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POTENTIAL INFLUENCE OF ALBIZIA LEBBECK ON CORROSION EFFECT OF THE BOND BETWEEN STEEL AND CONCRETE

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ABSTRACT: *This study aimed to investigate the effects of corrosion on the bond strength between reinforcing steel and concrete and the potential of using exudate coating to improve the bond strength in corrosive environments. The finding showed that the failure load and bond strength of corroded concrete cube specimens were significantly lower than non-corroded control cube specimens. The use of exudate coating on steel reinforcements, however, can significantly improve the pullout bond strength in corrosive environments. The study also showed a slight reduction in the measured rebar diameter for corroded specimens compared to non-corroded specimens. The Albizia lebbeck exudate-coated steel bars showed higher bond strength and maximum slip values compared to non-corroded control specimens, indicating that the exudate coating may have provided protection against corrosion. Further research into the long-term effects of using Albizia lebbeck exudate-coated steel bars and the cost-effectiveness of this method is required.*

KEYWORDS: Mild Steel; Corrosion Inhibitors; Albizia Lebbeck Exudates; Bond Strength

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INTRODUCTION

A common problem that reduces the bond strength of reinforced concrete buildings is corrosion. Rebar corrosion can significantly reduce the bond strength between concrete and steel (Zhang *et al*, 2019). This is caused by corrosion which causes the steel reinforcement to stretch and the concrete layer to crack and break. The use of corrosion inhibitors is one way to prevent corrosion and maintain the bond strength of reinforced concrete buildings.

These inhibitors are chemicals that are added to concrete mixes or sprayed onto concrete surfaces to protect steel reinforcement bars from corrosion. Steel bars and concrete have a strong affinity for each other. For a reinforced concrete structure to be load bearing, the bond strength between the steel bars and the concrete is very important. The bond strength between steel bars can be significantly reduced by corrosion, which can lead to premature failure of the structure.

The bond strength of reinforced concrete structures can be effectively protected by exudate and resin. Exudates and resins are widely used as steel corrosion inhibitors in concrete due to their ability to form a protective layer on the steel surface and reduce the corrosion rate (Zhang and Li, 2017). Tannins, lignins and phenols are only a small part of the exudates and resins that can be used as corrosion inhibitors. These substances can be produced chemically or come from plant sources. Tripathi and Gupta (2013) investigated natural extract-based self-healing coatings for steel corrosion protection. Venkatesan and Karthikeyan (2018) investigated eco-friendly coatings with Albizia lebbeck for steel corrosion protection.

Corrosion weakens the bond between reinforcement and concrete resulting in the bond damage (Shen *et al*, 2016; Li *et al* (2017). Qian and Stang (2016) found that rust made the bond less strong.

Several researches have been carried out on the use of plant extracts in the processes of corrosion reducing bond strength. The layer of corrosion products formed on the surface of the mild steel reduces the contact area, which further reduces stress transferred between the two materials and weakens the bond (Liu *et al*, 2019).

Corrosion has a negative impact on the bond strength between reinforcement and concrete under different environmental conditions (Huang *et al*, 2017; Khedr *et al* 2017; Khorami and Razmjoo, 2018; Titi *et al*, 2018; Cheng *et al*, 2018; Wang *et al*, 2018; Yang *et al*, 2018; Li *et al*, 2019; Zhou *et al* 2019; Al-Saadi *et al*, 2020; Ismail *et al*, 2020). Ghods *et al* (2020) found that organic coatings had a positive effect on corrosion of reinforcing steel embedded in concrete. These authors worked on several plant extracts as corrosion inhibitors in different media, environmental conditions and using various techniques.

Al-Omari *et al* (2017) found that the adhesive strength of corroded steel reinforcement was much lower than that of non-corroded reinforcement. Ahmad et al. (2018) investigated the ability of exudate/resin extracts to resist corrosion of mild steel reinforcement on concrete adhesive strength. The findings showed that the extract dramatically reduced corrosion at a rate of only 0.5 mm/year compared to the control specimen corrosion rate of 1.2 mm/year. Zhang et al. (2019) found that the bond strength of reinforced concrete increased significantly when the exudate/resin extract was used as a corrosion inhibitor. The authors conclude that the extract ability to create a barrier preventing corrosive substances from penetrating the steel surface is responsible for this improvement.

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Chen *et al* (2018) found that corrosion can cause the bond strength of reinforcing steel to decrease by up to 50%. Li et al. (2021) findings showed that the application of exudate/resin extract resulted in a 50% reduction in the corrosion rate and a 40% increase in bond strength compared to the control specimen.

In summary, corrosion is an important problem that can affect the ability of reinforced concrete buildings to maintain strong bonds. Exudates and resins are examples of corrosion inhibitors that can be used to stop corrosion and maintain the structural integrity of the structure. Hence, the research demonstrates the potential of exudate/resin extracts as mild corrosion inhibitors for steel reinforcement, increasing bond strength and service life.

MATERIALS AND METHODS

A. Materials Properties

The materials used in the experiment were Portland limestone cement of grade 42.5N which meets the requirements of cement (BS EN 196-6, 2010), the fine of grading zone II and coarse aggregates which both met the requirements (BS 882 (1992), was used for all concrete mixes in this test. Potable water free of contaminants met the requirements of water according to WHO standards was used for mixing the concrete (BS 3148). The structural steel reinforcements used in the test were sourced directly from the market at Port Harcourt and the met the steel requirement (BS4449: 2005 + A3, 2010). The extract of natural gum exudates (*Albizia lebbeck*) from the tree barks obtained for Auwaru community in Akko local Government Area of Gombe State, Nigeria and validated by Dr. Charles Kennedy of the department of Civil Engineering in the University of Port-Harcourt, Rivers State, Nigeria.

B. Sample Preparation and Methods

1) Test Procedures

The study examined the use of exudate/resin from a plant as an inhibitor against corrosion in reinforcing steel embedded in concrete structures in marine areas. The exudate/resin paste was coated on reinforcing steel of different thicknesses and embedded in concrete cubes, which were then exposed to high levels of salt in a simulated corrosion acceleration process using sodium chloride (NaCl). The goal of the study was to determine the eco-friendly potential of using commonly available materials to control the effects of corrosion on reinforced concrete structures in marine environments. To conduct the study, 36 reinforced concrete cubes were prepared using a standard concrete mixing ratio of 1:2:4 and a water-cement ratio of 0.65. The cubes were manually mixed using cement, water, and aggregates, and 12 mm diameter reinforcing steel was embedded in the center of each cube for bonding testing. The cubes were allowed to cure for 360 days before being submerged in sodium chloride for 28 days. The corrosive media solutions were modified monthly, and the solid samples were evaluated for changes and higher efficiencies. The test samples were used to determine the level of hard acid, which indicates the level of salt concentration in the marine atmosphere in reinforced concrete structures. The embedded reinforcing steel was completely submerged, and the samples were maintained in a pooling tank. The concrete mixing ratio and water-cement ratio were based on the standard method for preparing concrete, as specified in a manual by weight of the materials. The concrete was mixed manually on a

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clean surface, and water was gradually added to obtain a consistent, uniform color and stability. Overall, the study aimed to explore the potential of using exudate/resin from a plant as an eco-friendly method for controlling corrosion in reinforced concrete structures in marine environments. By coating the reinforcing steel with the exudate/resin paste and exposing it to high levels of salt in a simulated corrosion acceleration process, the study aimed to strengthen the steel and improve its performance in marine areas.

2) Accelerated Corrosion Set-Up and Testing Method

The natural phenomenon of corrosion effect on steel reinforcements embedded in concrete structures is a slow process that can take a many years to become significant. Hence, in the laboratory settings, an accelerated process was adopted to speed up the corrosion process of steel reinforcement in concrete members in the marine environment. The test studied the effects of corrosion on the surface and mechanical properties of the steel reinforcement and evaluated the effectiveness of the protective coatings of the steel against the effect of corrosion. The method involved immersing both non-coated and coated steel specimens with exudate/resin in a 5% sodium chloride (NaCl) solution for a period of 360 days.

