

**EFFECT OF HEAVY METALS PRESENT IN MIXING WATER ON THE
PROPERTIES OF CONCRETE**Dr. B. Madhusudana Reddy¹ and S.Al Thasneem²¹Assistant Professor, Department of Civil Engineering

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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. 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. Nowadays these are getting considerable attention under sustainable development. 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 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 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 where its effect is not hazardous. Cement concrete industry is one such areas, 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 certain heavy metals like Cadmium, Zinc and Iron on compressive strength development, split tensile strength, flexural strength and assessing the durability against acidic and alkaline attack. The results obtained yields insignificant variation in compressive strength, split tensile and flexural strength and durability when compared to reference concrete made of de-ionized water.

Keywords: Heavy metal, Cadmium, Zinc, Iron, Compressive strength, Split tensile strength, Flexural strength, Durability.

I. INTRODUCTION

Concrete is the most widely used construction material in the construction industry with annual consumption exceeding around 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 waste waters from industries if 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. However, studies have shown that water even though not fit for human consumption can 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, Chromium, Copper, Iron etc.

II. OBJECTIVE

This is aimed to study the effect of hazardous metals present in the waste water emerging from Electro-Plating Industry on the properties of concrete. The primary objective of the present study is to determine the suitability of waste water containing certain heavy metals like cadmium, zinc and iron 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 conforming to IS. Coarse Aggregate used in the present investigation is of nominal size 20 mm and 12 mm, obtained from the local quarry conforming 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 certain heavy metals like cadmium, zinc and iron is used as the mixing water. In the present investigation, Sulphuric Acid and Sodium hydroxide are used for assessing the durability of Concrete.

3.1 MIX DESIGN

3.1.1 Cement Mortar Mix Proportion:

Cement to sand proportion in this investigation is 1:3. The mix proportion of mortar is shown in Table 1.

Table 1. 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.

3.1.2 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 2. The coarse aggregate used is the blend of 20mm and 12mm sizes in the proportion of 60:40.

Table 2. Mix Proportion of M25 Grade Concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
1	1.95	3.59	0.46

IV. EXPERIMENTAL TESTS

4.1 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 combination mix ($CdCl_2 + ZnCl_2 + FeCl_3$) 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 controlled concrete specimens and the specimens made with combination mix ($CdCl_2 + ZnCl_2 + FeCl_3$) concentration of 1000 mg/l.

4.2 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 controlled concrete specimens and the specimens made with combination mix ($CdCl_2 + ZnCl_2 + FeCl_3$) concentration of 1000 mg/l.

4.3 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 two point load gradually till the specimen fails. This is done for the controlled concrete specimens and the specimens made with combination mix ($CdCl_2 + ZnCl_2 + FeCl_3$) concentration of 1000 mg/l.

4.4 Durability

a) 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.

b) 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 found by the % loss of weight of specimen and the % loss of compressive strength.

V. RESULTS AND DISCUSSIONS

5.1 General

The results of the present investigation were presented in graphical forms. The Compressive strength, Split tensile strength, Flexural strength and durability tests are estimated with mixing water containing certain heavy metals of varying concentrations were compared with those of the specimens prepared with distilled water. Regarding these properties, if the difference is less than 10%, it is considered to be insignificant, otherwise significant.

5.2 Cement Mortar

Physical tests on cement mortar of reference and spiked with different concentrations of combination of metals like cadmium, zinc and iron were conducted. Based on the results, it is aimed to find the optimum concentration of these metals conducted in mixing water.

5.2.1 Compressive Strength

Upon testing the compressive strength specimens of reference mix, the following compressive strengths were noticed at 3, 7 and 28 days.

