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An Experimental Study to Investigate Strength Parameters of Silica Fumed Concrete by Using Sea Water as an Alternative of Potable Water

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ABSTRACT

In this research work, the concrete specimens are casted and cured using sea water and compared with portable water. Therefore, this research work seeks to investigate the effect of sea water during curing on compressive, tensile and flexural strength of concrete. An experimental study is made on the nature of Silica fume and its influences on the properties of fresh and hardened concrete. In the present study, an attempt has been made to investigate the strength parameters of concrete made with partial replacement of cement by Silica fume. Moreover, no such attempt has been made in substituting silica fume with cement for low/medium grade concretes (viz. M20, M30). The effects of curing of concrete with seawater on compressive, tensile and flexural strength are investigated when 15% replacement of cement by silica fume in weight. The specimens are cured for 7days, 28 days and are tested for compressive, tensile and flexural strength. The obtained results are compared with the conventional concrete mix i.e. cured using potable water.

Keywords: experimental study, compressive, tensile and flexural strength.

I. INTRODUCTION

Concrete is the prime material used in any RCC structure. In this generation, we can observe the rapid urbanization and industrialization which was leading to the increase in the construction of the projects. So, in the construction of any structure concrete is main material to be used in completion of any RCC structure. Concrete is a composite material composed of water, aggregate, and cement. Concrete is used in large quantities; almost everywhere mankind has a need of structure. It is very tough to find an option for concrete in construction, which is durable and economic. Concrete is a mixture of several ingredients but the main ingredient is cement which helps to bind together of remaining ingredients. But, the cost of cement is high but it is important in concrete. So, in order to fulfill the requirement the cement can be replaced with cementitious material i.e. silica fume.The other important ingredient is water which helps a lot in mixing of all ingredients to produce concrete. When water is added to the mix it actively participates in chemical reaction with cement and that process is called heat of hydration. The Strength of concrete also depends on the quality of water used in mixing of concrete. Due to rapid growth of population the world is facing a number of problems. Many of the experts and researchers say that there will be scarcity of fresh water and difficult to get the water in the future. If we select the alternative for fresh water other than for drinking purpose there will be chance of getting water for drinking purpose. So, there is a need to explore alternative for potable water in construction industry as billons of water is used for mixing and curing of concrete. As we know that our planet earth is filled with 70% of oceans i.e. sea water. So, that the sea water can be used as an alternative for portable water.In the present study, an attempt has been made to investigate the strength parameters of concrete made with partial replacement of cement by Silica fume. The effects of curing of concrete with seawater on compressive, tensile and flexural strength are investigated when 15% replacement of cement by silica fume in weight. Mix design of M20 and M30 grade of concrete is prepared by using ordinary Portland cement (OPC) of 53 grade is adopted. And it has been replaced with silica fume at different percentages like 15% in weight. The mixed concrete is casted into concrete specimens are cured for 7days, 28 days and are tested for compressive, tensile and flexural strength. The obtained results are compared with the conventional concrete mix i.e. cured using portable water.

Sea water (ocean water) constitutes of chemical elements, namely chloride, sodium, magnesium, calcium, potassium. It has been analyzed that sea water contains percentage by weight of major salt compoundsIt can be seen from the above that sodium chloride is the predominant salt component of seawater. According to Bela (1989), NaCl2 and MgCl2 constitute a total 2 of 88.5% of entire salt content. Different sources of sea water have different concentrations, but the relative abundance of the major salt constituents of sea water is about the same everywhere. Sea water is an electrolyte and plays a major function in any electrolytic action between dissimilar metals and between salt concentration and steel (Bela, 1989). Sea water has considerably varying pH value.As per the literature available it is said that in near future there will be shortage of drinking water itself. Hence fresh water will not be available for concreting purpose. We use bore water for mixing as well as curing of concrete instead of fresh water. The bore water available is neither free from impurities nor considered as soft water. There are number of salts presents in bore water which results in hardness. Here in this research work we are working on the effect of sea water curing on concrete. We test the concrete for extreme case i.e. sea water case.

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II. LITERATURE REVIEW

Yogendran et al (1987) studied the properties of improving the high strength and some other properties of concrete by incorporating silica fume and super plasticizer. They studied the efficiency of silica fume in improving the properties of concrete and compared at medium and very low water cement ratios. They concluded that the optimum replacement of cement by silica fume for high strength concrete in the 28 days compressive strength range of 50 to 70MPa is seen to be nominally 15 percent for a water cementitious ratio of 0.34. The compressive strength of mixes with a W/C ratio of 0.34 was maximum at 15% silica fume replacement at all ages.

