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Study on the Effects of Corrosion on Steel Arch Bridges

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ABSTRACT

When steel is exposed to its surroundings and reacts with them, corrosion becomes one of the problems that steel bridges face. As it weakens and increases the likelihood of failure, corrosion is a concern to steel structures. Bridge fatigue life may be severely impacted by the resulting stress, which might end in catastrophic failure. The appearance and spread of fatigue cracks can be accelerated by corrosion, which causes the steel structure to deteriorate more quickly. Visual examinations frequently identify corrosion quickly, but a thorough assessment and study of corrosion damage are crucial. This research focuses on analysing the behaviour of a steel arch bridge under the influence of corrosion that occurs at the bridge. The study aims to determine the different stress levels resulting from corrosion. By employing SAP2000 software, three corrosion levels with 10%, 20%, and 50% of the selected section area at the bridge's centre span and abutment are considered by reducing the structure's cross-sectional area. Stress values are obtained by considering the most probable location of corrosion. The results and discussion reveal that steel arch bridges exhibit excellent flexibility and deformation. Segment of the bridge that located at the centre, experienced the highest stress range and potential concentrations. These finding underscore the importance of effective corrosion prevention and maintenance strategies. It is crucial to ensure their long-term durability and structural integrity.

Keywords: Steel bridge; arch bridge; corrosion; moving load; SAP2000

INTRODUCTION

Steel bridges are favoured for their ease of construction and widespread use in bridge engineering due to the high tensile strength of steel material. Compared to concrete bridges, steel bridges are designed to efficiently resist bending moments and shear forces, with the flexural strength of steel girders playing a vital role in ensuring structural integrity under applied loads (Naser et al. 2022) However, steel bridges may be affected and suffer extreme damage due to corrosion. The corrosive conditions enveloping numerous steel arch bridges, especially those located in coastal or industrial areas, subject these structures to accelerated degradation. The interaction of steel with environmental factors such as moisture, oxygen and pollutants initiates corrosion processes, leading to the formation of rust and subsequent deterioration of the steel components. As corrosion progresses, it weakens the structural elements, potentially leading to catastrophic failures if left unaddressed. This corrosion expressed concern about the overall strength of the bridge structure.

Engineers employ various strategies to address corrosion in steel bridges, aiming to protect the structural integrity and extend the lifespan of the infrastructure. For example, the corrosion inhibitors method. This method works by applying the chemical inhibitor directly to the steel surface. It can mitigate corrosion by forming a protective layer or altering the electrochemical conditions. Moreover, applying protective coatings, such as paint or specialised corrosion-inhibiting coatings, creates a barrier between the steel surface and the corrosive environment, preventing direct contact with moisture and oxygen.

To study the effect of corrosion on steel structures, this research investigates the stress behaviour and structural performance with a focus on steel arch bridges. The analysis incorporates both in 2D and 3D simulations to assess the structural response under varying corrosion conditions, highlighting the strengths and limitations of each approach. While 2D analysis offers an initial understanding of stress distribution, it is inherently limited in capturing the complexity of real-world scenarios. To address these limitations, 3D analysis is employed, providing a more comprehensive representations of the structural behaviour by modelling the full geometry and simulating realistic corrosion patterns.

Similarly, Homaioon Ebrahimi et al. (2018) underscore the critical importance of 3D finite element analysis in evaluating the performance of steel structures, particularly steel moment frame structures, under the risk of progressive collapse. Their study demonstrates that 3D analysis compared to foundational 2D approaches, provides a deeper understanding of structural vulnerabilities and the effectiveness of strengthening techniques such as steel cables and diagonal concentrically braced frames. These findings align with the current research's emphasis on the necessity of advanced 3D analysis for capturing the intricate effects of corrosion and ensuring the safety and resilience of steel structures under complex loading and environmental conditions.

Thus, by performing this dual analysis, the research aims to enhance understanding of the way corrosion interacts with steel arch bridges, influencing their structural integrity and long-term performance. The finding is expected to contribute valuable insights to bridge engineering practices, enabling the development of effective maintenance strategies, advanced corrosion prevention measures and improved design considerations for ensuring the safety, endurance, and longevity of these critical infrastructure elements. Furthermore, this study underscores the importance of integrating advanced tools, such as 3D simulations in bridge design and maintenance protocols to inform engineers' decisions and safeguard infrastructure in the face of environmental challenges.

To fulfil this study, the research flow begins with a literature review to a find deeper understanding, followed by research methodology, which simulates the 50-meter bridge to investigate the stress analysis of a steel arch bridge. Then the results and discussion are presented, followed by a conclusion. The simulation involves introducing corrosion effects and assessing their impact on the stress range of the bridge members. This paper takes into consideration the corrosion effects on a steel arch bridge that could further affect the fatigue life of the steel bridge.