3) Pull-out bond strength test

The tensile-bond strength of concrete cubes was conducted on a total of 36 concrete cubes specimen. Each set of 12 concrete cubes consisted of control specimen, uncoated specimen and coated specimen. The test was conducted using a Universal Testing Machine to apply a load of 50kN (BSN 12390-2 (2005). The specimen was cubes sizes of 150 mm x 150 mm x 150 mm, with 12mm diameter steel reinforcement embedded in the center of each concrete cube. The pullout-bond strength test conducted to ascertain the failure loads, bond strength, maximum slip, decrease or increase in cross-sectional area, and weight loss of the steel reinforcement.

4) Tensile strength of the reinforcement bars

To ascertain the yield and tensile strength of steel enforcement bars, a 12 mm diameter uncoated steel and coated steel reinforcement bar were subjected to direct pressure until the failure load was achieved and recorded through laboratory testing using a universal test machine (UTM). The remaining cut pieces of the steel enforcement bars were used in subsequent bond testing to determine the bond strength, maximum slip, reduction/increase in cross-sectional area, and weight loss/steel reinforcement.

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RESULTS AND DISCUSSION

A) Experimental Findings and Analysis

The interaction between concrete and reinforcing steel is necessary to ensure the structural integrity of the building. The presence of deformation of the reinforcement enhances the mechanical interlocking between the concrete and ribs at the surface of the reinforcement. Hence, the effect of the corrosion can significantly reduce the effectiveness of reinforced concrete structures, rendering them unusable and shortening their expected service life.

Experimental data presented in the figures 1 – 18 are based on tests conducted on 36 concrete cubes samples. Three groups of this sample consisted of 12 cubes each. The first group consisted of 12 cubes specimen immersed in fresh water for 360 days, the second group consisted of 12 cubes uncoated specimen, and the third group of 12 cubes specimen were coated with exudate/resin. All the specimens were embedded with reinforcing steel exposed to a 5% sodium chloride (NaCl) solution for 360 days. The performance of the sample specimen was evaluated at intervals of 90, 180, 270 and 360 days through examinations, monitoring and testing. Thus, given that the possibility that they may not accurately reflect the long-term performance of reinforced concrete buildings under actual conditions, it is important to emphasize that the results of these tests should be viewed with caution. More research and testing may be needed to fully understand the effects of corrosion on these structures and to develop effective techniques to reduce their effects**.**

B) Failure Load versus Bond Strength

Figures 1 shows the relationship between failure load and the bond strength for different levels of corrosion level of the reinforcing steel bars in concrete (American Concrete Institute [ACI] Committee 408, 2003; Almusallam *et al*, 1996; Auyeung *et al*, 2000; *Fang et al,* 2004). The study found that failure load and bond strength were significantly lower in the corroded concrete cube specimens than in the non-corroded control specimens. The corroded specimens had a failure load ranging from 15.323 kN to 17.010 kN and a bond strength ranging from 8.391 MPa to 9.416 MPa. In contrast, non-corroded control specimens had a failure load range of 26.894 kN to 29.911 kN and a bond strength range of 12.690 MPa to 15.080 MPa. These results indicate a significant reduction in the pullout bond strength of corroded reinforcing steel in concrete.

Exudate-coated steel bars, on the other hand, displayed higher bond strength than the corroded specimens. The failure load of the exudate-coated steel bars ranged from 29.090 kN to 30.432 kN, while the bond strength ranged from 13.907 MPa to 16.297 MPa. These findings suggest that exudate coating on steel reinforcing bars can significantly improve the pullout bond strength in corrosive environments.

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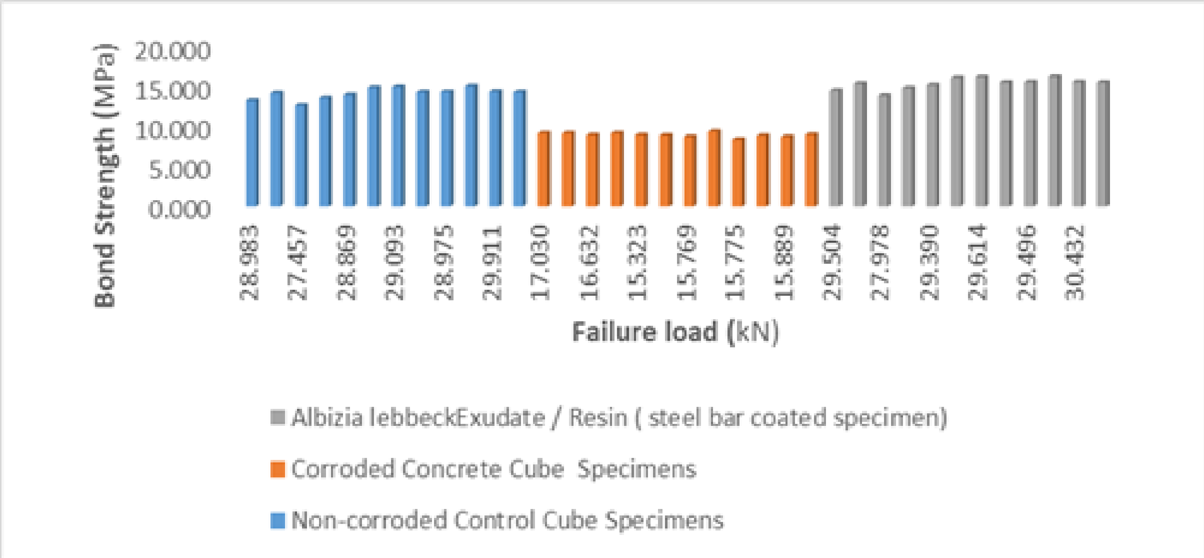

Figure 1: Failure Bond loads versus Bond Strengths

Figure 2 showed the average failure load against the average bond strength for each of the corroded level. The test result showed that the corroded specimens had significantly lower values than the non-corroded control and exudate-coated specimens. The non-corroded control specimens had an average failure load range of 27.468 kN to 28.647 kN and a bond strength range of 13.394 MPa to 15.394 MPa. In contrast, the corroded specimens had an average failure load range of 15.862 kN to 16.668 kN and a bond strength range of 9.022 MPa to 9.122 MPa. The exudate-coated specimens had an average failure load range of 27.778 kN to 29.018 kN and a bond strength range of 14.611 MPa to 15.394 MPa.

Figure 2: Average Failure Bond loads versus Bond Strengths

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Figure 3 shows the percentile average failure load and bond strength test indicating that the corroded specimens had a significant reduction in pullout bond strength compared to the non-corroded control and exudate-coated specimens. The non-corroded control specimens had a percentile average failure load range of 66.655 kN to 79.657 kN and a bond strength range of 46.843 MPa to 57.078 MPa. In contrast, the corroded specimens had a percentile average failure load range of -41.100 kN to -45.337 kN and a bond strength range of -37.572 MPa to -41.370 MPa. The exudate-coated specimens had a percentile average failure load range of 69.778 kN to 82.939 kN and a bond strength range of 60.185 MPa to 70.562 MPa.

Previous studies have found that corrosion on steel reinforcing bars significantly reduces the bond strength between the steel and surrounding concrete. For example, a study by Khedr et al. (2017) found that the bond strength of corroded reinforcing steel in concrete was significantly lower than non-corroded.

