Seismic Performance of Sheet Metal Deck

Hilti Corporation

Dr.-Ing. Thomas Engleder
Agenda

- Introduction
  - Hilti – Company Overview
  - Direct Fastening Technology
- Motivation
- Sheet Metal Decking in North America
- Shear Diaphragm Design
- Shear Diaphragm Testing Facility
- Seismic Behavior of Fastening Points and of Shear Diaphragms
- Summary and Outlook
Hilti – a worldwide presence

- Founded in 1941 in Schaan, Principality of Liechtenstein
- One of the global leading companies in providing products, systems and services to construction professionals
- Located in more than 120 countries on five continents
- More than 21,000 employees
- More than 50 nationalities at Group Headquarters in Schaan
- Direct sales model
- 2003 winner of the Carl Bertelsmann Prize for outstanding corporate culture
Core Trades – Overview

Building construction  Civil engineering  Mechanical installation

Steel and metal  Interior finishing  Electrical installation
Steel/Metal Key Applications

- Installation of roofs
- Installation of decks
- Installation of metal façades
- Flat roof insulation
- Installation of glass façades
- Installation of frames (windows, doors, ...)
- Structural Steel Fabrication & Erection
- Manufacturing & installation of steel structures
- Fastening steel columns to base
- Fabrication and installation of handrails, stairs, fences, balconies, etc.
- Roofing / Siding, Sheet Metal, Flat Roof Insulation
- Metal Frames, Glas Façades
- Metal Work and Other Steel
Direct Fastening Technology
Direct Fastening (DX) Technology

- Powder or gas actuated nailing
- Fastening in concrete and steel
- No drilling required
Hilti Piston Principle (no shooting)

- 5 tons of weight
- ~60 m/s
- one millisecond
- 1.5 MW (2,000 hp)
- 100…400 J
Anchoring in steel

- Nail displaces steel volume – deformation, friction
- Strong heating of contact zone → surface reactions, local welding and brazing
- Local positive locking (knurled surface of nail)
Motivation
Motivation

• Hazard analysis (e.g. earthquakes) gets increased importance.

• Building codes allow reduced seismic loads, provided that the structure is adequately designed as a ductile (energy dissipating) seismic load resisting system (SLRS).

• Many single story buildings are built using a steel roof shear diaphragm, which could then also be used as a SLRS. Currently thick deck is required to fulfill the requirements.

• Mechanical fasteners are key elements in these constructions.

• In the US welding of sheet metal deck is still common practice (~90%). In Canada a significant shift to mechanical fastener is observed. Hilti drives and supports this development also in the US.

• A detailed understanding and analysis of shear diaphragms in general together with optimized fastening technologies allow for a more cost efficient design of structures.
Sheet Metal Decking in North America

http://www.us.hilti.com/decking
Application – Roof Deck Diaphragm on Bar Joists
Application – Roof Deck Diaphragm on Bar Joists
Application – Consumables and Tools

- X-ENP19
- X-EDNK22
- X-EDN19

- S-SLC 01/02 HWH

DX 860 HSN/ENP

ST 1800 + SDT 30

bar joist / support

deck

www.hilti.com
Current Fastening Technology: Welding
High performing Sheet Metal Fastening Systems
Shear Diaphragm Design
Design Codes

• IBC (International Building Code)
• ICC-ES AC43 (International Code Council Evaluation Service)
• SDI DDM 03 (Steel Deck Institute Diaphragm Design Manual)
• TM 5-809 Seismic Design of Buildings (Tri-Services Manual)
• ASCE 7 (American Society of Civil Engineers)
• AISC (American Institute of Steel Construction)
• AISI Specification (American Iron and Steel Institute)
• CSA S16 (Canadian Standards Association)
• Eurocode 8
• ....
Application – Structural Design for Shear

frame

joint

beam

load

failure!

metal deck
~90%

brace frame

structural diagonal

US

EU
Roof Deck Diaphragm Model (SDI)

(SDI = Steel Deck Institute)
Structural Design for Shear – SDI Approach

Lap shear test data

- e.g. pin performance $Q_f$
- e.g. screw performance $Q_s$

System shear resistance calculated by adding up the pin & screw performance $Q_f$ and $Q_s$

Generic formula (allows any combination of fasteners)

(SDI = Steel Deck Institute)
Structural Design for Shear – SDI Approach

In general, the design is commonly done using design tables for maximum nominal loads supplied by SDI and deck manufacturers. The performance is based on analytical calculations or on test results.