CORROSION

In 2022, Yulin Deng and Luming Deng conducted an experiment on an 11-year-old concrete-filled steel tube arch bridge. They simulated corrosive conditions using acetic acid-accelerated salt spray tests on steel wire samples to replicate real-world scenarios. The study aimed to observe the corrosion effects, resulting in samples with varying degrees of corrosion. Subsequently, fatigue tests are carried out on each of these samples, including polished ones, and the resulting fatigue fractures are carefully observed. The findings reveal that samples with only a few surface cracks can be effectively treated through grinding, leading to an increase in the fatigued life of the specimens. This indicates a potential mitigation strategy for enhancing the structural integrity of materials subjected to corrosive environments, underscoring the practical implications of the research in addressing real-world challenges in materials science and engineering.

The study by Salem & Helmy (2013) investigates the collapse of the Minnesota I-35W Bridge by thoroughly analysing the structural details involved in the incident. The study considers various components including steel trusses, gusset plates, concrete slabs, and concrete piers. Furthermore, it considers all the loads acting on the bridge at the time of the collapse to provide a comprehensive understanding of the contributing factors. To simulate the behaviour of complex structures under diverse conditions, the investigation employs the Applied Element Method (AEM), a numerical technique renowned for its efficacy in such analyses. The findings of the study point towards the failure of the gusset plates as a critical factor in the bridge collapse. The gusset plates were found to have an under-designed thickness, making them susceptible to structural stress and compromise. Corrosion further weakened the plates, and the cumulative effect of loading from traffic exacerbated the situation, ultimately leading to the catastrophic failure of the bridge. This research underscores the importance of thorough structural assessments, proper design considerations, and vigilant maintenance practices in ensuring the safety and longevity of critical infrastructure such as bridges.

CLIMATE CHANGE

The fact that our climate is changing is unequivocal and has emerged as a significant concern for bridge health, as highlighted by Figueiredo et al. (2024). Figueiredo's research suggests that climate change introduces another layer of variability, affecting the long-term damage detection process when employing machine learning algorithms. This study pioneers the examination of climate change's impact on long-term damage detection within the realm of bridge Structural Health Monitoring (SHM). Consequently, climate change including increased temperatures and extreme weather event, significantly impacts the reliability and structural integrity of the bridges, potentially reducing their lifespan by decades (Palu & Mahmoud, 2019).

Several reviews and discussions have explored the potential impacts of climate change on metal corrosion (Cole & Paterson, 2010; Kumar & Imam, 2013; Roberge, 2010). They agree that the primary consequence of corrosion is the substantial loss of material in structural steel components, resulting in diminished cross-sectional thickness and consequently, worse, a reduction in structural resistance and stiffness (Orcesi et al. 2022).

The corrosion process in steel structures initiates after the degradation of applied corrosion protection coatings (Garbatov 2020). Protective coatings for low alloyed steel structures come in various types, including metallic, organic, or duplex coatings. Among metallic coatings, various forms of zinc or zinc-alloyed coatings are commonly used. However, climate change speeds up damage to coatings by making surfaces rougher, causing chemical breakdown, and exposing them to harsher weather (Loganina 2021). Understanding these effects is important to create stronger and longer-lasting coatings (Ivanovna 2019; Wang & Zhao 2020).

Fom (2017) investigated the impact of climate change on the buckling strength of steel plates, which represent components of bridge plate girders. Through a combination of diverse climate change scenarios and finite element analysis applied to various steel plate configurations, the study revealed that, under a high emissions scenario (RCP8.5), a potential reduction in plate buckling strength of up to 25% is anticipated by the 2100s, in contrast to a low emissions scenario (RCP2.6) (Orcesi et al. 2022).

In a separate study, Imam (2019) assessed the time-dependent reliability of a typical plate girder railway bridge under different climate change and atmospheric pollution scenarios. The findings indicated that the overall direct impact of an increase solely in average annual temperature on bridge reliability is relatively modest (Orcesi et al. 2022).

FATIGUE LIFE

Yuan et al. (2024) conducted a study to evaluate the corrosion fatigue life of bridge suspenders using a damage model that integrates the effects of both corrosion and varying loading conditions. The analysis considered different corrosion grades, assessing their impact on the suspenders' damage index. The results revealed that corrosion, including both uniform and pitting types affecting internal steel wires, significantly reduces the suspenders' fatigue life, underscoring corrosion as a critical factor in early failure mechanisms. Additionally, traffic load was identified as the primary contributor to fatigue damage, highlighting the combined impact of environmental and operational stressors on suspender durability.

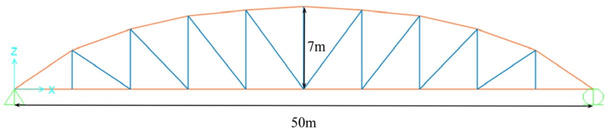
Corrosion reduces the effective cross-sectional area of load-bearing elements, diminishing their mechanical resistance to loads on the bridge's superstructure. The bridge's capacity to handle traffic load effects is measured by its "load-carrying capacity" (LCC), a key indicator for evaluating existing bridges (Gocál & Odrobiňák, 2020). LCC is a crucial not only for future planning but also for assessing whether current service loads can be safely accommodated. The interaction between corrosion and traffic load is critical, as corrosion-induced deterioration directly impacts LCC. This underscores the necessity for proactive maintenance and assessment strategies to ensure the safety and longevity of transport infrastructure (Gocál & Odrobiňák 2020).

