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A Study On The Efficacy Of Discrete Reinforcing Inclusions On The Strength Of Concrete In Marine Environment

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Abstract: **Today availability of plastic waste is enormous and of such nearly 50% to 60% are consumed for short time utility. Once used, plastic materials are thrown outside and they remain as waste. Plastic wastes are durable and non-biodegradable. The improper disposal is not ecofriendly as they pollute the environment. Under these circumstances, an alternative use of these plastic wastes is required. So any method that can use this Waste Plastics for purpose of construction is always welcome. The Fibre Reinforced Concrete (FRC) is a composite material essentially consisting of concrete reinforced by random placement of short discontinuous and discrete fine fibers of specific geometry. Hence, this project is aimed at increasing the various properties like workability, tensile strength of concrete, by way of conducting experimental program with the addition of Waste Plastic Inclusions (WPI) in desired percentages in order to increase the compressive strength. The durability studies of WPI with various percentage of addition to the cement and for M25, M30, M35, M40 and M45 grade reinforced concretes are also planned to compare submersed curing under potable water for 7 Days, 14 Days and 28 Days & exposing curing under marine environment (creating a marine exposure) for 0 Days, 7 Days, 14 Days and 28 Days.**

I. INTRODUCTION

Concrete is composite material which consists of cement, coarse aggregate, fine aggregate and water in required proportions. Due to its composite nature concrete is weak in tension but strong in compression.

Concrete has been employed in construction exposed to the action of sea water for as long as concrete has been used. Example of concrete used by the Romans 2000 years ago in structures exposed to sea water on the shores of the Mediterranean Sea are still intact. When concrete is to be employed under conditions in which it will be exposed to the effects of sea water, cognizance should be taken of these effects and appropriate precautions taken. However, generally, these precautions are not drastic, and do not involve the selection and use of unusual materials or procedures nor cause any significant increase in cost of production. The effects of sea water on concrete may conveniently be examined by considering, first, the factors characteristic of the sea-water exposure that can affect concrete; second, the elements of the specific concrete involved that may be affected by these factors; third, the consequences of the interaction of sea water with the concrete; and, finally, the precautions that should be taken to avoid undesirable performance of the concrete due to its interaction with sea water.

Most seawater is similar in composition, containing about 3.5% soluble salts (chlorides and sulphates) by weight. The pH of sea - water varies from 7.5 to 8.4, averaging about 8.2. Concrete ex- posed to seawater may deteriorate from the combined effects of chemical and physical processes:

- Sulfate attack
- Leaching of lime (calcium m hy- dioxide)
- Alkali-aggregate expansion
- Salt crystallization from alternate wetting and drying
- Freezing and thawing

Objective

The aim of the project is to compare the compressive strength of concrete with different grades at curing under Normal water & Marine water.

II. REVIEW OF LITERATURE

STRUCTURAL PROPERTIES OF CONCRETE

The studies have been conducted largely based on the structural properties of concrete and have been discussed below.

Compressive Strength

The compressive strength of concrete is one of the most important and useful properties of concrete. Strength is a measure of amount of stress acquired to fail a material.

Tensile Strength

It is attributed to the heterogeneous and complex structure of concrete it is mentioned that tensile strength of concrete is in the order of 10-15% of the compressive strength. The reason for such large

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difference between tensile and compressive strength is attributed to the heterogeneous and complex structure of the concrete.

Shear Strength

It is an engineering term used to describe the strength of a material or component against the type of yield or structural failure where the material or component fails in shear. Although pure shear is not encountered in concrete structures, an element may be subjected to the simultaneous action of compressive, tensile and shearing stress.

Bond Strength

Compatibility of two materials act together to resist the external load is called bond strength. In fact, the strength of concrete is really derived from the bond between paste and aggregates.

Impact Strength

Impact strength is of importance when concrete is subjected to repeated falling object, as pile driving, or a single impact of a large mass at a high velocity. The principal criteria are the ability of the specimen to with stand the high blows.

TYPES OF CONCRETE

The mechanical properties of concrete can be improved by adding admixtures, plasticizers and super plasticizers. The different types of concrete are

- Normal Strength Concrete,
- High Strength Concrete,
- Fiber Reinforced Concrete,
- High Performance Concrete,
- Self-consolidating Concrete.

