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Experimental Investigation on Behavior of Beam Column Joint Reinforced with King Cross Steel Profile

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Abstract

This study explores the import of incorporating an innovative King cross steel profile on the structural performance of beam-column joints in reinforced concrete frames. The research focuses on improving key structural attributes such as load-bearing capacity, cracks resistance, and overall durability.

After reviewing existing reinforced methods, the study identifies the need for enhanced techniques to bolster tensile strength and load-bearing capacity. In response, the King cross steel profile was developed and integrated into beam-column joints. This approach aimed to delay crack initiation and increase overall structural capacity.

The effectiveness of this reinforcement was tested by comparing two sets of beam-column frames one with the king cross steel profile and a control set without it under static loading conditions. Key metrics like crack initiation, ultimate load capacity, failure modes, cracks width, and deformation were closely monitored.

Result showed that the frames with the king cross profile outperformed the control frames, with delayed cracks initiation and higher load-bearing capacity. However, shear failure was observed in both sets, indicating the need for additional shear reinforcement. Variation in cracks width and deformation pattern between the two sets further underscored the potential of the king cross profile to enhance tensile strength and deformation capacity. Despite these advances, the study suggests that further research is needed to optimize shear resistance and cracks control.

In summary, the research offers valuable insights into the benefits of the King Cross steel profile as a reinforced concrete structure performance in various engineering applications.

Keywords: BCJ, Joint shear reinforcement, Steel reinforcement concrete, King cross steel profile, Interior beam column joint, Joint shear failure, King cross steel profile, Reinforced concrete frames, Load bearing capacity, Crack Resistance, Tensile strength, Crack initiation, Ultimate load capacity, Structural Performance

1. INTRODUCTION

1.1 BEAM COLUMN JOINT (BCJ)

Is an essential part of a building's structural system, serving as the crucial connection point where horizontal beams intersect with vertical columns. This joint play a vital role in distributing both the weight and the forces exerted on the structure, ensuring stability and integrity. In normal conditions, BCJs handle vertical loads caused by the building's own weight and the weight of its contents. However, during an earthquake, the situation changes drastically. Earthquake introduce dynamic, sideways forces Known as seismic Loads. These forces are sudden and intense, and they place a unique kind of stress on the BCJs different from the constant vertical forces experienced during normal times.

When seismic forces occur, the beam attached to the joints must resist moments, meaning they have to withstand forces that try to twist and bend them. This twisting and bending action significantly increase the shear force on the BCJ, which can be through of as pushing and pulling the joint from different directions at once. This complex set of forces can challenge the joints strength and stability.

To protect the building and its occupants during such events, BCJs need to be designed with enough strength and flexibility to handle these seismic forces. This often involves designing the joints to allow for some plastic deformation, which means they can bend and stretch permanently without breaking. This capability is crucial, because it helps the structure absorb and dissipate the energy released during an earthquake, reducing the risk of a catastrophic collapse.

CLASSIFICATION OF BEAM COLUMN JOINT

Beam column joints are essential parts of a building's structure, helping distributed loads and maintain stability. Understanding the different types of joints is important for engineers to design safe and efficient structures. Here's a breakdown of the main classifications.

1. Classification by Connection Location:

a. Interior Joints: These joints are located within the building, away from the outer edges. They connect beams to columns inside the structure, playing a key role in spreading loads evenly. They typically deal with different types of forces compared to joints located at the building's edges.

b. Exterior Joints: Positioned near the building's exterior walls, these joints connect beams to columns at the structure's perimeter. Exterior joints often face additional challenges, such as wind loads and temperature changes, making their design particularly important for maintaining structural integrity.

c. Corner Joints: Found at the corners where two perpendicular walls meet, these joints connect beams to columns. Due to their unique placement, corner joints experience distinctive forces and require careful design to ensure they can handle these loads effectively.

2. Classification by Load Type:

a. Non-Seismic Joints: Designed to handle everyday loads like those from people, furniture, and equipment, these joints are not specifically made to endure the intense forces generated during an earthquake. They focus on normal structural performance under typical conditions.

b. Seismic Joints: These joints are specially designed to withstand the stress and movements caused by earthquakes. They are built with extra strength and flexibility to absorb and dissipate anergy, helping to protect the building from severe damage during seismic events.

3. Classification by Joint Rigidity:

a. Flexible Joints (Pinned Joints): These connections allow for some rotational movement between the beams and columns, providing flexibility to the structure. This flexibility can help redistribute forces and accommodate slight movements without compromising the building's stability.

b. Rigid Joints (Fixed Joints): These joints do not permit rotational movement, making the connection between beams and columns firm. Rigid joints increase the structure's overall stiffness and load carrying capacity, reducing the potential for structural deformations.

