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Chemical Attack on Concrete in Wastewater Treatment Plant: A Review

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ABSTRACT

Wastewater treatment plant (WWTP) has become one of the most important structures nowadays and concrete is considered to be the most suitable material for the construction of this kind of structure for its several useful properties like durability, compressive strength, impermeability, abrasion resistance, etc. However in an aggressive environment, with the effects of constituents of wastewater and different chemicals applied in the treatment process of wastewater, concrete's performance is greatly challenged. Chemicals like acid, sulfides, sulfates, salt, and gases generated from different reactions, micro-organisms, etc. can cause chloride ingress, carbonation, corrosion, sulfate attack, bio-deterioration and erosion of concrete in wastewater treatment plants. As a consequence, a large amount of money is spent on the maintenance and repair works for wastewater treatment plants every year. Therefore, the quality of the concrete used in structures like WWTP must be very high. This study aims to explore of the detrimental effects of various harmful chemicals on concrete in wastewater treatment plants, degradation mechanisms, and different methods of enhancing the resistance of concrete. The study also represents the current scenario of Bangladesh regarding this issue with help of some excellent references, codes, and guidelines of important organizations and practical surveys.

Keywords: Concrete, Chemical attack, Durability, Wastewater, Relative humidity, pH, and WWTP.

INTRODUCTION:

A wastewater treatment plant is a system that treats wastewater that is generated from sources like as in the residential areas, commercial areas, industrial properties, agriculture lands etc. by the physical, chemical & biological process. Speedy industrialization all over the world generates huge amounts of industrial wastewater. To protect the environment from the harmful effects of these wastewaters, the industries must discharge their harmful effluent after necessary treatment. Thus the construction of the structures like ETP (Effluent Treatment Plant), STP (Sewage Treatment Plant), Agricultural wastewater treatment plants, CETP (Combined Effluent Treatment Plant), etc. has become essential for the industries. Concrete for its durability, compressive strength, impermeability, abrasion resistance, and resistance to a highly aggressive environment (Mihai *et al.,* 2011; Hussain *et al.,* 2010; Wong *et al.,* 2013) is the most suitable material used for building treatment plant facilities. However, in an exposed condition, elements like the humidity, pH value, temperature, different kinds of bacteria, acid, hydrogen sulfide, chlorides, carbonation can cause deterioration of concrete and affect the lifespan of concrete (Wong *et al.,* 2013; Sarray and Anmar, 2013). Studies on the effect of the chemical on concrete have revealed many causes of concrete deterioration. Sarray and Anmar, (2013) investigated the aggresive influence of the wastewater on the concrete of wastewater plants like Gazimağusa plant, the EMU campus plant and Baquba-Iraq plant and also performed Laboratory test for compressive strength and permeability tests. Such investigations suggested some steps to achieve suitable the properties of concrete for these structures like low W/C ratio, high strength concrete, proper aggregate size, adding mineral admixture like Silica fume or the blast furnace slag, ensuring proper construction practice etc. These studies have become very important since detail specifications and guidelines are not available in many countries like Bangladesh especially for the construction of structures like the WWTP (Mahmud *et al.,* 2016).

Olonade's, (2016) study showed the scenario of concrete deterioration in Nigeria and highlighted the need for advanced research and technology regarding this problem. Advanced Studies on producing chemical resistant concrete are making the solution of many durability problems in WWTP. There is the future scope of incorporating proper guideline for durability issues and also studies on improving concrete's quality by using advanced technology such as Self-healing concrete, polymer modified concrete and others. Bassuoni and Nehdi's, (2007) study investigated the performance of self- consolidating concrete against the low pH environment; Tomkins and William, (2011) studied the performance of OPC, FAGC (Fly Ash Geopolymer Concrete) & RMGC (Red Mud Geopolymer Concrete) against harmful chemicals, where the RMGC samples had shown significantly higher resistance. The objective of this study is to explore the effects of the chemicals in wastewater and also the chemicals used in the treatment process on concrete, steps to be taken in order to reduce the harmful effects of these chemicals on concrete, with the reference of some excellent research works and guidelines of codes. This study also aims at the representing the present scenario regarding this issue here in Bangladesh.

