

**Computational Investigation of Tunable Steel Plate Shear Walls for  
Improved Seismic Resistance**

Manasa Koppal

Thesis submitted to the faculty of  
Virginia Polytechnic Institute and State University  
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

IN

CIVIL ENGINEERING

Matthew R. Eatherton, Chairman

Cristopher D. Moen

Kamal B. Rojiani

August 3<sup>rd</sup>, 2012

Blacksburg, VA

*Keywords:* Steel Plate Shear Walls, Finite element modeling, Perforated plate, Seismic Behavior

Copyright © Manasa Koppal

**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 2-1 Idealized tension-field action in a typical SPW – Strip Model Representation [From (Sabelli and Bruneau, 2007)]

Report generated on: 08-13-2012 at : 15:49:52

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 2-2 Schematic representation of the Strip model of a SPSW (Thorburn et al. 1983)

Report generated on: 08-13-2012 at : 15:53:59

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 2-3 (a) Experimental Test set-up (Berman and Bruneau, 2005), (b) Hysteresis behavior of the SPSW (Berman and Bruneau, 2005)

Report generated on: 08-13-2012 at : 15:55:22

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 2-5 (a) SPSW Panel with a central circular hole, (b) Hinge assembly – Schematic of the test specimen (Roberts and Sabouri-Ghomi, 1992)

Report generated on: 08-13-2012 at : 15:56:19

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 2-7 (a) Schematic representation of SPSW with slits, (b) Experimental test set up, Hitaka and Mastui, (2006)

Report generated on: 08-13-2012 at : 15:57:41

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 2-9 SPSW divided into parts to show the forces [From (ICC/SEAOC, 2012)]

Report generated on: 08-13-2012 at : 15:58:36

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 2-10 Components of expected web strength applied to HBE and VBE [From (ICC/SEAOC, 2012)]

Report generated on: 08-13-2012 at : 15:59:20

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 3-2 Stress Strain curve for LYS steel for the web plate, [From (Vian and Bruneau, 2005)]

Report generated on: 08-13-2012 at : 16:00:26

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 3-3 Reduced Beam Section detailing incorporated in the experiment and the FE model, [From (Vian and Bruneau, 2005)]

Report generated on: 08-13-2012 at : 16:01:14

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 3-6 (a) Panel damage – buckling and yielding of the specimen S at 3% drift [From (Vian and Bruneau , 2005)]

Report generated on: 08-13-2012 at : 16:02:08

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 3-9 (a) Damage to panel at the end of testing for specimen P at 3% drift [From (Vian and Bruneau, 2005)]

Report generated on: 08-13-2012 at : 16:02:58

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 4-1 Building Elevation [From (ICC/SEAO, 2012)]

Report generated on: 08-13-2012 at : 16:03:54

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Manasa Koppal

Description of item under review for fair use: Figure 4-2 Typical floor and roof framing plan [From (ICC/SEAOC, 2012)]

Report generated on: 08-13-2012 at : 16:04:45

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***

