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Waste Foundry Sand as Fine Aggregate in Concrete for Resistance to Sulfuric Acid Attack

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***Abstract:*— The degradation of concrete sewer pipes by sulfuric acid attack is a problem of global scope, resulting in substantial economic losses each year. Waste Foundry Sand (WFS), offers a range of potential improvement mechanisms, used at various dosages to enhance the resistance of concrete made with Pozzolana Portland Cement to chemical sulfuric acid attack with variations in Concentration. The aim of this study is to observe the concrete resistance towards acid attack. The resistance to sulfuric acid of concrete specimens incorporating the Waste Foundry Sand was measured and compared to that of control specimen for both M20 and M40 grades. From the experimental results it is inferred that partial replacement of Waste foundry sand with Fine aggregate in concrete enhance the compressive strength of concrete specimen immersed for 7, 14 and 28 days in H2SO4 solution having concentration of 10%, 20% and 30% (by volume) with pH Value 1, compared with conventional Concrete. It has been observed that Waste foundry sand offers good resistance to acid effect with lesser loss in workability, particularly in higher grade of concrete as compared to lower grade. The mix with 15% waste foundry sand offered comparatively better solutions insisting the concrete modified with the same can be recommended for making good and acid resisting concrete. This study is very much beneficial since a sulfuric acid resistant concrete has been developed using Waste foundry sand as a substitute material to fine aggregate.**

***Index Terms*— acid resistance, Compressive Strength, Sulfuric acid, Waste Foundry Sand,**

I. INTRODUCTION

Concrete has been used as the main construction material for civil infrastructure systems such as sewage facilities. In these cases, bacteria react with hydrogen sulfate, producing sulfuric acid which causes the concrete to deteriorate rapidly. Concrete degrades by the concentration of acids and the porous nature of cement paste. Concrete is very aggressive towards nitric, sulfuric and hydrochloric whereas less damaging when attacked by phosphoric acid. Especially sulfuric acid is the most destructive acids amongst all. The degradation of concrete sewer pipes and waste water treatment facilities by sulfuric acid attack is a substantial challenge worldwide, resulting in economic losses. The most efficient way to extend the durability of concrete is to develop a concrete with an inherent resistance to sulfuric acid deterioration.

The cost of damage to waste water utilities alone was estimated at approximately US$30 billion. A study of sewer systems in the city of Los Angeles estimated annual cost associated with the repair and replacement of collection systems damaged by sulfuric corrosion at US$200 million. The US Environment Protection Agency (EPA) undertook an extensive study of the extent of sulfuric acid corrosion in municipal waste water collection and treatment systems and indicated that annual damage is in the order of tens of billions of dollars, a high price tag for a problem that has been known and studies for nearly a century. Sulfuric acid is neutralized by reacting with the hydration products of the concrete matrix to form gypsum and ettringite. Both gypsum and ettringite possess little structural strength, yet they have large volumes than the compound they replace. This results in internal pressures, formation of cracks and eventually the loss of aggregates and thinning of the wall of concrete pipes.

Foundry sand is high qualitysilica sand with uniform physical characteristics. Foundries attempt to reuse as much of sand as possible within the foundry process its self, but eventually a fraction becomes spent and unsuitable for further foundry processes. The environmental-related tests proved to show that Waste Foundry Sand is highly resistance to acid and thus will not corrode away in many applications of highly acidic applications such as sewer systems [3]. Waste Foundry Sand does not produce any harmful leachate that may be toxic to the waters or surrounding areas, even though the leachate of Foundry Sand contained heavy metals and can contaminate soil and water by land disposal and hence provides favorable opportunity for reuse in concrete instead of Land filling. Generally Foundry sand is too fine to permit for full substitution in aggregate and hence it is necessary to blend it with ordinary sand when used in concrete.

