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An Overview Assessment of Various Surveyed Corrosion Protection Approaches for Steel

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Abstract: - Steel is the most important engineering alloy but lots of money is used far more than for any other material to protect it from corrosion. The most important corrosion problem to contend with in all quarters worldwide is rusting of structural steel works. Steel frames that are properly protected will last infinitely but the best protection practices are not always used, so unavoidably allowing large tonnages of steel to rust away every single day with attendant effects. A steel structural design must therefore include reliable corrosion protection strategy that is strictly followed; otherwise an unpredictable failure or impaired service performance of the structure is prone to occur. This paper revisits the general approaches that have been in use to combat corrosion of steel in their relative pros, and cons. The assessment concludes that, the best steel corrosion prevention strategy for every characterized natural or comparable environment has to involve a practicable painting or organic coating system. The aim of the paper is to provide readily public-available information that can be consulted and used, and enable appreciation of need for more positive researches or rethinking in protection of steelworks.

***Keywords**: - Steelwork corrosion, problems, awareness, protection approaches, maintainable effectiveness, cost-affordability, organic coatings, more positive researches and rethinking.*

I. INTRODUCTION

An engineered product must not only comply with the immediate strength, aesthetic, and cost requirements; it must also ensure that these are maintained throughout its life. One of the most common causes of failure or unsatisfactory service performance in the long term is due to corrosion. Huge investments on physical facilities and manpower are made to combat corrosion of steel, yet some financial losses are still incurred because the best corrosion prevention practices are not always used. The situation is worsened by very low general awareness of corrosion, its social implications and methods of counteracting it to the extent that even no public policies are in place to minimize its impact in some quarters. The amount of steel which is allowed to rust away for lack of adequate protection worldwide amounts to about 1000 tonnes every single day. Corrosion resistance of steel increases with its carbon and or amount of alloy elements contents. Of all types of steel, stainless steel is most resistant to corrosion because of its high alloy contents but is the most costly and least available type, has the least fabrication and formability properties, and is used in special and fewer applications. On the other scale, low carbon steel accounts for about 90% of all steel used for all structural works because of its cheapness, greater availability, good fabrication and formability properties such as machinability, rollability, weldability, forgeability, drawability and bendability but is the least resistant to corrosion. The metalwork that suffers the greatest amount of destruction from corrosion each year embraces all types of steel used as columns, beams and roof trusses for farm buildings, factories, warehouses, dock sheds, schools, hospitals; steel structures of bridges, tin cans, viaducts, stairways, gantries and cranes; steel framework carrying water and oil tanks, chemical vessels and pipework, etc. If corrosion is not checked it will gradually eat away such buildings and structures, eventually causing them to collapse with possible loss of life. Different methodical levels of preventing or controlling steel corrosion for correspondingly different periods in different environments have been developed but the best is yet to come for all environments, so; there have been searches for more effective, efficient, economical and reliable methods of durably protecting this most important and versatile engineering alloy from corrosion in all its service environments. The choice of a protective method for a particular service environment is dictated mainly by its effectiveness, feasibility, cost and durability. It is possible to use a customized or any other protective method that can provide infinite life protection for all steel types but the cost of such approach can be prohibitive for mass or general use such as structural steelworks. Existing methods that are generally exploited to prevent or control corrosion of steelworks include design techniques, cathodic protection, chemical inhibition, conversion coatings formed by chemical reaction with the surface of steel, use of coating systems, using or developing better material properties of the steel, corrosion monitoring (Shreir, 1979; Guma et al, 2010; 2011a, b and 2013a). This paper is a highlight of these pragmatic approaches in their relative merits and demerits. The aim of the paper is to juxtapose facts from different sources into a readily available compendium of information for better appreciation of levels attained on the approaches and their inadequacies, and for application or positive research rethinking by researchers, academicians, students, practitioners and the general public.

II. METHODOLOGY

The assessment was based on literature information and experiences as engineering professionals, academics, researchers, fieldworkers.

