SHEAR BEHAVIOR OF REINFORCED CONCRETE SHORT SANDWICH PANEL WALLS UNDER STATIC AND LATERAL CYCLIC LOADING

By

FATIMA AL ZAHRAA IBRAHIM ABD EL-LATIF REFAIE

A thesis submitted to the

Faculty of Engineering at Cairo University

In partial fulfillment of the

Requirements for the degree of

DOCTOR OF PHILOSOPHY

In

STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

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Title of Thesis: "Shear behavior of reinforced concrete short sandwich panel walls under static and lateral cyclic loading"

Key Words: sandwich panel walls, lateral cyclic loading, softened strut and tie model

Summary:

The main objective of the research program is to evaluate the shear performance of short sandwich panel walls. The experimental work is divided into two phases. The first phase aims to determine the shear strength of square sandwich panels under static diagonal compression loads. The second phase objective is to study the behavior of sandwich panel short walls under lateral cyclic loads. The applicability of available shear strength prediction equations of convention concrete walls in prediction shear strength of the sandwich panel walls was evaluated. An analytical model to estimate the sandwich panel wall strength was developed based on the softened strut and tie model.

DEDICATED TO:

MY WONDERFUL **MOTHER**

MEMORY OF MY **FATHER**

MY LOVELY **SISTER**

&

MY GREAT **BROTHRS**

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ABSTRACT

Cast in situ reinforced concrete sandwich panel structural system is considered one of the promising panelized systems. The main advantage of this system is the combination of insulation properties and the ease of manufacturing and construction.

Walls in the sandwich panel structural systems play the role of bearing and shear walls. The previous research works on sandwich panel walls focused on the walls tested under vertical loads or the three dimensional structures under seismic loads. However, there is a lack of experimental works on sandwich panel walls subjected to lateral in-plane loads.

Shear behavior of reinforced concrete sandwich panels was investigated in this study through a two-phase experimental program. The first phase aimed to evaluate the shear strength of five square sandwich panels tested under diagonal compression loads. The effect of horizontal reinforcement ratio and compressive strengths of the concrete layers on the performance measures is evaluated.

The second phase included testing two-third scale eleven sandwich panel walls under quasi-static cyclic lateral loads accompanied with constant axial loads. The main parameters of the tested specimens were wall edge detailing, wall aspect ratio, lateral reinforcement ratio, concrete compressive strength of the structural layers, axial load level and the presence of window or door openings. The influence of the key parameters on the behavior of the tested walls was evaluated through the performance measures. These measures included shear strength, stiffness, ductility and energy dissipation.

The limited database in the literature disabled the opportunity for developing provisions for shear strength prediction of the sandwich panel walls. This resulted in the necessity of resorting to the provisions of reinforced concrete walls to predict the shear strength of the sandwich panel walls. Twelve prediction provisions from different codes, guidelines and research studies were presented. Statistical evaluation of the ratios between experimental and predicted shear strength values was conducted to select the most reasonable predictive provisions. The New Zealand Code NZS 3101:2006 presented the best code prediction provisions that correlated best with test results.

A rational analytical model was needed to simulate the behavior of short sandwich panel walls subjected to both axial and lateral loads. A softened strut-and-tie analytical model was proposed. The model satisfied the equilibrium of stresses, compatibility of strains and the constitutive relationships of concrete and steel. The proposed model was verified using the experimental results and exhibited reasonable shear strength predictions.

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