ANALYSIS OF ADHESIVE BOUNDED STEEL CONCRETE STRUCTURE

A THESIS

Submitted in partial fulfilment of the requirement for the award of the degree of

MASTER OF TECHNOLOGY

In

CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

Under the supervision of

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STUDENT'S DECLARATION

I hereby declare that the work presented in the project report entitled **"ANALYSIS OF ADHESIVE BOUNDED STEEL CONCRETE STRUCTURE."** submitted in partial fulfillment of the requirements for the degree of Master of Technology in Structure Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Kaushal Kumar.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of this project report.

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CERTIFICATE

This is to certify that the work which is being presented in the thesis titled "Analysis Of Adhesive Bounded Steel Concrete Structure" in partial fulfilment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in "Structural Engineering" and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Wakhnaghat is an authentic record of work carried out by Sankar Nath Sarkar (225024005) during a period from August 2023 to June 2024 under the supervision of Kaushal Kumar, Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: - ………………………

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ABSTRACT

This study presents a comprehensive analysis of adhesive-bonded steel-concrete structures, focusing on the mechanical performance, durability, and failure mechanisms of the adhesive interfaces under various loading conditions. Adhesive bonding offers a promising alternative to traditional mechanical connections, providing enhanced stress distribution, reduced stress concentrations, and improved fatigue resistance. The research investigates different types of adhesives, including epoxy, polyurethane, and acrylics, assessing their bonding strength, flexibility, and environmental resistance. Experimental tests are conducted on composite specimens subjected to tensile, shear, and cyclic loads, complemented by finite element analysis to simulate stress distribution and predict failure modes. The results demonstrate that adhesive-bonded joints exhibit significant potential in improving the structural integrity and longevity of steel-concrete composites, with specific adhesives showing superior performance in terms of load-bearing capacity and durability under adverse environmental conditions. This analysis contributes to the optimization of adhesive selection and joint design, promoting the adoption of adhesive bonding in civil engineering applications for enhanced performance and sustainability

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CHAPTER 1
INTRODUCTION

1.1 General

Adhesive bonded steel-concrete structures represent a significant advancement in the field of civil engineering and construction technology. These structures integrate the high tensile strength of steel with the superior compressive strength of concrete through the use of advanced adhesive bonding techniques. This hybrid approach leverages the complementary properties of both materials to enhance overall structural performance, durability, and efficiency.

Traditionally, steel and concrete have been combined in construction through mechanical means, such as bolts, welding, or reinforcing bars embedded in concrete. However, these methods often come with challenges related to differential thermal expansion, potential corrosion at the interface, and complex construction processes. Adhesive bonding emerges as a modern alternative that addresses many of these issues by providing a continuous bond over the interface, which distributes stresses more evenly and reduces the likelihood of localized failure.

The use of adhesives in construction is not entirely new; however, their application in steel-concrete bonding has been gaining traction due to advancements in adhesive formulations and improved understanding of bond mechanics. These adhesives are typically high-performance polymers that offer excellent adhesion, durability, and resistance to environmental factors. They can be applied in various forms, including epoxies, polyurethanes, and methacrylates, each selected based on specific performance requirements of the project.

The potential benefits of adhesive bonded steel-concrete structures are numerous. They include enhanced load-bearing capacity, improved fatigue resistance, and reduced construction time and costs. Additionally, the use of adhesives allows for more innovative architectural designs and the construction of lighter, yet stronger, structures. This method also opens up new possibilities for retrofitting and reinforcing existing structures, providing a versatile solution for extending the life of aging infrastructure.

In conclusion, adhesive bonded steel-concrete structures represent a transformative approach in modern construction. By combining the strengths of steel and concrete through advanced adhesive technology, these structures offer promising improvements in performance, efficiency, and durability, making them a pivotal development in the quest for more resilient and sustainable built environments.

1.2 Some of the benefits of adhesive-bonded steel-concrete structures

Adhesive-bonded steel-concrete structures offer several notable benefits, contributing to their increasing popularity in modern construction and civil engineering. These benefits include:

A. Enhanced Structural Performance

Adhesive bonding creates a continuous and uniform connection between steel and concrete, leading to improved load distribution and stress transfer. This results in higher load-bearing capacities and greater overall structural integrity compared to traditional mechanical connections.

B. Improved Fatigue Resistance

The continuous bond provided by adhesives reduces stress concentrations at the interface, which are common in mechanically connected structures. This leads to enhanced fatigue resistance, extending the lifespan of the structure under cyclic loading conditions.

C. Corrosion Resistance

Adhesive layers can act as a barrier to moisture and other corrosive agents, protecting the steel components from rust and corrosion. This increases the durability and longevity of the structure, particularly in harsh environmental conditions.

D. Reduced Construction Time and Costs

The use of adhesives can simplify and speed up the construction process by eliminating the need for complex mechanical fasteners or welding. This can lead to significant time and labor savings, as well as reduced overall construction costs.

E. Versatility in Design

Adhesive bonding allows for more flexible and innovative architectural designs. It enables the construction of lighter, more aesthetically pleasing structures without compromising strength or stability. This flexibility is particularly advantageous in applications requiring unique shapes or configurations.

F. Simplified Retrofitting and Strengthening

Adhesive bonding is highly effective in retrofitting and reinforcing existing structures. It allows for the addition of new elements or the strengthening of existing components without extensive modifications or disruptions, making it a cost-effective solution for infrastructure upgrades.

G. Enhanced Seismic Performance

The improved load transfer and uniform stress distribution provided by adhesive bonds contribute to better seismic performance. Structures bonded with adhesives can better withstand earthquake forces, reducing the risk of catastrophic failure during seismic events.

H. Thermal Compatibility

Adhesives can accommodate differential thermal expansion between steel and concrete, reducing the risk of stress buildup and potential damage due to temperature variations. This thermal compatibility ensures the long-term stability of the bonded interface.

I. Environmental Benefits

The reduction in the need for mechanical fasteners and welding can lead to less energy consumption and fewer emissions during construction. Additionally, the extended lifespan and reduced maintenance requirements of adhesive-bonded structures contribute to sustainability by decreasing the need for frequent repairs and replacements.

In summary, adhesive-bonded steel-concrete structures offer a range of benefits that enhance structural performance, durability, and efficiency. These advantages make them an attractive option for a wide variety of construction applications, from new builds to the retrofitting and reinforcement of existing structures.