THE PROTECTIVE APPROACHES

Design Method

Prevention of corrosion generally begins at the design stage of a project. Faulty geometrical design is a major factor in the corrosion of steel. A design may be sound from the structural and aesthetic points of view, but if it incorporates features that tend to promote corrosion, then unnecessary maintenance costs will have to be met throughout the life of component or part, or early failure may occur. Design can therefore have an important bearing on the corrosion of steel structures (Johnson, 1965; Shreir, 1979 and Johnson, 2001). The most common and easiest way of preventing steel corrosion once the alloy has been judiciously selected for a characterized corrosion environment is by observing important points such as; arrangement of features so that they do not trap moisture and dirt, allowing free circulation of air around the steel structure or part, not exposing steel to contact with water-absorbent material or wood, making parts of the structure accessible for maintenance, selecting structural shapes which will have a minimum exposed surface, avoiding shapes or details which catch dirt or debris, noting that large flat surfaces are easier to protect than more complicated shapes, ideally locating load-carrying members in the least corrosive locations and elimination or avoidance of pockets, low spots, sharp edges, sharp corners, cavities, crevices, lap joints, bolted joints, box sections which will trap moisture or water in all designs (Johnson 1965; Moore, 1966; Pludek , 977; Shreir, 1979 and Collins, 1981).Observance of some design details for the sake of corrosion protection will involve little or no increase in the cost of a structure and will result in substantially decreased maintenance cost, however the disadvantage of the method include (Pludek, 1977; Ross, 1977 and Shreir 1979):

i. The method may not be feasible or economical for some practical situations; and in most cases could only reduce corrosion but not prevent it completely.
ii. Occasionally a change in design or materials for the purpose of corrosion control may have serious effects that are not related to corrosion per se, or result in corrosion problems that were previously present in the old system ; and incur much costs.
iii. Very often the effects of corrosion cannot be clarified at the early stage of design because information is lacking either on the precise environmental conditions or on the behaviour of the material in a certain configuration or application under these conditions.

Cathodic Protection

Corrosion of steel in aqueous environments or damp soil is primarily electrochemical in nature and is due to a corrosion current passing from anodic areas of the metal into solution and returning to the metal at the cathodic areas. Cathodic protection is used to prevent or reduce the rate of corrosion of steel structures, immersed or imbedded in such environmental electrolytes by impressing a counter current on the metal in a sufficient amount to neutralize corrosion current, or making the structures cathodes. The principle is based on the fact that corrosion and cathodic protection are natural phenomena which occur when any two dissimilar metals immersed in an electrolyte are brought into electrical continuity. The more active metal becomes the anode, while the less active becomes the cathode and receives protection. There are two common techniques of affording cathodic protection. These are; by using sacrificial anodes and by impressing a current (power impressed). Cathodic protection is often applied to coated structures, with the coat providing the primary form of corrosion protection and the cathodic protection system acts as a supporting protection. The main applications of cathodic protection include: buried pipelines, acid storage tanks, offshore steel structures such as platforms and oil rigs, ships and concrete structures exposed to sea water such as bridges (IIIston et al 1979; Shreir, 1979 and INTERNET, 2014).

Cathodic protection is usually the only economic method of protecting major buried or immersed steel and other metallic structures from corrosion. The method is simple and when absolutely correctly applied, corrosion is impossible. It can be applied to any buried steel item without fully excavating the system. The forms of corrosion which can be controlled by cathodic protection are wide including all forms of general corrosion, pitting corrosion , crevice corrosion stress-corrosion cracking, corrosion fatigue, cavitation corrosion , bacterial corrosion, etc. In particular it can be applied in conjunction with some protection coatings to guard against any damage to the coating, or any break or discontinuities that may of necessity or accident exist. At any time, the efficiency of the protection can be checked by measuring the potentials of the reference points, and adjusting to compensate for any changes in local environment. Sacrificial cathodic protection needs no external power source, is easy to install, has low maintenance and cost, and provides uniform distribution of current. The impressed current cathodic protection has higher current and power outputs and adjustable protection levels, can be used for large-area works, requires lower number of anodes and can be used to protect poorly coated structures.