Chemical Used in Wastewater in the Treatment Plants

Common constituents of wastewater are organic and inorganic substances, different types of the ions, ammonia, various kinds of gases, excreta, protein, nitrate, and other pollutants like microorganisms, etc (Jinadasa *et al.,* 2018). In the different chamber of WWTP, chemicals are used such as for the pH correction alkaline substances like calcium oxide or lime, calcium hydroxide, a hydrated form of lime, magnesium oxide, Sodium hydroxide (caustic soda); magnesium hydroxide etc. Also acidic chemicals like Sulfuric acid (H_2S0_4), Hydrochloric acid (HCl) or muriatic acid and even sometimes gaseous sulfur dioxide or carbon dioxide (CO_2) are used in this tank. Coagulant chemicals like Ferric Chloride ($FeCl_3$), Aluminum Chloride ($AlCl_3$) and Aluminum Sulfate [$Al_2(SO4)_3$] etc. and the polymers as the flocculent chemicals are used in coagulation and flocculation chamber. The NaOCl, $Ca(OCl)_2Cl_2$, Chlora- mines, Ozone, UV irradiation as Disinfectants are used in the disinfection tank in WWTP (Tomkins and William, 2011). In case of the biological treatment process, both the aerobic and anaerobic micro-organisms are used to perform carbon oxidation, nitrification and de-nitrification, acidogenesis, and methanogenesis (Jinadasa *et al.,* 2018).

Effects of Wastewater on Concrete

There are different types of chemicals used in the different chamber of WWTP, which along with wastewater itself had different harmful effects on concrete. In neutralization tank, applied alkaline and the acidic solution can affect concrete by resulting in chloride ingress, sulfate attack, acid attack etc.

In aeration tank or anaerobic chamber, acidic chemicals are formed by the microbiological action when it breaks down the toxic elements of waste water. This acidic chemical increases the risk of corrosion of concrete as well as for the embedded reinforcement (Parker, 1945). Erosion also can take place in the aerated nitrification chamber due to biodeterioration of the concrete surface (Leemann *et al.,* 2010). After construction, the WWTP starts running the degradation process such as chloride ingress, the carbonation, corrosion, sulfate attack, bio-deterioration, erosion, etc (Bastidas *et al.,* 2008). Along with these chemical effects, external stress on concrete in this aggressive environment rises and speeds up the deterioration of the concrete (Schneider *et al.,* 2005).

Effects of WWTP's Environment on Concrete (Temperature, pH, Humidity)

Steel bar and concrete's properties are affected by the pH value of the wastewater to which concrete is exposed (Sarray & Anmar, 2013). Acidic chemicals discharged into the wastewater, hydrogen sulfide gas resulting from chemical reactions in the wastewater system is responsible for lowering the pH of concrete. Microbes are also known to produce acid in concrete and reduce its pH (Noeiaghaei *et al.,* 2017). The lower value of pH causes acid and sulfate attacks which are known to be the major factors which cause internal corrosion of embedded reinforcement in wastewater treatment plants (Parande *et al.,* 2006). When the value of pH in concrete reduces from 13 to 9, the increased permeability of concrete causes deterioration of concrete cover and steel bars (Islander *et al.,* 1991; Shi *et al.,* 2000). **Table 1** represents the effect of relative humidity (RH) on steel bar corrosion in concrete (Gonzalez & Carmen, 1982; Davis *et al.,* 1998; Sanchez & David, 2008; Sand & Wolfgang, 1987).

Table 1: The effect of relative humidity (RH) on steel bar corrosion in Concrete.

