iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** II **Month of publication:** February 2018

DOI: http://doi.org/10.22214/ijraset.2018.2116

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue II, February 2018- Available at www.ijraset.com

A Study on Strength and Durability of Cement Concrete Made with Industrial Waste Water Containing Iron Heavy Metal

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Abstract: Cement concrete is one of the most widely used material in the construction field. For producing good cement concrete, it is necessary to use selected ingredients like cement, aggregate and water. Due to growing population and rapid industrialization, there is a concomitant increase in waste water volume which is contaminated with various constituents i.e., organic, inorganic and biological substances. Industrial sector is one of the major water consuming areas. Because of over population and rapid growth of industries, fresh water resources have been drastically diminishing day to day. Electroplating industry in India is spread throughout the country. Metals used for plating are heavy metals having superior qualities like Nickel, Copper, Lead, Cadmium, Zinc, Iron, Platinum, Mercury, Silver, Chromium etc. It has been noted that out of the total amount of these metals used in electroplating, 4% goes as waste in sludge spent wash, electroplating solutions etc. If these waters are used for farming, drinking etc., it may give detrimental effect. Hence, use of these waters has to be thoroughly examined for the purpose for which they have meant. Cement concrete industry is one such which requires lot of water. Concrete is one of the highly consumable product in now a days. Experimental studies are carried out in the present investigation to check the suitability of industrial waste water containing heavy metallikeIronon compressive strength development, setting times, split tensile strength, flexural strength and assessing the durability against acidic and alkaline attack. The results obtained yields insignificant variation in compressive strength, setting times, split tensile and flexural strength and durability when compared to reference concrete made of de-ionized water.
Keywords- Iron, Setting time, Compresive strength, Split tensile strength, Flexural strength, Durability, Alkaline substances

I. INTRODUCTION

Concrete is the most widely used construction material in the construction industry with annual consumption exceeding almost 70 to 80 million cubic meters. Among the various ingredients that are necessary for making concrete, water is the vital ingredient next to the cement. Concrete requires fresh water as per standards mentioned in relevant codes. But for normal works it is suggested to use at least potable water. One of the major challenges of the present society is the protection of environment. Some of the important elements in this respect are the reduction in the consumption of energy, natural materials and consumption of waste materials. Due to scarcity of fresh potable water and simultaneously due to increased concrete demand day to day, it became inevitable to make use of other waters which are available freely from industries after their treatment up to the limited standards. Waste water disposed from industries are not fit for general use of society. If these materials coming from industries as waste can be suitably utilized in construction, the pollution and disposal problems may be partly reduced. Ever since concrete began to be used as a construction material, potable water has been and is still being used as the mixing water. Studies have shown, however, that water even though not fit for human consumption can also be used for mixing concrete. Electroplating industry in India is spread throughout the country. The common metals they contain in the water disposed from the electroplating industry even after treating them to limited standards are Cadmium, Zinc, Copper, and Iron etc.

II. OBJECTIVE

This is aimed to study the effect of hazardous metals present in the waste water emerging from Electro- Plating Industry. The primary objective of the present study is to determine the suitability of waste water containing iron heavy metal in the concrete used for construction industry. For assessing the suitability of this waste water, strength tests like compressive, split tensile, flexural strengths and durability tests subjecting the concrete specimens to acidic and alkaline environments have to be studied. The same have to be compared with that of the reference specimens. If the deviation in respective property is less than 10%, it will be considered as insignificant, otherwise significant.

III. MATERIALS

Cement used in the present investigation is 53 Grade Ordinary Portland Cement conforming to IS 12269-1987 specifications.Fine Aggregate used in the present investigation is Ennore sand,which satisfies the criteria for standard sand as specified in IS 650-1991.Further, locally available river sand conforming to IS 383-1970 specifications was used as the fine aggregate in the concrete preparation. The grading of this sand is of Grade-II confirming to IS. Coarse Aggregate used in the present investigation is of nominal size 20 mm and 12 mm, obtained from the local quarry confirming to IS 383-1970 specifications. Proportion of coarse aggregate was used in the ratio of 60 (20mm) and 40 (12mm).De-ionized water mixed with Iron heavy metal is used as the mixing water. In the present investigation, Sulphuric Acid and Sodium hydroxide are used for assessing the durability of Concrete.

A. *Mix Design*

1) *Cement Mortar Mix Proportion:* Cement to sand proportion in this investigation is 1:3. The mix proportion of mortar is shown in Table I.

Table i. Mix proportion of cement mortar

Cement	Fine Aggregate (Ennore Sand)		
	Grade I(2mm to 1mm)	Grade II(1mm to 0.5 mm)	Grade III(0.5mm to 0.09mm)
1	1	1	1
1	3		

Quantity of water to be mixed in the preparation of cubes is calculated according to IS 269-1976. It is given by ($\frac{P}{4} + 3$) percent of combined weight of cement and sand, where ‘p’ being percentage of water required to produce a paste of normal consistency.

