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Effect of Metakaolin on Performance of M40 Grade Concrete in Marine Environment

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Abstract

Nowadays maintaining durable concrete structures in a salt water environment is found to be difficult. Deterioration of structures is due to gradual penetration of salts and the subsequent formation of expansive and leachable compounds which ultimately corrodes the reinforcement and makes the structures fatigue. It is found that the setting time, compressive strength depends on the reaction between cement and water which eventually results in softening of concrete. This paper describes the effect of metakaolin on compressive strength, splitting tensile test, modulus of elasticity and pH of concrete when salt water is used for curing. Concrete specimens were cast for M40 grade of concrete for potable water and salt water curing. Till 28 days concrete specimens were cured under salt water and potable water. The test results showed better performance in compressive strength when replacement of cement by metakaolin and cured with salt water is made. But the splitting strength test values showed a slight decrease when cured with salt water. Optimisation in percentage replacement of cement by metakaolin was made.

Keywords: *Saltwater, Metakaolin, Compressive Strength, Splitting Tensile Strength, Modulus of Elasticity.*

INTRODUCTION

Cement is the most energy intensive structural materials in concrete and is the most durable construction material. Concrete is a combination of cement, water and aggregates in a desired proportions. Cohesion and strength plays a vital role in concrete. It is ensured based on the cohesion between aggregate grains. Cement is a binder medium that sets, hardens and adheres to other materials, binding them together. Concrete is produced by mixing cement with fine aggregate or with sand and coarse aggregate. It can either be hydraulic or non-hydraulic based on setting ability in the presence of water. Cement used in construction are usually inorganic, often lime or calcium silicate based.

Aggregate such as sand, gravel, crushed stone, crushed hydraulic – cement concrete, or iron blast – furnance slag, used with a hydraulic cementing medium to produce either concrete or mortar. Particles that are retained on the 4.75 mm (No.4) sieve, are called coarse aggregate. Those particles that are passing through 4.75 mm (No.4) sieve are called fine aggregate. The purpose of fine aggregate is to fill up the voids and coarse aggregate is to give shape to the concrete. Aggregates provide dimensional stability. Influence hardness, abrasion resistance, elastic modulus and other properties of concrete to make it more durable and cheaper.

Metakaolin

For high performance concrete mixes, Metakaolin is the widely used mineral admixtures. High performance and best economy can be achieved. Mineral admixtures play a very role in enhancing the properties of concrete namely workability, strength, durability, setting time. Various kinds of admixtures are available in the market. Unlike other mineral admixtures, metakaolin is not an industrial by-product. For cementing applications, metakaolin is produced from kaolin using thermal treatment. It produces highly reactive amorphous material with Pozzolanic and latent hydraulic reactivity makes its suitability. Concrete with metakaolin is very easier to pump to greater heights either vertically or horizontally.

For enhancing the workability, less amount of chemical admixture is required. Since cost is cheap and available abundantly, it is being accepted all over in high performance concrete.

OBJECTIVE

1. To study the mechanical properties of concrete by varying the percentage replacement of cement by metakaolin.
2. To compare the series of cubes, cylinders and prisms cured with potable water and salt water for its performance characteristics.
3. To optimize the percentage replacement of cement by metakaolin based on the properties.

METHODOLOGY

The flowchart will describe the sequence of process to be carried out to complete the work.