Normal Strength Concrete

Normal strength concrete is a composition of aggregate, sand and cement. Mix designs below M40 are termed as Normal strength concrete. These are used in ordinary construction of structures such as buildings, water tanks etc. Normal strength concrete is weak in tension and strong in compression.

High Strength Concrete

High-strength concrete has a compressive strength generally greater than 6,000 pounds per square inch (40 MPa = 5800 psi). High-strength concrete is made by lowering the water-cement (W/C) ratio to 0.35 or lower.

***High-Performance Concrete*:**

High-Performance Concrete is a relatively new term used to describe concrete that conforms to a set of standards above those of the most common applications, but not limited to strength. While all high-strength concrete is also high-performance, not all high-performance concrete is high-strength.

Self-Consolidating Concrete

During the 1980s a number of countries including Japan, Sweden and France developed concretes that are self-compacting, known as self-consolidating concrete in the United States. SCC can save up to 50% in labour cost due to 80% fast pouring and reduce wear and tear on the form work.

Fiber Reinforced Concrete

The term fiber reinforced concrete (FRC) is defined by ACI Committee 544 as a concrete made of hydraulic cements containing fine or fine and coarse aggregates and discontinuous discrete fibers.

CONCRETE UNDER MARINE CONDITIONS

For several reasons, effect of seawater on concrete deserves special attention. First, coastal and offshore sea structures are exposed to the simultaneous action of a number of physical and chemical deterioration processes, which provide an excellent opportunity to understand the complexity of concrete durability problems in practice.

Second, oceans make up 80 percent of the surface of the earth; therefore, a large number of structures are exposed to seawater either directly or indirectly (e.g., winds can carry sea water spray up to a few miles inland from the coast).

Most sea waters are fairly uniform in chemical composition, which is characterized by the presence of about 3.5 percent soluble salts by weight. The ionic concentrations of $Na+$ and $Cl-$ are the highest, typically 11,000 and 20,000 mg/litre, respectively. However, from the standpoint of aggressive action to cement hydration products, sufficient amounts of $Mg2+$ and $SO2- 4$ are present, typically 1400 and 2700 mg/later, respectively. The pH of seawater varies between 7.5 and 8.4, the average value in equilibrium with the atmospheric CO2 being 8.2. Attack on concrete due to any one of these causes tends to increase the permeability; not only would this make the material progressively more susceptible to further action by the same destructive agent but also to other types of attack.

Theoretical Aspects

From the standpoint of chemical attack on hydrated Portland cement in non-reinforced concrete, when alkali reactive aggregates are not present, one might anticipate that sulphate and magnesium are the harmful constituents in seawater. It may be recalled that with ground waters, sulphate attack is classified as *severe* when the sulphate ion concentration is higher than 1500 mg/litre; similarly, Portland cement paste can deteriorate by cation-exchange reactions when magnesium ion concentration exceeds, for instance, 500 mg/litre.

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Studies on Concrete under Marine Conditions:

Concrete has an excellent structural performance and durability, but is affected by early deterioration when subjected to a marine environment. The most common cause of deterioration is corrosion of the steel reinforcement, with subsequent sapling of concrete.

Therefore the selection of materials, mix design, and proper detailing of reinforcement are essential para- meters in producing a durable marine structure concrete *(Neville and Brooks 1994*). The durability of concrete is generally regarded as its ability to resist the effects and influences of the environment, while performing its desired function *(Hoff 1991).*

The chemical deterioration of concrete subjected to seawater has been a topic of interest to concrete researchers in the last few decades, and the findings have revealed some very important facts, but still it remains to be a dynamic subject for further study and research *(Kumar 2000).*

The primary chemical constituents of seawater are the ions of chloride, sodium, magnesium, calcium and potassium. In seawater containing up to 35,000 ppm of dissolved salts, sodium chloride (NaCl) is by far the predominant salt (about 88% by weight of salts *(McCoy 1996*). The pH value of seawater varies between 7.4 and 8.4.

Corrosion of reinforcing steel occurs below a pH of 11. Therefore, in cases where concrete is subjected to a highly severe environment, the cement must supply alkalinity *(Gani 1997).* The chemical reactions of seawater on concrete are mainly due to the attack by magnesium sulphate (MgSO4).

