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RESEARCH ARTICLE

INVESTIGATIVE STUDY ON CORROSION OF PILES DUE TO SEAWATER.

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Abstract

The key problem which has stemmed from our present pecuniary explanation of the use of steel piles in all of the waterfront terminuses and in and on sea structures like oil rigs, columns for bridges etc. is the corrosion of the piles in sea water. Timber piling has its insect problem, and steel has the corrosion problem. But due to greater strength and durability steel is mostly selected. Steel being an alloy having most of its content as iron, it is prone to rust and corrosion and as the sea water is salty in nature the rate of corrosion increases and so regular maintenance cost increases. In the following paper, we will be discussing Piles in sea and corrosion, acting on it with a case study.

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Introduction:-

On the explanation that steel piles are completely in sea water, the additional with chemicals actively charged surface areas, anodes are metallicly coupled to the less with chemically active surface areas cathodes, which causes electricity flow and corrosion of the anodic areas. Roughening of the surface happens once the native anodic and cathodic areas systematically shift throughout the corrosion method. There are times that there's no shifting of those active native areas from their positional end, and there's a localized attack on the metal and corrosion happens. Generally, depth of corrosion

= quantitative relation of the anodic areas / space of cathodic site [in contact with the solution (seawater)].

Because the anode space reduces in regard to the cathode space, the deeper is the corrosion.

Corrosion:-

What is Corrosion?

Corrosion is the destruction of metals and alloys by the chemical reaction with the environment. During corrosion the metals are converted to metallic compounds at the surface and these compounds wears away as corrosion product. Hence corrosion may be regarded as the reverse process of extraction of metals from ore. It changes the properties of the metal and may lead to loss of the metal and its mechanical properties such as strength, ductility and impact strength. The rate of incident is highest as a result of deterioration of the underwater structure. The economy, the environment, and the human beings will be seriously affected and also an interruption of working as a result of the collapse of even one pile. Usually, the "chip and patch" method (whereby all loose material is removed and the

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section re-formed with newmaterial to cover the affected areas) is used for repairing corrosion damage pile but due to its negative efficiency, there has been alternative methods such as cathodic protection, fiber reinforced polymer (FRP) wraps and fiber reinforced polymer incorporating cathodic protection are used for corrosion repair of piles. The costly repair and maintenance works might have additionally to be undertaken if timely remedial action is not taken. Hence, finally the repair of corrosion pile and cyclic inspection is essential before the collapse of the structure because demolition is intolerable and replacement is not feasible. Corrosion protection methods are used to additionally mitigate and control the effects of corrosion.

What is Corrosion Management?

Before deciding on the methods for control of corrosion to be applied, conceptual and feasibility studies have been carried out. Typically, corrosion management can be divided into three majorphases.

Phase 1 of the program is the programmatic assessment of the project. This phase is the planning stage for a corrosion management program to take place. It initiates the program to be implemented on structures that are found to be under the threat of corrosion. For the planning stage, three main requirements are sought, namely the strategy, budget and schedule needed overcome the problem raised from corrosion of reinforcement. This is seen as an important part for an effective management program as feasibility studies are normally conducted to determine the serviceability of the structure after treatment.

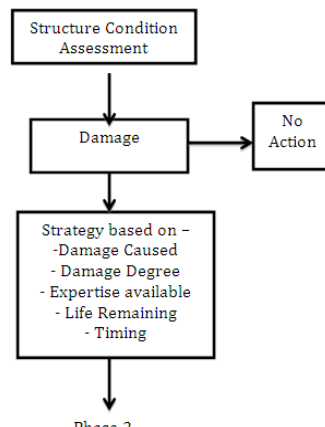


Fig.1:-Phase 1

Phase 2 of the program involves physical assessment and actual damages. Inspections for severity of corrosion areconducted during this section to see what strategy or ways are best suited to be applied. Development of corrosion management strategy would give a lot of choice to the management program. Remedial work would be allotted once the right strategy has been recognized.