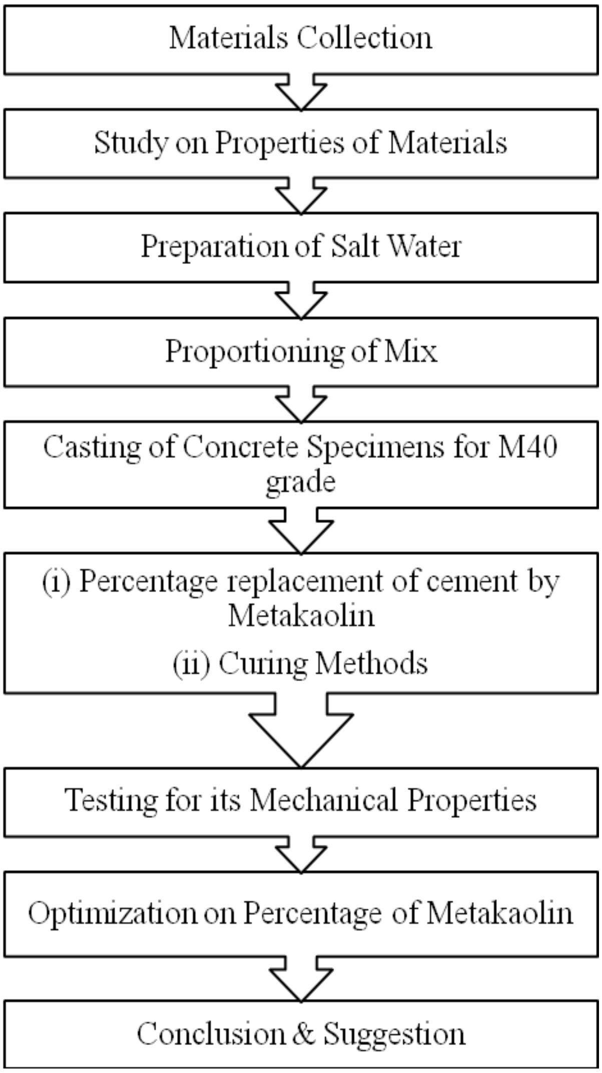

Fig: 1. *Methodology*

MATERIAL PROPERTIES

Concrete properties depend upon cement, water cement ratio, compaction, gradation of aggregates and its quality. This paper gives the detailed information about the testing procedure and the tests conducted for the same. The results are given in the tabulated format.

Cement

The type of cement used was Portland Pozzalona Cement. It was used in casting of specimens. The results of specific gravity, fineness, consistency and initial setting time of the cement are given in Table 1.

Table: 1. *Properties of Cement*

S.No	Description	Results
1	Specific gravity	3.15
2	Consistency	33%
3	Initial setting time	35 minutes
4	Final setting time	415 minutes

Coarse Aggregate

Those particles that are predominantly retained on the 4.75 mm (No.4) sieve, are called coarse aggregate. Testing of coarse aggregate was done as per IS383-1970.The test results are given in Table 2.

Table: 2. *Properties of Coarse Aggregate*

S.No	Description	Results
1.	Specific gravity	2.74
2.	Bulk density	1510 kg/m^3
3.	Fineness modulus	3.6

Fine Aggregate

Those particles passing through 4.75 mm (No.4) sieve are called fine aggregate. Testing of fine aggregate was done as per IS383-1970. The test results were given in Table 3.

Table: 3. *Properties of Fine Aggregate*

S.No	Description	Results
1.	Specific gravity	2.63
2.	Bulk density	1453 kg/m^3
3.	Fineness modulus	2.2

Metakaolin

Metakaolin was purchased from EICL, Trivandrum. The physical properties of metakaolin are shown in Table 4.

Fig: 2. *Metakaolin*

Table: 4. *Physical Properties of Metakaolin*

Characteristics	Observation
Appearance	White Powder
Colour	Off White
Odour / Taste	Odourless
Solubility Description	Insoluble in water
Bulk Density	0.35 kg/l
Explosive Properties	Non – Explosive
Specific Gravity	2.6

Preparation of Salt Water

Salt water pH is limited to the range of 7.5 and 8.4. For preparing salt water, 3.5 kg of crystal salt is dissolved in 100 litres of water. After preparation, it is tested for its chemical constituents. The value of obtained are shown in Table 5.

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Table: 5. *Physical Properties of Metakaolin*

Parameters	**Values Obtained**
pH	8.3
Chloride	15,243 ppm
Sulphate	212 ppm
Total Hardness	750 ppm
Total Dissolved Solids	18,514 ppm
Calcium	124 ppm
Magnesium	83 ppm
Total Alkalinity	612 ppm

EXPERIMENTAL INVESTIGATION

Mix Design

As per IS: 10262-2009 recommendations, the arrived mix ratio for M40 grade concrete is given in Table 6.

Table: 6. *Mix Proportion for M40 grade of concrete*

Cement	FA	CA	w/c ratio
1	1.44	2.67	0.42

Curing of Specimens

The test specimens after compaction were kept as such for a period of 24 hours. After that period of time the moulds were removed and the specimens were kept in ordinary curing tank and salt water curing tank and allowed to cure.

Compression Test

Compression test is the most common test on hardened concrete, because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. Usually testing is done after 7 days and 28 days. Atleast 3 specimens are tested immediately after curing period is over. It is shown in Fig 3.