The mode of attack is crystallisation. Potassium and magnesium sulphates (K2SO4 and MgSO4) present in salt water can cause sulphate attack on concrete because they can initially react with calcium hydroxide Ca(OH)2, which is present in the set cement formed by the hydration of dicalcium silicate (C2S) and tricalcium silicate (C3S). The attack of magnesium sulphate (MgSO4) is particularly dama- ging, forming soluble magnesium hydroxide (Mg(OH)2), which forces the reaction to form gypsum *(Swamy 1991)*.

Chloride ions can penetrate into the concrete and cause accelerated corrosion of the reinforcement. The chemical reaction of the cement paste with the high-chloride content of seawater is generally slight and not a primary cause of concern. Sodium and potassium ions may produce or intensify the alkali aggregate reaction if reactive types are used, and sulphate and magnesium ions cause a weakening action on the cement paste *(Uddin et al. 2004).*

It increases the risk of corrosion of the embedded reinforcing steel, if the structure is to be exposed to air in service. The most damaging effect of seawater on concrete structures arises from the action of chlorides on the steel reinforcement and the build up of salts *(Aburawi and Swamy 2008).* A number of studies have shown the effects of the mixing and curing of seawater on the compressive strength of cement–sand mortars and corresponding concrete.

Research indicates that seawater is not suitable for the mixing and curing of both plain and reinforced concrete in marine conditions *(Akinkuro- lere et al. 2007).* However, concrete made with the seawater may have a higher early strength than normal concrete and the reduction in strength with age can be compensated by reducing the water–cement ratio and that the microstructural examination of concrete detected chloro aluminate salts in some cracks *(Shayan et al. 2010). Naghoj and Abdel-Rahmna (2005)* reported that adding loam to a concrete mix can increase the compressive strength of the concrete under normal conditions and enhance the performance of hardened concrete to resist the aggressive mediums of salty seawater.

III. METHODOLOGY

Here a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study are briefly presented.

Materials Used and Their Properties

The details of the various materials used in the laboratory experimentation are reported in the following sections.

Cement

A 53 Grade Ordinary Portland Cement (OPC) was bought from Market. Properties of Cement are,

- Specific Gravity – 3.0
- Colure – Greenish Gray

Sand

For the present study, the sand has been brought from the Godavari River from Rajahmundry. Properties of sand are,

- Specific Gravity – 2.62
- Bulking of sand – 0.90

Coarse Aggregate

For the present study, the Coarse aggregate has been brought from Prathipadu Village. Properties of Coarse Aggregate are,

- Specific Gravity – 2.7
- Water Absorption – 0.6

Waste plastic Inclusions

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Waste Plastic Inclusions are used in the form of thin strips of 3mm in width and 100mm in height and thickness of 1.9mm.

List of Laboratory Tests

- Specific Gravity
- Compressive Strength of Cement
- Workability Test on Concrete Using Slump Cone

METHODOLOGY

Steps involved in the methodology of this research are,

- Casting of concrete cubes for M25, M30, M35, M40 and M45 with various proportions of WPI.
- Make them submission curing under potable water for 7 Days, 14 Days and 28 days.
- Then Make them curing under marine environment with sprinkling of marine water on that concrete cubes.
- While curing under marine environment cover that cubes with wet cloths i.e. like membrane curing.
- Test that cubes which cured under marine environment at 0 Days, 14 Days and 28 Days.

IV. RESULTS AND DISCUSSIONS

Details of the laboratory experimentation carried-out with different combinations of materials have been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from various laboratory tests done on concrete.

General

In the laboratory, various experiments were conducted by adding different percentages of Waste Plastic Inclusions in virgin concrete and make them curing under Normal water and marine environment to compare the compressive strength.

