Deterioration of Concrete in Aggressive Environment

P S R CH Ravi Varma, Dumpa Venkateswarlu, Alamanda Sai Kumar

Abstract: This paper mainly investigates about the effect of acidic curing environment on the strength and durability of concrete which is cured in water containing different percentages of nitric acid and hydro chloric acid. For this experimental procedures M40 concrete cubes of sizes 150mmx150mmx150mm, 150mmx150mmx300mm size concrete beams and 150mmx300mm concrete cylinders are adopted to find out the compressive, flexural and tensile strength respectively. The samples are made by using mix design concrete and those samples are cured in water having the chemical concentration water having the concentration respectively of 0,2,5,8 for both Nitric acid and Hydro chloric acid by volume of water for a curing period of 7,28 and 60days.The compressive strength of the cubes which are cured in the above mentioned percentage concentration of the acid is observed as decrease with increase in the age of curing. The percentage decrease in strength increases with both percentage of acid and curing age. Thus the rate of deterioration at 60 days curing will compare with 7, 28 days. From the past research works it is clear that thetensile and flexural strength tests at 28 days curing revealed that the strength decreased with increase in percentage concentration of acid. For a unique curing age, both the power and mass of concrete decreases with an extend in the concentration of acid, also for a precise awareness of acid, the strength and weight of concrete decreases with curing age. A close to linear relationship exists between weight loss and loss in compressive strength.it can therefore be concluded that deterioration of concrete cured in acidic medium will increase with attention of acid and curing age. The durability decreases faster as the concrete ages. Thus, concrete structures can't stand the check of time in acidic environment except extraordinary cements are used.

Index Terms: Hydro Chloric acid , Nitric acid, Compressive Strength, Split Tensile Strength, Flexural Strength, Durability and Weight loss

I. INTRODUCTION

Concrete is a homogenous mixture composed of coarse aggregate, fine aggregate and binding material (cement) and water, by mixing all the constituents we get a matrix paste with aggregates that hardens with time. Around the globe most used concrete is lime based like Portland cement concrete and cement fondue concrete. However, there is one more type of concrete which is mostly adopted for pavement construction is asphalt concrete, in this asphalt concrete the bitumen will act as binding material instead of cement. After mixture is mixed together with dry Portland cement and water, the mixture types a fluid slurry i.e. without problems poured and molded into any shape. In the strategies of Heat of hydration the cement responds chemically with water and other substances to shape a tough matrix that binds the substances together into a robust stone-like fabric that has various usages. Frequent, additives (for instance pozzolans or gorgeous plasticizers) are blanketed in the mixture to improve the physical properties of the moist combine or the finished material. Maximum concrete is poured by reinforcing materials (for example rebar) embedded to furnish tensile strength, yielding strengthened concrete.

Number of researcher's are worked on the fact that the acids will make a strong effect on durability parameters of concrete like strength, which is stated by MOHD.MutaffaAL.Bakri Abdullah, A.victorsandhu in 2013,Emmanuel,k.attigolle and shami H.rizkalla sallem Barbhuiya in 1958, Davinkumala in 2017. Along with these studies some other studies are carried out on effect of HNO_3 AND HCL and other chemicals that effect on the concrete durability and life. This project deal with HCL and HNO_3 ACIDS attack on concrete durability with different acidic concentrations.

A. Acid Attack on Concrete

Ordinary Portland Cement (OPC) is highly alkaline in nature and having the pH values above 12. So whenever the concrete or matrix paste comes into contact with the acids. The reaction between the concrete and acid will start and finally leads to disintegration of its components, this phenomenon is known as acid attack. If pH decreases to values decrease than steadiness limits of cement hydrates, then the corresponding hydrate loses calcium and decomposes to amorphous hydrogel. The last response merchandise of acid assault are the corresponding calcium salts of the acid in addition as hydrogels of siliceous, aluminum, and ferric oxides. When acid assaults the concrete at that time it dissolves both hydrated and un-hydrated cement compounds in addition as calcareous aggregates. In most of the instances the chemical response outcomes in water soluble calcium compounds that are leached away. Concrete vulnerability to acid assault rises as the pH of the acid in contact decreases from 6.5. Degree of aggression is Slight for pH: 6.5 to 5.5, Severe for pH: 5.5 to 4.5 and Very Severe for pH much less than 4.5.not only the pH values will have an effect on the concrete however additionally the presence of CO2.

