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A COMPREHENSIVE LITERATURE SURVEY ON THE CORROSION RESISTANT TECHNIQUES USED FOR THE STEEL BEAMS

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ABSTRACT

Due to the extreme circumstances to which our infrastructure is constantly subjected, its eventual deterioration is inevitable. Steel bridges and other outdoor constructions are particularly vulnerable to corrosion because of their constant exposure to the elements. All of these ageing buildings cannot be replaced immediately because of financial and other limitations. Because of this, it is crucial that they be rehabilitated successfully. The need to reinforce structural components is universal in the modern era. Therefore, FRP reinforcement seems to be a useful option for such retrofitting. While there are a number of case studies available for using FRP to reinforce concrete buildings, its application to steel presents certain challenges. Researchers have found a promising new use for the Carbon Fiber Reinforced Polymer (CFRP) in the fortification of steel structures, in particular steel beams.

Keywords: Steel Corrosion, Fiber Reinforced Polymer, Carbon Fiber Reinforced Polymer, steel beams

INTRODUCTION

Steel, as a building material, is hardy and reliable. The metal's durability and sturdiness are no match for the corrosive environment, however. Given that steel corrodes with time, we may assume that its strength and durability will degrade significantly. When steel corrodes, it weakens the integrity of the building or structure it was utilised in and increases the likelihood of collapse. That's why it's so important to regularly inspect steel buildings for rust and treat it with the care it needs if it's found to be present.

Corrosion is defined by civil engineers as the degradation of a material and its qualities over time due to a chemical or electrochemical interaction between the substance and its environment, often water. Corrosion causes the loss of ideal mechanical characteristics and the production of oxide that is two to four times as massive as the original steel when it is buried in concrete. Corrosion not only causes the cross-section of reinforcing steel to decrease, but it also causes peeling and cavities on the surface. Steel is used in reinforced concrete to increase its tensile strength, making it suitable for use in structural applications. This prevents concrete buildings from collapsing under the weight of vehicles, wind, dead weight, and temperature swings. But as the reinforcement rusts, the steel and concrete lose their grip on one another, and the concrete begins to flake and peel away. If this has gone undetected, the building might be in danger of collapsing. The strength of the steel is diminished when its cross-section is shrunk. This is particularly detrimental to the functioning of high elastic limit cables in the prestressed concrete.

To ensure the quality of the materials being utilised, civil engineers all around the globe have developed stringent quality assurance standards. The combination of materials is yet another method to ensure their durability and longevity. The local government is responsible for enforcing building codes and ensuring that structures are up to code to ensure the safety of the public. The most popular and widespread method of preventing corrosion is the use of a protective coating layer. This is where the name "barrier protection" comes from, since it acts as a barrier between the outside world and the underlying metal. In order to prevent corrosion, steel constructions benefit greatly from this method, which involves isolating the metal from its surroundings.

LITERATURE REVIEW

(Desouky, 2021) Reconstructing and renovating industrial buildings sometimes involves reinforcing structural surfaces in response to increased pressure in specific places. Slabs with hollow centres are modelled as T- and I-shaped beams for the sake of experimental and analytical evaluation. The size of the cavities inside the slab determines how narrow the beam's edge will become. In this study, the authors put hollow core slabs through a battery of strength tests to see how they fare under various reinforcement regimes and how easily they deform. Researchers also use a non-linear approach to calculate the effects of increasing stress on the samples until they are destroyed and a plastic hinge forms in the region stretched in the slab cross section. The ANSYS software was used to create the simulation and the graphical analysis. The stress-strain condition of the hollow core slabs is studied experimentally by the researchers at different loading rates. Researchers compared I-beam slab simulations with full-scale cross section form. However, the researchers focus on how the cross-section affects the outcomes of maximum slab deflections. In addition to discussing various strengthening techniques, this research indicates that the failure of large-scale slabs occurs after.