Table 4.1 *Variation of Slump Values*

Grade of Concrete	% of WPI			
	0	0.5	1	1.5
M25	38	34	30	32
M30	33	31	27	29
M35	28	26	24	25
M40	24	22	19	20
M45	20	19	16	18

Table 4.2 *Variation of Compressive Strength for M25*

% of Fiber	7 Days N.C			14 Days N.C			28 days N.C		
	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E
0	23.4	20.7	18.6	26.8	24	22.4	29.5	28.1	27.4
0.5	24.1	21.5	20	27	25.8	24.5	30.2	29	28.6
1	25.6	23.1	21.9	28.2	27.7	26.1	32	31.8	31.5
1.5	24.8	22.1	20.6	27.7	26	25.2	30.9	29.3	29

Table 4.3 *Variation of Compressive Strength for M30*

% of Fiber	7 Days N.C			14 Days N.C			28 days N.C		
	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E
0	28.2	26.8	24	32	31.1	30.6	35.4	34.9	33.7
0.5	29	28.3	24.8	32.8	32.5	31	36	36.1	35.9
1	29.9	29	25.6	33.6	33.4	31.8	37.1	37.3	36.4
1.5	29.1	28.5	24.5	32.9	32.6	31.1	36.2	36	35.8

Table 4.4 *Variation of Compressive Strength for M35*

% of Fiber	7 Days N.C			14 Days N.C			28 days N.C		
	0 Days M.C	14 Days M.C	28 Days M.C	0 Days M.C	14 Days M.C	28 Days M.C	0 Days M.C	14 Days M.C	28 Days M.C
0	33.5	30	27.6	39.4	35.6	33.1	43	40.2	37.9
0.5	34.1	31.7	29.3	40	38.2	36	44.2	44.5	43.4
1	36	32.4	31	41.5	40.7	38.2	45.9	46.4	44.5
1.5	34.3	32	30.1	40.2	40	37.4	44.1	44	43.9

Table 4.5 *Variation of Compressive Strength for M40*

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% of Fiber	7 Days N.C			14 Days N.C			28 days N.C		
	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E
0	36.3	35.8	32.6	40.6	38.7	37	43.4	41.5	40.1
0.5	37.1	36	33.8	41.4	39.5	37.6	44.2	43	41.3
1	37.9	36.5	34.3	43	40.2	39.1	45	44.1	42.4
1.5	36.7	36.2	33.9	42.3	39.4	37.9	44.4	43.2	41.5

Table 4.6 *Variation of Compressive Strength for M45*

% of Fiber	7 Days N.C			14 Days N.C			28 days N.C		
	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E	0 DM.E	14 DM.E	28 DM.E
0	40.4	38.9	38	46.4	45.1	43	48.2	47.8	47
0.5	41.6	39.5	38.7	47	45.9	43.6	49	48.5	47.6
1	42.3	40.7	39.5	48.5	46.7	45.1	49.8	49	48.1
1.5	41.8	39.9	39.1	47.3	46	44.7	49.3	48.6	47.7

Variation of Slump Values:

Fig 4.1, Table 4.1 shows that the variation of slump values with different grade of concrete and % of WPI.

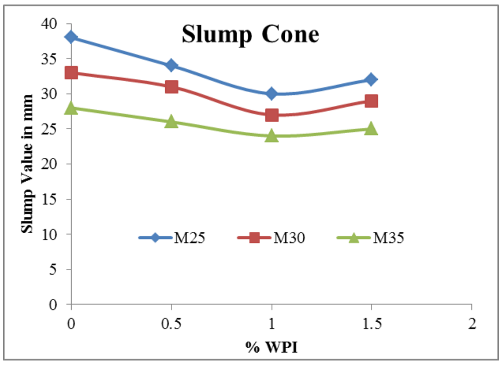

Fig 4.1 *Slump values of Different grades of concrete with % addition of WPI*

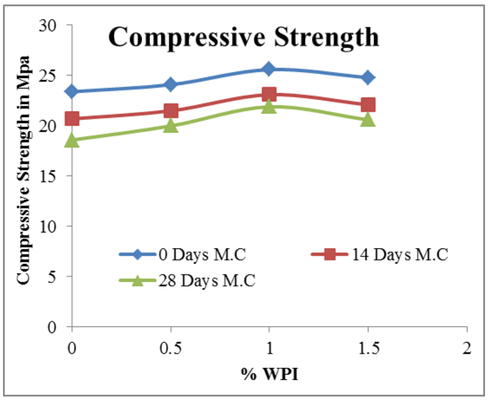

Fig 4.2 *Compressive Strength of M25 at different curing Periods under marine environment after 7 days of Potable water curing with % addition of WPI*

