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DETERIORATION OF CONCRETE DUE TO ACID ATTACK

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Abstract:

A developing country like India has to show its development rapidly in the fields of infrastructure development, transportation and communication systems. The peninsular India is having a lengthy costal belt of around 7700 kms .the area surrounded by the cost are being utilized since ages. So inevitably, several national and international authorities are doing research and development on costal structure potential problems associated with these costal structures is acid attacks. Infrastructure facilities are developing day by day. Acid attacks the concrete and deteriorate it in many ways as corrosion, leaching etc. The increase in the concentration of acid content is directly proportional to the performance of the concrete. Concrete gets changes in its properties like compressive strength, flexural strength and split tensile strength. Now by taking into account of acid attack we have done an experimental study to know the performance of concrete when the powerful acids HNO3 NITIC ACID and HCL HYDROCHLORIC ACID attack it. We have studied the various strength properties of concrete at different concentration of acids, discussed the results and conclusions are drawn.

Keywords: HNO_3 , NITIC ACID,HCL HYDROCHLORIC ACID ,compressive strength, flexural strength.

1. Introduction

Concrete is a composite material composed of coarse aggregate bonded in to be shared mutually by fluid cement that hardens done in time. Maximum concretes usage are lime-based concretes ,for example, Portland cement concrete or concretes complete by other cement, for example ,for example, cement fondue. However, asphalt concrete, that is frequent usage for road surfaces, is too a type of Concrete, where the cement material is bitumen, and polymer concretes are usage where the cementing material is a polymer. After aggregate is mixed together with dry Portland cement and water, the Mixture forms a fluid slurry i.e. easily poured and molded into shape. The cement performs responds chemically by the water and other ingredients to form a hard matrix that binds the materials together into a durable stone-like material that has several usages. Frequent, additives (for example perhaps pozzolans or super plasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Maximum concrete is poured by reinforcing materials (for example rebar) embedded to provide tensile strength, yielding reinforced concrete. Famous concrete structures include the Hoover Dam, the Panama Canal, and the Roman Pantheon. The initial large-scale usages of concrete technology were the ancient Romans, and concrete stood extensively usage in the Roman Empire.

The Colosseum in Rome stood built largely of concrete, and the concrete dome of the Pantheon is world's largest unreinforced concrete dome. Nowadays, large concrete structures (perhaps, dams and multi-story car parks) are usually complete by reinforced concrete. After the Roman Empire collapsed, usage of concrete became rare until the

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Technology stood redeveloped in the mid-18th century. Nowadays, concrete is maximum extensive usage human-complete material (measured by tonnage).

2. Composition of concrete

Several types of concrete are available, illustrious by the proportions of the main ingredients below. In this way or by the substitution for the cementations and Aggregate stages, the finished product can be tailored to its application. Strength, density, in addition, chemical and thermal resistance is variables.

Aggregate consists of large chunks of material in a concrete mix, generally coarse gravel or crushed rocks for example limestone, or granite, along by finer materials for example sand. To produce concrete from maximum cement (excluding asphalt), water is mixed by the dry powder and aggregate, that produces a semi-liquid slurry that can be shaped, typically by pouring it into a form. The concrete solidifies and hardens through a The Chemical process called hydration. The water reacts by the cement that bonds the other components together, making a robust stone-like material. The Chemical admixtures are added to achieve varied properties. These ingredients may accelerate or slow down the rate at that the concrete hardens, and impart several other useful properties including rise enlarged tensile strength, entrainment of air and water resistance.

CEMENT

Portland cement is maximum mutual type of cement in general usage. It is a basic ingredient of concrete, mortar and several plasters. British masonry worker Joseph Aspdin patented Portland cement in 1824.

Fig 1. Opc 53 grade cement bags

Water:

Combining water by a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids by it, and makes it flow extra freely.

Aggregates:

Sand, natural gravel, and crushed stone are usage mainly for this purpose. Recycled aggregates (from construction, demolition, and excavation waste) are Increasingly usage as limited replacement for natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are too permitted.

Reinforcement

Concrete is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail.

Fig 2.constructing a rebar cage

Chemical admixtures

Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable by plain concrete mixes. In normal usage, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing.

Property	Portland Cement
SiO2 content (%)	21.9
Al2O3 content (%)	6.9
Fe2O3 content (%)	3
CaO content (%)	63
MgO content (%)	2.5
SO3 content (%)	1.7
Specific surface b (m2/kg)	370
Specific gravity	3.15
General usage in concrete	Primary binder

Fig 3.Mineral admixtures and blended cement

3. ACID ATTACK ON CONCRETE

Ordinary Portland Cement (OPC) is highly alkaline in nature by pH values above 12. When the cement paste comes into contact by the acids its components Break down, this phenomenon is known as acid attack. If pH decreases to values lower than stability limits of cement hydrates, then the corresponding hydrate loses calcium and decomposes to amorphous hydrogel. The final reaction products of acid attack are the corresponding calcium salts of the Acid in addition as hydrogels of silicium, aluminum, and ferric oxides.