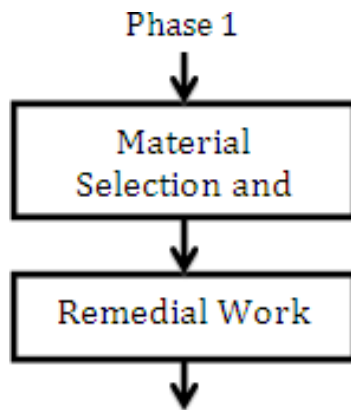


Fig.2:-Phase 2

Phase 3 of the program primarily deals with future observance of the repaired structure. Presently and traditionally, most of the corrosion management programs are driven by response to incident or pressing, instead of consistently distinctive and managing the prevailing resources. This could be overcome by implementing internal or external observance system oppression of the current technology practiced in oil and gas industries.

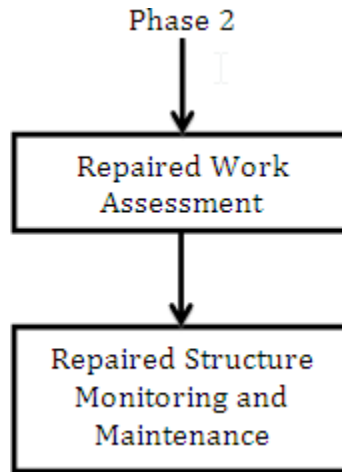


Fig.3:-Phase 3

Corrosion Protectionways:-

For protection of metals from corrosion, the metal and also the corrosive surroundings contact is needed to be brought to a halt. The surface of metals is coated with a continual non-porous material inert to the corrosive atmosphere to forestall it from corrosion. The coatings are classified into totally different categories:

1. Organic
2. Metallic
3. Inorganic

For Under Water Piles the types of coatings used are:

Inorganic Zn Silicates Primers:-

Structures that are immersed in seawater – jackets below the Splash Zone are typically not coated and guarded entirely by cathodic protection system. Several anti-corrosive pigmented primers, that passives the steel. Inorganic Zn salt primers are the foremost effective as they basically become electrode to the steel in a very corrosive method. The advantage of this coating is that it'll arrest rust creep, high degree of warmth resistance and spills of chemical.

Epoxy Coatings (HighBuild):-

Epoxies compared to primers and topcoats are chemical and abrasion resistance. It protects not solely the substrate, however conjointly the Zn primer and every one alternative harmful factors. One disadvantage of epoxy coatings is that, it's little resistance against radical violet rays from daylight. This results in the erosion of the coatings reducing the barrier protection.

Epoxy Primers (ZincRich):-

Epoxy anti-corrosives changed with Zn can guarantee a high level of service and are tolerant to totally different atmospheric condition and compromised surface preparation given that the Zn loading is ample. It's conjointly used only in maintaining the broken areas.

Aliphatic Polyurethane Topcoats:-

Polyurethane coats offer optimum resistance to actinic radiation rays and have high degree of flexibility and high chemical resistance. It conjointly helps to take care of a high degree of cosmetic gloss, color retention and it may be simply cleansed. Polyurethane finishes doesn't offer any real anti-corrosive or barrier protection, they offer a high degree of protection to integrity of the coatingssystem.

Non-Skid DeckCoating:-

These coatings are designed and built with anti-slip properties. These coatings incorporate coarse aggregates. The coatings are applied in terribly high film builds and frequently while not a Zn wealthy primer.

Cathodic Protection(CP):-

Most popular technique for mitigating underwater or marine corrosion is Cathodic Protection (CP) i.e. The Application or prevention of chemical science reactions for hindrance of steel structures from corrosion. The implementation of a cathodic protection system is kind of easy. It allow us to assume, there's chemical change steel in saltwater, all we tend to need is associate anode and power provided. A protecting circuit is achieved between the anode, steel (cathode), saltwater (electrolyte) and power.

