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STRUCTURAL PERFORMANCE OF NOVAL CFS INTEGRATED LIGHTWEIGHT LAMINATED WALL

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Abstract - This study presents a new method for constructing lightweight laminated walls by combining Cold-Formed Steel (CFS) and Recycled Plastic Lumber (RPL). The aim is to create a structural system that leverages CFS's strength and RPL's lightweight, sustainable properties, making it suitable for various applications, from architectural projects to mobile structures.

In this system, RPL blocks are strategically arranged and bonded with epoxy, then externally reinforced with CFS sheets to enhance structural integrity. Additionally, CFS components are incorporated internally in various patterns to optimize performance.

The research focuses on investigating the axial compression and bending performance of three wall configurations: externally strengthened, internally strengthened, and a combination of both. The methodology includes a comprehensive literature review to establish a foundation of existing knowledge. Following this, model validation processes are conducted to ensure the accuracy of computational models developed using ANSYS software. These models simulate the behavior of the three wall types under different loading conditions.

The results from these simulations are thoroughly analyzed to identify the most effective configurations in terms of structural performance. This research advances the understanding of how CFS and RPL can be combined to create lightweight yet strong laminated walls. It aims to provide practical guidance for implementing these innovative structural solutions in real-world settings.

Key Words: Cold-Formed Steel (CFS), Recycled Plastic Lumber (RPL), Axial loading

1. INTRODUCTION ON LIGHTWEIGHT LAMINATED WALL CONCEPT

A lightweight laminated wall typically incorporates multiple layers of materials strategically bonded together to optimize strength and durability while minimizing overall weight. Traditionally, materials such as plywood, foam, or composite panels are used in such systems to achieve a sturdy yet manageable structure. The integration of CFS and RPL introduces a novel approach by combining the benefits of steel and recycled plastics

1.1 Cold-Formed Steel (CFS):

Cold-formed steel is manufactured by shaping sheets of steel at room temperature through processes like roll-forming or pressing. Despite being lighter and more cost-effective compared to hot-rolled steel, CFS maintains robustness and dimensional precision suitable for various construction applications. In this integrated system, CFS components such as studs, joists, and panels play a pivotal role in reinforcing the laminated wall structure.

1.2 Recycled Plastic Lumbers (RPL):

recycled plastic lumber is an environmentally sustainable alternative to traditional wood materials, composed of recycled plastics that contribute to reducing environmental pollution from plastic waste. rpl exhibits versatility in both nonstructural and structural applications, offering durability and resilience while promoting sustainable construction practices

1.3 Integration and advantages of the laminated wall system

Enhanced Structural Integrity strategically is achieved by placing CFS components within the laminated structure—both externally laminating with CFS sheets and internally embedding CFS between RPL blocks—the wall system achieves enhanced load-bearing capacity and resistance to lateral forces.

Environmental Sustainability by Utilizing RPL reduces reliance on virgin materials and minimizes the environmental footprint associated with traditional construction materials. This aligns with global efforts towards sustainable building practices and contributes to LEED (Leadership in Energy and Environmental Design) certification objectives.

2. LITERATURE REVIEW

This provides a concise overview of the existing literature on the structural performance of novel CFS-integrated lightweight laminated walls. The review primarily examines current developments and findings in the field, summarizing them into the following main categories.

2.1 Jing Zhong Tong, Chao Qun Yu, Lei Zhang 2021

The paper focuses on investigating the sectional strength of PDSCWs under combined axial and out of plane bending loads It presents a nonlinear finite element (model to simulate this behaviour, validated through comparison with independent test results. A numerical parametric study explores various parameters, including faceplate thickness, wall depth, faceplate steel strength, infilled concrete strength, and faceplate type Interaction curves (N M curves) are derived from extensive modelling with different eccentricities. Additionally, the paper introduces a sectional analysis model considering the local buckling effect of faceplates to theoretically evaluate the sectional axial and bending strength of PDSCWs. By comparing the derived N M interaction curve with FE results, the study concludes that the proposed design formulas effectively predict the ultimate resistance of PDSCWs under combined axial and bending effects. These formulas offer valuable insights for practical design applications.

2.2 Juan P. Herrera, Daniel Bedoya Ruiz, Jorge E. Hurtado 2018

This paper outlines a study focused on the utilization of Recycled Plastic Lumber as a material for constructing structural walls in seismic resistant housing systems. The primary objective is to address environmental pollution by repurposing plastic waste while simultaneously addressing housing deficiencies,

particularly in seismic prone regions. The study employs a comprehensive experimental approach, testing full scale RPL walls under cycling loading conditions to evaluate various structural parameters critical for seismic design and assessment. These parameters include strength, hysteretic behavior, ductility, energy dissipation, equivalent damping, and characteristic failure modes of RPL walls.