(Bastani et al., 2020) Due to the extreme circumstances to which our infrastructure is constantly subjected, its eventual deterioration is inevitable. Steel bridges and other outdoor constructions are particularly vulnerable to corrosion because of their constant exposure to the elements. All of these ageing buildings cannot be replaced immediately because of financial and other limitations. Because of this, it is crucial that they be rehabilitated successfully. Fiber-reinforced polymers (FRP) are a viable option for restoring steel buildings. This article investigates the efficacy of using unidirectional basalt fibre reinforcement polymer (BFRP) fabric to repair damaged webs in steel I-shaped beams. By removing a circular section of web from the beam, a structural flaw was introduced. Wet lay-up was used to patch the section loss using BFRP fabric. Using a 4-point test setup, seven beams were evaluated, including a control (undamaged) beam, a control corrosion (damaged) beam, as well as five rehabilitated specimens. Horizontal and vertical attachments of BFRP textiles were used to accomplish two distinct rehabilitation patterns. Researchers found that repaired beams had the same yield load, elastic stiffness, as well as ultimate load capacity as their undamaged steel counterparts thanks to the use of BFRP textiles. The experiments also demonstrated a causal relationship between the thickness as well as orientation of the BFRP fabric and the enhanced structural behaviour. In this investigation, the best BFRP rehabilitation pattern was identified by using nonlinear finite element analysis.

(Gharabude & Hosur, 2020) The behaviour of steel I-beams that have been reinforced with steel plate as well as steel angle section has been studied, specifically their susceptibility to lateral buckling as well as Lateral Torsional Buckling. The research team collected five samples. Each specimen is 1800mm in length and has an ISMB150 section. Steel plate sections and steel angle sections are positioned in a variety of orientations relative to a steel I-beam to create the various strengthening patterns. In order to create the finite element model, we use ANSYS 19.2. The beam under consideration is a laterally unsupported beam. It was ANSYS 19.2 that was used to do the finite analysis. The analytical findings demonstrated that the lateral buckling as well as lateral torsional buckling of steel beams may be reduced by reinforcing the steel I-beam at its compression flange with steel plate section & steel angle section. When compared to a control beam, Specimen No. 4's lateral deflection is reduced by as much as 50 percent thanks to the steel angle section added to the Compression Flange over its entire length. Costs have gone up because of the Mweight rise in steel beams. When intermediate points are reinforced with steel plates, Specimen No. 2's lateral deflection drops to 42.85% and the cost is reduced. Ultimately, one can say that the addition of a steel plate to the compression flange of a steel beam is a novel method for lowering lateral deflection.

(Hong et al., 2019) In order to prevent pitting corrosion in 316L SS when exposed to high chloride conditions, a novel coating process is discussed in this research. Sunflower oil (SunFO) used as the base coating as well as binder for the molybdenum disulfide to provide an easy, eco-friendly process for coating the SS surface (MoS2). Scanning electron microscopy (SEM) coupled with an "energy dispersive spectrometer" (EDS) as well as X-ray diffraction were used to examine the coated surface (XRD). "Electrochemical impedance spectroscopy" (EIS) as well as open-circuit potential (OCP) measurements were used to investigate corrosion behaviour in a 3.5% NaCl solution. In comparison to SunFO & bare 316L SS, the SunFO coating with MoS2 demonstrated the best corrosion resistance as well as coating longevity during the immersion period. SunFO lamellar structure and MoS2 aggregations in the coating film are hypothesised to be responsible for the enhanced corrosion resistance by acting as a high order layer barrier protecting the metals from the electrolytes.

(Siwowski & Siwowska, 2018) Bonded carbon fibre reinforced plastic (CFRP) plates have recently been utilised as an alternative to welding or bolting plates onto steel bridges for reinforcement or repair. The primary purpose of this research is to evaluate the flexural behaviour of the steel beams reinforced with CFRP plates and compare the results to those of unreinforced steel beams. Passive adhesive-bonded plates as well as active adhesive-bonded plates were compared in the study. In all of these instances, the ductility as well as the yield/ultimate carrying capacity of the steel beams and the efficacy of strengthening have been verified. Depending on strengthening system (passive or active) as well as various system characteristics like the CFRP modulus of elasticity, the end plate anchoring, as well as plate prestressing level, the failure modes of the reinforced beams included either plate debonding or plate rupture. They have also spoken about how these variables affect how efficient the strengthening is.

(Wang et al., 2018) Plating steel is susceptible to the pitting corrosion when used in high-stress corrosion situations. This study presents the results of numerical research into the effects of random pitting damage on the structural behaviour as well as the ultimate strength of the plated steel structures. Due to the unpredictable nature of the pitting corrosion, stochastic simulations have been utilised to represent its variable pitting form, depth, as well as distribution. To investigate the processes of structural failure owing to random pitting damage, a number of nonlinear calculations have been run on both un-stiffened plates as well as stiffened panels. From the numerical data, empirical equations were constructed using regression analysis to forecast the decreases in the ultimate strength of both unstiffened plates as well as stiffened panels. Corrosion from random pitting causes a change in ultimate strength and may cause a failure mode changeover. In the failure of pitted structures subjected to the uniaxial compression, plasticity begins towards the unloaded edge of structure and spreads to connect the pits that have experienced the most stress. Pitted region with intensely stress-concentrated pits undergoes a locally amplified deformation which defines the failure mechanism, resulting to the structural collapse.