Table 3. Reference mix

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

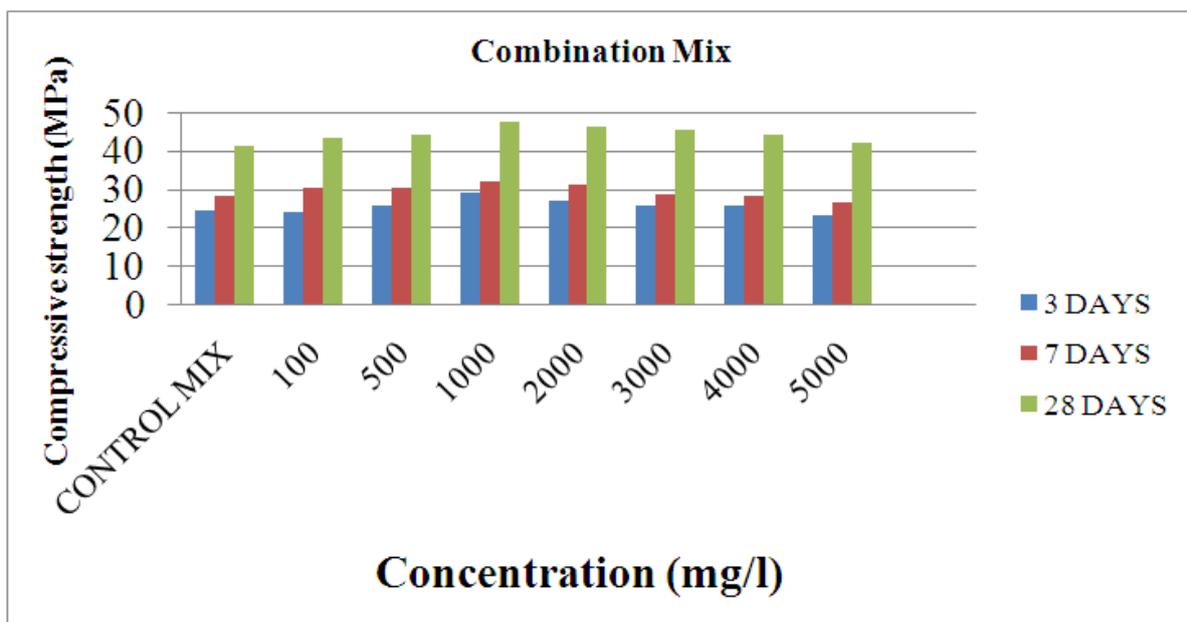


Figure 1| Variation of Compressive strength of cement mortar at different concentrations of certain heavy metals ($CdCl_2 + ZnCl_2 + FeCl_3$)

The effect of combination mix on compressive strength of cement mortar is shown in Fig.1. It is observed that the compressive strength of combination mix is maximum at 1000 mg/l concentration, which increases significantly at 1000 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 up to 5000 mg/l. The maximum compressive strength of 47.5 MPa is observed at 1000 mg/l of the combination mix.

