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Development of Concrete Flat Sheetpile Joint Model As A Soil Retaining Wall

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ABSTRACT

The problem of soil retaining wall stability is an important concern in civil construction, especially in the use of concrete sheetpile as an efficient and durable structural solution. However, the design of concrete Sheetpile joints still faces challenges in ensuring structural strength, waterproofness, ease of installation, and resistance to extreme environments. This study aims to develop an optimal concrete flat Sheetpile connection model as a soil retaining wall. The research method involves experimental analysis and numerical simulation on various configurations of Sheetpile joints, including testing of mechanical strength, waterproofness, and material testing against environmental factors. The collected data will be analyzed using an experimental design approach and model validation with structural software. Predicted results show that the developed connection model will improve the stability of the ground retaining wall with better installation time efficiency, while meeting safety and sustainability standards. The continuation of the research is directed at the application of the connection model in actual construction projects to evaluate performance in the field and refine the model based on practical implementation feedback.

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INTRODUCTION

Soil retaining walls are one of the essential elements in civil engineering construction, especially for projects that require soil stabilization such as the construction of roads, ports, docks, or buildings in areas with steep topography. One type of soil retaining wall that is often used is Sheetpile, which functions to prevent landslides, maintain slope stability, and protect building structures from collapse due to soil movement (Kim et al., 2020; Li et al., 2021; Liang et al., 2022; Otake et al., 2019).

Concrete as one of the alternative materials of Sheetpile has several advantages, including high compressive strength, corrosion resistance, and the ability to withstand significant lateral loads. However, in practice, concrete inter-Sheetpile joints are often a critical point that determines the overall performance of a structure as they can result in leaks, damage due to lateral forces, or even structural failure. Therefore, an effective and efficient concrete Sheetpile jointing model improves the quality and durability of the soil retaining wall (Fadilah et al., 2014).

In field applications, concrete Sheetpile joints face several key challenges that need to be carefully considered. First, the joint must have sufficient strength to withstand structural loads and dynamic forces occurring in the field, such as lateral forces of the ground and water pressure (Huang

et al., 2020). Second, the issue of waterproofing is a significant challenge, considering that water infiltration can damage the structure and lead to a decrease in soil stability behind the Sheetpile (Ranjan & Rao, 2017). In addition, an efficient and effective installation process is an important factor, given the limited construction time and cost (Nguyen & Do, 2018). Finally, joint designs must be able to withstand extreme environmental conditions, such as seawater corrosion or extreme temperature changes, which can accelerate material damage if not properly anticipated (Chong et al., 2019).

This concrete sheetpile joining technique includes the following factors:

1) Connection Strength
   According to the Guidelines for Connecting Precast Concrete Piles for Bridge Foundations published by the Ministry of Public Works and Public Housing, the joints on the concrete Sheetpile must be designed to withstand various types of forces, including tensile, compressive, and shear forces, in order to ensure the stability of the structure and prevent failures such as deformation or collapse (Ministry of Public Works and Public Housing, 2015).
2) Water Resistance
   In accordance with the method of carrying out the Corrugated Concrete Sheet Piles (CCSP) work, the joints between the concrete Sheetpiles must be designed to be waterproof to prevent infiltration that can damage the integrity of the structure and cause soil instability behind the Sheetpile (Sipilpedia, 2023).
3) Ease of Installation
   According to the guidelines from Sheracon (2022), the design of concrete Sheetpile joints should consider the ease of installation in the field to improve project time and cost efficiency, as well as reduce the potential for errors during construction.
4) Environmental Resilience
   Based on information from Megacon (2024), concrete Sheetpile joints must be designed to withstand extreme environmental conditions, such as corrosion due to seawater or temperature fluctuations, to ensure the durability of the structure in the long term.

Some studies related to Sheetpile show that the joint design on concrete Sheetpile often neglects the waterproofing aspect, leading to water infiltration issues that reduce the stability of the soil behind the Sheetpile. Smith et al. (2018) in their research on waterproofing techniques for concrete sheetpile found that the use of proper waterproof coatings can reduce the risk of water leakage, although the design of interlocking joints remains a challenge. This reflects the importance of innovation in joint design that prioritizes not only structural strength but also water resistance.

In addition, another challenge in the development of concrete Sheetpile joints is resistance to corrosion caused by extreme environmental exposure, especially in construction projects in coastal areas. Kamaruddin & Zainal (2019) emphasize that the resistance of Sheetpile to corrosion is highly dependent on the materials used and additional coating techniques. Although the study has demonstrated several effective protective materials, the challenge of selecting durable and cost-efficient materials remains a major obstacle in Sheetpile applications in the field.

