Independent Study Report

Studying the Bond Properties Between CRP and Steel Through Double Lap Specimens

MERVYN EARL JOHN MEDIDI
MCE DEPARTMENT
PUID: 035554294

Abstract:

Carbon fiber reinforced polymer (CRP) and steel composites have been increasingly used in various engineering applications due to their high strength, stiffness, and corrosion resistance. However, the bonding strength between CRP and steel is a critical factor in the design of structures using these materials. Therefore, the goal of this study was to investigate the bonding strength between CRP and steel using double lap specimens.

Proper surface preparation involved cleaning and grinding the surface of the steel to enhance the adhesion between the steel and the adhesive. As the adhesive type and curing time were also found to affect the bond strength.

The experimental program involved preparing a series of double lap specimens by bonding CRP to steel using an epoxy adhesive. The specimens were then tested under tensile loading conditions to determine the bond strength and failure modes of the specimens. The testing was to be conducted using a tensile strength testing machine, and the load-displacement curves were to be recorded during the tests.

The bonding strength between CRP and steel is an important factor in the design and analysis of structures using these materials. The bonding strength can be influenced by various factors, including surface preparation, adhesive type, and curing time. Therefore, studies on the bond properties between CRP and steel are essential for optimizing the mechanical and physical properties of the composites and ensuring the safety and reliability of structures using these materials, This is what we hoped to achieve through this study.

Introduction:

The status of steel infrastructure is a major concern in many countries, as these structures are often subject to various issues such as corrosion, aging, and fatigue cracks.

Corrosion is a common problem in steel infrastructure due to exposure to harsh environmental conditions such as salt water, humidity, and chemical pollutants.

Corrosion can lead to the loss of structural integrity and eventually to collapse if not properly managed.

Aging is another issue that affects steel infrastructure. Many of these structures were built decades ago and have reached or exceeded their design life, making them more susceptible to failure. Aging can also result in reduced strength and stiffness, which can compromise the structural integrity of the infrastructure.

Fatigue cracks are one of the most significant threats to the structural integrity of steel infrastructure, including bridges, buildings, and offshore platforms. They are caused by the repeated application of cyclic loads on the structure over an extended period of time. The loads may be caused by normal operating conditions or external factors such as wind, waves, or seismic activity.

Fatigue cracks are difficult to detect as they usually start from the inside of the material and grow slowly over time. They may not be visible on the surface until they become quite large, making it challenging to detect them during routine inspections. This can lead to catastrophic failure, as the cracks can continue to grow until the structure can no longer support the loads it was designed for.

To prevent fatigue cracks, it is essential to design steel structures with a thorough understanding of the cyclic loading environment they will be subjected to. This includes considering the effects of wind, waves, and seismic activity, as well as the frequency and magnitude of loads. Proper design, materials selection, and fabrication methods are critical for reducing the risk of fatigue failure.

In addition to design considerations, regular inspections and maintenance are essential for detecting and repairing fatigue cracks before they become a significant risk to the structure's safety. Inspection techniques such as visual inspections, ultrasonic testing, and magnetic particle inspection can help detect cracks early and allow for timely repairs.

Now when Steel Infrastructure gets damaged, repairing steel structures is a common practice to extend their life, reduce costs, and maintain safety. There are several traditional methods used for repairing steel structures, including:

Welding: Welding is a widely used method for repairing steel structures. It involves melting the base metal and adding filler material to create a strong bond between the two pieces. Welding can be used to repair cracks, holes, or other damage to steel structures.

Bolted connections: Bolted connections are another common method for repairing steel structures. This method involves drilling holes in the damaged section of the structure and attaching a new piece using bolts and nuts.

Riveting: Riveting involves using a metal pin to hold two pieces of metal together. This method is commonly used for repairing steel structures in which welding is not feasible due to the thickness of the metal or other factors.

Epoxy injection: Epoxy injection is a method of repairing steel structures in which an epoxy resin is injected into the damaged area. The resin hardens and forms a strong bond with the surrounding metal, effectively repairing the damage.

Corrosion protection: One of the most critical methods of repairing steel structures is to protect them from corrosion. This can be done by applying protective coatings, such as paints or galvanizing, to the surface of the steel.

Overall, these traditional methods are effective in repairing steel structures and extending their life.