1.3 COMPOSITE MEMBERS

Composite members in construction refer to structural elements that are made by combining two or more distinct materials to form a single unit that leverages the benefits of each material. The primary objective of using composite members is to enhance the performance characteristics of the structure by taking advantage of the complementary properties of the materials involved.

Key Characteristics of Composite Members:

Combination of Materials:

Composite members typically involve materials such as steel, concrete, timber, or fiber-reinforced polymers. Each material contributes its own unique strengths, such as steel's tensile strength and concrete's compressive strength.

Enhanced Performance:

The combination of materials results in a member that is often stronger, lighter, more durable, and more efficient than if the materials were used separately. For example, in steel-concrete composite beams, the steel provides tensile strength while the concrete handles compressive loads.

Synergy:

Composite action between the materials is crucial, meaning they work together in such a way that their combined performance exceeds that of the individual components acting alone.

Types of Composite Members:

Steel-Concrete Composite Members: These include composite beams, columns, and slabs where steel sections and concrete are combined. Examples include steel beams encased in concrete or concrete slabs connected to steel beams with shear connectors.

Timber-Concrete Composite Members:

These members combine timber and concrete to enhance the stiffness and load-bearing capacity of structures like floors and bridges, leveraging timber's light weight and concrete's strength.

Fiber-Reinforced Polymer (FRP) Composites:

FRPs are used to strengthen concrete structures or create new structural elements, providing high strength-to-weight ratios and corrosion resistance.

Benefits of Composite Members:

Increased Load-Bearing Capacity:

The combined materials often provide a higher load-bearing capacity than the individual materials.

Improved Stiffness and Stability:

Composite members can exhibit increased stiffness and stability, reducing deflections and vibrations.

Efficiency in Material Use:

By optimizing the use of materials, composite members can lead to more efficient and economical structural solutions.

Durability:

The combination can improve the durability of the structure, with materials protecting each other from environmental factors.

Construction Speed:

Composite construction can simplify and speed up the building process, as pre-fabricated components can be quickly assembled on site.

Applications of Composite Members:

Composite members are widely used in various types of construction, including:

Buildings:

Floors, beams, and columns in high-rise buildings.

Bridges:

Decks and girders in bridge construction.

Infrastructure:

Retrofitting and strengthening of existing structures such as tunnels and retaining walls.

Marine Structures: Piers, docks, and offshore platforms where corrosion resistance is crucial.

In summary, composite members represent a crucial advancement in structural engineering, allowing for the creation of more efficient, durable, and versatile structures by combining the best properties of different materials.

1.4 COMPOSIT MEMBERS: CONNECTION BETWEEN STEEL CONCRETE STRUCTURE

Composite members, specifically those that connect steel and concrete, represent a crucial innovation in structural engineering. This combination leverages the high tensile strength of steel and the superior compressive strength of concrete to create elements that perform better than the sum of their parts. Understanding how these materials are connected and work together is key to appreciating their benefits.

Mechanisms of Connection between Steel and Concrete:

1.Mechanical Connectors:

1.1 Shear Studs: These are small, steel elements welded to the steel beam or plate and embedded in the concrete. They ensure that the steel and concrete act together by transferring shear forces between them, preventing slip and ensuring composite action.
1.2 Bolts and Anchors: Bolts or other types of mechanical fasteners can be used to physically tie the steel and concrete together, often used in retrofit applications or precast concrete elements.

2. Adhesive Bonding:

2.1 Epoxies and Resins: High-performance adhesives can bond steel and concrete surfaces together. These adhesives fill any gaps and create a continuous bond that can transfer stresses efficiently across the interface.

3. Frictional Forces:

3.1 Preloading: In some composite structures, preloading techniques are used to enhance frictional forces at the interface between steel and concrete. This is typically achieved by tightening bolts or applying external forces during construction.

Types of Steel-Concrete Composite Members:

1. Composite Beams:

1.1 These beams consist of a steel beam and a concrete slab connected by shear connectors. The concrete slab provides compression strength while the steel beam provides tensile strength and stiffness, resulting in a highly efficient structural member.

2. Composite Columns:

2.1 Composite columns can be formed by encasing a steel section within a concrete column. This improves the load-bearing capacity and fire resistance of the column, as the concrete protects the steel from high temperatures.

3. **Composite Slabs:**

3.1 In composite slabs, a concrete topping is poured over a profiled steel decking. The decking serves as formwork during construction and acts as reinforcement after the concrete has cured, providing a strong and lightweight floor system.

Benefits of Composite Members:

1. Increased Load Capacity:

1.1 By combining the strengths of steel and concrete, composite members can support higher loads than their non-composite counterparts.

2. Enhanced Stiffness and Stability:

2.1 The synergy between steel and concrete in composite members results in increased stiffness and stability, reducing deflections and vibrations under load.

3. Improved Structural Efficiency:

3.1 Composite construction allows for more efficient use of materials, optimizing the structural performance while potentially reducing the amount of material required.

4. Durability and Fire Resistance:

4.1 Concrete encasement provides additional protection to steel components from environmental factors and fire, enhancing the durability and safety of the structure.

5. Construction Speed and Flexibility:

5.1 Composite members can be prefabricated and quickly assembled on-site, accelerating construction timelines and allowing for greater flexibility in design and execution.

Applications of Composite Members:

Building Construction: Composite beams, columns, and slabs are widely used in high-rise buildings, commercial structures, and residential complexes to provide efficient and robust load-bearing elements.

Bridge Construction: Composite girders and decks are common in bridge design, offering improved load capacity and resilience.

Infrastructure Projects: Composite members are utilized in tunnels, retaining walls, and other civil engineering projects where enhanced performance and durability are required.

In summary, the connection between steel and concrete in composite members is achieved through various mechanisms, including mechanical connectors, adhesive bonding, and frictional forces. These composite members offer numerous benefits, such as increased load capacity, improved stiffness, and enhanced durability, making them an essential component of modern structural engineering.

CHAPTER 2

LITRECHERE REVIEW

Adhesive-bonded steel-concrete structures utilize adhesives to bond steel components with concrete. This approach leverages the strengths of both materials, offering unique advantages and applications in construction. Here are some key points about adhesive-bonded steel-concrete structures:

2.a Enhanced Load Distribution:

The adhesive layer helps in uniformly distributing the load between the steel and concrete, reducing stress concentrations and improving overall structural integrity.

2.b Improved Durability:

Adhesives can provide a protective barrier against environmental factors, enhancing the durability and lifespan of the structure by preventing corrosion and other forms of degradation.

2.c Reduced Construction Time:

Using adhesives can simplify the construction process, reducing the need for extensive welding or mechanical fastenings. This can lead to faster assembly and potentially lower labor costs.