<table>
<thead>
<tr>
<th>FASTENER LAYOUT</th>
<th>SIDE-LAP CONN./SPAN</th>
<th>MAXIMUM NOMINAL SHEAR STRENGTH, PLF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SPAN, FT</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>36/9</td>
<td>0</td>
<td>1545</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1705</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1800</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1905</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2130</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2250</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>2380</td>
</tr>
<tr>
<td>36/7</td>
<td>0</td>
<td>960</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1140</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1305</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1460</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1610</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1750</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1885</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>875</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1030</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1170</td>
</tr>
</tbody>
</table>

\( \phi (\text{EQ}) : 0.65 \quad \Omega (\text{EQ}) : 2.50 \quad \leq \text{earthquake} \)

\( \phi (\text{WIND}) : 0.70 \quad \Omega (\text{WIND}) : 2.35 \)

\( \phi (\text{Other}) : 0.65 \quad \Omega (\text{Other}) : 2.50 \)
AISC Seismic Design - Loads

\[ V = \text{basic seismic base shear load} \]

\[ R = \text{Response Modification Coefficient (reduction factor for applied lateral force)} \]

\[ V - C_s W \quad \text{with:} \quad C_s = \frac{S_{DS}}{R / I} \]

\[ \leq \frac{S_{DL}}{T(R / I)} \quad \text{, for } T \leq T_L \]

\[ \leq \frac{S_{DL}}{T^2(R / I)} \quad \text{, for } T > T_L \]

\[ \geq 0.044S_{DS}I \]

\[ \geq 0.01 \]

\[ \geq \frac{0.5S_1}{(R / I)} \quad \text{, if } S_1 \geq 0.6g \]
AISC Seismic Design

Response Modification Coefficient

(reduction factor for applied lateral force, greater deformation capacity)

[ Source: AISC Seismic Design Manual, 2006 ]
Shear Diaphragm Testing Facility

Testing according to ICC-ES AC43 and AISI S907
Hilti Test Lab Accreditation

Hilti Seismic EPAQ Helsinki 2009 I XST/et

Fastening Systems Research Laboratory
Corporate Research & Technology

www.hilti.com
Test Rig Building (Schaan Hilti HQ)
Test Frame
Test Frame – Technical Data

size: 8 x 10 m  (24’ x 30’)

variable spans: 1.6, 2.5, 3.3 m  (5’, 7’-6”, 10’)

variable support thickness

static maximum load 700 kN (157’000 lbs)
maximum deflection 200 mm (8 inch)

dynamic maximum load 370 kN (90’000 lbs)
maximum deflection +/-200mm (8 inch)
Operating Principle (shear load)
Quasi Static and Seismic Test Setup
Seismic/Cyclic Behaviour of Fastening Points under Shear
Steel Deck Frame Fastener under Cyclic Loading

Source: Hilti, BGVB internal report, 1992
Steel Deck Frame Fasteners after Cyclic Loading

Weld

Screw

Powder-Actuated

Source: INELASTIC SEISMIC RESPONSE OF METAL ROOFDECK DIAPHRAGMS FOR STEEL BUILDING STRUCTURES. Hesham S. Essa, Robert Tremblay and Colin A. Rogers, 12th European Conference on Earthquake Engineering, Paper Reference 482
Seismic Performance of Shear Diaphragms
## Seismic Test Setup

<table>
<thead>
<tr>
<th>Description</th>
<th>Item No.</th>
<th>Lot No. / Ser. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2&quot; deep B deck, nestable, 20ga, full hard steel (F_y ~ 90 ksi)</td>
<td>-</td>
<td>see [13]</td>
</tr>
<tr>
<td>Support beams, 1/4 inch thickness (F_y = 50 ksi)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>X-ENP-19 L15 MXR (see [12])</td>
<td>283508</td>
<td>10509190</td>
</tr>
<tr>
<td>S-MD 12-14x1 HWH Stitch</td>
<td>378973</td>
<td>0608-1330</td>
</tr>
<tr>
<td>DX tool: DX 860 ENP</td>
<td>275636</td>
<td>03-000739-06</td>
</tr>
<tr>
<td>Screw tool: ST 1800 + SDT 25</td>
<td>347101</td>
<td>02-0095615-KH-06</td>
</tr>
</tbody>
</table>