2) *Concrete Mix Proportion:*Proportioning of ingredients of M25 grade concrete are determined by performing mix design as per IS 10262-2009. Mix Proportions of M25 grade concrete is shown in Table II.

Table ii. Mix proportion of m25 grade concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
1	1.95	3.59	0.46

IV. EXPERIMENTAL TESTS

A. *Setting Time*

Normal consistency and Setting times for the cement used in the present investigation are determined using Vicat’s apparatus conforming to IS 4031 (part 5) 1988. This is done for all the concentrations of $FeCl_3$.

B. *Compressive Strength*

Mortar cubes of size 70.7mm x 70.7mm x 70.7mm were cast to test the compressive strength of cement mortar at the age of 3,7 and 28 days. Compressive strength is determined by using Universal Testing Machine by applying load gradually till the specimen fails. This is carried out for the cement mortars of all the concentrations of all the concentrations of $FeCl_3$ considered.

Concrete cubes of size 150mm x 150mm x 150mm were cast to test the compressive strength of cement concrete at the age of 3,7,28,56 and 90 days. Compressive strength of concrete is determined by using Compressive Testing Machine by applying the load gradually till the specimen fails. This is done for the concrete specimens made with $FeCl_3$ concentration of 2000 mg/l.

C. *Split Tensile Strength*

Split tensile strength was conducted on the concrete specimens of 28 days age, as per IS 5816-1999. The cylindrical specimens of size 150mm x 300mm were cast. Split tensile strength is determined by using Compressive Testing Machine by applying the load gradually till the specimen fails.This is done for the concrete specimens made with $FeCl_3$ concentration of 2000 mg/l.

D. Flexural Strength

Flexural strength was conducted on the concrete specimens of 28 days age. The beams of size 100mm x 100mm x 500mm were cast. Flexural strength is determined by using Universal Testing Machine by applying the load gradually till the specimen fails.This is done for the concrete specimens made with $FeCl_3$ concentration of 2000 mg/l.

E. Durability

1) *Acid Resistance Test:*The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength by immersing the concrete cubes in acidic solution. Sulphuric acid (H_2SO_4) with pH of 1 at the concentration of 5% by weight of water was added to water in which the concrete cubes were stored. The cubes were immersed in acid solution for 28 days.
2) *Alkaline Resistance Test:*To determine the resistance of cement concrete to alkaline attack, the residual compressive strength of concrete cubes are immersed in alkaline solution. Sodium Hydroxide (NaOH) with pH of 13 at the concentration of 5% by weight of water was added to water in which the concrete cubes were stored. The cubes were immersed in alkaline solution for 28 days.The resistance of concrete to alkaline attack was be found by the % loss of weight of specimen and the % loss of compressive strength.

V. RESULTS AND DISCUSSIONS

A. General

The results of the present investigation were presented in graphical forms. The consistency of the reference mix and the mix containing Iron heavy metal concentration in de-ionized water is estimated. The initial and final setting times of cement samples prepared with mixing water containing heavy metal of varying concentrations under consideration were compared to those of the cement specimens prepared with distilled water. As per IS 456-2000, if the difference is less than 30 minutes, the change is considered to be negligible or insignificant and if it is more than 30 minutes, the change is considered to be significant. Regarding Compressive strength and other properties, if the difference is less than 10%, it is considered to be insignificant, otherwise significant.

B. Cement Mortar

Physical tests on cement mortar of reference and spiked with different concentrations of $FeCl_3$ were conducted. Based on the results, it is aimed to find the optimum concentration ofiron metal conducted in mixing water.