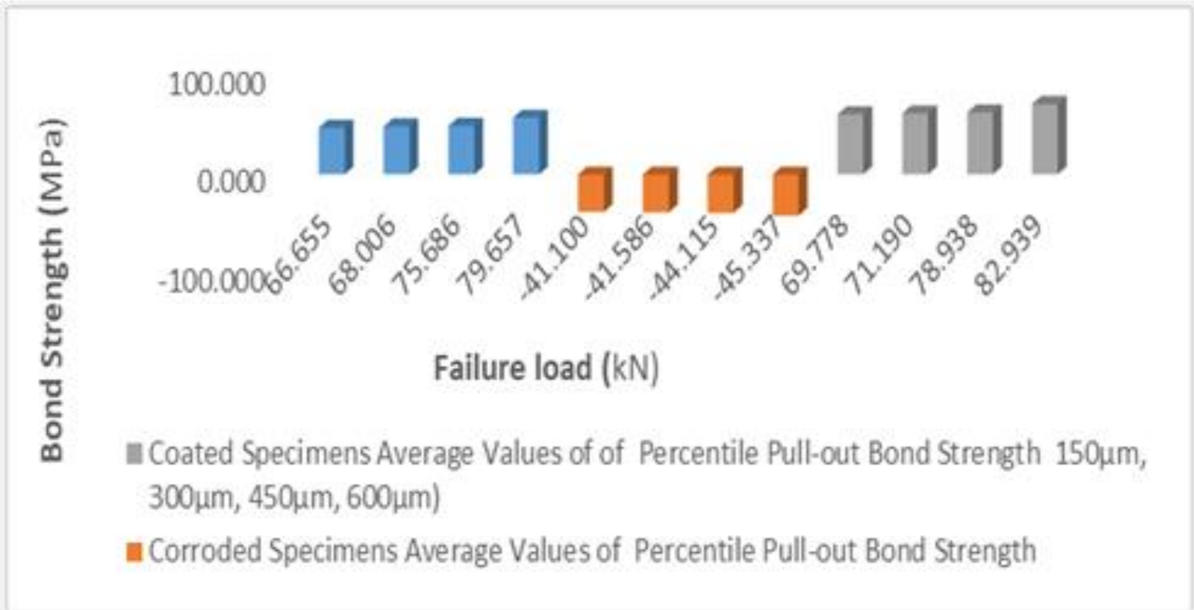

Figure 3: Average Percentile Failure Bond loads versus Bond

D) Bond strength (MPa) versus Maximum slip (mm)

Figure 4 shows the between the bond strength test (τu) and maximum slip (mm) for individual specimen under different levels of corrosion.

The average bond strength of non-corroded control cube specimens ranged from 13.300 MPa to 14.392 MPa for samples tested at different durations ranging from 90 to 360 days. Meanwhile, the average bond strength of corroded concrete cube specimens ranged from 8.728 MPa to 9.416 MPa for the same duration of testing. This implies that the bond strength of corroded concrete is significantly lower than that of non-corroded control specimens, which could result in reduced structural integrity and service life. The maximum slip values for the corroded concrete cube specimens were also observed to be higher than the non-corroded control specimens, indicating a weaker bond between the reinforcing steel and the surrounding concrete.

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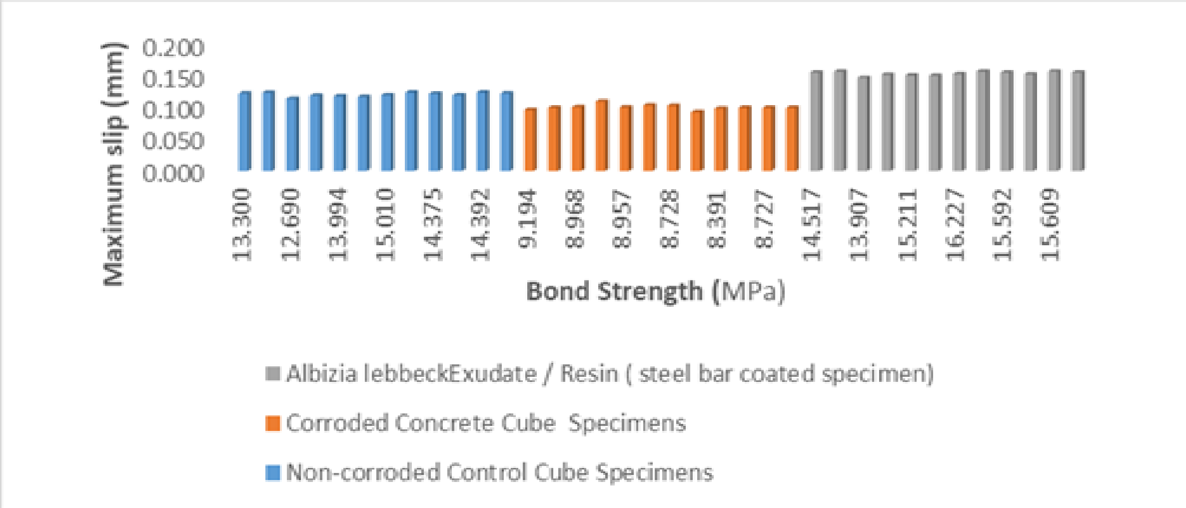

Figure 4: Bond Strengths versus Maximum Slip

Furthermore, the Albizia lebbeck exudate/resin-coated steel bar specimens showed an average bond strength ranging from 14.517 MPa to 15.609 MPa and maximum slip values ranging from 0.147 mm to 0.157 mm for the same duration of testing. These values are higher than the non-corroded control specimens, indicating that the exudate coating may have provided protection against corrosion and enhanced the bond strength between the reinforcing steel and the surrounding concrete.

Figure 5 shows the percentile average bond strength and maximum slip values for each corrosion level. For all specimens, the results showed that the Albizia lebbeck exudate/resin-coated steel bar specimens had the highest bond strength and lowest maximum slip values, followed by the non-corroded control specimens. The corroded concrete cube specimens had the lowest bond strength and highest maximum slip values.