Effect of Sulphuric Acid on Concrete:

Sulphur acid attack causes extensive formation of gypsum in the regions close to the surfaces, and tends to cause disintegration and mechanical stresses that Ultimately lead to spalling and exposure of the fresh interior surface. Normally, the chemical changes of the cement matrix are restricted to the regions close to the surfaces because of less penetration of the Sulfuric acid in concrete. The chemical reactions involved in sulphuric acid attack on cement based materials can be given as follows:

$$Ca(OH)_2 + H_2SO_4 \Longrightarrow CaSO_4.2H_2O$$
$$3CaO.2SiO_2.3H_2O + H_2SO_4 \Longrightarrow CaSO_4.2H_2O + Si(OH)_4$$

Effect of Nitric Acid on Concrete

Nitric acid usually occurs in chemical plants producing explosives, artificial manure and other similar products. Nitric acid can be formed from the compounds and radicals of nitrates in the presence of water.

$$3NO_2 + H_2O \Longrightarrow 2HNO_3 + NO$$

Nitric acid attack is a typical acidic corrosion for shrinkage of the corroded layer due to leaching of highly soluble calcium nitrate. Such volume contractions of the corroded layer, especially for the case of nitric acid, can result in the formation of visually observable cracks across the corroded layer.

Effect of Acetic Acid on Concrete:

The silage effluents containing mainly acetic and lactic acid may attack concrete in usage in agricultural applications. Acetic acid reacts by cement hydration products to form calcium acetate.

$$2CH_3COOH + Ca(OH)_2 \Longrightarrow Ca(CH_3COO)_2 + 2H_2O$$
$$2CH_3COOH + C\text{-}S\text{-}H \Longrightarrow SiO_2 + Ca(CH_3COO)_2 + 2H_2O$$

Hydrochloric Acid Attack on Concrete:

The chemicals formed as the products of reaction between hydrochloric acid and hydrated cement stages are some soluble salts and some insoluble salts. Soluble salts, maximum by calcium, are subsequently leached out, whereas insoluble salts along by amorphous hydrogels, remain in the corroded layer.

$$Ca(OH)_2 + 2HCl \Longrightarrow CaCl_2 + 2H_2O$$

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.

Carbonic acid attack:

Carbonic acid attack usually occurs in the case of buried concrete structures visible to acidic ground water fro a long time. Atmospheric carbon dioxide Absorbed by rain enters ground water as carbonic acid.

Carbonic acid attacks are:

- Quality of concrete
- Concentration of aggressive carbon dioxide
- External exposure conditions

$$H_2CO_3 + Ca(OH)_2 \Longrightarrow CaCO_3 + 2H_2O$$
$$H_2CO_3 + CaCO_3 \Longrightarrow Ca(HCO)_3$$

Decomposition of cement hydration products, leading to formation of gel-like layer consisting of hydro gels of silica, alumina and ferric oxide.

4. DIFFERENT ATTACKS ON CONCRETE

Concrete degradation may have various causes. Concrete can be damaged by fire, aggregate expansion, sea water effects, bacterial corrosion, calcium leaching, physical damage and chemical damage (from carbonization, chlorides, sulfates and distilled water). This process adversely affects concrete visible to these damaging stimuli

- **Aggregate expansion**

Various types of aggregate undergo chemical reactions in concrete, leading to damaging expansive phenomena. The maximum mutual are those containing reactive silica, that can react (in the presence of water) by the alkalis in concrete (K2O and Na2O, coming principally from cement).

Fig 4.Aggregate expansion

- **Corrosion of reinforcement bars**

the expansion of the corrosion products (iron oxides) of carbon steel reinforcement structures may induce mechanical stress that can cause the

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formation of cracks and disrupt the concrete structure.

- Chemical damage

a. **Carbonization**

Carbon dioxide from air can react by the calcium hydroxide in concrete to form calcium carbonate. This process is called carbonatation, that is essentially the reversal of the chemical process of calcination of lime taking place in a cement kiln.

b. **Chlorides**

Chlorides, particularly calcium chloride, have been usage to shorten the setting time of concrete.

c. **Sulfates**

Sulfates in solution in contact by concrete can cause chemical changes to the cement, that can cause significant micro structural effects leading to the weakening of the cement binder (chemical sulfate attack).

d. **Leaching**

When water flows through cracks present in concrete, water may dissolve various minerals present in the hardened cement paste or in the aggregates, if the solution is unsaturated by respect to them. Dissolved ions, for example calcium (Ca2+), are leached out and transported in solution some distance.

e. **Decalcification**

By set concrete there remains some free "calcium hydroxide" (Ca (OH) 2), that can further dissociate to form Ca2+ and hydroxide (OH−) ions". Any water that finds a seepage path through micro cracks and air voids present in concrete.

f. **Sea water**

Concrete visible to seawater is susceptible to its corrosive effects. The effects are extra pronounced above the tidal zone than where the concrete is permanently submerged. In the submerged zone, magnesium and hydrogen carbonate ions precipitate a layer of brucine, about 30 micrometers thick, on that a slower deposition of calcium carbonate as aragonite occurs.