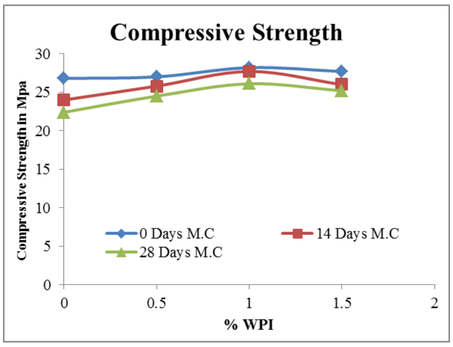

Fig 4.3 *Compressive Strength of M25 at different curing Periods under marine environment after 14 days of Potable water curing with % addition of WPI*

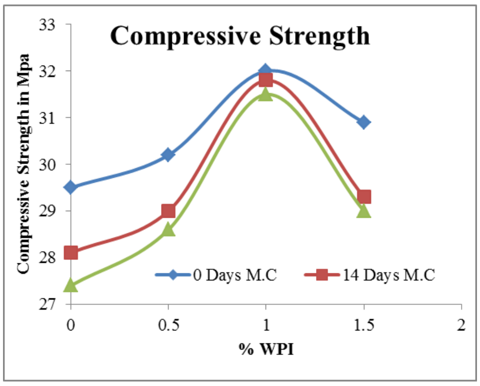

Fig 4.4 *Compressive Strength of M25 at different curing Periods under marine environment after 28 days of Potable water curing with % addition of WPI*

Variation of Compressive strength of M25

Table 4.2, Figures 4.2, 4.3 and 4.4 shows compressive strength of M25 concrete under normal water and marine conditions.

For 7 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 16.89%. For 14 days portable water curing and 28 days marine curing the

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compressive strength is decreased for 1.0% of WPI is about 8.04%. For 28 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 1.58%.

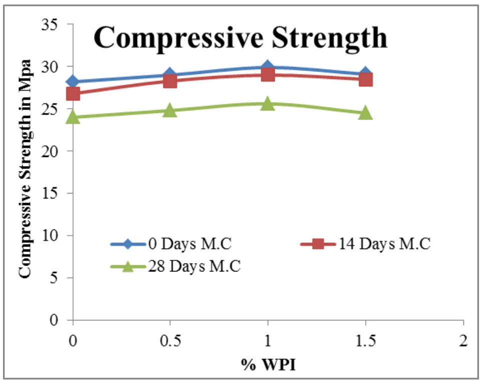

Fig 4.5 *Compressive Strength of M30 at different curing Periods under marine environment after 7 days of Potable water curing with % addition of WPI*

4.5 Variation of Compressive strength of M30

Table 4.3, Figures 4.5, 4.6 and 4.7 shows compressive strength of M30 concrete under normal water and marine conditions.

For 7 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 16.79%. For 14 days portable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 5.66%. For 28 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 1.92%.

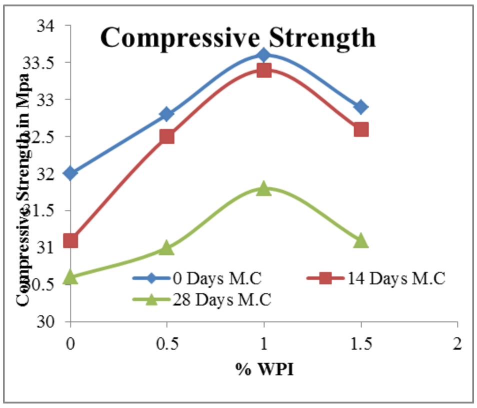

Fig 4.6 *Compressive Strength of M30 at different curing Periods under marine environment after 14 days of Potable water curing with % addition of WPI*

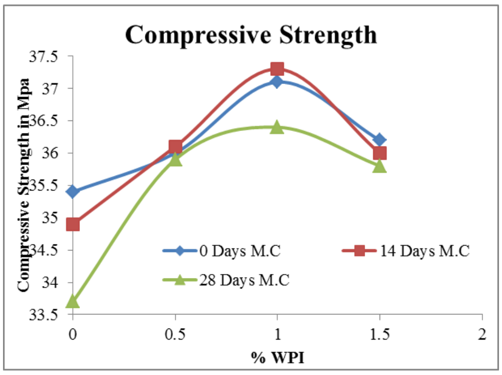

Fig 4.7 *Compressive Strength of M30 at different curing Periods under marine environment after 28 days of Potable water curing with % addition of WPI*