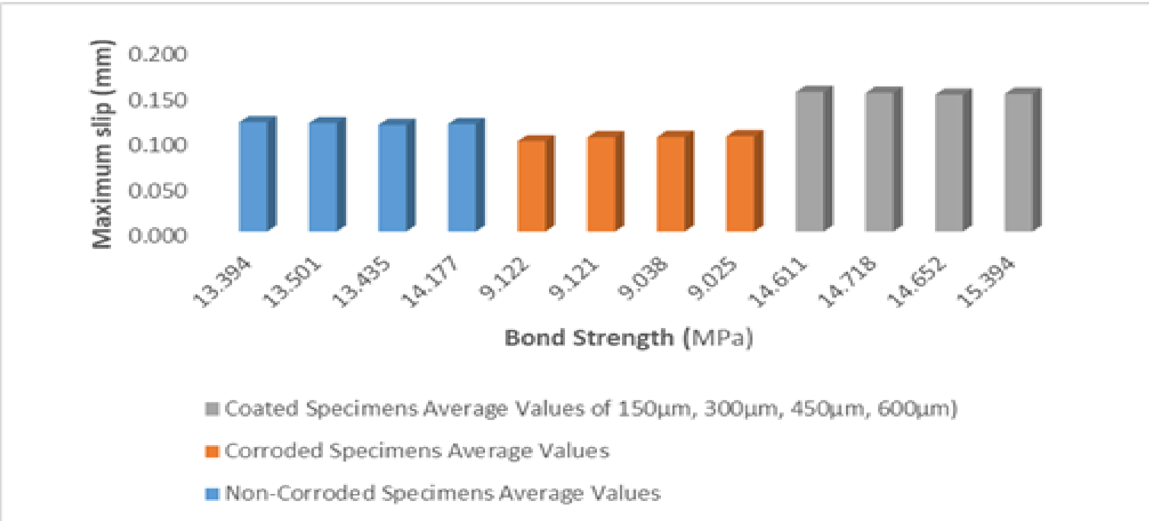

Figure 5: Average Bond Strengths versus Maximum Slip

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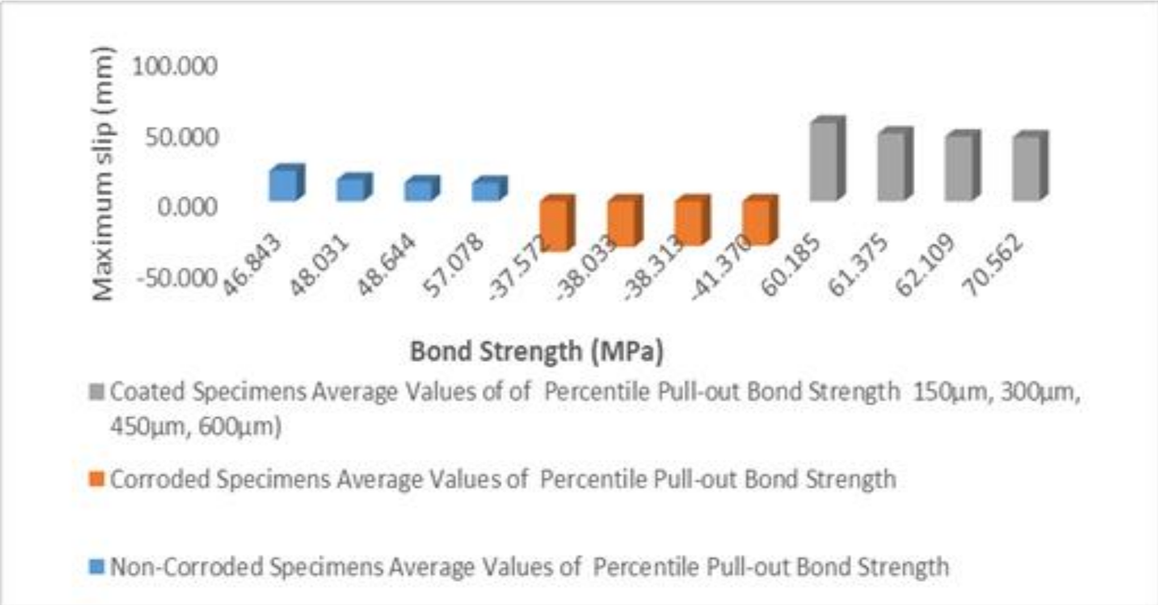

Figure 6: Average Percentile Bond Strengths versus Maximum Slip

The findings of this study are consistent with previous research on the effect of corrosion on bond strength. For example, Abo-El-Enein et al. (2017) observed a decrease in bond strength between corroded steel bars and surrounding concrete. Similarly, Liu et al. (2020) found that the bond strength between corroded steel bars and surrounding concrete decreased with an increase in the degree of corrosion.

To address the challenges posed by corrosion, various methods have been proposed, including the use of corrosion inhibitors, coatings, and cathodic protection systems. The results of this study suggest that the use of exudate/resin coatings may be a viable solution to mitigate the effects of corrosion on the bond strength of reinforcing steel and surrounding concrete.

In conclusion, the application of corrosion potential standards revealed that the bond strength of corroded concrete is significantly lower than that of non-corroded control specimens. However, the use of exudate/resin coatings may enhance the bond strength between reinforcing steel and surrounding concrete. These findings could inform the development of strategies to improve the durability and safety of concrete structures.

E) Nominal Rebar Diameter versus Measured Rebar Diameter before Test (mm)

Figure 7 shows the relationship between the nominal rebar and measured rebar diameter before testing reflects how reinforcement corrosion impacts on the rebar cross-section through diameter measurements with corrosion levels.

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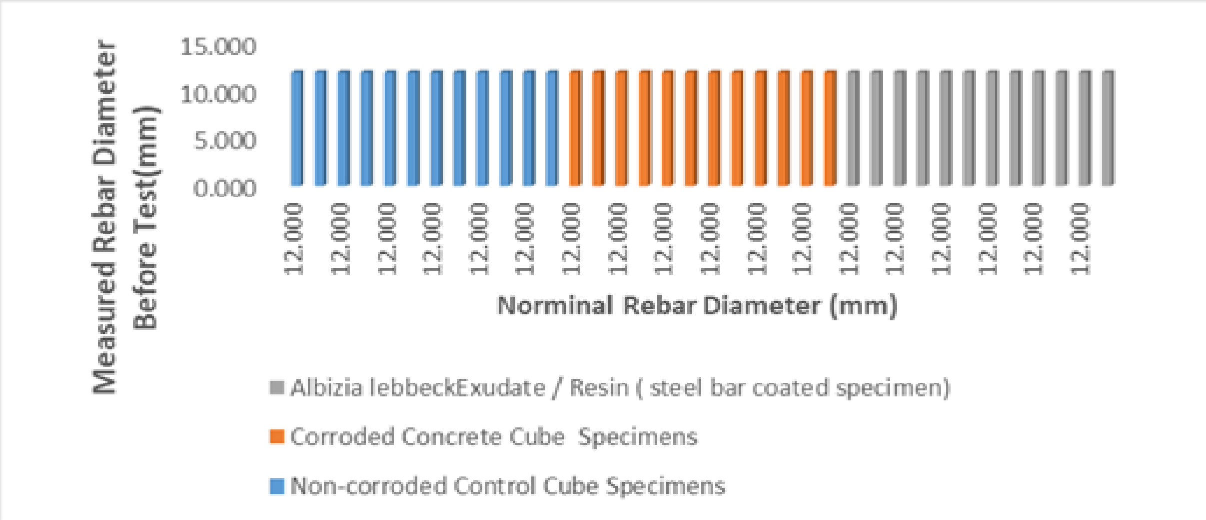

Figure 7: Measured (Rebar Diameter before Test vs Nominal Rebar Diameter

The nominal rebar diameter for all specimens was 12.000 mm, but the measured rebar diameter before the test ranged from 11.973 mm to 11.993 mm. Results indicated a slight reduction in the measured rebar diameter for corroded concrete cube specimens compared to non-corroded control cube specimens, but no significant difference for the Albizia lebbeck exudate/resin-coated steel bar specimens.

Figure 8 shows the average nominal and measured rebar diameter before testing for non-corroded specimens, corroded specimens, and coated specimens of various thicknesses. The results suggest that there was no significant difference in the average nominal rebar diameter between the three types of specimens, but a slight reduction in the measured rebar diameter for corroded specimens compared to non-corroded specimens.

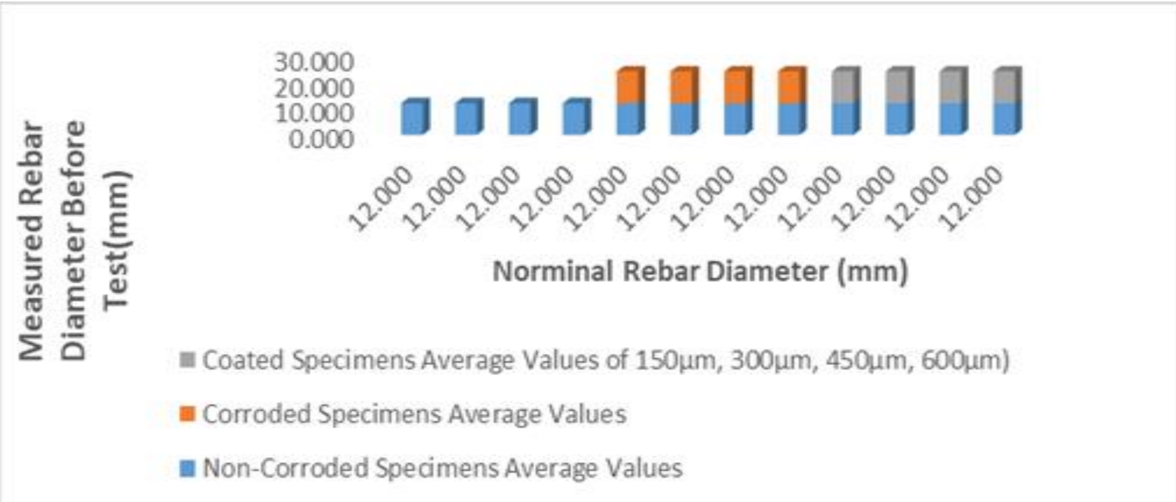

Figure 8: Average Measured (Rebar Diameter before Test vs Nominal Rebar Diameter

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Figure 9 displays the percentile average nominal and measured rebar diameter before testing for non-corroded control cube specimens, corroded cube specimens, and Albizia lebbeck exudate/resin-coated steel bar specimens. Results indicate a slight reduction in the percentile average nominal and measured rebar diameter before the test for corroded cube specimens compared to non-corroded control cube specimens, but no significant difference for Albizia lebbeck exudate/resin-coated steel bar specimens.