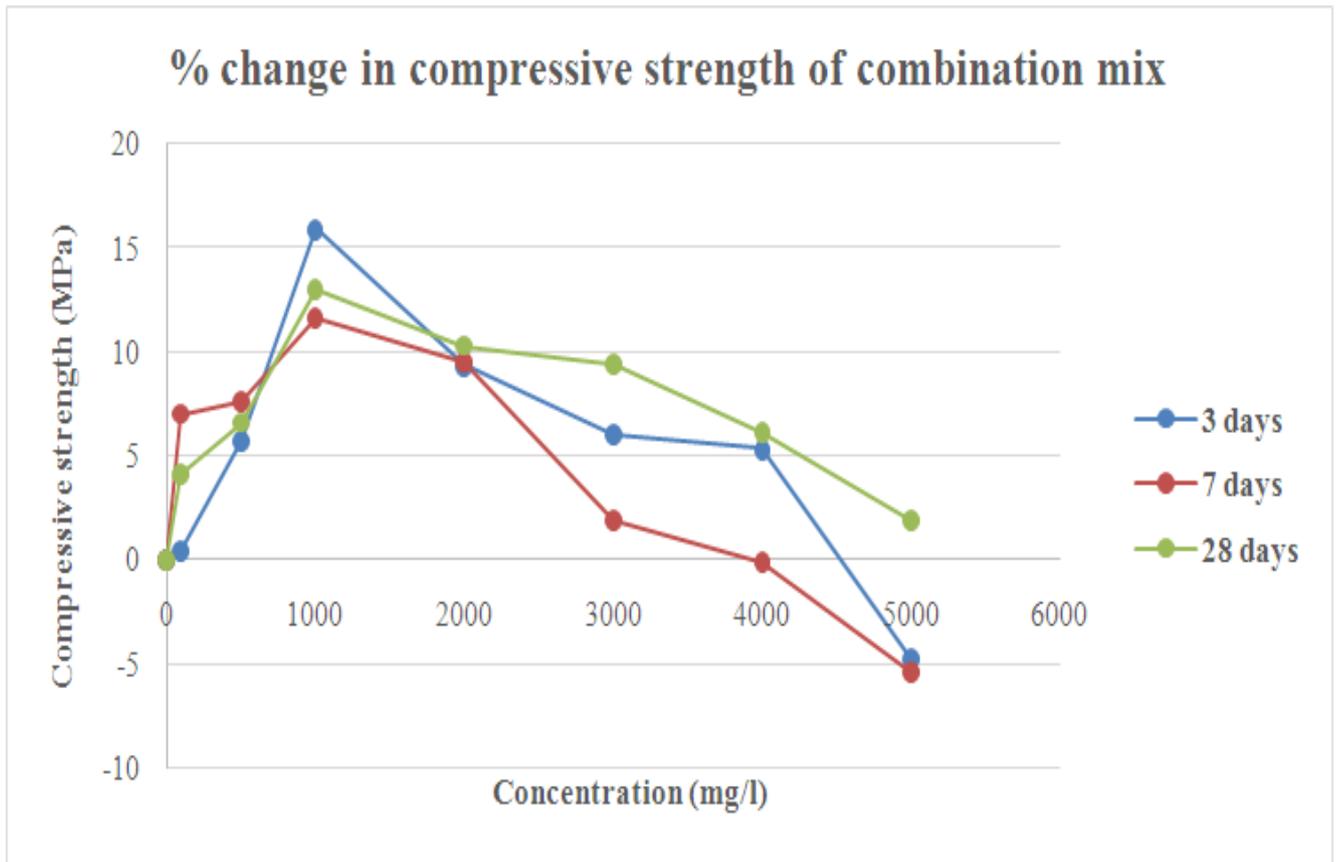


Figure 2. Percentage change in compressive strength of cement mortar at various concentrations of combination of metals at different ages

From Fig.2, the maximum % change in compressive strength is observed at the concentration of 1000 mg/l. Significant change is observed at this concentration for 3, 7 and 28 days. Insignificant change is observed as the concentration increases.

5.3 Cement concrete

5.3.1 Compressive Strength

Based on the mix design proportions obtained for M25, concrete cubes were cast and tested at different ages. The results are presented in Table.4. For the reference mix, the optimum concentration of 1000 mg/l combination of metals is spiked in de-ionized water and the same was used to cast the specimens. The compressive strength of concrete with combination of metals was tested at different ages and presented in the Table.4.

Table 4. 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
M25 (Combination mix)	18.43	26.68	35.97	37.98	40.06

