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# Behaviour of steel-foam concrete composite panel under in-plane lateral load

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ABSTRACT

This paper presents the details of experimental investigations on steel-foam concrete composite (SFCC) panel subjected to monotonic and cyclic in-plane lateral load. SFCC panel consists of profiled steel sheet as the outer skins and foam concrete of density 1200 kg/m$^3$ as the infill, connected together by using through-through mild steel studs. Two SFCC panels are tested under static loading and two similar specimens under cyclic loading. From the tests, it is observed that the number of studs provided are adequate to cause the failure of panel by yielding of steel sheets prior to buckling under static loading and tearing of steel sheets under cyclic loading. The ultimate cyclic load capacity of SFCC panel is not less than 80% of their monotonic load capacity and possesses high ductility after the peak load. The suitability of proposed SFCC panel to act as shear wall in seismic resistant buildings is verified.



## 1. Introduction

Reinforced concrete and steel plate shear walls are traditionally used as axial or cyclic load-resisting systems in structures such as mid and high-rise buildings. Double-skinned profiled steel sheet composite wall (DPSCW) infilled with concrete is the development from composite flooring system proposed by Wright et al. [1]. It has the potential for application as bearing, retaining and shear wall to resist axial, lateral and cyclic loads. The interaction between the profiled steel sheet and concrete has an important role in the composite action of the system. The interface shear bond failure is the limiting criterion for designing this kind of system. Hossain & Wright [2] described the individual behaviour of DPSCW shear panels with micro concrete against the equivalent plain concrete shear panels that can be used as core walls in framed construction. Hossain & Wright [3] carried out small-scale model tests on DPSCW with micro-concrete to provide information on the shear strength, shear stiffness, strain conditions and failure modes under monotonic and cyclic shear loading conditions. Hossain & Wright [4] also carried out extensive experimental investigations on DPSCWs to understand the bending and shear strength, strain characteristics and modes of failure. DPSCW system is preferred for seismic resistant structures due to the profiled sheet rather than the flat sheet, which provides improved shear capacity and ductile resistance to cyclic loads [5]. Rafiei et al. [6] presented about the development and validation of two FE models named as detailed and simplified by using ABAQUS for DPSCW. Edalati et al. [7] conducted nonlinear FEA studies on the behaviour of DPSCW with sinusoidal and trapezoidal corrugated plates under lateral pushover loads. Rafiei et al. [8] also investigated on the behaviour of DPSCW by using self-consolidating concrete (SCC) and engineered cementitious composites (ECC) as infills under in-plane monotonic shear loading.

Few studies were reported on the use of normal concrete, high strength concrete, self-consolidating concrete and the engineered cementitious composite as infill. The self-weight of DPSCW made of conventional concrete represents a very large proportion of the total load of the structure and does not contribute to strength. However, construction in earthquake prone areas demands a light weight system with high strength and ductility for in-plane and out-of-plane loading. Foam concrete (FC) is one type of cellular light weight concrete, which can be used as infill material in DPSCW to improve the performances such as dead load reduction, fire resistance and thermal conductivity of buildings. The use of FC in DPSCW panels can result in enormous reduction in the weight and considerable savings in the energy, however their behaviour is not investigated adequately. Hence, there is need and scope for development of light-weight SFCC panels and to conduct xperimental studies under different loading conditions. Prabha et al. [9,10] studied the axial compression and flexural behaviour of SFCC panels by conducting experiments. These studies revealed that the SFCC panels have sufficient axial compression and flexural load carrying capacity and ductile behaviour to be used as wall and floor/roof panels in low-rise residential constructions. In continuation with that, further

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experimental studies are conducted to understand the static and cyclic in-plane lateral load behaviour of SFCC panels.

## 2. Geometrical details and preparation of SFCC panel

The SFCC panel consists of profiled steel sheets (0.8 mm thick) as the facing and FC of density 1200 kg/m$^3$ as the infill. The use of light weight FC in composite panel reduces the self-weight of panel by 40% compared to an equivalent brick wall. The details of profiled steel sheet are given in Fig. 1. The SFCC panel is 685 mm wide, 130 mm thick and 1250 mm high. The dimensions of the SFCC panel are chosen based on the capacity of the existing loading facilities and the feasibility of specimen fabrication. The geometrical details of the SFCC panel are given in Fig. 2.

The interaction between sheet and concrete is achieved by using 16 nos. of 8 mm dia through-through mild steel studs of $f_y$ - 250 MPa. For the purpose of installation of hollow steel pipes, 21 nos. of 20.5 mm dia holes are drilled in the bottom portion of the sheet at a spacing of 100 mm in the length direction. Two numbers of panels for monotonic and cyclic loading type are tested for repeatability. The panels are given the id as MWP-1, MWP-2, CWP-1, CWP-2, where MWP and CWP stands for SFCC wall panel tested under static and cyclic in-plane lateral load respectively. The type of concrete and material properties for each set are identical. The stress-strain behaviour of the steel sheet obtained from the tension coupon test is given in Fig. 3. The steel sheet has yield strength of 197 MPa, ultimate strength of 320 MPa, ductility (elongation = 28%) and modulus of elasticity of 202,040 MPa. Foam concrete is produced by uniform distribution of air bubbles created by using KV LITE – a protein based chemical natural foaming agents throughout the mass of concrete consisting of cement, sand and fly ash. The mix ratio to achieve the desired FC density of 1200 kg/m$^3$ is 1:0.80:0.87:0.7:0.124 (cement:fly ash:sand:water:foam). The fresh density of FC mix obtained is 1170 kg/m$^3$. After casting of SFCC panels, a concrete block of size (785 mm × 300 mm) with matching holes (Fig. 4) is cast around the bottom portion of the panel for a height of 285 mm using M35 concrete consisting of cement, sand and 6 mm coarse aggregate. The SFCC panels above the concrete block are covered airtight by polythene sheets and the base concrete block is water cured for 28 days. The average compressive strength of FC cube and concrete block on the day of testing the panels (77 days) is 6.8 MPa and 40.36 MPa respectively. The 77th day compressive stress-strain behaviour of foam concrete cylinder obtained is shown in Fig. 5. The tensile strength ($f_t$) of FC obtained from the split tensile test is 1.29 MPa and the Young's modulus is 4960 MPa.