*Material list for static and cyclic testing.*
Quasi Static and Seismic Test Setup
Seismic Test – Load Protocol

<table>
<thead>
<tr>
<th>Site and R_d Factor</th>
<th>Number of Cycles</th>
<th>Distortion Level (×10^4 rad)</th>
<th>f (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East R_d = 3.0</td>
<td>5</td>
<td>0.4 γ_0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.8 γ_0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>(γ_u + γ_2)/2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.4 γ_0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.8 γ_0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.4 γ_0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>γ_u + 1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.8 γ_0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.4 γ_0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>(γ_u + γ_2)/2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.4 γ_0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

| West R_d = 2.0      | 1               | (γ_u + γ_0)/2                | 2.0    |
|                     | 1               | (γ_u + γ_0)/2                | 2.0    |
|                     | 2               | 0.4 γ_0                      | 2.0    |
|                     | 1               | (γ_u + γ_0)/2                | 2.0    |
|                     | 2               | 0.4 γ_0                      | 2.0    |
|                     | 0.5             | (γ_u + 10.0)/2               | 1.0    |
|                     | 1               | (γ_u + 3.0)/2                | 1.0    |
|                     | 1               | (γ_u + γ_2)/2                | 2.0    |
|                     | 2               | 0.4 γ_0                      | 2.0    |

[curve definition by R. Tremblay]
1. Step
Quasi Static Pre-Testing
Test Results & Failure Modes
Example (Quasi Static Pre-Test)

# 63_static monotonic

Side-lap softening (screw tilting) - Cross sectional deformation

Deck slotting - local deck buckling at the fixed lip

Sidelap openings

Pin pull out at endlap

Overall assessment: Sidelap Softening and Opening

Test load / Unit length [kN/m] vs. Shear angle (x 1'000) [rad]
Controlling Modes

Decking

- Global buckling
- Local buckling
Controlling modes

Frame Fasteners in shear
- Slotting of sheeting due to shear
- Pullout
- Fracture
Controlling Modes

Frame Fasteners in tension

• Pullout (predominantly at the end-overlap)
Controlling Modes

Sidelap screws

• Tilting, slotting, piling up
• Fracture
2. Step
Seismic Testing
Seismic Test – Load Protocol

[curve definition by R. Tremblay]
Seismic Test Video

Hilti AG Schaan, FSRL, DFC project

Co-operation partner

University of Montreal, R. Tremblay
Seismic/Cyclic Test Result

SDI allowable service load

load [Kips]

-3 -2 -1 0 1 2 3 4 5 6 7 8 9

-80 -60 -40 -20 0 20 40 60 80

cyclic load

displacement [inch]
Observed Failure

Tilting of screws and tearing of sidelap after the cyclic test and static reloading up to 8 inch displacement.
Observed Failure

- Slotting of deck at powder-actuated fasteners after the cyclic test and static reloading up to 8 inch displacement.
Seismic/Cyclic Test Result

- SDI allowable service load
- cyclic load
- quasi static capacity
- remaining capacity
Seismic/Cyclic Test Energy Dissipation
Test Reproducibility

Identical tests lead to same results!
Cyclic protocol

Cyclic protocol: Ram displacement
Test S 07 and S 08 based on pretest # 63
# Seismic Test Scope