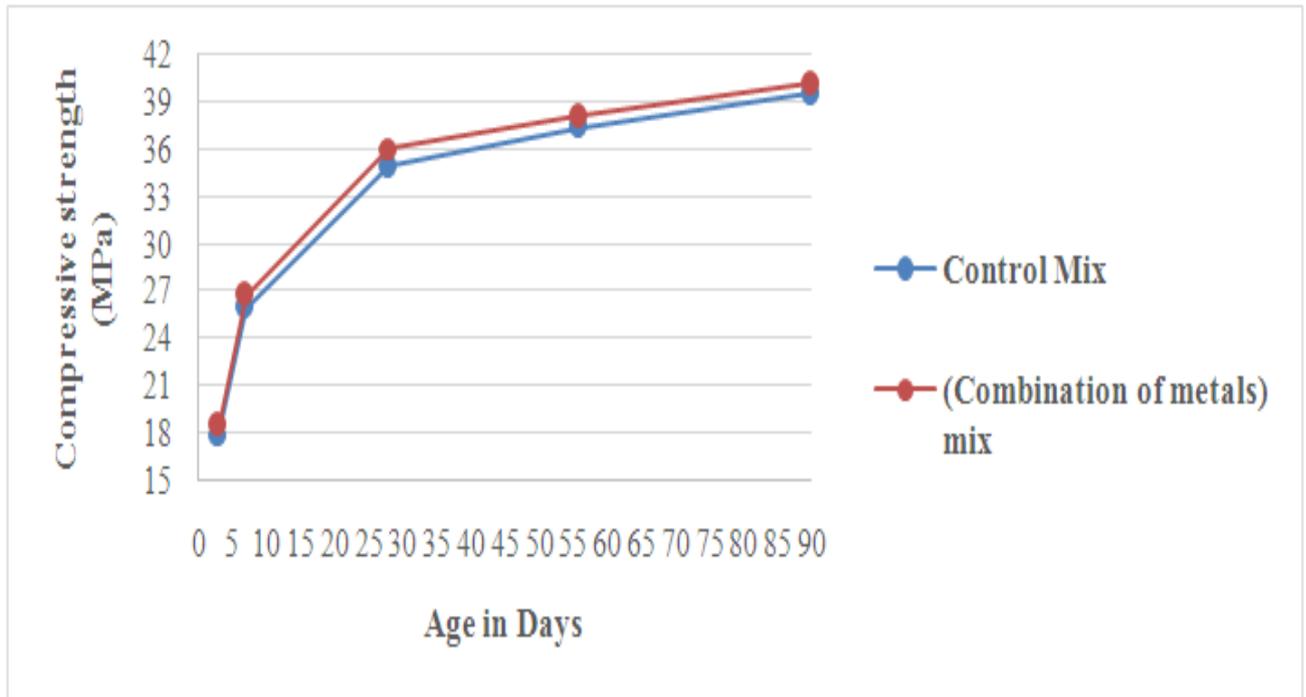


Figure 3. Variation of compressive strength for control mix and that of mix with combination of metals

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

5.3.2 Split Tensile Strength

- Split Tensile Strength = $\frac{2P}{\pi Dl}$

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

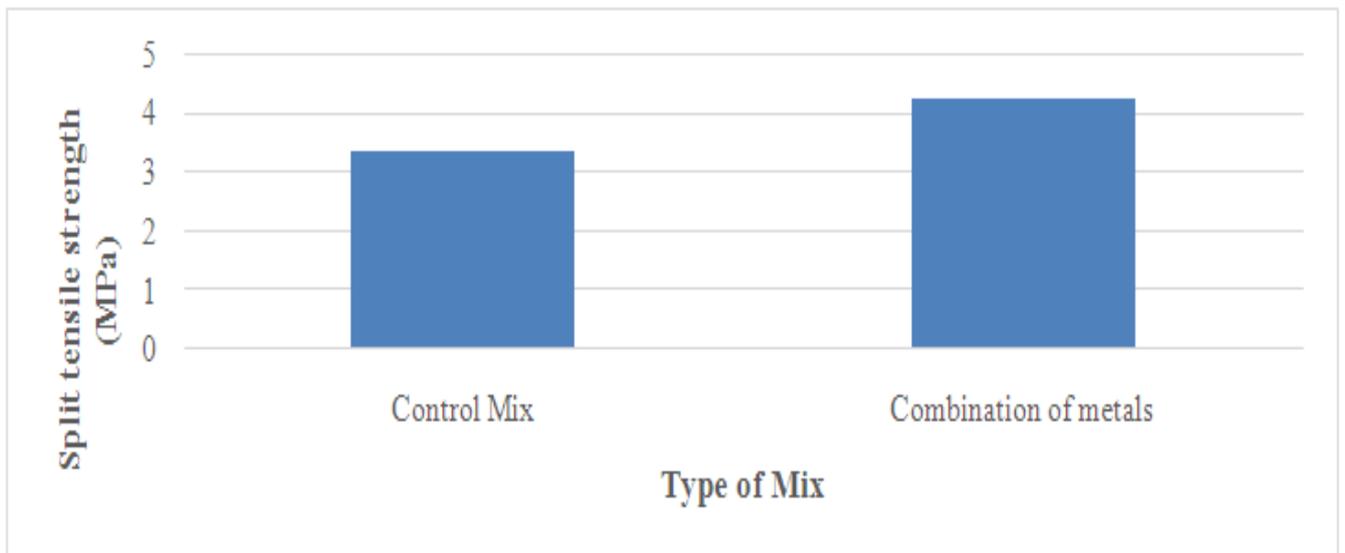


Figure 4. Split Tensile strength of control mix and that with combination of metals

