COMPARATIVE STUDY OF THE
BEHAVIOR OF REDUCED BEAM
SECTION RIGID CONNECTIONS

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INTRODUCTION

COMPARATIVE STUDY OF THE BEHAVIOR OF REDUCED BEAM SECTION RIGID CONNECTIONS

BACKGROUND


Failure in the conventional beam-column connection showed that steel moment frames wasn’t as ductile as believed

After years of research, it produced new types of connection, one of them is RBS (Reduced Beam Section) connection

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**INTRODUCTION**

**COMPARATIVE STUDY OF THE BEHAVIOR OF REDUCED BEAM SECTION RIGID CONNECTIONS**

**RBS?**

- **What**
  - Reduced the section of the beam flange near of the connection area.

- **Why**
  - The concept is to weakening the beam, which effectively make the connection area stronger than the beam.

- **Purpose**
  - Plastic hinges are expected to be formed in the RBS area.

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- \( a = 0.50 - 0.75 \, b_f \)
- \( b = 0.65 - 0.85 \, d_b \)
- \( c \leq 0.25 \, b_f \)
- \( s = a + b/2 \)
- \( r = (4c^2 + b^2) / 8c \)

EC 8. Part 3 [13]

- \( a = 0.60 \, b_f \)
- \( b = 0.75 \, d_b \)
- \( g \leq 0.25 \, b_f \)
- \( s = a + b/2 \)
- \( r = (4g^2 + b^2) / 8g \)
INTRODUCTION

COMPARATIVE STUDY OF THE BEHAVIOR OF REDUCED BEAM SECTION RIGID CONNECTIONS

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LOAD

PLASTIC HINGE

Conventional Portal
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PORTAL WITH RBS

PLASTIC HINGE

RBS
• Plastic Hinge will be formed in the RBS area.
• RBS could increasing the inelastic drift by 9% corresponding to a flange reduction of 50% (FEMA 350, 2011)
• With radius-cut RBS, which is using angular cut, cracks would tend to develop when the beams are subjected to large forces (Engelhardt, 1995)
Rigid Connections are kind of connections which have enough rigidity to keep the angle between the elements joint. Then, rigid connections could transfer significant moment to the columns and are assumed that there is no deformations.

**TYPES OF RIGID CONNECTIONS IN THIS RESEARCH**

- T-CONNECTION
- EXTENDED END PLATE CONNECTION
- WELDED RIGID CONNECTION

**REFERENCE:**
SIMPLE CONNECTION (D.T. Pachoumis, 2009)
This research aim to compare the behaviour (deformation, displacement, stress, and strain) of 4-types rigid connections, which all using RBS (Reduced Beam Section) at column face.

TYPES OF RIGID CONNECTIONS IN THIS RESEARCH:
- T-CONNECTION
- EXTENDED END PLATE CONNECTION
- WELDED RIGID CONNECTION

REFERENCE:
SIMPLE CONNECTION (D.T. Pachoumis, 2009)
METHODOLOGY

COMPARATIVE STUDY OF THE BEHAVIOR OF REDUCED BEAM SECTION RIGID CONNECTIONS

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Depth</th>
<th>Width</th>
<th>Thickness</th>
<th>r (mm)</th>
<th>A (cm²)</th>
<th>W (kg/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balok 1 (HE200A)</td>
<td>190</td>
<td>200</td>
<td>6.5</td>
<td>10</td>
<td>18</td>
<td>53.8</td>
</tr>
<tr>
<td>Balok 2 (HE220A)</td>
<td>210</td>
<td>220</td>
<td>7</td>
<td>11</td>
<td>18</td>
<td>64.3</td>
</tr>
<tr>
<td>Balok 3 (HE240A)</td>
<td>230</td>
<td>240</td>
<td>7.5</td>
<td>12</td>
<td>21</td>
<td>76.8</td>
</tr>
<tr>
<td>Kolom (HE300B)</td>
<td>300</td>
<td>300</td>
<td>11</td>
<td>19</td>
<td>27</td>
<td>149.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Depth</th>
<th>Width</th>
<th>Thickness</th>
<th>Zₓ (mm³)</th>
<th>Z_RBS (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balok 1 (HE200A)</td>
<td>190</td>
<td>100</td>
<td>6.5</td>
<td>406962.5</td>
<td>226962.5</td>
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<tr>
<td>Balok 2 (HE220A)</td>
<td>210</td>
<td>110</td>
<td>7</td>
<td>543432</td>
<td>302642</td>
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<tr>
<td>Balok 3 (HE240A)</td>
<td>230</td>
<td>120</td>
<td>7.5</td>
<td>707407.5</td>
<td>393487.5</td>
</tr>
</tbody>
</table>