1) *Setting Times*

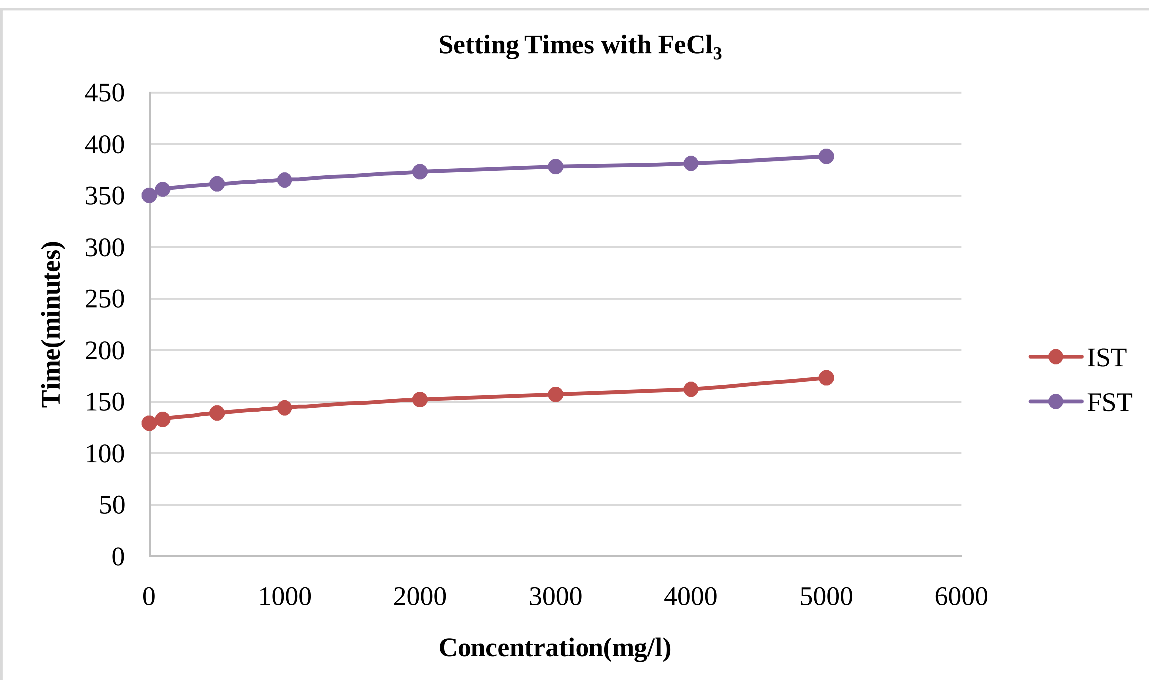

Fig.1 Variation of Setting times of cement mortar at different concentrations of $FeCl_3$

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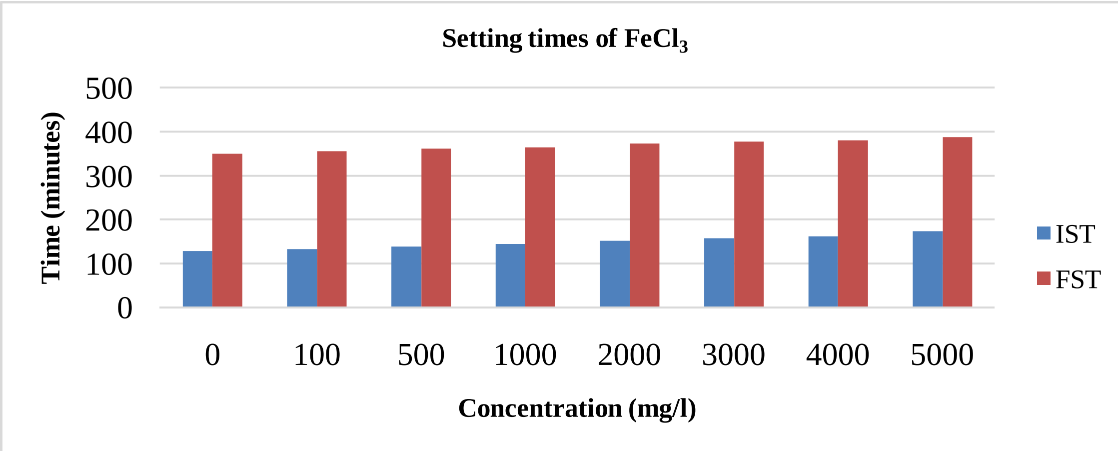

Fig.2Variation of IST and FST at different concentrations of $FeCl_3$

The effect of Iron on initial and final setting times are shown in Fig.1 and Fig.2. It is observed that both initial and final setting process of cement get decelerated with the increase of ironconcentration in de-ionized water. The Initial setting time is 129 minutes and Final setting time is 350 minutes for reference mix. The maximum increase in the initial setting time is 44 minutes and that for the final setting time is 38 minutes with reference mix were observed. It is observed that there is a significant increase from 3000 mg/l in IST and FST.

2) *Compressive Strength:* Upon testing the compressive strength specimens of reference mix, the following compressive strengths were noticed for control mix at 3,7 and 28 days as shown in Table III.

Table iii. Reference mix

Mix	Compressive Strength (N/mm^2)		
Control Mix	3 days	7 days	28 days
	24.60	28.51	41.36