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Effect of Nitric Acid on Concrete:

Nitric acid (HNO3), additionally known as aqua Fortis (Latin for "strong water") and spirit of niter, is a fairly corrosive mineral acid.The pure structure of sparkling compound is colorless, but if maintain the sample for days it turns into yellow colour, this is broadly speaking due to decomposition into oxides of nitrogen and water. In accepted basically reachable nitric acid has a concentration of 68% in water. When the solution contains more than 86% HNO3, it is referred to as fuming nitric acid. Depending on the quantity of nitrogen dioxide present, fuming nitric acid is further characterized as white fuming nitric acid at concentrations above 95%, or red fuming nitric acid at concentrations above 86%.

Nitric acid is the important reagent used for nitration – the addition of a nitro group, typically to an organic molecule. While some resulting nitro compounds are shock- and thermally-sensitive explosives, a few are stable ample to be used in munitions and demolition, while others are nevertheless extra stable and used as pigments in inks and dyes. Nitric acid is additionally typically used as a robust oxidizing agent.

Nitric acid normally released from chemical flowers during two explosives, artificial manure and different comparable products. The nitric acid additionally formed in the form of the radicals two of nitrate in the presence of water.

$$3NO_2 + H_2O ==> 2HNO_3 + NO$$

Though HNO3 is not as sturdy as H2SO4, its impact on concrete at short exposure is greater unfavorable seeing that it transforms CH into noticeably soluble calcium nitrate salt and low soluble calcium nitro-aluminate hydrate.

Due to nitric acid impact the concrete get corroded along with shrinkage, the shrinkage is commonly due to the leaching of noticeably soluble calcium nitrate. Such extent contractions of the corroded layer, one can look at the visible cracks across the corroded layer due to the nitric acid attack. In the presence of these cracks the transport charge of acid and corrosion products to and from the corrosion the front rises and this hastens the process of deterioration.

Hydrochloric Acid Attack on Concrete:

Hydrochloric acid or muriatic acid is a colorless inorganic chemical machine with theformula H2O:HCl. Hydrochloric acid has a distinct pungent smell. It is classified as strongly acidic and can assault the pores and skin over a large composition range, in view that the hydrogen chloride totally dissociates in aqueous solution.

Hydrochloric acid is the simplest chlorine-based acid gadget containing water. It is a blended answer of hydrogen chloride and water, and a variety of different chemical species, which includes hydronium and chloride ions. It is an necessary chemical reagent and industrial chemical, used in the production of polyvinyl chloride for plastic. In households, diluted hydrochloric acid is frequently used as a descaling agent. In the food industry, hydrochloric acid is used as a meals additive and in the manufacturing of gelatin. Hydrochloric acid is additionally used in leatherprocessing.

Hydrochloric acid was once located through the alchemist Jabir IbnHayyan around the 12 months 800 AD.[7][8] It was once traditionally referred to as acidumsalisand spirits of salt because it used to be produced from rock salt and "green vitriol" (Iron(II) sulfate) (by BasiliusValentinus in the fifteenth century) and later from the chemically comparable frequent salt and sulfuric acid (by Johann Rudolph Glauber in the seventeenth century). Free hydrochloric acid was once first formally described in the sixteenth century with the aid of Libavius. Later, it used to be used with the aid of chemists such as Glauber, Priestley, and Davy in their scientific research. Unless pressurized or cooled, hydrochloric acid will turn into a gas if there is round 60% or less of water. Hydrochloric acid is also regarded as hydronium chloride, in distinction to its anhydrous mother or father recognized as hydrogenchloride, or dry HCl. The chemicals shaped as the products of response between hydrochloric acid and hydrated cement ranges are some soluble salts and some insoluble salts. Soluble salts, most through calcium, are as a result leached out, whereas insoluble salts alongside by means of amorphous hydrogels, stay in the corroded layer. Besides dissolution, the interaction between hydrogels may also too end result in the formation of some Fe-Si, Al-Si, Ca-Al-Si complexes that show up to be secure in pH range above 3.5.

$$Ca(OH)_2 + 2HCl ==> CaCl_2 + 2H_2O$$

The reaction essentially causes leaching of $Ca(OH)_2$ from the set cement.

Hydrochloric acid attack is a typical acidic corrosion that can be characterized by the formation of layer structure. Chandra divided the cross section of damaged prisms into three main zones; undamaged zone, hydroxide mixture zone or brown ring, and attacked zone. By hydroxide mixture zone, he referred to a layer formed by undissolved salts seen as a dark brown ring.

II. MIX DESIGN

Material	Water	Cement	Fine aggregate	Coarse aggregate
Kgs/cum	197.2	493	604	1164
Ratio	0.40	1	1.23	2..36

III. EXPERIMENTAL PROCEDURES

Fig 1.Curing the cube in HCL AND HNO3 solution

Fig 2. Testing the cube in HCL solution

Fig 3.Compressive Strength testing

Table 1: Effect of HNO_3 on compressive strength at 7, 28and 60 days .