Similarly, changes in wave climate play a crucial role in fatigue damage assessment throughout the design life, yet these factors are often overlooked, as noted by Du et al. (2020). Recently, some researchers have focused their efforts on exploring the influence of wave climate change on the safety and reliability of structures. Bitner-Gregersen et al. (2018) delved into the effects of wave variations on structural design, underscoring the significance of accounting for such changes. Vanem & Bitner-Gregersen (2013) also contended that an increase in wave height corresponds to a heightened probability of structural failure.

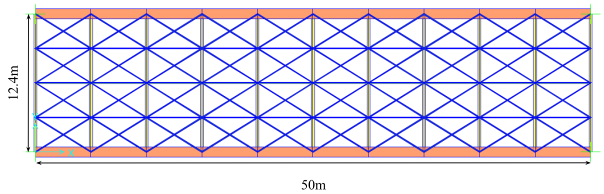
MODELLING AND ANALYSIS

BRIDGE STRUCTURAL MODEL

The size of the bridge is taken according to the dimensions of the Sungai Durian Bridge in Kuala Krai. However, for this study, this model only applies to a one-way carriageway bridge configuration. In this context, the bridge is designed to accommodate one-way traffic only. While the dimensions generally follow those of the reference bridge, it is important to note that this adaptation is specific to one-way conditions. With its single carriageway design spans 50 meters in length and a width of 12.4 meters on each side. Standing tall at 7 meters high, the arch of the new bridge symbolises both resilience and progress. Figure 1(a)(b) illustrates the dimensions of the bridge model. The full 3-Dimensional (3D) model incorporates both views to ensure a comprehensive evaluation of the bridge's structural behaviour. However, the 2-Dimensional (2D) analysis is limited to the XZ plane, as shown in Figure 1(a), for simplicity and to focus on critical stress distributions along the arch profile.



(a)



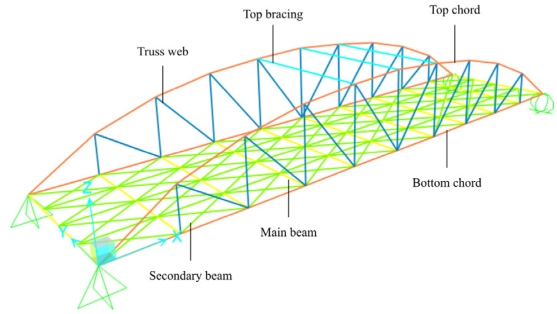
(b)

FIGURE 1. (a) Dimension of the bridge in XZ view; (b) Dimension of the bridge in XY view

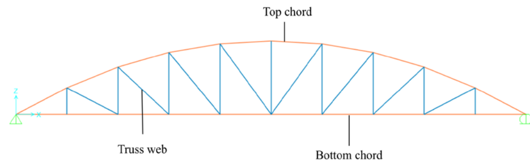
STRUCTURAL ANALYSIS

These models of the bridge were developed in SAP2000 to get precise values of member stresses. The steel sections used were made with 355 N/mm^2 yield stress steel. A 2.1×10^8 N/mm^2 Young's Modulus was adopted for the steel beam. The bridge modelled using frame element for all members to simulate the behaviour under self-weight and corrosion effects. As the model uses frame elements, explicit meshing was not applied. The members are inherently determining the element discretisation within the analysis. Different cross sections were adopted as presented in Table 1. It depicts the geometrical characteristics of the steel sections used in the structural model. Figure 2 shows the structural sections used to model the bridge.

In the 3D model, the structure includes a total of 40 members for the top and bottom chord elements. Additionally, 44 members are allocated for the main beams, 110 members for the secondary beams, 34 members for the truss web, and 3 members for the top bracing. In contrast, the 2D model comprises a total of 37 members, with 20 members used for the top and bottom chords and 17 members for the truss web. The structures are discretised into smaller, manageable elements, and for this case, the chosen element is the line element. The supports in the analysis are modelled as pinned and roller jointed, reflecting the real-world conditions where structures are often connected in such a manner. Trusses, which are common structural elements, are simulated by using joints to represent the connections between the structural members. These joints play a crucial role in determining the overall behaviour and stability of the truss. Additionally, boundary conditions are imposed to replicate the constraints and external forces acting on the structure, providing a comprehensive representation of the system's response to various loading scenarios.



