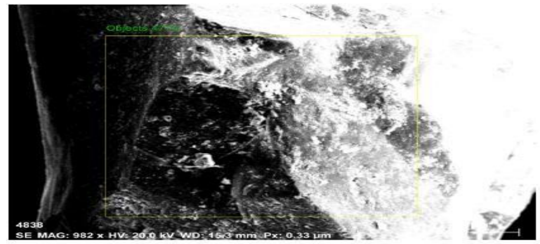
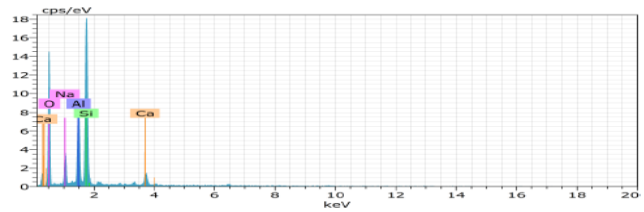


Fig 19 EDS report of FaL-G concrete (part 3)

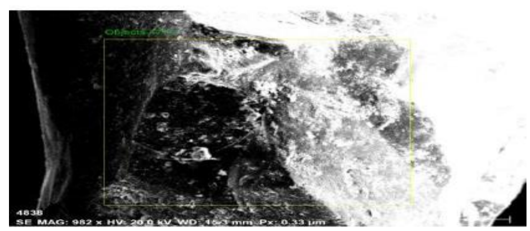


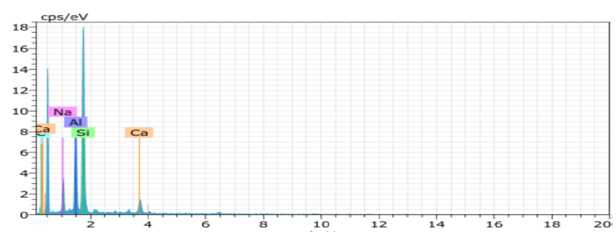


Spectrum: Objects 4774

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
O	8	K-series	36.52	53.01	66.24	5.48
Si	14	K-series	16.90	24.53	17.46	0.78
Al	13	K-series	8.30	12.04	8.92	0.45
Na	11	K-series	4.07	5.91	5.14	0.33
Ca	20	K-series	3.10	4.50	2.25	0.16
		Total:	68.89	100.00	100.00	

Fig 16 EDS report of FaL-G concrete (part 1)





Spectrum: Objects 4774

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Si	14	K-series	19.22	35.62	24.43	0.88
C	6	K-series	18.20	33.72	54.08	5.18
Al	13	K-series	9.11	16.88	12.05	0.50
Na	11	K-series	4.26	7.89	6.61	0.35
Ca	20	K-series	3.18	5.88	2.83	0.17
		Total:	53.96	100.00	100.00	

Fig 17 EDS report of FaL-G concrete (part 2)

Typical EDS y-axis depicts the number of counts and x-axis the energy of the X- rays. The position of the peaks leads to the identification of the elements and the peak height helps in the quantification of each element's concentration in the sample.The data that is generated by EDS analysis consists of spectra with peaks corresponding to all the different elements that are present in the sample. EDS can be used for qualitative (the type of elements) as well as quantitative (the percentage of the concentration of each element of the sample) analysis. In most SEMs, dedicated software enables auto-identification of the peaks and calculation of the atomic percentage of each element that is detected. The peak value in the graph and the summation of the unit weight of each constituent element of conventional concrete and FaL-G concrete gives a clear idea of the strength of FaL-G concrete being equivalent to that of Conventional concrete at the 28th day of testing.

The permeability test has been carried out and the calculations were made to the coefficient of permeability of concrete.

Table 12 Permeability Test result of conventional concrete and FaL-G concrete

Sl.No.	Mix	Permeability Coefficient (cm/sec)	
		conventional concrete	FaL-G concrete
1	M20	5.03	5.09
2	M20	5.28	4.98
3	M20	5.08	5.02

The observation of the obtained data shows that the permeability of FaL-G concrete is similar to that of conventional concrete on the 28th day of testing. This gives an impression that the permeability would be even lesser in the long run.

Results and Discussion

The study has dealt with the finding of the optimum proportion of foundry waste sand replacement for Msand in a fixed ratio of flyash replacement in FaL-G concrete. The experimentation for finding the strength was carried out and the mix ratio was decided. This mix ratio of the concrete was used for durability parameter studies.

The test result makes it evident that the chloride permeability in FaL-G concrete is lesser than that of conventional concrete. Hence the FaL-G concrete exhibits better resistance to permeability.

The images obtained through SEM shows that the density of FaL-G concrete is slightly lesser than that of conventional concrete. It is because of the reason that FaL-G concrete attains strength in a longer duration and the tests were carried out within a short period.

The EDS reveals the chemical composition and properties of the constituent in terms of unit weight. The interpretation of the obtained data proves FaL-G concrete has better qualities.The FaL-G concrete and conventional concrete were tested in the apparatus for 24 hours and the results obtained shows that the permeability in FaL-G concrete is much lesser than that of the permeability of conventional concrete.

From all the tests that were carried out, it is found that the durability parameters of FaL-G concrete comprising of corrosion resistance and permeability is of standard levels and thus FaL-G can be widely used real time.

Conclusion

The optimal percentage for replacement of foundry waste sand and flyash was determined after performing a number of strength tests. The durability tests were also carried out which confirms that the FaL-G concrete is more durable than conventional concrete. Replacement of cement using flyash and replacement of fine aggregate using foundry waste sand seems to be beneficial to the concretewithout compromising the quality. This technology is to make the concrete more economical and that is effectively proven, since flyash and foundry waste sand is not costly.It becomes an eco-friendly concrete with reduced usage of cement and Msand.

The durability parameters such as corrosion resistance and permeability were tested by casting specimens as per the requirements.This study is thus helpful to understand the two different durability parameters of FaL-G concrete and conventional concrete.

FaL-G concrete is more durable than the conventional concrete ie, the service life of the structure constructed using FaL- G concrete will be more strong, durable and economical.

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