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Experimental Evaluation of Modified T-Stub Connections for Seismic Applications

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ABSTRACT

This study aims to analyze the structural behavior of Modified T-Stub steel connections under cyclic loading, with the expectation that the results can be applied to steel construction in Indonesia, particularly for structures requiring high seismic performance. In this research, conventional 4ES and Double T-Connections were modified into Modified T-Stub configurations to improve their deformation capacity, strength, and energy dissipation performance. Experimental cyclic loading tests were conducted to evaluate the structural response of the modified connections, focusing on parameters such as strength, stiffness degradation, and drift capacity. **Two test specimens** were used, namely WF 450×200×9×14 and WF 500×200×10×16, which represent commonly used steel profiles in Indonesian construction practice. Numerical simulations were also performed to support and validate the experimental results. **The test results** indicate that both specimens exhibited stable hysteretic behavior and satisfactory performance under repeated cyclic loading. **The numerical analysis** showed that the connections were able to achieve drift ratios of up to 5% radian, while the experimental tests demonstrated drift capacities of approximately 4% radian without significant strength degradation or premature failure. **These findings** demonstrate that the Modified T-Stub connections meet the performance requirements for certified Special Moment Connections (SMC). This study provides valuable insights into the development of high-performance steel connection systems and contributes to enhancing the safety, efficiency, and structural quality of steel buildings in seismic regions of Indonesia.

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1. INTRODUCTION

Earthquake-resistant steel structure design is one of the crucial aspects of modern civil engineering, especially in regions with high seismic activity. Structural connections play a central role in ensuring the overall integrity of the system, as failure of the connections can significantly reduce the structure's deformation capacity and energy dissipation [1]. The T-Stub connection, which is a beam flange connection to a base plate or column, has been widely used due to its ability to withstand bending moments and axial forces [2]. However, the effectiveness of these connections under cyclic loading, which simulates real earthquake conditions, remains a topic requiring in-depth research to ensure they can meet the Special Moment Connection (SMC) criteria as stipulated in the latest earthquake design standards [3].

The impact of earthquakes on structures can have fatal consequences for structures made of steel.

Intensive research on the failure of steel structures due to the effects of earthquakes was conducted after the 1994 Northridge Earthquake. According to the FEMA-350 failure report, building failures with steel structures occurred beyond expected expectations, as the failures were caused by brittle connections [4, 5]. Generally, typical failures occur at the weld joints between the lower flange beam and the flange column, with the weld failure then developing into cracks in the flange column at the back of the weld joint. Additionally, in the world of construction practice, we are required to always innovate and create easily applicable methods to achieve good time and cost efficiency [6, 7]. The connection type approved in SNI 7972:2020 T-Double has become the connection used as a reference for modifying steel connections [8, 9]. The modification is done by changing the Double T-Weld connection on the lower beam flange and installing it with bolts on the beam flange [10, 11].

Various previous studies have examined the behavior of conventional T-Stub connections under static and cyclic loads [10, 12]. Experimental and numerical studies have shown that T-Stub connections can withstand bending moments up to a certain point before experiencing local yielding in the flange plates or connecting plates [13]. Research such as that conducted by [4] emphasizes the importance of plate thickness distribution and thread length in influencing the moment capacity and deformation of the connection [14]. Nevertheless, many of these studies are limited to standard T-Stub geometry and a limited range of parameter variations, so their application in SMC design in earthquake-prone regions still has limitations [15, 16].

Although previous research provided an initial understanding of the behavior of T-Stub connections, there is a significant gap regarding the performance of connections that have been modified to improve deformation capacity and energy dissipation under cyclic loading. The novelty of this research lies in its focus on the behavior of modified T-Stub connections under cyclic loading, with the explicit aim of evaluating their suitability against SMC prequalification criteria [17]. This approach considers not only the maximum moment capacity but also aspects of plastic rotation, energy dissipation, and connection failure behavior that may occur during real earthquake cycles. By combining experimental analysis and numerical simulations, this research is expected to provide more accurate and relevant data for the design of special moment connections in seismic environments [18].

The purpose of this research is to explore the behavior of modified T-Stub connections thru experimental testing under cyclic loading, in order to understand the connection's response to conditions that simulate real earthquakes. Additionally, this research aims to determine the prequalification criteria for modified T-Stub connections to meet the requirements of special moment connections, so that the results can be used as a reference in the design of safer and more effective earthquake-resistant steel structures [19]. The limitations of the study are as follows:

- Test object 1: WF column 588x300x12x20 and WF beam 450x200x9x14.
- Test object 2: WF column 588x300x12x20 and WF beam 500x200x10x16.
- Properties of ST41 steel material: fy = 300 MPa and fu = 400 MPa.
- Properties of A325M bolt material: fy = 660 MPa and fu = 830 MPa.
- Properties of E70xx weld material: fy = 57,000 psi and fu = 70,000 psi.
- Cyclic testing at the Housing and Settlement Engineering Directorate Laboratory of the Ministry of Public Works and Housing.