ACI Committee 226 (1987) in their report has described about the physical and chemical properties of silica fume and gives possible application and limitations of its use in concrete. Silica fume, because of its extreme fineness and high silica content, is highly 8 effective pozzolanic material. The main contribution of silica fume to concrete strength development at normal curing temperature takes place from about 3 to 28 days. They reported that silica fume with high range water reducers has been used to produce very high strength concrete. Compressive strengths of the order of 100MPa and higher have also been reported.

Rachel Detwiler and Kumar Mehta (1989) conducted compression tests on cylinders of size 10cm diameter with 20cm height and concluded that the silica fume concrete showed the greatest improvement in strength due to the combination of cement hydration and the pozzolanic reaction between 7 and 28 days.

Akthem et al (1992) have studied the effects of silica fume and super plasticizer on viscosity, bleed, setting time strength and shrinkage of the grout. Experimental programs were conducted on 50mm grout cubes to know the compressive strength. The compressive strength of the grout is a property that relates directly to the structure of the cement paste. They concluded that setting times are delayed by temperature. The addition of silica fume can help offset this trend to a limited extent. Unconfined compressive strengths were found to be very high for all mixes incorporating silica fume (i.e. about 100MPa). Shrinkage strains were low for all grout mixes studied.

The Raw materials that are used in the production of concrete are mentioned below.

Coarse aggregates Fine aggregates Cement
Silica Fume Portable water Sea water

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Table 1: quantities of materials used in concrete

Type of Concrete	Mix Grade	Water lits	Cement Kg/ m³	Silica Fume Kg/m3	Fine aggregate Kg/ m³	Coarse aggregate Kg/ m³
Normal Concrete	M20	161.67	323.00	0	723.21	1211.75
		0.50	1		2.23	3.75
	M30	161.67	367.00	0	686.02	1209.89
		0.44	1		1.86	3.29
Cement with 15% Silica Fume	M20	161.67	275	48	723.21	1211.75
		0.50	1		2.23	3.75
	M30	161.67	312	55	686.02	1209.89
		0.44	1		1.86	3.29

It was proposed to investigate the properties of concrete, cast with partial replacement of cement with Silica Fume in the ratio of 15% and proportions and cured in Potable water and Sea water. The Number of specimens casted for deterring hardened properties as shown in Table 1.

In this experimental work, Physical properties of materials used in the experimental work were determined. Two grades of concrete M20 and M30 were mixed and cured in Potable water, The same grades of concrete with 10 percent Silica Fume were mixed with Potable water and cured in Sea water. The specimens were cured for 7 and 28 days and tested for Compressive strength, spilt tensile strength and flexural strength.

Table 2: Specimens casted to find mechanical properties

Specimen Cast	Specimen Size in mm	No. of specimen curing in potable water								Sea water Curing			
		Normal mix				15% Silica Fume				15% Silica Fume			
		M20		M30		M20		M30		M20		M30	
		Days		Days		Days		Days		Days		Days	
		7	28	7	28	7	28	7	28	7	28	7	28
Cubes	150x150x150	3	3	3	3	3	3	3	3	3	3	3	3
Cylinders	150x300	3	3	3	3	3	3	3	3	3	3	3	3
Beams	150x150x500	3	3	3	3	3	3	3	3	3	3	3	3

Aggregates

The coarse aggregate was kept completely immersed in clean water for 24 hours for water absorption. After 24 hours, the aggregate was gently surface dried. It was then spread out and exposed to the atmosphere until it appears to be completely surface dry. For fine aggregate, considering the huge time to be taken to become surface dry from wet condition, it was not immersed in water. Instead the water was sprinkled then it was spread out and exposed to the atmosphere until it appears to be completely surface dry.

Batching

Batching means measuring the quantities of constituents of concrete required for the preparation of concrete mix. Weight batch method is adopted to measure the quantities. The quantities of fine aggregate, coarse aggregate, cement, water and Super plasticizer and adding Silica Fume dosages of 10% each batch were measured by a weighing balance according to the mix proportions obtained by the mix design.

Mixing

The object of mixing is to coat the surface of all aggregate particles with Cement paste and to blend all the ingredients of concrete into a uniform mass. Though mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. In this study the process of machine mixing was adopted.

