

Deterioration of Concrete in Marine Structure

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Abstract Concrete is a hard composite material got by blending the fitting extents of bond and totals (fine and coarse) with water, which in mix with steel fortification structures an amazing Civil Engineering material. Concrete, being great in pressure and steel in strain, end up being extremely solid and strong, if effectively outlined and cast. There are many components which prompt the decay of cement. The most widely recognized components which prompt the decay are the natural factors the materials and the throwing methodology, (for example, shameful cementing techniques, utilization of permeable totals, utilization of totals from saline sources, utilization of saline water in solid, poor vibration, disgraceful cover to support, spilling formwork, utilization of permeable and delicate totals), basic plan surrenders temperature and uncalled for utilize. A solid structure experiencing the weakening gives the accompanying demonstrative suggestions: breaking, spalling, scraped spot, stains, disintegration, diversion, and erosion. The most widely recognized variables prompting crumbling are the natural components prompting consumption of support, dishonorable utilize whereby over-burdening happens on a structure and the development techniques prompting permeable cement. This report introduces the investigation of the different components and their instruments prompting disintegration, their outcomes and the restoration of such structures. This report additionally talks about the scientific device for measurement of decay of cement in seaward structure.

1. Introduction

Concrete is an imperative development material. It is exceedingly impervious to pressure strengths, however feeble under footing powers. Strength of a fortified solid structure relies upon the earth in which it is uncovered, as additionally on the time and properties of cement. Internal reasons for harm are compound responses happening inside solid, volume changes caused by contrasts in

physical and synthetic properties of totals and bond glue and especially to its water porousness Durability of Concrete structures in marine condition has been an issue for a long time, because of the impression of ocean water as forceful to cement and fortification and the long administration life that is normal for marine framework, for example, harbor and waterfront guard structures. The crumbling of cement presented to marine condition is a consequence of aggregate activity of physical, substance and natural components.

Progressively regularly, concrete is the material of decision for the development of structures presented to outrageous conditions whether it be seaward oil stages in frosty water or dangerous waste control vessels covered in the earth.

As interest for development in cruel conditions expands, so do the coveted administration lives of these structures. Normally, solid structures are intended to perform, with insignificant support, 50 to 100 years. The formability of basic cement speaks to its one of a kind value with noteworthy structural difficulties. Along these lines it turns into a financial catastrophe when urban abodes, substantial scaffolds, or significant marine structures weaken soon after a couple of years in benefit. The solid furnishes strengthening steel with a magnificent erosion assurance under ordinary conditions. The high soluble condition in solid outcomes in the arrangement of firmly following movies which shields the steel from consumption. Consumption of strengthened steel happen in concrete because of low quality, insufficient thought of administration condition or change in condition the administration life of the solid structures.

Many studies about deterioration of concrete in marine exposure are under development worldwide. However much more advanced knowledge in this area is still needed. With respect to deterioration, concrete structures have some important characteristic properties, which differ fundamentally from structures made from other structural materials. These properties are the following (fib 1999):

1. The quality and the performance of concrete adopted at the design and contracting stages are assumed values.

2. The true quality and performance characteristics of structural concrete are created through the actual execution process during construction on site. Hence, this very short period of time (hours and days) constitutes the most important phase during which the true initial qualities are established.

3. If durability performance turns out to be sub-standard, this is most often not apparent nor detectable until some time has passed due to the nature of the deterioration of concrete structures. The time passed before premature deterioration becomes apparent may often be longer than the contracted liability period, but very much shorter than the service life expected by the owner. To manage these special properties of concrete structures a durability based design concept, a conscious execution, and a planned inspection and maintenance is needed. Testing techniques and destructive investigation to establish the necessary dimensional and material parameters.

2. Causes and Effect of Deterioration of Concrete in Marine Structure

2.1. Physical causes

Solid that is absolutely and ceaselessly inundated in water, regardless of the possibility that the water contains broke up salts, for example, are found in ocean water, for the most part might be viewed as being in a secured presentation. These drenched cement are being subjected to disintegrating impacts as ice activity, volume change because of wetting and drying, and differential volume change because of dampness content contrasts between the surface and the inside. Physical disintegration may happen because of solidifying defrosting, rehashed drying and wetting, scraped spot because of waves and littoral float.

2.1.1 Frost activity

In the event that the structure is found where the temperatures fall underneath solidifying, at that point the solid that is presented to the air with falling tide is most likely subjected to as extreme ice activity just like any solid in common introduction. The acknowledgment that solid uncovered in the tidal zone in a locale of low winter temperatures would be subjected to exceptionally extreme ice activity. Wet cement and solidifying conditions are an awful blend. Water grows when it solidifies. In the event that caught in solid, it makes outward weight on the encompassing material. The main

frame is that Freeze/defrost cycles steadily fall apart the solid surface, uncovering total and leaving the solid with a dissolved appearance. As the surface separates, it turns out to be more permeable, which thusly advances much further disintegration. The second type of stop/defrost harm is related with water solidifying in splits. A bigger convergence of water can gather in a split than in a normally happening surface pores. Subsequently, the subsequent harm regularly happens all the more rapidly and seriously. Breaks likewise enable water to infiltrate specifically to strengthening steel. This may start or quicken erosion and other dampness related types of crumbling. Despite the fact that the stop defrost resistance of cement has been the subject for broad research all through a noteworthy piece of the most recent century, this kind of disintegration still speaks to a strength issue in numerous nations. Now and again, the activity of ocean water on concrete is joined by the dangerous activity of ice, of wave affect and of scraped spot. Extra harm can be caused by burst of cement encompassing fortification which has eroded due to electro-coaction activity set up by assimilation of salts by the solid.