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

5.3.3 Flexural Strength

- Flexural Strength is calculated by the formula: $\frac{pl}{bd^2}$

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

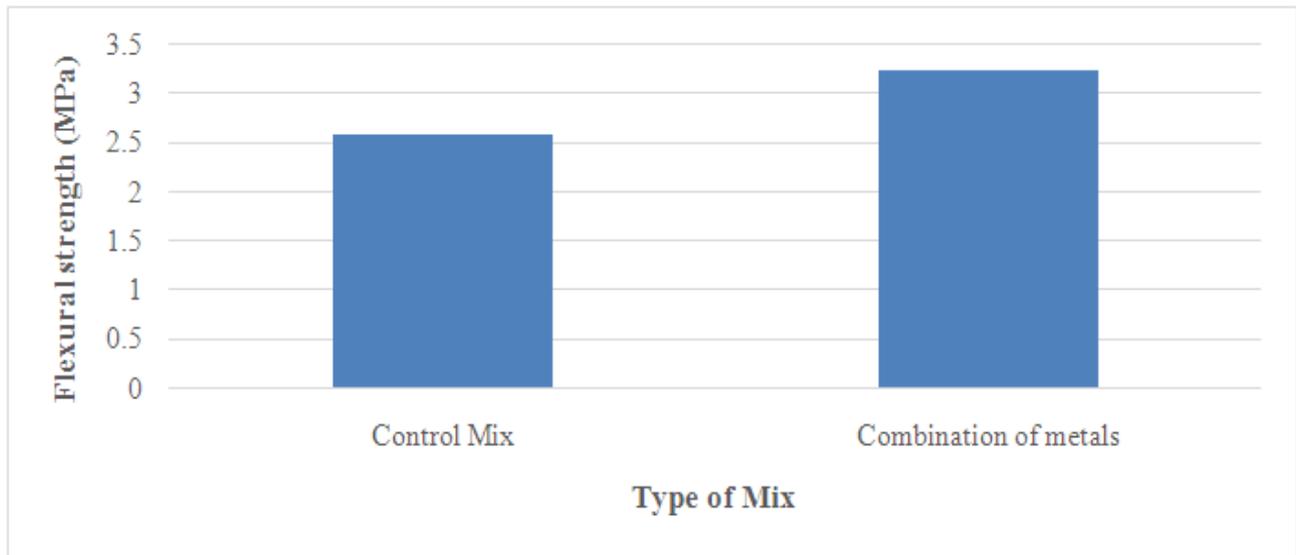


Figure 5. Flexural strength of control mix and with combination of metals

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

5.3.4 Durability Tests:

As a part of durability study, the specimens under consideration were exposed to acidic and alkaline conditions by immersing the concrete cubes in respective waters.

- **Resistance against acid attack - Sulphuric Acid (H_2SO_4)**

The acidic environment is prepared by mixing 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 immersed. After 28 days, the concrete cubes were tested for strength loss and weight loss. They are reported herewith.

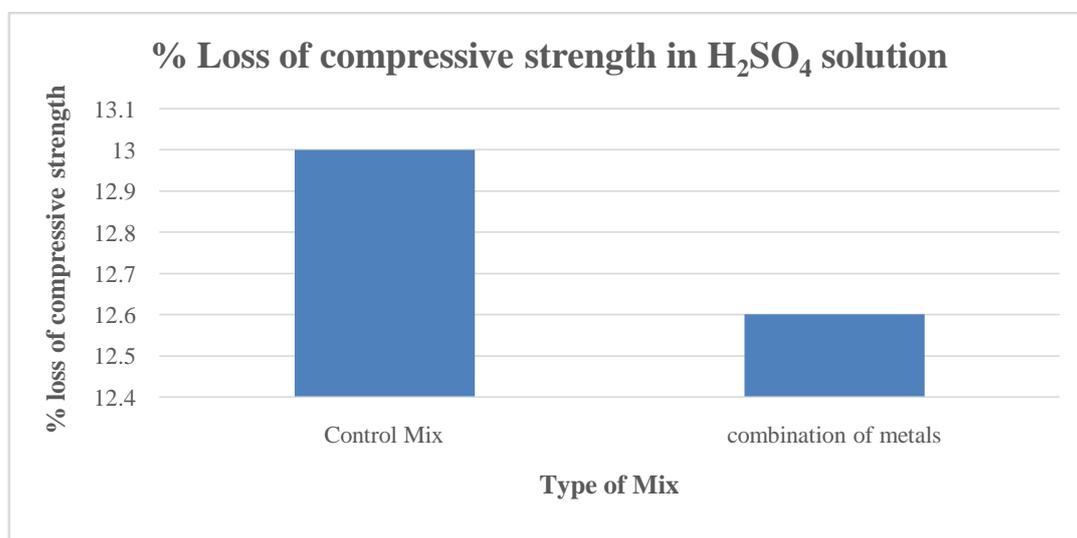


Figure 6. Variation of % loss in compressive strength of concrete cubes of reference mix and that of mix with combination of metals immersed in sulphuric acid solution

From the above Fig.6, the loss of percentage in compressive strength is more for Control mix concrete cubes when compared to combination of metals concrete cubes.