1.2 KING CROSS STEEL PROFILE

The King Cross steel profile is custom-made steel section designed specifically for construction projects, setting it apart from standard, premade profiles. Unlike off-the-shelf steel profiles, the King Cross is tailored to meet the unique of each project. This custom approach ensures that the King Cross profile fits perfectly into construction designs, allowing architects and engineers to enhance the structural strength and efficiency of their projects. By adjusting the profile's dimensions and specifications, it aligns precisely with architectural goals and improves the durability and sustainability of structure. The King Cross profile is known for its innovation and precision. Its custom fabrication process guarantees high quality and reliability, making it a preferred choice for complex construction projects. Its flexibility and meticulous design contribute to success.

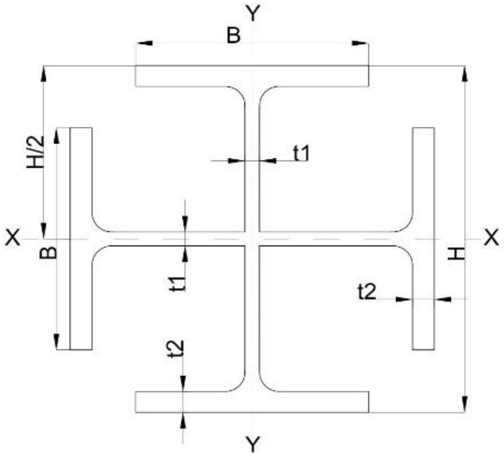

Figure 1: The dimension of king cross profile.

GAP ANALYSIS

Enlarge web width and reduce flange width of king cross profile to optimize joint filling and shear capacity.

Research should focus on comparing king cross profiles with traditional reinforcement methods, determining upper limits of horizontal stirrup ratios, and evaluating various joint reinforcement techniques performance in seismic environments.

OBJECTIVES

- ***a.*** ***Study the Strength Enhancement:*** To evaluate how the king cross steel profile improves the overall strength and robustness of beam column joints in comparison with conventional beam column joint.
- ***b.*** ***Failure mode analysis:*** To gain insight into the failure modes exhibited by joints with the King cross steel profile, understanding how this unique steel shape influences and controls these modes.

2.EXPERIMENTAL

2.1 MATERIAL PROPERTIES

The 28 days curing period of compressive strength of concrete 25Mpa (Megapascal). The concrete mix consists of Portland cement, fine and coarse aggregates, water, and admixture if required, following the mix design.

The yield strength of Fe 500 steel is a minimum of 500 Newtons per square millimeter (N/mm^2). Which is the defining characteristic indicated by the "500" in its name, making it a high-strength steel ideal for construction projects needing good load-bearing capacity, the ultimate tensile strength around 545 N/mm^2 and elongation around 12%. The slump cone test is conducted onsite to assess the workability of the concrete mix. This test provides an indication of the water cement ratio and the ease with which the concrete can be placed. The slump cone test is used to measure the consistency and workability of fresh concrete. The test provides a valve called the slump, which indicated the workability of the concrete mix. As per test we consider slump valve 100mm.

Table1: Material property

MATERIAL	GRADE
Concrete	M25
Steel grade of longitudinal and transverse bar	Fe500
Steel grade of king cross profile	Fe500

2.2 TEST SET UP OF THE SPECIMENS:

The following procedure outlines the detailed steps involved in setting up an experiment to test a beam column frame under two-point static loading conditions. This procedure is designed to accurately measure the deflection and strain in the specimen, ensuring reliable and reproducible results.

a. Preparation of the Test Specimen: Specimen Selection: Begin by selecting or fabricating the test specimen, typically a beam column frame, according to the specified design and dimensions. Ensure that the specimen is free from any pre-existing defects that could affect the test results.

b) Marking Points: Mark the specific points on the specimen where the loads will be applied and where the deflection and strain measurements will be taken. These markings help in the accurate placement of measuring instruments and loading devices.

2.3. PLACEMENT ON THE LOADING FRAME

a) Positioning the Specimen: Carefully place the test specimen onto the loading frame, ensuring that it is aligned correctly. The specimen should be positioned such that the two designated load points are directly below the loading mechanisms.

b) Fixed Support Condition: To simulate a fixed support condition, clamps are used to securely fasten the ends of the specimen to the loading frame. This setup prevents any rotational or translational movement at the supports, thereby ensuring that the test conditions accurately represent a fixed support scenario.

2.4 INSTALLATION OF DIAL GAUGES

a) Dial Gauge Setup: Dial gauges, which are precise instruments used to measure small deflections, are installed at critical locations on the specimen. In this setup:

Column Measurement: Dial gauges are fixed at the external ends of both columns to measure any vertical or horizontal deflection that occurs during the loading process.