The method however has noteworthy disadvantages. The structure to be protected and the anode used for protection must be in both metallic and electrolytic contact hence it is applicable only in aqueous electrolyte or some damp soil environments. It cannot be applied in controlling atmospheric corrosion of steel, since it is not feasible to immerse an anode in thin condensed film of moisture or droplets of rain in the atmosphere. The spread of the protective current is dependent on the resistivity of the environment. As a result, cathodic protection is not practicable for large structures in fresh water and high resistivity soils. Under such conditions a large number of widely distributed anodes would be required. Fortunately, however poor conductance and high resistivity also reduce the risk of steel corrosion taking place, or at least keep it to significant proportions so that protection is not necessary. Specifically, the disadvantages of sacrificial cathodic protection include: limited current and power output, requirement of a large number of anodes for high resistivity environments or large structures, periodic replacement of anodes. The disadvantages of impressed current cathodic protection include: complex equipment and installation costs, possible interference problems with foreign structures and risk of incorrect polarity connections (Shreir, 1979 and INTERNET, 2014).

Corrosion Inhibition

Rusting of steel depends on both moisture and oxygen contents and the degree of pollution of an environment. The rate of the process can be affected by modifying the environment. This can be achieved principally, by inhibition of the corrosion process or its agents by addition of certain chemicals or substances that can restrain it, to requisite environments. Corrosion inhibition is an economical method of protecting steel used in certain environments such as boilers and pipework of central heating systems, re-circulating systems such as internal combustion engines, cooling systems of road vehicles and railway locomotive; steam condensate lines; the oil industry at every stage of production from initial extraction to refining and storage prior to use, storage tanks, domestic and industrial water supplies, store rooms, and packages (Shreir, 1979; Legrand and Leroy, 1990 and Callister, 2004). Many inhibitors such as: acetylenic alcohols, aromatic aldehydes, alkenyphenones, amines, sodium benzoate, nitrites, toluylalanine, cyclohexylamine, dicyclohexylamine, methycyclohexylamine, phenythiourea, sebacic acid, calcium silicate, sodium phosphate, imminium salts, triazoles pyridine and its derivatives, thiourea derivatives, thiosemicarbazide, thiocyanates have been reportedly used to prevent steel corrosion (Kahraman, 2002; Guma et al, 2013b; Matjaz Finsgar and Jennifer Jackson, 2014).The main advantages of preventing or controlling steel corrosion by chemical inhibition are (Ross, 1977; Shreir, 1979; Harrop, 1990 and Legrand and Leroy, 1990):

i. It is the most feasible and economical method of protecting steel that is used in recirculation systems and some other confined environments of liquid nature, from corrosion.
ii. Most inhibitors are cheap and their application is easy and fast, once the right application conditions are established.

Corrosion inhibition process however has the following problems or limitations (ASM Handbook, 1975; Ross, 1977; Shreir, 1979 and Harrop, 1990):

i. For effectiveness of inhibition, the process is applicable only where chemical and conditions monitoring is feasible. All inhibitors have a pH range in which they are effective, so close Ph control is often necessary to ensure continued efficiency of inhibitive treatments. To be fully effective, inhibitors require to be present above a certain minimum concentration, otherwise corrosion that occurs with insufficient inhibitor may be more severe than the complete absence of inhibitor. Effective inhibitor application is affected by the liquid composition such as; oil and the water composition ratio, the types of oil and the water composition. Other factors that affect the application include fluid velocity, type of geological formation, solubility and specific gravity of the inhibitor to be used, smoothness of the materials to be protected, and the prevailing temperature. This makes inhibitor application difficult or complex for many practical situations.
ii. The process is not applicable to prevention of atmospheric corrosion of steel. This is because it is difficult to achieve and maintain the required inhibitor concentration in air due to wind; and hence the inability of the inhibitor to remain suspended in the air at the right concentration for any reasonable time.
iii. Some inhibitors present toxicity hazards to human beings or animals and often there arises the problem of detoxifying or disposal of some inhibitor-treated waters of large volume. For example, waters treated with chromate and phosphate inhibitors, are known to be toxic. The problem of toxicity is complicated by difficulty that arises in describing the precise chemical nature of many inhibitor formulations that are actually used in practice. This is because, with the advancing technology of inhibitor applications there are increasing number of formulations that are marketed under trade names; their corrosion are for various

reasons, frequently not disclosed. This makes safeguarding against inhibitor toxicity while using them difficult.

iv. The lives of inhibitors vary from hours to days, months and years depending on the type, and type of environment. It could therefore require some preliminary test in an environment with a particular inhibitor for some time, before a design concentration of the inhibitor for the environment is made. This can incur much cost.