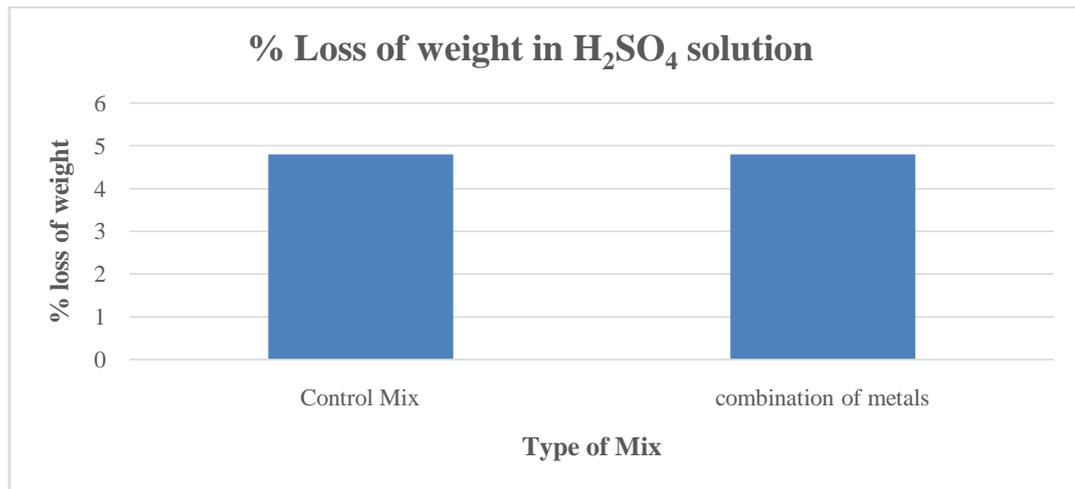


Figure 7. Variation of % loss in weight of concrete cubes of reference mix and that of mix with combination of metals immersed in sulphuric acid solution

From the above Fig.7, the loss of percentage in weight is almost same for both Control mix concrete cubes and combination of metals concrete cubes.

- **Resistance against alkaline attack-Sodium Hydroxide (NaOH)**

The alkaline environment is prepared by mixing 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 immersed. After 28 days, the concrete cubes were tested for strength loss and weight loss. They are reported herewith.