(Wu et al., 2018) Deterioration of the beam ends owing to local corrosion, hence reducing their end patch loading resistances, is an issue that plagues steel bridges. The effects of web as well as flange corrosions on end patch loading behaviour of steel I-beams have been examined in a recent work by the authors. Since web or flange corrosions sometimes occurred together, this work gives additional experimental data for the specimens with both types of corrosion. This research looked at two popular kinds of sliding plate bearings—flat as well as curved plate bearings. Test findings demonstrate that, notably for the corroded beams, the end patch loading resistances of the specimens with the flat plate bearings are greater than those of the equivalent specimens with curved plate bearings. The combined impact of the web and the flange corrosions on the end patch loading resistance of the specimens with flat plate bearings is smaller than the total of the effects of each acting alone. Steel beams that have been severely corroded in one area can benefit from a new approach to strengthening. After welding on a pair of stiffeners, the corroded beam end is partly encased in high-strength grout. It is discovered that the stiffeners may greatly increase the end patch loading resistance of corroded beam, and that this resistance can be further improved by encasing the beam in high-strength grout. The suggested technique has the potential to lessen the amount of time that traffic is disrupted while simultaneously protecting the beam ends from the secondary corrosion.

(Kianmofrad et al., 2017) Unbonded retrofit systems save time and money since they don't need any surface preparation before bond application. Different variations of the retrofit systems may be designed to facilitate field deployment since the carbon fibre reinforced polymer (CFRP) plate in the un-bonded (tendon) systems is not attached to a metallic substrate. Four distinct types of prestressed un-bonded retrofit (PUR) systems are discussed in this paper: triangular PUR (TriPUR), trapezoidal PUR (TPUR), flat PUR (FPUR), as well as contact PUR (CPUR). To foretell how metal beams would react after being outfitted with PUR systems, we offer analytical methods based on flexibility approach. To represent the functioning of the modified beams, a finite element (FE) model is developed. The analytical answers are tested against the FE model's findings. Experimental findings on PUR-reinforced steel and aluminium beams have been compared with those from analytical and computational models. Several parametric tests are conducted to learn how factors like PUR system type and CFRP pre-stress level affect the performance of the upgraded beams. The findings reveal that, for a given degree of CFRP pre-stress, the stress reduction in steel beam bottom flanges is almost the same for all four PUR systems. As a result, any one of the 4 pre-stressing methods may be used, as long as it meets the needs of the building.

(Manalo et al., 2016) Fibre-reinforced polymer (FRP) composites have become increasingly important in recent years due to their use in the reinforcement and rehabilitation of structural parts. Most studies and innovations, however, have concentrated on FRP strips or plates, which can only be utilised to enhance metallic constructions with flat steel surfaces. Corrosion damage is usually localised in the beam, necessitating a more adaptable composite repair technique. Mechanical testing of tensile, structural testing of rehabilitated I-beams and double strap shear joint specimens are used to assess the effectiveness of a pre-impregnated carbon fibre reinforced epoxy repair method. Better mechanical qualities were seen when vacuum was used to consolidate the fibre layers during the manufacturing of the laminate. Bond lengths of 120 mm are indicative of the bond strength of the rehabilitated steel beam, which allows for a more uniform and stable adhesively bonded junction. At the end of the day, the patched carbon prepreg system was able to effectively repair the simulated fracture and corrosion flaws in steel I-beams, returning them to their original load bearing capability and stiffness.

(Ghafoori & Motavalli, 2015) In this study, the elastic response of steel beams reinforced with bonded as well as unbonded CFRP laminates of varying moduli (normal, high, and ultra-high) is examined. For the purpose of designing fatigue strengthening systems, knowledge of the elastic behaviour of retrofitted beams is quite helpful. In a simply supported four-point bending set-up, seven steel beams (one control unstrengthened beam, and six reinforced beams) were statically tested to failure. "Carbon fiber-reinforced polymer" (CFRP) laminates with nominal Young's moduli, ranging from 165 to 440 GPa, were used to retrofit the steel beams. The laminates were classified as normal modulus (NM), high modulus (HM), as well as ultra-high modulus (UHM). Laminates of both bonded reinforcement (BR) & un-bonded reinforcement (UR) types were used to secure the laminates to the steel beams. The BR and UR systems are not directly compared in the existing literature. The primary objective of this work is to provide a clearer comprehension of the stress distribution along the bottom flange of a beam strengthened with either the BR or UR systems. Lateral-torsional buckling was the cause of failure for all samples (LTB). It was also investigated how various strengthening techniques affected the retrofitted specimens' buckling strength. To prevent the steel profile from yielding before buckling, researchers found that bonding UHM laminates together may boost the composite section's stiffness.