Casting of Concrete Cubes, Cylinders and Beams

The test moulds were kept ready before preparing the mix. Moulds were cleaned and oiled on all contacts surfaces then fixed on vibrating table firmly. The concrete is filled into moulds in three layers and then vibrated. The top surface of concrete is struck off to level with a trowel.

Figure 1- Casting of Specimens

Curing

The cast moulds are dried then the moulds are un moulded, then cubes, cylinders and beams were kept for curing in potable water for Normal

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Mix and using Silica Fume specimens were kept for curing in potable water and sea water.

Workability

Workability is a property of fresh concrete. It is, however, also a vital property as far as the finished product is concerned because concrete must have workability such that compaction to maximum density is possible with a reasonable amount of work or with the amount that we prepared to put in under given conditions.According to ACI, workability is that property of the freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished. Workability of the concrete can be measured in many ways. Here, workability in terms of slump and compaction factor was considered for the present study.

Slump Cone Test

This test is used extensively in site all over the world. The slump test does not measure the workability of concrete, but the test is very useful in detecting variations in the uniformity of a mix of given nominal proportions. The slump test is done as prescribed by IS: 516-1959.The apparatus for conducting the slump test essential consists of a metallic mould in the form of a cone having the internal dimensions as under Bottom diameter : 200 mm Top diameter : 100 mm

The mould for slump is a frustum of a cone, 300 mm high. It is placed on a smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer is tamped twenty five times with a standard 16 mm diameter steel rod, rounded at the end, and the top surface is tapered off by means of sawing and rolling motion of the tamping rod. The mould must be firmly fixed against its base during the entire operation; this is facilitated

by handles or foot- rests brazed to the mould. Immediately after filling, the cone is slowly lifted vertically up, and the unsupported concrete will now slump – hence the name of the test. The difference in level between the height of the mould and that of highest point of subsided concrete is measured. This difference in height in mm is taken as slump of concrete.

The slump cone test was conducted for all the six mixes. Slump for different mixes are shown in Table 3.

Table 3 Slump Cone Results

S. No	Mix	Slump (mm)
1	Normal Mix for M20 grade	100
2	Normal Mix for M30 grade	120
3	Silica Fume -15% for M20 grade	70
4	Silica Fume -15% for M30 grade	75

Compaction Factor Test

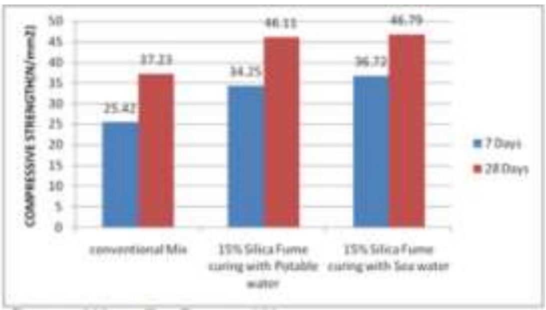
Compaction factor test was conducted for all the mixes and the observation are shown in Table 4.

Table 4: Compaction test Results

S. No	Mix	Compaction factor
1	Normal Mix for M20 grade	0.89
2	Normal Mix for M30 grade	0.91
3	Silica Fume -15% for M20 grade	0.91
4	Silica Fume -15% for M30 grade	0.91

Compressive Strength

The compressive strength of the concrete was done on 150 x 150 x 150 mm cubes. A total of 36 cubes were cast for the four mixes. i.e., for each mix 6 cubes were prepared. Testing of the specimens was done at 7 days, and 28 days at the rate of three cubes for each mix on that particular day. The average value of the 3 specimens is reported as the strength at that particular age The compressive strength test was conducted for all the mixes .



Graph 1- Graph of compressive strength of M20 grade of concrete

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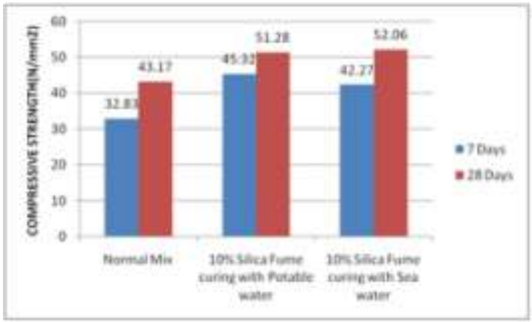
From the above graph, the compressive strength values obtained by testing standard cubes made with 15 percentage of Silica fume curing with potable water and sea water. The normal mix has strength above the 25.42Mpa in compression. It was observed that the Compressive Strength of cured concrete at the age of 7 days is 25.42 N/mm2 and 28days is 37.23 N/mm2. By using 15% of Silica fume it was observed that the Compressive Strength of cured with potable water at the age of 7 days is 34.25 N/mm2 and 28days 46.11 N/mm2. Then the Compressive Strength of cured with sea water at the age of 7 days is 36.72 N/mm2 and 28days is 46.79 N/mm2.