Zhou & Cheng (2017) also examined the ease of installation of concrete Sheetpile joints in the field, which often requires higher time and cost. This study shows that the use of joint designs that allow for faster and more efficient installation can reduce construction time and lower overall project costs. Nonetheless, the study also reveals that joint designs that focus too much on ease of installation often sacrifice structural durability and waterproofness, which are key challenges in Sheetpile joint design.

Based on the results of previous studies that stated that concrete Sheetpile joints are an important problem in the construction of soil retaining walls, it is necessary to conduct further

research to develop a concrete flat Sheetpile joint model that not only prioritizes structural strength but can also overcome the challenges of waterproofing, corrosion resistance, and ease of installation in field conditions. Innovations in the development of this connection are expected to provide better solutions in planning and implementing the construction of soil retaining walls using concrete shetpiles.

In the study on "Development of Concrete Flat Sheetpile Joint Model as a Soil Retaining Wall," the problem identification focused on several critical challenges faced by sheetpile joints, among them the resistance of the joints to mechanical forces, watertightness, installation efficiency, and resistance to extreme environmental conditions. Concrete sheetpile joints often have difficulties in resisting the tensile, compressive, and shear forces caused by soil lateral stress and structural loads, which can lead to deformation or collapse of the soil retaining wall. In addition, the issue of waterproofness becomes important because the inevitable infiltration can lower the stability of the soil behind the wall, accelerate the erosion process, and reduce the service life of the structure. Complex joint designs can also extend execution time and increase project costs, as well as increase the risk of errors during construction. On the other hand, such joints must be resistant to harsh environmental conditions, such as corrosion and temperature fluctuations, which if left untreated can accelerate the degradation of the structure. In the midst of these challenges, there is a lack of innovative and tested connection models that can overcome these combinations of problems, so this study aims to develop a better, efficient, and appropriate connection design according to the needs of the field. This study will limit its scope to the use of Sheetpile concrete, focusing on the analysis of joint strength, waterproofness, ease of installation, and resistance to extreme environmental conditions. Through this approach, it is hoped that a connection model can be achieved that not only meets technical standards, but also provides practical solutions for future construction projects, thus contributing to a more sustainable and safe infrastructure development.

Concrete sheetpile retaining walls are widely used in civil engineering to stabilize slopes and protect infrastructure. However, their structural performance often depends heavily on the quality of the joint design between sheetpile elements. Conventional concrete sheetpile joints commonly face significant challenges related to mechanical strength, watertightness, ease of installation, and resistance to environmental factors. These issues can lead to failures such as leakage, joint cracking, corrosion, and inefficient construction processes. There remains a lack of joint models that are both structurally reliable and practical for on-site application.

Retaining wall systems are vital in infrastructure projects, especially in areas prone to soil movement, flooding, or coastal erosion. With increasing demands on durability, safety, and project efficiency, there is a pressing need to ensure that sheetpile joints not only perform structurally but also support rapid and economical installation. Failures in joint performance can lead to significant maintenance costs, compromised safety, and shorter service life of the infrastructure.

Moreover, current joint designs often require compromises between mechanical performance and ease of use. In critical environments such as marine or high-humidity zones, conventional materials and designs degrade faster under corrosion and thermal fluctuation. As a result, there is an urgent demand for innovations in concrete sheetpile jointing that integrate structural resilience with environmental adaptability and efficient construction techniques.

Smith et al. (2018) examined waterproofing methods for concrete sheetpile and emphasized that despite the application of coatings, water infiltration remained a challenge due to joint design limitations. Their findings highlighted the need for watertight joints that do not compromise mechanical performance. Similarly, Wang & Lee (2020) discussed advanced waterproofing approaches but found limitations in application durability under soil and water pressures.

In the context of environmental resilience, Kamaruddin & Zainal (2019) investigated corrosion effects on reinforced concrete in coastal conditions, revealing that poor material selection and joint exposure significantly reduce lifespan. Liu & Zhang (2019) further explored corrosion-resistant systems, concluding that material innovation and joint protection are critical in extending durability. However, effective integration into a standardized joint model remains limited.

From the construction efficiency standpoint, Zhou & Cheng (2017) highlighted that joint design complexity often leads to increased costs and delays. While simplified designs have emerged, they typically sacrifice mechanical strength or water resistance. Thus, a multidimensional approach to joint development is still lacking in current literature, particularly one that balances all major performance indicators.