(a)



(b)

FIGURE 2. Structure of the bridge. (a)3D; (b)2d

TABLE 1. Steel sections and sizing used

	Section and Size
Top and Bottom Chord	Square Hollow Section (SHS) 900x900x24 mm
Main Beam	I-Beam 762x267x197 kg/m
Secondary Beam	I-Beam 305x102x21 kg/m
Truss Web	I-Beam 400x300x94 kg/m
Top Bracing	I-Beam 610x229x101 kg/m

CORROSION ASSESSMENT

Three different levels of corrosion are considered, 10%, 20% and 50%. Different degrees of corrosion can have varying effects on the structural integrity and safety of the bridge. Analysing the structure at 10%, 20% and 50% corrosion levels can assess the corrosion progress, its impact on the bridge's load-bearing capacity and overall stability. The steel structure in the real world is subject to various degrees of corrosion over time due to environmental factors. Conducting structural analysis at multiple levels of corrosion enhances the comprehensiveness and applicability of research and provides a more realistic understanding of the corrosion effects on the steel arch bridge.

To simulate corrosion effects on the steel arch bridge, this study adopts a cross-sectional area reduction approach on the affected members within SAP2000. A similar approach has been effectively applied by Zaghian et al. (2023), who reduced the cross-sectional area of reinforcing bars to simulate corrosion impacts in the nonlinear finite element analysis of bridge piers under concentric loads. This demonstrates that cross-sectional reduction is a valid and accepted method for representing corrosion effects in numerical modelling of bridge structures.

The analysis of the bridge was conducted using both 2D and 3D models to comprehensively assess its structural integrity. In the investigation focused solely on corrosion effects, attention was directed towards understanding the impact of the bridge's self-weight on its degradation. In the 2D analysis, all members were analysed for potential corrosion vulnerabilities, ensuring a thorough examination of the structure's susceptibility. Conversely, the 3D analysis provided a more complex perspective, with only select members chosen to demonstrate the indication of corrosion effects. This approach allowed for a detailed examination of specific areas prone to degradation while efficiently utilising computational resources. By employing both 2D and 3D analyses, engineers could effectively evaluate the bridge's resilience to corrosion and devise targeted maintenance strategies to enhance its longevity and safety.

The application of corrosion is performed on a selected member, which is highlighted in a dark red colour in Figure 3. Members are specifically chosen at the abutment of the bridge and at the centre of the bridge for 3D model and all members for 2D model. Abutments, positioned directly in contact with the ground, are particularly susceptible to corrosion due to the retention of moisture in the surrounding soil. This moisture, combined with exposure to air, fosters the formation of differential aeration cells, thereby accelerating electrochemical reactions that contribute to corrosion. Moreover, the inaccessibility of abutments complicates regular maintenance efforts, resulting in delayed detection and treatment of corrosion issues. Similarly, the centre span of the bridge faces heightened exposure to environmental elements such as rain and wind, further increasing the risk of corrosion. Additionally, the abutments and centre span of the bridge endure elevated stress levels due to their critical role in supporting and distributing the bridge's load, rendering them more prone to corrosion over time.

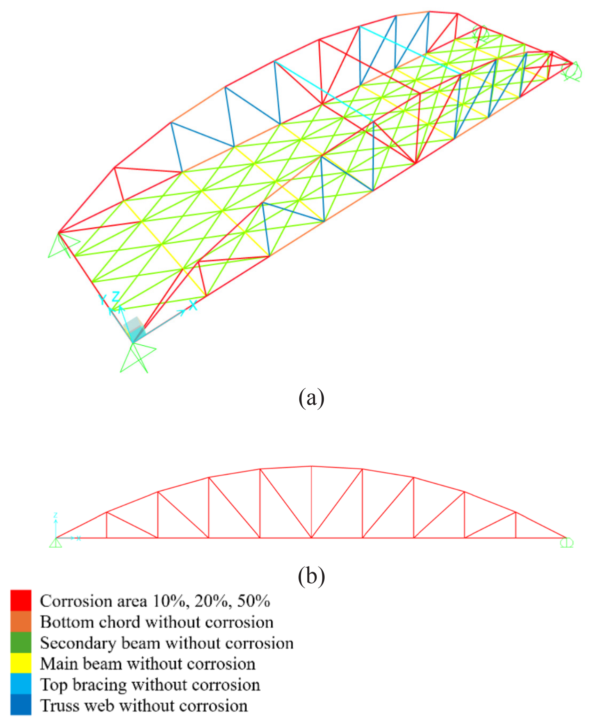


FIGURE 3. Location of the corrosion applied at (a)3D; (b)2D

Abey et al. (2016) investigated the sensitivity of bridge seismic response in relation to both Seat-type Abutments (SA) and Integral Abutments (IA). Their study employed response spectrum analysis to evaluate the global seismic behaviour of 3D finite element bridge models using SAP2000. The findings highlight that abutment behaviour plays a crucial role in the seismic response of short-span bridges. Notably, stiff superstructures, commonly found in highway overpasses, exhibit high sensitivity to abutment responses (Abey et al. 2016). This sensitivity to abutment behaviour is further influenced by additional factors such as traffic load and corrosion.