2.1.2. Wetting and Drying

The second essential impact on concrete identified with wetting and drying is the volume change relations because of changes in, or changes in consistency of, dampness content. This marvel regularly alluded to as "drying shrinkage" impacts. Concrete between tide marks, subjected to substituting wetting and drying, is extremely assaulted, while for all time drenched cement is assaulted slightest. Be that as it may, the assault via ocean dilute is impeded by the obstructing of pores in the solid because of the affidavit of magnesium hydroxide which is framed, together with gypsum, by the response of magnesium sulfate with Ca(OH)_2

2.1.3. Temperature change

Temperature variations will cause changes in the concrete volume. When temperature rises, the concrete slightly expands, and when temperature falls, the concrete contracts. If the concrete was unrestrained, these normal volume changes in concrete would have little consequences. This volume change may lead to development of stress in concrete. Tensile stresses can cause the concrete to crack. The temperature changes may occur in two forms and are classified as seasonal change and daily fluctuations.

Seasonal changes in temperature are considerably greater than the daily fluctuations. Seasonal changes in temperature range up to 50°C (90°F) between the summer and winter. Seasonal

temperature changes cause higher stresses than daily temperature changes, and they result in more extensive cracking. In, some cases, cracks developed at low temperatures may close when the concrete temperature increases in the summer. If dirt in air and debris floating on water may enters the cracks when the openings are at their maximum, an increase in temperature will cause the compressive stresses to develop. If large compressive stresses are developed due to the expansion of the concrete, the deck slab present at water front may buckle upward and crack.

Daily changes in temperature can be up to 20°C (36°F) at the coast and somewhat higher inland. The limiting tensile strain for concrete is frequently quoted to be between 10-4 and 2X10-4. If the coefficient of thermal expansion of concrete is assumed to be 10 millionths per degree Celsius (5.5 millionths per degree Fahrenheit), a temperature change of 10°C to 20°C (18°F to 36°F) would be sufficient to cause the restrained concrete to crack. Repeated tensile stresses cause the cracks to grow and lead to scaling, spalling, and delamination. If the cracks develop to the level of the reinforcing steel, ingress of salt and moisture will cause the steel to corrode.

The effects of temperature on rate of reactions, solubility of salts, and the effect of relative humidity on carbonation and corrosion are good illustrations of how the effect of ambient conditions affects deterioration rates. As a rule of thumb, increases in the temperature range of 10°C will approximately double the reaction rate.

3.2. Chemical factors

3.2.1. Presence of chlorine ions

Early decay because of harm from chloride in a marine locale happens as the infiltrating diffusing rate of the chloride particles is considerably higher than anticipated. Crumbling of strengthened solid structures in a marine domain happens because of many variables. These incorporate substance consumption of cement because of Cl-and sulfate particles. The unequivocally soluble nature of concrete, because of Ca(OH)₂ with a pH of around 13, keeps the consumption of the steel support by the arrangement of a thin defensive film of iron oxide on the metal surface. This insurance is known as detachment. Notwithstanding, if the solid is porous to the degree that carbonation achieves the solid in contact with the steel or solvent chlorides can enter straight up to the support, and water and oxygen are available, at that point consumption of fortification will happen. The detached iron oxide layer is annihilated when the pH falls underneath around

11.0. Carbonation brings down the pH to around 9. The development of rust outcomes in an expansion in volume contrasted and the first steel with the goal that swelling weights will cause breaking and spalling of the solid.

The extremely portable chloride particles scatter through solid pores in arrangement and where they come into contact with the fortifying steel they assault the detached layer. Steel oxidizes within the sight of air and water to form rust which has a volume of up to 10 times that of the steel devoured. As concrete has a low rigidity it will break when as meager as a tenth of a millimeter of steel has been devoured. Level breaks shape, making corners "spall" and surfaces to "delaminate" as the support's solid cover winds up plainly withdrew and falls away in sheets.

Chloride particle, display in marine breeze and seawater is viewed as the fundamental outside specialist to harm strengthened cement in marine conditions. It influences the resignation of steel film and incites the start of erosion.

3.2.2 Sulfate attack

Solid salts do not attack concrete, but when they are in the form of a solution, they can directly react with the hardened cement paste. Some soils contain alkali, magnesium and calcium sulphates. Seawater may also contain significant sulphate content. Attack of the hardened cement paste occurs when the sulphates react with the Ca(OH)₂ and the calcium aluminate hydrates. This reaction is called sulphate attack. Due to the increase in volume, these expansive reactions can produce a sufficient pressure that disrupts the cement paste. This disruption of the cement paste results in concrete cracking and disintegration.