## 3. Experimental set-up

The test matrix for four SFCC panels tested under monotonic and cyclic loading is shown in Table 1. The schematic diagram and the photograph showing the cantilever type of experimental set-up is shown in Figs. 6 and 7 respectively. The SFCC panel is turned through 90° with the foundation end connected to vertical column of the reaction frame. There are 36 nos. of holes of 17.5 mm diameter (21 nos. for connecting panel to fixture and 15 nos. for connecting fixture to reaction frame) on the steel fixture to mount the fixture to reaction frame and SFCC panel to the fixture. The SFCC panel embedded inside the concrete block is sandwiched between these two supporting plates by using 21

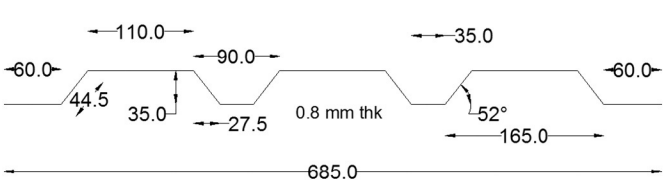


**Fig. 1.** Details of profiled steel sheet.

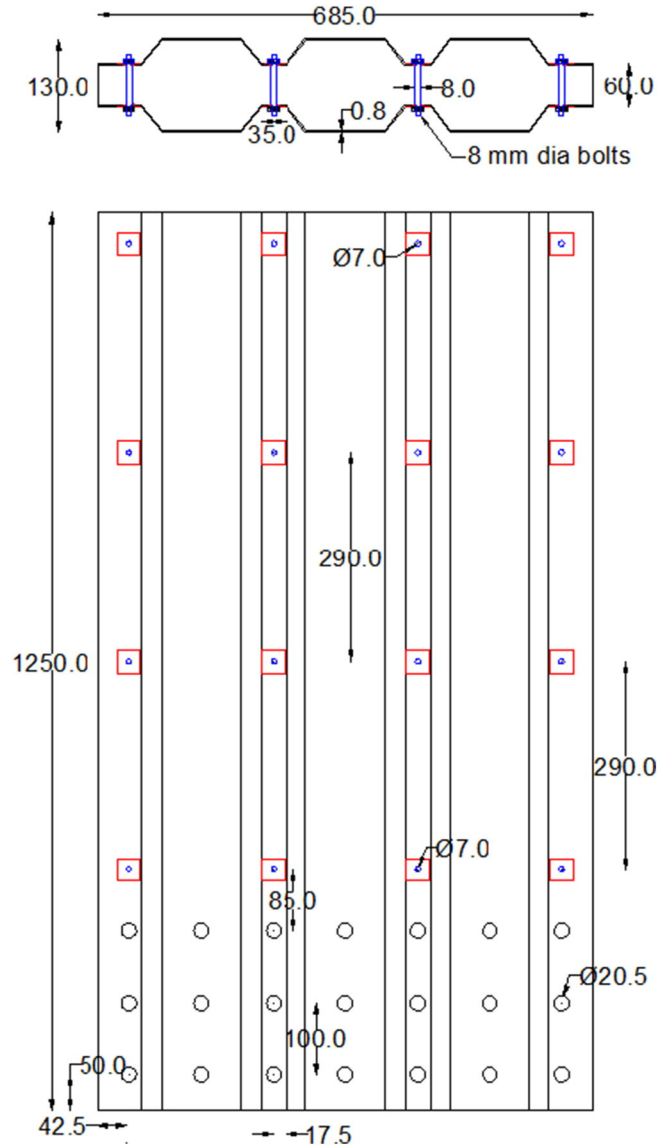


**Fig. 2.** Geometrical details of SFCC panel.

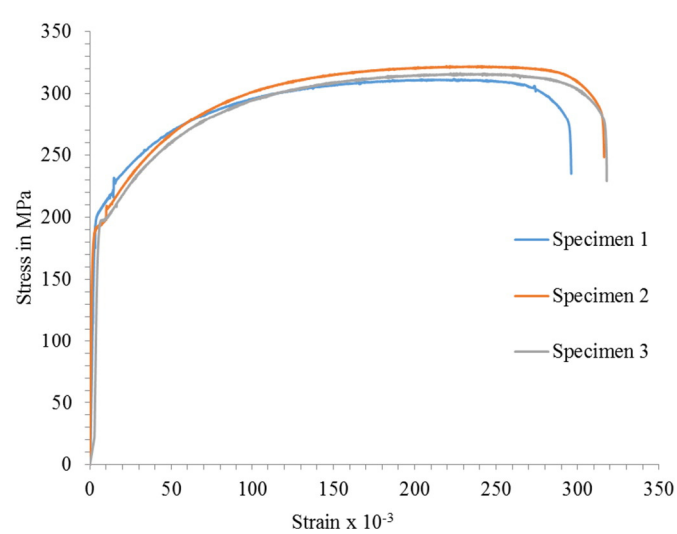


**Fig. 3.** Stress-strain behaviour of steel sheet.