Relative Humidity (%)	Corrosion threat	Remarks
Concrete submerged in water	Very small threat	Calcium hydroxide solution fills the Capillaries but difficult for oxygen to reach to steel
90 - 95	Small to medium threat	Pores filled solution makes it difficult for oxygen to reach the steel
60- 90	The greatest threat	Partially filled pores make it easy for Water and oxygen to reach steel
Below 60	No threat	Very little solution is available in pores
Concrete submerged in water	Very small threat	Calcium hydroxide solution fills the Capillaries but difficult for oxygen to reach to steel

At the time of the acid attack, the temperature of the sulfuric acid solution increases the deterioration by weakening the bonds between aggregates and cement paste (Mahmoodian *et al.,* 2017). Relative humidity is another important factor affecting bio-deterioration. The increased relative humidity of the concrete of WWTP increases the biological activity by increasing water availability and thus increases the deterioration (Noeiaghaei *et al.,* 2017). Under very high level of relative humidity, the oxygen accessibility gets limited as the pores of concrete gets blocked with moist and corrosion rate decreases as the flow of oxygen to cause the steel surface reduction (Hussain *et al.,* 2010). Under RH 60-90% pores are partially filled with water with access to oxygen which keeps concrete under high corrosion risk.

Effects of Microorganisms

Microbiologically Induced Deterioration (MID) of materials is known to be a very significant problem in the industrial sector and also in the wastewater treatment plants (Davis *et al.,* 1998). Even in case of unnoticeable cracks, microorganisms can penetrate into the concrete through the micro cracks and capillaries (Sanchez-Silva *et al.,* 2008). However, because of concrete's high alkalinity, it is less affected by the microorganisms immediately after construction when the pH is high (Sand *et al.,* 1987). Fungi, bacteria, algae, microorganisms etc. are mostly responsible for the erosion of concrete (Setareh and Javaherdashti, 2006; Gaylarde *et al.,* 2003). These organisms create a bio-film when they fix their position on a concrete surface and precede the chemical bio-deterioration of concrete. According to Sanchez-Silva and Rosowsky (Sanchez-Silva *et al.,* 2008) the steps of degrading concrete by micro-organisms happens gradually when they start eroding the exposed surface of the concrete. The clear cover gets reduced due to erosion and the increased porosity allows the free entry of degrading substances into the concrete that can speed up cracking, erosion, and other damages and reduce the durability of the structure. Both aerobic and the anaerobic bacteria can be present in WWTP. **Fig. 1** shows the effect of microorganism on Concrete Surface. The oxidation of organic substances by aerobic bacteria produces ammonia and hydrogen sulfide in the intermediary stages. Sulfates generated from oxidization of sulfur dioxide and sulfur can cause sulfate attack and organic acids like acetic, butyric, lactic acid and carbon dioxide can cause serious corrosion of concrete (Siripong *et al.,* 2007).

Fig. 1: The Effect of Microorganism on Concrete Surface.

The organism that settled on the concrete surface transforms the hydrogen sulfide into sulfuric acid which results in the corrosion of steel bars (Jahani *et al.,* 2001).

Effects of Sulfates and Acids

Sylhet Low pH industrial discharge and the silage Organic acids are discharged from canneries, the breweries, dairies and wood-pulp mills etc (ACI, 1979). Sulfuric acid (BSA), resulting from oxidization of the H_2S by aerobic bacteria where Sulfur stored as nutritive material in its cells can cause the acid attack on concrete in WWTP. In WWTP, Sulfate solutions can lead to sulfate attack and cause deterioration of concrete. Calcium sulfoaluminate or ettringite is formed in this process with the reaction of cement paste of concrete which has the largest volume and responsible for the crack in the concrete. Sulfuric acid has a severe effect on concrete because, besides the effects of sulfates, it adds the dissolution effects caused by the hydrogen ions (Attiogbe *et al.,* 1988; Mindess *et al.,* 1981). The sulfuric acid induced corrosion of concrete can be explained by following reactions (Monteny *et al.,* 2000; Marchand *et al.,* 2001).

