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Compressive behaviour of normal weight concrete confined by the steel face plates in SCS sandwich wall

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HIGHLIGHTS

- Steel skin in SCS sandwich wall increases its compressive resistance and ductility.
- Increasing stud height improves compressive behaviours of SCS sandwich wall.
- Through connectors increases compressive resistance and ductility of SCS sandwich wall.
- Theoretical model considers confining effect of steel skin in SCS sandwich wall.
- Numerical models predict well compressive behaviour of SCS sandwich wall.

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ABSTRACT

This paper presented a test program with seven specimens on steel-concrete-steel (SCS) sandwich walls with headed studs (or through connectors) and in-fill concrete core under in-plane compression. The studied parameters in this test program are height of the headed stud, thickness of steel face plate, and type of shear connectors. The test results revealed the influences of these parameters on the ultimate compression behaviour of SCS sandwich walls. Theoretical models were also developed to predict the ultimate compressive resistance of SCS sandwich walls. The developed theoretical models considered confining effect of steel face plates working with shear connectors on compressive resistance of the SCS sandwich wall. This confining stress on the concrete core is determined by the tensile resistance of headed studs used in SCS sandwich walls. Three-dimensional finite element model (FEM) was also developed to simulate the ultimate compressive behaviour of SCS sandwich walls with headed studs and through connectors. The FEM considered the geometric and materials nonlinearities, and made detailed simulation on the stud-concrete interactions. The accuracies of the theoretical models and FEM were checked through validations of predictions against test results.

1. Introduction

Steel-concrete-steel (SCS) sandwich composite wall typically comprises two external steel face plates, concrete core, and connectors as shown in Fig. 1. The two external steel face plates act as the flexural reinforcement and formwork for the casting of concrete core whilst the connectors are used to bond these three layers of materials as an integrity and act as the shear reinforcement to resist transverse shear or punching shear forces acting on the cross section. This type of structure exhibits extensive advantages over reinforced concrete wall in terms of easy construction, saving formworks and site labour force during construction, avoiding detailing of the reinforcement, and improved ductility as well as energy absorption under cyclic seismic loading [1]. The SCS sandwich composite wall has been used in high-rise building as shear walls [2], in nuclear reactor facilities as the shielding structure and containment structure [3], and in Arctic offshore structure as the ice-resistant walls [4,5].

In SCS sandwich walls, different types of connectors have been evented and used. The pilot research carried out by Wright and Gallocher [6] adopted the profiled steel sheeting without using

Abbreviations: COV, coefficient of variation; LBS, local buckling of steel face plates; SCS, steel-concrete-steel; SPC, splitting failure mode in concrete core; Stdev, standard deviation; FEM, finite element model; FM, failure mode.