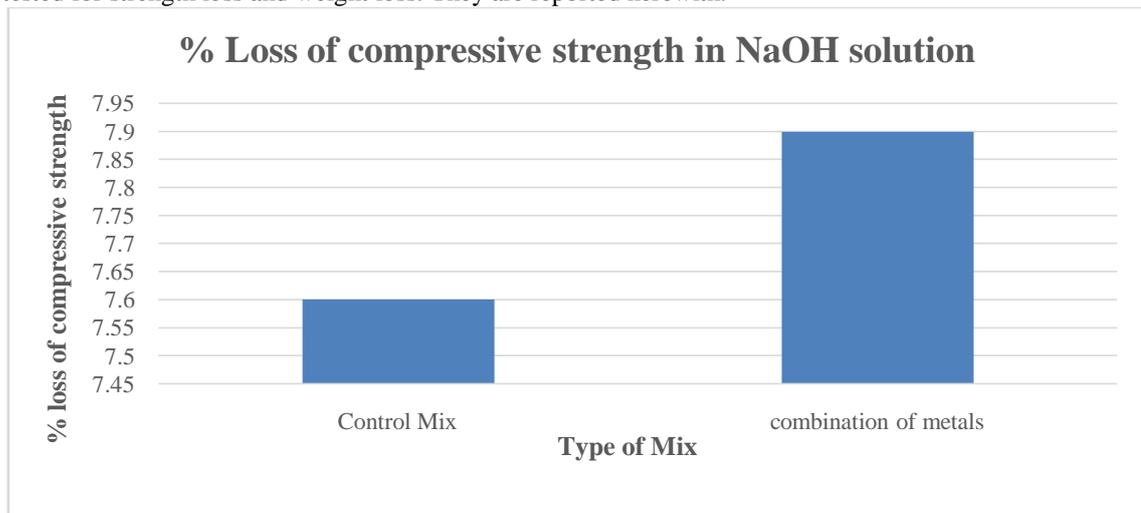


Figure 8. Variation of % loss in compressive strength of concrete cubes of reference mix and that of mix with combination of metals immersed in sodium hydroxide solution

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

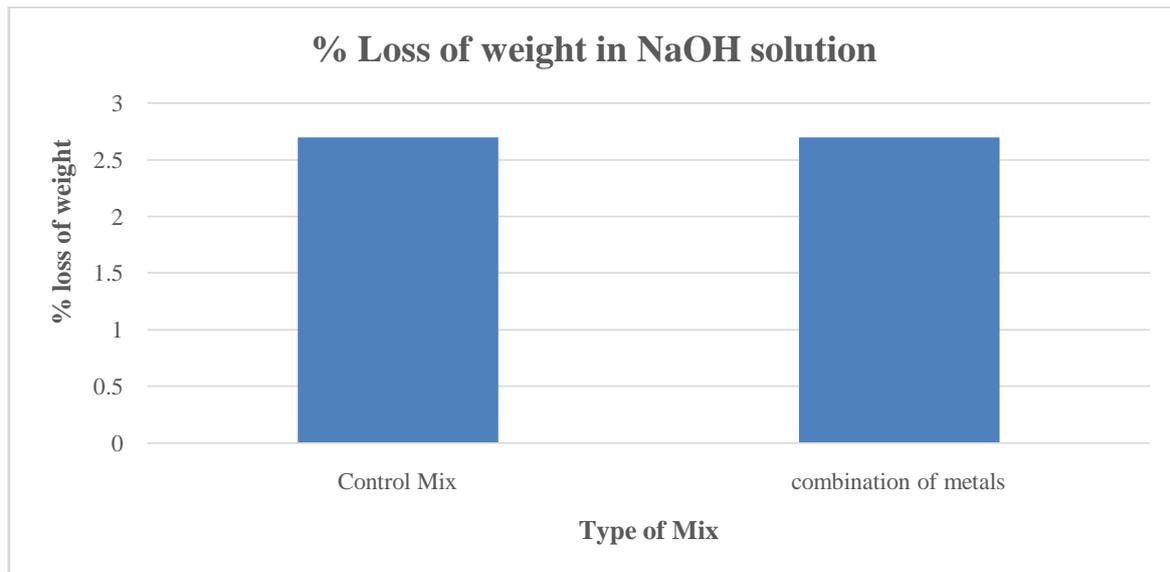


Figure 9. Variation of % loss in weight of concrete cubes of reference mix and that of mix with combination of metals immersed in sodium hydroxide solution

From the above Fig.9, the loss of percentage in weight is almost same for both Control mix concrete cubes and combination of metals concrete cubes.

VI. CONCLUSIONS AND SCOPE FOR FURTHER STUDY

6.1 Conclusions

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

- 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.
- When combination of metals are mixed with de-ionized water, it is observed that the compressive strength of cement mortar is maximum at 1000 mg/l concentration of combination mix, beyond that the change is insignificant and further as the concentration increases, the compressive strength decreases.
- At the optimum concentration of 1000 mg/l, the compressive strength of concrete is 35.97 MPa, the Flexural strength is 3.23 MPa and the Split tensile strength is 4.22 MPa respectively were obtained at 28 days.
- 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 combination of metals mixed de-ionized water and % loss of weight is same for both control mix concrete cubes and combination of metals mix concrete cubes in sulphuric acid solution.
- As part of durability study, the loss of percentage in compressive strength is more for concrete cubes made with combination of metals mixed de-ionized water when compared to concrete cubes of control mix and % loss of weight is same for concrete cubes made with control mix and combination of metals mixed de-ionized water concrete cubes in sodium hydroxide solution.

6.2 Scope for Further Study

In the present study, the effect of combination of heavy metals like cadmium, zinc and 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 industries like beverages, 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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