Berger & Haller (2023) present findings on the redistribution of internal forces from the span to the support areas using nonlinear finite element analysis. Their evaluation highlights that, for single-span bridges, the flexural reinforcement in the span is often a critical factor. The centre span endures significant bending moments, resulting in higher stress levels in the reinforcement compared to the support areas. Redistribution of internal forces to the support areas may become necessary when the existing reinforcement in the span is inadequate. Consequently, the centre span's reinforcement must be thoroughly assessed and, if needed, strengthened to ensure it can safely bear the applied loads without failure (Berger & Haller, 2023).

Thus, the centre span and abutments are critical areas in bridges due to their roles in accommodating movements, dissipating energy, and ensuring structural integrity (Abey et al. 2016; Berger & Haller, 2023). This critical nature of the centre span and abutment necessitates a focus on its design and reinforcement to maintain structural integrity. These factors underscore the importance of proactive measures, including protective coatings and regular inspections, to mitigate corrosion and uphold the structural integrity of the bridge.

RESULTS AND DISCUSSION

The numbering of bridge's members for the 2D model is shown in Figure 4. Based on Figure 6, the graph shows the high-stress concentrations were observed primarily in members 1 to 5. These members are in tension, as indicated by the positive stress values, ranging between 9x10^{-3} kN/mm^2 to 12x10^{-3} kN/mm^2. These members experience elevated stress levels due to their positioning at critical points of the bridge structure. Following this, members 11 to 15 exhibited compression, with stress values around 6x10^{-3} to 9x10^{-3} kN/mm^2, indicated in negative value. This compression phenomenon arises from the arched configuration of the members, which inherently subjects them to compressive forces. Subsequently, members 21 to 29 displayed stress values ranging between 1x10^{-3} to 6x10^{-3} kN/mm^2, representing the trusses of the bridge. The difference in the highest stress between member 1, near the abutment, and the member 4, near the centre span, is approximately 14%. This variation highlights the increased stress concentration near the abutment. All members play a crucial role in distributing loads and maintaining structural stability across the bridge span. Overall, the 2D analysis provided valuable insights into stress distributions and critical zones within the bridge structure, supporting the optimisation of design and the selection of materials, such as high-strength steel or corrosion-resistant options, to enhance durability.

In the 3D analysis, the entire bridge structure was modeled to ensure a comprehensive evaluation. The model consisted of 227 frames, as illustrated in Figure 5. Thus, the analysis focused on selected members located at both the abutment and centre span of the bridge to capture critical stress distributions across different sections.

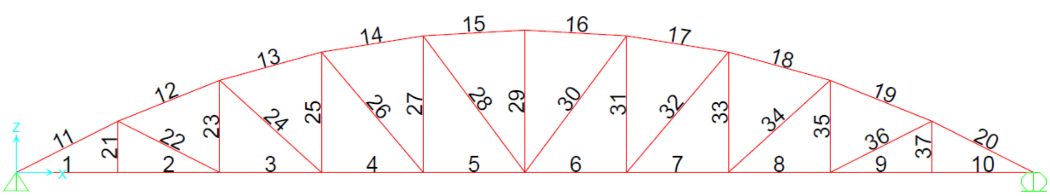


FIGURE 4. Number of members in 2D modelling

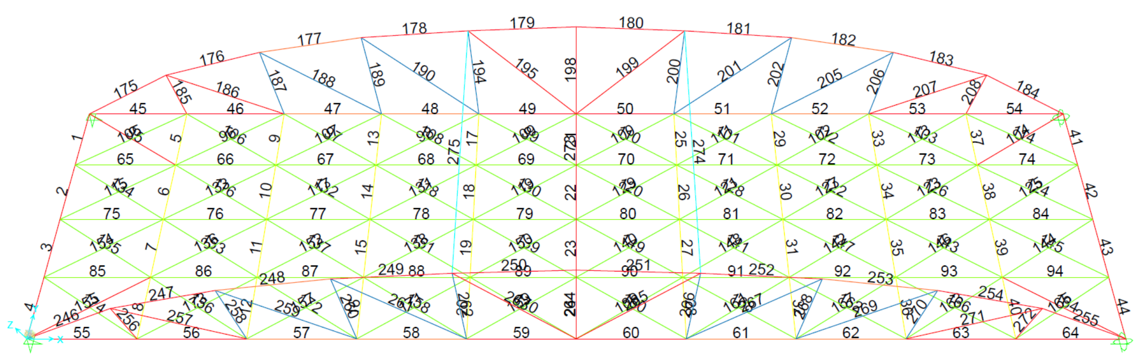


FIGURE 5. Number of members in 3D modelling

Figure 7 illustrate the stress analysis of the members located within the centre span of the bridge, members 178 to 181, positioned at the crown of the arch, exhibited stress values ranging between 8x10^{-3} to 10x10^{-3} kN/mm^2 in compression. Notably, truss member 198 displayed the highest stress, reaching 12x10^{-3} kN/mm^2 under normal conditions and 13x10^{-3} kN/mm^2 with 50% corrosion. This was followed by members 49 and 50, with stress values ranging between 10x10^{-3} to 11x10^{-3} kN/mm^2. Additionally, the main beam members 21 and 22 showed stress values of 6x10^{-3} kN/mm^2 and 9x10^{-3} kN/mm^2, respectively, while top bracing member 273 exhibited a stress value of 5x10^{-3} kN/mm^2.

