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Seismic performance of reinforced concrete squat walls with embedded cold-formed and thin walled steel truss

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ABSTRACT

To investigate the seismic performance of squat reinforced concrete (RC) walls with embedded cold-formed and thin walled (CFTW) steel truss, experimental and analytical studies were conducted. Four one-third scaled composite wall specimens were tested to failure subjected to cyclic load reversals under constant axial load. The experimental behaviors of test specimens including damage development process, load-deformation responses, stiffness degradation, energy dissipation capacity, failure pattern and ductility were discussed. Test results indicate that the embedded CFTW steel truss web braces can effectively avoid web concrete crushing and improve the energy dissipation capacity of shear walls with low aspect ratios, resulting in a more ductile failure pattern due to the failure of boundary elements. Nonlinear finite element analysis (FEA) on test specimens was carried out based on suggested modeling techniques and the accuracy of the numerical method was verified. Influences of critical parameters such as axial load ratio, amounts of embedded CFTW steel truss chord and web braces on the performance of the composite shear walls were further examined through comprehensive parametric analysis. It shows that the axial load ratio has a significant impact on the post-yielding behavior of composite shear walls. Good displacement ductility can be achieved under medium level of axial load ratio. Increasing the amount of embedded truss chord cannot significantly improve the performance of composite walls. The embedded truss web braces are noticeably beneficial to the energy dissipation capacity and ductility behavior of squat composite walls.

1. Introduction

In order to ensure the safety of high-rise buildings located in seismic regions, lateral force resisting systems consisting of reinforced concrete (RC) structural walls have been widely used for high lateral strength and stiffness. In recent years, the steel-concrete composite walls have been extensively studied and applied in practice aiming to provide further improved seismic performance without much increase in wall thickness as compared with conventional RC walls. For portions of super high-rise buildings where the axial load and shear demand are very high (e.g. basement, core walls on lower stories or the outrigger story), steel shapes have been combined with RC walls in various forms to obtain load carrying capacity and ductility required by stringent seismic design provisions [1–10]. More recently, a new type of composite wall system with embedded steel truss members has been developed, where the diagonal web bracing members are intended to increase the shear capacity and energy dissipation capacity of the walls subjected to high shear demand [11–16]. For lower stories of high-rise buildings located in regions of high seismicity, the high shear demand often requires large amount of steel reinforcement, which often results in the steel congestion problem since the wall thickness cannot be increased for maximizing the usable floor area. In order to ensure the constructability and avoid the congestion of reinforcing bars, cold-formed and thin-walled (CFTW) steel truss can be embedded in RC walls to reduce the amount of reinforcing bars. In addition, other construction advantages can be achieved. The CFTW steel truss can first be erected and plumbed in both directions, which can be designed to have sufficient strength and stiffness to carry all the constructional loads. Reinforcing bars can be attached to the embedded CFTW steel truss, and even the formwork screwed with spaces for the cover. In this way the conventional formwork could be largely reduced.

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Nomenclature

h_w	height of shear wall	E	Young's modulus
l_w	length of shear wall	G_c	the total compressive fracture energy
ρ_c	the steel ratio of embedded CFTW steel truss chord	G_f	the total tensile fracture energy
ρ_{vb}	the volumetric ratio of the embedded CFTW steel truss web braces	h	the characteristic element length
$\varepsilon_{c/3}$	the strain at which one-third of the maximum compressive strength is reached	τ_{max}	the bond strength
ε_c	the strain at which the maximum compressive strength is reached	τ_f	the residual bond stress
ε_u	the ultimate strain at which the material is completely softened in compression	S	the relative slip between steel and concrete
f_c	compressive strength of concrete	β	the empirical coefficient
f_t	tensile strength of concrete	A	the axial load ratio
		μ	displacement ductility
		Δ_y	displacement corresponding to yielding
		Δ_u	displacement corresponding to failure

In this research program, four one-third scaled RC squat walls with embedded CFTW steel truss were tested to investigate the seismic behavior in terms of hysteretic responses, stiffness and strength degradation characteristics, failure pattern, energy dissipation capacity and ductility. Finite element simulation of test specimens based on suggested numerical techniques was carried out and compared with experimental results to verify the analysis accuracy. Then parametric investigation on the influences of key parameters such as axial load ratio, amounts of embedded CFTW steel truss members on the performance of the composite shear walls was conducted.

2. Experimental program

2.1. Details of specimens

Four one-third scaled composite wall specimens, identified by CTSRCW-1, CTSRCW-2, CTSRCW-3 and CTSRCW-4, were constructed and tested subjected to constant axial load and cyclic reversed lateral loading at the structural lab of Chongqing University. All the four specimens had the same overall dimensions, including a 900 mm × 300 mm × 300 mm loading block on top, a 800 mm × 120 mm × 650 mm wall portion and a

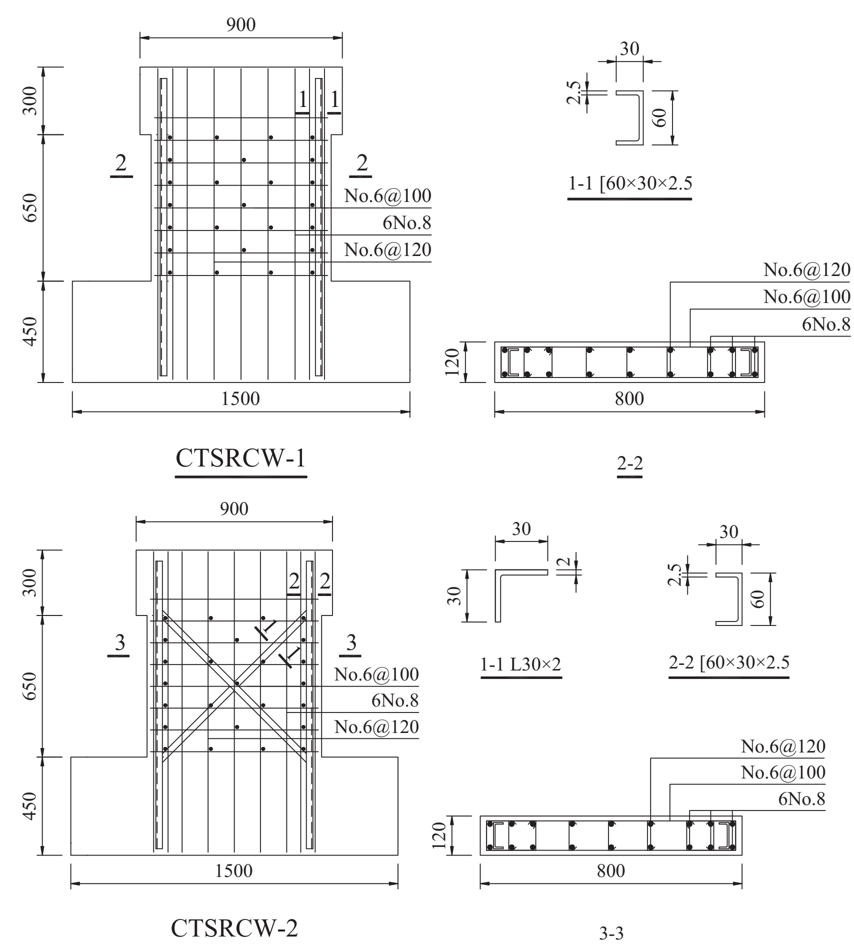

Fig. 1. Details of the specimens.