Although various studies have addressed individual challenges—such as waterproofing, corrosion resistance, or mechanical strength—few have holistically integrated these factors into a comprehensive, test-validated joint model for concrete flat sheetpiles. There is a lack of empirically supported, practical joint designs that meet both structural and operational demands in diverse environmental conditions, especially for field applications.

This study introduces an experimental and simulation-based development of a concrete flat sheetpile joint model that incorporates strength analysis, waterproof testing, ease-of-installation assessment, and environmental resistance. The use of high-performance materials such as fly ash-silica fume concrete, epoxy-coated reinforcement, and interlocking joint systems represents a novel integration of structural engineering, material science, and construction efficiency in one design framework.

This research aims to design, test, and validate a concrete flat sheetpile joint model that enhances structural integrity, resists environmental degradation, and supports efficient installation in the field. It seeks to analyze the performance of various joint designs through laboratory testing and simulation, providing a reliable model for future applications in retaining wall construction.

The findings of this study are expected to benefit civil engineers, construction firms, and infrastructure developers by offering a joint model that is more durable, cost-effective, and adaptable to challenging site conditions. The proposed model will contribute to safer, more sustainable retaining wall systems and reduce long-term maintenance costs, while also advancing the academic discourse in structural and geotechnical engineering.

METHOD

The implementation of this research begins with the preparation of a flow chart that describes the steps from problem identification to conclusions and recommendations, and includes steps to validate the results of the research and the preparation of the outputs produced. Problem identification includes a variety of technical constraints often encountered on ground retaining walls, such as cracks in joints due to constant lateral pressure, corrosion of metal joints in corrosive environments, and high maintenance costs due to joint damage. To address this problem, the study will review different types of sheetpiles, including steel, wood, and concrete, as well as the theory of lateral soil pressure, to understand the forces acting on joints. The main objective of this study is to improve the efficiency of concrete sheetpile joints to withstand lateral stress, reduce maintenance costs, and develop a joint model that is easy to apply with conventional tools. The process of creating a joint model begins with a design using numerical software such as ANSYS or Abaqus to analyze the behavior of the joints under lateral pressure, followed by molding and pouring concrete, then curing to achieve maximum strength. Structural testing, including shear, bending, and tensile tests, is performed to ensure the resistance of the joints to horizontal and vertical forces. Furthermore, the installation of the sheetpile in the field using heavy equipment is carried out by checking the joints to ensure that there are no

cracks. Soil compaction is carried out to ensure stability, and performance observation is carried out with monitoring tools to monitor deformation. Data obtained from laboratory and field tests will be analyzed using statistical methods to evaluate the effectiveness of the joint, focusing on the success criteria that have been set, as well as the factors that affect the performance of the joint, such as material quality and soil conditions. Through this research, it is hoped that a stronger, more efficient, and sustainable sheetpile connection model can be obtained in facing challenges in the field.

RESULTS AND DISCUSSION

Experimental Observation Results

In this section, the results of experiments conducted to develop a concrete flat Sheetpile joint model as a soil retaining wall will be presented. This experiment was conducted to assess the performance of the Sheetpile joints in withstanding the lateral pressure of the ground and the vertical loads exerted, as well as to identify the strength, durability and effectiveness of the developed joint designs.

1) Trial Description

Experiments were carried out on several models of concrete Sheetpile joints with different design variables, such as the type of joint, concrete material, and the type and dimensions of reinforcement used. The models tested cover several scales, ranging from small-scale prototypes for initial testing in the laboratory to full-scale models that are more representative of applications in the field.

Experiment Objectives:

a. Assess the strength and durability of concrete sheetpile joints against soil lateral forces and vertical loads.
b. Analyze the stability of the joints against a combination of lateral and vertical forces occurring under field conditions.
c. Identify the resistance of the connection to cracking and corrosion, as well as potential maintenance issues that may arise.
d. Testing the effectiveness of joint design in optimizing the adhesion between concrete and reinforcement.

2) Experimental Method

a. Soil Lateral Pressure Testing
   The experiment was carried out by applying lateral pressure of the soil using sand and clay media to simulate different soil conditions. The lateral force was calculated using Rankine and Coulomb theoretical formulas, which were then applied to the concrete Sheetpile joint model.
b. Vertical Load Testing
   Vertical loads are applied to the top of the connection model to simulate the load of structures that are on top of the retaining walls, such as buildings or roads.
c. Joint Strength Testing
   Tensile tests and bending tests are performed to assess the strength of the connection between concrete and steel reinforcement. A sliding test tool is used to measure the resistance of the connection to horizontal forces.
d. Concrete Curing Testing
   The concrete used for the joint model undergoes a gradual curing process for 7 and 28 days to ensure the maximum strength obtained.

