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Degradation of Building Materials by Corrosive Pollutants

Rajesh Kumar Singh[1,*], Pankaj Kumar Singh[2], Deepmala Kumari[3]

Abstract

Fiber reinforced polymers (FRP) is used for the corrosion suppression of reinforced concrete structures (RCS). One of the main issues with reinforced concrete constructions is corrosion. It interacts with acids, alkalis and salts to produce disintegration in building materials components. Pollutants and effluents speed up disbanding inside and outside reinforced structures. Bio-wastes come in contact of building materials to develop miro and macro-organism and these organisms release acid substances to accelerate corroding effect. Hostile agents like acid rain, greenhouse gases, global warming, heat waves, climate change, humidity and moisture also create deformation in building block components. Sea weather has availability of chloride ions to corrode iron bar in reinforced concrete. Building materials corrosion enhance due to increase atmospheric temperature. Particulates aggravate corrosion of building materials. Corrosive substances attack on interface of reinforced structures and some enter inside osmosis or diffusion process thus chemical, biochemical and electrochemical occurs among them. Rebar steel corrodes in such ambient environment and develop various form corrosion like galvanic, pitting, crevice, stress, intergranular, blistering, embrittlement, erosion, cavitations etc. It produces disbanding between rebar steel and concrete. Some gases absorb moisture to exhibit swelling and dissolving corrosion on the surface concrete structures. Corrosion reactions alter physical, chemical and mechanical properties of building block components and tarnish facial appearance. The fiber reinforced polymers used to control corrosion reinforced concrete. Developed countries spend 4% of their gross national product on corrosion prevention, part replacement, and upkeep. The primary sources of corrosive substances include mining, thermal power plants, petroleum refineries, burning fossil fuels, chemical wastes, biological wastes, human wastes, household wastes, agricultural wastes, animal wastes, food grain wastes, hospital wastes, chimney flue gases, and industrial effluents. As effluents, these sources emit acids, alkalis, salts, organic compounds, metals, carbon oxides, nitrogen oxides, sulfur oxides, halogen oxides, sulfur hydride, nitrogen hydride, volatile organic compounds as flue gases, and various wastes. Water, air, and soil are all contaminated by these toxins. The fundamental building elements for R C structures include sand, stones, cements, iron bars, bricks, and water. The corrosive compounds listed above create an unfavorable environment for building materials. This corrosive impact shortens the life of RC structures and causes internal and external disintegration, raising doubts about their stability, lifespan, and durability. RC structures can be protected from corrosion using a variety of methods. However, these methods did not provide them with adequate protection. Therefore, fiber-reinforced polymers will be used in this effort to control RC structure corrosion.

Keywords: Building materials, effluents, pollutants, flues gases, wastes, acid rain, weather, r c structures and fiber reinforced polymers.

***Author for Correspondence**
Rajesh Kumar Singh
E-mail: rks_jpujc@yahoo.co.in

[1]Associate Professor, Department of Chemistry, Jagdam College, J.P. University, Chapra, Bihar, India
[2]Research Scholar, Department of Chemistry, J.P. University, Chapra, Bihar, India
[3]Research Scholar, Department of Chemistry, Jagdam College, J.P. University, Chapra, Bihar, India

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INTRODUCTION

Corrosive substances [1] attack on concrete external of surface and produce destructive effect. Contaminated cement, water, and ballast are the main causes of corrosion reactions in concrete. Concrete is typically mixed with natural water [2]. Before the cement hardens, a variety of chemicals undergo chemical interactions with water. Corrosive environments are created by substances such as heavily contaminated waterways, bog waters, and industrial effluents that may contain carbohydrates or other organic compounds. Through an electrochemical process, chloride ions erode reinforcement. Pure water must be used in order for concrete to develop. In the process of making cement [3], chalk, magnesia, and sulfate are applied with difficulty. External corrosive contaminants cause set concrete to corrode.

In general, water or aqueous solutions have an impact on chemical attack on concrete and mortar. Dust particles and corrosive gasses can have a detrimental impact on mortar and concrete. These contaminants [4] penetrate the interior of mortar and concrete, starting a chemical reaction that causes disbonding between them.