v. Effective protection by inhibitor relies on the continued access of an inhibitor to all parts of steel surfaces, where this condition is difficult to achieve due to presence of crevices at points, dead-ends in pipes, gas pockets., deposit of corrosion products, etc, corrosion will then occur at these sites even though the rest of the system remains adequately protected.

vi. Inhibitors that are effective in the absence of conjoint action of mechanical factors such as fretting or cavitations, applied stress and fatigue effects may not be so in the presence of such factors.

vii. Many inhibitors will lose their effectiveness in the presence of effects of some micro-organisms in aqueous solution of inhibitor in some way by acting as nutrients to them.

viii. Economical factors can prohibit the application treatment for many practical situations.

Protection by Metallic Coatings

A preventive metallic coating for steel corrosion is an applied adherent metallic coat on the surface of the alloy, which can protect it sacrificially and or mechanically. The coating is intended to perform the function by acting as an impervious interface between the steel and the environment and hence prevent any corrosion activity between them. The coating can also have inhibitive capabilities on steel corrosion. In sacrificial protection, the metallic coat corrodes at a rate higher than that of steel. The metallic coating can be formed by a variety of methods. The choice between these may be dictated by convenience, but successful coats depend upon adherence produced by a method (Carter, 1977; Barton 1976 and Shreir, 1979).

There are four commonly used methods of applying protective metallic coatings to steel surfaces, hot-dip galvanizing, metal spraying, electroplating, and sherardizing. The last two process are not used in structural steelwork because of some infeasibilities, or higher costs; but are used for fittings fasteners and other small items. The methods are common because they are the optimal ones, applicable to coating steel with zinc, aluminium, lead, and tin. These four metals offer the most effective protection of steel, at economical costs since they are the most common and cheap non-ferrous metals (Shreir, 1979 and Johnson, 2001).

Hot-dip galvanizing

This is the most common method of applying a metal coating to structural steel. It is the most economical method of zinc-coating steel. It is estimated that approximately 40% of the world production of zinc is consumed in hot-dip galvanizing of steel, and this adequately demonstrates the world-wide use of zinc as a protective coating. This is mainly because the metal itself resists corrosion and is available at comparatively cheap price. Hot-dipping is used for the application of other metals such as aluminium, lead/tin but these metals are not commonly used for structural steelworks. The specification of hot-dip galvanized coatings is covered by British Standards-BS729 which requires for sections not less than 5mm thick, a minimum mean zinc coating weight of $610g/m^3$ equivalent to a coating thickness of 0.085mm. Galvanizing provide barrier as well as cathodic protection. It results in coatings of very high corrosion resistance that are also highly resistant to damage during transportation, storage and handling. The finish appearance of the coating is not particularly attractive and its thickness can be variable, thus precluding the use of galvanizing for components which are required to have good visual finish and fine limits. There is also health hazard to the operator as zinc fumes are toxic (Johnson, 2001).

Metal spraying

Alternative method of applying a metallic coating to structural steelwork is by metal spraying of either zinc or aluminium. The main advantage of metal spraying compared to other metallic coating processes is cheapness. Metal spray coatings can be applied in shops or on site after a structure has been erected because of portability of spraying equipment and there is no limitation to the work size as there is with hot-dip galvanizing. The surface of the workpiece remains cool during the process so there are no distortion problems. The main disadvantages of the coating process are; the tools are rather awkward to handle as they contain molten metal, the metal used for spraying must be easily fusible, there is good deal of erosion on the nozzle orifice which may affect control of the process, spray coatings are porous due to their structure of overlapping flakes after having solidified instantly on contact with the surface and is more expensive than hot-dip galvanizing (Johnson, 2001).