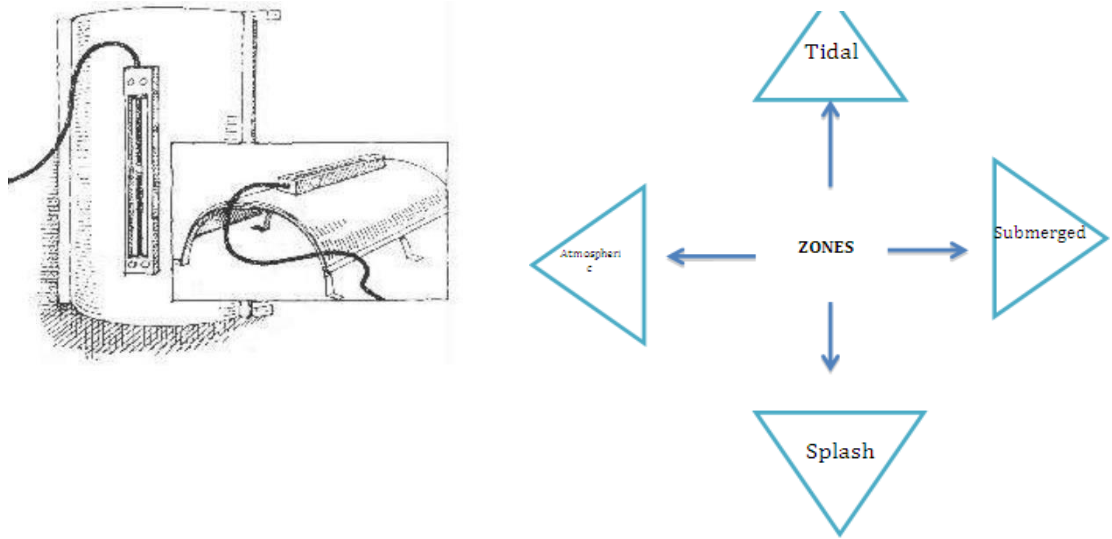


Fig.4:-Cathodic Protection

Pile Mounted Anode:-

This methodology of anode delivery is employed once the anode is tied or hooked up to the piles or cathode directly. These anodes are redesigned for economical distribution of current into and round the stilt.

Sled Anode:-

These anodes are designed and built for operation in either H₂O (electrolyte) or it is buried within the mud. anode mounted on the ocean bottom ensures the most effective unfold or distribution of protection for a marine structure. The advantage of this anode is its low profile, thence limiting the probabilities of harm by fishing nets, ships anchor, etc.

Corrosion Zones of Steel Pipes:-

Examination of unsound marine piles reveals many distinct areas of attack. It's convenient to divide these areas into 5 zones, every having a characteristic corrosion rate as shown in Fig.5 & Fig.6.

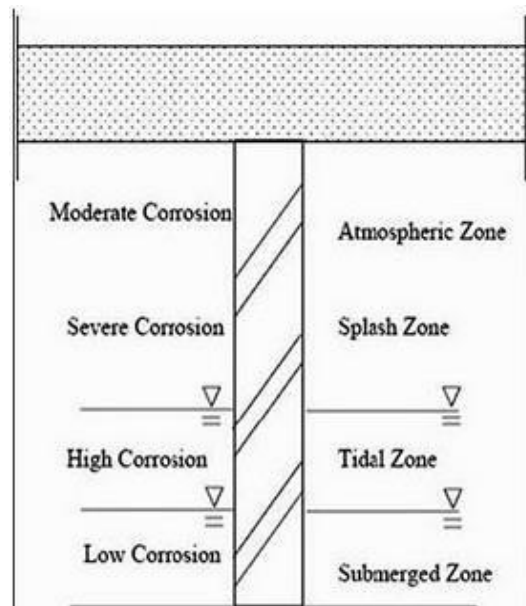


Fig.5:-Corrosion Rates in Different Zones

Fig.6:-Zones of Corrosion

Tidal:-

It is surroundings wherever the metals are submerged within the water and exposed to the splash zone alternately because the tide fluctuates.

Submerged:-

This surroundings zone is typically characterized by well-aerated water, together with the marine organism, animal and therefore the plant.