II. LITERATURE REVIEW

M Sowmya and J D Chaitanya Kumar[1] presented study of usage of alternate materials in concrete. This covered the applications of the waste foundry sand in concrete. The

Control mix suffered the most deterioration in terms of mass loss when immersed in 5% H2SO4 solutions. The mass loss of 28 days cured M25 grade normal mix concrete specimen was 6.68%, 8.89% and 12.79% at 14, 28 and 56 days respectively. The mass losses of the WFS concrete specimens were reduced when the WFS content increases.

S.DurgaDevi1, Dr.P. Chandrasekaran[2] found that Foundry sand can be partially replaced with cement or as a partial replacement of fine aggregate or as a total replacement of fine aggregate to obtain different properties of concrete. The percentage of replacements of fine aggregates with Waste Foundry Sand were at five different proportions 10%, 20%, 30%, 40%, and 50% conducted on M40 grade concrete to determine the optimum percentage of foundry sand for which the concrete exhibits higher strength. In acid attack, considerable weight loss and compressive strength was observed for 30%WFS with 0.5% carbon fiber. This may be due to the presence of siliceous aggregates which are resistant to most acids. i.e., WFS contains high-quality silica which improves the acid resistance of concrete.

C. Sudalai Muthum, N.Sakthieswaran, G.Shiny Brintha, O.Ganesh Babu [3] studied the durability property of concrete with the replacement of fine aggregate. Concrete mix of M40 with Marble powder and green sand replacement of 5%, 10%, 15% and 20% with fine aggregate and Metakaolin replacement is about 5% by weight of cement. The water cement ratio is to be kept as 0.4. Superplasticizer is added to improve the workability of the concrete. Acid attack test, Porosity and Sorpitivity test are to be performed along with the compression test and flexural test. Further the variation in the micro structure in each mix are to be performed using Scanning Electron Microscopy.

The aim of Priyanka M, Sakthieswaran N [4] is to observe the concrete resistance towards acid attack. This is studied on M40 grade concrete, in which 5% by weight of binder is replaced with metakaolin and fine aggregate is replaced partially with the range of 5 to 20% by marble sludge powder and green sand simultaneously. The two different acids taken for this study are Hydrochloric Acid and Sulfuric Acid. It is inferred that the control mix when cured under both 1% concentrated HCl and H2SO4 solutions showed a high loss in weight comparing with modified concrete. The mix with 10% marble powder and green sand offered comparatively better solutions insisting the concrete modified with the same can be recommended for making good and acid resisting concrete.

Emmanuel K. Attiogbe[5] et al. studied the response of four different concrete mixes to sulfuric acid attack. Photomicrograph of the concrete microstructure showed that the concrete deterioration starts from the acid-exposed surface and progresses inward. The degree of concrete deterioration is increased by alternate wet-dry cycles of exposure to sulfuric acid. The rate of concrete deterioration along the penetration depth of sulfuric acid could be described by a variation in sulfur concentration with the depth of acid penetration.

III. MATERIALS AND PROPORTIONS

A. Materials used

1. Cement

PPC – Portland Pozzolana cement (ACC cement conforming to I.S. 1489 –part1) 53 grade was used. The cement had specific gravity 3.15, fineness 6.5%, normal consistency as 33% and initial setting time of 67 minutes.

2. Aggregates

For the experimental work, locally available natural sand with 4.75 mm maximum size was used as fine aggregate. The fine and coarse aggregates were tested as per the procedure given in IS: 383-1970. Natural sand has fineness modulus 2.68, specific gravity 2.53 and water absorption 1%. Specific gravity of 20 mm and 10 mm coarse aggregate was 2.85 and 2.79 respectively. Aggregate impact value was 4.23% and Crushing value was found to be 18.114 % with water absorption as 0.5%.

3. Waste Foundry Sand (WFS)

Waste Foundry Sand was collected from the Neco group of Industries. The WFS was used as a partial replacement of natural river sand in concrete. WFS passed through 4.75 µ sieve with specific gravity 2.76. It was a raw sand having 86.2 % SiO2 satisfying all the requirements of I.S. 383- 1970.