TYPES OF CORROSION ON STEEL

Steel, one of the most resilient metals on the market, is employed in a wide variety of structures at manufacturing facilities. Steel, though, is costly and vulnerable to even the most fundamental corrosive elements, which shortens its lifespan. To make sure your building lasts for the decades to come, keep these corrosion kinds in mind:

1. Galvanic Corrosion

The joining of two metals with very different properties causes this effect. A stainless bolt through a steel beam is a good illustration of this. Of course, the two metals are dissimilar, with the more noble metal eventually succumbing to corrosion while the less noble metal holds up rather well for a while. Usually the most dangerous kind of corrosion, it may cause fast structural decay.

So, what can we do about it? Using a combination of power tools with cleaning, or sandblasting back to clean metal and treating it before recoating, small localised sections can usually be brought back to bare steel. Extensive galvanic corrosion of the structural parts, on the other hand, usually necessitates an engineer's evaluation of the structural integrity and proposal of a superior design to avoid reoccurrence.

2. Localised Corrosion

This may happen anyplace on a steel surface, as well as the source is often unknown. Scratches in the paint (maybe from another machine) or structural alterations without proper recoating processes are two common sources of localised corrosion.

So, what can we do about it? Repairing localised corrosion often entails stripping down to the bare steel, applying a zinc-infused coating, as well as recoating. Being so little, however, they are frequently allowed when they should not be, resulting in more harm. A potential problem with corrosion must be found and fixed before it worsens.

(a) (b) (c)

Figure Error! No text of specified style in document. **(a) Galvanic Corrosion (b) Localised Corrosion (c) General Corrosion**

3. General Corrosion

This represents a surface-wide loss of mass at a same rate. Although it may have a deteriorated appearance, the steel's structural integrity is usually unaffected. More rust means the steel is in better condition, in most cases.

As a rule, sandblasting is unnecessary for these spots, and they should be repaired as soon as possible to prevent the problem from becoming worse. Wire wheels, grinding, as well as a new coat of paint are low-cost solutions that may significantly increase the longevity of the building.

4. Pitting Corrosion

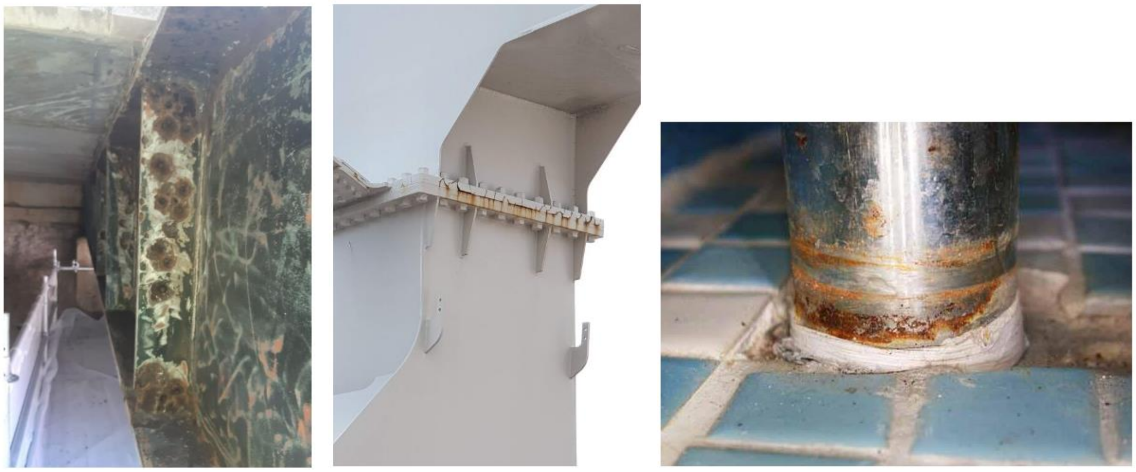
Corrosion has been going on for some time as seen by the little holes it has created in the steel. It often occurs on the unprotected steel buildings and uncovered pipes. While the pitting may be difficult to see at first glance, it may completely eat away at a steel flange with just a tiny amount of the metal loss, compromising the structure.