This research offers dual benefits the modified T-Stub connection can be applied as a special moment connection that meets prequalification criteria, while also providing an easier and more time-efficient method for installing steel beams. The implications of this research include improved safety and resilience of steel structures against earthquakes, efficiency in the construction process, and the potential for developing more practical and widely applicable special moment connection design standards for seismic engineering projects [20, 21]. The results of this research are expected to make a significant contribution from both academic and practical perspectives. From an academic perspective, this research fills an existing gap regarding the performance of modified T-Stub connections under cyclic loading and their evaluation against SMC criteria. From a practical standpoint, the results of this research can be used as a reference in the design of more reliable special moment connections, thereby improving the safety and resilience of steel structures against earthquakes.

2. LITERATURE REVIEW

There are 10 connections regulated prequalification in SNI 7972-2020 (AISC 358-16). Connection beam to inner steel column system frame bearer moment special and also intermediate must capable accommodate a minimum drift of 0.04 rad and resistance minimum flex 0.8 M.p from capacity moment plastic beam (SNI 7972, 2020).

Reference modify T-Stub connection taken from one of connection that is T-Double Connection. Connection with system wing molding columns and wings beam use T-Section profile crazy as well as addition plate single welded to the wing columns and bolted to the beam body as retainer style sliding. Detail of the Double T-Joint arranged in SNI is shown in Figure 1 and Figure 2. Melting zone and joints plastic planned occurs on the beam near T0Stab body tip.

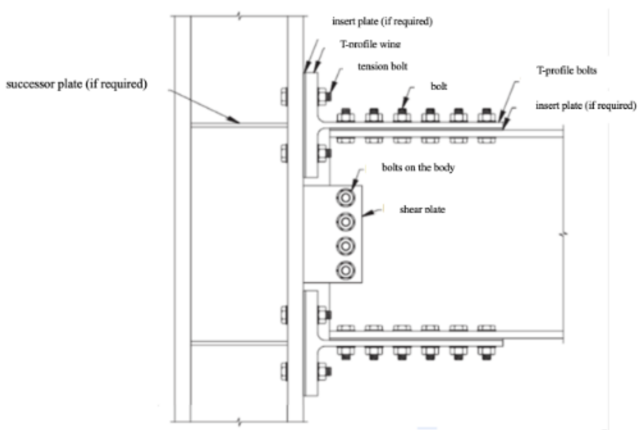

Figure 1. Connection Double T-Type
Source: (SNI 7972, 2020)

SNI does not limit use connection other types that do not listed, only just before connection used need existence a series of prequalification tests based on SNI 7860-2020 and approved by the authorized party. According to a number of journal research that discusses modification connection explain as following.

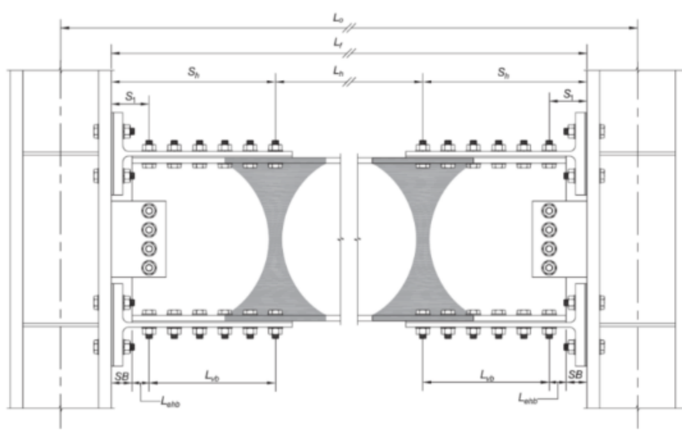

Figure 2. Shaded Image of Joint Zone plastic
Source: (SNI 7972, 2020)

Bolted Flange Plate (BFP) connections are modification connection moment special aiming For streamline cost construction and retaining style seismic [19, 22]. Based on results study all specimen fulfil AISC Seismic Provision criteria and a minimum drift of 0.06 rad [23, 24]. During bolt slip test happen more before and the slip-bearing deformation gives impact big to the total deformation [2, 3, 25]. Experimental connection to burden cyclic with specimen "24 bolted extended end-plate connection with haunches" conducted at Polytechnical University of Timisoara shows that connection plate end extension given bolt with elbow capable fulfil prequalification For application seismic and shows stable performance under loading cyclic [6, 26–28]. Another experiment regarding Double T-Connection is done modification with add Voute between connection use plate [29]. Test results show change behavior connection become more rigid and failure at first happen T-Wing tipping column become fail outside connection precisely on the beam [28, 30].

3. METHOD

This research was conducted using an experimental testing method that simulated cyclic loads on modified T-Stub connections. The specimens used were selected from high-strength steel profiles, making them suitable for earthquake-resistant construction.