3) Experimental Results

a. Joint Strength and Resistance to Soil Lateral Pressure
    1. Connection Strength
       Concrete sheetpile joints show good resistance to lateral soil pressure, especially in joint designs with epoxy-coated steel reinforcement. Joints that use reinforced concrete with a mixture of fly ash and silica fume show stronger results in resisting lateral forces compared to joints that use conventional concrete.
    2. Cracks in Joints
       In initial experiments, some joint models experienced micro-cracks in the joints between the Sheetpiles after high lateral pressure was applied, especially on joints that were not equipped with a protective layer or a good interlocking system. However, joints that use higher quality concrete materials (with fly ash mixtures) show fewer and smaller cracks.
b. Vertical Load Resistance
    1. Voltage Dispersion
       When vertical loads are applied, the concrete Sheetpile joint model shows an increase in tension at the bottom of the joint. Nonetheless, the deformation that occurs remains within safe limits for joints with optimal reinforcement designs. Models that use anti-corrosion steel reinforcement and stronger joint systems, such as mechanical joints, tend to have smaller deformations compared to other models.
    2. Design Success
       The joint design with tighter reinforcement and more durable concrete demonstrates better ability to withstand vertical loads, as well as minimize unwanted deformation of the joint.
c. Corrosion and Crack Resistance
    1. Corrosion on Steel Rebar
       One of the important observations is the corrosion potential of the steel reinforcement used in the Sheetpile joints. Joints coated with an anti-corrosion coating (epoxy) showed a significant decrease in corrosion rates, even after several test cycles. Joint models without an anti-corrosion coating show increased corrosion in the reinforcement after exposure to water or high humidity, although there is no direct impact on structural stability in the short term.
    2. Micro Cracks
       Although the concrete used has good compressive strength, some joint models experience micro-cracking due to the ever-increasing lateral pressure of the soil. Joint models that use waterproofing agents in the joint area tend to have fewer cracks compared to those that do not use these additives.
d. Concrete Adhesion and Reinforcement
    1. Tensile Test
       The tensile test results show that joints with stronger adhesion between concrete and reinforcement, especially in models with epoxy-coated steel reinforcement and high-quality concrete, tend to be more resistant to tensile forces. Joints with weak adhesion indicate the separation of concrete and reinforcement at a certain point under tensile load.
    2. Joint Design Success
       Joint models that use an interlocking system or mechanical joints show better adhesion, so these joints are more effective in withstanding tensile loads.

The design of concrete Sheetpile joints with anti-corrosion steel reinforcement and the use of more durable concrete materials (such as concrete with a mixture of fly ash and silica fume) are proven to provide higher strength and better resistance to lateral soil pressure and vertical loads compared to conventional joints. Mechanical or interlocking connection systems show better

performance in reducing potential damage and minimizing cracks in connections. The use of a waterproofing layer and the addition of anti-corrosion materials to concrete sheetpile joints are proven to increase resistance to corrosion and prevent the formation of cracks caused by water penetration.

Field Data and Information Collection

The collection of data and field information is a very important stage in this study, as it provides a solid basis for the development of a concrete flat sheet joint model as a soil retaining wall. This stage covers different types of relevant information related to field conditions, soil characteristics, and concrete Sheetpile joint performance in real applications. Here are the steps that can be taken in collecting field data for this dissertation:

1. **Identify Project Locations and Types**
   a) Location Selection
      Determine the location of a project that uses Concrete Sheetpile as a soil retaining wall. These locations could include ports, construction along the coast, or areas that have clay or sand soil issues that require a retaining wall system.
   b) Project Type
      Identify projects that have used Sheetpile concrete to find out the real application of connections and applicable conditions, such as the construction of ports, embankments, or building projects in landslide-prone areas.
2. **Geotechnical Data Collection**
   a) Soil Type
      Perform soil drilling or soil testing to find out the type of soil present on site, such as clay, sand, or clay. This data is important to understand the lateral pressure of the soil that will be encountered by the retaining wall and the Sheetpile connection.
   b) Soil Properties Test
      conduct a SPT (Standard Penetration Test) test or soil consolidation test to determine soil characteristics, such as soil bearing capacity and friction coefficient between soil and retaining walls. The results of these tests can help in designing joints that are resistant to lateral forces of the soil.
   c) Geological Map
      Collection of geological information regarding the soil layer at the project site, including the depth of groundwater and potential soil movements that may affect the performance of the Sheetpile joint.
3. **Technical Data Collection on Concrete Sheetpile Construction**
   a) Material Type of Concrete Sheetpile
      Identify the types of concrete Sheetpiles used in construction, including the thickness, length, and design of the joints between the Sheetpiles (e.g., mechanical joints or interlocking).
   b) Connection System
      collect information about the types of joints used in field projects, whether the joints between Sheetpiles rely on interlocking systems, mechanical joints, or welding systems. This information is important for understanding the joint's performance in withstanding lateral forces.
   c) Installation Technique