The study is in consistence with previous research indicating that corrosion can decrease the bond strength between reinforcing steel and concrete. However, using Albizia lebbeck exudate/resin-coated steel bars can reduce the negative impacts of corrosion. Further investigation could explore the long-term effects and cost-effectiveness of this method compared to other corrosion mitigation strategies.

Overall, this study highlights the potential negative effects of corrosion on the bond strength between steel and concrete and suggests the use of Albizia lebbeck exudate/resin-coated steel bars as a possible solution to mitigate these effects.

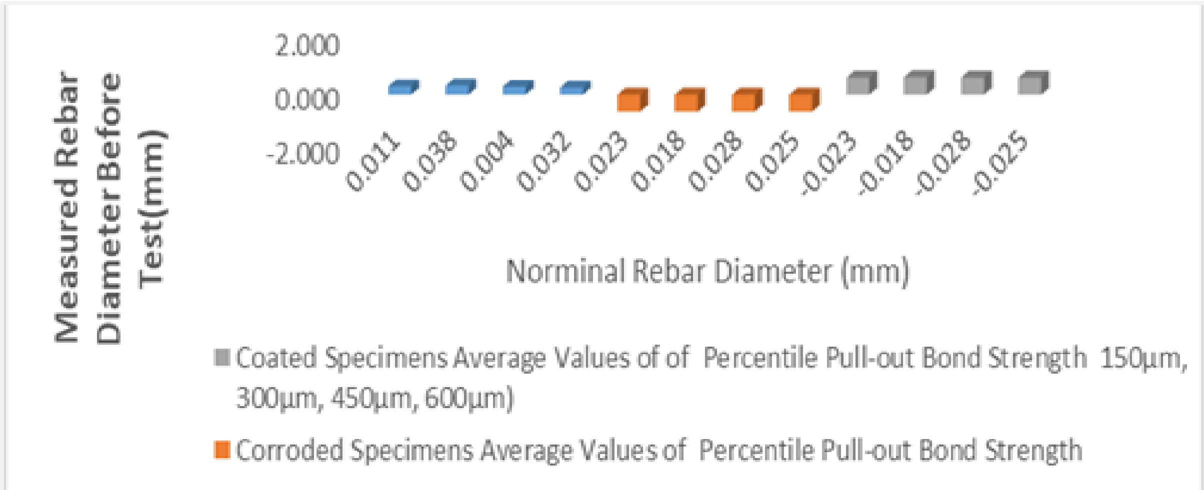

Figure 9: Average Percentile Measured (Rebar Diameter before Test vs Nominal Rebar Diameter

F) Rebar Diameter- After Corrosion (mm) versus Cross- Sectional Area Reduction/Increase (Diameter, mm)

Figure 10 shows Rebar Diameter-After Corrosion versus Cross-Sectional Area Reduction/ Increase of cross sections after 90, 180, 270 and 360 days.

The non-corroded control cube samples had an average reinforcement diameter of 0.580-0.582 mm without changes in cross-sectional area reduction or increase. However, the corroded concrete cube samples experienced an average reduction in reinforcement diameter of 0.533-0.537 mm with a reduction in cross-sectional area of 0.045 mm.

Meanwhile, Albizia lebbeck's exudate/resin coated steel bar samples had an average diameter of 12.015-12.027 mm with a reduction in cross-sectional area of 0.043 mm.

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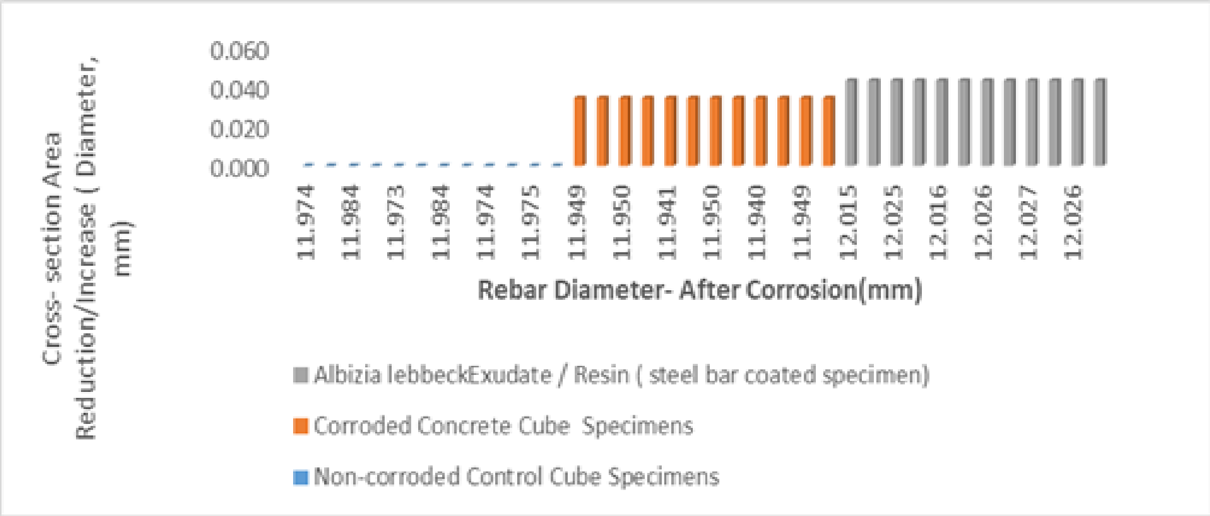

Figure 10: Rebar Diameter- After Corrosion (mm) and Cross- Sectional Area Reduction/Increase (Diameter, mm)

The average diameter of the reinforcement bars after corrosion as represented in figure 10 shows that the coated sample has the largest diameter, followed by the control cube sample that is not corroded and the corroded concrete cube sample which has the smallest diameter. The largest reduction in cross-sectional area occurred in the coated sample, followed by the corroded concrete cube sample, and the uncorroded control cube sample did not experience a change in cross-sectional area.

The average percentile of reinforcement diameter after corrosion as represented in figure 11 showed that the uncorroded control cube samples had an average percentile of 0.295-0.321, while the corroded concrete cube samples had an average percentile of -0.614 to -0.609. Coated samples have an average percentile of 0.618-0.623. The largest reduction in cross-sectional area occurred in the coated sample, followed by the corroded concrete cube sample, and the uncorroded control cube sample did not experience a change in cross-sectional area.