2,d Flexibility in Design:

Adhesive bonding allows for more flexible design options, enabling the use of complex shapes and configurations that might be challenging with traditional mechanical joining methods.

2.e Cost Efficiency:

While high-performance adhesives might have a higher initial cost, the reduction in labor, maintenance, and potential for lighter-weight structures can result in overall cost savings.

2.f Seismic Performance:

Adhesive-bonded joints can offer improved performance under seismic loading due to their ability to dissipate energy and accommodate movements without significant loss of bond strength.

2.g Thermal Compatibility:

Adhesives can help mitigate thermal expansion mismatches between steel and concrete, reducing the risk of cracking or other damage caused by temperature variations.

2.h Enhanced Aesthetics:

The use of adhesives can eliminate the need for visible bolts or welds, resulting in a cleaner and more aesthetically pleasing finish for exposed structural elements.

2.i Maintenance and Repair:

Adhesive-bonded structures can be easier to repair since damaged areas can often be rebounded without the need for extensive deconstruction.

2.j Application Areas:

Common applications include bridge construction, prefabricated building components, façade systems, and retrofitting or strengthening existing structures.

2.k Adhesive Selection:

The choice of adhesive is critical and depends on factors such as load conditions, environmental exposure, and the specific materials being bonded. Epoxy resins are commonly used due to their strong bonding capabilities and resistance to environmental factors.

2.l Bonding Surface Preparation:

Proper surface preparation is essential to achieve optimal adhesive performance. This typically involves cleaning, roughening, and sometimes applying primers to the surfaces to be bonded.

2.m Regulatory and Testing Standards:

Adhesive-bonded steel-concrete structures must comply with relevant building codes and standards. Extensive testing is usually required to ensure the reliability and safety of the bonded joints.

2.n Environmental Impact:

The use of adhesives can have environmental benefits, such as reducing the need for heavy construction machinery and lowering the carbon footprint associated with manufacturing and transporting mechanical fasteners.

By combining the strengths of steel and concrete through adhesive bonding, these structures offer innovative solutions that can meet the demands of modern construction projects

2.1 Literature Survey

The following presents a thorough review of significant research findings and ideas from numerous key studies, each presenting distinct views on Analysis on Adhesive Bounded Steel Concrete Structure

The study by **Ren, Sneed, Gai, and colleagues, published in the "International Journal of Concrete Structures and Materials" on March 7, 2015**, investigates the effectiveness of using bonded steel plates to strengthen reinforced concrete (RC) T-beams, commonly used in structures like bridges and buildings. By attaching steel plates with high-strength adhesives and subjecting the beams to various loading conditions, the research demonstrated significant improvements in load-bearing capacity and ductility, enabling the beams to withstand higher loads and larger deformations before failure. Experimental testing and nonlinear finite element analysis revealed that the strengthened beams typically failed due to debonding or yielding of the steel rather than concrete cracking. These findings suggest that bonded steel plates are an effective, cost-efficient method for retrofitting and rehabilitating RC structures, with practical implications for design guidelines and future research on long-term and cyclic loading performance

Yangjun Luo, Alex Le, and Zhan Kang's study titled "Parametric study of bonded steel–concrete composite beams by using finite element analysis," published in January 2012 in Engineering Structures, investigates the behavior of steel–concrete composite beams. The research focuses on analyzing these beams through finite element analysis (FEA) to understand the influence of various parameters on their structural performance. Key parameters explored include the bond strength between steel and concrete, the material properties of the components, and the geometric characteristics of the beams. The study provides valuable insights into optimizing the design and enhancing the performance of steel–concrete composite structures.

The study by Zheng, X., Li, W., Huang, Q., et al., titled "Finite Element Modeling of Steel-concrete Composite Beams with Adhesive Bonding," published on January 20, 2021, in the International Journal of Steel Structures, explores the application of finite element modeling (FEM) to steel-concrete composite beams that utilize adhesive bonding. The research aims to evaluate the structural behavior and performance of these composite beams under various loading conditions. Through detailed FEM analysis, the study examines the effects of adhesive properties, bonding quality, and other critical factors on the strength, stability, and overall performance of the beams. The findings contribute to a better understanding of adhesive-bonded composite beams and offer guidance for improving their design and application in construction

The paper **by Yvonne Ciupack, Hartmut Pasternak, Christoph Mette, and Elisabeth Stammen, titled "Adhesive bonding in steel construction," published in December 2017 in Procedia Engineering (Vol. 172, pp. 186-193)**, explores the application of adhesive bonding in steel construction. The study investigates the potential benefits and challenges of using adhesives as an alternative to traditional mechanical fastening methods such as welding and bolting. The authors analyze various adhesive materials, bonding techniques, and their impact on the structural integrity and performance of steel components. The research highlights the advantages of adhesive bonding, including improved stress distribution, reduction in weight, and ease of assembly, while also addressing concerns related to durability, environmental effects, and long-term performance. The study provides valuable insights and recommendations for the practical application of adhesive bonding in steel construction, aiming to enhance efficiency and innovation in the field.

The study by **B. B. Adhikary and H. Mutsuyoshi, titled "Numerical simulation of steel-plate strengthened concrete beam by a non-linear finite element method model," published in 2002 in Construction and Building Materials (Vol. 16, Issue 5, pp. 291–301)**, focuses on the numerical simulation of concrete beams strengthened with steel plates using a non-linear finite element method (FEM). The research aims to assess the effectiveness of steel plates in enhancing the structural performance of concrete beams. By employing a non-linear FEM model, the study examines the stress distribution, load-carrying capacity, and failure mechanisms of the strengthened beams. The findings demonstrate the potential of steel-plate strengthening to significantly improve the flexural strength and ductility of concrete beams, providing valuable insights for the design and implementation of such reinforcement techniques in construction practices.

The study by **U. Cicekli, G. Z. Voyiadjis, and R. K. Abu Al-Rub, titled "A plasticity and anisotropic damage model for plain concrete," published in 2007 in the International Journal of Plasticity (Vol. 23, Issue 10, pp. 1874–1900)**, presents a comprehensive model to describe the behavior of plain concrete under various loading conditions. The authors develop a plasticity and anisotropic damage model that accounts for the material's inherent anisotropy and the progressive damage due to loading. The model integrates both plastic deformation and damage evolution, offering a detailed understanding of concrete's response, including its failure mechanisms. Through numerical simulations and comparisons with experimental data, the study validates the model's accuracy in predicting the complex behavior of concrete. This research provides significant contributions to the field of material modeling, with implications for the design and analysis of concrete structures.