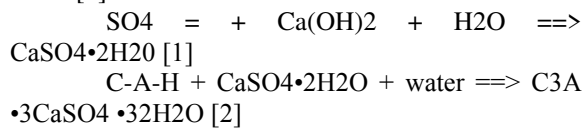
Sulphate attack is the most common form of salt attack on concrete. The concrete is exposed to sulphates usually due to environmental actions, but they can also be present in the binder or aggregates. Sulphates may follow moisture into the concrete and be concentrated locally. Damages caused by sulphate attack can for example be strength loss, expansion and spalling. Solid salts do not attack concrete but when present in solutions they can react with hydrated cement paste. The most common solutions are sulphates of sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca). The natural origins of sulphates are in ground water but they may also come from fertilizers and industrial activities.

Concrete attacked by sulphates has a characteristic whitish appearance, damage usually starting at the edges and corners and followed by cracking and spalling of the concrete. The reason for this appearance is that the essence of sulphate attack is the formation of calcium sulphate (gypsum) and

calcium sulphoaluminate (ettringite), both products occupying a greater volume than the compounds which they replace so that expansion and disruption of hardened concrete take place.

The effects of sulphate attacks in concrete can be reduced in two different ways, Reduction of the C3A in the binder. This is done by the usage of sulphate resistant cements in the concrete. Reduction of the quantities of Ca(OH)₂ in the cement paste. This is done by the usage of blended cements, containing GGBS or pozzolans, in the concrete. The effects of blended cements are: (1) Pozzolans react with the Ca(OH)₂ so that Ca(OH)₂ is no longer available for reaction and (2) Blended cements contain less Ca(OH)₂ than PC. The consequences of sulphate attack include not only expansion, which disrupt the concrete, but also loss of strength of the concrete due to loss of cohesion in the hydrated cement paste and between the particles in the aggregate.

The sulfate attack is based on the formation of gypsum (CaSO₄•2H₂O) produced by reaction [1] of sulfate ion with Ca(OH)₂ of the hydrated portlandcement and that of the subsequent expansive formation of ettringite (C₃A•3CaSO₄•32H₂O) produced by reaction of gypsum with the calcium aluminate hydrates (C-A-H) of the hardened cement matrix in the presence of water [2]:



Not necessarily the ettringite formation produces a damaging effect. When it occurs homogeneously and immediately (within hours or days) in a mixture or in a deformable concrete - Early Ettringite Formation (EEF) - the related expansion does not cause any significant localized disruptive action.

On the other hand, when ettringite forms heterogeneously and later (after months or years) - Delayed Ettringite Formation (DEF) - the localized related expansion in a rigid hardened concrete produces cracking, spalling, and strength loss. Therefore only DEF - and not EEF - is associated with a damaging sulfate attack

2.2.3. Alkali-silica reaction

Due to interaction between certain aggregates (containing amorphous silica or strained quartz) and the highly alkaline solution of the pore aqueous phase, concrete can deteriorate and this reaction is known as "Alkali-Silica Reaction"(ASR). The alkali content of the pore aqueous phase depends primarily on the alkali content of the clinker phase and even on the exposure to environmental sodium

salts as in sea water. Alkali-Silica Reaction allows penetration of ions from sea water into concrete. Alkaline pore solutions in the concrete react in moist conditions with certain types of aggregate to form an expansive gel, resulting in the internal disruption of the concrete. The reaction is slow and its effects only become noticeable after several years of service. Depending on the severity of the attack, the consequences of alkali-aggregate reaction (AAR) are: • degradation of appearance • deterioration in strength • decrease in durability. The main and most obvious indicator of ASR is cracking of the concrete. The cracks become just noticeable after about 5years, but may develop with time to fissures more than 1mm wide. Where mass concrete is relatively free to expand in all directions, map or pattern cracking develops, but restraint in any direction will influence this crack pattern. In reinforced concrete the cracking tends to follow the orientation of the main reinforcement and maximum stress directions. If the cracks extend to the reinforcement, the steel will start to corrode because the protective effect of the cover concrete has been nullified. Rust stains will start to appear from the cracks, suggesting that corrosion of the reinforcement is the cause of the crack formation. However, in this case the appearance of rust stains is the result, not the cause, of crack formation.

2.3 Biological causes

The weakening of cement caused because of natural variables is known as bio decay. The bio decay of solid structures is identified with microorganisms (microbes, growths, green growth, or potentially lichens), however it can likewise be related to settlement of naturally visible living beings, for example, mussels or with creatures that disintegrate and puncture the solid The most widely recognized live-life forms related with bio crumbling of development materials might be gathered as: Marine borers (e.g., gribble and shipworms) Mosses and lichens and Macroalgae

2.3.1. Marine borers

For example, mollusks and wipes, tend to frame drill gaps into submerged solid structures. Marine borers lessen the solid's heap conveying limit and additionally uncover the solid's external fortifying steel to the destructive seawater. Drilling wipes deliver interconnected drill gaps. As the level of interconnection expands, the surface material of the solid disintegrates. Deterioration of the surface layer uncovered another substrate of the solid to the exhausting wipes. Disintegration of cement because of an exhausting wipe assault is generally moderate.