Cement, ballast, and reinforced steel make up concrete [5]. When confronted with hostile media, the ballast usually stays stable. On the other hand, gypsum can crystallize in the presence of sulphate and cause the concrete structure to crack by swelling in ballasts that contain mica sheets, limestone, and some other ballasts that dissolve in acidic water. Although polymeric compounds are used to protect reinforced concrete structures from corrosion [6], they do not perform well in corrosive environments. After penetrating coated polymers and causing disbanding, corrosive pollutants eventually find their way within reinforced concrete, corroding building components, including rebar steel. The attacks of corrosive contaminants slow down when it is reinforced with fiber [7].

Experiment

The component of concrete that is most vulnerable to assault is the cement. One of the most crucial building materials available today is Portland cement. It is made by heating a clay and limestone mixture to extremely high temperatures. It is combined with a small amount of water and solidifies into a product that resembles hard stone in a matter of hours. Chemically speaking, Portland cement [8] is a finely ground mixture of silicates and calcium aluminates of different compositions that hydrate when combined with water to create a solid, rigid structure with high compressive strength [9]. Portland cement is made by combining the ingredients in Table 1 [10].

Table 1. Composition of Portland cement

Formula	Abbreviation	Name
$2CaO.SiO_2$	C2S	Dicalcium silicate
$3CaO.SiO_2$	C3S	Tricalcium silicate
$3CaO.Al_2O_3$	C3A	Tricalcium aluminate
$4CaO.Al_2O_3.Fe_2O_3$	C4AF	Tetracalcium alumino ferrite
$CaSO_4.2H_2O$	Cs.2H	Gypsum

It is created through interactions with water from the Portland cement clinker phase [11]. Tricalcium aluminate is a common reaction that produces over 50% of Portland cement by weight. It demonstrates the intricate process of cement hydration;

$$2(3CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2 \quad (1)$$

Calcium hydroxide, hydrated calcium silicate [12], and reaction products from calcium aluminate (such as hydrated tetracalcium aluminate) and calcium aluminate ferrate make up the set cement. Calcium hydroxide is the cause of the alkaline character of the set cement (PH > 12), although hydrated calcium silicate in particular strengthens concrete [13]. Figure 1 illustrates the detrimental effects of various aggressive media on concrete. The products of hydration [14] behave differently against these media.

Set concrete corrodes when a variety of corrosive substances react, such as chemically pure water, inorganic and organic acids, alkalis, plant and animal fats and oils, mineral oils, coal tar distillates, and aqueous solution, as seen in Figure 2 [15]. When these unfriendly materials [16] come into contact with cured concrete, a chemical reaction occurs and material damage occurs.

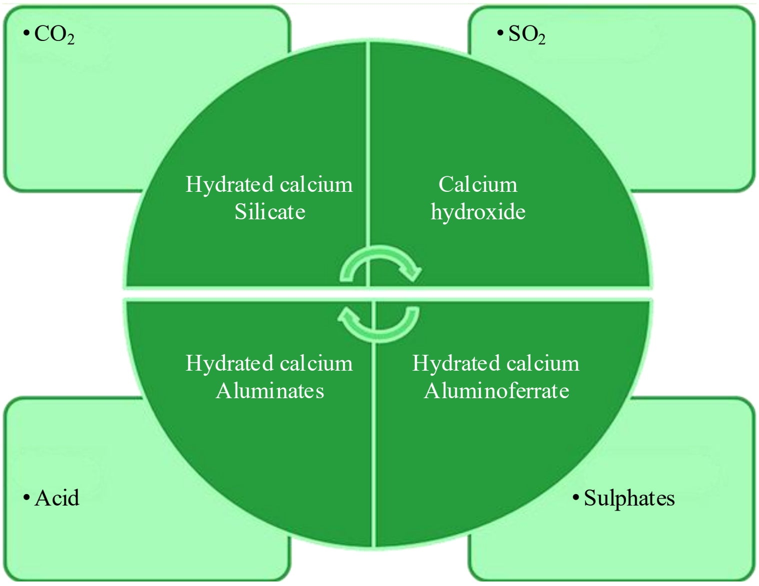

Figure 1. Corrosive substances attack on concrete.