The study by **Q. Fang, Y. Huan, Y. D. Zhang, and L. Chen, titled "Investigation into static properties of damaged plasticity model for concrete in ABAQUS," published in 2007 in the Journal of PLA University of Science and Technology (Natural Science Edition) (Vol. 3, p. 010)**, examines the static properties of concrete using the damaged plasticity model implemented in the finite element software ABAQUS. The research focuses on understanding how this model represents the behavior of concrete under static loading conditions, particularly in terms of damage and plasticity. Through numerical simulations, the study evaluates the model's ability to predict the material's response, including stress-strain relationships, cracking, and failure mechanisms. The findings provide insights into the applicability and accuracy of the damaged plasticity model in ABAQUS for analyzing concrete structures, contributing to more reliable and effective structural analysis and design.

The paper by **J. Lee and G. L. Fenves, titled "Plastic-damage model for cyclic loading of concrete structures," published in 1998 in the Journal of Engineering Mechanics (Vol. 124, Issue 8, pp. 892–900)**, introduces a plastic-damage model tailored for analyzing concrete structures subjected to cyclic loading. The model combines plasticity and damage mechanics to capture the degradation of concrete stiffness and strength under repeated loading and unloading cycles. It accounts for both the accumulation of irreversible deformations and the progressive damage due to cyclic stresses. Through numerical simulations and validation against experimental data, the study demonstrates the model's effectiveness in predicting the cyclic behavior of concrete structures, including phenomena such as hysteresis and stiffness degradation. This research provides valuable tools for the analysis and design of concrete structures exposed to dynamic loading conditions, such as seismic events.

2.2 SUMMARY

Adhesive bonded steel-concrete structures involve the use of adhesives to join steel and concrete components, offering an alternative to traditional mechanical fastening methods such as welding and bolting. This technique enhances structural performance by providing improved stress distribution, reducing weight, and simplifying assembly processes. Adhesive bonding can also enhance the aesthetic appeal of structures by eliminating visible fasteners and welds. Research in this area focuses on understanding the properties of various adhesives, the quality of the bond, and the long-term durability and performance under different environmental conditions. These studies aim to optimize adhesive formulations and bonding techniques to ensure the reliability and safety of bonded steel-concrete structures in construction

2.3 RESEARCH GAPS

2.3.1 Long-term Durability:

Limited studies on the long-term performance of adhesive bonds under various environmental conditions (e.g., moisture, temperature changes, UV exposure).

2.3.2 Creep and Fatigue Behavior:

Insufficient understanding of how adhesive bonds behave under sustained loads (creep) and repeated loading (fatigue).

2.3.3 Adhesive Material Properties:

Need for more comprehensive data on the mechanical and chemical properties of different adhesives used in bonding steel and concrete.

2.3.4 Bonding Techniques:

Optimization of surface preparation techniques to enhance bond strength and durability.

2.3.5 Failure Mechanisms:

More research needed on the modes of failure and crack propagation in adhesive bonds under various loading conditions.

2.3.6 Modeling and Simulation:

Development of more accurate and reliable computational models to predict the behavior of adhesive bonds in steel-concrete structures.

2.3.7 Quality Control and Testing:

Establishment of standardized testing methods for assessing the quality and performance of adhesive bonds in structural applications.

2.3.8 Compatibility with Construction Practices:

Investigations into the practical challenges and solutions for integrating adhesive bonding into conventional construction workflows.

2.3.9 Environmental Impact and Sustainability:

Analysis of the environmental impact of using adhesives, including their production, application, and end-of-life disposal.

2.3.10 Structural Health Monitoring:

Development of techniques for real-time monitoring and assessment of the integrity of adhesive bonds in existing structures.

2.3.11 Adhesive Bond Behavior in Hybrid Structures:

Research on how adhesive bonds perform in hybrid structures that incorporate both bonded and mechanically fastened components.

2.3.12 Cost-Benefit Analysis:

Comprehensive studies evaluating the cost-effectiveness of adhesive bonding compared to traditional methods over the lifecycle of a structure