Atmospheric:-

It depends upon the temperature, pollutants, time of condition. It's conjointly mostly to blame for massive fraction of corrosion.

Splash:-

It is characterized as aerated surroundings of water wherever the exposed material is regularly wet and there's no attachment of bio organism.

Corrosion Mechanism of Steel in Sea Water:-

On steel structure in water, there are lot of chemicals with active surface areas (anodes) are metallicly coupled through the structure itself to the less active, with chemicals active surface areas (cathodes) leading to a flow of

electricity and corrosion of the anodal areas. General surface roughening happens once these native anodal and cathodic areas regularly shift haphazardly throughout the corrosion process. Typically these active native areas don't shift positional ends, therefore, the metal suffers localized attack and roughness happens. In general, the depth of roughness is expounded to the quantitative relation of the anodal sites to the world of cathodic site connected with the solution (seawater). The smaller the anode space relative to the cathode space, the deeper the roughness.

Corrosion Protection Methods:-

Corrosion activity is important to assess the severity or rate of corrosion. It's needed for sturdiness, safety of structure, and confirming repair or maintenance process. The process also can be used for checking the potency of corrosion process i.e. to see whether or not the adequate corrosion management has been achieved:

Half-cell potential:-

This was developed within the Nineteen Sixties for corrosion activity and comprised by ASTM C876. It's chemistry technique to assess the speed of corrosion and classify the chloride infected boundaries. This contains high resistivity and a typical reference conductor like copper- copper salt conductor. The reference conductor is placed by drilling a hole into the structure. The holes ought to be cleansed with water and compressed gas for removing the harmful substance. Before putting reference conductor, holes ought to prefill with low resistance grout then when reference conductor inserted in holes. The reference conductor is connected to the copper wire and therefore the wire can fix into the grooves created in concrete and lined with grout. This copper wire for reference conductor was routed into the junction box wherever they were connected to the reinforcement and guarded from the surroundings. This is conducted by connecting the negative and positive finish of the meter to the reference conductor and steel bars severally.

After arrangement, half-cell potential readings are taken and may be premeditated on equipotential relief map. Potential recorded within the half-cell potential is employed to interpretation of corrosion reading. For illustration, the positive reading of potential usually indicates the less corrosion.

S.no.	Half-cell potential readings (in volts)	Corrosion probability
1	Less than -0.200	90% probability of no corrosion
2	-0.200 to -0.350	Uncertain
3	More than -0.350	90% probability of corrosion

Table.1:-Corrosion Probability using half-cell potential test.

Linear polarization

Linear polarization is that the best methodology for mensuration the corrosion rate of metal embedded in concrete and conjointly called polarization resistance. The PR-Monitor, the executive agency Device (Nippon steel business firm.), the Gecor Device, and therefore the 3LP Device etc. used to measure the corrosion rate. Linear polarization depends on the linear relationship between the corrosion current its potential once the equilibrium potential is disturbed by applying of a progressive current or progressive voltage. The slope of linear polarization curve as follows:

$$R_p = \frac{\Delta E}{\Delta i_{app}} = \frac{11 \times 10^6 \times B}{X \times A} \dots\dots\dots(i)$$

Where,

R_p = Polarization resistance in ohm (volts/amperes).

B = Tafel constants, for concrete vary usually from twenty six to fifty two mV depending on the passive or active condition of the steel.

A = exposure of the steel measured.

X = Corrosion rate in small meter p.a. ($\mu\text{m}/\text{year}$) or mils p.a. (m/year)

The activity of the corrosion rate requires:

An operating conductor, the part whose corrosion rate is to be determined.

A reference conductor, to live the electrical potential of the operating conductor

An auxiliary or counter conductor, to use a current and complete the circuit.

