Simple for Dead load and Continuous for Live load (SDCL) steel bridge system: Seismic Application

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Brief Introduction to Simple for Dead Load and Continuous for Live Load Steel Bridge System (SDCL)
Conventional Method
Conventional Method
Conventional Method
Conventional Method
Conventional Method
Longitudinal Reinforcement Is Placed in the Deck for Live Load Continuity
M+ Increases
M- Decreases
No Bolted Connection
Ease of Construction
Enhanced Service life
Minimized Traffic Interruption
PIER DETAIL
Test 1

WELDED BOTTOM FLANGE
Test 3

END CAP PLATES
FIELD DEMONSTRATION BRIDGE
\[ Mn = As \, fy(d - H/2) \] (1)
Based on Research
\[ Mn = As \ f_y(d - H/2) \] (1)

Based on Research

Where:

- \( Mn \) = Moment Capacity
- \( As \) = Area of Slab Reinforcement (Tension)
- \( f_y \) = Yield Stress of Reinforcement
- \( d \) = Bottom of Girder to Slab Reinforcement
- \( H \) = Height Steel Block
Calculation for Test Specimen:

Two Span Bridge – Each Span 97 Ft

\( Mu(\text{LL}) \) 34,770 in.-kip (Required)

Slab Width \( be = 92 \) in. (effective)
Slab Thickness \( t = 8.5 \) in.

Distance to Reinforcement, \( d = 47.75 \) in.

Strength reduction factor, \( \phi = 0.9 \)

\( W40 \times 249 \)
\( D = 43.375 \) in
\( bf = 15.75 \) in
Rearrange Capacity Equation:

\[ Mn = A_s f_y (d - H/2) \quad \rightarrow \quad A_s = \frac{M_u}{\phi f_y (d - H/2)} \]

Using Sample Values:

\[ A_s = \frac{34,770}{0.9(60)(47.75 - 2/2)} = 13.8 \text{ in.}^2 \]
Bearing Check:

Max Bearing Stress (Steel Block) = 1.7 $F_y$

Equate Tension (T) and Compression (C) Components to Determine Minimum Height of Block to Resist Tension in Reinforcement

$$H_{\text{min}} = \frac{1.7A_s f_y}{b_f F_{ypl}}$$

$$H_{\text{min}} = \frac{1.7(13.8)(60)}{15.75(50)} = 1.79 \text{ in.}$$

Note: Block Width = Flange Width ($b_f$)
Other Details Used in Practice
Fig. 21. Detail used by the Ohio DOT.
Fig. 22. Detail used in construction of the State Route 35 Bridge in Maryville, Tennessee.
GIRDER ELEVATION

Splices shall have one-half of the holes filled with erection bolts and cylindrical erection pins (half bolts and half pins) before driving wedge kicker plates.

Fig. 23. Second detail for an SDCL steel bridge system, used for the DuPont Access Road Bridge in New Johnsonville, Tennessee.
SDCL Application Example
Non-Seismic
Temporary Bracings were not used
System Greatly Reduces Falling Hazard
SDCL: ABC Application  Non-seismic
Moderate to High Seismic Detail: SDCL
Types of Forces, Seismic Detail Should Resist

Push-down loading

Push-up loading

Inverse loading

Simulating gravity loads

Simulating vertical component of seismic loads

Simulating longitudinal component of seismic loads
1. **Tie bars and shear studs on the compression flange**

2. **Steel blocks at the end of the compression flanges**

3. **End stiffeners**

4. **Dowel bars**

5. **Live load continuity reinforcement**
ABC Application of SDCL Using Envisioned Connection
Column to Cap beam Connection

1. Precast Cap-beam
2. Concrete Filled UHPC Tube
3. UHPC
Construction Sequence

- Footing and Column reinforcement
- Precast UHPC Shell
- Placing Shell as Formwork
- Connecting Shell to Footing (UHPC)
- Casting Column (Normal Concrete)
- Connecting Column to Cap beam (UHPC)
Fig. 25. Deflected shape of a three-span bridge in the longitudinal (parallel to traffic) direction.
Fig. 26. Deflected shape of the pier column in the (a) longitudinal and (b) transverse directions.