Dimension of beam and column

Design of RBS (50% cut)
- Plastic Section Modulus of RBS: 
  \[ Z_{RBS} = 2(t_w \cdot \left(\frac{1}{2} \cdot d_b - t_f\right)^2 \cdot \frac{1}{2} + t_f \cdot b_f \cdot \left(\frac{1}{2} \cdot h - \frac{1}{2} \cdot t_f\right) \]

- Plastic moment in RBS area: 
  \[ M_p^{act} = 1.1 \cdot Ry \cdot fy \cdot Z_{RBS} \]

- Shear at the inflection point: 
  \[ V_{pd} = \frac{M_p^{act}}{L/2} \]

- Plastic moment of beam: 
  \[ M_{p\,beam} = 1.1 \cdot Ry \cdot fy \cdot Z_{beam} \]

- Total moment at the column face: 
  \[ M_f = V_{pd} \cdot (L_b/2) < M_{p\,beam} \]
## Capacity Analysis of RBS

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Mp beam (kgcm)</th>
<th>Mp act (kgcm)</th>
<th>Mf (kgcm)</th>
<th>Vpd (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balok I (HE200A)</td>
<td>1501895</td>
<td>837605.1</td>
<td>1054918</td>
<td>10549.18</td>
</tr>
<tr>
<td>Balok 2 (HE220A)</td>
<td>2005536</td>
<td>1116900</td>
<td>1444890</td>
<td>14448.9</td>
</tr>
<tr>
<td>Balok 3 (HE240A)</td>
<td>2610687</td>
<td>1452166</td>
<td>1931071</td>
<td>19310.71</td>
</tr>
</tbody>
</table>
### METHODOLOGY

#### Design Analysis of Bolt Connections

<table>
<thead>
<tr>
<th></th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear strength of bolts</td>
<td>$V_d = n \cdot \phi_f \cdot V_n = n \cdot \phi_f \cdot r_1 \cdot f_{ub} \cdot A_b$</td>
</tr>
<tr>
<td>Tensile strength of bolts</td>
<td>$T_d = \phi_f \cdot T_u = \phi_f \cdot 0.75 \cdot f_{ub} \cdot A_b$</td>
</tr>
<tr>
<td>Compressive strength of bolts</td>
<td>$R_d = \phi_f \cdot R_n = 2.4 \cdot \phi_f \cdot d_b \cdot t_p \cdot f_u$</td>
</tr>
<tr>
<td>Shear strength of friction bolts</td>
<td>$V_d = \phi \cdot V_n = 1.13 \cdot \phi \cdot \mu \cdot m \cdot T_b$</td>
</tr>
</tbody>
</table>
**METHODOLOGY**

**COMPARATIVE STUDY OF THE BEHAVIOR OF REDUCED BEAM SECTION RIGID CONNECTIONS**

**Design Analysis of Weld Connections**

- **Groove Weld (Axial forces)**
  \[ \phi_y R_{nw} = 0.9 t_c f_y \] (bahan dasar)
  \[ \phi_y R_{nw} = 0.9 t_c f_{yw} \] (las)

- **Groove Weld (Shear forces)**
  \[ \phi_y R_{nw} = 0.9 t_c (0.6 f_y) \] (bahan dasar)

- **Fillet weld**
  \[ R_u \leq \phi R_{nw} \]
  \[ \phi R_{nw} = 0.75 t_c (0.6 f_{uw}) \]
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Finite element analysis using ABAQUS v.6.7

Behavior of the connection (deformation, displacement, stress-strain)

Compare the behavior of all types connections
RESULTS

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Behavior of The Connections in Profile Beam 2 (HE220A)
Behavior of The Connections in Profile Beam 3 (HE240A)
## RESULTS