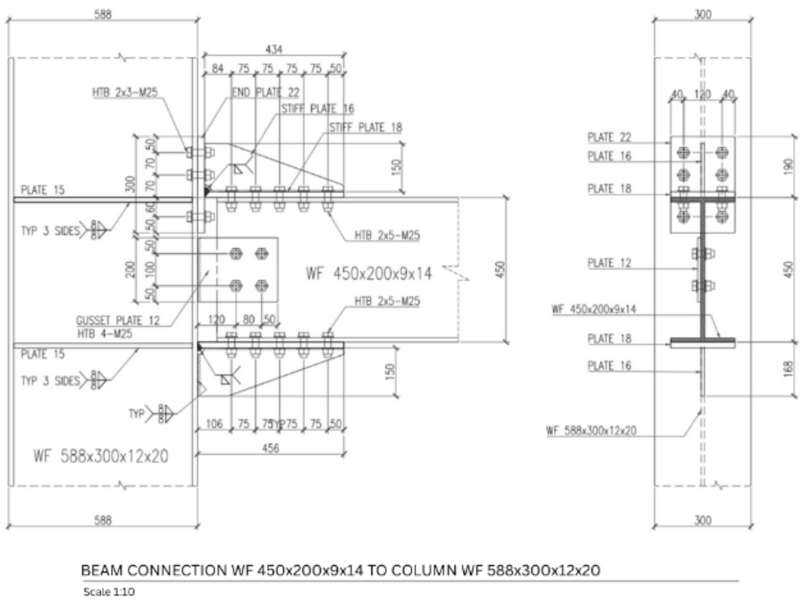

Figure 3. Details of Test Object Connection 1

The first test object consisted of a WF 588x300x12x20 column paired with a WF 450x200x9x14 beam, while the second test object used a column with the same specifications paired with a WF 500x200x10x16 beam, as shown in the following Figure 3.

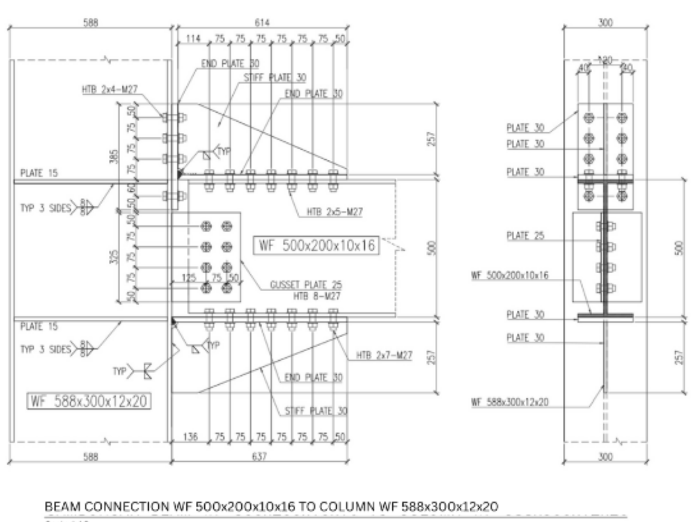

Figure 4. Details of Test Object Connection 2

Experimental testing was conducted by constructing complete physical models of specimens and test equipment, as shown in the following Figure 4. Each specimen, including beams, columns, and modified T-Stub joints, was thoroughly prepared and documented to ensure measurement accuracy and ease of replication [31–34]. The testing process took place at the Laboratory of the Directorate of Housing and Settlement Engineering Development, Ministry of Public Works and Public Housing, so that all procedures complied with technical standards and the results could be used as a valid reference for earthquake-resistant steel construction applications as shown in Figure 5.

Figure 5. Documentation Test Object Manufacturing

As shown in Figure 6 test tools used in experimental Modified T-Stub connection is made with series steel profile as a retaining frame test object with hydraulic autotator as implementation from burden earthquake at work [35, 36]. Instruments used in study experimental including, 25 Transducers Displacement Linear Variable (LVDT), 11 strain gauge and 2 cells burden [37, 38].

Figure 6. Test Object Specimen 1

As shown in Figure 7 LVDT 1 is used for measure maximum deformation for determine rotation on the T-Stub Modified Steel Connection. LVDT 2 to 25 is controller movement in the sample what is the test object? happen deformation to out of plane direction [38, 39]. Strain gauge for control strain on the plate and bolts. In the study This assumed that moment on T-Stub Modified Steel Connection [40, 41].

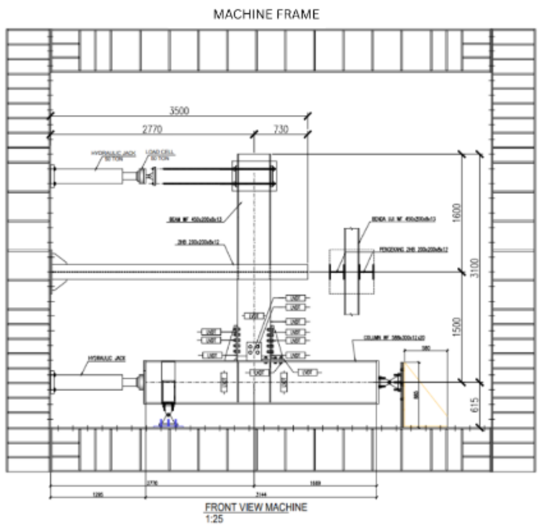

Figure 7. LVDT Installation

The main assumption in this study is that the moment at the modified T-Stub connection can be estimated based on the measured deformation and strain distribution [42–45]. With this approach, the study not only tests the practical performance of the connection, but also strengthens the theoretical understanding of the development of T-Stub connections in earthquake-resistant design, so that the results of the study can be an important reference for steel construction applications in Indonesia [46].

4. RESULT AND DISCUSSION

Research result in a way experimental Test object 1 obtained a drift ratio of 5% at the ultimate moment of 1,101 kN.m and test object 2 obtained a drift ratio of 4% at the ultimate moment of 712 kN.m. Documentation results testing displayed under this Figure 8.