Fig: 3. *Specimen failed due to compression*

Split Tensile Test

The determination of tensile strength of concrete is essential to estimate the load at which the concrete members may crack. As it is difficult to determine the tensile strength of concrete by conducting a direct tension test, an indirect method, such as Splitting Tension Test is used. It is shown in Fig 4.

Fig: 4. *Specimen failed due to splitting tensile test*

Flexural Strength Test

Flexural strength is one measures the tensile strength of concrete. It is the measure of the unreinforced concrete beam to resist failure in bending. The flexural strength is expressed as modulus of rupture (MR). It is shown in Fig 5.

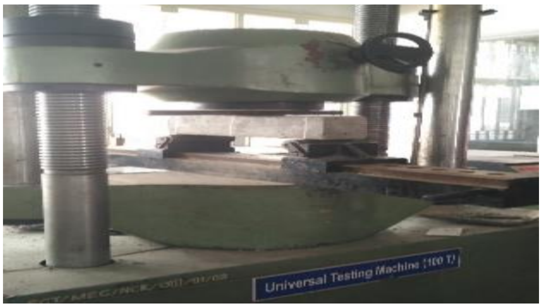

Fig: 5. *Testing of Specimen for flexural strength*

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TEST RESULTS AND DISCUSSION

Compressive Strength

Table 7 gives the details on compressive strength values at 7 and 28 days respectively for conventional curing, salt water curing, 5% replacement of cement by metakaolin.

Table: 7. *Comparison on compressive strength between conventional and 5% Metakaolin cured with PW & SW*

Curing Methods	Conventional		5% Metakaolin	
	7 days	28 days	7 days	28 days
PW	36.89	50.04	40.65	55.15
SW	38.37	51.58	41.25	55.19

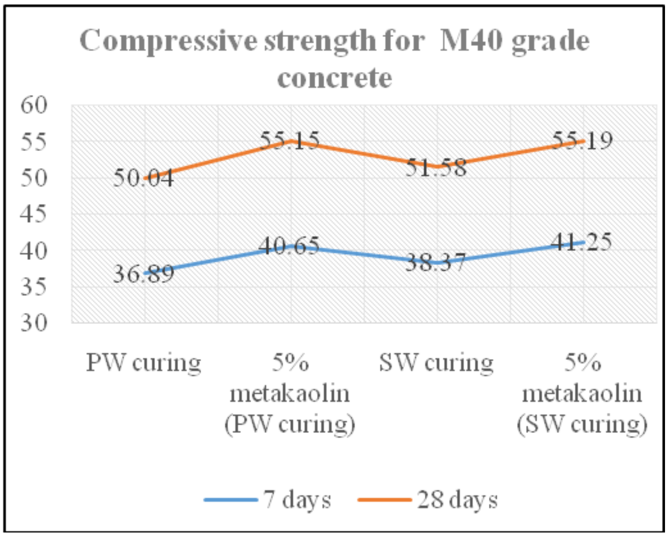

Fig: 6. *Comparison on compressive strength between conventional and 5% Metakaolin cured with PW & SW*

Inference

The compressive strength of M40 grade of concrete cured with potable water and salt water with different exposure period have been presented in Fig 6. From the Fig 6 it is seen that, the strength increases with the increase of exposure period for all the concretes. Almost all the concrete specimens exposed to a salt water environment showed rapid increase in early strength as compared to potable water cured concrete. 28 days strength ratio for concrete is 10.2% (PW curing and 5% metakaolin PW curing) and 6.9% (SW curing and 5% metakaolin SW curing).

Split Tensile Strength

Table8 gives the details on splitting tensile strength values at 7 days and 28 days respectively for conventional curing, salt water curing, 5% replacement of cement by metakaolin.

Table: 8. *Comparison on split tensile strength between conventional and 5% Metakaolin cured with PW & SW*

Curing Methods	Conventional		5% Metakaolin	
	7 days	28 days	7 days	28 days
PW	3.46	3.9	3.8	4.09
SW	3.9	4.1	4	4.13