But, newer methods such as Carbon fiber-reinforced polymer (CRP) composites and advanced welding techniques are becoming more prevalent in repairing steel structures due to their increased durability, reduced cost, and ease of application. This is the goal of our study.

Carbon Fiber Reinforced Polymer (CRP) composites have become increasingly popular for repairing steel structures in recent years, as they offer several advantages over traditional repair methods. Some of these advantages include:

Strength: CRP composites have a high strength-to-weight ratio, meaning they can offer the same or higher levels of strength as traditional steel repairs, but with significantly less weight.

Corrosion resistance: Steel structures are vulnerable to corrosion, which can weaken the structure over time. CRP composites are resistant to corrosion, making them ideal for repairing steel structures in harsh environments.

Durability: CRP composites are highly durable and resistant to environmental factors such as UV radiation and temperature extremes, making them ideal for long-term repairs.

Cost-effectiveness: Traditional steel repair methods can be expensive and time-consuming. CRP composites can be applied quickly and with minimal disruption, making them a cost-effective alternative.

Flexibility: CRP composites can be shaped to fit any contour or shape, making them ideal for repairing complex steel structures.

Non-conductive: Unlike steel, CRP composites are non-conductive, making them ideal for repairing electrical infrastructure or structures in sensitive environments.

Overall, CRP composites offer several advantages over traditional steel repair methods, including increased strength, durability, and cost-effectiveness. They are also highly versatile and can be used in a variety of applications, making them a popular choice for repairing steel structures. We wish to explore the viability of CRP as a possible replacement for traditional methods of repairing steel structures.

Methodology:

Test variables listed, Bond length (lb) for CRP 070, studying =3’’ (75 mm), 5’’ (125 mm), 7’’(175 mm), 9’’ (225 mm). Number of rods= 7.

Bond length (lb) for CRP 195, studying =3’’ (75 mm), 5’’ (125 mm), 7’’(175 mm), 9’’ (225 mm). Number of rods= 2.

Bond width (Bf) & Bf over steel width (Bs) (Bf / Bs) ratio for CRP 070, studying Bf =12.5, 25.4, 50 mm, corresponding to (Bf / Bs) ratios of 0.25, 0.50, 1.00. Those respective (Bf / Bs) ratios correspond to the number of rods = 2, 4, 7.

Bond width (Bf) & Bf over steel width (Bs) (Bf / Bs) ratio for CRP 195, studying Bf =19, 38 mm, corresponding to (Bf / Bs) ratios of 0.38, 0.76. Those respective (Bf / Bs) ratios correspond to the number of rods = 2, 4.

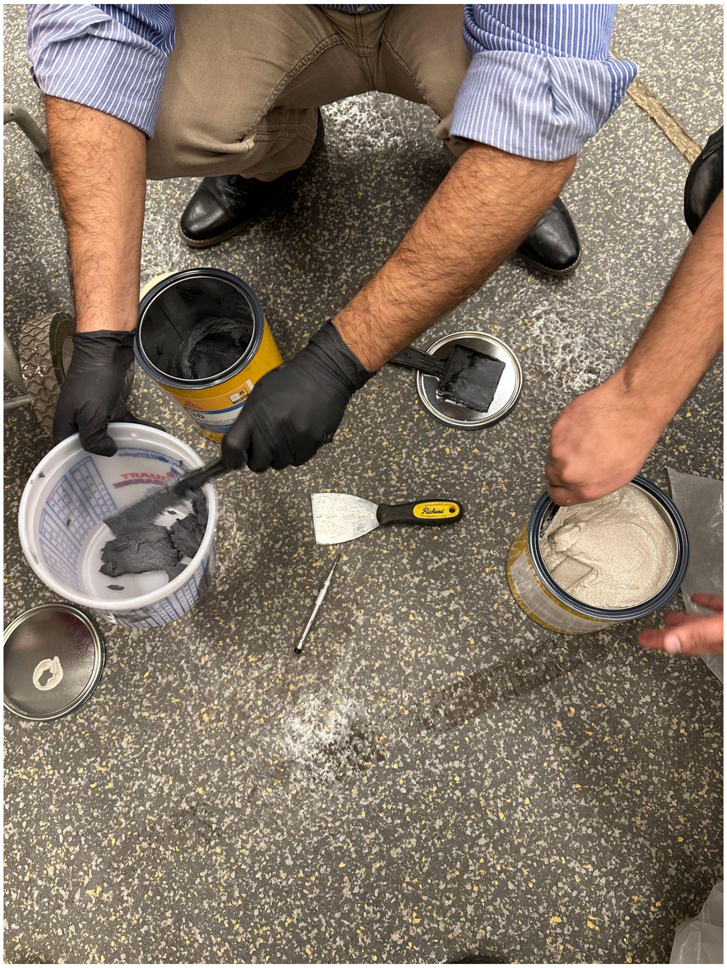
Rod spacing over diameter (S/D) ratio for diameter =2 mm, studying (S/D) = 3.2, 5.00, 8.33. Those respective ratios correspond to the number of rods = 7, 5, 3.