Beam Measurement: On the beam, dial gauges are placed at the midpoint, which is typically the location of maximum deflection, and at the points where the loads will be applied. These gauges are critical for capturing the deflection data, which is essential for analyzing the structural performance of the specimen under load.

b) Calibration: Before the test begins, each dial gauge is carefully calibrated to ensure accurate readings. The gauges are then set to zero, or or the initial position is noted, to serve as a reference point for measuring deflection during the test.

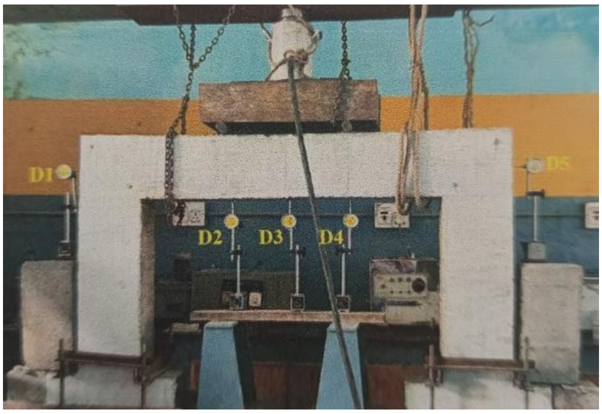

Figure 2: Installation of Dial gauges

2.5 INSTALLATION OF STRAIN GAUGES

- ***Strain Gauge Placement:*** Strain gauges are affixed to the specimen at the connection points between the beam and columns. These gauges are designed to measure the deformation or strain in the material, providing valuable data on how the specimen deforms under load.
- ***Surface Preparation:*** The surface where each strain gauge is to be placed must be thoroughly cleaned and smoothed to ensure proper adhesion and accurate readings. Any dust, grease, or irregularities can affect the performance of the strain gauge
- ***Adhesion:*** Once the surface is prepared, the strain gauges are carefully adhered to the specimen using a specialized adhesive. They are then connected to a data acquisition system that records the strain readings throughout the test.

2.6 LOAD APPLICATION

- ***Two Point Loading Configuration:*** The test is conducted under a two-point static loading condition, where loads are applied at two specific points on the beam. These points are symmetrically located with respect to the beam's midpoint to create a uniform bending moment in the central section.
- ***Loading Device Setup:*** Load cells or hydraulic jacks are used to apply the loads at the marked points on the beam. The load application is controlled to ensure a gradual and steady increase, allowing for precise measurement of deflection and strain as the load increases.

2.7 DATA COLLECTION AND MONITORING

- **Loading Process: Loads are incrementally applied to the structure to observe its response under increasing stress.**
- **Dial Gauges:**
  - Function: Measure deflection at critical points on beams and columns.
  - Calibration: Carefully calibrated to ensure precision in deflection measurement.
  - Purpose: Provides data on how the structure bends or deforms under load.
  - Measurement Points: Typically placed at midspan and near supports of beams.
- and at critical nodes on columns.
- **Strain Gauges:**
  - Function: Monitor material deformation at key stress points and connections.
  - Sensitivity: Capable of detecting even minor changes in strain.
  - Installation Locations: Positioned at locations where stress concentrations are
- expected, such as joint connections and areas of high load transfer.

- **Data Acquisition System:**
  - Realtime Data Transmission: Continuously receives and records data from dial gauges and strain gauges.
  - Data Storage: Captures and stores data for later retrieval and analysis.
  - Data Organization: Systematically organizes data to facilitate easy analysis and comparison.
  - Immediate Feedback: Provides live updates on the structure's behavior under applied loads.
- **Data Analysis: Comparison with Theoretical Models: Actual deflections and strains are compared with predictions from structural models.**
- **Verification: Helps verify the accuracy of theoretical models and assumptions.**
  - Identification of Anomalies: Spot any deviations from expected behavior, indicating potential issues or areas of concern.
  - Design Improvement: Insights from data help in refining and improving future structural designs.
- **Observation of Failure Modes:** During the test, carefully observe the specimen for any signs of cracking, yielding, or other forms of failure. This observation helps in understanding the behavior of the structure under load and can provide insights into the failure mechanisms.

2.8. TERMINATION OF THE TEST

- ***Load Removal:*** Once the test reaches its desired load level or when the specimen fails, the loads are gradually removed t to prevent any sudden release of energy that could damage the equipment or cause safety hazards.
- ***Post-test Inspection:*** After the test, inspect the specimen for any residual deformations or damage. This inspection, combined with the data collected, will provide a comprehensive understanding of the specimen's performance under the applied loads.

This detailed experimental setup ensures that all relevant parameters are accurately measured, providing a robust framework for evaluating the structural performance of the beam column frame under two-point static loading conditions. The procedure is designed to yield reliable and reproducible results, which are crucial for validating design assumptions and improving future structural designs.