Electroplating

Electroplating is application of electro-deposition to produce a thin, coherent and adherent coating of solid metal on a base. The process is used to protect steel from corrosion by producing metallic coatings of suitable metals on it. The process is used to protect steel from corrosion by producing metallic coatings of suitable metals on it. Thickness of electroplated metals on steel varies from 0.00762 to 0.001524mm. Deposit thickness appropriate to various conditions of service of the steel metal are laid down in a number of specifications such as the International Standards, British Standards and American Standards for Testing Materials. Electroplatable metals on steel for corrosion protection include metals that offer sacrificial protection such as zinc, tin, aluminium, copper and bronze; and the noble metals such as lead, nickel, gold, chromium, titanium and platinium. The process requires high-quality surface pretreatment of the base steel, good operator skills to control process variables such as electricity current density. On the side of advantages, protective coatings of the required minimum thickness produced by the electroplating process are generally more adherent, smoother, cleaner, and thinner than those of other coating processes. The disadvantages of the process include (Ross, 1977; Shreir, 1979 and Degarmo et al, 2003):

i. Electroplating relies on electricity; hence it can be accomplished only at a workshop where facilities are installed and electricity is available, but not at worksites.
ii. The process is slower compared to painting, hot-dip galvanizing and metal spraying.
iii. The need for very high quality cleanliness of the steel and proper process control makes electroplating unsuitable for structural steelwork. It is therefore more applicable to small steel parts.
iv. All electroplating contain pores and the only certain way of eliminating them is to plate to an uneconomic thickness to eventually abridge over the pores.
v. Many electroplating are deposited in a state of residual stress which can be considerable up to 225MN/m^2, if conditions in the plating bath are not properly adjusted. Such stresses may cause the plating to break away, or result in distortion of the plated steel; and can also have dangerous consequences if the plated part or article is then subjected to tension, fatigue or corrosion during service.
vi. No electroplating bath has perfect throwing power, that is, the measure of the ability of the bath to produce a uniform thickness of the plating. Uniformity in thickness is important, both for economy and adequate protection.

Sherardizing

Sherardizing is zinc-coating steel by diffusion process. By this process, the chemical composition of the steel surface is modified by diffusing zinc into it. This is accomplished by first cleaning the steelworks thoroughly, by pickling and sandblasting. The works are then placed in a suitable steel drum with zinc dust and heated to a temperature of about 260 to 315^{o}C, depending on their sizes and shapes whilst the drum being rotated so as to promote rumbling of the contents. This results in coatings in coatings on the works that are not pure zinc, but an alloy of about 90% zinc and 10% iron; which is highly resistant to corrosion. The process is especially suited for screws, bolts and nuts, chains, pipe fittings, nails, and such other high strength articles that may conveniently be placed within the drum. The cost varies with character of the steelwork coated. The protective coating that is produced by the process is the most adherent, thinnest, more uniform thickness and damage-tolerant with long-term-corrosion protection compared to those of galvanizing and spraying processes; but the cost involved is highest. Coating thickness usually varies from 0.012 to 0.04mm, and the coating is continuous and uniform even on threaded or irregular parts. Sherardizing is limited to works of small size. It is more laborious and takes longer time than hot-dip galvanizing and metal spraying. The process is covered by BS 4921 (Price, 1963 and Jackson and Ravindra, 1996).

Overall advantage and disadvantage of metallic coatings

Metallic coatings are much more resistant to degradations such as cracking, blistering and peeling compared to paint coatings. They are strong and insensitive to light and moderate heat, for the most part they are more wear resistant than paints and are amenable to soldering. On the other hand, if corrosion once starts it will proceed faster because of the galvanic conditions which are set up and because it is not possible impregnate metallic coatings with inhibitive compound that are present in paints. The equipment for applying metallic coatings is more elaborate than that for painting, which puts up costs and may make it difficult to replace coatings which have failed on structures as compared with the relatively straightforward task for repainting. The coatings also change the chemical, physical and mechanical properties of steel (IIIston et al, 1979).

Paints or Organic Coatings

Paint or organic coating is the principal method of protecting structural steelwork from corrosion. About 90% of all steel are corrosion-protected by paint or organic coatings. A paint or organic coating is required mainly to prevent corrosion of the substrate in the presence of moisture and corrosive electrolytes over an indefinite period; and to stifle corrosion in the event of its onset because of any incomplete covering, mechanical damage or breakdown of the coating through age and factors of exposure environment. There laid down types of paint or organic coatings for different soil, water, atmospheric and other comparable environments and procedures for applying them by different, industries, organizations and authorities such as the International Standards Organization, American Standards for Testing Material, National Association for Corrosion Engineering, British Standards, Army, Navy, etc which must always be consulted and properly used (Diamant, 1967; IIston et al, 1979; Shreir, 1979 and Johnson, 2001). The comparative advantages of using paint or organic coatings for corrosion protection of steel include the following (Laque, 1975: Pludek, 1977 and Shreir, 1979):