Figure 8. Cyclic Test Results Test Object 1

As shown in Figure 9, the test results show that the first test object was able to achieve a drift ratio of 5% at an ultimate moment of 1,101 kN.m, while the second test object achieved a drift ratio of 4% at an ultimate moment of 712 kN.m [3, 7, 47]. This difference indicates that the dimensions of the beam affect the moment capacity of the connection, with specimens with smaller beam profiles exhibiting higher moment capacities under ultimate conditions [48]. Nevertheless, both specimens were able to withstand considerable cyclic deformation before reaching failure, proving that the modified T-Stub connection has good toughness in resisting seismic loads [49]. These findings provide evidence that T-Stub modification can be an effective design alternative to improve the performance of steel connections in earthquake-resistant construction [50].

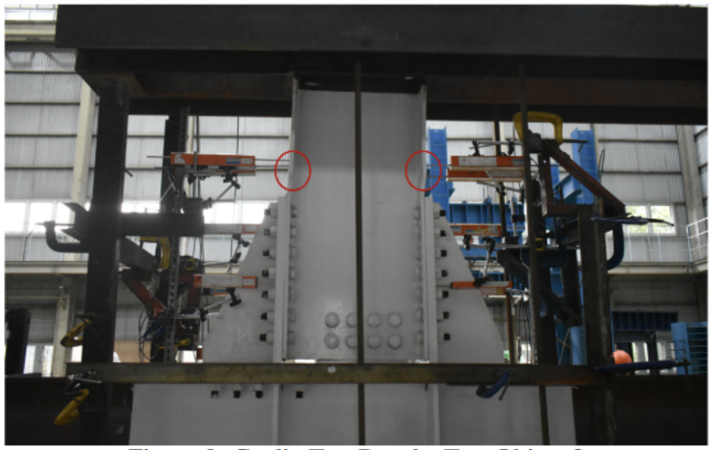

Figure 9. Cyclic Test Results Test Object 2

Based on Figure 10 testing connection with loading cyclic can see happen failure as planned. Joint zone plastic formed outside Modified T-Stub connection and connection Still in the same shape No show failure. Following is output curve result hysterical connection test specimens 1 and 2 due to loading cyclic.

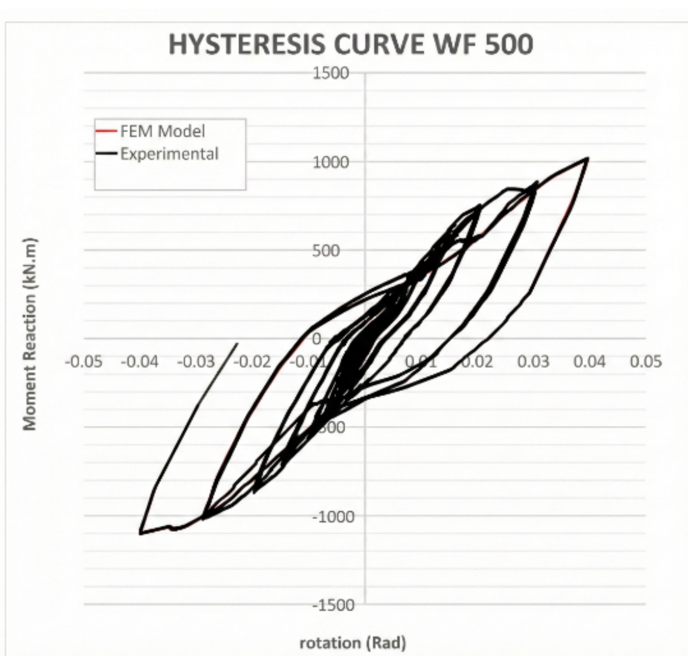

Figure 10. Documentation LVDT Transducer Installation

Hysteresis analysis shows in Figure 11 a plastic zone forms outside the Modified T-Stub joint, while the joint itself retains its shape without failure. This finding indicates that joints designed for specific moments tend to deform in controlled weak zones, thereby keeping the main joint intact and safe. This confirms that the modified T-Stub successfully directs deformation energy to the desired area, increasing the joint's energy dissipation capacity under seismic loads.

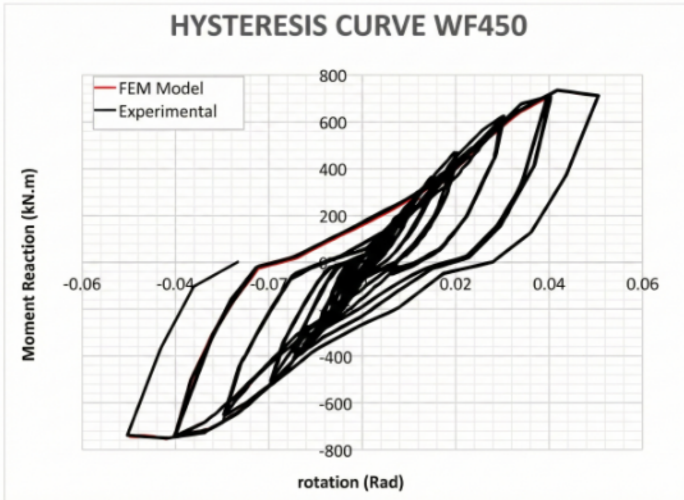

Figure 11. Documentation LVDT Transducer Installation

Backbone graph output indicates the peak load experienced by the actuator and the corresponding failure load of the test specimen. Based on shown in Figure 12, the experimental results for Test Object 1, the maximum load recorded reached 179 kN, which represents the highest load-bearing capacity before structural degradation or melting occurred.