Sl. No	Grade of concrete M40	Cured in different % of HNO_3 solution	7 days strength (MPa)	28 days strength (MPa)	60 days strength (MPa)
1	M40	Water	31.50	46.40	46.60
2	M40	2% HNO3	31.00	46.00	46.20
3	M40	5% HNO3	30.04	44.20	44.60
4	M40	8% HNO3	30.00	42.20	42.40

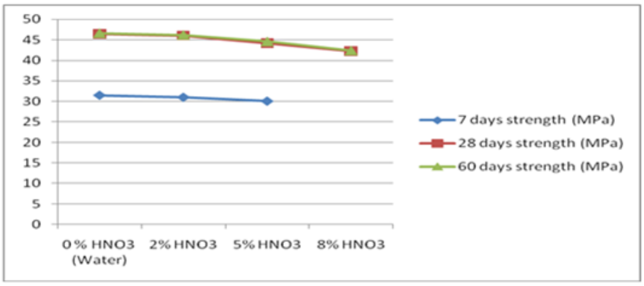

Fig 4.Effect of HNO_3 on compressive strength at 7, 28 and 60 days.

Table 2: Effect of HCL on compressive strength at 7, 28 and 60 days .

Sl. No	Grade of concrete M40	Cured in different % of HCL Solution	7 days strength (MPa)	28 days strength (MPa)	90 days strength (MPa)
1	M40	Water	31.5	46.4	46.6
2	M40	2% HCL	30.5	44.2	45.0
3	M40	5% HCL	29.2	41.8	41.2
4	M40	8% HCL	28.1	39.8	40.0

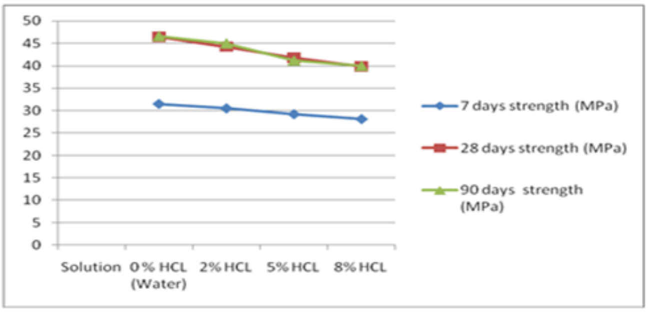

Fig 5.Effect of HCLon compressive strength at 7, 28 and 60 days.

Fig 6. Split tensile testing

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Table 3.Effect of HNO_3 on split tensile strength of concrete at 7, 28 and 60 days

Sl. No	Grade of concrete M40	Cured in different % of HNO_3 solution	7days Split tensile strength(Mpa)	28 days split tensile strength (Mpa)	60 days split tensile strength (Mpa)
1	M40	Water	3.1	4.12	4.13
2	M40	2% HNO3	3.06	4.00	4.04
3	M40	5% HNO3	2.98	3.96	4.1
4	M40	8%HNO3	2.64	3.62	3.96

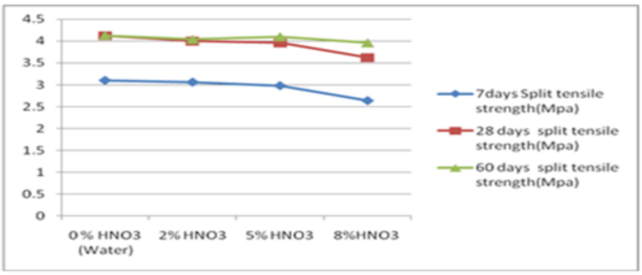

Fig 7.Effect of HNO_3 on split tensile strength of concrete at 7, 28 and 60 days

Table 4.Effect of HNO_3 on split tensile strength of concrete at 7, 28 and 60 days

Sl. No	Grade of concrete M40	Cured in different % of HNO_3 solution	7days Split tensile strength(Mpa)	28 days split tensile strength (Mpa)	60 days split tensile strength(Mpa)
1	M40	Water	3.1	4.12	4.13
2	M40	2% HNO3	3.06	4.00	4.04
3	M40	5% HNO3	2.98	3.96	4.1
4	M40	8%HNO3	2.64	3.62	3.96

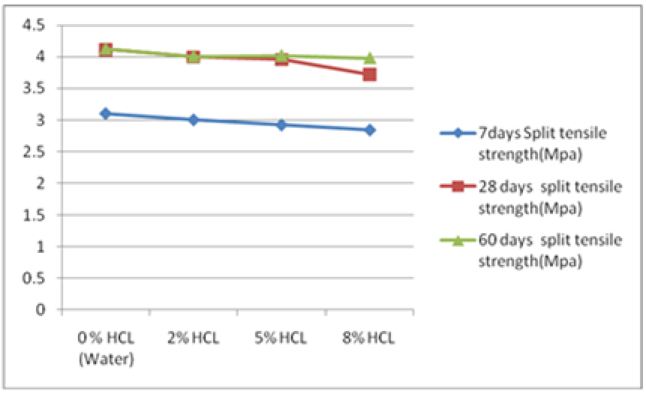

Fig 8.Effect of HNO_3 on split tensile strength of concrete at 7, 28 and 60 days

Fig 9.Flexural Testesting

Table 5.Effect of HNO_3 on flexural strength of concrete at 7, 28and 60 days.

