EXTENDED ABSTRACT

Experimental investigation into distortional buckling behavior of web-tapered I-section steel beams under point load

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۱. Introduction

This research investigates the distortional buckling capacity in steel beams with variable web height under concentrated loads using both experimental and numerical approaches. Distortional buckling, a combination of local and lateral-torsional buckling, significantly influences the instability of thin-walled beams. In this study, three variable-height steel beam specimens were fabricated and tested. The results revealed that increasing the web height and continuous changes along the beam length significantly reduce the buckling capacity. Numerical analyses using ABAQUS also confirmed the experimental findings, highlighting the importance of geometric imperfections and loading types on buckling behavior. This study demonstrates that current code methods are insufficient for accurately predicting distortional buckling capacity and require improvement. Finally, suggestions for future research to improve analytical models and design methods are presented.

۲. Methodology

۲،۱ *Experimental Study*

Three variable web height steel beam specimens were fabricated and subjected to experimental testing. The beams were tested on a custom-built test rig with strain gauges installed according to predefined locations to measure deformation.

۲،۲ *Numerical Modeling*

Numerical simulations were conducted using ABAQUS software, with detailed modeling of geometric imperfections and boundary conditions. The simulations provided further insights into the buckling modes and deformation patterns observed in the experiments.

۳. Results and discussion

۳،۱ *Impact of Geometrical Parameters*

The experimental and numerical results revealed that geometric parameters, particularly the web height variation, significantly impact the buckling behavior of steel beams. In the tests, increasing the web height from 200 mm to 340 mm led to a considerable reduction in the distortional buckling capacity. The effect was more pronounced in beams with steeper web slopes, which amplified the interaction between local buckling modes and overall structural instability. This finding is consistent with previous studies that suggest non-prismatic beams are particularly sensitive to web height changes due to stress redistribution along the member.

Additionally, the presence of geometric imperfections, particularly initial out-of-plane deformations, played a crucial role in the initiation of distortional buckling. The experimental results showed that even minor deviations from the intended geometry can lead to earlier-than-predicted buckling failure, especially when the beams were subject to concentrated loading. In the numerical simulations, incorporating these imperfections further confirmed their impact on the overall buckling behavior.

The data from strain gauges installed along the length of the beams indicated non-uniform stress distribution, particularly near the points of maximum web height. As shown in Figure 1 for first tapered specimen, the web area experiences a combination of lateral displacement and local buckling near the peak loading region. This complex deformation is particularly evident in the beams with varying web thickness, which further exacerbates the non-uniform stress concentrations along the beam.

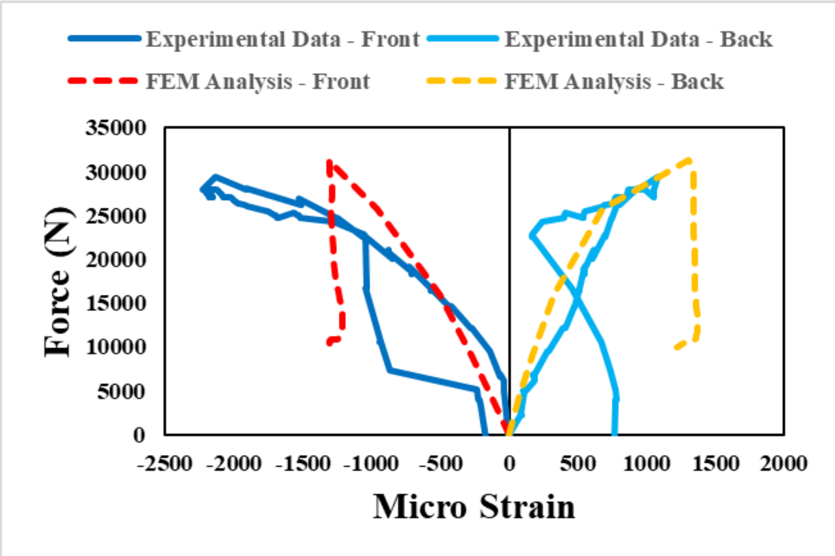

Fig. 1 Mocro strain results vs. load for EXSPT4

٣,٢ Numerical Analysis Findings

The numerical analysis using ABAQUS provided a deeper understanding of the buckling behavior observed during the experiments. Through a modal analysis, it was determined that the first buckling mode typically involved the compression flange and the adjacent web region, leading to distortional buckling. For beams with higher web slenderness, the initial mode was predominantly distortional buckling , where the displacement and rotation of the compression flange were linked to web instability.

The finite element models were calibrated using the experimental data, ensuring the accuracy of the numerical predictions. This allowed for an extensive parametric study on various geometric parameters, such as web height, web thickness, and flange width, providing insight into how each factor influences the onset of distortional buckling.

٤. Conclusions

This study provides a comprehensive evaluation of distortional buckling in steel beams with variable web height under concentrated loads. The key findings from both the experimental and numerical investigations are summarized as follows:

١. **Web Height Influence**: Increasing the web height significantly reduces the distortional buckling capacity of steel beams. This effect is particularly pronounced in non-prismatic beams where web height varies along the beam length. The experimental results demonstrate that the interaction between local buckling and distortional buckling is highly sensitive to changes in web geometry, particularly near the beam's maximum depth.

٢. **Geometric Imperfections**: Even slight imperfections in the initial geometry, such as web waviness or misalignment, drastically affect the buckling behavior. The numerical analysis confirmed that incorporating these imperfections into the models provides a more accurate prediction of the buckling modes and capacity.

٣. **Interaction of Buckling Modes**: The experimental data and the finite element analysis demonstrated that distortional buckling often occurs in tandem with other forms of instability, such as lateral-torsional buckling. In beams with steep web slopes, this interaction becomes more severe, leading to complex deformation patterns and earlier failure.

٤. **Parametric Design Equation**: The results of this research suggest the need for new or modified parametric design equations for predicting distortional buckling capacity in steel beams with variable web height. Current design codes, such as AISC, may not adequately account for the complex interactions between web geometry and buckling modes in non-prismatic beams. The proposed parametric equations derived from this study provide a more accurate tool for assessing distortional buckling, particularly in offshore and industrial applications where such beams are commonly used.

٥. **Future Research Directions**: Future studies should focus on expanding the database of experimental results for beams with varying web geometries and boundary conditions. Additionally, further research is needed to refine the parametric equations for design purposes and to investigate the effects of different loading conditions and support arrangements on distortional buckling capacity.

In conclusion, this research highlights the critical role that web geometry plays in the stability of steel beams under concentrated loads. The findings provide a basis for improving current design practices and ensuring the safe and efficient use of non-prismatic steel beams in structural applications.