4. Sulfuric Acid

H2SO4 solution with PH value 1 of different percentage (0%, 10%, 20% and 30%) was used and 144 cubes were casted for two grades of concrete with 0% and 15% WFS for three periods of curing days. All the properties of materials helped in designing mix proportion of concrete.

B. *Mix Design*

Concrete mix has been designed for M20 and M40 grade of concrete based on Indian Standard Recommended Guidelines IS: 10262-2009. The water-cement ratio used in the experimental work was 0.55 for M20 and 0.4 for M40. The replacement of the Waste foundry sand was 0% and 15% with Fine aggregate. The different mixes were conveniently designated as A1, A3, A5, A7, A9, A11, A13, A15 for M 20

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grade of concrete and A2, A4, A6, A8, A10, A12, A14, A16 for M 40 grade of concrete.

Strength of M20 and M40 grade of concrete were tested at 7, 14 and 28 days and compared with control concrete. For this 15% replacement of the waste foundry sand was done and concrete was immersed in H2SO4 of 0%, 10%, 20%, and 30% added in water and further tested. The mix designation and quantities of various materials for each designed concrete mix has been tabulated in Table I & II.

Table I: Mix Proportion for M20 grade of concrete

Mixture no.	Cement Kg/m³	Natural sand Kg/m³	% WFS	WFS Kg/m³	Natural sand Kg/m³	Coarse aggregate Kg/m³		Water Kg/m³	Slump (mm)
						20 mm (70%)	10 mm (30%)		
A-1	480	598	0	0	598	837.9	359.1	192	85
A-3	480	598	15	89.7	508.3	837.9	359.1	192	70
A-5	480	598	0	0	598	837.9	359.1	192	82
A-7	480	598	15	89.7	508.3	837.9	359.1	192	72
A-9	480	598	0	0	598	837.9	359.1	192	84
A-11	480	598	15	89.7	508.3	837.9	359.1	192	71
A-13	480	598	0	0	598	837.9	359.1	192	83
A-15	480	598	15	89.7	508.3	837.9	359.1	192	69

Table II: Mix Proportion for M40 grade of concrete

Mixture no.	Cement Kg/m³	Natural sand Kg/m³	% WFS	WFS Kg/m³	Natural sand Kg/m³	Coarse aggregate Kg/m³		Water Kg/m³	Slump (mm)
						20 mm (70%)	10 mm (30%)		
A-2	473	603	0	0	603	844.2	361.8	189	80
A-4	473	603	15	90.4	512.5	844.2	361.8	189	78
A-6	473	603	0	0	603	844.2	361.8	189	80
A-8	473	603	15	90.4	512.5	844.2	361.8	189	80
A-10	473	603	0	0	603	844.2	361.8	189	75
A-12	473	603	15	90.4	512.5	844.2	361.8	189	75
A-14	473	603	0	0	603	844.2	361.8	189	76
A-16	473	603	15	90.4	512.5	844.2	361.8	189	78

The effects of WFS on Slump for M20 and M40 Grade concrete mixes were determined. It was observed that on addition of 15% WFS, slump reduces by 15 percent in M20 grade of concrete and maximum slump was 72mm while slump remains approximately same as of controlled mix in M40 grade of concrete where maximum slump was 80mm. Hence, for lower grade due to water absorption by WFS the workability reduces but in higher grades of concrete the workability remains unturned.

IV. TESTS RESULTS

The compressive strength was carried out at an interval of 7, 14 and 28 days for M20 grade and M40 grade of concrete and tabulated in table III and IV respectively.