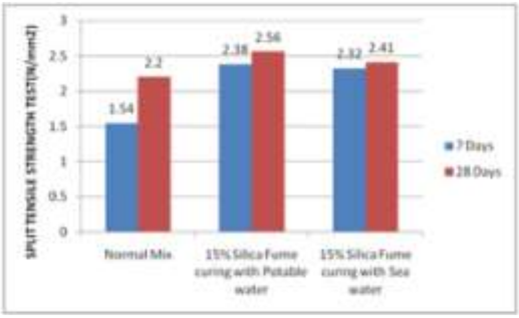
Graph 2- Graph of compressive strength of M30 grade of concrete

From the above graph, the compressive strength values obtained by testing standard cubes made with 15 percentage of Silica fume curing with potable water and sea water. The normal mix has strength above the 32.83Mpa in compression. It was observed that the Compressive Strength of cured concrete at the age of 7 days is 32.83 N/mm2 and 28days is 43.17 N/mm2. By using 15% of Silica fume it was observed that the Compressive Strength of cured with potable water at the age of 7 days is 45.32 N/mm2 and 28days 51.28 N/mm2. Then the Compressive Strength of cured with sea water at the age of 7 days is 42.27N/mm2 and 28days is 52.06 N/mm2.

Split Tensile Strength

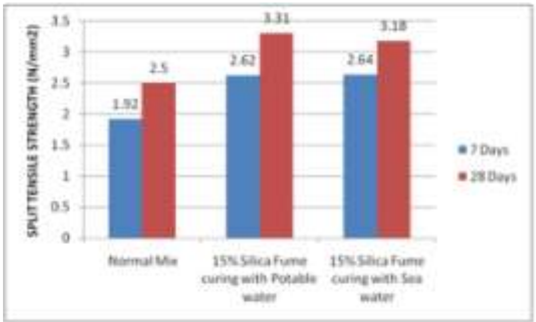
The indirect tensile strength was measured on 150 x 300 mm cylinders .

A total of 36 cylinders were cast for the five mixes. Three specimens were tested each time and the average value at the particular age was reported as the tensile strength of the concrete.



Graph 3- Graph of split tensile strength of M20 grade of concrete

From the above graph, the split tensile strength values obtained by testing standard cylinders made with 15 percentage of Silica fume curing with potable water and sea water. It was observed that the split tensile Strength of cured concrete at the age of 7 days is 1.54 N/mm2 and 28days is 2.20 N/mm2. By using 15% of Silica fume it was observed that the split tensile Strength of cured with potable water at the age of 7 days is 2.38 N/mm2 and 28days 2.56 N/mm2. Then the split tensile Strength of cured with sea water at the age of 7 days is 2.32 N/mm2 and 28days is 2.41 N/mm2.



Graph 4- Graph of split tensile strength of M30 grade of concrete

From the above graph, the split tensile strength values obtained by testing standard cylinders made with 15 percentage of Silica fume curing with potable water and sea water. It was observed that the split tensile Strength of cured concrete at the age of 7 days is 1.92 N/mm2 and 28days is 2.50 N/mm2. By using 15% of Silica fume it was observed that the split tensile Strength of cured with potable water at the age of 7 days is 2.62 N/mm2 and 28days 3.31 N/mm2. Then the split tensile Strength of cured with sea water at the age of 7 days is 2.64 N/mm2 and 28days is 3.18 N/mm2.