$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4.2H_2O$ (Gypsum)	(1)
$CaSiO_2.2H_2O + H_2SO_4 \rightarrow CaSO_4 + Si(OH)_4 + H_2O$	(2)
$3CaO.Al_2O_3.12H_2O + 3.(CaSO_4.2H_2O) + 14.H_2O \rightarrow 3CaO.Al_2O_3.3CaSO_4.32H_2O$ (Ettringite)	(3)

Gypsum is generated on the concrete surface as the reaction product and is involved with the volume expansion. This can induce a large increase in the stress in concrete, resulting in cracks (Monteny *et al.,* 2001). If not cleared, gypsum can gather on the surface of concrete and decrease the corrosion rate by sealing the surface (Rendell *et al.,* 1999). Further reaction of gypsum can form ettringite when it has no cohesiveness (Mori *et al.,* 1992) with the calcium aluminates hydrates (C_3A) (equation 3) (Monteny *et al.,* 2000). Ettringite has more volume than that of gypsum. The rate of volume increase is 124% and 227% for the gypsum and ettringite respectively (Marchand *et al.,* 2001). As a consequence, this leads to more micro and macro-cracking in concrete. Moreover, sulfuric acid reduces the strength and durability of concrete (Aviam *et al.,* 2004; Haile *et al.,* 2010; Wei *et al.,* 2010) as it decalcifies calcium silicate hydrate (C–S–H).

Effects of Sulfates and Acids

H2S is formed by the action of sulfur-reducing bacteria and considered to be a strong corrosive agent (Olmstead & Hamlin, 1900). Generally, the effects of H_2S is not directly on concrete. Aerobic bacteria oxidizes H2S and produces sulfuric acid which is responsible for the deterioration of concrete that is called concrete Corrosion (Olmstead & Hamlin, 1900; Nica *et al.,* 2000; Roberts *et al.,* 2002). This sulfuric acid is known to be biogenic sulfuric acid or BSA. In closed structures like sewage facilities, wastewater treatment plants and other similar structures this type of problem is found very frequently. The reaction between BSA with the cementitious material can lead to a corrosion that weakens the concrete by forming ettringite and gypsum. If the capacity of concrete is damaged by this corrosion the structure may collapse.

Carbonation

Carbonation occurs when gaseous carbon dioxide penetrates within partially saturated concrete and series of different chemical reaction occurs at this time due to the diffusion into surface pores of the concrete. Calcium silicate hydrates (CSH) and calcium hydroxide mainly involve with the reaction (Jonkers *et al.,* 2010). Gaseous carbon dioxide first penetrates into concrete and generates CO_3^{2-} and HCO_3^-. The CO_3^{2-} precipitates $CaCO_3$ or calcite when reacts with dissolved calcium. This leads to the dissolution of portlandite when these reactions decrease the pH value (Glasser *et al.,* 2008). As a result of these reactions, concrete gets deteriorated and also having the risk of corrosion of the embedded steel bars. However, the environmental factors like humidity and temperature are the most influencing for carbonation because of the absence of water. CO_2 can't attack calcium hydroxide. A higher rate of carbonation is observed when the relative humidity is in the range of 50 to 70% (Neville and Adam, 2003). The carbonation rate also increases with the rising temperature (Maslehuddin *et al.,* 1996).