3.RESULTS

3.1 COMPREHENSIVE STRENGTH OF CUBE

Comprehensive analysis of the performance of beam column frames subjected to static loading. The analysis is divided into observation and technical analysis for both the control frame and the frame reinforced with the king cross steel profile, followed by a comparative analysis. This detailed examination provides insights into the structural behavior, failure modes, and performance improvements offered by the king cross reinforcement.

Table2: Cube compressive strength test result

Days	**Characteristic Compressive strength (Fck)**
7 days	10.8 N/mm^2
14 days	15.6 N/mm^2
28 days	25.2 N/mm^2

3.2 CONTROL FRAME PERFORMANCE

3.2.1 CRACK INITIATION

a) observation: The control frame development its first visible crack at a load of 42KN this crack was observed in the concrete, often occurring at the locations subjected to the highest tensile stresses due to the applied loads.

b) Technical Analysis: The initiation of cracks at 42 KN indicates that the tensile stresses within the concrete have reached and exceeded its tensile strength Concrete is inherently we in tension, and as the load increases, the tensile stresses build up until they surpass the material's capacity, leading to crack formation. This early occurrence of cracks suggests that the frame's tensile reinforcement was inadequate to resist the applied stresses. The analysis highlights the need for improved reinforcement strategies, such as increasing the amount of steel reinforcement or optimizing the concrete mix design to enhance tensile strength and reduce the likelihood of early cracking

3.2.2 ULTIMATE LOAD CAPACITY

a) Observation: The ultimate load capacity of the control frame was measured at 162kN, representing the maximum load that the frame could sustain before failure.

b) Technical Analysis: The ultimate load capacity of 162kN is a critical parameter for assessing the strength and safety of the frame. This value indicates the maximum load the frame can bear before it experiences failure, providing an important measure of the frame's loadbearing capabilities. The relatively lower ultimate load capacity compared to the King Cross profile frame suggests that the control frame's design may lack sufficient strength to handle higher loads. This underscores the need for design improvements to enhance loadbearing capacity, which could involve increasing the size of structural elements, optimizing reinforcement details, or employing stronger materials.

3.2.3 FAILURE MODE IN SHEAR ZONE:

a) Observation: The failure mode in the control frame was predominantly shear failure, characterized by sudden and brittle collapse due to excessive shear stresses.

b) Technical Analysis: Shear failure occurs when the shear stresses within the frame exceed the shear strength of the material, leading to a sudden and often catastrophic collapse. In the control frame, the shear failure indicates that the shear reinforcement, such as stirrups or shear links, was insufficient to handle the applied shear forces. This type of failure is less ductile compared to bending or tensile failures and can lead to rapid structural collapse. The analysis highlights the need for enhanced shear reinforcement to improve the frame's resilience against shear stresses and t prevent brittle failures. This may involve increasing the density of stirrups or using high strength shear reinforcement materials.

3.2.4 MAXIMUM CRACK WIDTH:

a) Observation: The maximum crack width observed in the control frame was 2.33 mm, measured at the widest point of the crack that developed during loading

b) Technical Analysis: A crack width of 2.33 mm is significant and indicates potential issues related to the durability and serviceability of the structure. Wide cracks can permit the ingress of moisture, chemicals, and other corrosive agents, which can lead to deterioration of the concrete and reinforcement over time. The analysis suggests that the control frame's design may have been inadequate in controlling crack formation and propagation. To address these issues, better crack control measures, such as improved reinforcement detailing, use of crack resistant concrete mixtures, or application of surface treatments, are necessary to enhance the frame's durability and long-term performance.