Living beings can develop on solid surfaces under specific conditions: lifted relative moistness,

long cycles of humidification and drying, or solidifying and defrosting; high carbon dioxide fixations; high convergence of chlorides or different salts; high centralization of sulfates and little measures of acids. Assault of living beings to cement can be: (a) physical or mechanical (by dissolving or puncturing solid); (b) fouling or ruining, by framing a layer of shaded biofilm; and, (c) by synthetic response by utilizing an auxiliary part as sustenance source or by discharging waste items that influence the material. At the point when biofilms cover solid surfaces, they can shape limited anodic destinations, forestalling dispersion of oxygen, and encompassing territories end up plainly cathodic, advancing erosion.

2.3.2. Greeneries and lichens

Greeneries are plants of a higher request, make unimportant harm concrete. These plants create feeble acids in the fine hair roots. The roots empower greeneries and lichens to cling to the solid. The acids that are created from greeneries and lichens will assault the bond glue and make the solid break down and scale. At times, carbonic acids are created from plants, for example, greeneries and lichens, when substances from these plants deteriorate. The carbonic corrosive that is delivered will assault the solid.

2.3.3. Macroalgae

Numerous types of green growth become appended to rough and solid substrates on or close to the sea's surface. These macroalgae can acquire diverse components for their digestion e.g. calcium, aluminum, silicon, press and so forth by biosolubilization of materials. Such biosolubilization includes the creation of natural acids by the metabolic movement of macroalgae. This corrosive disintegration is a standout amongst other known biogeochemical systems of solid rot.

The biogenic (created by living beings or natural procedures) arrival of destructive acids is presumably the best known and most usually researched biogeochemical harm system in inorganic materials like cement. The procedure, known as bio erosion, is known to be caused by the microbial discharge of inorganic and natural acids (acidolysis and complexation). These specialists are fit for draining the mineral network with consequent debilitating of the authoritative. The arrival of metabolic acids is extraordinary compared to other known biogeochemical dangerous instruments on solid surfaces with draining of solid restricting materials and ensuing debilitating of the precious stone structure. These acids are likewise equipped for chelating cations, for example, Ca, Al, Si, Fe, Mn and Mg from minerals shaping stable buildings. It

has been demonstrated that biogenic natural acids are significantly more successful in mineral preparation than inorganic acids and are considered as one of the major harming specialists influencing solid disintegration.

2.4 Effects of deterioration of concrete

Concrete structure undergoing the deterioration shows the following indicative signs: cracking, spalling, abrasion, stains, deflection, and corrosion.

2.4.1 Cracking

Contingent on the reason for deformity or weakening each split in concrete should differ inside and out, width, example and area. The splits can be dynamic or torpid. Plastic settlement splits might be i) fine sort as observed on surface amid the settlement of crisp cement or ii) the more extensive sort seen over the backings when settlement of establishments happen amid setting of cement. Plastic shrinkage splits are pretty much parallel to each other, yet rather shallower. Drying shrinkage breaks are better ones with irregular introduction. Auxiliary breaks are the all-around characterized splits happening because of the intersection of the limit of flexural, tractable, compressive or shear stresses. They might be corner to corner if there should be an occurrence of shear breaks. AAR breaking, otherwise called delineate is seen like a web or system of splits at first glance.

2.4.2 Spalling

Spalling is the falling of bits of cement of shifting size because of erosion of support, neighborhood, fire harm, over-burdening, affect, solidify defrost activity, and intemperate relative development of parts because of seismic movement.

2.4.3 Erosion/scraped spot

Disintegration is the wearing out of the solid surface prompting disfiguration. Disintegration of cement may happen from delayed introduction of the solid to persistent whittling down by stones and shingle conveyed by water, as may happen in pressure driven structures or in ocean water. Great thick solid will typically with-stand a high-speed stream of water, gave the stream is smooth and streamlined. Solid will rub where presented to the powers of cavitation, i.e. the implosion of air rises, as happens in those segments of pressure driven structures intended to disseminate vitality by fusing deterrents to the free stream of water. The holes

crumple with affect and sudden alters in course, bringing about weight which may cause wearing (setting) of the solid surface.

2.4.4 Stains

Strains are the patches created on the surface of cement because of filtering, or consumption of steel fortification. The patches might be white in shading because of draining or AAR, and darker hued because of erosion of support.