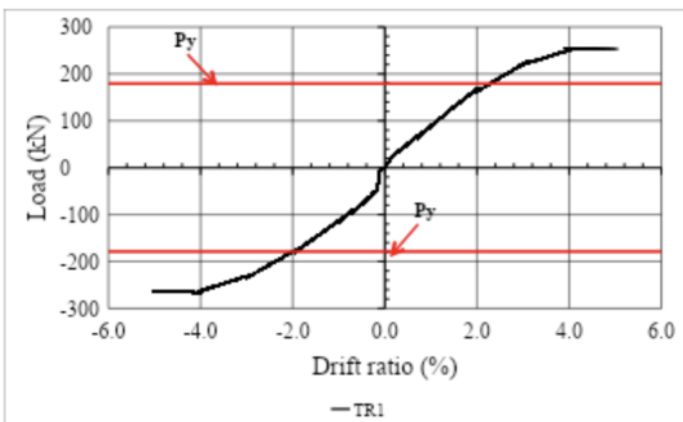

Figure 12. Graphic of Object Backbone Test Object 1

Backbone graph output is obtained peaks load on the actuator and load melting on test object 1 result experimental of 179 kN. Based on Figure 13, the numerical data processing ductility connection known from the maximum drift ratio melting limit final shared with a minimum drift ratio limit melt first on steel material. Ductility value 0.06/0.006 = 10.

The results of the backbone curve from the testing show a peak load on the actuator of 179 kN for test object 1 and 224 kN for test object 2. This difference indicates the influence of beam size on the ultimate load capacity of the joint. Further analysis of the numerical data shows a joint flexibility value of 10, calculated from the ratio of the maximum displacement at the final yield limit (0.06) to the first yield limit at the minimum displacement ratio (0.006). These results indicate that the connection has a high deformation capacity before failure, consistent with the characteristics of flexible yet strong special moment connections [51]. Furthermore, the connection's behavior of maintaining its shape without significant damage also shows that the modification to the T-Stub successfully improved structural performance. Previous studies, such as those by [52, 53], have emphasized the importance of plastic distribution outside the joint to enhance energy dissipation capacity and overall structural stability. The findings of this study reinforce this concept, while also demonstrating that modified T-Stub connections can be safely applied to earthquake-resistant steel structures in Indonesia.

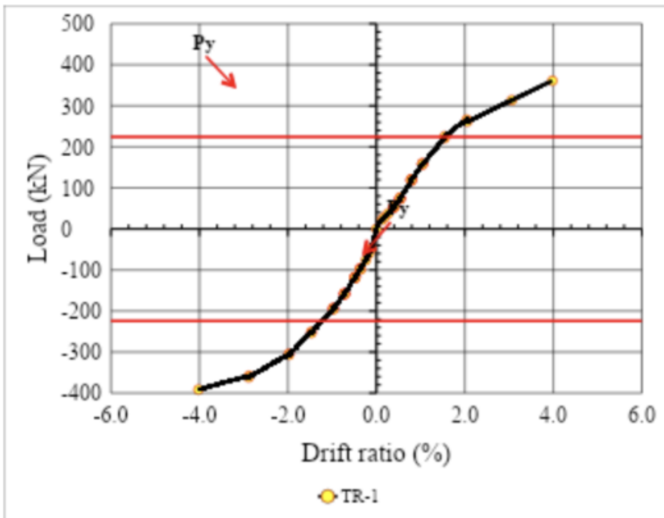

Figure 13. Graphic of Object Backbone Test Object 2

In conclusion, the research results indicate that the modified T-Stub connection not only meets the SMC prequalification criteria but also exhibits good energy dissipation capacity, high flexibility, and predictable performance. This finding provides a strong foundation for the application of modified T-Stub connection designs in modern steel construction projects, while also offering relevant experimental evidence for the development of local standards and a reference for future studies on earthquake-resistant connection design.

5. MANAGERIAL IMPLICATION

The findings of this experimental study provide several important managerial implications, particularly for decision-makers involved in structural design, construction management, and seismic risk mitigation in building projects. The proven performance of the Modified T-Stub connection in achieving the requirements of Special Moment Connection (SMC) prequalification offers practical guidance for engineers, project managers, and construction firms in selecting reliable and code-compliant connection systems for seismic-resistant structures.

From a design management perspective, the demonstrated ability of the connection to sustain drift ratios exceeding the minimum requirement of 4% rad allows structural designers greater flexibility in optimizing beam column configurations without compromising seismic performance. This flexibility can contribute to more efficient structural layouts, reduced overdesign, and better allocation of material resources, ultimately leading to cost-effective construction solutions while maintaining safety standards.

In terms of construction and project execution, the Modified T-Stub connection presents advantages related to constructability and quality control. The predictable plastic hinge formation in the beam region reduces the likelihood of brittle failure at the column or connection interface, minimizing the risk of unexpected damage during seismic events. For project managers, this behavior translates into reduced post-earthquake repair costs, shorter recovery time, and improved building resilience, which are critical factors in lifecycle cost management.