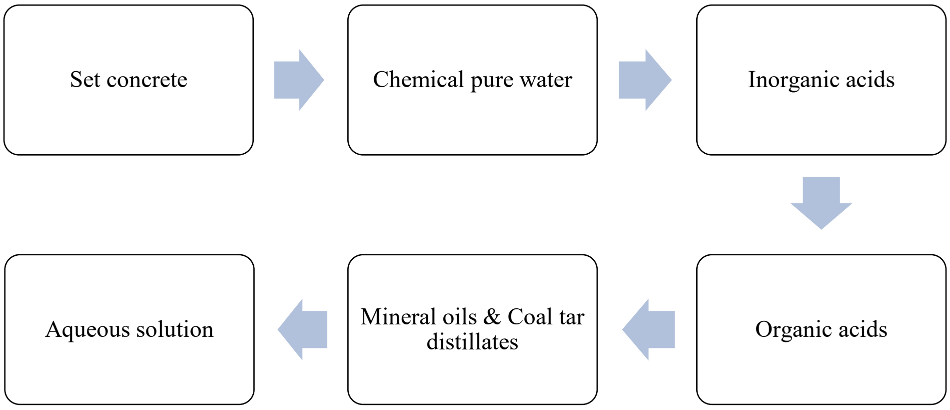

Figure 2. Set cement corroding substances.

Table 2 describes the many kinds of corrosive materials [17] and also shows how they corrode. Table 2's findings show that controlling corrosion in RCS is a difficult undertaking. However, FRP [18] coatings provide RCS with satisfactory results.

Table 2. Action of corrosive materials on set concrete.

S.N.	Material	Occurrence	Action
1	Chemical pure water	Water of condensation rainwater, molten snow soft spring water	Dissolves, leaches out active in practice
2.	Inorganic acids (HCl, H_2SO_4, H_2SO_3, HNO_3 H_3PO_4, H_2SiO_4, H_2CO_3)	Chemical industry carbonic and sulphrous acids, natural waters	Dissolves, the stronger the acid the more intensely corrosive it is. Increasing activity is also found with falling pH value. H_2SO_4 Swelling effect. Carbonic acid corrosion. Depends upon free CO_2.
3.	Organic acids (acetic acid, lactic Acid, tannic acid, Formic acid, Oxalic acid)	During fermentation in dairies, canneries, fodder silos, dye works	Dissolves slowly can slow down setting process

	Humic acid	In soils and impure Ballast	Can attack slowly, depending upon type of humic acid
	Oxalic acid	Dyeworks, chemical Factories	Nondestructive
	Alkalis (sodium & Potassium	In the chemical industry	Dissolves only when highly concentrated
	Hydroxides) Plants & animal oils and fats	food industry and food trade	Loosens the structure dissolves by reaction of the fatty acids with calcium salts to form soft calcium soaps. Turpentine has no destructive effect.
4.	Mineral oils and Coal tar distillates	Engineering sheds, filling stations, refineries	As these materials are non-acidic, they are Nondestructive. All low Viscosity oils penetrate Concrete and act as Lubricants between set Cement and ballast to lossen structure. Phenol and cresol slowly corrode concrete.
5	Aqueous solution Mg2+	In natural and Industrial waters	Softens
	NH_4^+	Agricultural undertakings Artificial fertilizer factories	Dissolves
	SO_4^{2-}	In natural and industry waters	Swells
	pH <6.5	In natural and industry waters	Dissolves
	CO, CO_2	In natural water	Dissolves
	Na^+, K^+, Ca^{2+} & H_2CO_3 Na^+, K^+, Ca^{2+} Fe^{2+}, Fe^{3+} Al^{3+}, Si^{4+}, NO_3^-, PO_4^3 and SiO_3^{2-}	In natural and industrial waters	Not Harmful

Acid Corrosion: The strength [19] and concentrations of acids determine how corrosive they are. The powerful acids are hydrochloric acid, sulfuric acid, and nitric acid. All of the ingredients in set cement are dissolved by these acids [20], producing silica gel, calcium, aluminum, and iron salts. Weak acids, such as carbonic acid, and a variety of organic acids, including lactic acid and humic acid, combine with calcium molecules to generate water-soluble salts. After extended exposure, several kinds of damage are seen.