Sl.No	Grade of concrete M40	Cured in different % of HNO_3 solution	7days Flexural strength (Mpa)	28days Flexural strength (Mpa)	60days Flexural strength (Mpa)
1	M40	Water	3.60	4.78	4.79
2	M40	2% HNO3	3.60	4.76	4.77
3	M40	5% HNO3	3.50	4.72	4.73
4	M40	8% HNO3	3.42	4.64	4.66

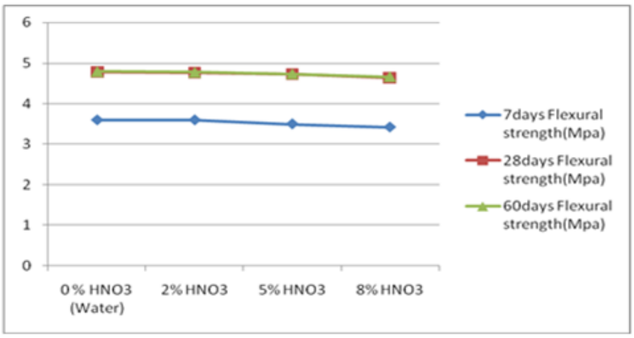

Fig 10.Effect of HNO_3 on flexural strength of concrete at 7, 28and 60 days.

Table 6.Effect of HCL on flexural strength of concrete at 7, 28 and 60 days .

Sl.No	Grade of concrete M40	Cured in different % of HNO_3 solution	7days Flexural strength (Mpa)	28days Flexural strength (Mpa)	60days Flexural strength (Mpa)
1	M40	Water	3.6	4.78	4.79
2	M40	2% HNO3	3.6	4.76	4.77
3	M40	5% HNO3	3.5	4.72	4.73
4	M40	8% HNO3	3.42	4.64	4.66

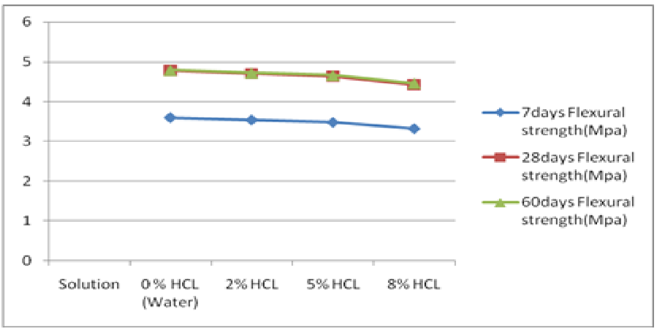

Fig 11.Effect of HCL on flexural strength of concrete at 7 , 28 and 60 days .

Durability Test Resistance Against Acid Attack

For acid attack test concrete cube of size 150 X150X 150 mm are prepared .The specimen are cast and cured in mould for 24 hours, after 24 hours, all the specimen are demoulded and kept in curing tank for 7-days. After 7-days all specimens are kept in atmosphere for 2-days for constant weight, subsequently, the specimens are weighed and immersed in 5% sulphuric acid (HNO_3) solution for 60-days. The pH value of the acidic media was at 0.3. The pH value was periodically checked and maintained at 0.3. After 60-days of immersing in acid solution, the specimens are taken out and were washed in running water and kept in atmosphere for 2-day for constant weight. Subsequently the specimens are weighed and loss in weight and hence the percentage loss of weight was calculated

IV. CONCLUSION

The following conclusions are drawn

1. Acidic curing environment have a negative effect on the compressive, flexural and tensile strengths as well as density of concrete cured in acidic water.
2. The strength of concrete decreases with both curing age and percentage concentration of acid in the curing water
3. A near linear relationship exists between loss in weight and strength as the percentage of acid increases
4. For Concrete structures that are to be set up in acidic environment, particular attention must be given to the design, a higher factor of safety for strength used and if possible, special cements used to sustain the effect of the deterioration due to the acidic environment.

5.To over come the acid attacks on concrete, acid resistant Novolac Epoxy floor coatings provides the highest level of protection against hundreds of different chemicals and acids. Novolac epoxies are a class of epoxy coatings that are specially made to resist caustic acid and chemical spills.

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