Table III: Compressive strength for M20 grade of concrete

Mixture No.	Compressive strength at 7 days in (N/mm²)	Compressive strength at 14days in (N/mm²)	Compressive strength at 28 days in (N/mm²)
A-1	26.0741	26.0741	26.6667
A-3	27.1111	27.4074	27.7037
A-5	23.7037	24	24.1481
A-7	25.6296	25.7778	26.5185
A-9	22.5185	23.7037	25.037
A-11	23.5556	25.037	27.5556
A-13	20.8889	24.1481	24.5926
A-15	21.4815	24.4444	25.3333

Table IV: Compressive strength for M40 grade of concrete

Mixture no.	Compressive strength at 7 days in (N/mm²)	Compressive strength at 14days in (N/mm²)	Compressive strength at 28 days in (N/mm²)
A-2	43.2593	43.5556	43.7037
A-4	46.3704	47.4074	47.4074
A-6	41.3333	41.9259	42.2222
A-8	43.4074	43.8519	44.2963
A-10	41.1852	41.7778	42.0741
A-12	42.963	43.1111	43.5556
A-14	40.5926	41.4815	41.6296
A-16	41.3333	42.2222	43.1111

Increasing the amount of WFS to 15% caused an increase in compressive strength at 7 and 14 days by 5% and at 28 days by 6.75% for M20 grade of concrete. Also WFS increased the compressive strength at 7 and 14 days by 7% and at 28 days by 8.5% for M40 grade of concrete. Test results also indicate that application of WFS did not much improved the later-age compressive strength of both M20 and M40 grade concrete. This may be due to a less uniform distribution of hydration products in the paste because of the rapid initial hydration.

B. Acid test

Acid test was conducted to determine the durability properties of concrete containing WFS (15 %). This test was carried out on the concrete cube of 150mm size. Each container carried the H2SO4 solution with PH value 1 of different percentage (0%, 10%, 20% and 30%) by volume. The concrete cubes were immersed in 10%, 20% and 30% sulfuric acid solution for about 7, 14 and 28 days. The observations were then made after 7, 14 and 28 days from the date of immersion in sulfuric acid. The compressive strength was determined and shown in Table V, VI & VII.

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Table V: Compressive strength after 7 days immersion in sulfuric acid

	7th DAY TEST			
	M20		M40	
ACID	0% WFS	15%WFS	0% WFS	15%WFS
0%	26.0741	27.1111	43.259	46.3704
10%	23.7037	25.6296	41.3333	43.4074
20%	22.5185	23.5556	41.1852	42.963
30%	20.8889	21.4815	40.5926	41.3333

Table VI: Compressive strength after 14 days immersion in sulfuric acid

	14th DAY TEST			
	M20		M40	
ACID	0% WFS	15%WFS	0% WFS	15%WFS
0%	26.074	27.407	43.5556	47.4074
10%	24.148	25.7778	41.9259	43.8519
20%	24	25.037	41.7778	43.1111
30%	23.704	24.444	41.4815	42.2222

Table VII: Compressive strength after 28 days immersion in sulfuric acid

	28th DAY TEST			
	M20		M40	
ACID	0% WFS	15%WFS	0% WFS	15%WFS
0%	26.6667	27.7037	43.7037	47.4074
10%	25.037	27.5556	42.2222	44.2963
20%	24.5926	26.5185	42.0741	43.5556
30%	24.1481	25.3333	41.6296	43.1111

The compressive strength of M20 and M40 grade of the conventional concrete is 26.6667MPa and 43.7037MPa respectively after 28 days curing i.e., before immersion in acid. The compressive strength decreased to 24.5926MPa and 41.6296MPa for M20 and M40 grade respectively after acid attack. It was observed that the compressive strength of the concrete before immersion in the sulfuric acid prepared by replacing 15% WFS was lowered by 8.56% and 9.06% for M20 and M40 grade concrete respectively after immersion at 28 days. Though the compressive strength of the controlled concrete without WFS in the sulfuric acid was lowered by 7.78% and 4.74% for M20 and M40 grade concrete respectively after immersion at 28 days, adding WFS showed better strength than normal concrete. The loss of strength is shown in Fig. 1, 2 & 3.