When organic molecules break down, hydrogen sulfide [21] is produced as wastewater. Weak acid is produced when it dissolves in water [22]. It can be oxidized to form sulfur and sulfuric acid after being absorbed by the concrete's humidity [23]. In both cases, there is an acidic attack.

Flue gases contain SO_2 gas. In the presence of moisture and through oxidation, it can be transformed into sulfuric acid. Acid is also mostly to blame for this.

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While bog waters [25], paint and dyes, pharmaceuticals, food processing and preserving businesses, fruit juice manufacturers, breweries, and dairies all produce acids, effluents may contain strong acids [24].

[26] Limestone dissolves in carbonic acid. Its pH value is not the only indicator of its assault potential. It happens in water. Its even minute amounts give concrete a corrosive atmosphere. Lime can be dissolved from concrete by carbonic acid, which functions similarly to other weak acids. Although lime stone is only partially soluble in water, the presence of carbon dioxide increases its solubility [27]. This corrosion is not stopped by the addition of limestone.

$$\underset{\text{(Sparingly soluble)}}{CaCO_3} + H_2O + CO_2 \rightarrow \underset{\text{(Very soluble)}}{Ca(HCO_3)_2} \quad (2)$$

Salts Corrosion with Ion Exchange Properties: The set cement reacts with magnesium chloride [28] and ammonium chloride [29] to produce magnesium carbonate, magnesium sulphate, ammonium oxalate, and ammonium carbonate. The set cement contains calcium hydroxide [30], which combines with chloride to create compounds that dissolve in water. Swelling may result from magnesium compounds separating as hydroxide, a soft, gel-like material, either inside or outside. A gas known as ammonia [31] is emitted.

Soft Water Corrosion: There are fewer calcium and magnesium salts in soft water [32]. Because of this, comparatively high amounts of these salts can be dissolved by water in concrete. Although the surface can be attacked by very soft water (less than 1.1 milliequivalent total hardness), well built dense concrete can withstand even very soft water.

Fats and Oils Corrosion: Organic compounds, including plant and animal fats and oils, erode concrete [33]. Free fatty acids, which destroy concrete like other weak acids, are present in varying amounts in all of them. Calcium salts (soaps) of the fatty acids and glycerol can be formed when the fatty acids react with the calcium compounds in the set concrete. Concrete softens as a result of the fat's breakdown (saponification). Mineral oils [34] and fats don't damage concrete as long as they don't contain any acids or resins. If concrete is completely impregnated with fats and oils, it loses its hardness and strength of adherence to the steel reinforcement. In general, swelling activity is possible. When sulphate [35] solutions seep into concrete, chemical interactions between the calcium aluminate hydrates and various components of the set cement occur. Within the concrete, these create substantial new structures. The equation that follows provides:

$$3CaO.Al_2O_3 + 3(CaSO_4.2H_2O) + 26H_2O \rightarrow 3CaO.Al_2O_3.3CaSO_4.32H_2O \quad (3)$$

The addition of a significant amount of water of crystallization results in the production of crystalline trisulphate, which has a volume significantly greater than the solid starting components. Because of the restricted amount of area it can occupy, it puts pressure on its surroundings, which causes cracking.

Cements with low trisulphate content can prevent this sulphate expansion. Very high sulphate concentrations (1200 mg SO42-/litter) in the cured concrete may cause gypsum to segregate from the calcium hydroxide solution. Swelling is another effect of this. Sulfate is mostly found in wastewater and groundwater.