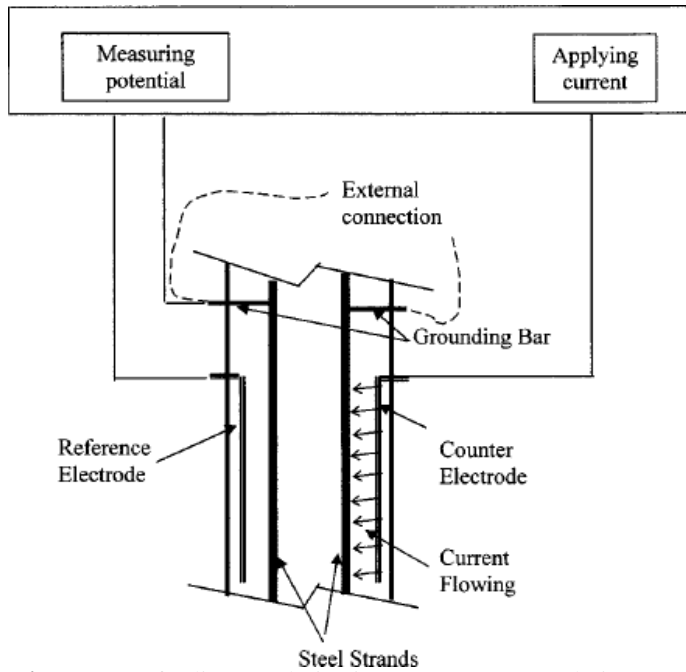


Fig.7:-Setup for linear polarization measurement technique.

The reference conductor and counter conductor embedded in concrete and connected to the PR-monitor. The reading is taken by varied the voltage in steps from zero to fifteen mV, with the present adjusted consequently. The slope of the amendment in potential and applied current provides the polarization resistance, R_p . when finding R_p , the corrosion rate is calculated by equation. Interpretations of values summarized.

Sr.no.	i_{corr} ($\mu\text{A}/\text{cm}^2$)	Corrosion level
1	< 0.1	Low corrosion
2	0.1 to 0.5	Low to moderate corrosion
3	0.5 to 1	Moderate to high corrosion
4	> 1	High corrosion

Table.2:-Interpretation of Linear Polarization Results

Sr.no.	i_{corr} ($\mu\text{A}/\text{cm}^2$)	Section loss (mils/year)
1	0.1	0.04
2	0.5	0.22
3	1	0.45
4	10	4.49

Table.3:-Correlation of corrosion rates to section loss.**Advantages:-**

1. This technique could also be used for accurately mensuration of the terribly low corrosion rate.
2. This technique may be used for speedy corrosion rate activity.

Disadvantages:-

1. This causes error up to five hundredth as a result of the approximation contains by this methodology within the calculation.
2. Another disadvantage is that it is sensitive to factors like humidness and temperature. Corrosion rate measurements can increase in heat conditions. Since the resistance of concrete decreases once the concrete is wet, corrosion rate measurements increase in wet conditions.

Galvanic currents:-

The performance and observation of the FRP system are given by the present density. Current density needed to be measured electrical phenomenon and therefore the expanse of protected steel. It maintains the protection level of steel and provides speedy polarization. The information loggers used to mechanically record the electrical current and recorded data is frequently downloaded from the positioning end. The present density is determined by dividing the measured electrical phenomenon by the expanse of protected steel. The measured electrical phenomenon isn't constant however influenced by the water speed and therefore the concrete resistance. Generally, dry concrete incorporates a higher resistance compared to the wet concrete. On the comparison, the system has less current density shows the reduced corrosion rate.

Case Studies:-**Allen Creek Bridge:-**

Allen Creek Bridge is found on the busy United States nineteen main road connecting Clearwater and St. Petersburg, FL. the initial bridge in-built 1950 was supported on ferroconcrete piles driven into Allen Creek. In 1982, the bridge was widened and this new section was supported on thirty five cm (14 in.) sq. pre-stressed piles. The waters from Allen Creek flow east into recent bay that successively joins then Gulf of North American nation to the south. The surroundings are incredibly aggressive; all the ferroconcrete piles from the initial construction had been restored many times. At low water, the water level within the deepest portion of the creek is regarding 0.76 m (2.6 ft.). Most high water is regarding 1.89m (6.2 ft.). This shallow depth meant that the underwater wrap might be administrated on a ladder.