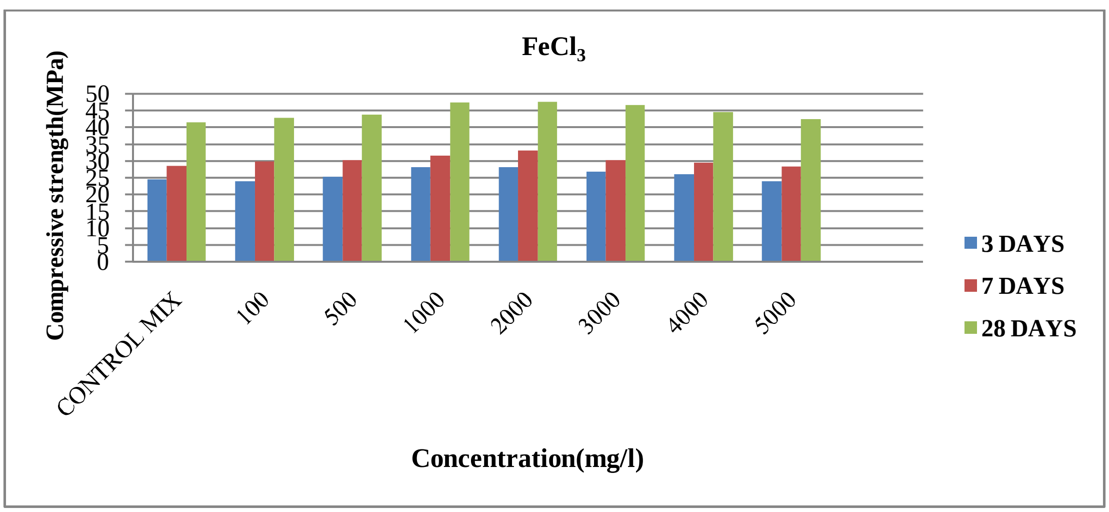

Fig.3Variation of Compressive strength of cement mortar at different concentrations of $FeCl_3$

The effect of ironon compressive strength of cement mortar is shown in Fig.3. It is observed that the compressive strength of $FeCl_3$ is maximum at 2000 mg/l concentration, which increases significantly at 1000 mg/l and 2000 mg/l for 3 days, 7 days and 28 days, and beyond that the change is insignificant and further as the concentration increases, the compressive strength decreases.

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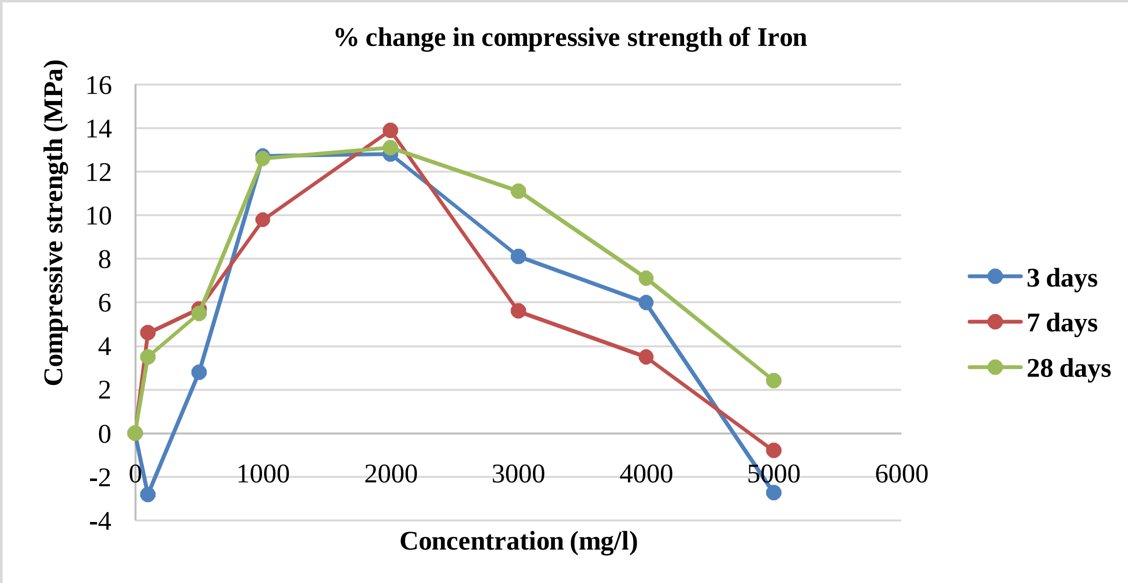

Fig.4 Percentage change in compressive strength of cement mortar at various concentrations of $FeCl_3$ at different ages

From Fig 4, the maximum % change in compressive strength is observed at the concentration of 2000 mg/l, but it is significant at 1000 mg/l and 2000 mg/l for 3 days, 7 days and 28 days, and then it is insignificant.

C. Cement Concrete

1) *Compressive Strength:*Based on the mix deign proportions obtained for M25, concrete cubes were cast and tested at different ages. The results are presented in Table.IV. For the reference mix, the optimum concentration of 2000 mg/l $FeCl_3$is spiked in de-ionized water and the same was used to cast the specimens. The compressive strength of concrete with '$FeCl_3$' was tested at different ages and presented in the Table.IV.