3. OBJECTIVES OF THE STUDY

To study the effect of axial compression behavior and the bending performance of:

Laminated wall strengthened externally using CFS sheets in various thickness and finding the appropriate thickness required.

Laminated wall strengthened using CFS sheets in different type casing and finding appropriate casing.

Laminated wall strengthened using CFS sheets in different orientation of RPL

4.METHODILOGY OF WORK

The ANSYS Workbench platform was employed to analyze the wall system. The Design Modeler platform within ANSYS Workbench was used for modeling the wall system, Element used for modelling is SOLID186 and over all dimensions of wall1000 x 600 as specified in base journals is taken (1) and (2). Additionally, the engineering properties of Cold-Formed Steel and Recycled Plastic Lumber were derived from these base journals, as listed in the table below.

4.1 Material Properties of Plastic lumber block

Properties	Values
Young’s Modulus (MPa)	1102.5
Poisson’s ratio	0.3
Density (Kg/m^3)	872
Bulk modulus (Pa)	9.1875E+08
Shear modulus (Pa)	4.2404E+08
Yeild strength (MPa)	19.32

4.2 Material Properties of Cold form steel

Properties	Values
Young’s Modulus (MPa)	2E+05
Poisson’s ratio	0.3
Density (Kg/m^3)	7850
Bulk modulus (Pa)	1.6667E+11
Shear modulus (Pa)	7.6923E+08
Yeild strength (MPa)	390

This study has three objectives. The first objective is to compare models with a conventional wall system made of M25 concrete, examining the thickness of steel casing needed for equivalent load-bearing capacity. Six versions with thicknesses ranging from 10mm to 5mm were modeled to determine the appropriate thickness.

The second objective involves analyzing various types of CFS sheet casings using the thickness determined in the first objective. Eight variations were modeled, and the one with the highest load-bearing capacity was selected for further study. The casing was arranged in different ways: external C casing from the front and side, internal back-to-back C casing, and internal dual C casing, with plastic lumbers placed both bonded and layered.

The final objective is to change the orientation of the recycled plastic lumber blocks to find the model with the highest load-bearing capacity. Using the thickness and casing selected from the previous objectives, the blocks were arranged longitudinally, transversely, and in both directions combined, placed as layered and bonded, to analyze which model performs best

5.ANLAYTICAL STUDY

5.1 Analysis Of PLB Wall Exterior C encasement in Side by Varying Thickness

Models with thickness of casing from 5-10mm are created using ANSYS

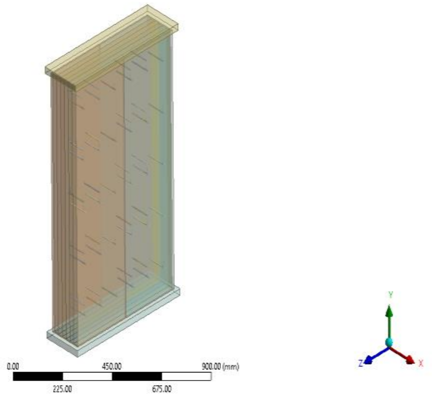


Fig. 1 : PLB wall – exterior c casing with 6 mm thickness

5.1.1 Finite Element Meshing

Meshing was performed to divide the model into elements and nodes. Hexahedral meshing was applied using ANSYS tools. The results were calculated by numerically solving the relevant governing equations at each node of the mesh. The element type SOLID 185 was used, with each element sized at 25mm.

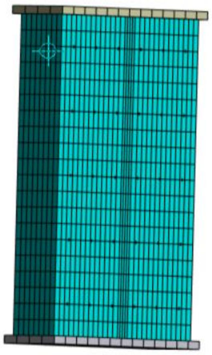


Fig. 2: Mesh of PLB wall exterior C 6mm thickness

5.1.2 Results for PLB wall exterior – C casing

The different models with different thickness are analyzed and we get the matching result corresponding to the conventional system in 6 mm thickness.