- Bacterial corrosion

Bacteria themselves do not have noticeable effect on concrete. However, sulfate-reducing bacteria in untreated sewage tend to produce hydrogen sulfide, that is in oxidized by aerobic bacteria present in biofilm on the concrete surface above the water level to sulfuric acid.

- **Physical damage**

Damage can occur during the casting and de-shuttering processes. For instance, the corners of beams can be damaged during the removal of shuttering because they are less effectively compacted by means of vibration (improved by using form-vibrators).

- **Thermal damage**

Due to its low thermal conductivity, a layer of concrete is frequently usage for fireproofing of steel structures. However, concrete itself may be damaged by fire. An example of this stood the 1996 Channel fire, where the fire reduced the thickness of concrete in an undersea tunnel connecting France by England.

- **Radiation damage**

Exposure of concrete structures to neutrons and gamma radiations in nuclear power plants and high-flux material testing reactor can induce radiation damages in their concrete structures.

4. Literature review

Madhusudhana Reddy,et.al, Presented the effect of sulphuric acid (H2SO4) on Blended Cement (fly ash based(BC)) and its concrete. The BC and its concrete BCC produced with H2SO4 dosage of 100, 150, 300, 500 and 900 mg/l added in deionised water. In addition to this control specimens were prepared with deionised water (without H2SO4) for comparison. The setting times and compressive strength were evaluated for 28 and 90 days apart from studying rapid chloride ion permeability. The results show that, as H2SO4 concentration increases, there is retardation in initial and final setting of cement (BC). The compressive strength of BCC has come down with an increase in the32 concentration of H2SO4 at both 28 and 90 days. Compressive strengths of BCC have decreased in the range of 2 to 23%, with an increase in H2SO4 concentration, when compared with the control specimens. It was also observed that chloride ion permeability has increased with an increase in the concentration of the acid. X-ray diffraction analysis has been carried out for BCC specimens at H2SO4 concentration of 300 mg/l in

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deionised water. The following observations were made from the experimental work.

1. Both initial and final setting times of BC got retarded with an increase in sulphuric acid concentration in deionised water.
2. The retardation for initial and final setting times is significant (i.e., more than 30 minutes), when the acid content exceeds 300 mg/l.
3. Continuous decrease in compressive strength BCC specimens prepared with H_2SO_4 acid solution is observed as the acid concentration increases till the maximum concentration (900 mg/l) tested.

5. MIX DESIGN

MIX DESIGN FOR M 40 GRADE :

Material	Water	Cement	Fine aggregate	Coarse aggregate
Kgs/cum	197.2	493	604	1164
Ratio	0.40	1	1.23	2.36

6. EXPERIMENTAL STUDIES

A. slump cone test

B. compaction factor test:

C. Concrete test procedures

Now we are considering two acids HNO_3 Nitric acid and HCL Hydrochloric acid with different concentrations and mixing separately into water and treating cubes in the tubs which contain acid mixed water . After treating for 7, 28 and 60 days we use to takes cubes out for the interval of times and tests under lab.

D. Compressive strength

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

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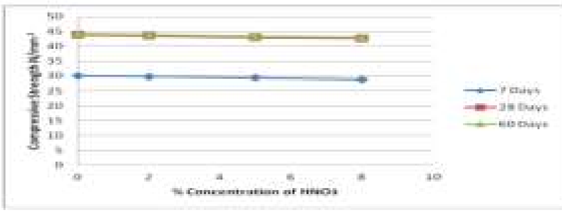
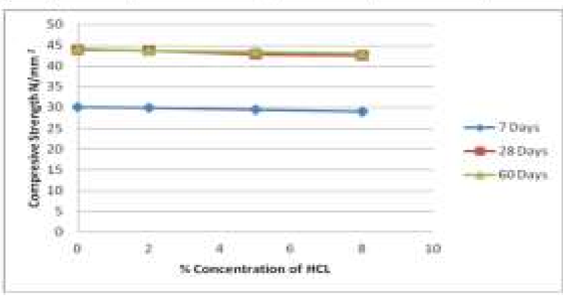
Sl. No	Grade of concrete M40	Cured in different % of HNO_3 solution	7 days strength (MPa)	28 days strength (MPa)	60 days strength (MPa)
1	M40	0 % HNO3 (Water)	30	44	44.3
2	M40	2% HNO3	29.8	43.6	43.9
3	M40	5% HNO3	29.4	43.1	43.4
4	M40	8% HNO3	28.9	42.8	43.0