Fig. 27. Transfer column moment to the concrete diaphragm through an integral connection.
Component test

*Design of Test Specimen*

Inverted setup
Component test

Test Setup

Bridge system

Inverted Specimen

Deflected shape

Moment diagram

Shear diagram
Component test

*Design of Test Specimen*

Capacity Design using M-ϕ and finite element analysis

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**Column M-ϕ**

- **Graph 1**: Column moment curvature, Caltrans Idealized Model, Overstrength Capacity
  - Curvature (rad/m)
  - Moment (kN-m)

**Bent cap M-ϕ in transverse direction**

- **Graph 2**: Bent-cap - Transverse, Column Overstrength Capacity
  - Curvature (rad/m)
  - Moment (kN-m)

**Bent cap M-Δ in longitudinal direction (FE)**

- **Graph 3**: Bent-cap - Longitudinal, Column Overstrength Capacity
  - Drift (m/m)

(Separate Check at Face of Cap – Dashed line)
Component test *Design of Test Specimen*

AASHTO Seismic Guide Spec
Component test *Design of Test Specimen*

**AASHTO Seismic Guide Spec**

Bent Cap Details, Section at Column for Bridges with 0 to 20° Skew.
(Detail Applies to Sections Within 2 x Diameter of Column, Centered About Centerline of Column).
(Detail Applies to T-Beam and Box Girder Bridges Where Deck Reinforcement is Placed Parallel to Cap).

*Not shown*
Component test *Design of Test Specimen*

*AASHTO Seismic Guide Spec*

Bent Cap Details, Section at Column for Bridges with 0 to 20° Skew.
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(Detail Applies to T-Beam and Box Girder Bridges Where Deck Reinforcement is Placed Parallel to Cap).

\[
A_{f}^{\text{n}} = 0.2 \times A_{t} \\
A_{f}^{\text{h}} = 0.1 \times A_{t} \\
A_{f}^{\text{d}} \geq \max \left\{ 0.1 \times A_{f}^{\text{n}}, 0.1 \times A_{f}^{\text{h}} \right\}
\]
Component test

*Design of Test Specimen*

Joint Shear Reinforcement Detail

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Required</th>
<th>Provided</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{st}$</td>
<td>3.72</td>
<td>3.72</td>
<td>Column Longitudinal 12 #5</td>
</tr>
<tr>
<td>$A_{sv}^v$</td>
<td>0.744</td>
<td>0.88 &amp; 0.77</td>
<td>Vertical bars 8 #3 for area 3 and 4, 7 #3 for area 1 and 2</td>
</tr>
<tr>
<td>$A_{sh}^h$</td>
<td>0.37</td>
<td>0.88</td>
<td>Horizontal bars 2 set of 4 #3 on each side of column</td>
</tr>
<tr>
<td>$A_{sf}^f$</td>
<td>0.2</td>
<td>0.33</td>
<td>Side bars 3 #3 each side</td>
</tr>
</tbody>
</table>
Component Test Setup
Component testing (Plastic Hinge Damage)
Component testing
Strain and Curvature Measurements (Column)

- Strain (x10^-6)
  - 1Δy
  - 2Δy
  - 3Δy
  - 4Δy
  - 5Δy

- Curvature (rad/m)
  - 1Δy
  - 2Δy
  - 3Δy
  - 4Δy
  - 5Δy

- Distance from Cap-beam (cm)
  - Steel yield strain
  - 5000
  - 10000
  - 15000

- Distance from Cap beam (cm)

FIU
Component testing
Strain Measurements (Cap beam)

![Diagram of strain measurements](image)

**Strain (×10^-6)**

**Distance from column centerline (cm)**

- E, Max. Principal
- Multiple section points (Avg. 75%)
- +1.984e-03
- +1.651e-03
- +1.320e-03
- +9.903e-04
- +6.602e-04
- +3.301e-04
- +0.000e+00

- 1Ay (Experimental) - 6Ay (Experimental)
- 1Ay (Numerical) - 6Ay (Numerical)
Component testing
Strain Measurements (Deck)
Conclusions:
- Details and associated design criteria are developed to apply the SDCL steel bridge system to moderate to high seismic areas.
- The recommendations are verified through shake table test.
- The suggested seismic detail is slightly different than non-seismic detail that has been used for more than 15 years successfully.
- The recommended design provisions matches those already in AASHTO seismic design specifications.