Finally, the successful prequalification of the Modified T-Stub connection encourages its adoption in standard design practice and supports its inclusion in organizational design guidelines or construction specifications. For policymakers and engineering managers, these results can serve as empirical evidence to support updates to internal standards, promote innovation in seismic connection design, and enhance overall structural safety performance in future building developments.

6. CONCLUSION

The experimental test results demonstrate that plastic deformation in the connection joints predominantly occurred in the beam region, specifically after the end-plate connection, indicating that the intended strong-column weak-beam mechanism was successfully achieved. This behavior confirms that the plastic hinge formed away from the column face, thereby reducing the risk of brittle failure at the connection zone and enhancing the overall ductility of the structural system. The drift ratio observed during the experimental testing varied between the two test specimens. Test Object 1 reached a maximum drift ratio of 5% rad, while Test Object 2 achieved a slightly lower drift ratio of 4% rad. These drift ratios indicate the ability of the connection system to undergo significant inelastic deformation while maintaining structural integrity under cyclic loading conditions. The difference in drift capacity between the two specimens may be attributed to variations in connection configuration, material properties, or energy dissipation characteristics.

In terms of flexural capacity, Test Object 1 exhibited a plastic moment capacity (Mp) of 503 kN·m and an ultimate moment capacity (Mu) of 1,101 kN.m, demonstrating a substantial reserve strength beyond the plastic limit. Meanwhile, Test Object 2 showed a plastic moment capacity of 601 kN.m and an ultimate moment capacity of 712 kN.m. These results suggest differing post-yield behavior and stiffness degradation patterns between the two specimens, as reflected in their respective hysteresis responses.

Furthermore, the hysteresis curves obtained from both experimental tests exhibited stable and symmetric behavior with adequate energy dissipation capacity and limited strength degradation up to the target drift levels. The backbone and hysteresis plots confirm that the Modified T-Stub connection system satisfies the requirements for Special Moment Connection (SMC) Prequalification, particularly in meeting the minimum drift ratio requirement of 4% rad as stipulated by relevant seismic design provisions. Consequently, the Modified T-Stub connection can be considered suitable for application in seismic-resistant moment-resisting frame structures.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: TA, AN, and SM; Methodology: TA, AN and SM; Software: TA, and AN Formal Analysis: TA, AN, and SM; Investigation: TA, AN and SM; Resources: TA, SM, and AN; Data Curation: AN, SM and TA; Writing Original Draft Preparation: TA and SM; Writing Review and Editing: TA, AN, and SM; Visualization: TA, AN, and SM; All authors, TA, AN, and SM have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The datasets used to support the findings of this study are available from the direct link in the dataset citation.

7.4. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

[1] S. S. Shareef, "Earthquake consideration in architectural design: Guidelines for architects," *Sustainability*, vol. 15, no. 18, p. 13760, 2023.

[2] L. M. Bezerra, J. Bonilla, C. S. Freitas, and B. Massicotte, "Behavior of t-stub steel connections bolted to rigid bases," *Journal of Constructional Steel Research*, vol. 192, p. 107242, 2022.