Methods for Improving the Chemical Resistance of Concrete

Concrete Composition

In case of wastewater treatment plant concrete, selection of concrete components such as cement, aggregates, water, and admixtures and proportioning should be done properly considering the effect of different harmful chemical and must reduce the permeability of concrete. Permeability in concrete can also be reduced by reducing the water-cement ratio below 0.5 and increasing the moist-curing period (Seifan *et al.,* 2016; Lawrence *et al.,* 2001). ACI 201.2R (ACI, 2001) describes in detail the general durability of concrete determined largely by the selection of the cement, aggregates, water, and admixtures. The class of cement plays an important key role in maintaining the chemical resistance of concrete in constructing structures like WWTP, from the viewpoint of the structures service life assessment. For the concrete subjected to severe exposure to sulfates and sulphuric acid solution, the low w/c ratio in concrete mixing and use sulfate resisting cement decrease the loss of mass of concrete (Hewayde *et al.,* 2007). C_3A is the most important factor of cement component in choosing cement against sulfate attack and for moderate exposure. Type II cement is limited to C_3A percentage of 8 under ASTM C150 (Tabat *et al.,* 2001). The cement paste generally retains the corrosion resistance of embedded steel by its alkaline character but this resistance can be lost by chloride ions (Barberon *et al.,* 2005) and carbonation. In case of chloride ions, higher- alkali cement provides a higher pH environment surrounding the steel and reduce the corrosion possibilities of the steel but Higher-alkali cement at the same time can increase the risk of alkali-aggregate reaction (ACI, 2001). The influence of aggregate in maintaining proper standard concrete for the WWTP should also be considered carefully. The size and grade of aggregate affect the water content and the workability because smaller aggregate sizes require more water. According to the ACI 222 (ACI, 2001) by considering the structural conditions & maintaining proper gradations, the water and cement contents can be reduced for a particular required w/c ratio. So, In case of structures like WWTP, low w/c ratio and low- permeability concrete are desirable and in the viewpoint of aggregate selection, preparing a low w/c ratio mixture is more economical based on 1-1/2 in. (37.5 mm) coarse aggregates than with 3/8 in. (9.5 mm) coarse aggregates. Further, the size and grade of aggregate also influence operation like pumping, placement, and by controlling slump (ACI, 2001). After the selection of the source of aggregate, once an aggregate source has been selected, careful observation is needed to monitor the moisture content of the course and fine aggregates as the failure in assessing the moisture content can increase the w/c ratio of the mixture, which can lead to the increase in permeability. Incorporation of the various kinds of admixtures, supplementary cementitious materials, and polymers are helpful in preparing lower w/c ratio and low permeable concrete (ACI, 2010). Admixtures like water reducers, super plasticizers, and air entraining agents are added to reduce the permeability of concrete. To produce high strength, low permeability concrete it needs a lower w/c ratio, but the low w/c ratio reduced the work- ability. To reduce the water required for a particular slump, the admixture is added and generally, 5% to 10% reduction of water content can be achieved by using typical water reducers (Seifan *et al.,* 2016). Application of supplementary cementitious material is effective to increase the durability. Limestone, blast furnace slag, fly ash and silica fume are used to improve the durability of concrete (Polder and Rob, 2012; Caballero *et al.,* 2007; Goyal *et al.,* 2009). The application silica fume (SF) and fly ash to ordinary Portland cement (OPC) increases concrete's the resistance against magnesium sulfates, hydrochloric acid, nitric acid, acetic acid, phosphoric acid and sulfuric acid (Roy *et al.,* 2001).

Self-Healing Technology

Technology For the environment like in WWTP, permeability is the most important factor for concrete as it is considered to be the fundamental property representing durability (ACI, 2010). Cracks can't be avoided in concrete (Seifan *et al.,* 2016). Moreover, in the WWTP environment, chemical effects influence crack formation and greater permeability of the concrete permits easy transportation of water can cause serious damage and it is essential to healing the cracks (Van *et al.,* 2010).

Self-healing agents such as epoxy, resin, bacteria like Bacillus cohnii (Jonkers *et al.,* 2010), Bacillus sphaerieus (Wang *et al.,* 2014), Escherichia coli, fiber-like polyethylene (PE) fibers (Li *et al.,* 2011), polyvinyl alcohol (PVA) fibers (Li *et al.,* 2011; Sahmaran *et al.,* 2009), chemical like calcium sulfoaluminates based agents and crystalline admixtures (Sisomphon *et al.,* 2011) etc are used to heal the cracks in concrete. Among this, the use of the bacterial agent to form self- healing concrete is more popular and effective than the others. Self- healing mechanism in concrete can be developed in three ways as capsule based healing, intrinsic healing and vascular healing (Blaiszik *et al.,* 2010).