<table>
<thead>
<tr>
<th>Test Id.</th>
<th>Type</th>
<th>Gage</th>
<th>Span [ft]</th>
<th>Base metal thickness</th>
<th>Nail</th>
<th>Pattern</th>
<th>Endlap (2 inch overlap)</th>
<th>Screw</th>
<th>Spacing</th>
<th>Static reference test</th>
</tr>
</thead>
<tbody>
<tr>
<td>S 07</td>
<td>B</td>
<td>22</td>
<td>7.5</td>
<td>3/16</td>
<td>X-EDNK-22 THQ12M</td>
<td>36/7</td>
<td>Nailed</td>
<td>S-MD 12-14x1 HW/H</td>
<td>6&quot; o.c.</td>
<td>#63</td>
</tr>
<tr>
<td>S 08</td>
<td>B</td>
<td>22</td>
<td>7.5</td>
<td>3/16</td>
<td>X-EDNK-22 THQ12M</td>
<td>36/7</td>
<td>Screwed</td>
<td>S-MD 12-14x1 HW/H</td>
<td>6&quot; o.c.</td>
<td>#63</td>
</tr>
<tr>
<td>S 05</td>
<td>B</td>
<td>20</td>
<td>5</td>
<td>3/16</td>
<td>X-EDNK-22 THQ12M</td>
<td>36/9</td>
<td>Nailed</td>
<td>S-MD 12-14x1 HW/H</td>
<td>6&quot; o.c.</td>
<td>#64</td>
</tr>
<tr>
<td>S 04</td>
<td>B</td>
<td>20</td>
<td>5</td>
<td>3/16</td>
<td>X-EDNK-22 THQ12M</td>
<td>36/9</td>
<td>Screwed</td>
<td>S-MD 12-14x1 HW/H</td>
<td>6&quot; o.c.</td>
<td>#64</td>
</tr>
<tr>
<td>S 03</td>
<td>B</td>
<td>18</td>
<td>5</td>
<td>3/16</td>
<td>X-EDNK-22 THQ12M</td>
<td>36/9</td>
<td>Nailed</td>
<td>S-MD 12-14x1 HW/H</td>
<td>6&quot; o.c.</td>
<td>#65</td>
</tr>
<tr>
<td>S 06</td>
<td>B</td>
<td>18</td>
<td>5</td>
<td>3/16</td>
<td>X-EDNK-22 THQ12M</td>
<td>36/9</td>
<td>Screwed</td>
<td>S-MD 12-14x1 HW/H</td>
<td>6&quot; o.c.</td>
<td>#65</td>
</tr>
</tbody>
</table>
Seismic Load-Deflection Behaviour

22-Gauge
B-deck, 3/16" framing steel
X-EDNK-22 THQ12, 36/7 pattern
Sidetap: S-MD 12-14x 1 HWH, 6" o.c.

Test load / Unit length [kN/m]

Shear angle (x 1'000) [rad]

S 07
S 08_screwed endlaps
# 63_static monotonic
Seismic Test Results

<table>
<thead>
<tr>
<th>Test Id.</th>
<th>Type</th>
<th>Gage</th>
<th>Span [ft]</th>
<th>Pattern</th>
<th>Endlap</th>
<th>Decking</th>
<th>Cyclic test results</th>
<th>Static reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Material</td>
<td>Max. [kN]</td>
<td>Min. [kN]</td>
</tr>
<tr>
<td>S 07</td>
<td>B</td>
<td>22</td>
<td>7.5</td>
<td>36/7</td>
<td>Nailed</td>
<td></td>
<td>276.8</td>
<td>-275.1</td>
</tr>
<tr>
<td>S 08</td>
<td>B</td>
<td>22</td>
<td>7.5</td>
<td>36/7</td>
<td>Screwed</td>
<td></td>
<td>258.6</td>
<td>-239.8</td>
</tr>
<tr>
<td>S 05</td>
<td>B</td>
<td>20</td>
<td>5</td>
<td>36/9</td>
<td>Nailed</td>
<td></td>
<td>309.9</td>
<td>-286.5</td>
</tr>
<tr>
<td>S 04</td>
<td>B</td>
<td>20</td>
<td>5</td>
<td>36/9</td>
<td>Screwed</td>
<td></td>
<td>306.4</td>
<td>-293.4</td>
</tr>
<tr>
<td>S 03</td>
<td>B</td>
<td>18</td>
<td>5</td>
<td>36/9</td>
<td>Nailed</td>
<td></td>
<td>399.8</td>
<td>-368.7</td>
</tr>
<tr>
<td>S 06</td>
<td>B</td>
<td>18</td>
<td>5</td>
<td>36/9</td>
<td>Screwed</td>
<td></td>
<td>383.8</td>
<td>-362.0</td>
</tr>
</tbody>
</table>

\(\) Span in the static reference test was 7.5 ft.
\(\) Prediction formula based on the AC-43 Hilti test program [8]. Prediction calculated for the X-EDNK22 THQ12 deck to frame fastener neglecting the use of deck to frame screws in the tests S 08, S 04 and S 06.
Summary & Outlook
Summary and Outlook

• Sheet steel shear diaphragms fastened with mechanical fasteners (nail, screws, etc.) show a ductile behavior under cyclic/seismic loading.