RESULTS AND DISCUSSIONS

Fiber reinforced polymers for RCS Protection: Over time, different environmental conditions have less of an impact on fiber-reinforced polymers than on other construction materials. Weather fluctuations, such as changes in ambient temperature, air moisture in the form of fog, rain, snow, hail, and water vapor, air pollutants, UV radiation, wind, etc., do not have an immediate impact on the aging process. Chemical agents (such as oxygen and salt solution) and physical elements (such as mechanical forces and static electricity) have no bearing. The use of FRP can help reduce other variable processes, such as chemical reactions including oxidation, displacement, and double displacement reactions. Fiber-reinforced polymers prevent reinforced concrete structures from cracking by preventing water absorption, evaporation, swelling, dissolution, precipitation, and all other processes involved. Fiber-reinforced polymers [36] offer color, embrittlement, stability of surface structure, and chemical resistance. Special additives can be added to slow down the aging process. The additions, known as stabilizers, light filters, and antioxidants, respectively, are supposed to reduce oxidation tendencies, stabilize the chemical structure, and filter out UV and longer wave radiation. Fiber-reinforced polymers have excellent weather resistance and can prolong the life of construction components. Fiber-reinforced polymers, including polytetrafluorethylene (Teflon, etc.), polyamides, polystyrene, polyethylene, polyvinyl chloride, phenolic and amino plastics, and others, show good corrosion protection and weather resistance [37]. These reinforced polymers and concretes are not negatively impacted by the aging reactants. Table 3 lists several significant polymeric compounds that can shield reinforced concrete in both acidic and alkaline environments.

Table 3. Chemical resistance fiber reinforced polymers in acidic and alkali

Polymers	**Acids**		**Alkalis**	
	Weak	***Strong***	***Weak***	***Strong***
Polyvinly Chloride(PVC)	Effective	Effective	Effective	Effective
Polyethylene(PE)	Effective	Effective	Effective	Effective
Polypropylene(PP)	Effective	Effective	Effective	Effective
Polyisobutylene(PIB)	Effective	Effective	Effective	Effective
Polystyrene(PS)	Effective	Effective	Effective	Effective
PolymethylMethacrylate (PMMA)	Effective	Effective	Effective	Effective
Phenolic resins	Effective	Noneffective	Effective	Noneffective
Melamine formaldehyde	Effective	Noneffective	Effective	Noneffective
Urea Formaldehyde	Effective	Noneffective	Effective	Noneffective
Polyesterresins(UP)	Effective	Effective	Effective	Non effective
Polyamides(PA)	Noneffective	Noneffective	Effective	Noneffective
Polyurethane(PUR)	Effective	Noneffective	Effective	Effective
PolytetraFluoroethylene PTFE)	Effective	Effective	Effective	Effective
Epoxy Resins(EP)	Effective	Effective	Effective	Effective
Polycarbonate(PC)	Effective	Effective	Effective	Effective

The polymeric polymers listed in Table 4 can prevent organic solvents from attacking reinforced concrete. These polymeric compounds are applied to the surface of RC structures and shave foundation building materials.

In RC, fiber-reinforced polymers [38] are utilized to prevent corrosion. The structures provided in Tables 5 and 6 describe how stable plastic protective coatings are against various aggressive media. Rebar steel is protected by epoxy resins with polyamide hardener and chlorinated rubber. Pipelines that are to be buried in concrete are wound around with polyethylenes [39]. Polyvinyl chloride is used to make acid-proof coatings and claddings. For instance, polytetrafluorethylene can be used to coat sheet steel and cover exterior buildings in marine weather environments because of its exceptional resistance to aggressive media. Polyurethane lacquer is applied to aluminum to increase its resistance to chemicals and weather. Specific applications of fiber reinforced polymers for corrosion protection of building materials are often mentioned in conjunction with the relevant building material. In the conditions listed in Table 5, these fiber-reinforced polymers can effectively prevent corrosion in RC structures [40].

The building materials listed in Table 6 are corroded by certain minerals, plants, animals, oils, and fats. The use of specific fiber-reinforced polymers can safeguard RC structures in this climate.

