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REVIEW PAPER ON IMPACT OF CONNECTION DETAILING ON PROGRESSIVE COLLAPSE: BOLTED VS. WELDED JOINTS IN STEEL FRAMES

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Abstract

The increasing demand for tall and slender structures in modern architecture has necessitated the development of efficient lateral load-resisting systems. Among these, steel Diagrid systems have emerged as a highly effective solution due to their geometric efficiency, structural rigidity, and architectural flexibility. This study focuses on the optimization of steel diagrid systems to enhance their performance under seismic and wind loads. A parametric analysis is conducted by varying diagrid angles, member sizes, and spacing to evaluate their impact on structural Behavior, including lateral stiffness, drift control, and base shear. Advanced finite element modelling and dynamic analysis methods, such as response spectrum and time history analyses, are employed to simulate realistic loading conditions. Optimization techniques, including genetic algorithms and multi-objective optimization, are used to identify the best-performing configurations in terms of strength, stability, and material efficiency. The results demonstrate that optimized diagrid configurations can significantly improve the lateral performance of tall buildings, reduce material consumption, and enhance seismic resilience. The findings provide valuable insights for structural engineers and designers aiming to achieve sustainable and high-performance tall building designs.

INTRODUCTION

Steel structures have become a cornerstone of modern construction due to their superior strength-to-weight ratio, ductility, speed of erection, and architectural flexibility. They are widely used in high-rise buildings, industrial sheds, bridges, and offshore platforms. However, the safety and reliability of these structures under extreme or accidental events such as explosions, vehicular impacts, fire, or the collapse of a disproportionate part of or the entire structure." In steel frames, connections are the most critical components during this process, as they govern the transfer of forces, rotations, and deformations when local failure occurs.

Sudden column loss largely depend on the connection detailing between beams and columns.

Connections play a pivotal role in transferring forces and moments across members and in maintaining the overall integrity of the frame. Their performance dictates how the structure responds not only under normal loading but also during abnormal or unforeseen events. If a key structural element (such as a column) is

Bolted Connection

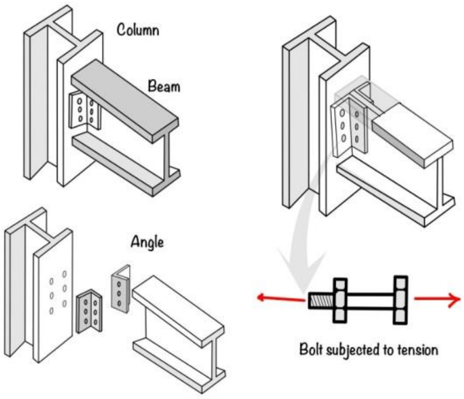

Fig. 1 Bolted Connection

Welded Connection

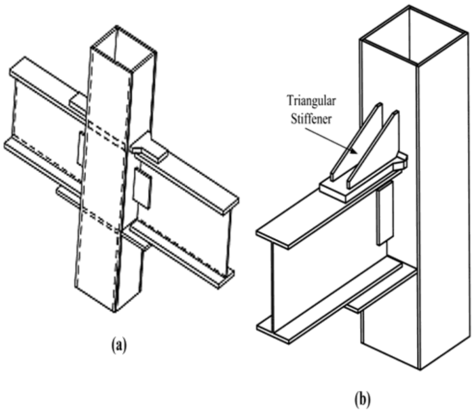

Fig. 2 Welded Connection

Aim and Objectives

Aim: To investigate the impact of connection detailing—specifically bolted and welded joints on the progressive collapse resistance of steel moment-resisting frames using analytical modeling and simulation.

Objectives:

- To review existing literature on progressive collapse mechanisms and connection behavior in steel frames.
- To develop 3D numerical models of steel frames with bolted and welded connections in ETABS.
- To apply the Alternate Path Method (APM) by simulating column removal at critical locations.
- To perform nonlinear static and dynamic analyses to evaluate displacement, internal forces, and energy absorption.
- To compare the progressive collapse performance of bolted and welded connections.
- To propose recommendations for connection detailing to enhance rob**ustness and prevent disproportionate failure.**

LITERATURE REVIEW

Damian Kukla[etal] (2025)

The structural response of two steel substructures in a beam-column-beam arrangement under accidental loads was studied in the experimental impact tests. Both versions of the bolted joint, the classic flush end-plate and the innovative one were tested with the same impact energy level applied by dropping the free-falling steel-concrete package.