Preparatory work:-

Pile surfaces were lined with marine growth that had to be scraped off. In addition, 2 of the 4 corners that weren't rounded however chamfered had to be ground prevention air- powered grinder. This was a tough operation notably for sections that were below the water line. Quick-setting Portland cement was to fill any depression, discontinuities and supply a swish surface. Simply before wrapping the whole surface was pressure washed, fresh to get rid of all mud and marine protectant.

Instrumentation:-

Instrumentation was put in to permit linear polarization and corrosion potential measurements to be created. Innovative instrumentation theme was developed that eliminated the necessity for wiring and junction boxes. This was a vital thought since the piles were situated in comparatively shallow waters that were accessible on foot. Many piles supporting the structure had been marred and therefore the chance of malicious mischief was terribly real.

FRP wrapping - 2 totally different schemes victimization 2 different materials were evaluated. In every theme four piles were wrapped with 2 alternative instrumented piles serving as controls. Within the 1st theme, caisson construction was used and therefore the piles wrapped employing a bi-directional FRP in an exceedingly wet disable underneath dry conditions. As this was wrapped underneath „perfect“ conditions, its performance provided means that for evaluating piles that were directly wrapped in water employing new water activated organic compound the latter theme was a pre-prig system developed by Air supply. The pre-prig was simple to put in since all the fabric came in labeled hermetically sealed packets. When applying initial epoxy layer, the packets were opened in keeping with the layout theme and therefore the FRP material applied. A shrinkage wrap was applied at the tip to permit the FRP to cure. On a median, it took between half-hour to forty five minutes to wrap a pile over 1.5 m depth betting on the quantity of layers of fabric that had to be applied

Friendship Trails Bridge:-

This is the oldest of the Gandy street bridges crossing bay. It had been originally created in 1956 and was slated for demolition in 1997 due to community activists, the bridge was saved, refurbished and restored. In 1999, the bridge was re-opened as a overcrossing and re-christened because of the “Friendship Trails Bridge”. The 4.2 km (2.6 mile) structure is currently the longest over-water recreational path within the world. The bridge has 275 spans supported by 254 ferroconcrete pile bents and twenty two column kind piers situated at the most channel crossing. Seventy seven percent of the 254 piers supporting this bridge have required to be repaired indicating that the surroundings is incredibly aggressive.

Preparatory work:-

All piles wrapped were 50.8 cm x 50.6 m (20 in. x 20 in.) ferroconcrete piles and wrapped over a depth of 1.5 m that extended all the thanks to the side of the pile cap. The waters are about 4.88 m (16 ft) deep. This meant that ladders might not be able to apply the FRP during this state of affairs. Innovative system was designed. It had been light-weight, standard however sufficiently rigid once assembled to support 4-6 folks. The system was suspended from the pile cap and extended a pair of 0.74 m (9 ft) below. Its mesh flooring provided a secure platform round the pile that allowed the wrap to be administrated unobstructed in knee deep waters.

Instrumentation:-

Unlike, the Allen Creek Bridge wherever malicious mischief was a true concern, the piles of the relationship Trails Bridge are situated in deeper in a lot of turbulent waters. Moreover, because the majority of the piles supporting this bridge had been repaired and a few were instrumented, the part of novelty was absent creating malicious mischief less probably. Visible of this, Instrumentation system developed by the Florida Department of Transportation was hand-picked. This needed each wiring and junction boxes. The theme uses rebar probes that are put in a totally different elevations getting ready to the reinforcing steel. Changes within the direction of the corrosion current between these locations will indicate if the FRP is functioning for sure. Reductions within the measured current compared to unwrapped controls were conjointly expected to produce index of the effectuality of the FRP wrap. The disadvantage with this method is that it takes time for the equilibrium state round the probe to be earned. Till now, knowledge might not be enough.