• All tests done show that the remaining diaphragm performance after cyclic/seismic loading exceeds the allowable service load.

• Further testing and analysis in currently ongoing.

• Expectation: Research activities will lead to design provisions, providing the necessary structural safety with the possibility of thinner sheet metal deck, allowing for a lighter, more economical design.
Thank you!
## Key figures for 2007

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>CHF 4,667 million</td>
</tr>
<tr>
<td>Operating result</td>
<td>CHF 533 million</td>
</tr>
<tr>
<td>Net income</td>
<td>CHF 422 million</td>
</tr>
<tr>
<td>Expenditures for research and development</td>
<td>CHF 177 million</td>
</tr>
<tr>
<td>Employees worldwide (average)</td>
<td>18,930</td>
</tr>
</tbody>
</table>
We create enthusiasm through innovation

- We want our customers to work efficiently and safely.
- We anticipate their future needs by looking over their shoulder.
- This is how we discover possibilities for innovation and develop new and high-quality products.
Research and development expenses

In CHF million

- 2005: 151
- 2006: 164
- 2007: 177
Hilti Siding & Decking Direct Fastening Selector

<table>
<thead>
<tr>
<th>Roof</th>
<th>Fastening point</th>
<th>Base material</th>
<th>Technology</th>
<th>Consumables</th>
<th>Tools</th>
<th>Approvals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single skin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Sheet to base</td>
<td>SF</td>
<td>S-MD 51 (LJS)</td>
<td>ST 1800</td>
<td>DEI Z-11,5-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 53 S</td>
<td>ST 2500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 65 S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-NP 62 S (+12mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 51 S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double skin</td>
<td>1. Sheet to base</td>
<td>SF</td>
<td>S-MD 09.2 M</td>
<td>ST 1800</td>
<td>DEI Z-11,5-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-NP 09.80 MX</td>
<td>ST 1800</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP 09.80 MX</td>
<td>JGDT 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP 09.80 MX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP 09.80 MX</td>
<td>DX 76 PPR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Sheet overlapping (inner skin)</td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td>DX 600-ASN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Intermediate profile to sheet</td>
<td>SF</td>
<td>S-MD 05 Z M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Sheet to intermediate profile</td>
<td>SF</td>
<td>S-MD 02 Z M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Sheet overlapping (outer skin)</td>
<td>SF</td>
<td>SF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandwich panel</td>
<td>1. Panel to base</td>
<td>SF</td>
<td>S-CS 60 S</td>
<td>ST 1500</td>
<td>DEI Z-11,5-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-CS 60 S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-NP 62 S (+12mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-CS 60 S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 51 S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Overlapping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat roof insulated</td>
<td>1. Sheet to base</td>
<td>SF</td>
<td>S-MD 09.2 M</td>
<td>ST 1500</td>
<td>DEI Z-11,5-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-NP 09.80 MX</td>
<td>ST 1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP 09.80 MX</td>
<td>JGDT 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP 09.80 MX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP 09.80 MX</td>
<td>DX 76 PPR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Sheet overlapping</td>
<td>SF</td>
<td>S-MP 53 Z</td>
<td>DX 600-ASN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Insulation</td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td>DX 76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td>DX 600-ASN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td>DX 76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-NP 62 S (+12mm)</td>
<td>DX 76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-NP 62 S (+12mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

www.hilti.com

Hilti Seismic EPAQ Helsinki 2009 I XST/iet
# Hilti Siding & Decking Direct Fastening Selector