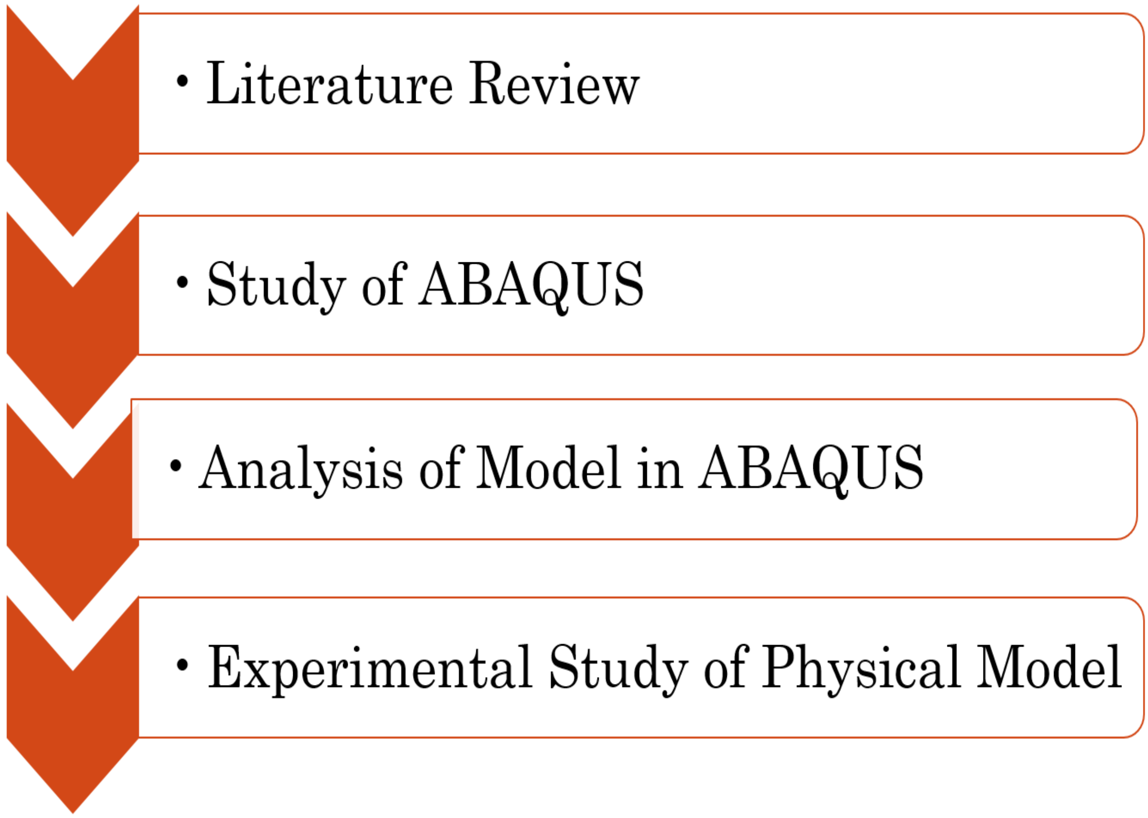
2.4 RESEARCH OBJECTIVES

- **Optimization of Adhesive Formulations**: Develop adhesive formulations that maximize bond strength, durability, and compatibility with steel and concrete materials.
- **Long-Term Durability Assessment**: Investigate the long-term durability of adhesive bonds in steel-concrete structures, considering factors like environmental exposure, temperature fluctuations, and moisture.
- **Development of Design Guidelines**: Create design guidelines and standards specific to adhesive-bonded steel-concrete structures, ensuring safe and reliable construction.

CHAPTER 3

METHODOLOGY

The methodology for developing and studying adhesive bonded steel-concrete structures involves several key steps, ranging from material selection to testing and analysis. Below is a comprehensive methodology outline:



3.1 SOME PROBLEMS OF ADHESIVE BOUNDED STEEL CONCRETE STRUCTURE

Bond Strength: The bond between the steel and concrete may not achieve the desired strength, leading to potential failure under load. Factors such as surface preparation, adhesive selection, curing conditions, and environmental exposure can influence bond strength.

Durability Issues: Adhesive bonding may be susceptible to degradation over time due to environmental factors such as moisture, temperature variations, chemical exposure, and UV radiation. Degradation of the bond can compromise the structural integrity of the system.

Surface Preparation: Proper surface preparation is crucial for achieving a strong bond between steel and concrete. If surfaces are not adequately cleaned, roughened, or primed before application of the adhesive, it can lead to poor adhesion and subsequent failure

3.2 ANNALISYS ON ABAQUS

Analyzing an adhesive bonded steel-concrete structure in ABAQUS software typically involves several steps. Here's a general outline of the process:

BV Model Geometry Creation:

Create the geometry of the steel and concrete components using appropriate modeling techniques in ABAQUS.

Define the interface region where the adhesive will be applied between the steel and concrete surfaces.

Mesh Generation:

Generate finite element meshes for the steel, concrete, and adhesive regions using appropriate meshing techniques.
Ensure that the mesh is sufficiently refined in critical areas where stress concentrations or interface interactions are expected.

Material Properties Assignment:

Define material properties for the steel, concrete, and adhesive materials.
Specify the mechanical properties such as elastic modulus, Poisson's ratio, density, and any nonlinear material behavior.

Boundary Conditions:

Apply boundary conditions to simulate the loading and support conditions of the structure.
Define constraints, displacements, or applied loads to represent the real-world loading conditions accurately.

Contact and Interaction Definition:

Define contact interactions between the steel and concrete surfaces and between the adhesive and the steel/concrete surfaces.
Specify the contact behavior, such as friction coefficients and adhesive properties, to accurately model the bonding behavior.

Analysis Setup:

Define the analysis type (e.g., static analysis, dynamic analysis, etc.).
Specify solution controls, such as time increments, convergence criteria, and output requests.

Solution:

Run the analysis in ABAQUS to solve for the structural response of the bonded system.
Monitor convergence and check for any warning messages or errors during the solution process.

Post-Processing:

Evaluate and visualize the results using ABAQUS post-processing tools.
Examine key output quantities such as stresses, strains, displacements, and contact forces to assess the performance of the structure.
Identify any areas of concern, such as regions of high stress or potential bond failure.

Validation and Interpretation:

Compare the analysis results with experimental data or analytical predictions to validate the model.
Interpret the results to gain insights into the behavior of the adhesive bonded steel-concrete structure under different loading conditions.
Identify any design improvements or modifications based on the analysis findings.

3.2 EXPERIMENTAL STUDY

Test Setup Preparation:

Prepare the test specimens consisting of steel and concrete adherends bonded together with the adhesive.
Ensure that the specimens are properly fabricated according to the required dimensions and specifications for the pushout test.

Instrumentation:

Install strain gauges or displacement transducers at strategic locations on the test specimens to measure deformations and displacements during the test.
Connect the instrumentation to data acquisition equipment to record the test data accurately.

Test Configuration:

Set up the testing apparatus, which typically includes a loading frame equipped with hydraulic or mechanical actuators capable of applying vertical loads.
Align the test specimen within the loading frame and ensure proper alignment and contact between the specimen and loading platens.

Preparation for Testing:

Apply any preloading or conditioning cycles to the test specimen to ensure proper seating and initial contact between the adherends and adhesive.
Allow sufficient time for the adhesive to cure or set according to the manufacturer's recommendations before conducting the pushout test.

Test Execution:

Gradually apply a vertical load to the test specimen using the loading frame while continuously monitoring the applied load and displacements.
Apply the load at a constant rate or follow a predefined loading protocol to ensure consistency and reproducibility of the test results.
Record the load-displacement response of the specimen until failure occurs, typically characterized by debonding or rupture of the adhesive interface.

Data Acquisition:

Collect data from the instrumentation system throughout the duration of the test, including load

versus displacement curves and any other relevant parameters.
Ensure that the data acquisition system is calibrated and functioning properly to capture accurate measurements during the test.