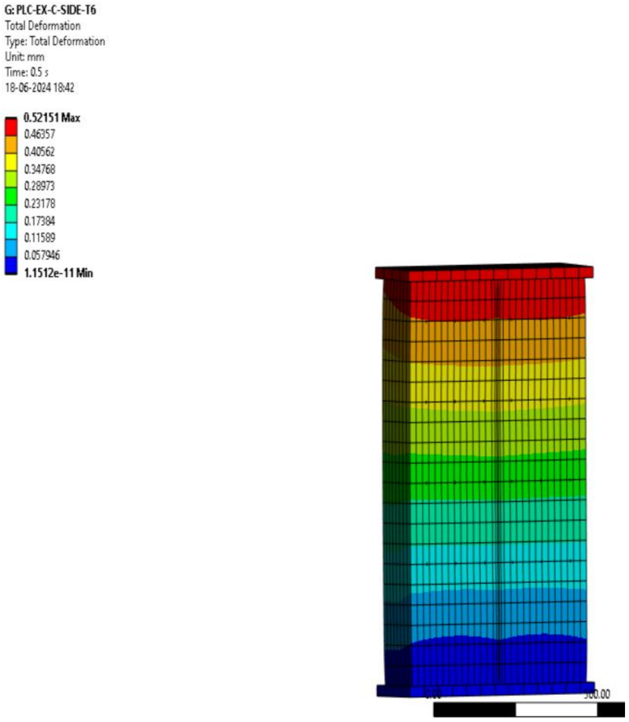


Fig. 3: Total deformation

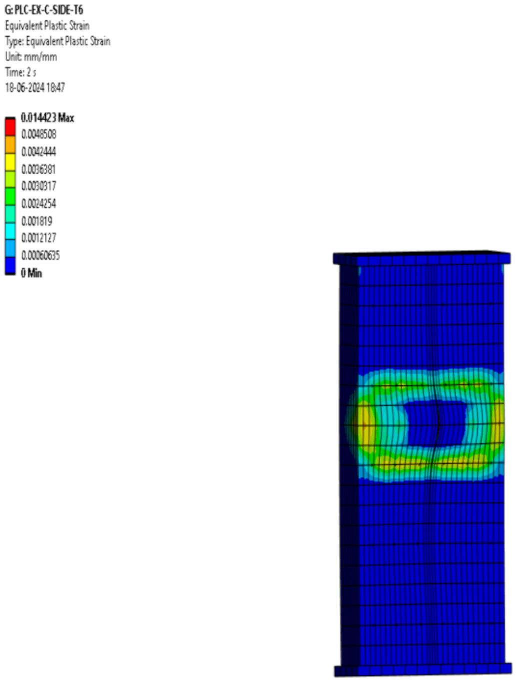


Fig. 4: Plastic strain deformation

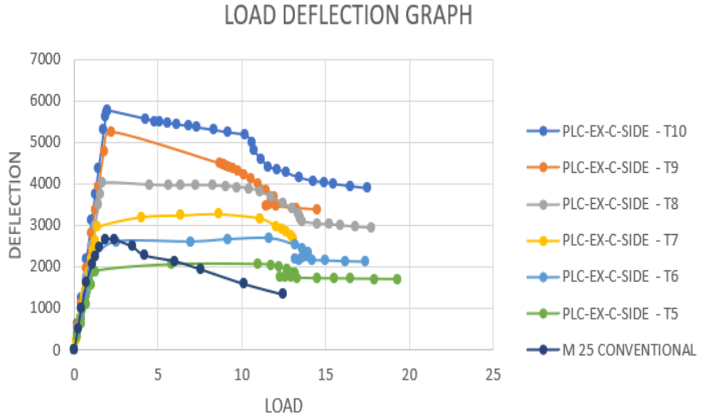


Fig. 5: Load-Deflection curve

SI NO	NAME	LOAD (KN)	DEFLECTION (mm)
1	PLC-EX-C-SIDE -T10	5770	1.9804
2	PLC-EX-C-SIDE - T9	5247.8	2.201
3	PLC-EX-C-SIDE - T8	4012.4	1.6799
4	PLC-EX-C-SIDE - T7	3267.8	8.6083
5	**PLC-EX-C-SIDE - T6**	**2678.8**	**11.643**
6	PLC-EX-C-SIDE - T5	2056.6	10.991
7	M 25 CONVENTIONAL	2659.3	1.8642

Table-1: Analysis results of PLB wall exterior C casing

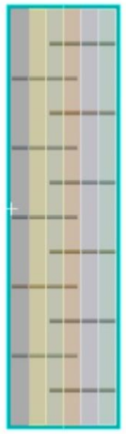
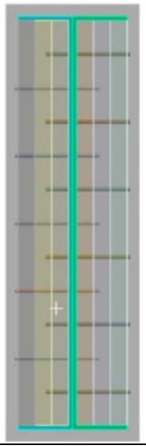
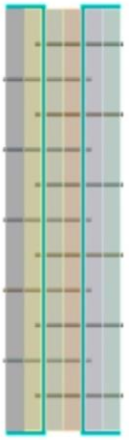
5.2 .ANALYSIS OF PLB WALL WITH VARIOUS TYPE OF CASING

PLB wall with layered lumbers type casing

a) Exterior C side
b) Exterior C front
c) Back-to-back C
d) Dual C back

PLB wall with layered lumbers type casing

a) Bounded PLB Exterior C front
b) Bounded PLB Exterior C side
c) Bounded PLB back-to-back C
d) Bounded PLB Dual C back

