BEHAVIOR OF AXIALLY LOADED COLD-FORMED STEEL WALLS LINED WITH FERRO-CEMENT BOARDS

By
Mohamed Gamal Abo El Kasem Salama

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

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Title of Thesis:

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Key Words:

Cold-formed steel wall; Ferro-Cement board; Axial loading capacity; Finite element modelling; Buckling

Summary:

This study includes three-dimensional nonlinear finite element models which have been established using multipurpose finite element software (ANSYS) to study the behavior of CFS wall panels. Material nonlinearity, geometric imperfection, and contact surface were taken into consideration to achieve effective modeling. The numerical models' results have been verified against both numerical and experimental works in the literature. A parametric study has been conducted to investigate the influence of various parameters in failure load of wall panel. Two shapes of stud sections have been studied; unlipped C-section and lipped C-section with different thickness and depth. In addition, stud material and screw spacing have been included in the parametric study. The results of unlined stud have been compared to the prediction failure load based on AISI-S100-12 to develop appropriate effective length factors. The summary indicated how these parameters were effective.

Acknowledgments

The author is honored to obtain his M.Sc. degree from Cairo University under distinguished supervision. He would like to express his deepest gratitude to **Prof. Metwally H. Abu-Hamd** for his advice, guidance, encouragement and remarks throughout the work presented herein.

The author also would like to acknowledge his colleague **Eng. Yassien Salah El Dien** for his help in learning the computer program ANSYS and his continuous support. And thanks to **Eng. Sarah Ibrahim** for her assistance and help.

Finally, the author would like to thank his parents as well as his family, especially his brother **Dr. Ahmed**, sisters **Dr. Esraa** and **Dr. Fatma** for their continuous support and believing in him even through hardest times. To them the author says thank you, but he knows that no words of appreciation could be sufficient. The author would not have achieved this work without their help.

Mohamed Gamal

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Abstract

Cold-formed steel (CFS) sections are widely used for floors, roofs, and walls for modern buildings. they are typically used in industrial, commercial and residential buildings as a main structural system or non-load bearing elements such as partitions. Because of its numerous advantages compared with other construction materials; such as light weight, effective cost, high strength-to-weight ratios and less harmful effect to the environment by decreasing pollution in fabrication.

One of the major growth areas for CFS is using it as main structural system consists of two components; load-bearing walls and joists. Particularly, cold-formed steel wall consists of tracks and studs sheathed by board. Generally, Studs are comprised of thin walled elements which fail by yielding, global or local buckling. For a long stud, the failure mode is governed by buckling due to high slenderness ratio. Sheathing from one side or two sides adds restrain on the stud at fasteners locations. Current design codes are highly predicted failure load and behavior of individual cold-formed steel members like beams and columns, but the effect of sheathing in braced stud and increased load capacity is still not fully addressed.

This research focused on cold-formed steel walls subjected to axial load and sheathed with ferro-cement board. Wherefore, three-dimensional nonlinear finite element models have been established using multipurpose finite element software (ANSYS) to study the behavior of CFS wall panels. Material nonlinearity, geometric imperfection, and contact surface were taken into consideration to achieve effective modeling. The numerical models' results have been verified against both numerical and experimental works in the literature. A parametric study has been conducted to investigate influence of various parameter in failure load of the wall panel. Two shapes of stud sections have been studied; unlipped C-section and lipped C-section with different thickness and depth. In addition, stud material and screw spacing have been included in the parametric study.

The results of finite element models with different parameters have been analyzed, it is found that: (a) using lining board has a significant influence on the stud failure load as it decreases buckling length by adding lateral support at screws location;(b) the effectiveness of the ferro-cement board in improving wall capacity increases when the stud depth decreases; (c) distance between screws has a small influence in improving wall capacity for screws spacing less than 300mm; (d) For the unlined stud, changing stud material has an unnoticeable effect on increasing the failure load so the unlined stud fails by the global buckling; (e) Changing stud material from ST37 to ST52 increases the failure load by approximately 25% and 30% for one side lined and two sides respectively; (f) For lipped C-section stud, the lining wall frame with ferro-cement board has a less effect on increasing the stud load capacity Compared to that effect in case of unlipped C-section.