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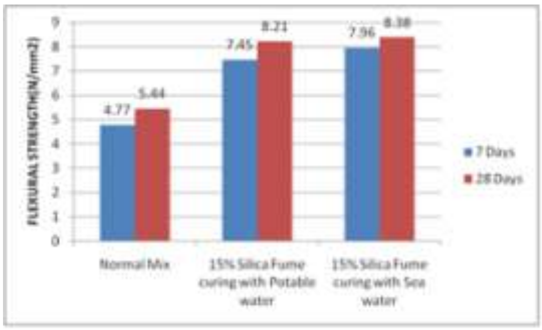
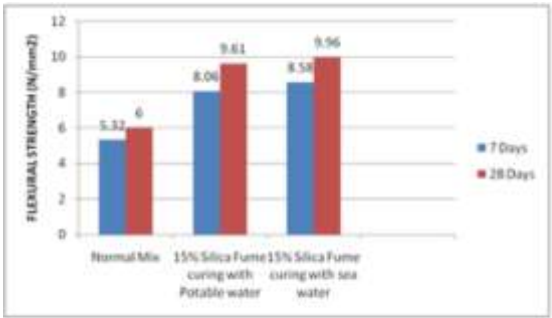
Flexural Strength

Flexural strength of the concrete was determined from modulus of rupture test on beam specimens of 100 x 100 x 500 mm size. Here also, a total of 36 specimens were cast out of which three specimens were tested for each mix at 7days, 28 days



Graph 5- Graph of flexural strength of M20 grade of concrete

From the above graph, the flexural strength values obtained by testing standard cylinders made with 15 percentage of Silica fume curing with potable water and sea water. It was observed that the flexural Strength of cured concrete at the age of 7 days is 4.77 N/mm2 and 28days is 5.44 N/mm2. By using 15% of Silica fume it was observed that the flexural Strength of cured with potable water at the age of 7 days is 7.45 N/mm2 and 28days 8.21 N/mm2. Then the flexural Strength of cured with sea water at the age of 7 days is 7.96 N/mm2 and 28days is 8.38 N/mm2.



Graph 6- Graph of flexural strength of M30 grade of concrete

From the above graph, the flexural strength values obtained by testing standard cylinders made with 15 percentage of Silica fume curing with potable water and sea water. It was observed that the flexural Strength of cured concrete at the age of 7 days is 5.32 N/mm2 and 28days is 6.00 N/mm2. By using 15% of Silica fume it was observed that the flexural Strength of cured with potable water at the age of 7 days is 8.06 N/mm2 and 28days 9.61 N/mm2. Then the flexural Strength of cured with sea water at the age of 7 days is 8.58 N/mm2 and 28days is 9.96 N/mm2.

III. CONCLUSIONS

Based on the study, following conclusions can be drawn.It may be concluded that use of silica fume is a necessary in production of not only for high strength concrete but also for low/medium strength concrete as this material facilitate the adoption of lower water - cement ratio and better hydration of cement particles including strong bonding amongst the particles.

The increase in strength development is due to the fact that silica fume dissolves in saturated solution of Ca(OH)2 within few minutes. As soon as enough Portland cement has hydrated to result in saturation of the pore water with Ca(OH)2, Calcium Silicate Hydrate (C-S-H) gel is formed on the surface of silica fume particles. This C-S- H gel produced by Silica fume concrete has a lower C: S ratio than that resulting from the hydration of Portland cement concrete without silica fume.

It is clear from the above discussion that till 15% replacement of cement by Silica fume, there are marked improvement in compressive strengths, split tensile strength and flexural strength. This type of Silica fume concrete may be recommended in places where high early strength development is essential. This high strength Silica fume concrete which is being produced with a designed mix of lower grade, i.e, M20 and the same can be used as a suitable alternative of lower grade normal concrete. With all high performance materials for making this type of concrete, appropriate care should be taken in its use and proper guidelines may be sought from

the concerned authorities to ensure the maximum benefits.

As the Silica fume concrete is more compact and there by more durable in nature and hence with some degree of quality control, it may be used in places of construction where there is a chance of chemical attack, frost action etc. Moreover with 15% of cement replaced by silica fume, the characteristic strength of higher grade of cement concrete namely M30 is achieved only by using the M20 grade designed mix proportion and consequently this Silica fume concrete can certainly be used as a supplement to M20 grade normal concrete with at least 6% of cost reduction.

From the above finding we can conclude that there is no remarkable variation in the compressive strength if sea water is used for curing the concrete. This concrete can be safely is used for mass concreting without any alteration in strength properties.

Based on this study, it is recommended for sea water should be used for curing. A long term study is required to assess the amount and extent of strength deterioration of concrete in sea water

Lastly with good quality control, high early strength can be achieved in Silica fume concrete which may be useful in various structural constructions such as high- rise buildings, bridges, chimneys, machine foundations, run ways etc., wherein, the timeframe of completion vis-à-vis the economy is an important driven factor for the targeted purpose as well as for the contractors and owners alike as this concrete will provides quick stage by stage or floor to floor construction.

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