



# NUMERICAL STUDY ON PLASTIC STRENGTH OF STEEL PLATE SHEAR WALLS

By

Hazem Mohamed Ahmed Abdelhady

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the degree of  
MASTER OF SCIENCE  
in  
STRUCTURAL ENGINEERING

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Under the Supervision of

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**Title of Thesis:**

Numerical Study on Plastic Strength of Steel Plate Shear Walls

**Key Words:**

Steel Plate Shear Wall; Plastic Analysis; Boundary Frame; Boundary Element; Infill-Plate.

**Summary:**

The strength of steel plate shear wall (SPSW) introduced by design codes assumes that the acting lateral loads are resisted by only the infill plate, which results in uneconomic solution. In addition, the design codes require that any opening within in the infill plate should be surrounded by both horizontal and vertical stiffeners to anchor the infill plate tension. This, in turn, further affects the cost effectiveness of the SPSW solution. The objective of this study is to evaluate the plastic strength of the unstiffened perforated SPSWs considering the boundary frame (BF) moment resisting (MR) action. SPSW FE models have been established and designed according to AISC design guide<sup>20</sup>. A parametric numerical study has been performed on the SPSW with different geometrical and mechanical characteristics, using ABAQUS software. Equations have been formulated and proposed based on the plastic collapse mechanism to quantify the plastic strength of SPSWs with solid infill plate, considering the BFMR action. Furthermore, a reduction factor has been proposed to evaluate the reduction in the plastic strength due to infill plate perforations.

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## Abbreviations

AISC	American Institute of Steel Construction
ASTM	American Society for Testing and Materials
BFMR	Boundary Frame Moment Resisting
HBE	Horizontal Boundary Element
LBE	Local Boundary Element
RBS	Reduced Beam Section
SPSW	Steel Plate Shear Wall
VBE	Vertical Boundary Elements

## Nomenclatures

$A_c$	Cross-sectional area of the VBE
$A_b$	Cross-sectional area of the HBE
$A_i$	Area of the equivalent truss member at story $i$
$A_{co}$	Area of the VBE at which the yield load capacity equals to the vertical loads resulting from the infill plate yielding
BC	Boundary condition of the VBEs as being hinged or fixed
$C_r$	Number of column-restrainers
$d$	Infill plate depth
$D$	Perforation diameter
$F$	Fixed Base
$F_y$	Yield strength of the infill plate
$F_{yf}$	Yield strength of the boundary frame
$F_u$	Ultimate strength of the infill plate
$h$	Story height
$h_i$	The elevation of story $i$ measured from the SPSW base
$h_{si}$	The elevation of soft story measured from the SPSW base
$h_1$	Height of story 1
$H$	Hinged Base
$H_{panel}$	Panel height measured between the HBEs flanges
$I_b$	Moment of inertia of the HBE
$I_C$	Moment of inertia of the VBE
$K$	Percentage of the shear force assigned to the infill plate
$K_{balanced}$	Percentage of the shear force assigned to the infill plate, when $\Omega_K = 1$
$K_{op}$	Elastic stiffness of the perforated infill plate
$K_{sp}$	Elastic stiffness of the solid infill plate
$L$	SPSW bay width measured from the center lines of the VBEs

$L_h$	Length of the HBE measured from the plastic hinges centerlines
$L_p$	Clear length of the infill plate
$M_L$	Left end moment acting on the HBE due to the frame sway
$M_{max}$	Maximum moment within the HBE span
$M_R$	Right end moment acting on the HBE due to the frame sway
$M_{pb}$	Plastic moment of the HBE
$M_{pc}$	Plastic moment of the VBE
$M_{pc1}$	Plastic moment of the VBE at story 1
$M_{pcn}$	Plastic moment of the VBE at story n
$M_{pb}$	Plastic moment of the HBE at story
$M_{pbi}$	Plastic moment of the HBE at story i
$n$	Number of stories
$N_{tension}$	Gravity load applied on the VBE under tension
$N_{compression}$	Gravity load applied on the VBE under compression
$N_{rc}$	Maximum number of diagonal strips to be cut by perforations
$N_r$	Number of horizontal rows of perforations
$P$	Perforation type
$P_u$	Ultimate concentrated load (if exist) acting vertically on the HBE
$R$	Response modification factor
$R_y$	Factor to calculate the expected yield stress
$S_{diag}$	Diagonal strip spacing
$S_h$	Position of the plastic hinge formation in the HBE measured from the centerline of the VBE
$t_w$	Thickness of the infill plate
$t_{wi}$	Thickness of the infill plate at story i
$V$	Total base shear
$V_F$	Shear strength of the boundary frame
$V_{FB}$	Plastic strength of the boundary frame due to only the fixed base
$V_{FF}$	Plastic strength of the boundary frame with VBEs fixed to the ground
$V_{FH}$	Plastic strength of the boundary frame with VBEs hinged to the ground
$V_i$	Lateral load applied above story i
$V_{si}$	Lateral load applied at story i
$V_j$	Lateral load applied above story j
$V_n$	Nominal shear strength of the infill plate
$V_{OP}$	Shear strength of the perforated infill plate
$V_P$	Shear force acting on the HBE at the position of the plastic hinge formation and resulting from the full yielding of the infill plate
$V_{SP}$	Expected shear strength of the solid infill plate
$V_{SPi}$	Expected shear strength of the solid infill plate at story i