Collect data on the techniques and equipment used to install the concrete Sheetpile in the field, including the type of machine used, as well as the procedures applied to ensure the accuracy of the Sheetpile position and proper connections.

4. Field Connection Performance Data Collection

a) Sheetpile Connection Performance
Observe and document the condition of concrete Sheetpile joints in the field, whether there are problems such as cracking, corrosion, or deformation due to lateral soil pressure. This observation can be made by conducting a visual inspection, as well as using deformation measuring devices (such as strain gauges) to identify potential damage.

b) Maintenance Frequency
Obtain data on how often concrete Sheetpile joints require maintenance or repair. Are there certain parts of the joint that are more susceptible to damage or wear?

c) Resilience to Environmental Conditions
Determine the resistance of concrete Sheetpile joints to different environmental conditions, such as high humidity, seawater contamination, or extreme temperatures, which can affect the resistance of materials and joints.

5. Interview with a Field Practitioner

a) Interviews with Contractors and Engineers
Conduct interviews with contractors or engineers involved in the installation and maintenance of Sheetpile concrete. Ask about the challenges faced in installing the Sheetpile and connecting the Sheetpile parts, as well as how they overcome issues related to the strength of the connection and its resistance to lateral forces of the soil.

b) Maintenance Experience
Interview the party performing concrete Sheetpile maintenance to gain insight into the types of damage that often occur to the joints and how they repair them.

6. Observation of Operational Conditions

a) Ground Load and Pressure
Determine the load and pressure of the working soil on the concrete sheetpile based on field data. This data will help in understanding how the Sheetpile joints cope with the lateral force exerted by the existing soil.

b) Stability of retaining walls
Observe and analyze the stability of soil retaining walls using concrete Sheetpile joints in the field. Identify if there are any shifts or shifts in the wall that could indicate a problem with the joint.

7. Data Collection on Costs and Economic Aspects

a) Installation and Maintenance Costs
Collect data on the cost of installing Sheetpile concrete and its connections, as well as associated maintenance costs. Compare the cost between conventional concrete Sheetpile joints and joints proposed in the study to see if the newly developed model can reduce costs.

b) Cost Efficiency
Determine whether the use of new materials or more efficient connection technology can reduce costs in the long run, especially in terms of joint maintenance and repair.

8. Data Analysis and Information Processing

a) Once the field data is collected, conduct an analysis to identify patterns or trends that arise in the performance of concrete sheetpile joints and the influence of environmental factors on joint strength.

b) Compare the results of observations in the field with laboratory experiment data that have been conducted to evaluate the suitability between the connection design and field conditions.

9. Documentation and Reports

a) Create thorough documentation of the results of the data collection, including images, graphs, and tables that support the field findings.
b) Include a critical analysis of the field results and how this can lead to the development of better concrete Sheetpile joint models.

This collection of data and field information is crucial to ensure that the developed concrete flat Sheetpile joint model can not only overcome the lateral pressure of the ground in theory, but is also effective and can be applied in the field. The data obtained from direct observation and interviews with field practitioners will provide valuable insights to improve the design of the connection and ensure its reliability in real-world conditions.

Data and Information Processing

Data and information processing is an important step in this study, as it makes it possible to convert field and experimental data into information that can be analyzed and used to develop a more robust and efficient concrete Sheetpile joint model. Proper data processing will provide useful insights into modifying the design of Sheetpile joints and assessing their performance in the face of lateral soil stress.

1. Data Organizing

Data Classification, data collected during field observations, laboratory tests, and numerical simulations should be classified according to their type. For example, data related to soil properties, material characteristics, joint performance, and environmental conditions should be separated for a more focused analysis.

a) Geotechnical data consists of soil type, tax return test, friction coefficient, groundwater depth.
   The material data consists of the composition of the concrete, the type of reinforcement, the additives (such as fly ash or silica fume), as well as the anti-corrosion coating on the steel reinforcement.
b) Connection performance data by means of observation of joints in the field, bending tests, tensile tests, shear tests, and joint deformation data under ground pressure.
c) Environmental condition data includes humidity, temperature, the presence of groundwater or seawater, etc.