Coating may help protect it for longer, but if the pitting is severe enough to develop holes in steel, it has to be replaced per an engineer's specifications for the structure to be safe again. It is not until work has disclosed the harm behind a covering that the full degree of this is revealed. Do not allow the situation to deteriorate further!

5. Crevice Corrosion

This takes place on a metal surface which is partially protected from the elements by another material that fills the space between them.

When steel beams are linked, it is important to check for signs of crevice corrosion, which may be reduced using wax sealers or something similar. This may be challenging since, as the figure indicates, galvanic corrosion typically occurs along with this problem, and the structure usually cannot be disassembled to clean them adequately. The lifespan of any building may be extended via consistent upkeep.



(a) (b) (c)

Figure 2 (a) Pitting Corrosion (b) Crevice Corrosion (c) HASCC- The Invisible Corrosion

All of these may be avoided with good design and upkeep, and steel buildings can last for generations when cared for properly.

6. Rusting Corrosion

The corrosive action of rust on steel causes it to degrade and weaken. Steel rusts more quickly in humid environments, particularly if the water includes chlorides (salts), which is typical in coastal, industrial, and urban settings. When working with steel, it is important to take precautions against corrosion on both the fasteners as well as the linked pieces.

7. HASCC- The Invisible Corrosion

Failure may also occur as a subsequent outcome of a galvanic response, which is why it is so deadly. Standard fasteners may be weakened and eventually fail by hydrogen, a byproduct of galvanic corrosion. It causes rust that shows no outward signs until it's too late. In HASCC, hydrogen embrittlement is the first step. When hydrogen is present, galvanic activity occurs, leading to embrittlement. Galvanic corrosion, however, does not weaken steel fasteners.

8. Biochemical corrosion

Due to their propensity to interact with oxygen to produce oxides, metals are susceptible to chemical corrosion, a process that sees them dissolved in acids as well as caustic solutions of varying intensities.

This trend becomes more pronounced as the metal's nobility decreases. Atmospheric acids, such as sulphuric acid, which is produced when sulphur dioxide is released during the combustion of fossil fuels, can be found in urban as well as industrial settings; chlorine, nitric oxides, hydrogen chloride, acetic acid, formic acid, etc. can be found in close proximity to corresponding industrial plants; chloride as well as sodium chloride, in particular, are the common atmospheric pollutants in the coastal settings.

9. Aeration cell corrosion

As a result of being kept at an unnaturally warm temperature, oxygen levels drop. Condensation forms in bed linens, attracting pollutants. Corrosion may occur even in non-polluted, high-pH locations if oxygen supply is cut off there. Corrosion rates are higher in environments with a lower pH value, as might occur when other contaminants are present.

(a) **(b)** **(c)**

Figure 3 (a) Biochemical corrosion (b) Aeration cell corrosion (c) Bimetallic corrosion

10. Bimetallic corrosion

Corrosion happens when two metals that aren't chemically compatible (like iron & aluminium) are brought together in an electrolyte. Since the electric potential of different metals can be mapped out in a chart known as the "galvanic series," this makes sense.

11. Stress Corrosion

This takes place when a certain corrosive environment is combined with static tensile tension. Some areas of the body (particularly the stress hotspots) become more anodic due to stress than others. While corrosion like this is uncommon with ferrous metals, it may happen with certain types of stainless steel.

12. Fretting corrosion

The oxide coating may be mechanically removed from high areas between contacting surfaces if two oxide coated films or corroded surfaces are rubbed together. When contrasted to the surrounding surfaces, these openings function as anodes and start the corrosion process. Corrosion like this is typical in mechanical parts.

(a) (b) (c)

Figure 4 (a) Stress Corrosion (b) Fretting Corrosion (c) Bacterial Corrosion

13. Bacterial corrosion

This is a product of microbial activity and may take place in both soils and water. Pipelines, underground infrastructure, and marine constructions are particularly vulnerable to bacterial corrosion.

CONCLUSION

Corrosion products accumulate in localised portions of the metal as the corrosion process continues. The elemental makeup of these corrosion byproducts has changed from their initial form. Because of the different compositions now near the surface, both the anodic as well as cathodic regions have shifted. When the metal undergoes a shift in the ratio of its anodic to cathodic regions, formerly uncorroded portions become vulnerable to attack and corrosion. The surface of the steel will corrode more quickly as a result. This paper reviews the literature related to the corrosion preventive techniques that have been analysed recently along with a brief summary about different types of corrosions that occur in the steel structures.

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