2.4.5 Corrosion

Erosion is the aftereffect of response of steel fortification for the most part because of assault of chloride particles and carbonation. Because of consumption staining, broad splitting and spalling happen in the solid. Erosion of steel happens due to the electro-compound activity which is typically experienced when two divergent metals are in electrical contact within the sight of dampness and oxygen. Be that as it may, a similar procedure happens in steel alone on account of contrasts in the electrochemical potential at first glance, which shapes anodic and cathodic areas, associated by the electrolyte as the salt arrangement in the hydrated bond. The decidedly charged ferrous particles Fe^{2+} at the anode go into arrangement while the adversely charged free electrons e^- go along the steel into the cathode, where they are consumed by the constituents of the electrolyte and consolidate with water and oxygen to frame hydroxyl particles $(OH)^-$. These then consolidate with the ferrous particles to frame ferric hydroxide and this is changed over by assist oxidation to rust. Thus, it can be composed: $Fe \rightarrow Fe^{2+} + 2e^-$ (anodic response) (2.1) $4e^- + O_2 + 2H_2O \rightarrow 4(OH)^-$ (cathodic response) (2.2) $Fe^{2+} + 2(OH)^- \rightarrow Fe(OH)_2$ (ferrous hydroxide) (2.3) $4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3$ (ferric hydroxide) (2.4)

As indicated by M. Collepari, the harm procedure dictated by the concurrence of the accompanying three main components,

i) Interconnected porosity. It is connected not exclusively to smaller scale splits caused by the natural activity (weathering and stacking impacts) however even to the hairlike porosity of the bond lattice (caused by high w/c and deficient curing) and dishonorable union delivering macrovoids especially when firm solid blends are put.

ii) Exposure to forceful specialists. It is identified with the principle three synthetic systems of corruption of RCS: a) sulfate assault; b) consumption of fortifying bars; c) soluble base silica response (ASR). iii) Presence of water. It is identified with the discontinuous or nonstop

infiltration of the ecological water deciding the strength conduct of RCS. Water can go about as forceful operator without anyone else (solidifying defrosting) or simultaneously with other forceful specialists (CO_2 , O_2 , Cl^- , SO_4^{2-} , soluble base) in the three specified debasement systems. In addition, water likewise goes about as fluid transporter for reactant particles diffusing through the interconnected pores of the concrete lattice. An engineered portrayal of the all-encompassing methodology for the harm of RCS can be inspected through the assistance of Fig. 1 where every component compares to a circle. Every range of the three circles relates to a framework in which just a single of the three components of the framework is available, and this circumstance does not present any hazard whatsoever for the harm of RCS. The territory in the center, where the three circles cover, compares to circumstances of genuine hazard for the harm since all the three required components are available: interconnected porosity, natural water, and introduction to forceful operators.

Time or their plan is lacking. It is important to supplant or fortify the scaffolds by some methods. Different techniques for fortifying have been utilized, a standout amongst the most prominent being saddling. Here, the fill is expelled with the goal that the best surface of the curve barrel is uncovered. A fortified solid seat is then thrown set up finished the first barrel. Saddling without a doubt raises the quality by an adequate edge yet has the disadvantages of cost, impressive intrusion to activity and conceivably major ecological aggravation. It is hence suitable to take a gander at other more practical and adaptable strategies for fortifying.

3. Quantification method for Deterioration of Concrete in Marine Structure

Mathematical tools used for Quantification of Deterioration of Concrete in Marine Structure. For calculating the amount of deterioration it is necessary to quantify chloride contents in concrete. Chlorides in concrete can be present as a result of various sources. Chlorides from the environment can diffuse into concrete as a result of the sea salt spray and direct sea water wetting; the deicing salts or the use of chemicals (structures used for salt storage, brine tanks, aquaria, etc.). For this dissertation report it is case of chlorine diffusion in concrete structure constructed at offshores or in marine environment. This diffusion of chlorine can be calculated using mathematical total that are namely Nernst Plank equation and Fick's second law.

4. Control and Repair

4.1 Deterioration controlling techniques before construction

The following are the various deterioration controlling techniques used to control deterioration process so that structure may require minimum maintenance. These various techniques are classified on the selection of material used for construction. These techniques are as follows:

4.1.1 Cement / binding material

The concrete is made of mainly two phases that are paste phase and aggregate phase. The aggregate phase is studied further in this chapter here it is discussed about the use of various types of cements to control the deterioration of concrete in extreme exposure conditions that are marine structures. Use of following types of cement can be done to control the deterioration process.

4.1.1.1 Sulphate resisting cement

Ordinary Portland cement is susceptible to the attack of sulphates. Sulphates react with free calcium hydroxide in cement to form calcium sulphate and with hydrate of calcium aluminate to form calcium sulphoaluminate, the volume of which is approximately 227% of the volume of original aluminates. Their expansion in frame work of hardened cement paste results in cracks and subsequent disruption. This is known as sulphate attack. To remedy the sulphate attack, the use of cement with low C3A content is found to be effective. Such cement with low C3A and comparatively low C4AF content is known as sulphate resisting cement.

4.1.1.2 Super sulphated cement

This cement has high sulphate resistance. Because of this property this cement is particularly recommended for use in marine works, where chemically aggressive conditions exist.

4.1.1.3 Portland cement

Portland cement have poor chloride resistance and should only be used with high cover depths to reinforcement. A cover depth of 75 mm was therefore selected whilst a w/c ratio of 0.39 was required. Chloride conductivity values of 1.6 mS/cm at 28 days should be achievable with this concrete. Due to the high cement content, granite coarse aggregate was selected together with a high quality pit sand.