[3] J. J. J. de Cisneros Fonfría, A. M. G. Amador, A. Q. Gonzalez, and L. P. Fernandez, "Investigating the t-stub connection with different web-to-flange joint configurations," *Engineering Structures*, vol. 294, p. 116715, 2023.
[4] J. Su, J. Zhou, W. Liu, Y. Li, H. Yu, and Q. Li, "Study on damage index for beam–column joints with flush end-plate connections," *Buildings*, vol. 14, no. 11, p. 3637, 2024.
[5] S. Pratama and L. A. M. Nelloh, "Leveraging influencer marketing in higher education: Key roles, sectors, platforms, and influencer types for institutional branding," *Startupreneur Business Digital (SABDA Journal)*, vol. 4, no. 2, pp. 134–145, 2025.
[6] Y. Wang, L. Sun, P. Wang, G. Hou, X. Cai, and M. He, "Feasibility study of tsob replacing standard high-strength bolt in t-stub connection," in *Structures*, vol. 62. Elsevier, 2024, p. 106246.
[7] B. Meng, D. Qiangqiang, W. Zhong, Z. Tan, and K. You, "Tensile resistance and deformation of novel bending t-stub connections against progressive collapse," *Journal of Constructional Steel Research*, vol. 201, p. 107733, 2023.
[8] Y.-F. Zhang, J.-h. Zhang, and K. Demoha, "Further analysis on mechanical behaviors of blind-bolted t-stub connections to cfdst columns," in *Structures*, vol. 48. Elsevier, 2023, pp. 1964–1976.
[9] C. Lukita, M. Hardini, S. Pranata, D. Julianingsih, and N. P. L. Santoso, "Transformation of entrepreneurship and digital technology students in the era of revolution 4.0," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 5, no. 3, pp. 291–304, 2023.
[10] P. Wang, L. Sun, C. Xia, H. Gu, Y. Liu, M. Liu, and F. Liu, "Cyclic behavior of t-stub connection to hollow section steel column using tsobs," *Journal of Constructional Steel Research*, vol. 185, p. 106874, 2021.
[11] R. A. Sunarjo, M. H. R. Chakim, S. Maulana, and G. Fitriani, "Management of educational institutions through information systems for enhanced efficiency and decision-making," *International Transactions on Education Technology (ITEE)*, vol. 3, no. 1, pp. 47–61, 2024.
[12] G. J. Berrospi Aquino, A. M. Gómez Amador, J. H. Alencastre Miranda, and J. J. Jiménez de Cisneros Fonfría, "A review of the t-stub components for the analysis of bolted moment joints," *Applied Sciences*, vol. 11, no. 22, p. 10731, 2021.
[13] T. Li, J. Men, Q. Zhang, J. Li, and C.-H. Huang, "Seismic fragility and resilience assessment of steel frame with replaceable t-stub connection components," *Engineering Structures*, vol. 314, p. 118396, 2024.
[14] M. Atar and B. Çete, "Enhancing structural resilience: Exploring the novel sleeve method for steel t-stub connections," *Fırat Üniversitesi Mühendislik Bilimleri Dergisi*, vol. 36, no. 1, pp. 147–158, 2024.
[15] J. Feng, J. Jin, J. Xia, and Y.-Z. Fang, "Experimental study on seismic performance of pec composite column-steel beam frame with welded t-stub strengthened connections," *Advanced Steel Construction*, vol. 17, no. 3, pp. 264–272, 2021.
[16] R. Herrera, E. Nunez, and M. Hernández, "Seismic-resistant performance of double built-up t moment connections," *Journal of Structural Engineering*, vol. 151, no. 1, p. 04024193, 2025.
[17] M. Hardini, H. Hetilaniar, S. E. E. Girsang, S. N. W. Putra, and I. N. Hikam, "Advancing higher education: Longitudinal study on ai integration and its impact on learning," *International Journal of Cyber and IT Service Management*, vol. 5, no. 1, pp. 23–30, 2025.
[18] D. Dinarwati, M. G. Ilham, and F. Rahardja, "Cybersecurity risk assessment framework for blockchain-based financial technology applications," *ADI Journal on Recent Innovation*, vol. 6, no. 2, pp. 168–179, 2025.
[19] B. Meng, K. You, B. Yang, D. Kong, and J. Wen, "Anti-progressive collapse performance and design method of novel t-stub connections," *Engineering Structures*, vol. 319, p. 118880, 2024.
[20] Q. Aini, P. Purwanti, R. N. Muti, E. Fletcher *et al.*, "Developing sustainable technology through ethical ai governance models in business environments," *ADI Journal on Recent Innovation*, vol. 6, no. 2, pp. 145–156, 2025.
[21] C. Lukita, S. Suwandi, E. P. Harahap, U. Rahardja, and C. Nas, "Curriculum 4.0: Adoption of industry era 4.0 as assessment of higher education quality," *IJCCS (Indonesian Journal of Computing and Cybernetics Systems)*, vol. 14, no. 3, pp. 297–308, 2020.
[22] W. khaleel Nayel, I. H. Nayel, A. Zohdi, and A. Ghamari, "Improving the conxl connection behavior using t-stub fragments," *Steel and Composite Structures*, vol. 57, no. 1, p. 077, 2025.
[23] Ö. Y. Onuralp, "Post-fire behavior of thin-plated unstiffened t-stubs connected to rigid base," *Buildings*, vol. 15, no. 22, p. 4113, 2025.