<table>
<thead>
<tr>
<th>Wall Type</th>
<th>Fastening Point</th>
<th>Base Material</th>
<th>Technology</th>
<th>Consumables</th>
<th>Tools</th>
<th>Approvals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single skin</td>
<td>1. Sheet to base</td>
<td>SF</td>
<td>S-MD 51 (LS)</td>
<td>ST 1800</td>
<td>DBR Z-14.1-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Sheet overlapping</td>
<td></td>
<td>S-MD 53 S</td>
<td>ST 2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S-MD 55 S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S-MP 52 S (≥20mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S-MD 51 S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S-MD 51 (LS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double skin</td>
<td>1. Intermediate profile to base</td>
<td>SF</td>
<td>S-MD 01 Z</td>
<td>ST 1800</td>
<td>DBR Z-14.1-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Profile to profile</td>
<td>DX</td>
<td>X-ENP20-20 MX</td>
<td>DX 76 PTR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Sheet to interi. profile</td>
<td>DX</td>
<td>X-ENP19 MX</td>
<td>DX 76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(horizontal/vertical)</td>
<td>DX</td>
<td>NPH4-42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandwich panel</td>
<td>1. Panel to base</td>
<td>SF</td>
<td>S-MD 50 S</td>
<td>ST 1800</td>
<td>DBR Z-14.1-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Overlapping</td>
<td>SF</td>
<td>S-MD 50 S</td>
<td>ST 2500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MP 52 S (≥20mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 51 S</td>
<td>ST 1800</td>
<td>DBR Z-14.1-4</td>
<td></td>
</tr>
<tr>
<td>Composited Floor</td>
<td>1. Sheet to base with</td>
<td>DX</td>
<td>X-HVG + X-ENP-01 HVG</td>
<td>DX 76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>shear connectors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Sheet overlapping</td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td>ST 1800</td>
<td>DBR Z-14.1-4</td>
<td></td>
</tr>
<tr>
<td>With shear connectors</td>
<td>3.</td>
<td>SF</td>
<td>X-ENP20-20 MX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.</td>
<td>SF</td>
<td>X-ENP20-20 MX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without shear connectors</td>
<td>1. Sheet to base</td>
<td>DX</td>
<td>X-ENP50 MX</td>
<td>DX 860-PTR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP50 MX</td>
<td>DX 860-HSN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>X-ENP19 MX(R)</td>
<td>DX 76 PTR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX</td>
<td>NPH4-42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td>ST 1800</td>
<td>DBR Z-14.1-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF</td>
<td>S-MD 01 Z M</td>
<td>ST 2500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[www.hilti.com](http://www.hilti.com)
Software Tools – Profis DF / Profis DF Dia

Software ⇒ PROFIS DF

Planning- and design tool for siding & Decking

- Wind load design of metal sheet fastening
- Pre design of metal sheets
- Faster placement due to wind load areas
- Bill of material and ordering
Direct fastening: products for decking

High performance deck fastening systems

X-ENP

X-EDNK

DX 860-ENP

DX 76 PTR

SDT 30 & ST 1800

S-MS (Speedy screw)
Innovative system solutions
Terminology
Deck Attachment with Arc Spot Welds

- Traditional / Low Cost Material
- Quality control highly variable
- Slow production rate
- Health risks – toxic fume exposure
- Weather dependent (rain/snow)
- Back stress / worker comp injuries
- Deck coating & paint burn-off
- Requires 2nd step corrosion protection
- Visible vs. effective diameter
- Problems with multi-layer thick deck
Application – Metal deck fastening
Fastening of 4 sheet metals

- Prediction of sheet deformation
- Optimization of nail geometry
- Analysis of loads on tool and piston
- Evaluation of driving forces

Cross-section of fastening
Research Papers on Inelastic, Seismic Performance of Steel Deck Diaphragms with Welds and Mechanical Fasteners

Behavior of Roof Deck Diaphragms under Quasi-static Cyclic Loading
Issue Date: December 2003
Hesham S. Essa¹, Robert Tremblay² and Colin A. Rogers³
¹Post-Doctoral Research Associate, Dept. of Civil, Geological, and Mining Engineering, Ecole Polytechnique, Montreal PQ, Canada H3C 3A7.
²Professor, Dept. of Civil, Geological, and Mining Engineering, Ecole Polytechnique, Montreal PQ, Canada H3C 3A7.
³Assistant Professor, Dept. of Civil Engineering and Applied Mechanics, McGill Univ., Montreal PQ, Canada H3A 2K6.

A series of 18 large-scale tests was carried out on corrugated cold-formed steel deck diaphragms for single-story buildings to investigate the diaphragm's ability to function as the main source for absorbing earthquake induced energy through inelastic behavior. Tests were performed using a cantilever type configuration for the test setup, in which the steel deck was laid in a horizontal plane. Diaphragm assemblies made with 0.76 and 0.91 mm thick metal deck sheets and with nine combinations of deck-to-frame and deck-to-deck (side lap) fasteners were tested. For each fastening combination, two tests were conducted: monotonic and quasistatic cyclic. Both the strength and failure modes under quasistatic cyclic loading are different from those under monotonic loading. Test results indicate that diaphragms with welded deck-to-frame fasteners without washers have limited ductility and cannot sustain cyclic loading at relatively large displacement amplitudes. The use of mechanical and welded-with-washer deck-to-frame fasteners enhances the strength, ductility and energy dissipation characteristics of the diaphragm considerably.
Research Papers on Inelastic, Seismic Performance of Steel Deck Diaphragms with Welds and Mechanical Fasteners