Remedies And Alternatives:-**Remedies:-****Cathodic protection:-**

Cathodic protection was fictitious by the Sir Davy within the year 1824. Cathodic protection removes whole corrosion, whereas operating cathodic protection is exclusive, steady method and continuously needs precise information regarding the standard of corrosive medium. The essential principle of cathodic protection is that the continuous offer of electron to the steel by external sources i.e. to produce electrical phenomenon to steel. If electrons are equipped to the steel by external supply, then the anodal reaction are blocked. Because of block of

anodal reaction, results lowering the potential of steel and there's no flow of electron between the anode and cathode, thus corrosion are stopped.

Prevention of corrosion within the cathodic protection method depends on the present density. The present density is outlined because the cathodic protection current per unit space of steel surface i.e. ampere per per that maintain the protection level of steel and supply speedy polarization. It's typically laid low with gas and water speed therefore, these factors ought to be thought of in cathodic protection method.

For achieving the cathodic principle, it's essential to assemble the chemistry cell with auxiliary anode which will work properly in solution and steel being the cathode. There are 2 ways of achieving these needs, one is galvanic anodes or execution anode and second is immersed current and typically combination of each ways used for underwater structure, wherever there's adequate physical phenomenon to keep up the correct operating of the cell.

Galvanic anodes or sacrificial anode method:-

In this methodology, cathodic protection is achieved by attaching a less noble or a lot of active anode to a structure, leading to the new anode being unsound quicker than the protected material. The driving electrical phenomenon between anode and structure is provided directly by the electric potential between the materials i.e. generation of a cell between 2 metals with totally different potential. The new anode is unsound throughout the protection of steel therefore, it's referred to as putting to sacrifice anode. The galvanic anode ought to be placed terribly getting ready to or connected with the protected structure by either attachment or clamp. Zinc, magnesium, and Al are most generally used the fabric as sacrificial anode for safeguarding the steel structure as a result of they're reactive than the steel. Sacrificial anode doesn't need any maintenance except replacement at an appropriate interval once to corrode. Usually it's terribly tough to exchange the anode on the stationary structure therefore, galvanic anode system ought to be designed for ten years or more.

Impressed Current Method:-

In this methodology, cathodic protection is achieved by application of a current from external supply like DC transformer or rectifier, connected to inert anode. The structure is cathodically polarized or down potential of steel, thus defends the structure. The negative terminal and positive terminal of the external supply is connected to the structure and anode severally, with the assistance of cable. The consumption rate or corrosion rate of immersed current anode.

Is incredibly low compared to a galvanic anode, even at high current densities as a result of anodes are inactive. The affected current anode ought to be placed well separated from the protected structure and if it's needed to position terribly getting ready to the structure, then nonconductor protect ought to be provided between anode and structure. Impressed current system needs high maintenance value and will be designed for twenty years or larger life. This methodology is used for structure, wherever electrical phenomenon is obtainable. High semiconducting material iron, platinized metallic element, lead-silver alloy, black lead are most generally used as immersed current anode.

Alternatives:-

Application Of Fibre bolstered compound Composites:-

Fiber Reinforced Polymers (FRP) are largely used for the repair and rehabilitation of concrete structural components. The composites are very light in weight, are proof against chemicals, have high strength and in cloth type have high degree of flexibility. The FRP composite once mixed with wet concrete makes it economical to conduct repairs on sub structure elements. Once the FRP is employed, then the unsound part of the structure is rigorously removed and therefore the FRP composite elicited concrete is applied. The FRP provides the lost tensile capability and it also provides the steel with lateral support. Once the FRP is applied with concrete, the spreading of corrosion to alternative piles is protected and it conjointly ensures protection from ultraviolet radiation.