Chapter 1 : Introduction

1.1. General

Cold-formed steel profiles are being increasingly common in construction. Because of its advantages like rapidity, lower cost, light weight, mass production, easy to work and friendly to the environment. However, CFS is traditionally used as secondary structures systems such as covering or partitions. It is also used as independent structure system consist of joist floor and wall panels as shown in Figure 1.1. Regards to CFS wall panels, it is influential to study the behavior of steel stud with a different configuration. In practical, wall panels are used with sheathing boards. therefore, it is impressive to take the advantage of sheathing in improving buckling behavior of the stud. Sheathing boards work as lateral support of the stud at fasteners locations. The previous research [6-19] indicated a significant increase in wall capacity due to sheathing from one or two sides. The Egyptian Code of Practice (ECP-205-ASD) does not provide any provision for CFS wall sheathing by the board. The AISI specification (AISI-S100-12) provides an equation for predicting the load capacity of a compression member fastened to one side sheathing.

This chapter presents the scope of the thesis and its objectives. In addition, it shows the organization of the implemented work.

Figure 1.1 : Low rise building consists of CFS floors and walls.

1.2. Problem statement

The CFS walls typically consist of studs and tracks. For cold-formed steel section subjected to compression stress, buckling is the dominant failure mode due to large slenderness ratio. Stud fails by the local buckling, torsional buckling, flexural buckling or combination of buckling modes. It is uneconomic solution to neglect the effects of sheathing board in improving buckling behavior of studs. Therefore, the researches and the design codes recent focused on the influence of the sheathing in design wall panels. However, the Egyptian code does not offer any provision for effects of sheathing in design and the AISI specification provides formula with many limitations in case of sheathing from one side. Furthermore, there are various parameters still needed to be studied to fully understand the behavior of CFS walls and predict the failure load. This research aims to investigate the failure load and behavior of CFS wall braced by the ferro-cement board under axial loads. In addition to comparing the results with the unlined studs to clarify the effect of the ferro-cement board in different stud sections (C-section with and without lip).

1.3. Objective of the research

The objective of this research is to investigate the behavior of cold-formed steel stud lined with ferro-cement board and the capacity of cold-formed steel walls by considering different stud sections, stud material, and screw distance.

The Thesis objectives can be summarized as follows:

- Study the previous experimental and analytical research for cold-formed steel wall panels.
- Preparation a realistic finite element model that represents the practical wall configuration.
- Verify the finite element model with the available previous experimental works.
- Present sets of graphs display the variation of the failure load of the stud with the various parameters.
- Investigate the effect of various parameters on the failure load of the cold-formed wall subjected to axial load.
- Comparison of the failure load from models with those obtained from previous design codes using modified effective length.

1.4. Scope of the research

To achieve the thesis objectives that previously mentioned a research plan has been stated. This research plan includes investigation of cold-formed steel wall subjected to an axial compression force numerically.

The numerical investigation uses three-dimensional numerical models using ANSYS 11.0 [1] finite element analysis software. The main goal of the numerical models is to investigate the behavior of cold-formed steel wall to perform the parametric study that stated to cover a wide range of parameters. The different parameters used in this study are shown as the following:

- Lining board (without lining, lining from one side or two sides)
- Screws location (distance between screws)
- Stud section (C-section with and without lip, stud thickness, and stud depth)
- Stud material

These models are subjected to an axial compression force to study the effect of these parameters on the failure load.

1.5. Organization of the thesis

This thesis focuses on the behavior of cold-formed steel wall subjected to an axial compression force. The numerical model performed based on the parametric study, to cover a wide range of parameters using finite element software ANSYS. The numerical model results were verified against both the previous experimental work and numerical models. In addition to the comparison between the results and the design codes. The remainder of this thesis organized as follows:

- In chapter two, the theoretical background of flat plate buckling under compression stress and the design codes formulas to calculate critical buckling stress have been introduced. Furthermore, this chapter included an overview of previous research works focused on the behavior of cold-formed steel wall. The shown previous researches investigated experimental and numerical models using finite element software. In addition, some researches established analytical models to predict the failure load of stud subjected to compression stress.
- In chapter three, the numerical model preparation using finite element analysis software ANSYS has been presented. Moreover, the numerical models' verifications with the previous experimental and numerical results have been established.
- In chapter four, the finite element models' results have been reported. Sets of graphs have been presented to indicate the effectiveness of various parameters on the failure load. In addition to analysis of results and comparison with the previous researches and the design codes have been investigated.
- In chapter five, the summary of the thesis work and the conclusion of the numerical results based on chapter four have been elucidated. Furthermore, the recommendations for the future research work in this point have been presented.