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Nomenclature

A_N	The projected area of conical concrete breakout failure surface
A_a	Cross-sectional area of reinforcement
A_{brg}	Bearing area of the headed stud under tension.
A_c	Cross-sectional area of the concrete core
A_e	Equivalent area of the cross section of the SCS sandwich wall
A_s	Cross-sectional area of the steel face palte
DI	Ductility index of SCS sandwich wall
E_c	Elastic modulus of concrete
E_s	Elastic modulus of steel
G_f	Tensile fracture energy of concrete
H	Height of the SCS sandwich wall
$K_a = E_c A_e/H$	theoretical initial stiffness of the SCS sandwich wall under compression
$K_e = P_{0.3}/\Delta_{0.3}$	initial stiffness of the SCS sandwich wall under compression
L	Laterally unbraced length of the member.
P_e	elastic critical buckling load, and equals to $\pi^2(EI_{eff})/(KL)^2$
P_{n0}	$f_y A_s + f_{ysr} A_{sr} + 0.85 f_c A_c$
P_u	Ultimate compressive resistance of SCS sandwich wall
P_{uc}	Compressive resistance of the concrete core,
P_{us}	Compressive resistance of the steel face plates
P_{w1}	Ultimate compressive resistance of SCS sandwich wall W1
$P_{0.3}$	30% of ultimate compressive resistance P_u
S	Average spacing of the shear connectors in the SCS sandwich wall
T_{CB}	Concrete breakout resistance of the shear connector
T_H	Tensile resistance of the connectors.
T_{pl}	Pullout resistance of the shear connector
T_{ps}	Punching shear failure resistance of the steel face plate
T_s	Tensile fracture resistance of the steel shank of the connector
d	Diameter of shear connector
f_c	Compressive strength of concrete cylinder
f_y	Yield strength of the steel plate
f_{ya}	Yield strength of the steel reinforcement
f_{yd}	Design yield strength of the steel plate
t	Thickness of the steel face plate in SCS sandwich wall
Δ_u	deflections corresponding to P_u
$\Delta_{85\%}$	displacements corresponding to 85% P_u during the recession stage
$\Delta_{0.3}$	displacements corresponding to 30% P_u at the elastic stage
α_s	shear yielding coefficient of concrete
ε_0	Strain corresponding to f_c
ε_c	Compressive strain of the concrete
ϕ	Partial safety factor, and equals to 0.85 as specified in EC4 and AISC 360–10
γ	Strength enhancing coefficient varying from 1.15 to 1.30
γ_c	Partial safety factor for concrete
γ_{M2}	Partial factor and may be taken as 1.25
σ_c	The ultimate compressive stress of the concrete
σ_h	Confining stress acting on the concrete core side surface

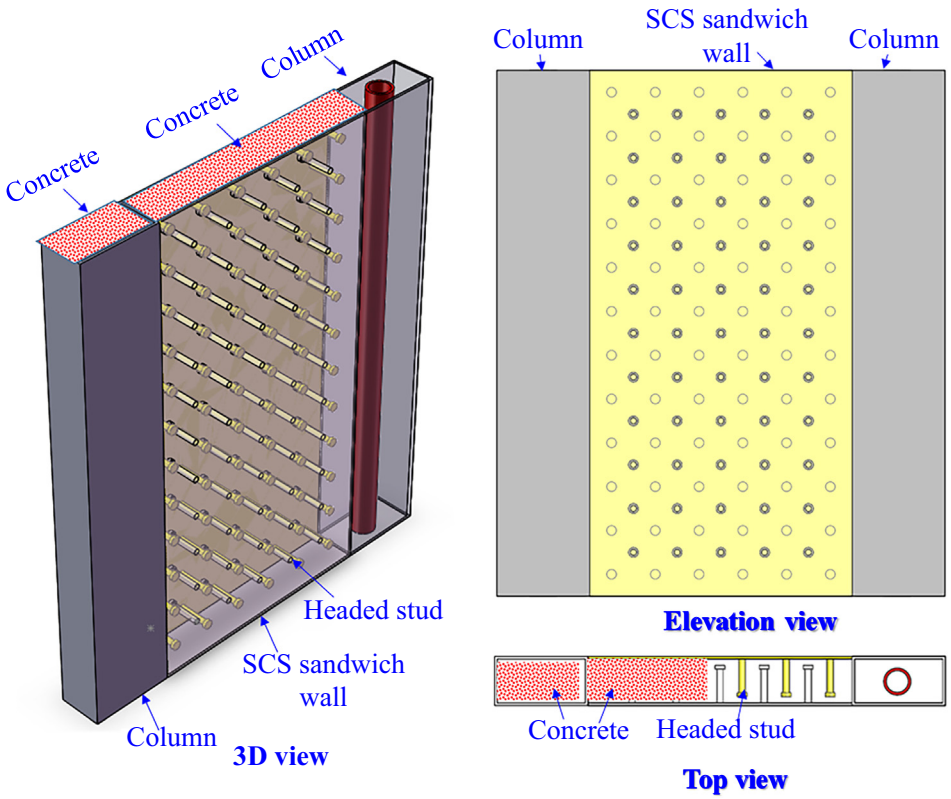

Fig. 1. SCS sandwich wall in high-rise building.