Fig. 1: Compressive Strength at 7 Days immersion

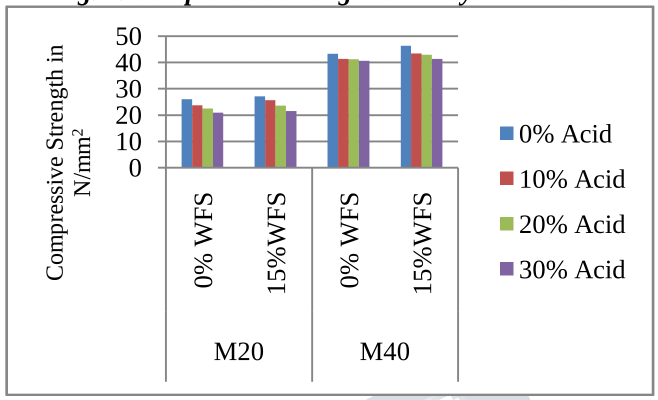


Fig. 2: Compressive Strength at 14 Days immersion

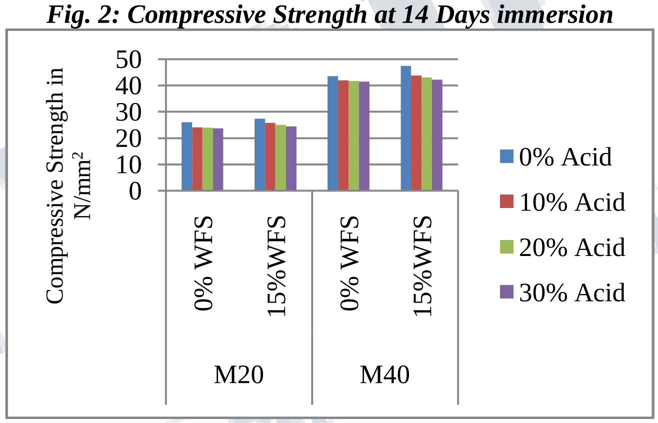
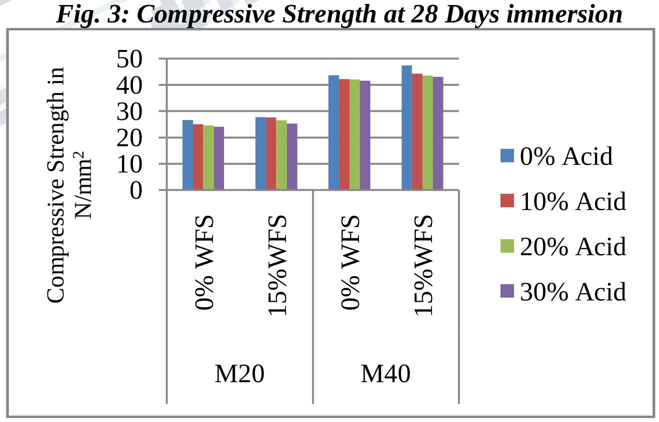


Fig. 3: Compressive Strength at 28 Days immersion



V. CONCLUSION

This experiment investigated the effect of waste foundry sand on the resistance of concrete to sulfuric acid attack by studying its compressive strength. Based on the test data and analyses of results presented in this experiment, the following conclusions can be drawn.

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- Use of WFS resulted in low-medium slump due to its fine binding nature. Plasticizer will be required to maintain a good workability for lower grades of concrete while workability for higher grades remains approximately same.
- Waste foundry sand significantly improves the compressive strength of concrete by 3 to 5% for M20 grade and 7 to 8% for M40 grade of concrete.
- It is observed that at each 10% increase in acid percentage there is decrease in strength of around 9% for M20 grade and only 4% decrease in strength for M40 grade of concrete. Hence, Waste foundry sand offers good resistance to acid effect, particularly in higher grade of concrete as compare to lower grade of concrete.
- Compressive strength of concrete with Waste foundry sand is increasing in all percentage of H_2SO_4 solution as compare to concrete without Waste foundry sand.
- After Acid attack, the compressive strength of the concrete specimen with WFS is still greater than concrete without WFS for both M20 and M40 grade of concrete.
- As the percentage of H_2SO_4 solution increases, the compressive strength of concrete decreases.

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