[24] A. Pambudi, N. Lutfiani, M. Hardini, A. R. A. Zahra, and U. Rahardja, "The digital revolution of startup matchmaking: Ai and computer science synergies," in *2023 Eighth International Conference on Informatics and Computing (ICIC)*. IEEE, 2023, pp. 1–6.
[25] M. Gillieaux *et al.*, "Steel joint ductility-coupling and membrane effects in adjacent t-stubs," 2025.
[26] X. Huang, Z. Zhou, R. Li, Z. Wang, J. Zhao, and Y. Shen, "Fracture prediction and structural enhancement of ly225-steel t-stub joints using a continuous-damage-model," *Journal of Constructional Steel Research*, vol. 231, p. 109599, 2025.
[27] S. Xiao, X. Bu, Y. Chen, and X. Wang, "Investigating the damage-based seismic performance of the blind bolt-connected steel framework," in *Structures*, vol. 69. Elsevier, 2024, p. 107388.
[28] S. Oliveira, R. Costa, A. F. Santos, L. S. da Silva, Y. Harada, and V. Piluso, "A decoupled t-stub component model for the cyclic modelling of steel joints," *Journal of Constructional Steel Research*, vol. 209, p. 108044, 2023.
[29] Y. Shen, M. Li, and Y. Li, "Surrogate-based calibration and prediction of hysteretic model parameters for steel beam-column bolted t-stub connections," *Journal of Building Engineering*, vol. 103, p. 112082, 2025.
[30] H. Zhao, L.-H. Sun, H.-B. Chen, and X.-G. Liu, "Numerical investigation on the pulling resistant capacity of steel beam-concrete wall joints with t-stub connectors," *Buildings*, vol. 13, no. 2, p. 566, 2023.
[31] A. Hermawan, W. Sunaryo, and S. Hardhienata, "Optimal solution for ocb improvement through strengthening of servant leadership, creativity, and empowerment," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 5, no. 1Sp, pp. 11–21, 2023.
[32] Y. Chen, X. Bu, B. Shen, X. Yin, X. Wang, Q. Huang, and Z. Zhang, "Seismic performance testing and damage analysis of reinforced t-stub connections," *Buildings*, vol. 15, no. 22, p. 4112, 2025.
[33] S. Yuliani, T. Hidayat, H. Herawaty, and Hernani, "Characteristics of cocoa drinks formulated with nanoencapsulated vitamin and mineral," in *AIP Conference Proceedings*, vol. 2957, no. 1. AIP Publishing LLC, 2024, p. 060058.
[34] K. Roy, H. Rezaeian, Z. Fang, G. M. Raftery, and J. B. Lim, "Experimental and numerical study of a novel cold-formed steel t-stub connection subjected to tension force," *Journal of Constructional Steel Research*, vol. 197, p. 107466, 2022.
[35] R. Tartaglia, M. D'Aniello, and M. Zimbru, "Experimental and numerical study on the t-stub behaviour with preloaded bolts under large deformations," in *Structures*, vol. 27. Elsevier, 2020, pp. 2137–2155.
[36] X. Guo, P. Kyvelou, J. Ye, and L. Gardner, "Experimental investigation of wire arc additively manufactured steel t-stub connections," *Journal of Constructional Steel Research*, vol. 211, p. 108106, 2023.
[37] R. Khani, Y. Hosseinzadeh, M. D'Aniello, and M. H. Asl, "Nonlinear response of coupled and tied-to-rigid base t-stub connections," *Journal of Constructional Steel Research*, vol. 215, p. 108550, 2024.
[38] X.-C. Liu, Y.-N. Zhu, X. Chen, and Y.-M. Li, "Seismic performance of bolted double-web t-stub connections with t-shaped steel column," *Journal of Constructional Steel Research*, vol. 191, p. 107168, 2022.
[39] R. Khani, Y. Hosseinzadeh, and M. H. Asl, "Investigating the prying force magnitude and location in the t-stub connection based on the energy method," *Engineering Structures*, vol. 280, p. 115655, 2023.
[40] G. Kendall, A. Belyi, and A. Elkady, "Experimental investigation of welded steel t-stub components under high loading rates," *Journal of Constructional Steel Research*, vol. 220, p. 108851, 2024.
[41] J. Wilson and E. Erika, "Empowering eco-innovation through digitalization in startup enterprises," *Startupreneur Business Digital (SABDA Journal)*, vol. 4, no. 2, pp. 146–154, 2025.
[42] H. Saberi, A. Kheyroddin, and M. Gerami, "Welded haunches for seismic retrofitting of bolted t-stub connections and flexural strengthening of simple connections," *Engineering Structures*, vol. 129, pp. 31–43, 2016.
[43] H. Derakhshan and B. Shekastehband, "Seismic performance of bolted t-stub beam-to-box column connection," in *Structures*, vol. 56. Elsevier, 2023, p. 104873.
[44] N. Lutfiani, D. A. Astrieta, V. Wildan, H. Sulistyaningrum, M. R. Anwar, and E. D. Astuti, "Emotional well-being and psychological support in infertility a multi-modal ai approach," *International Journal of Cyber and IT Service Management*, vol. 5, no. 1, pp. 81–92, 2025.
[45] P. Wang, Y. You, Q. Wang, H. Gu, G. Wang, Y. Liu, and F. Liu, "Post-fire tensile behavior of hole-anchored bolted t-stub connection," *Journal of Constructional Steel Research*, vol. 187, p. 106941, 2021.
[46] G. Xu, B. Lin, and Y. Du, "Residual capacity of friction-type high-strength bolted t-stub connection with nut corrosion damage," *J. Harbin Inst. Tech*, vol. 30, no. 3, pp. 68–84, 2023.

[47] S. Dhamane, S. K. Mushahary, and K. D. Singh, "Experimental study on s700 t-stub in heating and cooling during fire," *Thin-Walled Structures*, vol. 195, p. 111342, 2024.

[48] J. J. Jiménez de Cisneros, A. M. Gómez Amador, A. Quesada González, and L. Prieto Fernández, "Investigating the t-stub connection with different web-to-flange joint configurations," 2023.

[49] T. J. de la Croix Kombate and K. Taşkın, "State-of-the-art review on the behaviour of t-stubs and prying action," *Journal of Constructional Steel Research*, vol. 191, p. 107203, 2022.

[50] Y. MC *et al.*, "Numerical analysis on bolted t-stub to square hollow section connections under tension," in *Proceedings of the International Conference on Systems, Energy and Environment*, 2022.

[51] P. S. Yuana, M. Moestopo, D. Kusumastuti, and M. Suarjana, "Development of beam-column connection in special moment-resisting frame steel structures," in *International Conference on Architecture and Civil Engineering Conference:*. Springer, 2023, pp. 869–877.

[52] X. Liu, Z. Hao, X. Luo, and Z. Jin, "Experimental behavior and modelling of steel bolted t-stub connections," *Buildings*, vol. 13, no. 3, p. 575, 2023.

[53] S. Ebrahimi, S. R. Mirghaderi, and S. M. Zahrai, "Beam-to-gusset plate connection using a new method to shift the plastic hinge to the outside of the connection," *Journal of Structural Design and Construction Practice*, vol. 30, no. 1, p. 04024088, 2025.