The stresses in the abutment region of the bridge are shown in Figure 8, especially members 175, 176, 183, and 184. These members demonstrated compression conditions like other sections, with stress values ranging from $4x10^{-3}$ kN/mm² to $8x10^{-3}$ kN/mm². The highest stress values were observed in members 45 and 54, corresponding to the bottom chord and trusses of the bridge, including members 186 and 207, with stress values ranging between $18x10^{-3}$ kN/mm² and $21x10^{-3}$ kN/mm². Main beam members 1 and 2 showed stress values of $7x10^{-3}$ kN/mm² and $8x10^{-3}$ kN/mm², respectively without corrosion, while members 41 and 42 exhibited stress values of $5x10^{-3}$ kN/mm² and $6x10^{-3}$ kN/mm² without corrosion. Secondary beam members 95 and 104 without corrosion displayed stress values of $16x10^{-3}$ kN/mm² and $14x10^{-3}$ kN/mm², respectively. The highest stress values for member 186, near the abutment, and member 198, near the centre span, differ by approximately 35%, highlighting a notable increase in stress concentration near the abutment compared to the centre span region. This detailed analysis offers valuable insights into stress distributions across various sections of the bridge, assisting in identifying critical areas and guiding targeted damage repairs to ensure optimal structural performance and safety.

As shown in the results of the 2D analysis, it is generally evident that the critical members with the highest stress are located at the abutment region. However, to gain a more detailed and realistic understanding of the bridge's behaviour in real-world conditions, a 3D analysis is essential. The difference becomes apparent when comparing the results of 2D stress in Figure 6, the web trusses display relatively low stress values for members 21 to 29. However, 3D stresses in Figure 8 shows certain truss members, particularly those near the abutment, such as members 186 and 207, exhibit significantly higher stress values. The stress in these members is approximately three times greater than the values observed in the 2D model.

This difference highlights the limitations of the 2D model, which oversimplifies the structural behaviour by neglecting the interactions between members in three dimensions and the effects of out-of-plane forces. On the other hand, the 3D analysis provides a more comprehensive insight into the bridge's stress distribution as shown by members 186 and 207.

Apart from that, based on the trend graph shape as illustrated in Figures 6 to 9, the stress changes as the bridge condition gets worse, from no corrosion to 50% corrosion. In some cases, the stress increases, like in member 198 in Figure 7, which shows an upward trend. However, some members, such as member 195, show a decrease in stress as the corrosion level increases to 50%. This is because the analysis focuses solely on the self-weight of the steel arch bridge in the analysis. As self-weight is a fundamental load specific to each structure, determined by its material properties, element dimensions, and overall geometry. For this study, the structure analysed is the Sungai Durian steel arch bridge, which utilises mild steel (with a density of 78.5 kN/m³), consistent with JKR design specifications. Focusing solely on the self-weight allows the analysis to isolate the basic load-bearing behaviour of the structure without the interference of live or additional external loads. As a permanent load, self-weight is applied directly to the structure without load multipliers (Ferrari et al. 2016), ensuring the analysis targets the structure's inherent properties. For elements such as cables and struts, self-weight can be represented as concentrated forces at the end nodes, while for rigid bodies, it is applied by treating the centre of mass as an active node (Xue et al. 2025). This approach simplifies load application within the analysis process.

In a steel arch bridge, the self-weight of the structure results in only tension and compression forces. Compression is generally observed in the upper parts of the arch, while tension forces are typically found in the lower sections or in the tie rods, where components experience forces pulling them outward. Compression forces are predominant in the upper parts of the arch, which effectively distributes weight and resists the tendency to collapse under load. A steel arch bridge will fail under self-weight primarily due to buckling and material yielding in compression zones, and fatigue or stress corrosion in tension zone (Błonka & Skrętkowicz 2022). This understanding is crucial for ensuring that all parts of the structure can adequately handle the compressive and tensile stresses generated by the self-weight, a key aspect of structural integrity and safety. The distribution of tension and compression can vary based on the bridge's design, load combinations, and structural parameters (Lagos et al. 2023).