		
PLB wall Bounded Exterior C side	**PLB wall Bounded double C**	**PLB wall Bounded Dual C back**

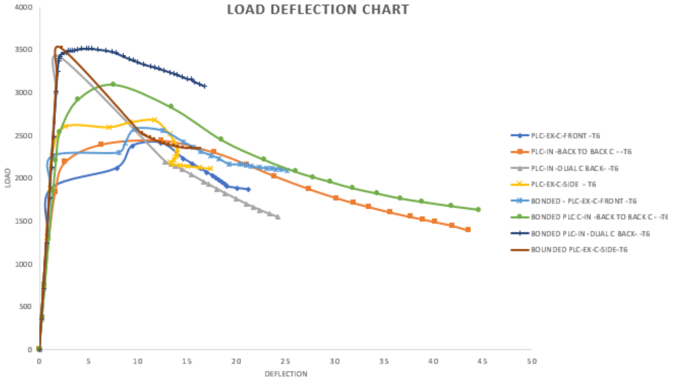


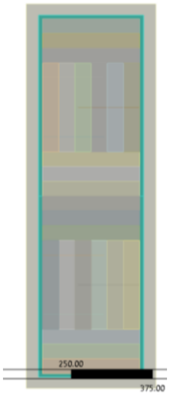
Fig. 6 : Load-Deflection curve- of PLB wall with various type of casing

SI NO	CASE		NAME	LOAD (KN)	DEFLECTION (mm)
1	LAYRED	EX	EX-C-SIDE	2678.8	11.643
2			EX-C-FRONT	2412	12.295
3		IN	BACK TO BACK C	2435.2	12.403
4			DUAL C BACK	3413.5	2.0748
5	BONDED	EX	BONDED -PLC-EX-C-FRONT	2572.2	9.7192
6			BONDED PLC C-EX -BACK TO BACK C	3087.7	7.5607
7		IN	BONDED PLC-IN -DUAL C BACK	3515.4	5.0099
8			**BOUNDED PLC-EX-C-SIDE-T6**	**3524**	**2.2101**

Table 2 Analysis results of PLB walls with different casing

5.3 ANALYSIS OF PLB WALL WITH VARIOUS TYPE OF ORIENTATION

a) PLB wall bond transverse exterior C side
b) PLB wall partial bond transverse exterior-C-side
c) PLB wall bond transverse ex-C
d) PLB wall partial transverse -ex-C

	
PLB wall Bounded transverse exterior c side	**PLB wall Bounded both longitudinal & transverse exterior c side**

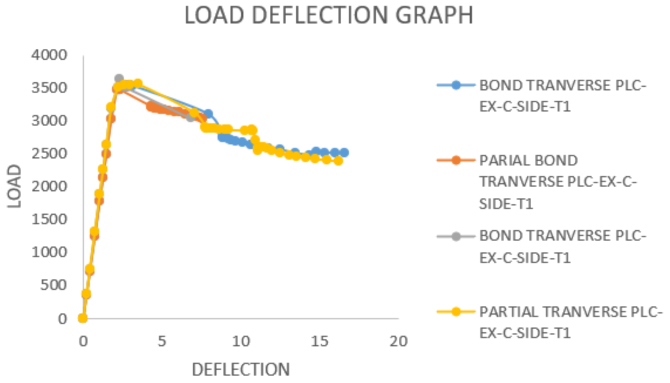


Fig. 7 : Load-Deflection curve- of PLB wall with various type of orientation

SI NO	NAME	LOAD (KN)	DEFLECTION (mm)
1	BOND TRANVERSE PLC-EX-C-SIDE-T1	3543.90	2.97
2	PARIAL BOND TRANVERSE PLC-EX-C-SIDE-T1	3500.30	2.27
3	**BOND TRANVERSE PLC-EX-C-SIDE-T1**	**3642.20**	**2.29**
4	PARTIAL TRANVERSE PLC-EX-C-SIDE-T1	3563.30	3.51

Table 2 Analysis results of PLB walls wall with various type of orientation

6.CONCLUSION

Different models were prepared and analyzed using ANSYS, yielding the following conclusions:

For the first objective, plastic lumber walls with exterior side C casing in various thicknesses were analyzed. It was found that a 6mm casing thickness approximately matched the load-bearing capacity of the conventional M30 model.

Using the determined thickness of 6mm for subsequent objectives, various PLB wall systems with different casings were analyzed. The maximum load-bearing capacity was observed in the bonded PLB wall with exterior side C casing.

Further analysis of different orientations of the lumber blocks (both partially and fully bonded) indicated that the bonded transverse PLB with exterior side C casing had the highest load-bearing capacity.

Thus, the bonded transverse PLB with exterior side C casing can be used as an alternative to the conventional wall system.

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