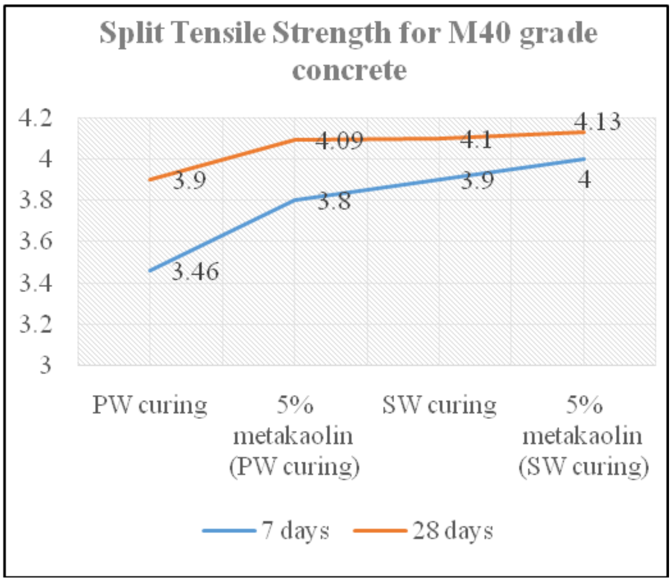

Fig: 7. *Comparison on split tensile strength between conventional and 5% Metakaolin cured with PW & SW*

Inference

The split tensile strength of M40 grade of concrete cured with potable water and salt water with different exposure period have been presented in Fig 7. From the Fig 7 it is seen that, the strength increases with the increase of exposure period for all the concretes. Almost all the concrete specimens exposed to a salt water environment showed rapid increase in early strength as compared to potable water cured concrete. 28 days strength ratio for concrete is 4.87% (PW curing and 5% metakaolin PW curing) and 0.73% (SW curing and 5% metakaolin SW curing).

Flexural Strength

Table 9gives the details on splitting tensile strength values at 7 days and 28 days respectively for conventional curing, salt water curing, 5% replacement of cement by metakaolin.

Table: 9. *Comparison on flexural strength between conventional and 5% Metakaolin cured with PW & SW*

Curing Methods	**Conventional**		**5% Metakaolin**	
	7 days	**28 days**	**7 days**	**28 days**
PW	4.02	4.2	4.48	4.6
SW	4.05	4.3	4.55	4.6

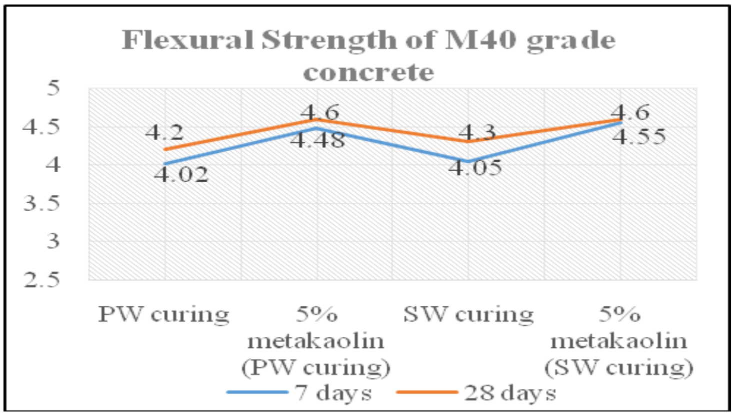

Fig: 8. *Comparison on flexural strength between conventional and 5% Metakaolin cured with PW & SW*

Inference

The Flexural strength of M40 grade of concrete cured with potable water and salt water with different exposure period have been presented in Fig 8. From the Fig 8 it is seen that, the strength increases with the increase of exposure period for all the concretes. Almost all the concrete specimens exposed to a salt water environment showed rapid increase in early strength as compared to potable water cured concrete. 28 days strength ratio for concrete is 9.5% (PW curing and 5% metakaolin PW curing) and 6.9% (SW curing and 5% metakaolin SW curing).

CONCLUSION

From the results and discussions, it is concluded that,

1. The strength increases with the increase of exposure period for the concrete cured with salt water and potable water.
2. The concrete specimens exposed to a salt water curing showed increase in early strength as compared to potable water cured concrete.
3. The compressive strength of concrete is increased by 10.2% (PW curing and 5% metakaolin PW curing) and 6.9% (SW curing and 5% metakaolin SW curing) at the end of 28 days.
4. The split tensile strength of concrete is increased by 4.87% (PW curing and 5% metakaolin PW curing) and 0.73% (SW curing and 5% metakaolin SW curing) at the end of 28 days.
5. The flexural strength of concrete is increased by 9.5% (PW curing and 5% metakaolin PW curing) and 6.9% (SW curing and 5% metakaolin SW curing) at the end of 28 days.
6. From the values obtained, it is evident that 5% replacement of cement by metakaolin yields good results in compression splitting tension and flexural for potable water and salt water curing. Hence 5% is optimum.

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