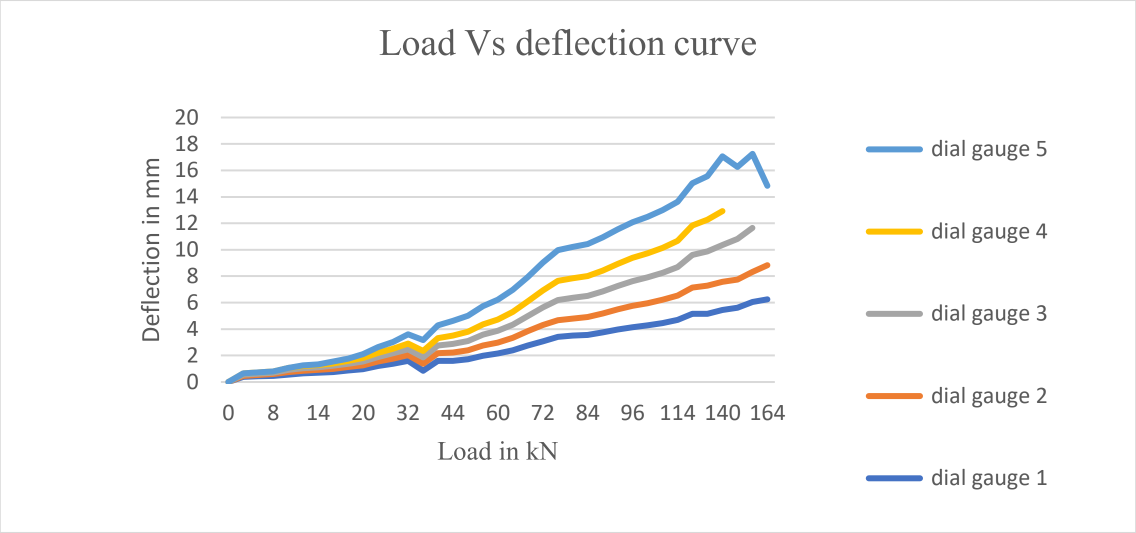

Figure 3: Load Vs deflection curve control frame

3.2.5 MAXIMUM DEFORMATION:

a) Observation: The maximum deformation in the control frame was 362.1 mm at a load of 140kN representing the vertical displacement experienced by the frame under the applied load

b) Technical Analysis: The observed deformation of 362.1 mm reflects a significant loss of stiffness in the frame under load. This considerable deflection indicates that the frame experienced excessive bending, which can lead to serviceability issues, such as excessive sagging or deformation, affecting the usability and safety of the structure. The analysis points to a potential need for increasing the frame's stiffness through design modifications, such as enlarging the cross-sectional dimensions of structural elements or adding additional support structures. Enhancing the stiffness can help reduce deformation and ensure that the structure remains within acceptable serviceability limits under applied loads.

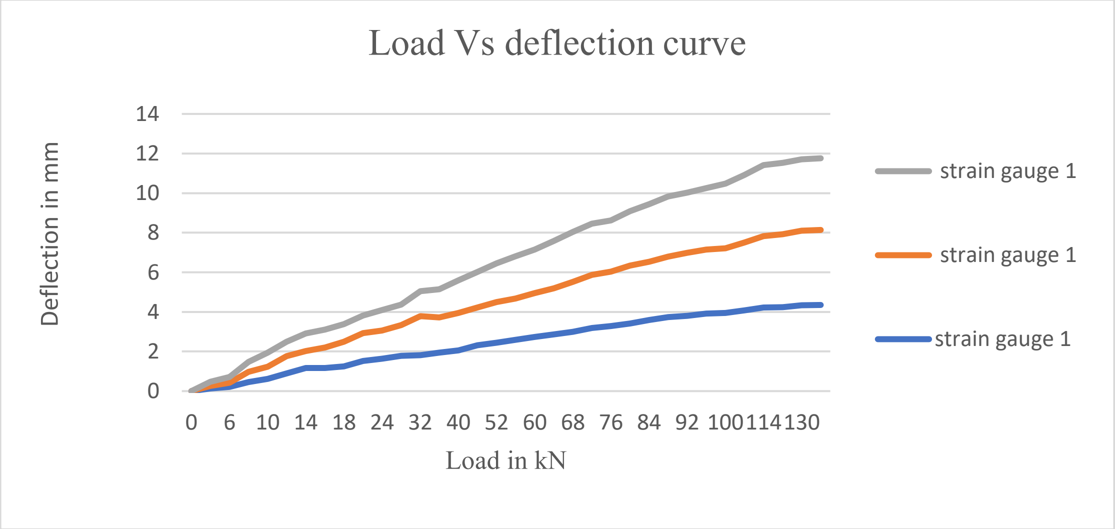

Figure 4: Load Vs deflection curve control frame.

Figure 5: Failure pattern of control frame

3.3 FRAME WITH KING CROSS STEEL PROFILE PERFORMANCE

3.3.1 CRACK INITIATION:

a) Observation: The frame with the King Cross steel profile exhibited its first crack at a higher load of 48kN This improvement indicates that the reinforced frame was able to endure higher loads before crack initiation.

b) Technical Analysis: The higher crack initiation load of 48 kN reflects the enhanced tensile strength and performance of the frame with the King Cross steel profile. The presence of the King Cross reinforcement improved the frame’s ability to resist tensile stress delaying the onset of cracks and contributing to the overall structural performance This improvement highlights the effectiveness of the King Cross steel enhancing the frame's resistance to tensile forces and potentially increasing service life by delaying the onset of visible damage.