Inelastic Seismic Response of Frame Fasteners for Steel Roof Deck Diaphragms
Issue Date: December 2003
Colin A. Rogers¹ and Robert Tremblay²
¹Assistant Professor, Dept. of Civil Engineering and Applied Mechanics, McGill Univ., Montreal QC, Canada H3A 2K6.
²Professor, Dept. of Civil, Geological and Mining Engineering, École Polytechnique, Montreal QC, Canada H3T 1J4.

An experimental program was undertaken to investigate the inelastic seismic response of metal deck roofing systems. The load carrying capacity of roof diaphragms for low-rise steel buildings, subjected to lateral loads from wind and/or earthquakes, is directly dependent on the performance of the connections. This paper provides information on the inelastic cyclic response, including load versus displacement hysteresis and energy absorption capacity of 144 deck-to-frame screwed, powder-actuated fastener, and welded connection tests for different steel deck and structure thickness. Powder-actuated fastener connections were able to provide the highest energy dissipation results, followed closely by screwed connections. In many cases, the welded connections exhibited significant ultimate capacities, but failed at small displacements, resulting in low energy dissipation values. However, when welds with washers were used, the ductility and energy absorption ability of the connection were substantially improved.

© 2003 American Society of Civil Engineers
Inelastic Seismic Response of Frame Fasteners for Steel Roof Deck Diaphragms
Issue Date: December 2003
Colin A. Rogers¹ and Robert Tremblay²
¹Assistant Professor, Dept. of Civil Engineering and Applied Mechanics, McGill Univ., Montreal QC, Canada H3A 2K6.
²Professor, Dept. of Civil, Geological and Mining Engineering, École Polytechnique, Montreal QC, Canada H3T 1J4.

…. This paper provides information on the inelastic cyclic response, including load versus displacement hysteresis and energy absorption capacity of 144 deck-to-frame screwed, powder-actuated fastener, and welded connection tests for different steel deck and structure thickness. Powder-actuated fastener connections were able to provide the highest energy dissipation results, followed closely by screwed connections. In many cases, the welded connections exhibited significant ultimate capacities, but failed at small displacements, resulting in low energy dissipation values. …

© 2003 American Society of Civil Engineers
Hilti Test Lab Accreditation

DAP Deutsches Akkreditierungssystem Prüfwesen GmbH

Signatory to the Multilateral Agreement of EA for Mutual Recognition and to the Mutual Recognition Arrangement of ILAC represented in the

Deutscher AkkreditierungsRat

Accreditation

The DAP Deutsches Akkreditierungssystem Prüfwesen GmbH herewith confirms that

Hilti AG
Fastening Systems
Research Laboratory
Feldkircherstraße 100
5494 Schaan
Liechtenstein

is competent under the terms of DIN EN ISO/IEC 17025:2005 to carry out mechanical-technological testing of fasteners and fastening tools in the construction business using electro hydraulic, electro mechanic, and mechanical actuators; Examination of the electrical insulation properties of fastening elements in the construction business; Determination of the strength properties and the surface roughness of concrete using destructive and non-destructive material testing methods

In accordance with the test methods listed in the annex.

The accreditation is valid from 2006-10-27 to 2011-10-26.

DAR registration number: DAP-PL-4106.00
Berlin, 2006-10-27

Prof. Dr.-Ing. habil. H. Ziegler
Managing Director
DAP Deutsches Akkreditierungssystem Prüfwesen GmbH

Translation for information purposes only. The German certificate is authoritative. 1st issue

Hilti Seismic EPAQ Helsinki 2009 / XST/et
www.hilti.com
Seismic Zones

Global Seismic Hazard Map
Produced by the Global Seismic Hazard Assessment Program (GSHAP)
a demonstration project of the UN/International Decade of Natural Disaster Reduction, conducted by the International Lithosphere Program.
Global map assembled by D. Giardini, G. Grünthal, K. Shedlock, and P. Zhang
1999