Table 4. The Chemical resistance of solvents important polymers

Plastics	Solvents		
	Alcohols	Esters	Ketones
Polyvinly Chloride(PVC)	Effective	Noneffective	Noneffective
Polyethylene(PE)	Effective	Effective	Effective
Polypropylene(PP)	Effective	Effective	Effective
Polyisobutylene(PIB)	Effective	Effective	Effective
Polystyrene(PS)	Effective	Noneffective	Effective
PolymethylMethacrylate (PMMA)	Effective	Noneffective	Noneffective
Phenolic resins	Effective	Effective	Effective
Melamine formaldehyde	Effective	Effective	Effective
Urea Formaldehyde	Effective	Effective	Effective
Polyester resins(UP)	Effective	Effective	Effective
Polyamides(PA)	Effective	Effective	Effective
Polyurethane(PUR)	Noneffective	Effective	Effective
Polytetra Fluoroethylene (PTFE)	Effective	Effective	Effective
Epoxy Resins(EP)	Effective	Effective	Effective
Polycarbonate(PC)	Effective	Noneffective	Noneffective

Table 5. The chemical resistance of fuels important plastics

Fiber Reinforced Polymers	Benzene	Gasoline	Mixture of fuels
Polyvinly Chloride(PVC)	Noneffective	Effective	Effective
Polyethylene(PE)	Noneffective	Effective	Noneffective
Polypropylene(PP)	Effective	Effective	Effective
Polyisobutylene (PIB)	Noneffective	Effective	Effective
Polystyrene(PS)	Noneffective	Effective	Noneffective
PolymethylMethacrylate (PMMA)	Effective	Effective	Effective
Phenolic resins	Effective	Effective	Effective
Melamine formaldehyde	Effective	Effective	Effective
Urea Formaldehyde	Effective	Effective	Effective
Polyester resins(UP)	Effective	Effective	Noneffective
Polyamides(PA)	Noneffective	Effective	Noneffective
Polyurethane(PUR)	Effective	Effective	Effective
PolytetraFluoroethylene (PTFE)	Effective	Effective	Effective
EpoxyResins (EP)	Effective	Effective	Effective
Polycarbonate(PC)	Noneffective	Effective	Effective

Table 6. The Chemical resistance of fuels important fiber reinforced polymers

Fiber Reinforced Polymers	Mineral	Animal and plant	Oils and fats
Polyvinly Chloride(PVC)	Noneffective	Effective	Effective
Polyethylene(PE)	Noneffective	Effective	Noneffective
Polypropylene(PP)	Effective	Effective	Effective
Polyisobutylene(PIB)	Noneffective	Effective	Effective
Polystyrene(PS)	Noneffective	Effective	Noneffective
Polymethyl Methacrylate (PMMA)	Effective	Effective	Effective
Phenolic resins	Effective	Effective	Effective
Melamine formaldehyde	Effective	Effective	Effective
Urea Formaldehyde	Effective	Effective	Effective

Polyesterresins(UP)	Effective	Effective	Effective
Polyamides(PA)	Noneffective	Effective	Effective
Polyurethane(PUR)	Effective	Effective	Effective
Polytetra Fluoroethylene (PTFE)	Effective	Effective	Effective
Epoxy Resins(EP)	Effective	Effective	Effective
Polycarbonate(PC)	Effective	Effective	Effective

Table 7 lists a few reinforced elastomers that prevent RC structures from corroding in the specified environment.

Table7. The chemical resistance of important elastomers

Elastomer	Mineral oil	Organic solvent	Water, acids, alkalis
Natural rubber	Noneffective	Noneffective	Effective
Chlorinated rubber	Effective	Noneffective	Effective
Polysulphide rubber	Effective	Effective	Effective
Silicone rubber	Effective	Effective	Noneffective
Polyurethane rubber	Effective	Effective	Noneffective

CONCLUSION

Reinforced concrete structures are coated with fiber-reinforced polymers, which do create a link between them. Osmosis and diffusion, which are produced by many hostile environments, are reduced by these protective compounds. Building materials disbond as a result of these two processes, which allow corrosive contaminants to penetrate concrete and start a corrosion reaction. For RC structures, the FRP coatings serve as reinforcement. However, because the surface of FRP has many porosities, which make it difficult to effectively control the osmosis and diffusion of pollutants, this form of coating does not yield satisfactory results over an extended period of time. They are capable of corroding RCS and FRP. Applying a nanocoating on the surface of FRP to prevent osmosis and diffusion is the solution to this issue.

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