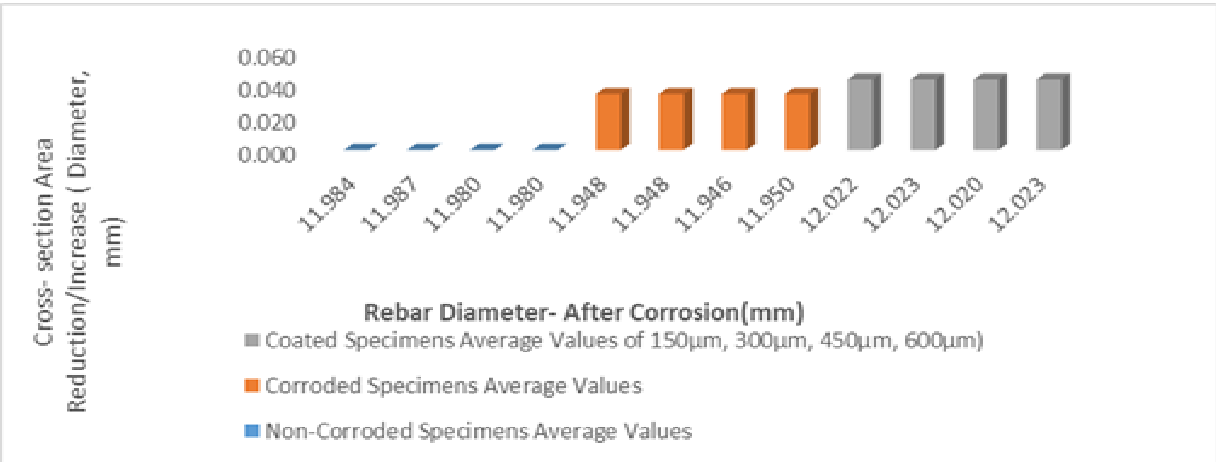

Figure 11: Average Rebar Diameter- After Corrosion (mm) versus Cross- Sectional Area Reduction/Increase (Diameter, mm)

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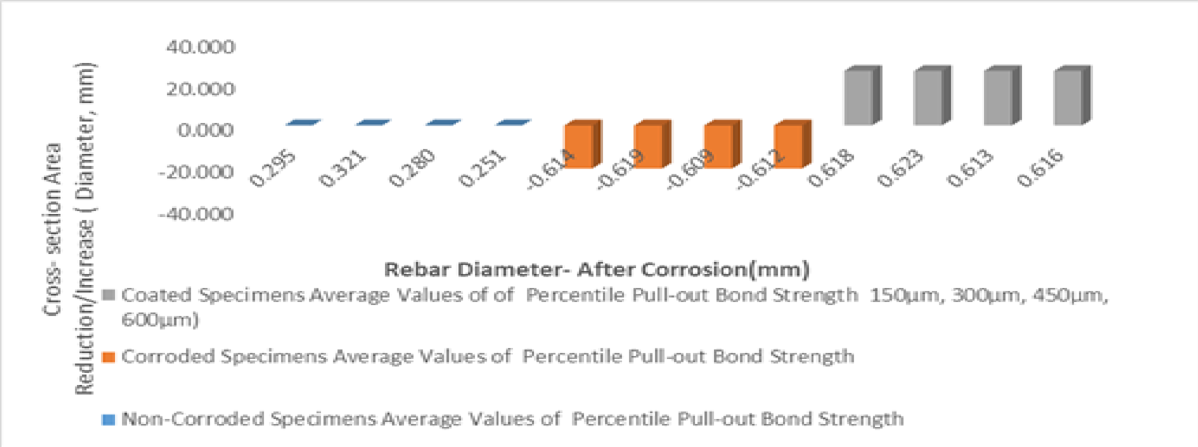

Figure 12: Average Percentile Rebar Diameter- After Corrosion (mm) versus Cross-Sectional Area Reduction/Increase (Diameter, mm)

The results showed that corrosion had a significant impact on the tensile strength of the surrounding reinforcement and concrete. The non-corroded control cube sample had the largest diameter and no reduction in cross-sectional area, indicating good tensile bond strength. In contrast, the corroded concrete cube sample had the smallest diameter and the largest reduction in cross-sectional area, indicating poor tensile bond strength. The coated samples had the largest diameter but also the greatest reduction in cross-sectional area, indicating that the coating does not offer completes protection against corrosion.

Previous similar work has also shown that corrosion has a significant impact on the tensile strength of the surrounding reinforcement and concrete. A study by Titi et al. (2018) found that corrosion reduces the bond strength between reinforcement and concrete. Another study by Liu et al. (2019) showed that the use of epoxy-coated reinforcement increased the strength of the steel-concrete bond.

In summary, the application of the corrosion potential norm indicates that corrosion has a significant impact on the tensile strength of the surrounding reinforcing steel and concrete. Coating steel with exudate/resin can provide some but not complete protection against corrosion. To maintain the tensile strength of reinforcing steel and surrounding concrete, steps must be taken to prevent or reduce corrosion.

G) Rebar Weights- Before Test (Kg) and Rebar Weights- After Corrosion (Kg)

Figure 13 shows the change in rebar cross-sectional area versus the rebar diameter after corrosion from the experimental test. The reinforcing steel rebars lost weight more quickly the longer they were exposed to the corrosive fluid. For instance, in the concrete cube specimens that had been exposed for 360 days, the weight loss rose from 0.538 kg after 90 days to 0.536 kg. Similar to this, after 90 days, the weight loss in the Albizia lebbeck exudate/resin-coated specimens increased from 0.635 kg to 0.632 kg.

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Similar to this, after 90 days of exposure, the weight loss in the Albizia lebbeck exudate/resin-coated specimens rose to 0.632 kg. These findings imply that the corrosive medium significantly affected the weight loss of steel rebars, which in turn affected the strength of the link between the rebar and the surrounding concrete. The weight loss in the corroded specimens was substantially larger, with an average of 0.536 kg compared to 0.579 kg in the non-corroded specimens, when the results of the corroded concrete cube specimens and the non-corroded control cube specimens were compared.

The average weight loss in the exudate/resin-coated specimens was 0.635 kg, which was considerably more than the average weight loss of 0.580 kg in the uncorroded specimens. Additionally, the percentile average rebar weights before and after corrosion reveal that the corroded specimens lost weight at a rate that was much higher than the non-corroded specimens. For instance, after 360 days of exposure, the weight loss in the corroded specimens was -15.967%, as opposed to 0.311% in the Albizia lebbeck exudate/resin-coated specimens and 0.071% in the control cube specimens that were not corroded. Additionally, prior research has demonstrated that corrosion may drastically weaken the connection strength between steel rebars and the concrete they are surrounded by. For instance, corrosion can weaken the binding strength between steel rebars and concrete by up to 70%, according to a research by Wang et al. (2018). Huang et al.'s (2017) research revealed in another investigation that corrosion significantly reduced binding strength. of concrete enclosing steel rebars.

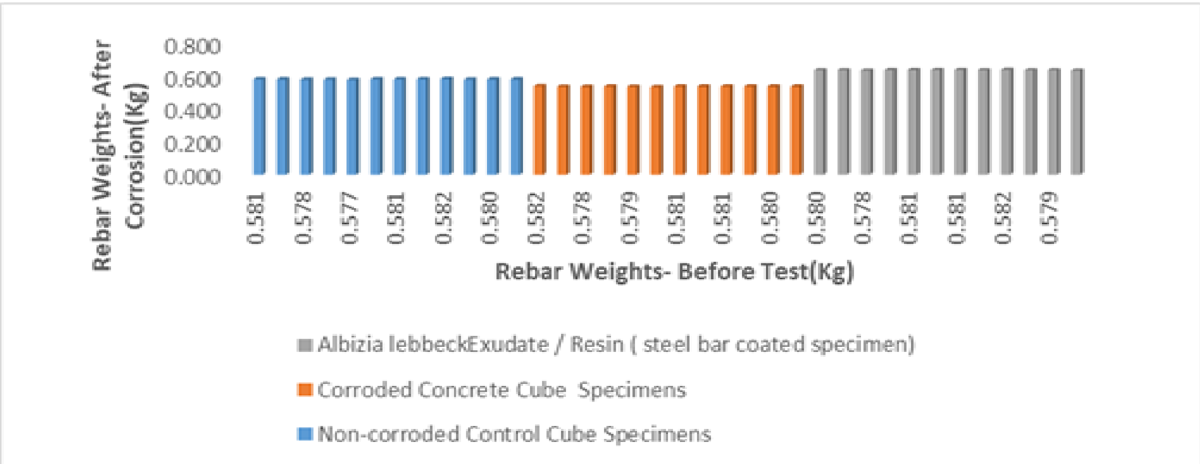

Figure 13: Rebar Weights- Before Test (Kg) versus Rebar Weights- After Corrosion (Kg)