Table iv. Compressive strength for reference mix concrete

Mix	Compressive strength (MPa)				
	3 days	7 days	28 days	56 days	90 days
M25 (Reference Mix)	17.93	25.93	34.82	37.33	39.41
(With FeCl3) mix	18.52	26.22	35.85	37.63	39.85

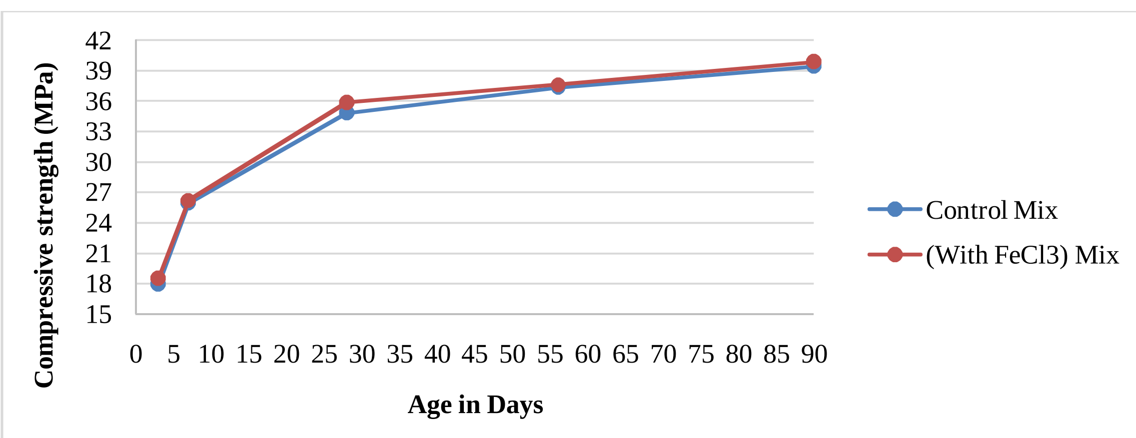

Fig.5 Variation of compressive strength for control mix and that of mix with $FeCl_3$

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It is observed that there is a slight increase in the compressive strength at all the ages for concrete specimens of 'FeCl3' when compared to the specimens of reference mix.

2) Split Tensile Strength: Split Tensile Strength $= \frac{2P}{\pi D l}$

Where P, load in Tons, diameter of specimen, D = 150mm and length of specimen, l = 300mm

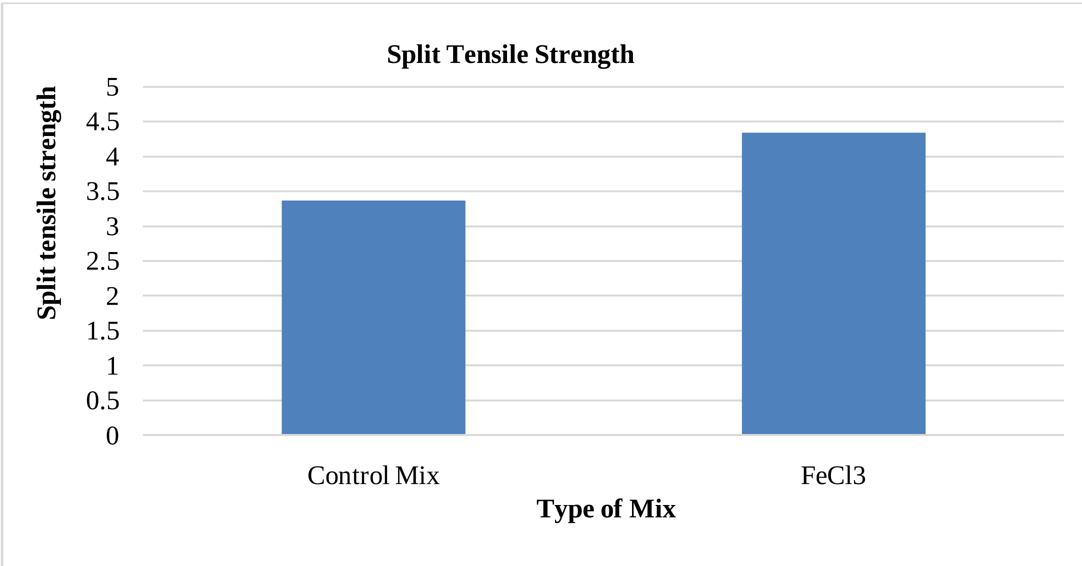

Fig.6 Split Tensile strength of control mix and that with iron metal

It is observed that there is a slight increase in the split tensile strength of specimen with iron metal when compared to the reference mix specimen.

3) Flexural Strength: Flexural Strength is calculated by the formula: $\frac{Pl}{bd2}$

Where Load p, in Newton, equivalent length of specimen, l = 400 mm, breadth of specimen,
b = 100mm and depth of specimen, d = 100mm