Materials that have intrinsic self-healing properties of the cementitious mixture are responsible for intrinsic healing and in this mechanism, healing happens based on autongenous healing. Mainly the reaction of the polymeric substances is responsible for autogenous healing inside polymer- modified concrete. The autogenously healing mechanism is noticed as very effective in the healing of micro-cracks that develops on the surface of the concrete. The bacteria used as self-healing agent creates a film on the cracks of concrete and calcium carbonate is precipitated by the Microbiological action (Jonkers *et al.,* 2010; Wang *et al.,* 2014; Li *et al.,* 1998; Sahmaran *et al.,* 2009; Sisomphon *et al.,* 2011; Blaiszik *et al.,* 2010; Pei *et al.,* 2013). This precipitation assists the healing of the microcracks and also helps to hold the other materials like sand, gravel together in concrete (Dhami *et al.,* 2012). The mechanism of Capsule based self-healing is based on capsules inside of which an isolated a healing agent exists. At the time of damage when the capsules break the self-healing agents are released and by the reaction, it started the self-healing mechanism at that place.

Polymer and Polymer Modified Concrete

The use of polymer for modification of cement paste or concrete can also be a good option in case of the WWTP construction. In the polymer concrete, the polymer is used as a binder in the aggregate, whereas in polymer-modified concrete, the polymer is used along with Portland cement. ACI 548.1R-97 (ACI, 1997) provides the guideline for the application of polymer in concrete. The performance of these kinds of concrete has been studied for improving the resistance in case of exposure to aggressive chemicals like lactic, acetic, and sulfuric acid (Beeldens *et al.,* 2001). The application of polymers in the concrete reduces its permeability and slows down the entry of harmful chemicals like hydrogen sulfide, carbon dioxide, and different kind of micro- organisms. Reduction in permeability of concrete is achieved introducing polymer, because it provides reduces the pore dimension and block the pores by polymer particles (Beeldens *et al.,* 2001) and due to the blockage by the polymer film, pores cannot provide the access of gas, liquid, and other harmful chemicals through the concrete. The polymer can also assist in preparing high strength concrete as it helps to improve workability through its water reducing properties which help to prepare concrete with low w/c ratio. Polymer modification also improves the properties of the transition zone by improving the bridging action between the cement paste and the aggregates and providing relatively high-density polymer particles in the transition zone (Bijen & Su, 1995).

Some geopolymer concrete can also be a good option as it performs better than ordinary concrete as it provides high strength, high chemical and thermal resistance, reduced shrinkage, and the expansion (Tomkins & William, 2011). In the Geopolymer concrete, the alkaline activator solution is used which activates the geo polymeric source materials like fly ash and GGBS containing Si and Al and polymerizes these materials into molecular chains and networks to make an improved binder. Tomkins, (2011) investigated chemical resistance properties of OPC, FAGC (Fly Ash Geopolymer Concrete) & RMGC (Red Mud Geopolymer Concrete) and the RMGC samples had shown significantly higher resistance than all other samples.

Concrete Cover and Barrier Systems

When the quality of concrete cannot resist the effects of harmful chemicals special barrier system needs to be incorporated to control the deterioration. The effects of the aggressive chemicals can be resisted by applying the impermeable coating, the water stops, sealants etc. ACI 515.1R-85 (ACI, 1979) refers four major types of barriers as waterproofing; Damp-proofing; Protective; and Paint. In WWTP concrete can be attacked by different chemicals, produced harmful gasses, biological effects of bacteria, fungi, algae, so Selection of barrier system needs to consider these factors (Tabat *et al.,* 2001). Providing an increased clear cover is one of the simple practices to protect the embedded reinforcement.

Scenario in Bangladesh

Increasing Industrialization is increasing the factories and thus use of harmful chemicals in Bangladesh. In this circumstance, wastewater treatment plants have become one of the most important structures in the country. Due to the severe level of pollution of the growing industries like the pollution of tanneries, textile, pharmaceuticals, and fertilizer industries, the country has given importance in constructing WWTP. The Bangladesh Small and Cottage Industries Corporation (BSCIC) have built a Central Effluent Treatment Plant (CETP), a reinforced concrete structure that will treat tannery wastewater at Savar, Bangladesh, although it is not fully functional yet. Also, Pagla sewage treatment (PST) plant in Saidabad of capacity 120000 m^3/day is another big project. Otherwise, factories building their own treatment plant due to the imposed guideline of Department of Environment (DoE). These concrete structures are at high risk of deterioration if proper designing and construction procedure are not followed regarding the effects of harmful chemicals.

