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

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

Assoc. Prof. Dr. Mohammed Hassanien Serror

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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 guide20. 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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Hazem Mohamed

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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