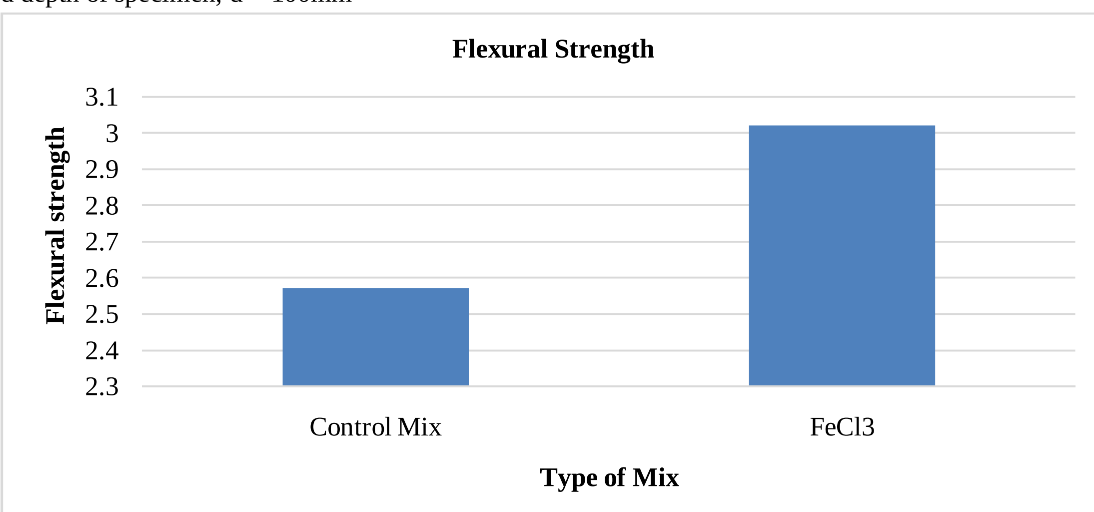

Fig.7 Flexural strength of control mix and that with iron metal

It is observed that there is a slight increase in the flexural strength of specimen with iron metal when compared to the reference mix specimen.

4) Durability Tests:

a) Resistanceagainstacidattack- Sulphuric Acid (H_2SO_4):

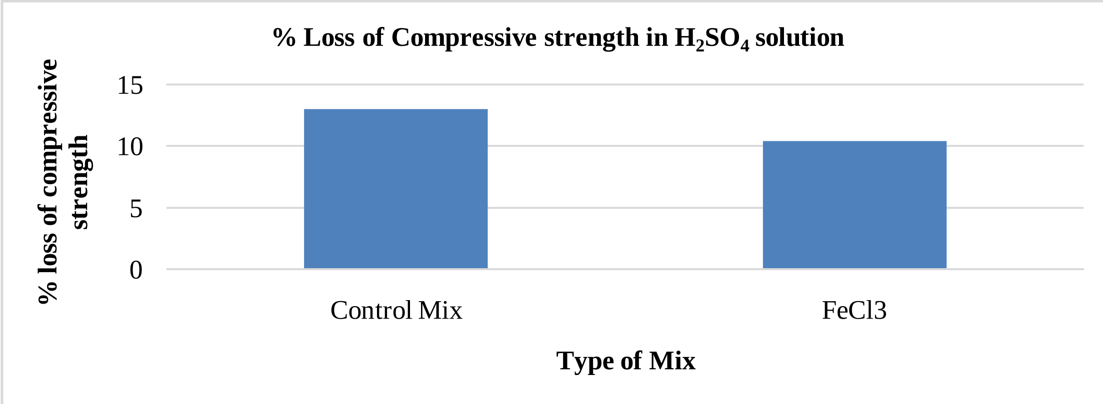

Fig.8 Variation of % loss in compressive strength of concrete cubes of reference mix and that of mix with $FeCl_3$immersed in sulphuric acid solution

From the above Fig.8, the loss of percentage in compressive strength is more for Control mix concrete cubes when compared to Iron metal concrete cubes.

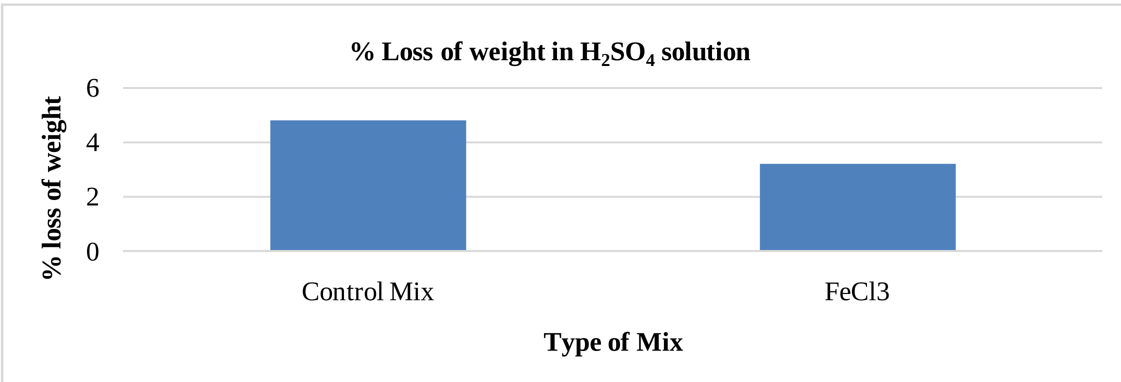

Fig 9. Variation of % loss in weight of concrete cubes of reference mix and that of mix with $FeCl_3$immersed in sulphuric acid solution