4.1.1.4 Fly ash cement

Only moderate cover to reinforcement of 50 mm is required for fly ash concrete due to the high chloride resistance of the material. Effective curing is however essential to produce dense near-surface properties in the concrete. The required w/b ratio for the concrete is 0.45 in order to achieve a 28-day chloride conductivity of 1.5 mS/cm. Aggregates selected were greywacke stone and blended pit and dune sand.

4.1.1.5 Slag cement

Slag concrete has good chloride resistance and 50 mm cover to reinforcement should be sufficient to protect the reinforcement. Special care with regard to curing is required to achieve a dense and durable concrete surface. In order to achieve a chloride conductivity value of less than 0.8 mS/cm at 28 days, a w/b ratio of 0.50 was selected. Aggregates selected were greywacke stone and blended pit and dune sand.

4.1.2 Aggregates

Aggregates are important constituents of concrete. They give volume to concrete mix achieve economy and reduce shrinkage. Initially aggregates were considered chemically inert but it has now been recognized that some of the aggregates are chemically active. As aggregate occupy 70-80% of total volume of concrete, their characteristics and proportion which have impact of concrete characteristics need to consider. From the standpoint of long-term durability of concrete in the seawater environment, the aggregates for making the concrete mixture should be mineralogically homogeneous, strong, hard, and clean. This is especially necessary for the splashing zone concrete, which is subject to heavy abrasion/erosion. From field experience with good quality concrete mixtures (30–40 MPa), it seems that under conditions of severe abrasion/erosion usually the coarse aggregate-cement paste bonding fails and the aggregates tend to pull out from the concrete matrix. Superplasticized, low water/cement ratio, concrete mixtures, containing highly active pozzolans (such as silica fume) have strong transition zones, and are therefore resistant to the aggregate pull-out phenomenon. When the aggregate particles are able to withstand the abrasive/erosive attack of the environment without being pulled out of the cement paste matrix, it is beneficial to use a high coarse/fine aggregate ratio in the concrete mixture (viz. 65/35) and an exceptionally hard rock as coarse aggregate.

4.1.3 Admixtures

Since corrosion of reinforcing steel in concrete is a major potential problem with marine structures, the use of corrosion inhibiting chemicals, such as calcium nitrite and sodium thiocyanate, as concrete admixtures has been advocated. Although calcium nitrite has been used commercially, there is a controversy about the long-term effectiveness of corrosion inhibiting admixtures. For instance, maintain that the concentration of nitrite ions in pore solution decreases with time, and therefore its corrosion-inhibiting effectiveness is likely to be reduced in applications where the ingress of chloride from external sources is unrestricted, as in the case of bridge decks, parking garages, and marine structures. Accordingly, the use of good-quality concrete, such as super plasticized concrete containing silica fume, can prevent steel corrosion more effectively than the use of a corrosion inhibitor. By improving the workability and homogeneity of concrete, reducing the heat of hydration, and increasing the strength of the transition zone, the mineral admixtures are able to enhance the resistance of concrete to cracking from a variety of causes. Since both the strength and permeability of concrete in service are determined by the degree of internal microcracking, it should be obvious why the use of a suitable mineral admixture is so important when long-term durability of concrete in the hostile sea water environment is one of the primary design considerations.

4.1.4 Protection of reinforcing steel

Available techniques have been developed for protection of reinforcing steel from corrosion in concrete. The most commonly known systems of protection of reinforcing steel from corrosion which are in popular use and deployed in substantial volumes of reinforced concrete are:

4.1.4.1 Fusion Bonded Epoxy Coated (FBEC)

Re-bars The Fusion Bonded Epoxy Coating is a process where epoxy powder is applied by electrostatic spray on hot steel at pre-set temperature level. The powder, when in contact with the hot bar, melts, flows, gels, cures cools and produces a well-adhered continuous corrosion resistant protective coating. This thermosetting is an irreversible process and provides the protection to rebar against corrosion. It prevents attack of chloride ion on the metallic surface and occurrence of electrochemical reaction initiating corrosion of steel.

4.1.4.2 Corrosion-resistant Steel (CRS)

Re-bars Corrosion-resistant Steel rebars have dual micro structures i.e. the surface layer is

tempered martensite while the inner shell is ductile ferrite pearlite. To increase corrosion resistance of these bars certain elements like nickel, chromium, copper and phosphorus are also added. These bars form a protective layers on the surface when they come in contact with atmospheric oxygen and moisture.

4.1.4.3 Zinc Coated/ Hot-dip Galvanized

Re-bars Galvanizing is the process of deposition of zinc over the surface of rebar's. One of the methods to prevent the steel from undergoing corrosion is to galvanized rebar's. Zinc coating offers protection in more than one way. Firstly, inter-metallic and metallic layers of zinc act as a physical barrier between the steel material and corrosion environment. In this case, corrosion resistance of the steel owes to the corrosion resistance of zinc. Further, wherever steel is exposed to the corrosive environment due to the breakdown of the protective coating, steel is still protected by the selective dissolution of zinc.