Specimen ID	# of repetitions	Varied parameters						
		D (mm)	L_b (mm)	S/D ratio	# of rods	B_f (mm)	B_f / B_s ratio	
1	3	2	75	3.2	7	50	1	
2	=	=	125	=	=	=	=	
3	=	=	175	=	=	=	=	
4	=	=	225	=	=	=	=	
5	=	4	75	2.4	2	19	0.38	
6	=	=	125	=	=	=	=	
7	=	=	175	=	=	=	=	
8	=	=	225	=	=	=	=	
9	=	2	175	5.00	5	50	1	
10	=	2	175	8.33	3	50	1	
11	=	2	175	3.2	2	12.5	0.25	
12	=	2	175	3.2	4	25.4	0.5	
13	=	4	175	2.4	4	38	0.76	
14*	=	NA	175	NA	NA	14.9	0.30	
15*	=		175	NA	NA	17	0.34	

Proper surface preparation of the steel substrate is critical to ensure a strong bond between the CRP composite and steel. Surface preparation typically involves cleaning the steel surface to remove any contaminants and roughening the surface to enhance adhesion. Studies have shown that the bond strength is significantly affected by the degree of surface roughness, with higher roughness resulting in a stronger bond.

Steel Specimen grinded for finish and is cleaned using Acetone

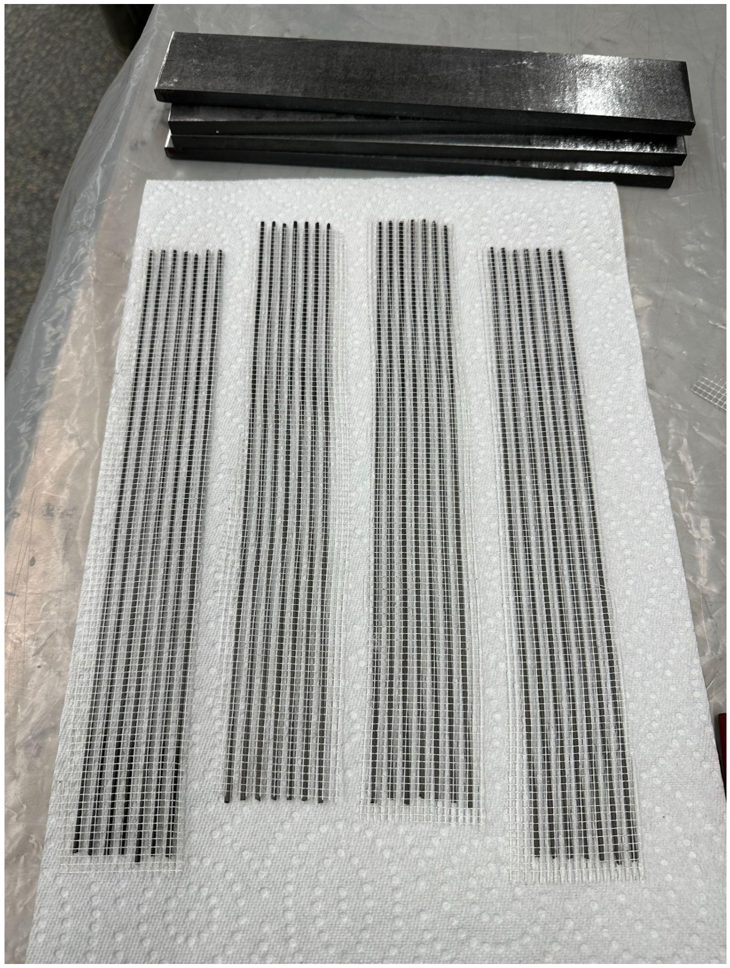
The type of adhesive used to bond the CRP composite to the steel substrate can also affect the bond strength and failure mode. Studies have shown that epoxy-based adhesives generally result in a stronger bond than other types of adhesives, such as polyester. We used Epoxy to bond the CRP to the steel specimen.