3.3.2 ULTIMATE LOAD CAPACITY:

a) Observation: The ultimate load capacity of the frame with the King Cross steel profile was recorded at 242kN, representing a significant increase compared to the control frame.

b) Technical Analysis: The ultimate load capacity of 242kN demonstrates the substantial impact of the King Cross steel profile on improving the frame's strength. This increase in loadbearing capacity indicates that the reinforcement effectively enhanced the frame's ability to support higher loads before experiencing failure. The higher load capacity underscores the benefits of incorporating advanced reinforcement techniques, such as the King Cross profile, to enhance structural strength and stability, allowing the frame to handle greater loads and provide better performance under static loading conditions.

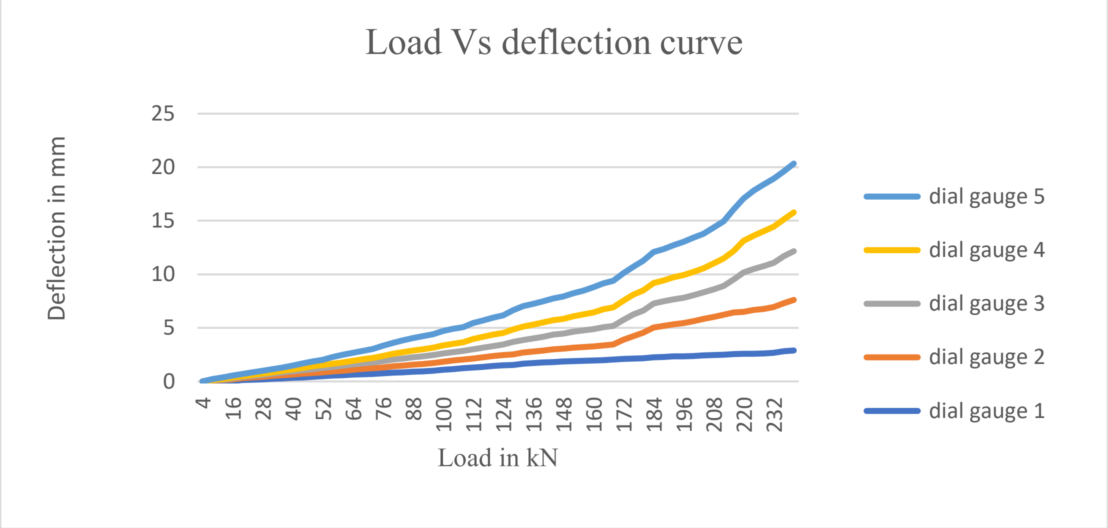

Figure 6: Load Vs deflection curve control frame

Figure 7: Crushing of column at end

3.3.3 FAILURE MODE IN SHEAR ZONE

a) Observation: The frame with the King Cross steel profile also experienced shear failure, similar to the control frame.

b) Technical Analysis: Despite the increased load capacity provided by the King Cross steel profile, the frame still failed in the shear zone. This indicates that while the profile improved overall strength, it did not fully address the shear stress vulnerabilities inherent in the frame design. The persistence of shear failure suggests that additional shear reinforcement measures are necessary to enhance the frame's resilience against shear stresses and to prevent sudden, brittle failures. This may involve incorporating additional shear reinforcement or exploring alternative reinforcement methods to address shear vulnerabilities more effectively.

3.3.4 MAXIMUM CRACK WIDTH

a) Observation: The maximum crack width in the frame with the King Cross steel profile was which is wider than the crack width observed in the control frame.

b) Technical Analysis: The wider crack width of 3 mm in the King Cross reinforced frame indicates that, although the profile improved the frame's strength, it did not effectively control crack propagation. This suggests that the reinforcement may not have sufficiently addressed issues related to crack formation or width management. To improve crack control, further investigation into reinforcement techniques and material properties is necessary. This could involve using high strength reinforcement materials or optimizing the concrete mix to reduce crack widths and enhance overall durability.

3.3.5 MAXIMUM DEFORMATION:

a) Observation: The frame with the King Cross steel profile exhibited a maximum deformation of 370 mm at a load of 190 kN, showing greater deformation capacity compared to the control frame.

b) Technical Analysis: The increased deformation of 370 mm reflects the improved ductility and energy absorption capacity of the reinforced frame. This greater deformation capacity allows the structure to endure higher loads and absorb more energy before reaching failure, demonstrating enhanced flexibility and resilience.