Post-Test Analysis:

Analyze the recorded data to determine the peak load at failure and corresponding displacement.
Calculate the adhesive shear strength using the maximum applied load and the bonded area of the specimen.
Evaluate the failure mode observed during the test (e.g., adhesive failure, cohesive failure, or mixed-mode failure) based on visual inspection and analysis of the test specimen

CHAPTER 4

ANNALISYS ON ABAQUS

4.1 GENERAL

Analyzing adhesive bonded steel-concrete structures in ABAQUS involves creating a detailed finite element model encompassing the steel, concrete, and adhesive layers, with assigned material properties reflecting elasticity, strength, and bonding characteristics. Boundary conditions are then applied to mimic real-world loading scenarios, while contact interactions account for adhesive bonding and potential separation at the interface. Running simulations allows prediction of structural responses, with post-processing revealing key parameters such as stresses, strains, displacements, and contact forces. This thorough analysis assesses factors like bond strength, durability, and structural stability, guiding engineers in refining models and parameters for optimal design and performance, ensuring safety and reliability in practical applications

4.2 BV MODEL GEOMETRY CREATION

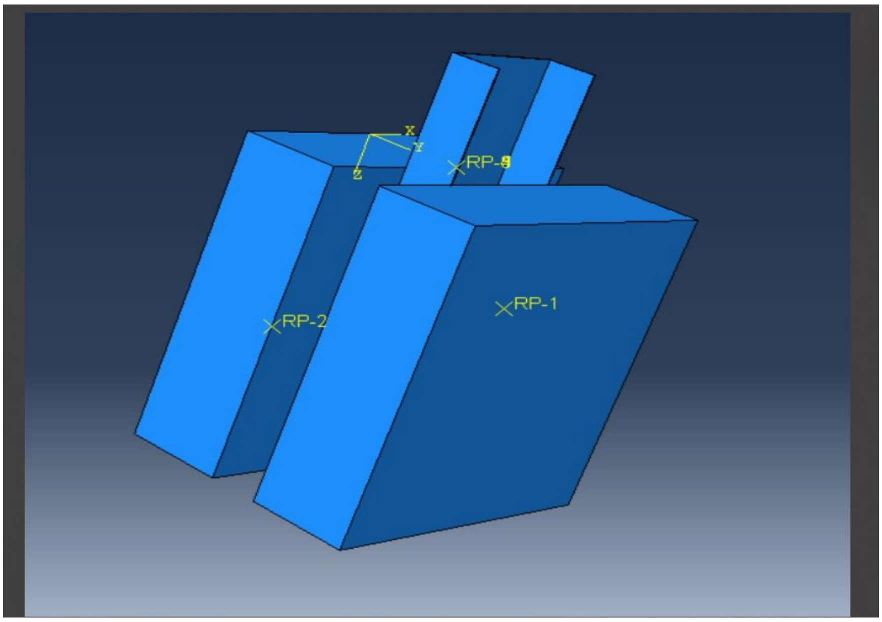


FIG 1

4.3 MESH GENERATION

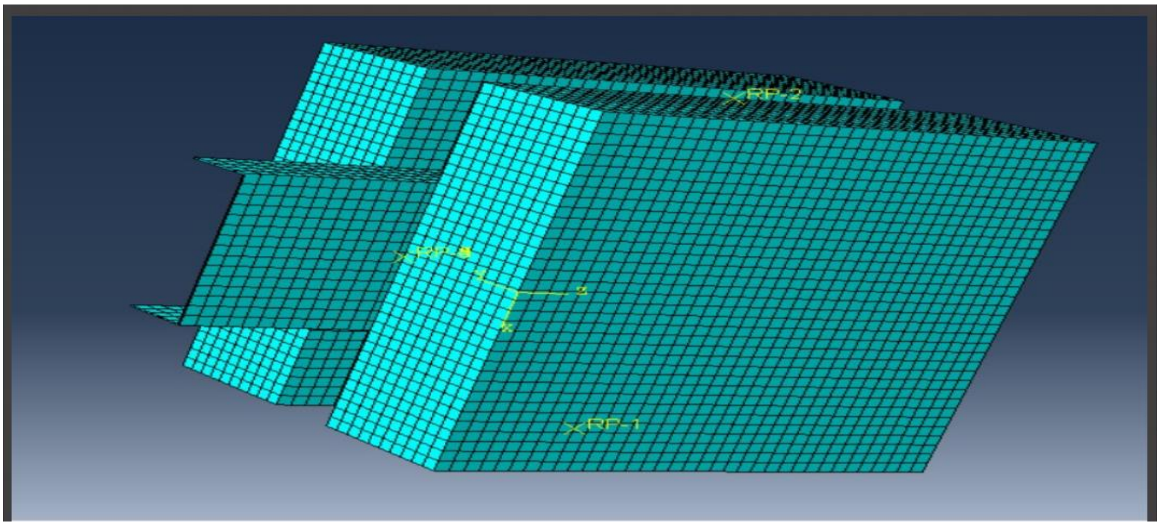


FIG 2

4.4 METERIAL PROPERTIES ASSIGNMENT:

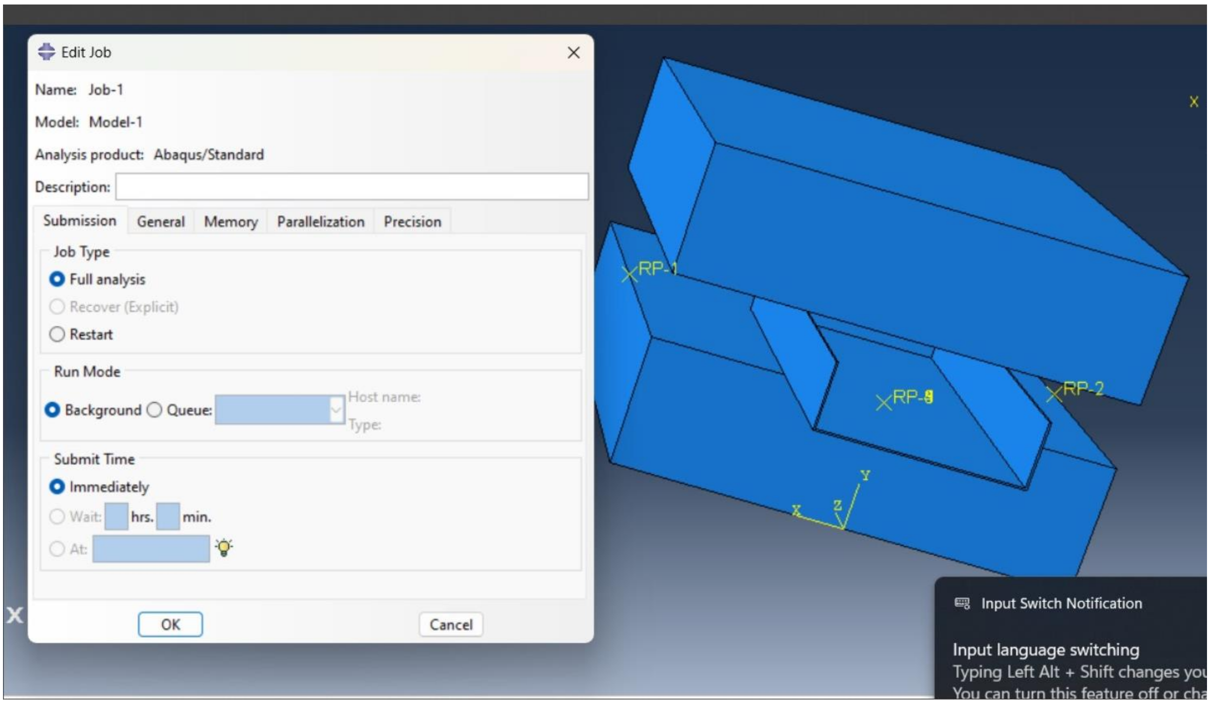


FIG 3

4.5 BOUNDARY CONDITIONS:

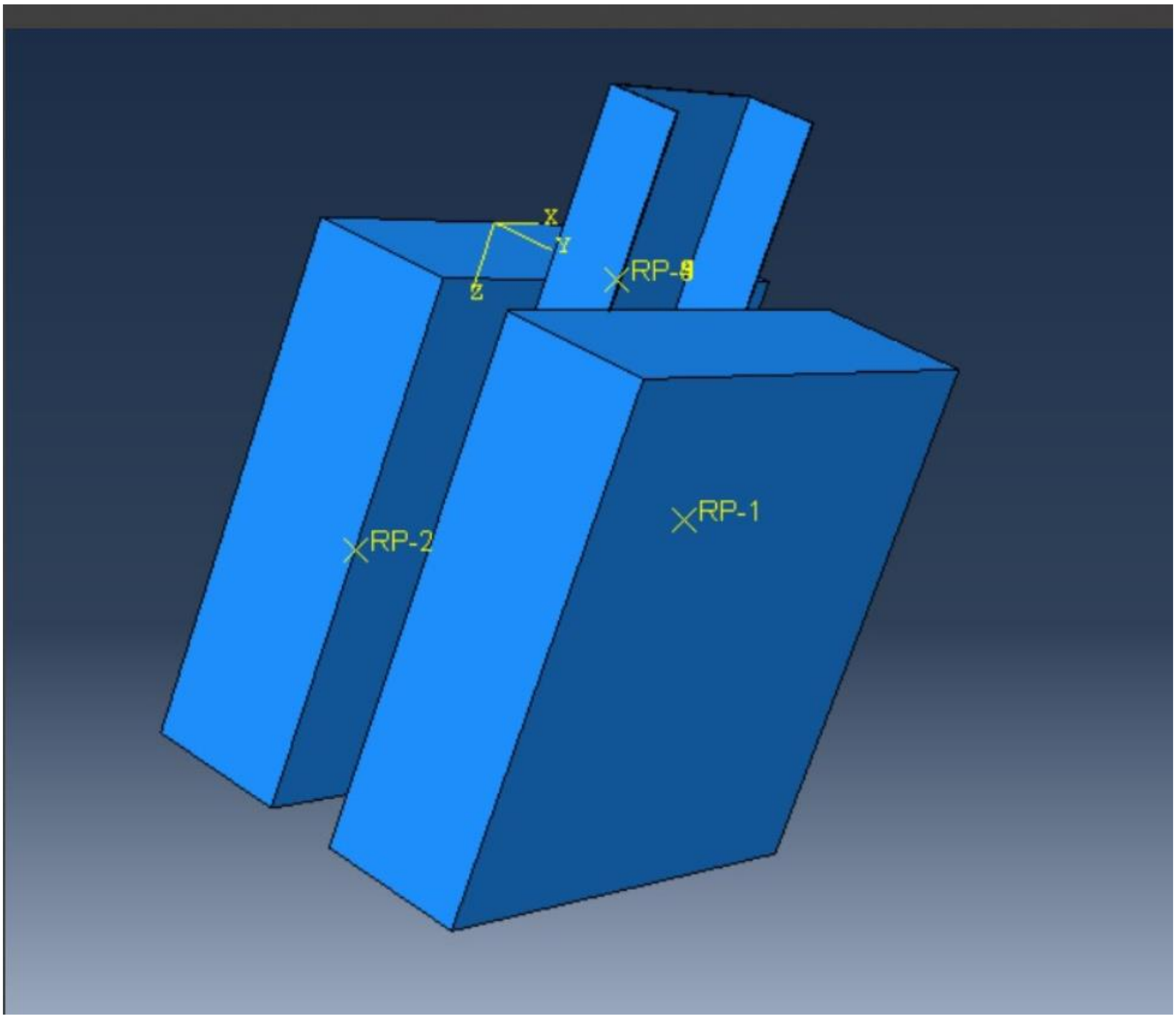


FIG 4

CHAPTER 5

EXPERIMENTAL WORK

5.1 GENERAL

The vertical pushout test is an experimental method used to evaluate the shear performance and bond strength of adhesive-bonded interfaces in steel-concrete composite structures. This test simulates the conditions that these structures may encounter in real-life applications, providing valuable data on the mechanical behavior and failure mechanisms of the adhesive joints.

