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**Evaluasi Kinerja Seismik Dan Retrofitting Bangunan Industri Baja Menggunakan Sistem Rangka Bresing
Konsentris Khusus (RBKK) Tipe X**
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INTISARI

Bangunan industri baja bertingkat yang direncanakan sebelum pemberlakuan standar ketahanan gempa terkini berpotensi tidak memenuhi persyaratan kinerja seismik yang berlaku. Penelitian ini bertujuan untuk mengevaluasi kinerja seismik struktur baja eksisting, merancang solusi *retrofitting* dengan sistem Rangka Bresing Konsentris Khusus (RBKK), menganalisis kapasitas elemen pasca-*retrofitting*, serta pemeriksaan sambungan *bresing* ke *gusset plate* berdasarkan prinsip *capacity design*.

Objek penelitian adalah Bangunan Industri tiga lantai di Semarang dengan dimensi bangunan 171 m × 51 m, ketinggian antar lantai sebesar 8 m, dan puncak bangunan berada pada elevasi 27,325 m. Struktur eksisting merupakan struktur baja yang telah dilengkapi bresing konsentris pada *bay* tertentu, namun distribusi dan jumlah bresing tersebut belum mencukupi untuk memenuhi kebutuhan kekakuan lateral standar gempa terkini. Analisis struktur dilakukan secara tiga dimensi menggunakan ETABS dengan metode respons spektrum sesuai SNI 1726:2019. Kelas situs SE digunakan sebagai kelas situs *default* mengingat tidak tersedianya data penyelidikan tanah spesifik di lokasi, sesuai ketentuan SNI 1726:2019 Pasal 5.1 yang mensyaratkan pemilihan kondisi tanah terburuk sebagai pendekatan konservatif apabila sifat tanah tidak teridentifikasi secara jelas.

Evaluasi kondisi eksisting menemukan nilai simpangan yang melebihi batas izin dan sejumlah elemen dengan *Demand Capacity Ratio* (DCR) > 1,0. Untuk mengatasi permasalahan tersebut, diusulkan dua alternatif *retrofitting* berupa penambahan *bay* bresing tipe X yang dibedakan berdasarkan lokasi distribusinya. Alternatif 1 menambahkan *bay* bresing pada *core* dan tepi bangunan, sedangkan Alternatif 2 memusatkan penambahan *bay* bresing pada sisi tepi bangunan; hasil evaluasi kinerja menetapkan Alternatif 2 sebagai alternatif terpilih karena memenuhi seluruh kriteria kinerja SNI sekaligus memberikan penambahan berat minimum sebesar 23,16 kN, atau 31,3% lebih efisien dibandingkan Alternatif 1. Kapasitas elemen pasca-*retrofitting* menghasilkan DCR tekan bresing 0,911, interaksi aksial-lentur kolom 0,603, dan DCR lentur balok 0,297. Sambungan bresing ke *gusset plate* menggunakan dinyatakan memenuhi kapasitas geser baut, tumpu, *block shear*, penampang Whitmore, dan persyaratan zona engsel $2t_g$, dengan rasio kegagalan (DCR) maksimum sebesar 0,959 terjadi pada kondisi batas las slot. Penambahan *bay* bresing tipe X dengan sistem RBKK secara selektif pada sisi tepi bangunan terbukti efektif meningkatkan kinerja seismik bangunan industri baja eksisting dengan gangguan operasional yang minimal.

Kata kunci: *retrofitting* struktur baja, RBKK, bresing tipe X, *capacity design*, *gusset plate*, ETABS

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ABSTRACT

Multi-story industrial steel buildings designed prior to the enforcement of current seismic resistance standards have the potential to fail to meet the required seismic performance criteria. This study aims to evaluate the seismic performance of the existing steel structure, design a retrofitting solution using a Special Concentrically Braced Frame (SCBF) system, analyze the capacity of elements post-retrofitting, and inspection the brace-to-gusset plate connection based on the capacity design principle.

The object of this study is a three-story industrial building in Semarang, with a plan dimension of 171 m x 51 m, an inter-story height of 8 m, and a roof elevation of 27.325 m. The existing structure is a steel frame already equipped with concentric bracing in certain bays; however, the distribution and number of these braces are insufficient to meet the lateral stiffness and high-ductility classification requirements of the current seismic standard. Structural analysis was performed three-dimensionally using ETABS with the response spectrum method according to SNI 1726:2019. Site Class SE is used as the default site class given the unavailability of site-specific soil investigation data, in accordance with SNI 1726:2019, which requires selecting the worst soil condition as a conservative approach when soil properties cannot be clearly identified. Connection design followed SNI 7860:2020 Section F2, using design forces based on the expected strength.

The evaluation of the existing condition found several members with a Demand Capacity Ratio (DCR) > 1.0 and slender sections that failed the high-ductility classification. To address these issues, two retrofitting alternatives were proposed, both involving the addition of X-type braced bays under the SCBF system, differentiated by their distribution location. Alternative 1 adds braced bays at the core of the building, while Alternative 2 concentrates the added braced bays on the building perimeter; the performance evaluation results established Alternative 2 as the selected alternative because it satisfied all SNI performance criteria while providing a minimum weight addition of 23.16 kN, or 31.3% more efficient than Alternative 1. Post-retrofitting capacity checks yielded a maximum brace compressive DCR of 0.911, a column axial-flexural interaction of 0.603, and a beam flexural DCR of 0.297. The brace-to-gusset plate connection, using A325 M30 bolts in a 3x3 configuration, was found to satisfy the bolt shear capacity, bearing, block shear, Whitmore section, and 2tg hinge zone requirements, with a maximum failure ratio (DCR) of 0.959 occurring at the slot weld limit condition. The selective addition of X-type braced bays with the SCBF system along the building perimeter proved effective in improving the seismic performance of the existing industrial steel building with minimal operational disruption.

Keywords**:** *steel structure retrofitting,* SCBF*, X-type bracing, capacity design, gusset plate,* ETABS