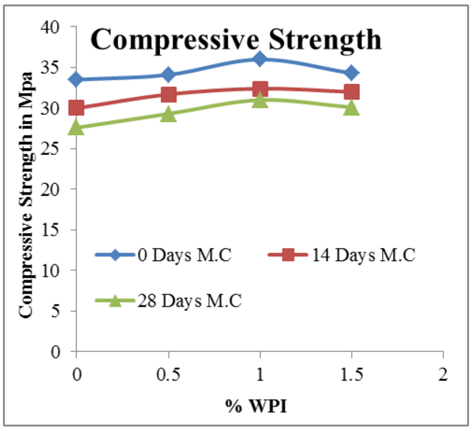

Fig 4.8 *Compressive Strength of M35 at different curing Periods under marine environment after 7 days of Potable water curing with % addition of WPI*

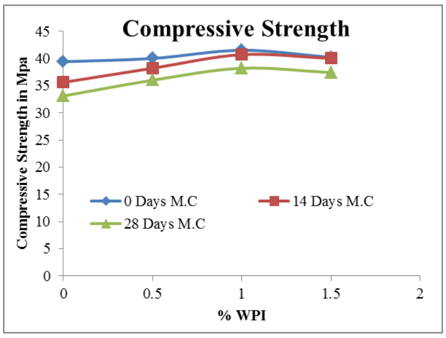

Fig 4.9 *Compressive Strength of M35 at different curing Periods under marine environment after 14 days of Potable water curing with % addition of WPI*

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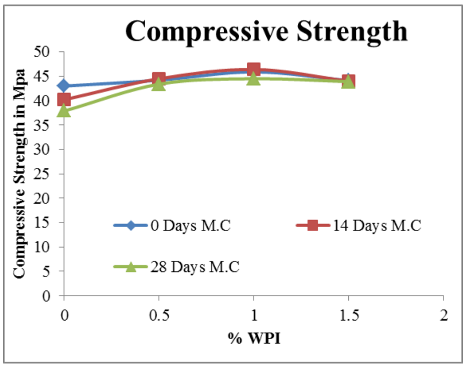

***Fig 4.10** Compressive Strength of M35 at different curing Periods under marine environment after 28 days of Potable water curing with % addition of WPI*

4.6 Variation of Compressive strength of M35

Table 4.4, Figures 4.8, 4.9 and 4.10 shows compressive strength of M35 concrete under normal water and marine conditions.

For 7 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 16.12%. For 14 days portable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 8.63%. For 28 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 3.14%.

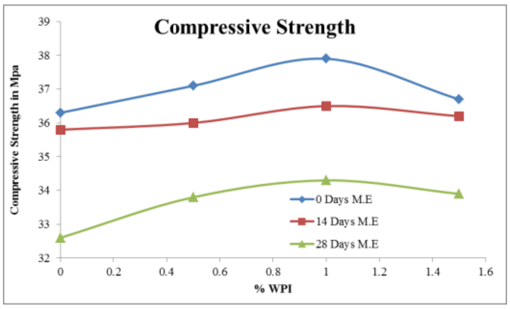

***Fig 4.11** Compressive Strength of M40 at different curing Periods under marine environment after 7 days of Potable water curing with % addition of WPI*

4.7 Variation of Compressive strength of M40

Table 4.5, Figures 4.11, 4.12 and 4.13 shows compressive strength of M35 concrete under normal water and marine conditions.

For 7 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 10.49%. For 14 days portable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 9.97%. For 28 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 6.13%.