Environmental Condition

Environmental parameters like temperature, humidity, CO_2 content can affect the concrete structures, especially structures like WWTP as discussed before. According to (Srinivasana *et al.,* 2018), in future, the temperature can rise up 1.38-1.42°C by 2030 and 1.98- 2.35°C by 2050 in Bangladesh that can promote the degradation of concrete by increasing shrinkage and thermal cracking. The recent study (Ahmmed & Begu, 2010) reveals that the concentration of CO_2 in the air exceeds 500 ppm in Dhaka city. The increasing CO_2 content also is a threat as the CO_2 emission in 2005 is 40 Mt in Bangladesh, and in future, without improvement in energy efficiency, the emission will be 628 Mt by 2050 (15 times to 2005 value). This increase of CO_2 will increase the rate of carbonation for concrete and corrosion possibility for reinforcement (Gunter *et al.,* 2012). Uddin *et al.* (2013) investigated the Carbonation Coefficient of Concrete in Dhaka City Based on the field and laboratory experiment. The study showed a higher carbonation coefficient for outdoor exposure condition. Therefore, structure subjected to the outdoor exposure condition is more vulnerable to carbonation than indoor exposure condition which is a very important factor for structures like WWTP as it is highly exposed to the outdoor condition.

Design and Construction Practices

For the construction of structures like a wastewater treatment plant in-depth guideline is not available in Bangladesh regarding the material selection and the suitable methods (Mahmud *et al.,* 2016). The detrimental effect of chemicals and microorganism on the concrete surface can be prevented or controlled by developing resistant property of concrete by either improving concrete's microstructure or application of barrier systems. Based on practical field survey, it can be said that engineers are more focused in barrier protection of concrete used in WWTP than its internal improvement against the exact exposure condition. Using a barrier system without improving concrete performance can also be problematic in many ways.

Fig. 2: Protected concrete surface.

Fig. 2: Shows the practice of protected concrete surface in WWTP.

Fig. 3: Protected beam unprotected column.

Fig. 3 shows the practice of protected beam and unprotected column in WWTP. If improper curing or increased w/c ratio weakens the surface of the concrete on which the barrier system is applied, the concrete may fail to owe to the applied stresses on it even for a light barrier system (ACI, 1979). Moreover, any the concrete motion due to temperature variation or applied stress can disable the barrier system (ACI, 2001). Encapsulation of concrete also creates a problem when water trapped in the concrete increases the risk of damage by freezing and thawing. Sometimes the exposed elements are not properly covered.

Fig. 4: Protected concrete surface.

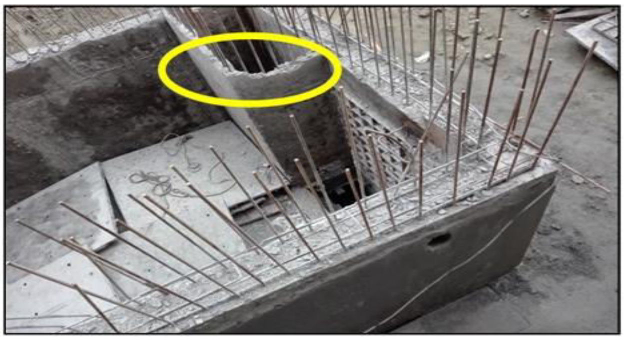

Fig. 5: Protected concrete surface.

Fig. 4 & 5 shows the practice of protected concrete surface in different part of WWTP. So, Barrier system involves complexities in selection proper barrier system, preparing application surface etc. Engineers also find it difficult to select the proper barrier system when the economy is given more preference than their performance.