Ismael García García[etal] (2025)

Demountable joints play a key role in enabling structural reuse and sustainable construction. By reducing material waste and facilitating future adaptability, they contribute to more resource-efficient building lifecycles. disassembly and structural reuse in alignment with circular economy principles. The proposed connection, composed of four angle cleats and welded studs, is evaluated through full-scale testing and validated finite element modelling. A validated numerical model was first developed using data from eight experimentally tested joints, achieving good agreement with measured rotational stiffness, with a mean absolute percentage error of 1.87 %. This model was then used to simulate an extended set of 23 configurations to investigate the influence of geometric parameters.

Akshay Udaysingh Yadavetal (2024)

Progressive collapse is a catastrophic failure mechanism that can lead to the sudden and widespread collapse of structural systems. Steel moment-resisting frames, particularly ordinary and intermediate moment frames, are commonly used in buildings due to their ability to resist lateral forces and provide stability. However, the resistance to progressive collapse in these frames is highly influenced by the design and detailing of the connections between structural elements. This review paper presents a comprehensive comparison of the progressive collapse resistance capacities of steel ordinary and intermediate moment frames, with an emphasis on the role of connection details.

Feiliang Wangetal (2020)

This paper presents experimental efforts in steel framed substructure with bolted flange plate (BFP) connections subjected to progressive collapse. A simplified modelling approach based on the shell element and ductile fracture criterion is introduced. The method shows a close correlation to the existing experimental data and demonstrates better computing efficiency than solid element based simulation strategy. A number of parametric studies were conducted based on the validated numerical method to evaluate the influence of varying connection configurations on the progressive collapse resistance of the steel substructures. It is indicated that the connection with welded flange plates can lead to greater flexural strength than that with bolted angles and the application of welded haunch plates can arrest fracture failure on the welds within the beam-column joint. Predictions are made for fracture potential of different connections in resisting progressive collapse.

Research Gap

Existing studies focus separately on bolted or welded joints, lacking direct comparison under identical progressive collapse scenarios. Most analyses neglect realistic semi-rigid behavior, dynamic effects, and strain-rate sensitivity influencing ductility and load redistribution. The transition from flexural to catenary action and the effect of connection detailing parameters remain poorly understood. Hence, a comprehensive comparative study using performance-based analysis is needed to evaluate bolted vs. welded connections for enhanced collapse resistance.

METHODOLOGY

Structural Configuration and Modeling

Model Type: 3D steel moment-resisting frame.
Geometry: Multi-storey (3 to 5 storeys), with regular bays (6 m) and storey height (3 m).
Material: Structural steel (E = 210 GPa, fy = 250–355 MPa).
Software: ETABS, SAP2000, or ABAQUS for detailed nonlinear analysis.
Boundary conditions: Base fixed; floor diaphragms rigid in-plane.

Connection Modeling

1. Bolted Joints: Modeled as semi-rigid connections using nonlinear spring or link elements with moment–rotation (M–θ) curves based on experimental data or design standards (AISC 358, Eurocode
2. Welded Joints: Modeled as fully rigid or partially restrained depending on detailing, with equivalent stiffness properties.
3. Connection nonlinearity and potential failure (slip, fracture, or yielding) are incorporated through plastic hinge or link element calibration.

Load Application

Gravity Loads: Dead load + 25% of live load (as per GSA 2016 guidelines for progressive collapse).
Lateral Loads: Applied as per IS 1893 (2016) or ASCE 7-16 for seismic design (optional comparison).
Load combinations as per IS 800 (2007) or AISC 360-22 provisions.

Column Removal Scenarios (Alternate Path Method)

Simulate sudden loss of critical columns to assess robustness:
1. Corner column removal.
2. Edge column removal.
3. Interior column removal.

The analyses are conducted one at a time to determine the ability of the remaining structure to redistribute loads and prevent progressive collapse.

ANALYSIS PROCEDURE

1. Perform Linear Static Analysis to understand initial load paths.
2. Conduct Nonlinear Static (Pushdown) Analysis following APM:
 Apply gravity loads up to design level.
 Remove target column suddenly.
 Incrementally increase vertical load until collapse (load–displacement curve).
3. Perform Nonlinear Dynamic Analysis for selected cases to capture inertia effects (optional).
4. Track plastic hinge formation, stress redistribution, and energy dissipation in joints and beams.

5. CONCLUDING REMARK

- A literature survey has been carried out to understand the existing research and identify knowledge gaps.
- The aim and objectives of the study have been clearly defined.
- The problem statement has been formulated based on the findings from the literature review.
- The research methodology has been outlined to guide the investigation effectively.
- A detailed research plan has been prepared to structure the overall study process.

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