4.2 Deterioration controlling techniques during service life

The following are the various deterioration repair techniques used to repair deteriorated concrete structure. These various techniques are classified on the selection of material used for repair and methods adopted for repair. These techniques are explained accordingly as material and methods as follows:

4.2.1 Inorganic Cementitious Materials

Cementitious grouts, mortars, and concretes containing Portland cement, high-alumina cement, sodium silicate cement, or calcined gypsum cement are commonly used for repair of cracked and deteriorated concrete structures. They are readily available almost anywhere, relatively inexpensive, safe and easy to handle, and generally compatible with old concrete. Their main disadvantages are high drying shrinkage and cracking tendency, slow setting and strength development rates, and sometimes poor bonding properties. Owing to their low permeability, high durability, high early and ultimate strength, and excellent bond strength, superplasticized portland cement mortar or concrete mixtures, with or without fly ash or silica fume, are becoming increasingly popular for repair and rehabilitation of concrete sea structures. They are especially suitable for application by shotcreting

4.2.2 Epoxy Resins

Epoxy resins are cyclic ethers, such as oxacyclopropanes, which normally harden by polymerization at room temperature. These are the most expensive and yet the most used among all the organic adhesives for concrete sealing, patching, and bonding. This is primarily because of their ability to adhere well to any type of surface, whether dry or wet. They develop high strength, show very low shrinkage and creep, and possess excellent resistance to abrasion, chloride penetration, and chemical attack. Generally, epoxy resins are highly viscous (epoxy mortars may show putty-like consistency) and relatively slow-setting, and therefore continue to gain strength for weeks. Curing at very low or high temperatures requires special attention. With suitable chemical formulation, cure rates at room temperature can be varied from several minutes to several days.

4.2.3 Polymer Coating

For enhancing the life of structure, coatings like IPN (Interpenetrating Network) or other equivalent polymer should be applied on all the concrete surface of the structure. The coating prevents any future ingress of air & harmful chlorides, sulphates etc. into the structure. It thus protects the entire structure from corrosion & spalling. However, these coats are to be applied periodically, normally with interval of 5 years or so, depending on type of product being used.

4.3 Methods of Removing the Deteriorated Concrete

Solid that is broken however generally solid and sound can be repaired by epoxy infusion, more often than not without the requirement for annihilation of the split part. Any disintegrated, unsound, and free cement must be evacuated before applying the repair fix. Chosen solid expulsion methods (take note of that a similar evacuation procedure may not be reasonable for all parts of the structure) ought to be protected, sparing, and efficient.

4.3.1 Shotcreting

Where thin repair segments (e.g., under 150 mm thickness) having extensive surface ranges with sporadic shapes are required, establishment of the repair material by shotcreting might be more efficient than customary cementing on account of funds in the framing cost. With the approach of high-quality and firm solid blends, for example, those containing superplasticizers and consolidated silica smoke or fly fiery remains, the wet-blend shotcreting

process is progressively being utilized to repair weakened solid seawalls, heaps, and other water driven structures. The weakened and spalled concrete were repaired utilizing steelfiber-fortified, silica-seethe shotcrete tied down with grouted dowels. Morgan16 depicts his palatable involvement with more than fifty distinct structures that have been as of late repaired utilizing wetmix shotcrete frameworks containing superplasticized concrete with silica rage. As per the creator, contrasted with the ordinary dry-blend technique, the wet-blend strategy is a critical change for repair of vertical countenances. In dry-blend shotcreting the single-pass thickness of an overhead splash is restricted to 2–3 in. (50–75 mm), and the utilization of set quickening agents is for the most part adverse from the point of view of solidness. The shotcreting innovation has additionally risen as an answer for beat the trouble of repairing structures in the tidal zone. Morgan16 depicted shotcreting the substance of a bulkhead wharf structure from a canal boat which rose and fell with the 8 m high tide (the scow dropped at the rate of 1•2 m 60 minutes). Shotcrete, up to 9 in (225 mm) thick, was connected on the falling tide. No quickening agents were utilized and the solid did not set for 6 to 8 hours in frosty temperatures, yet no shotcrete was lost by the tidal activity. Ice safe shotcrete can be acquired by utilizing an airetrained blend and a pipe firearm in the wet-blend process.

4.3.2 Epoxy Injection

Epoxy infusion has been utilized effectively in the repair of breaks in caissons, heaps, decks, ocean dividers, and establishments. Breaks as thin as 0•002 in (0•05 mm) can be reinforced by the utilization of the epoxy infusion procedure. Saucier10 cautions that unless the break is steady or lethargic (or the reason for splitting has been expelled, along these lines making the break torpid), it will presumably repeat, perhaps elsewhere in the structure. The general strides in the epoxy infusion repair process are as per the following:

- 1) Cleaning the breaks and surface fixing: Before infusion, surface splits ought to be fixed to shield the epoxy from spilling out before it has solidified.
- 2) Installing the passage ports: At close interims along the splits, openings must be penetrated and for the most part section ports for epoxy infusion must be introduced.
- 3) Injecting the epoxy: Hydraulic pumps, weight pots, or air actuated caulking firearms can be utilized for infusing the epoxy blend underweight. The utilization of extreme weight can proliferate the current breaks and is, thusly, to be kept away from.