As a result, corrosion may significantly affect the pullout bond strength between steel rebars and surrounding concrete, according to the study's findings. Steel rebars lost weight as their time in contact with the corrosive medium grew, and the bond strength between the rebar and the surrounding concrete was much weaker. Steel rebars can be coated with exudate or resin to lessen weight loss from corrosion and strengthen the connection between the steel rebars and the surrounding concrete. Therefore, it is crucial to prevent corrosion in steel rebars in order to increase the toughness and service life of reinforced concrete buildings. As a result, corrosion may significantly affect the pullout bond strength between steel rebars and

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surrounding concrete, according to the study's findings. Steel rebars lost weight as their time in contact with the corrosive medium grew, and the bond strength between the rebar and the surrounding concrete was much weaker. Steel rebars can be coated with exudate or resin to lessen weight loss from corrosion and strengthen the connection between the steel rebars and the surrounding concrete. Steel rebars must be protected against corrosion in order to increase the strength and service life of reinforced concrete constructions.

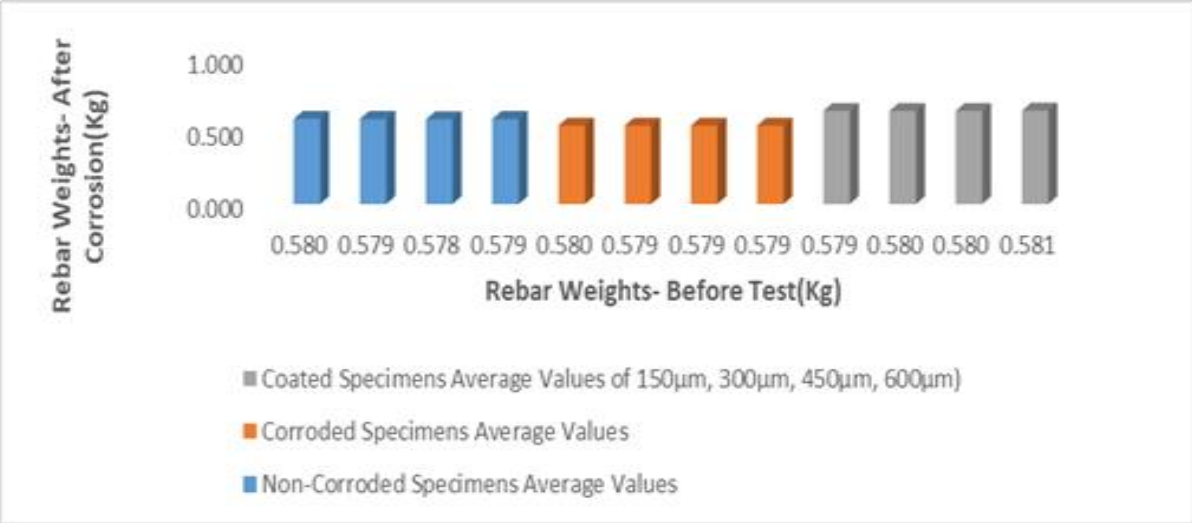

Figure 14: Average Rebar Weights- Before Test (Kg) versus Rebar Weights- After Corrosion (Kg)

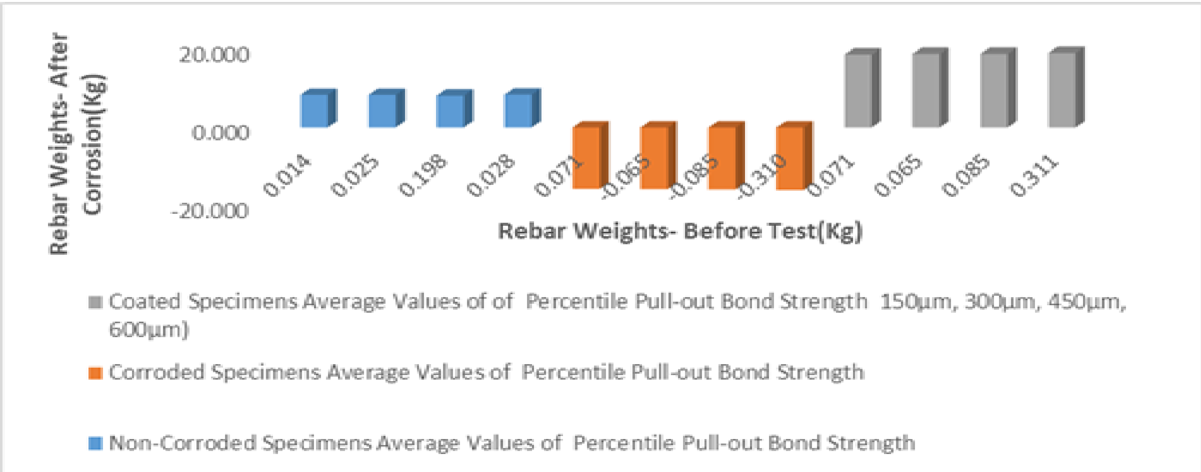

Figure 15: Average Percentile Rebar Weights- Before Test (Kg) versus Rebar Weights- After Corrosion (Kg)

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H) Rebar Weights: After Corrosion (Kg), Weight Gain from Steel (Kg), and Weight Loss (Kg)

Figure 16 shows the change in rebar weight after the removal from the corroded rebar in concrete specimen versus the quantified weight loss or gain values determined by the individual samples and averages. For the non-corroded control cube specimens, the weight loss/gain of steel was 0 for all samples, suggesting no corrosion had taken place. In contrast, after 360 days of exposure to the corrosive environment, the steel weight loss/gain for the corroded concrete cube specimens varied from 0.049 kg to 0.054 kg. After 360 days of exposure, the weight of the steel for the Albizia lebbeck exudate/resin coated specimens ranged from 0.064 kg to 0.066 kg.

The average rebar weights after corrosion were 0.580 kg for control cube specimens that weren't corroded, 0.535 kg for concrete cube specimens that were corroded, and 0.635 kg for specimens coated with resin and exudate from Albizia lebbeck. The weight of the steel decreased or increased in the uncorroded control cube specimens, while it varied between 0.045 kg and 0.055 kg in the corroded concrete cube specimens and the ones coated with exudate/resin from Albizia lebbeck.