5.2 MIX DESIGN OF M35 GRADE CONCRETE

Depth = 10cm

Length and Breath = 35cm.

Volume = Length x Breadth x Depth

Volume = 35 cm x 35 cm x 10 cm

Volume = 12,250 cubic centimeters (cc) or 0.01225 cubic meters (m^3)

For M35 grade concrete, used mix ratio by weight is 1:1.63:2.82 for

cement : sand : coarse aggregates.

Cement Content ≈ 0.00164 cubic meters (2.366 kg of cement)

Sand Content ≈ 0.00267 cubic meters (4.272 kg of sand)

Coarse Aggregate Content ≈ 0.00494 cubic meters (7.904 kg of coarse aggregates)

5.3 Objectives:

The primary objectives of conducting the vertical pushout test are:

To determine the shear capacity of the adhesive bond between the steel and concrete components.
To analyze the failure modes of the adhesive bond under vertical loading.
To assess the influence of different types of adhesives on the bond strength and performance.
To provide empirical data for validating finite element models and improving the design of adhesive-bonded joints.

Materials and Specimens

The test specimens typically consist of:

Steel plates or sections that are adhesively bonded to concrete blocks or slabs.
Various adhesives such as epoxy, polyurethane, or acrylics, selected based on their mechanical properties and compatibility with both steel and concrete.

Test Setup

Specimen Preparation: The steel and concrete components are prepared by cleaning and roughening the bonding surfaces to enhance adhesive bonding. The adhesive is then applied, and the components are joined and allowed to cure under controlled conditions.

Test Rig: The vertical pushout test is conducted using a hydraulic testing machine equipped with load cells to accurately measure the applied load. The test rig is designed to apply vertical loads to the steel component, pushing it through the concrete block.