Mixing and preparation of epoxy

We used Fiber Adhesive in our study on the bond properties between carbon fiber reinforced polymer (CRP) and steel, we utilized a fiber adhesive to ensure that the CRP rods were equidistant from each other during the application of epoxy. This was essential to achieve a strong bond between the CRP and steel and ensure uniform distribution of the epoxy.

After applying the fiber adhesive, we allowed three to four days for the fiber adhesive to settle and harden, ensuring that the CRP rods remained equidistant from each other. This not only helped us achieve uniform distribution of the epoxy later but also facilitated a better bond between the CRP and steel, resulting in increased strength and durability.



Fiber Adhesive being used to place the CRP equidistantly

The use of fiber adhesive in combination with epoxy is a proven technique for achieving a strong bond between CRP and steel, as it helps to maintain uniform spacing between the CRP rods and ensures consistent application of the epoxy.

Applying a initial layer of Epoxy on the steel specimen

Initially, a layer of epoxy was applied on the steel specimen, which served as the base for placing the CRP on top. This layer of epoxy helped to strengthen the bond between the steel specimen and the epoxy.

Pacing the CRP on top of the layer of Epoxy

To further enhance the bond between the steel and CRP, another layer of epoxy was applied on top of the CRP. This facilitated a stronger bond, which was tested under tensile loading conditions to determine the bond strength and failure modes of the specimens.

Application of Epoxy on both sides of the CRP

The application of epoxy on both the steel specimen and CRP ensured a uniform distribution of the adhesive and created a strong bond between the two materials. The two layers of epoxy acted as a barrier against moisture and other environmental factors, preventing the bond from weakening over time.

Environmental factors, such as temperature and humidity, can also affect the bond strength between CRP and steel. High temperatures can soften the adhesive and reduce the bond strength, while high humidity can affect the cure rate of the adhesive and reduce the bond strength. Hence we made use of the controlled temperatures of Purdue University Design Studio and used plastic wrap insulators for protecting the bond against environmental factors at all times.

Results:

In preparation for testing the bond strength between the carbon fiber reinforced polymer (CRP) and the steel specimen, we used white and black spray paint to mark the bond along its length. The black spray paint was applied at an angle, as seen in the image below. This technique allowed us to measure the distance between each individual black spray paint after the test was recorded on a DSLR camera.

white and black spray paint to mark the bond along its length

The software then analyzed the distance change between the initial image captured on the camera and the image obtained after the bond failure occurred. This allowed us to determine the exact location and timing of the failure based on the changes in the distances between the black spray paint marks.

The testing procedure was conducted on the MTS machine, and the use of the DSLR camera and spray paint markings provided a precise and accurate method for measuring the bond failure. This technique can be applied in similar testing scenarios to accurately measure and analyze the failure modes of bonded materials.

Conclusion:

In this study, we assume that the carbon fiber reinforced polymer (CRP) specimen will be bonded, and as the length of the CRP specimen increases, the time taken for the MTS machine - used for the tensile strength test - to debond will increase.

The specimen with the CRP double bond will continue to withstand the tensile strength test until it reaches a point where an increase in the length of CRP will not affect the tensile force resistance. At this point, we will conclude the testing of CRP and plot the results to obtain the point on the graph at which maximum resistance is offered to the applied tensile strength test.

Furthermore, the test will reveal the ideal length of CRP that can be installed on the steel plates, which will offer the best resistance. This will provide economic benefits by reducing the amount of CRP used and minimizing wastage, making it more environmentally viable.

By determining the ideal length of CRP, this study will contribute to the optimization of the mechanical and physical properties of CRP and steel composites, which are commonly used in aerospace, automotive, and construction industries. This will ensure the safety and reliability of structures using these materials, making them suitable for a range of applications.

This study provides valuable insights into the bond properties between CRP and steel, which will help in the repair, design and analysis of structures using these materials. The results obtained from this study will be relevant to researchers, engineers, and designers working in the field of composite materials, and will have implications for the development of more efficient and cost-effective composite materials in the future.