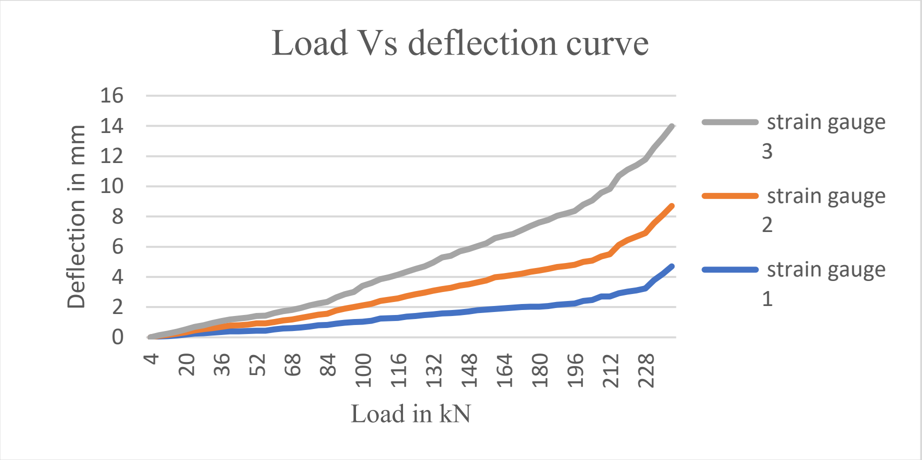

Figure 8: Load Vs deflection curve control frame reinforced with king cross steel profile

Figure 9: Failure pattern of frame with king cross steel profile

Figure 10: Failure pattern of crack at shear zone

3.4 COMPARATIVE ANALYSIS

3.4.1 CRACK INITIATION:

The King Cross steel profile frame exhibited crack initiation at 48kN, compared to 42kN for the control frame. This delay in crack initiation highlights the effectiveness of the King Cross reinforcement in improving the frame's ability to resist tensile stresses.

3.4.2 ULTIMATE LOAD CAPACITY:

The ultimate load capacity of the frame with the King Cross steel profile (242kN) was significantly higher than that of the control frame (162kN). This substantial increase demonstrates the impact of the reinforcement in enhancing the frame's strength and loadbearing capabilities.

3.4.3 FAILURE MODE:

Both frames failed in the shear zone, indicating a common vulnerability in both designs. While the King Cross profile improved strength, it did not fully address the shear stress issues, highlighting the need for enhanced shear reinforcement.

3.4.4 MAXIMUM DEFORMATION:

The King Cross steel profile frame exhibited a maximum deformation of 370 mm at 190 KN, compared to 362.1 mm at 140kN for the control frame. This increase in deformation Capacity highlights the improved ductility and flexibility provided by the King Cross reinforcement

4. SUMMARY

The experimental study aimed to evaluate the effectiveness of the King Cross steel profile in enhancing the performance of beam column frames under static loading conditions. The following key findings were observed:

- **Delayed Crack Initiation**
  - ***Observation***: The application of the King Cross steel profile led to a noticeable delay in the initiation of cracks within the frame.
  - ***Technical Context:*** This improvement can be attributed to the enhanced tensile strength and stiffness provided by the King Cross profile. By effectively distributing and resisting tensile stresses, the profile helps to mitigate the early formation of cracks, which often occur due to excessive tensile forces and

stress concentrations. The delayed crack initiation suggests that the King Cross profile contributes to a longer service life for the structure by reducing the likelihood of premature

- **Increased Ultimate Load Capacity:**
  - ***Observation:*** The beam column frames reinforced with the King Cross profile exhibited a significant increase in ultimate load capacity compared to the control frames.
  - ***Technical Context:*** The ultimate load capacity is the maximum load that a structural element can sustain before failure. The King Cross profile enhances the structural strength by providing additional reinforcement, which improves the loadbearing capacity of the frame. This result highlights the effectiveness of the King Cross profile in augmenting the overall strength and robustness of the structure, making it more capable of supporting higher loads before reaching its failure point.
- **Persistent Shear Failure Modes:**
  - ***Observation:*** Both the reinforced and control frames experienced shear failure during the experiments.
  - ***Technical Context:*** Shear failure is a common mode of failure in structural frames. often occurring due to inadequate shear reinforcement or high shear stresses. The persistence of shear failure in both types of frames indicates that despite the reinforcement provided by the King Cross profile, shear failure remains a critical design vulnerability. This suggests the need for enhanced shear reinforcement strategies, such as the inclusion of additional shear stirrups or using higher strength materials, to better manage and mitigate shear related issues
- **Larger Crack Widths:**
  - ***Observation:*** The presence of the King Cross profile did not significantly control or reduce the width of cracks.
  - ***Technical Context:*** Crack width control is crucial for maintaining structural integrity and durability. The lack of significant improvement in crack widths with the King Cross profile suggests that while the profile may enhance tensile and loadbearing properties, it does not adequately address issues related to crack propagation and width control. This finding indicates a need for supplementary measures, such as improved concrete mix designs or additional crack control techniques, to manage and reduce crack widths effectively.
- **Improved Deformation Capacity:**
  - ***Observation:*** The frame reinforced with the King Cross profile demonstrated a greater capacity for deformation and ductility
  - ***Technical Context:*** Deformation capacity refers to the ability of a structure to undergo deformation and absorb energy without failing. The enhanced deformation capacity observed with the King Cross profile suggests improved ductility, which allows the frame to accommodate larger deformations and absorb more energy before reaching failure. This increased ductility is beneficial for structures subjected to dynamic loads or seismic events, as it helps in dissipating energy and reducing the risk of catastrophic failure.
- These findings underscore the strengths and limitations of the King Cross steel profile in enhancing the performance of beam column frames. While the profile improves certain aspects of structural behavior, such as tensile strength and load capacity, it also highlights areas where additional design considerations and reinforcement strategies are needed to address persistent issues like shear failure and crack width control.