Instrumentation: Strain gauges and displacement transducers are installed on the specimen to measure the strain and displacement during the test. This instrumentation helps in understanding the deformation behavior and identifying the onset of failure.

Test Procedure

Loading: The specimen is positioned in the testing machine, and a vertical load is applied at a controlled rate. The load is gradually increased until failure occurs.

Data Collection: Throughout the test, data on the applied load, displacement, and strain are continuously recorded. This data is used to plot load-displacement curves, which provide insights into the shear behavior and stiffness of the adhesive bond.

Observation of Failure Modes: The test is continued until the adhesive bond fails. The failure modes are observed and documented, which could include adhesive failure, cohesive failure within the adhesive, or failure at the adhesive-substrate interface

CHAPTER 6

RESULT AND DISCUSSIONS

6.1 GENERAL

The collected data is analyzed to determine the shear strength of the adhesive bond. Key parameters such as the maximum load, bond strength, and displacement at failure are extracted from the load-displacement curves. Comparative analysis is performed to evaluate the performance of different adhesives and identify the factors influencing bond strength and failure mechanisms.

6.2 RESULTS

Adhesive Thickness (ta) (mm)	Applied Load (Exp.) (Pu) (kN)	Applied Load (FE) (Pu) (kN)	Difference in Applied Load (%)	Ultimate Slip (Exp.) (su) (μm)	Ultimate Slip (FE) (su) (μm)	Difference in Ultimate Slip (%)
1.00	165.88	153.45	7.49	20.5	21.94	7.02
2.00	173.99	164.11	5.63	26.0	26.47	1.81
3.00	194.33	182.07	6.29	33.0	32.90	0.30

The results of the experimental and finite element (FE) analysis for adhesive-bonded steel-concrete structures with varying adhesive thicknesses are summarized in the table above. The analysis focuses on the applied load and ultimate slip, comparing experimental data with finite element simulations.

For an adhesive thickness of 1.00 mm, the experimental load capacity was recorded at 165.88 kN, whereas the FE model predicted a load of 153.45 kN. This corresponds to a difference of 7.49%, indicating a reasonably close correlation, though the FE model slightly underpredicts the load. In terms of ultimate slip, the experimental measurement was 20.5 µm, while the FE simulation showed 21.94 µm, resulting in a 7.02% difference, suggesting the FE model's prediction of slip is slightly higher than the experimental observation.

When the adhesive thickness was increased to 2.00 mm, the experimental load capacity rose to 173.99 kN, with the FE model predicting a slightly lower load of 164.11 kN. The difference here was 5.63%, showing improved agreement between the experimental and FE results compared to the 1.00 mm adhesive thickness. The ultimate slip for this thickness was 26.0 µm experimentally and 26.47 µm in the FE model, yielding a minimal difference of 1.81%. This indicates a very close match between the experimental and FE results for this adhesive thickness.

For the adhesive thickness of 3.00 mm, the experimental load capacity was 194.33 kN, while the FE model predicted 182.07 kN, resulting in a difference of 6.29%, which is slightly higher than the 2.00 mm thickness but still within an acceptable range. The ultimate slip was recorded at 33.0 µm experimentally and 32.90 µm in the FE model, with a difference of only 0.30%, demonstrating excellent agreement between the experimental and FE data.

The analysis reveals that the adhesive thickness significantly impacts both the applied load and the ultimate slip of adhesive-bonded steel-concrete structures. As the adhesive thickness increases from 1.00 mm to 3.00 mm, the applied load capacity also increases. The finite element model provides a reasonably accurate prediction of the experimental results, with differences in applied load ranging from 5.63% to 7.49% and in ultimate slip from 0.30% to 7.02%. The best correlation between experimental and FE results is observed for the 2.00 mm and 3.00 mm adhesive thicknesses, with the smallest differences in both applied load and ultimate slip. This suggests that the FE model is particularly effective in predicting the behavior of adhesive bonds with these thicknesses.

Overall, the findings validate the use of finite element analysis as a reliable tool for predicting the performance of adhesive-bonded steel-concrete structures, aiding in the optimization of adhesive thickness for enhanced structural integrity

6.3 DISCUSSION

The analysis reveals that the adhesive thickness has a significant impact on both the applied load and the ultimate slip of adhesive-bonded steel-concrete structures. As the adhesive thickness increases from 1.00 mm to 3.00 mm, the applied load capacity also increases. The finite element model provides a reasonably accurate prediction of the experimental results, with the differences in applied load ranging from 5.63% to 7.49% and in ultimate slip from 0.30% to 7.02%.

The best correlation between experimental and FE results is observed for the 2.00 mm and 3.00 mm adhesive thicknesses, with the smallest differences in both applied load and ultimate slip. This suggests that the FE model is particularly effective in predicting the behavior of adhesive bonds with these thicknesses.

Overall, the findings validate the use of finite element analysis as a reliable tool for predicting the performance of adhesive-bonded steel-concrete structures, aiding in the optimization of adhesive thickness for enhanced structural integrity.

CHAPTER 7

CONCLUSION

The study on adhesive-bonded steel-concrete structures demonstrates the significant potential of adhesive bonding as an alternative to traditional mechanical connections. Through a series of vertical pushout tests and finite element (FE) analyses, we have evaluated the performance of different adhesive thicknesses in terms of applied load capacity and ultimate slip.

The results indicate that increasing the adhesive thickness from 1.00 mm to 3.00 mm enhances the load-bearing capacity of the bonded joint. Specifically, the experimental and FE analyses showed reasonably close agreement, with differences in applied load ranging from 5.63% to 7.49% and differences in ultimate slip ranging from 0.30% to 7.02%. The FE model was particularly effective in predicting the behavior of joints with adhesive thicknesses of 2.00 mm and 3.00 mm, exhibiting minimal differences from the experimental results.

The analysis highlights that adhesive bonding can distribute stresses more evenly across the bonded interface, reducing stress concentrations and improving the overall structural integrity. Additionally, the close correlation between experimental and FE results validates the reliability of FE models in predicting the performance of adhesive-bonded joints.

In conclusion, adhesive-bonded steel-concrete structures offer enhanced performance and durability, particularly with optimized adhesive thicknesses. This study provides valuable insights into the mechanical behavior of such joints, supporting the broader adoption of adhesive bonding in civil engineering applications. Future research should focus on long-term durability and environmental effects to further establish the feasibility of adhesive bonding in diverse construction scenarios.

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