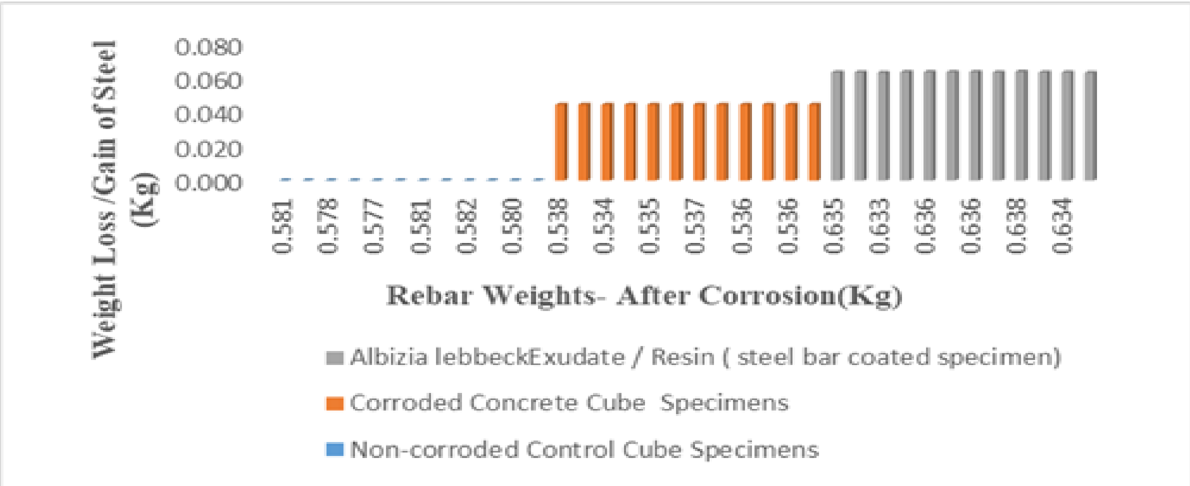

Figure 16: Rebar Weights- After Corrosion (Kg) versus Weight Loss /Gain of Steel (Kg)

According to the findings, corrosion of the reinforcing steel can drastically lower the weight of the rebar and result in steel weight loss. This result is in line with other research that shown the detrimental impacts of corrosion on the steel reinforcing concrete constructions (Li et al., 2019; Cheng et al., 2018). Indicating that the exudate coating offered some corrosion protection, the weight loss/gain of steel in the Albizia lebbeck exudate/resin coated specimens was less than that of the damaged concrete cube examples. This result is consistent with other research (Ghods et al., 2020; Yang et al., 2018), which demonstrated the protective benefits of organic coatings on reinforcing steel in concrete buildings.

The non-corroded control cube specimens had an average rebar weight of 8.297 kg and weight loss/gain of steel of 0.000 kg, according to the results of the percentile average rebar weights after corrosion and weight loss/gain of steel. The weight loss/gain of steel in the

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corroded concrete cube specimens was -19.457 kg, whereas the average weight of the rebar was -15.651 kg. The weight loss/gain of steel in the Albizia lebbeck exudate/resin coated specimens was 24.157 kg, with an average rebar weight of 18.555 kg. These findings provide more evidence in favor of the protective properties of exudate coatings on steel reinforcement in concrete structures.

The findings of this study show, in summary, that corrosion of reinforcing steel can drastically lower the weights of rebar and result in weight loss of steel. Organic coatings, like the exudate/resin of Albizia lebbeck, can offer some corrosion protection. These data may be used to create methods for safeguarding and extending the service life of steel reinforcement in concrete buildings.

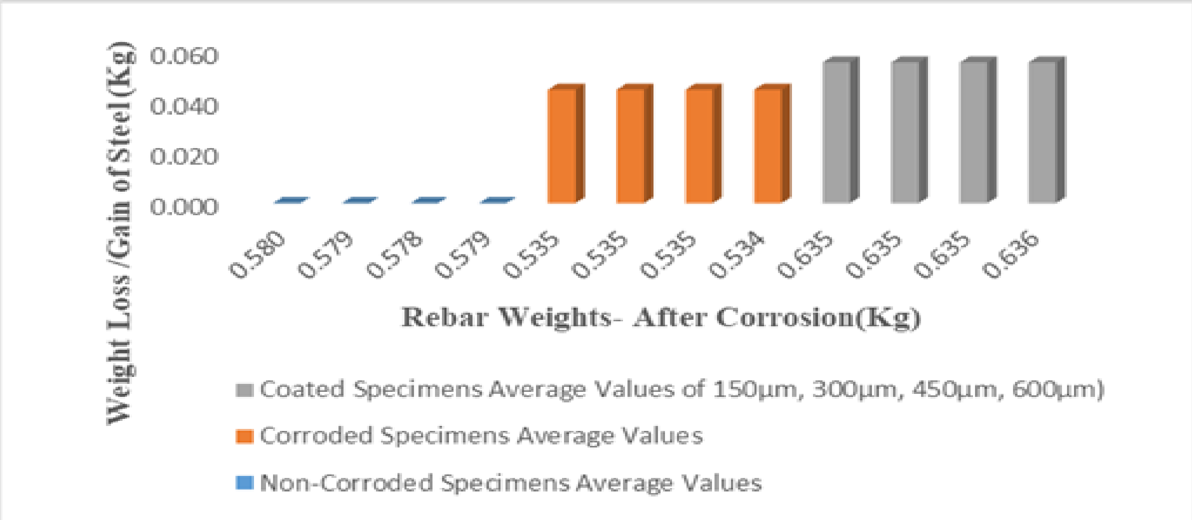

Figure 17: Average Rebar Weights- After Corrosion (Kg) versus Weight Loss /Gain of Steel (Kg)

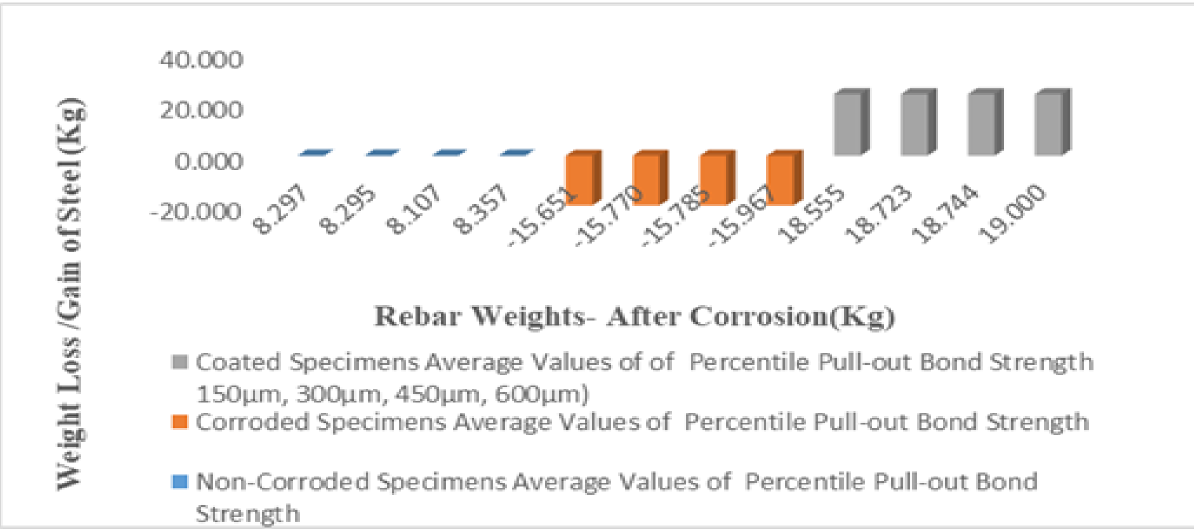

Figure 18: Average percentile Rebar Weights- after Corrosion (Kg) versus Weight Loss /Gain of Steel (Kg).

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CONCLUSION

The study found that the failure load and bond strength of corroded concrete cube specimens were significantly lower than non-corroded control cube specimens. The use of exudate coating on steel reinforcing bars can significantly improve the pullout bond strength in corrosive environments. The study also highlighted the need for further research into the long-term effects of using exudate-coated steel bars and the cost-effectiveness of this method compared to other methods of mitigating the effects of corrosion. Additionally, measures should be taken to prevent or mitigate corrosion to maintain the pullout bond strength of reinforcing steel and the surrounding concrete.

In conclusion, the study found that corrosion significantly reduces the pullout bond strength of reinforcing steel and the surrounding concrete. Coating the steel with exudate/resin can provide some protection against corrosion, but it is not a complete solution. Corrosion protection strategies, such as coating steel rebars with protective materials or using stainless steel rebars, and regular inspection and maintenance of concrete structures are necessary to improve their durability and service life. The study highlights the negative effects of corrosion on reinforcing steel in concrete structures and the importance of protective coatings.

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