The analysis results in this study indicate that increased corrosion levels significantly affect the distribution and magnitude of tension and compression forces in the bridge members. Corrosion reduces the cross-sectional area of steel members, which directly decreases their stiffness and load-carrying capacity, altering the way forces are distributed across the arch. In compression zones, corrosion can cause localised buckling and increase compressive stress concentration. In tension zones, it raises stress levels in the remaining effective cross-section, resulting in higher tensile stresses that may accelerate crack initiation and propagation. For example, the results for member 5 in the 2D model as shown in Figure 6 and member 49 in the 3D model as presented in Figure 7 showed a notable increase in tensile stress under corrosion. Meanwhile, members 17 in 2D and 179 in 3D exhibited elevated compressive stresses at higher corrosion levels, indicating a greater risk of buckling. These confirm that corrosion impact depends on the member's original force type, geometry and location within the arch system.

Thus, focusing on self-weight in this corrosion analysis helps in assessing the baseline performance and stability, isolating the way of different corrosion levels influence tension and compression behaviour within the structure before considering additional external forces. This insight is critical for maintenance prioritisation, targeted, and effective life-cycle management of steel arch bridges under corrosive environments.

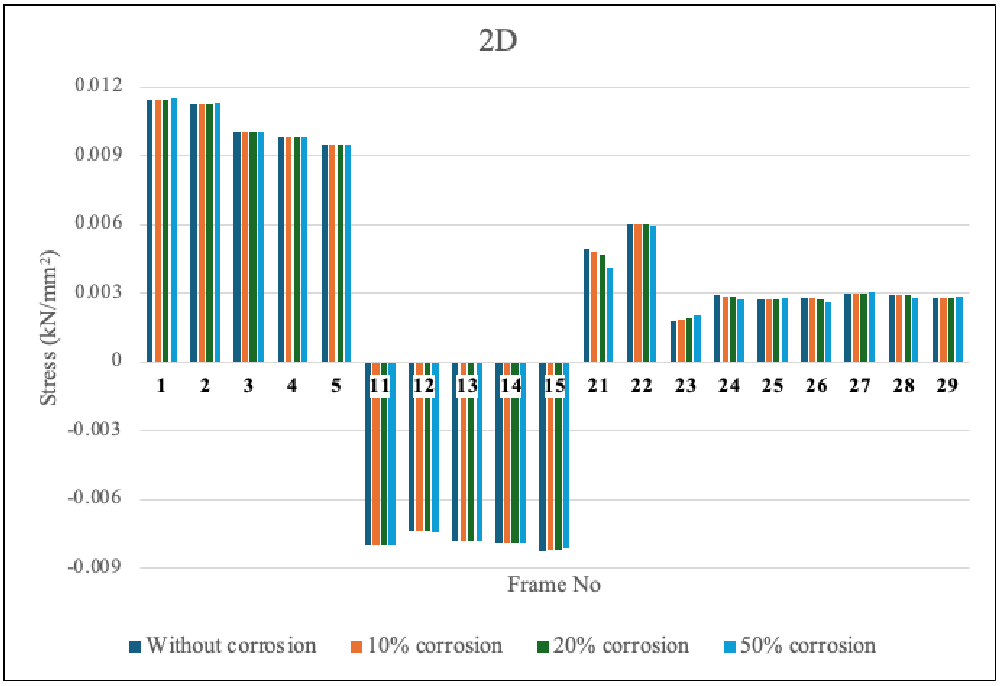


FIGURE 6. Stress on 2D members

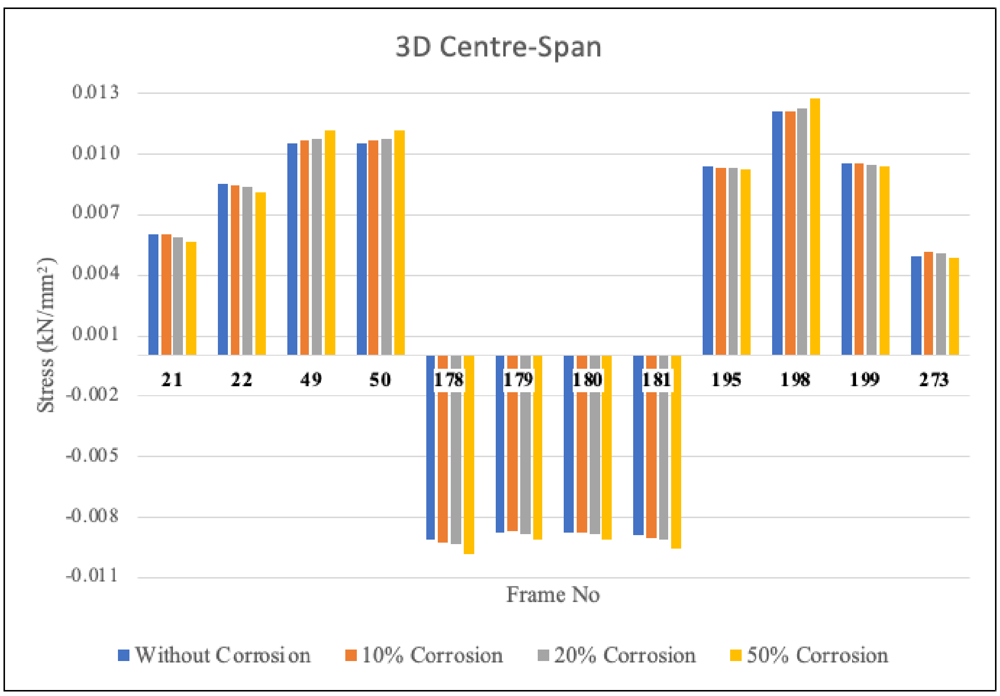


FIGURE 7. Stress on 3D at centre span members

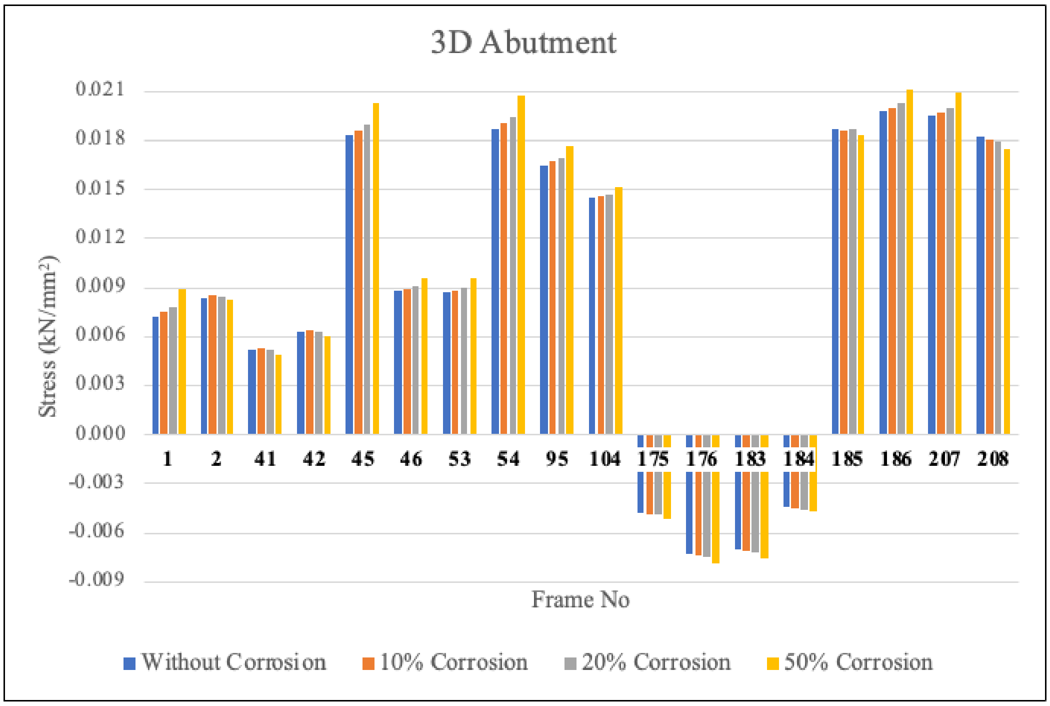


FIGURE 8. Stress on 3D abutment members

CONCLUSION

In conclusion, the 2D analysis provides a basic understanding of stress patterns, while 3D analysis is indispensable for capturing the complex behaviour of steel arch bridges, particularly under the influence of environmental factors such as corrosion. The 2D analysis identified that critical stress zones in the steel arch bridge are located at the abutment. However, the 