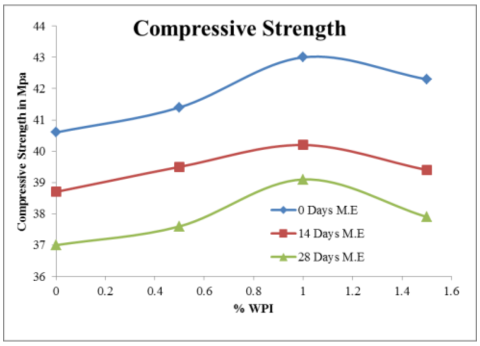

***Fig 4.12** Compressive Strength of M40 at different curing Periods under marine environment after 14 days of Potable water curing with % addition of WPI*

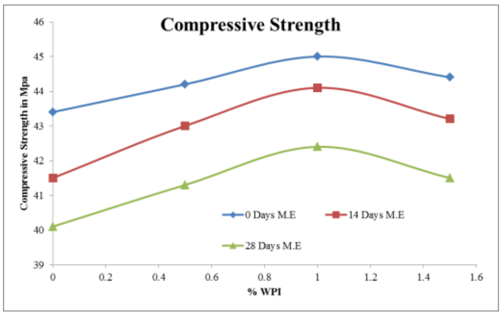

***Fig 4.13** Compressive Strength of M40 at different curing Periods under marine environment after 28 days of Potable water curing with % addition of WPI*

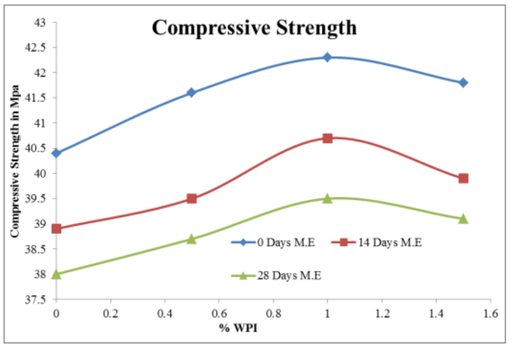

***Fig 4.14** Compressive Strength of M45 at different curing Periods under marine environment after 7 days of Potable water curing with % addition of WPI*

4.7 Variation of Compressive strength of M45

Table 4.6, Figures 4.14, 4.15 and 4.16 shows compressive strength of M35 concrete under normal water and marine conditions.

For 7 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 7.08%. For 14 days portable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 7.53%. For 28 days potable water curing and 28 days marine curing the compressive strength is decreased for 1.0% of WPI is about 3.53%.

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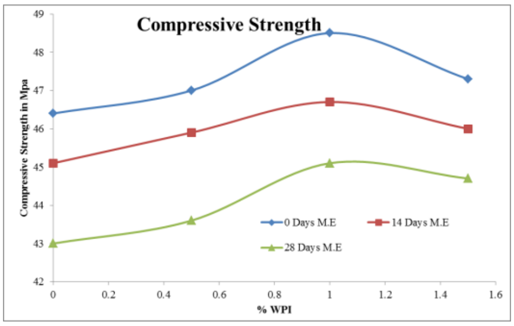

Fig 4.15 Compressive Strength of M45 at different curing Periods under marine environment after 14 days of Potable water curing with % addition of WPI

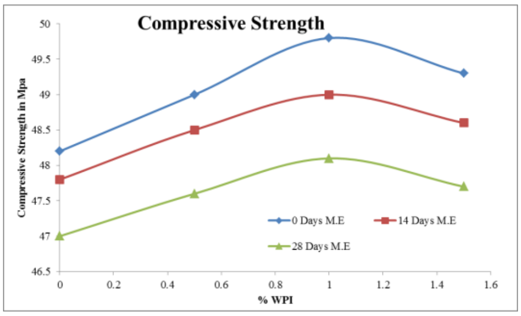

Fig 4.16 Compressive Strength of M45 at different curing Periods under marine environment after 28 days of Potable water curing with % addition of WPI

4.7 SUMMARY

In this chapter the results of various tests carried out in the laboratory are presented, analyzed and discussed. Detailed conclusions derived from the discussions are presented in the next chapter.

V. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

- Workability is decreased with increase in % of WPI up to 1% then for 1.5% it increased.
- Compressive strength of concrete is increased with increase in WPI up to 1% then it get reduced for 1.5%
- Under marine environment conditions concrete loss its strength with increase in curing period.
- For M25 at 1% of WPI strength increased by 14.96% compared to 0% fiber after 56 Days of curing. For M45 it is about only 2.34%.
- As the grade of the concrete increase the % increase in strength is reduces due to increase in micro cracks that leads to orientation of fiber is parallel to the crack pattern.
- As in construction it is proved that usage of concrete with 1.0% of WPI is gave better result that plain concrete.

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