From the above Fig.9, the loss of percentage in weight is more for Control mix concrete cubes when compared to Iron metal concrete cubes.

b) Resistance against alkaline attack-Sodium Hydroxide (NaOH):

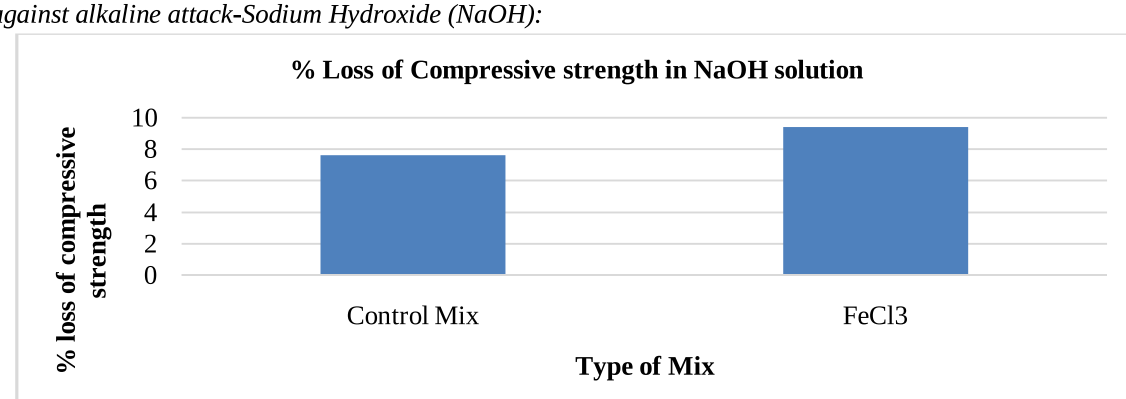

Fig 10. Variation of % loss in compressive strength of concrete cubes of reference mix and that of mix with $FeCl_3$immersed in sodium hydroxide solution

From the above Fig.10, the loss of percentage in compressive strength is more for Iron metal concrete cubes when compared to Control mix concrete cubes.

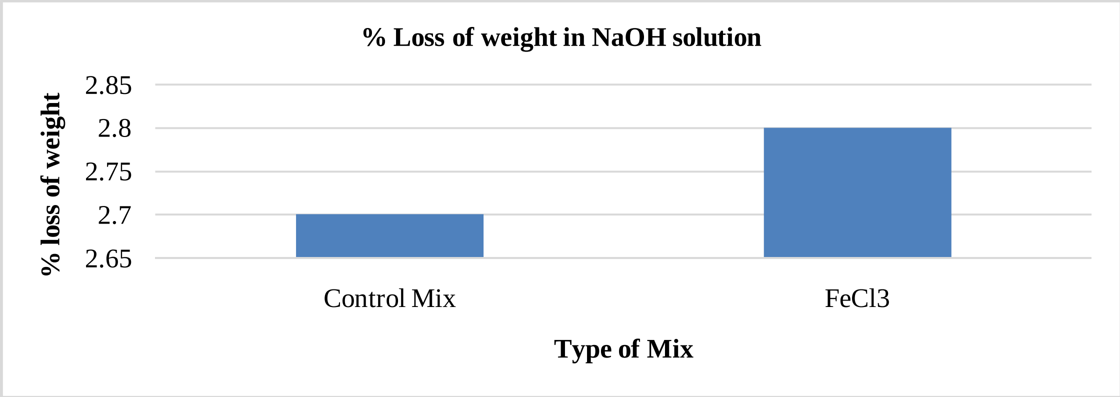

Fig 11. Variation of % loss in weight of concrete cubes of reference mix and that of mix with $FeCl_3$immersed in sodium hydroxide solution

From the above Fig 11, the loss of percentage in weight is more for Iron metalconcrete cubes when compared to Control mix concrete cubes.

VI. CONCLUSIONS AND SCOPE FOR FURTHER STUDY

A. Conclusions

Based on the results obtained in the present investigation, the following conclusions are drawn:

1) The Compressive Strength of Reference Cement Mortar is obtained as 41.36 MPa for comparing the compressive strength values of cement mortar cubes made with different metals.
2) When iron metal is mixed with de-ionized water, it is observed that both initial and final setting process of cement get decelerated with the increase of iron concentration in de-ionized water. It is observed that there is a significant increase of setting times from the concentrations above3000 mg/l.
3) It is observed that the compressive strength of cement mortar is maximum at 2000 mg/l concentration of $FeCl_3$, beyond that the change is insignificant and further as the concentration increases, the compressive strength decreases.
4) At the optimum concentration of 2000 mg/l, the compressive strength of concrete as 35.85 MPa, the Flexural strength as3.02 MPa and the Split tensile strength as4.34 MPa respectively were obtained at 28 days.
5) As part of durability study, the loss of percentage in compressive strength is more for concrete cubes of control mix when compared to concrete made with $FeCl_3$ mixed de-ionized water and % loss of weight is also more for control mix concrete cubes in sulphuric acid solution.
6) As part of durability study, the loss of percentage in compressive strength is more for concrete cubes made with $FeCl_3$ mixed de-ionized water when compared to concrete cubes of control mix and % loss of weight is also more for concrete cubes made with $FeCl_3$ mixed de-ionized water when compared to control mix concrete cubes in sodium hydroxide solution.