Codes and Researches

In Bangladesh, Bangladesh National Building Code BNBC, (2006) provides design and construction guidelines for structures. Design parameters like the clear cover, w/c ratio, and others requirement are suggested for the different environmental condition. For extreme environmental condition, the concrete clear cover is 60mm for concrete having 35 N/mm_2 strength. In case of exposure to sulfate solution, according to BNBC (2006), w/c ratio should be maximum 0.45, and type V cement with pozzolans should be used. But detail specifications and guidelines for material selection, resistance against chemical attack, barrier systems for concrete like ASTM C1370-00 (ASTM, 2012), BS EN 13529 (EN, 2003), PR EN 1504-2 (EN, 2015) etc. which are available in other countries, are not available in Bangladesh especially for the construction of structures like WWTP (Mahmud *et al.,* 2016). Investiga-tions on arising problems on concrete exposed to adverse condition and Researches to improve the durability of the concrete are one of the important fields of studies. Selection of a suitable type of ingredient helps to increase the durability of concrete. Portland Composite Cement (CEM II) and Ordinary Portland Cement (CEM I) are the mainly available cement in Bangladesh (Uddin *et al.,* 2013; BNBC, 2006; ASTM, 2012; EN, 2003; EN, 2015; Nahar, 2011). Supplementary cementitious materials like fly ash and slag are present in Portland Composite Cement as inert filler in different percentage (Sriniviasan *et al.,* 2019). The performance of these two types of cement was investigated in micro-structural level by Manzur *et al.* (2018) when exposed to tannery wastewater (TWW). There are lots of tannery industries in Bangladesh discharges large quantities of wastewater and Performances of OPC and PCC against this waste- water were measured in terms of strength, expansion, and weight loss. The study revealed that the performance PCC cement against tannery waste- water is better than OPC in terms of properties like strength, expansion, and weight loss. But in Bangladesh, surveys in the practical field reveal that the general standpoint of contractors and concrete manufacturers regarding this issue is somewhat different. CEM I based concrete performance is considered to be better in terms of all properties including durability than CEM ll, because of the large strength characteristics of CEM I used concrete (Srinivasan *et al.,* 2019).

The performance of cement paste that is generally used in wastewater treatment plant is also studied in case of exposure condition against tannery waste-nwater which was collected from Hazaribagh

(Mahmud *et al.,* 2016). The cement mortar samples were made using Ordinary Portland Cement (OPC) and the effects of the harmful constituents of tannery wastewater on cement paste in terms of compressive strength and weight loss was investigated over a period of one year. The result of the experiment showed a clear detrimental effect of Tannery wastewater constituents like sodium chloride, sodium sulfate, ammonium nitrate, and sodium sulfide on cement mortar samples and degrading effects of the ammonium and the sulfate were the most severe.

The Scope of Future Research

Although concrete is the most suitable material for structures like WWTP, there are still lots of causes for its deterioration. As a complex and versatile material in nature, concrete provides a much more possible way to improve its quality and make the best uses of it as a material for WWTP structures. Modification of concrete for improving its different properties by advanced technologies is one of the most important fields of researches. In fact, Simpelveld, in the Netherlands, a treatment plant is turned into a full-size laboratory to perform advanced experiments for finding new methods and material properties (Dutch Water Sector, 2016). The project used special bacteria in producing self-healing concrete that can be functional in cement for over 200 years.

CONCLUSION:

WWTP is one of the most important structures nowadays and durability of these kind structures has become a common concern as harmful chemicals and aggressive environment can cause degradation of concrete by chloride ingress, sulfate attack, acid attack, bio-deterioration, corrosion, erosion etc. So a huge amount of money is spent on repairing works of these structures. Concrete's durability is one of the most important properties that should be ensured for these kinds of structures. Concrete resistance can be improved in such cases either by improving microstructure of concrete or incorporating barrier system. A proper construction practice is very import- ant for these kinds of structures. In many countries like Bangladesh, limited guidance and specifications are available regarding this issue. There is the future scope of preparing a details guideline, especially for the durability of the concrete used in wastewater treatment plants. Researches on advanced technology for increasing the concrete resistance and the availability of such technology in all the countries improve the scenario.

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CONFLICTS OF INTEREST:

The authors declare that there is no conflict of interest to publish it.

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