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

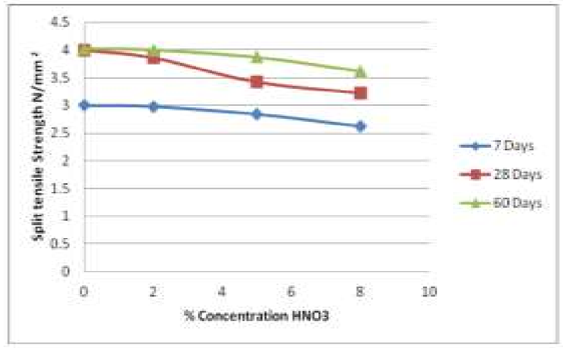
Sl. No	Grade of concrete M40	Cured in different % of HCL Solution	7 days strength (MPa)	28 days strength (MPa)	90 days strength (MPa)
1	M40	0 % HCL (Water)	30	44	44.3
2	M40	2% HCL	29.84	43.8	43.76
3	M40	5% HCL	29.42	42.88	43.5
4	M40	8% HCL	29.02	42.64	43.1



E. Split tensile strength

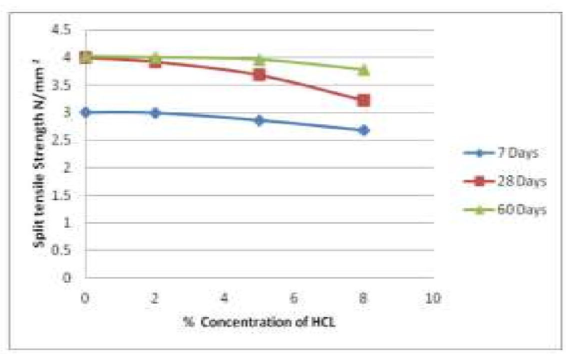
Effect of HNO3 on Split tensile strength of concrete at 7 days, 28 days and 60 days .

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	0 % HNO3 (Water)	3.0	4.0	4.02
2	M40	2% HNO3	2.98	3.86	4
3	M40	5% HNO3	2.84	3.42	3.87
4	M40	8% HNO3	2.62	3.22	3.62



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

Sl. No	Grade of concrete M40	Cured in different % of HCL Solution	7days Split tensile strength(Mpa)	28 days split tensile strength(Mpa)	60 days split tensile strength(Mpa)
1	M40	0 % HCL (Water)	3.0	4.0	4.02
2	M40	2% HCL	2.99	3.92	4
3	M40	5% HCL	2.86	3.68	3.96
4	M40	8% HCL	2.68	3.22	3.78



F. Flexural Strength

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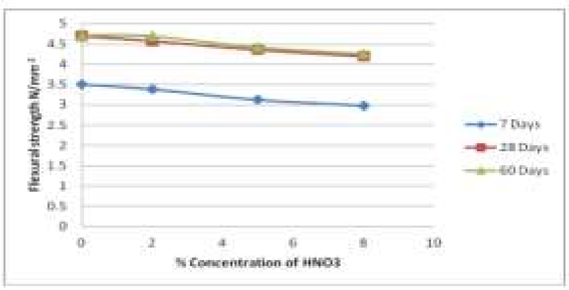
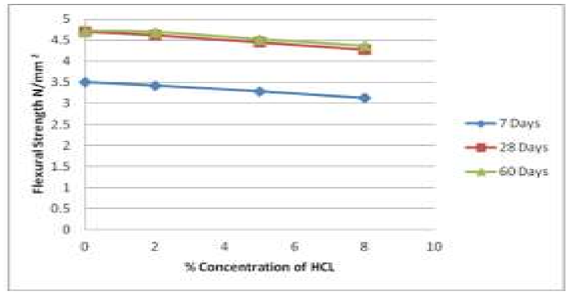
Effect of HNO3 on flexural strength of concrete at 7 days, 28 days and 60 days .

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	0 % HNO3 (Water)	3.5	4.7	4.72
2	M40	2% HNO3	3.38	4.58	4.7
3	M40	5% HNO3	3.12	4.36	4.42
4	M40	8% HNO3	2.98	4.20	4.26



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

Sl.No	Grade of concrete M40	Cured in different % of HCL Solution	7days Flexural strength(Mpa)	28days Flexural strength(Mpa)	60days Flexural strength(Mpa)
1	M40	0 % HCL (Water)	3.5	4.7	4.72
2	M40	2% HCL	3.42	4.62	4.69
3	M40	5% HCL	3.28	4.45	4.52
4	M40	8% HCL	3.12	4.28	4.36



7. CONCLUSIONS

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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