3D analysis revealed additional high-stress areas in web trusses near the abutment. This demonstrates the limitation of 2D modelling in fully capturing the complexity of stress distribution across the structure. The 3D analysis provided a more realistic and detailed representation of the stress distribution, accounting for the interactions between structural components and out-of-lane forces. It highlighted areas of high stress that were not evident in the 2D analysis, emphasising the necessity of 3D modelling for accurate and comprehensive bridge evaluations.

The findings underscore the importance of using 3D models in the design and analysis of steel arch bridges to identify critical members and ensure adequate structural performance under real-world conditions. This enhanced understanding of the structural degradation caused by corrosion and provided valuable information for the maintenance and rehabilitation of steel bridges. 3D modelling provided a more comprehensive understanding of the spatial distribution of corrosion along the bridge components. By visualising the corrosion patterns in three dimensions uncover deeper insights into the complex interactions between environmental factors and structural elements, providing a clearer understanding of their effect on material degradation.

However, it is important to acknowledge the limitations of this study, including the simplifications made in the modelling assumptions and the need for further validation with field data. Future research should focus on refining the modelling techniques and incorporating real-time monitoring systems to better understand the nature of corrosion in steel bridges. In conclusion, this study contributes to the ongoing efforts in bridge maintenance and safety by advancing our understanding of the corrosion effect on steel arch bridges. By combining numerical modelling with practical insights, the resilience and longevity of infrastructure systems can be enhanced to better withstand environmental challenges.

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DECLARATION OF COMPETING INTEREST

None.

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