Likewise, mind must be taken to set up the measure of glue blend that can be utilized securely before the initiation of solidifying amid the infusion procedure.

4.3.3 Protective Coatings and Linings

Repaired concrete and even new solid individuals are often given extra insurance from the physical-compound procedures of crumbling by the utilization of surface coatings and linings. The approach hidden the solid surface security systems is either to diminish the retention of water (i.e. to keep the solid dry on the grounds that without water no debasement can happen) or to avert contact between the solid surface and the forceful condition, (for example, seawater). The main approach includes the utilization of either hydrophobic operators which don't respond with the constituents of concrete or certain receptive specialists which may top off the pores with response items. The second approach relies upon the utilization of surface linings, for example, pre-assembled polymer layers, elastic linings, sheets of plastic or stainless steel, and artistic tiles or stone boards.

4.3.4 Repair Methods Involving Cathodic Protection of Steel

For an assortment of reasons, cathodic insurance of steel in concrete is by and large progressively utilized for repair of chloride-harmed solid structures. To begin with, for auxiliary reasons or attributable to clog it may not be attainable to evacuate the chloride-tainted cement. In any case, for palatable repair, it is required that the repair mortar should completely encompass this support. Second, here and there it is hard to dispose of all the consumption pits by wire brushing or sand-impacting. Third, the repaired ranges begin going about as cathodes, and the unrepaired zones move toward becoming anodes and begin eroding if adequate oxygen and electrolytic conductance are available.

Conclusion

Deterioration of concrete in marine structure is caused principally because of two reasons to be specific physical causes and concoction causes. It is noticed that disappointment investigation of cement in cutting edge condition of debasement demonstrates the disintegration of cement is associated of physical and concoction causes. More research is required on the systems that quicken bio deterioration in solid structures in waterfront zone. Additionally, proceeding with improvement of solid blend configuration to forestall or decrease bio deterioration of cement is required. There are many factors because of which the solid can get crumbled.

Lion's share of the components connected to the procedure of development and the development materials. The most imperative factor making significant harm to concrete is consumption. The appraisal, assessment and repair improve it basic for a comprehension of the disintegration approach and their execution under various natural conditions. Repair strategies can be completed yet the similarity of the substrate and the repair coats ought to be kept up. Diverse strategies, for example, fix repairs technique, cathodic insurance strategy, desalination, re-alkalization and break repair are accessible, yet all come at a high cost.

References

- [Ardehana A.L and Dr Desai Atul (2012) "Durability of Fiber Reinforced Concrete of Marine Structures" International Journal of Engineering Research and Applications, Vol. 2, Issue 4, pp.215-219
- Civjan S and LaFave J.M (2005). "Effectiveness of corrosion inhibiting admixture combinations in structural concrete". ELSEVIER Cement and Concrete Composite, Vol- 27, pp. 688-703.
- Collepari M (1999.)"A Holistic Approach to Concrete Durability – Role of Superplasticizers" Infrastructure Regeneration and Rehabilitation. A Vision for the Next Millennium, Sheffield, pp. 15-25,
- Hitesh Kodwani and Sanjeev Kumar Verma (2015) "Deterioration of Concrete Structures" International Journal of Computer and Advanced Engineering Research Volume 02 – Issue 06, Nov. pp.26-32.
- Godbole Kishanrao and Sawant Priyadarshi (2014) "Reinforcement Corrosion Assessment through Half – Cell in Concrete Structure Exposed in Marine Environment" International Journal of Engineering Technology, Management and Applied Sciences, Volume 2 Issue 7, pp.69-75
- Mehta P.K (1997) "Durability-Critical Issues for the Future", Concrete International, Vol. 19, No. 7, pp. 27-33.
- Ming-Te Liang and Chin-Sheng Kao (2010) "The Nernst-Planck Equation in Cylindrical Space and Time Coordinates for the Chloride-Ion Transport Phenomenon in Concrete Materials Using Theoretical Study", Tamkang Journal of Science and Engineering, Vol. 13, No. 3, pp. 257-266.
- Rob B. Polder and Mario R. de Rooij (2005) "Durability of marine concrete structures – field

investigations and modelling” HERON, Vol. 50, No 3, pp 133-153.

Sandberg P (1998). "Recurrent Studies of Chloride Ingress in Uncracked Marine Concrete at Various Exposure Times and Elevations." Cement and Concrete Research, Vol. 28, No.10, pp. 1489-1503.

Senthil Kumar and Naveenraj (2014) “Estimation of Marine Salts Behavior around the Bridge Structures” Vol. 3, No. 4, pp 152-156.

Steen Rostam [2000] “Service Life Design of Concrete Structures - An Experience-Based Discipline Becoming Scientific” Scientific Papers in Structural Engineering and Materials. Vol.37,pp 132-150

Rajendran V and Murugesan R (2013) “On Site Monitoring of Corrosion of Marine Structure Using Self Sacrificial Galvanic Anodes – Case Study” Journal of Civil Engineering and Science, Vol. 2 Iss. 3, pp. 193-201.