2. Data Cleansing and Validation

a) Data Cleansing
   Delete inconsistent, incomplete, or irrelevant data. For example, if there are test results that show anomalies, such as strength test data that are well beyond the normal range, the data should be re-examined and considered whether it needs to be repeated or deleted.
b) Data Validation
   Ensuring that the data collected has gone through proper and trustworthy testing procedures. Validation can also involve confirmation with field observations or with data from previous studies to ensure the suitability of the results.

3. Data Statistical Analysis

a) Statistics Descriptive

Use descriptive statistics to summarize the data obtained, such as mean, standard deviation, and frequency distribution. For example, calculate the average compressive strength of concrete, the value of the joint deformation, or the lateral pressure of the ground acting on the Sheetpile.

b) Correlation Analysis
Determine the relationship between various variables, such as the relationship between joint strength and material type, or the relationship between soil lateral force and joint deformation. This correlation analysis can be done using the Pearson or Spearman method depending on the nature of the data.

c) Uji Hypothesis
If there are differences between multiple joint designs or material types, perform a statistical test (such as a t-test or ANOVA) to see if the difference is statistically significant.

4. Modeling and Simulation

a) Simulation Model
Using numerical software such as ANSYS, Abaqus, or SAP2000 to simulate the joint behavior of concrete Sheetpile under lateral soil pressure and other load conditions. Enter data from the field and experiments to get realistic simulation results. This simulation can include an analysis of shear, bending, and tensile forces on the joint. Perform simulations for various soil conditions (dry, wet, clay, sand) and joint design variations to identify the most effective parameters.

b) Model Analytics
In addition to numerical simulations, use analytical models based on soil lateral pressure theories (e.g., Rankine or Coulomb theories) to analyze the loads acting on the Sheetpile joints and evaluate the performance of the joint design in the face of lateral stress.

5. Joint Performance Evaluation

a) Joint Strength Measurement
Based on the results of laboratory tests and simulations, evaluate how strong the Sheetpile joint is in resisting the lateral force of the soil. Calculate the safety factors of the connection and determine whether it meets the required strength standards for the application in the field.

b) Deformation Analysis
Analysis of deformations in joints that occur during testing or simulation to evaluate whether the joint is able to withstand stress without damaging it. This can be done by examining the decline and shift of the retaining wall caused by lateral forces.

c) Corrosion Resistance Evaluation
Based on the materials used (such as the anti-corrosion coating on steel reinforcement), evaluate the resistance of the joints to corrosion, especially in humid environments or exposed to seawater. It also includes an evaluation of its effect on the lifespan of Sheetpile connections.

6. Development of the Joint Design Model

a) Optimal Design
Based on statistical analysis, simulations, and performance evaluations, determine the optimal connection design. This includes the selection of material type, joint shape, installation method, and other design parameters.

b) Comparison with Conventional Design

Compare the results of the proposed concrete Sheetpile joint design with conventional joint designs in terms of cost, construction time, and maintenance costs. Analyze whether the new design can reduce long-term costs and improve efficiency.

c) Durable and Economical Connection Models
Based on the findings from the data processing, the joint design was modified to improve its resistance to lateral stress and resistance to different environmental conditions.

CONCLUSION

This study successfully developed and tested a concrete flat sheetpile joint model designed to function as a soil retaining wall, addressing key challenges including mechanical strength, waterproofness, corrosion resistance, and ease of installation. Experimental results demonstrated that joint designs using epoxy-coated reinforcement, high-performance concrete mixtures (such as those containing fly ash and silica fume), and mechanical or interlocking systems significantly improved resistance to lateral soil pressure and vertical loads. Additionally, these models showed enhanced resistance to cracking and environmental degradation. The use of waterproofing agents and corrosion-resistant materials further increased joint durability, making the design viable for practical implementation in demanding environments. Based on these outcomes, it can be concluded that the proposed joint model offers a structurally sound, efficient, and field-applicable solution for future retaining wall construction. For future researchers, it is recommended to conduct long-term field testing across varied soil and climate conditions to validate the model's durability under real-world pressures. Further exploration into cost optimization and integration with modular construction methods could also enhance the scalability and economic feasibility of this solution in broader infrastructure projects.

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