i. A wide range of solid and liquid materials of organic or inorganic nature are available and are used, or can be exploited for formulating paints of desired characteristics. This flexibility is not common with any other coating method.
ii. A painting system can be formulated anywhere, anytime under normal conditions for a particular application, and the formulation is modifiable to meet any change in the service requirement.
iii. Painting is generally more economical, easier and faster to accomplish than metallic and other coating methods.
iv. A wide range of paint application methods, ranging from hand brushing to fully automated ones are available, which can be conveniently or suitably exploited for particular situations of the work.
v. The protection provided by a properly selected and applied paint, is reasonable during its life.
vi. Painting is the most important method of protecting steel from atmospheric corrosion. It is applicable to almost all other environments.
vii. Maintenance work with paints is easier and cheaper and can be carried out at a worksite without necessarily bringing the work to the workshop.
viii. The material, equipment, and labour costs incurred in procurement, paint formulation, surface preparation of the work, and maintenance are in totality minimal for painting compared to other coating costs.
ix. Painting applicable to jobbing, or batch, or mass works at economical cost.

Despite these advantages, painting systems have some disadvantages which include (Laque, 1975; Pludek , 1977 and Shreir,1979):

i. Some of the paints contain toxic materials that are health-hazardous to personnel if exposed to them for some time through inhalation or skin contact. For example, lead contained primers used for corrosion protection of steel.
ii. The protection lives of paint coatings are generally less than those of metallic and some other coating of the same thickness, under the same environmental conditions.
iii. Most paint coatings are more porous, and are generally less adherent rougher, and less hard, compared to most properly applied metallic coating which also posses other characteristics that are much better.
iv. Formulation of a paint of suitable or desired characteristics, requires as, its chemical compositions and their compatibility.
v. Some paints are prone to fire and explosion hazard

Encasement

Encasement is often used as protective method for corrosion of steel parts or structures in certain environments, where the method is found to be the only feasible one. The method is used to provide permanent or semi permanent corrosion protection of steelwork by encasing or sheathing the entire or part of the work with a suitable non-corrodible material. Concrete encasement, and reinforced bitumen coatings (wrappings) are the optimal encasements for the protection (Johnson, 2001; Shreir, 1979 and Callister, 2004).

Concrete encasement

Concrete encasement of steel sections is most frequently used for protection of; waterfront steel structures in the tide zone, and below the waterline, buried pipe structures, lining pipes, structural elements which will be inaccessible in the final work and for structural subjected to particular corrosive atmosphere such as those exposed to locomotive blast or those in chemical plants (Johnson, 2001). The disadvantages of the method include (Johnson, 1965; Basalo, 1992; Perkins, 1997; Callister, 2004 and Uche, 2006):

i. The method is slow and laborious for mass work.
ii. In reality, even a well-constructed concrete encasement will not protect steel from corrosion completely, due to electrolyses. This is because most concrete are somehow porous.
iii. It can mostly be accomplished at the worksite. This requires moving materials, equipment, and workmen to sites; and hence addition of incurred costs.

iv. For stability, integrity, feasibility and convenience; concrete encasements are ground-based but not aerial-based. This makes application of the method difficult and costly if not feasible when the structure to be protected is very tall and the protection is to be provided at sections of the structure that are high above the ground. This difficulty may exacerbate if the structure is slanted.
v. It is more applicable to immoveable installed structures.
vi. Where the steel may be required to discharge stray current to the ground, some form of suitable cost-incurred grounding system must be provide.
vii. Generally the costs involved are very high compared to paint and metallic coatings for particular application.

Reinforced bituminous coatings (wrappings)

The coatings provide excellent protection against corrosion, and are widely used for the encasement of buried steel members in highly corrosive soils such as river bottoms marshlands, cinder fills, fills containing organic debris such as garbage and in tidal regions. Wrappings are particularly used to protect, pipes, the tie rods and fittings that anchor retaining structures, and elsewhere where high-quality long-lasting protection is desired. The coatings have the advantages of impermeability to water, high electrical resistance, good adhesion and resistance to bacteria. They are however, not commonly used for protecting structural steel from atmospheric corrosion, because of higher costs involved compared to painting galvanizing and metal spraying and somewhat appearance (IIIston et al, 1979; Shreir; 1979 and Basalo, 1992).