5. CONCLUSION

This chapter will synthesize the conclusions drawn from the experimental study, highlighting the implications for structural design, construction practices, and future research directions based on the detailed analysis of beam column frames with and without King Cross steel profile reinforcement.

The experimental assessment of beam-column frames-one incorporating a King Cross steel profile and the other serving as a control-clearly demonstrates the substantial advantages of utilizing the King Cross profile in structural reinforcement. The analysis reveals that integrating the King Cross profile significantly enhances the overall performance of the frame, particularly with regard to toad-bearing capacity and resistance to initial cracking.

In the experiment, the frame featuring the King Cross steel profile showed considerable improvements over the control frame. One of the most notable benefits was ability to sustain a higher load before the onset of cracking. Specifically, the first crack the control frame occurred at a load of 42kN, whereas in the frame with the King profile, cracking did not occur until a higher load of 48kN was applied. This dela crack formation highlights the superior stress resistance afforded by the King Cross profile. It indicates that the frame with the King Cross profile can endure greater loads before exhibiting visible signs of damage, thus contributing to its overall durability structural integrity.

When evaluating ultimate load capacity, the differences between the two frames become even more pronounced. The King Cross-reinforced frame supported a maximum load of 242kN, a significant increase compared to the control frame's capacity of 162kN This improvement represents an approximate 49% enhancement in load-bearing capability. which underscores the effectiveness of the King Cross profile in bolstering the structural strength and stiffness of the frame. This increased capacity allows the frame to handle more substantial loads without compromising safety or performance, making it particularly valuable in applications where high load resistance is critical. Despite these notable improvements, it is important to acknowledge that both frames ultimately experienced failure due to shear. This common failure mode indicates that while the King Cross profile contributes to increased load capacity and delayed cracking, shear failure remains a significant factor. This observation highlights the necessity for further investigation into alternative reinforcement methods or design modifications that can address shear-related issues more effectively. Understanding and mitigating shear failure is essential for optimizing the performance and safety of reinforced structures.

The deformation data further supports the benefits of the King Cross profile. In the control frame, the maximum deformation observed was 362.1 mm at a load of 140kN in contrast, the frame reinforced with the King Cross profile exhibited a maximum deformation of 370 mm at 190kN Although the King Cross frame showed slightly greater deformation, this is consistent with its higher load-bearing capacity. The enhanced ability of the reinforced frame to sustain greater loads before experiencing significant deformation suggests that the King Cross profile contributes to improved structural resilience. It allows the frame to endure larger loads while managing deformation in a controlled manner.

In conclusion, the King Cross steel profile offers substantial improvements in structural performance for beam-column frames. It effectively delays the onset of cracking, increases the ultimate load capacity, and enhances the overall strength and stiffness of the frame While both frames ultimately experienced shear failure, the King Cross profile demonstrates clear advantages in terms of load-bearing capacity and structural resilience as a reinforcement solution, the King Cross profile provides valuable enhancements making it an effective choice for improving the performance and durability of beam-column frames.

6. FUTURE SCOPE:

1. **Advanced Strengthening Techniques:** Investigate and compare various methods for strengthening beams, such as the application of additional steel plates, fiber-reinforced polymers, or advanced post-tensioning systems. These techniques could potentially offer even greater improvements in structural performance and resistance to failure
2. **In-depth Joint Behavior Studies:** Conduct detailed experimental and analytical studies focusing on the behavior of joints under varying loading conditions. This research will provide a deeper understanding of joint strength and failure mechanisms, which is crucial for improving overall frame stability and integrity.
3. **Enhanced Analytical and Numerical Models:** Develop and utilize advanced analytical models and finite element analysis (FEA) to simulate the behavior of frames with different reinforcement techniques. These models can help predict structural performance under various conditions and refine future experimental designs.
4. **Evaluation of Alternative Reinforcement Profiles:** Explore and test other types of steel profiles or reinforcement methods to assess their impact on structural performance. This research could identify more effective reinforcement solutions and lead to improved structural design practices.
5. **Long-Term Durability and Fatigue Analysis**: Perform studies to evaluate the long- term durability and fatigue resistance of reinforced frames under cyclic or dyna loading conditions. Understanding how frames perform over extended per ensure their reliability and safety in practical applications.

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