Application Of FRP Composites:-

Fiber Reinforced polymers (FRP) have long been used for the repair and retrofit of concrete structural components. Their light-weight, high strength and resistance to chemicals provide obvious edges. In cloth type, they supply uneven flexibility. Moreover, as fibers are directed in any direction, their use is optimized. This makes FRP notably fitted to emergency repairs wherever harm is multi-directional and speed of strength restoration critically vital. The emergence of latest adhesives that enable FRP to be warranted to wet concrete surfaces makes it potential to

economically conduct emergency repairs on sub-structure components. Impact harm that semiconductor diode do to each cross-sectional loss and breakage of the spiral ties. Standard repairs would require the cross-sectional to be enlarged to accommodate new ties. If instead, FRP were used it'd solely be necessary to re-form the cross-sectional and apply bi-directional layers that would restore lost tensile capability whereas providing equivalent lateral support to the longitudinal steel. Moreover, the applying of a protecting ultraviolet radiation (ultra-violet) coating on the wrap of the proper color can render the repaired pile indistinguishable from alternative uninjured piles. The aesthetics of FRP repair is one amongst its unpredicted edges.

FRP wrapping:-

Two totally different FRP systems were used. One was identical pre-prig system with a water-activated organic compound employed in the Allen Creek Bridge. The opposite was Fyfe system that used resin that cure in water. The pre-prig system was used to wrap four piles – 2 Prevention carbons and 2 Prevention glass. The wet-layup system from Fyfe needed on-the-scene saturation of the fibers. 2 piles were wrapped with covering material prevention in this process. Of the two, one was experimental FRP system that combined wrapping with a sacrificial cathodic protection system. 2 alternative unwrapped piles in an exceedingly similar initial state of unsoundness were used as controls to gauge the performance of the wrapped piles. Application was expedited through the employment of a system. The pre-prig system was applied as within the Allen Creek Bridge and posed no issues. The Fyfe system was more difficult since the FRP material had to be saturated on-the-scene. Access to foundations of adjacent bridge provided a convenient staging post for the on-the-scene impregnation. On a median the operation took ninety minutes to finish.

Application of FRP Composites for Corrosion Protection of Underwater Piles:-

The use of FRP is just, that it's mixed with the wet concrete, which makes it economical to conduct repairs on sub structure elements. Ordinarily the repair of those elements needs the enlargement to accommodate new ties. However once FRP are used the utterly unsound a part of the part is rigorously removed and this FRP elicited concrete is applied, that provides the lost tensile capability and conjointly provides the lateral support to the steel. Because the FRP is applied with concrete, spreading of corrosion to alternative piles is protected and at identical time it protection from ultraviolet radiation coating on the wrap of the proper color. The aesthetics of FRP repair is one amongst its unpredicted edges.

Standard Codes:-

There are no Indian standards codes as such for the control of corrosion. The latest editions of the following organizations' standards, codes, and guidelines shall be used for the design of corrosion control systems:

1. NACE International (formerly The National Association of Corrosion Engineers)
2. RP0169 – Control of External Corrosion on Underground or Submerged Metallic Piping Systems
3. American Society for Testing and Materials (ASTM)
4. ASTM D512 – Standard Test Methods for Chloride Ion in Water
5. ASTM D516 – Standard Test Method for Sulfate Ion in Water
6. ASTM G51 – Standard Test Method for measuring pH of Soil for Use in Corrosion Testing
7. American Railway Engineering and Maintenance-of-Way Association (AREMA)
8. Federal Highway Administration (FHWA)
9. Publication FHWA-NHI-00-044 – Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil slopes.

Conclusion:-

Though there's no absolute thanks to eliminate all corrosion on beneath water piles, there square measure some effective measures to manage them. The electrode protection is found to be quite easy to use and principally employed in marine conditions. The protecting coatings square measure employed in immense and pricey structures. The FRP composites have several benefits over standard strategies such they're light-weight, possess high strength and chemical resistance and furthermore have alone flexibility. Of the varied ways that of wrapping of FRP composites thwart wise wrapping is found to be the simplest as otherwise, the longitudinal items square measure awkward to handle and tough to position. Bi-directional material is that the best choice. Staging measures throughout the appliance of materials ensures safety and simplifies installation. Out of the 2 system of FRP application, the pre-

prig system is simpler to use. On-site FRP saturation are often problematic. High winds and high tides ought to be avoided throughout the method.

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