### COMPARATIVE STUDY OF THE BEHAVIOR OF REDUCED BEAM SECTION RIGID CONNECTIONS

#### Results of the connections in Beam 1 (HE200A)

<table>
<thead>
<tr>
<th>Profil Balok</th>
<th>Jenis Sambungan</th>
<th>Kode</th>
<th>σ (N/mm²)</th>
<th>Pengurangan tegangan (%)</th>
<th>U₁₂ (mm)</th>
<th>Pengurangan displacement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balok 1 (HE200A)</td>
<td>T-Connection</td>
<td>TC-200</td>
<td>63.414</td>
<td>31.52</td>
<td>0.186</td>
<td>14.68</td>
</tr>
<tr>
<td></td>
<td>Extended End Plate Connection</td>
<td>EP-200</td>
<td>92.185</td>
<td>0.45</td>
<td>0.218</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Welded Rigid Connection</td>
<td>WR-200</td>
<td>89.937</td>
<td>2.88</td>
<td>0.199</td>
<td>8.72</td>
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<tr>
<td></td>
<td>D.T. Pachoumis (2009)</td>
<td>DT-200</td>
<td>92.606</td>
<td>0.00</td>
<td>0.218</td>
<td>0.00</td>
</tr>
</tbody>
</table>

#### Results of the connections in Beam 2 (HE220A)

<table>
<thead>
<tr>
<th>Profil Balok</th>
<th>Jenis Sambungan</th>
<th>Kode</th>
<th>σ (N/mm²)</th>
<th>Pengurangan tegangan (%)</th>
<th>U₁₂ (mm)</th>
<th>Pengurangan displacement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balok 2 (HE220A)</td>
<td>T-Connection</td>
<td>TC-220</td>
<td>60.301</td>
<td>40.67</td>
<td>0.242</td>
<td>9.70</td>
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<tr>
<td></td>
<td>Extended End Plate Connection</td>
<td>EP-220</td>
<td>101.574</td>
<td>0.07</td>
<td>0.266</td>
<td>0.75</td>
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<td></td>
<td>Welded Rigid Connection</td>
<td>WR-220</td>
<td>82.621</td>
<td>18.71</td>
<td>0.257</td>
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<tr>
<td></td>
<td>D.T. Pachoumis (2009)</td>
<td>DT-220</td>
<td>101.643</td>
<td>0.00</td>
<td>0.268</td>
<td>0.00</td>
</tr>
</tbody>
</table>

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## RESULTS

### COMPARATIVE STUDY OF THE BEHAVIOR OF REDUCED BEAM SECTION RIGID CONNECTIONS

#### Results of the connections in Beam 3 (HE240A)

<table>
<thead>
<tr>
<th>Profil Balok</th>
<th>Jenis Sambungan</th>
<th>Kode</th>
<th>$\sigma$ (N/mm$^2$)</th>
<th>Pengurangan tegangan (%)</th>
<th>$U_{12}$ (mm)</th>
<th>Pengurangan displacement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balok 3 (HE240A)</td>
<td>T-Connection</td>
<td>TC-240</td>
<td>96.297</td>
<td>18.16</td>
<td>0.286</td>
<td>9.49</td>
</tr>
<tr>
<td></td>
<td>Extended End Plate Connection</td>
<td>EP-240</td>
<td>116.541</td>
<td>0.96</td>
<td>0.313</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Welded Rigid Connection</td>
<td>WR-240</td>
<td>111.057</td>
<td>5.62</td>
<td>0.301</td>
<td>4.75</td>
</tr>
<tr>
<td></td>
<td>D.T. Pachoumis (2009)</td>
<td>DT-240</td>
<td>117.669</td>
<td>0.00</td>
<td>0.316</td>
<td>0.00</td>
</tr>
</tbody>
</table>
From the results of this study, it conclude that:

1. Extended End Plate Connection and Simple Connection (D.T. Pachoumis, 2009) have a similar behavior, it can be seen from the results of stress-strain behavior and the displacement occurred in 5 cm from column face (connection area).

2. Welded Rigid Connection is more rigid than the two connections before, it could reduce the stress by 2-18 % and also the displacement occurred by 4-8 % in 5 cm from column face (connection area).

3. T-Connection is the most rigid connection than the others connection, it could reduce the stress by 18-40 % and also the displacement occurred by 9-14 % in 5 cm from column face (connection area).

4. From those results, the behavior of rigid connections are still same for all kind of beam profile. So, smaller or bigger profile, the behavior of connections are same.


Departemen Pekerjaan Umum, 2002, Tata Cara Perhitungan Struktur Baja Untuk Bangunan Gedung (SNI 03-1729-2002), Yayasan LPMB, Bandung

Departemen Pekerjaan Umum, 2002, Tata Cara Perencanaan Ketahanan Gempa Untuk Bangunan Gedung (SNI 03-1726-2002), Yayasan LPMB, Bandung


Thank You!

Merci BCP.