B. Scope for Further Study

In the present study, the effect of heavy metal iron, contained in waste water from the electroplating industry is used to find the properties of the normal strength cement mortar. In the same way, the effect of heavy metals contained in the other waste waters emerging from other industris like bewerages, textiles, etc. can be used to find the properties of the High Strength Cement Mortar and concrete.

Not only this metal, there are many other metals like Nickel, Lead, Copper, Mercury etc., and can be studied for the normal and high strength concretes also.

The effect of heavy metals present in industrial waste water may also be studied for Self-Compacting concrete.

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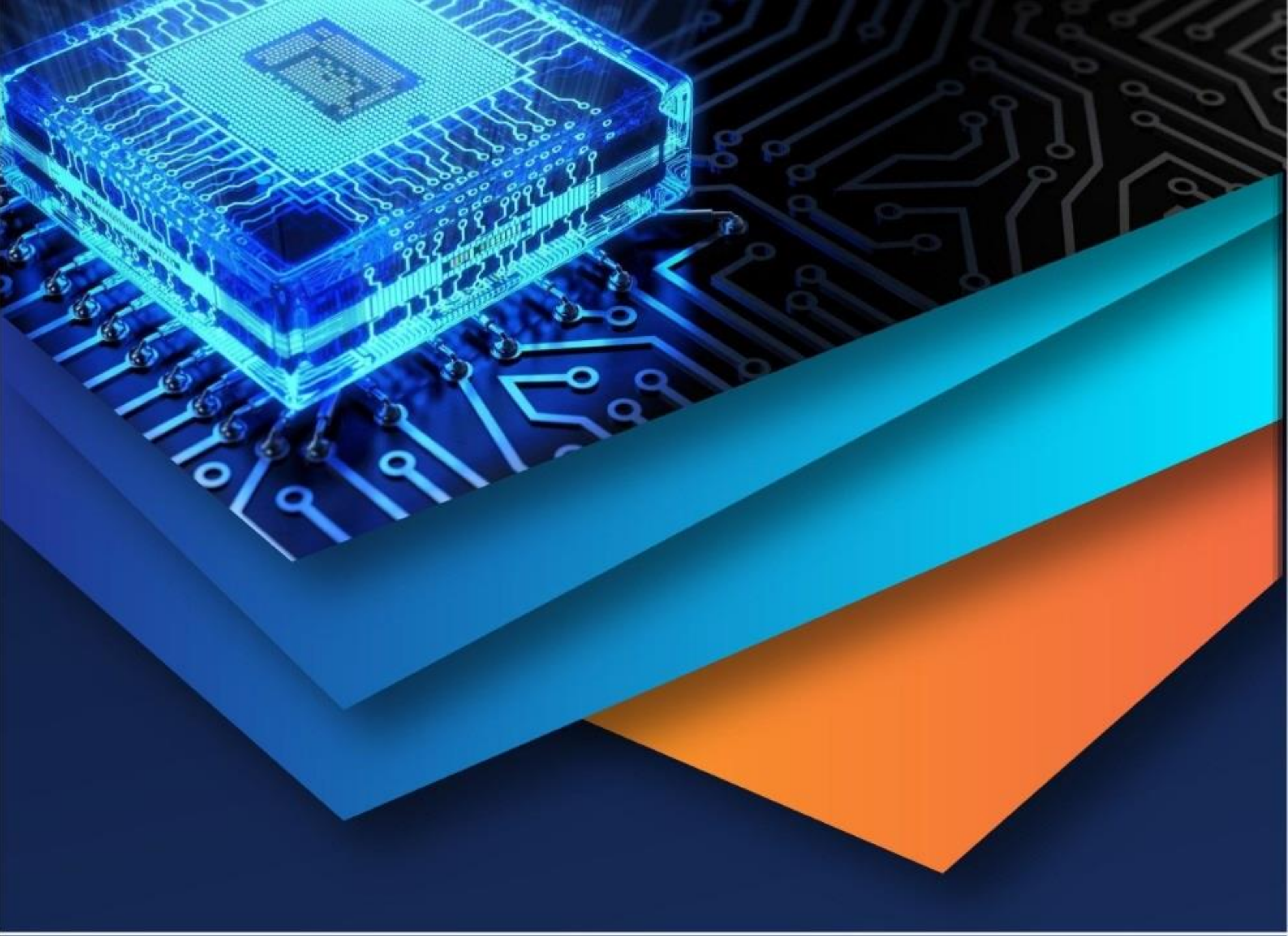

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