Corrosion Monitoring

The rate of corrosion dictates how long any process plant can be useful or safely operated. Corrosion monitoring refers to corrosion measurements performed under industrial or practical operating conditions. Its main purpose is to acquire data on the rate of material deterioration. A number of different technologies of directly monitoring corrosion are available and include; electrical resistance (ER), linear polarization (LPR), Galvanic, ceion, continuous temperature analysis, continuous chemical analysis, electronic hydrogen analysis, and weight loss coupons techniques. Non-destructive techniques including radiography, ultrasonics, eddy current testing, magnetic particle inspection and dye penetrant inspection are also available and can be used to indirectly monitor corrosion. Each method has its own relative advantages and limitations (Bartholomew, 2003; Protan, 2014 and TN Guma et al, 2014). The overall benefits of corrosion monitoring include (Bartholomew, 2003; Protan, 2014 and TN Guma et al; 2014):

i. Provision of early warnings that damaging process condition exists, which may result in a corrosion-induced failure or malfunction to enable preventive action to be taken when corrosion rates approach unacceptable levels.
ii. Provision of understanding on the correlation of changes in process parameters and their effects on system corrosivity.
iii. Diagnosis of a particular corrosion problem, identification of its cause and rate-controlling parameters, such as pressure, temperature, Ph, flow rate, etc.
iv. It enables evaluation of the effectiveness of a corrosion control/preventive technique such as chemical inhibition and determination of optimal applications.
v. It provides management information relating to the maintenance requirements and ongoing condition of plant.
vi. It is the most common and economical means of ascertaining deterioration of *insitu* structural materials where accessibility is difficult.
vii. It can assist in optimizing maintenance and inspection schedules.
viii. It can be used to apply corrosion control selectively, when and where it is actually needed and use corrosion prevention systems (chemical inhibitors, coatings, resistant materials, etc).
ix. Most of the instruments and techniques used in corrosion monitoring are simple and the skills required to get true results are not much.

Corrosion monitoring however has the following shortcomings:

i. Corrosion monitors are most accurate and effective only when monitoring uniform or nearly uniform corrosion and least effective and accurate in monitoring mechanical phenomena, pitting or localized corrosion, stress corrosion cracking, thermal effects etc.
ii. Most of the techniques used in corrosion monitoring are more reliable and applicable to confined environments or *insitu* materials where the monitored variables do not change appreciably.
iii. For a large part, structure or system, whose corrosion rates are different at different points on it; applying corrosion monitoring to obtain reliable results becomes more tedious.

III. SUMMARY AND CONCLUSION

There are many different approaches of protecting steel from corrosion in different environments but none is the same for every environment in terms of effectiveness, cost-affordability and feasibility so the protection practitioner is often faced with choice of the best approach for characterized environments. An overview assessment of general approaches in their relative pros and cons that have been in use to combat corrosion of steel is presented in this paper. It is demonstrable from the paper that, combating steel corrosion comprises those protective measures that provide its separation from environment, those that give it cathodic protection or anodic polarization and those which cater for adjustment of environment. These methods can be used individually or in various combinations, the latter affording greater degree of protection than the individual effects. Painting or organic coating is the most versatile and widely used method in combating steel corrosion based on its many comparative advantages including cheapness, flexibility in formulation from inexhaustible combinations of available materials, effectiveness and ease of application. Nevertheless not all types of paint or organic coating systems are suitable for corrosion protection of steelworks in every characterized environment. There are laid down suitable coating types for different types of environments and procedures for applying them by different standards or authorities which have to be consulted and used for desired environments. About 90% of all steel surfaces in the global economy are corrosion protected by paints or organic coatings. It can thus be appreciated that so far, the best protection of steelwork for a characterized environment must be the one that is based on a practicable organic coating for the environment where no other method is feasible or supplemented by it if other methods are feasible**.** Despite the so-far developments in protection technologies, corrosion of structural steelworks persists due to lack of adequate protection. The best is yet to come, it is suggested that more positive researches and developments in the area of paint and organic coatings with single and various combinations of the abundant materials worldwide will contribute immensely towards that.

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