AN INNOVATIVE HYBRID LATERAL LOAD RESISTING SYSTEM FOR COLD FORMED STEEL STRUCTURES

[1]MINA MORTAZAVI, [2]PEZHMAN SHARAFI, [3]KAMYAR KILDASHTI, [4]BIJAN SAMALI, [5]HAMID RONAGH

Centre for Infrastructure Engineering, Western Sydney University, Penrith NSW 2751,Australia
E-mail: M.Mortazavi@westernsydney.edu.au, P.Sharafi@ westernsydney.edu.au, K.Kildashti@westernsydney.edu.au, B.Samali@ westernsydney.edu.au, H.Ronagh@ westernsydney.edu.au

Abstract- This paper provides an introduction to the lateral behaviour of an innovative hybrid panel system, and investigates the possibility of further improvements to that. Each hybrid panel consists of a hot rolled steel (HRS) frame, laterally attached to a cold formed steel (CFS) panel. The study evaluates the lateral behaviour of hybrid panels with: i) a cold formed steel top chord acting as a collector ii) a hot rolled steel profile acting as the lateral load collector. The specimens are studied under both monotonic and cyclic loads, and their design is enhanced according to the results. The results revealed that although the cold formed top chord can be improved regarding to strength criterion, the hysteretic behaviour of the hybrid panel is not improved in case of cold formed steel chord acting as the collector. On the other hand, relying on the cold formed part to resist the major amount of gravity loads, while the hot rolled collector transfers the whole lateral load to the hot rolled frame, results in significantly improved hysteretic behaviour. Once the strength target is achieved, the hot rolled steel frame is improved, considering the stiffness criterion while the connections are also improved accordingly.

Index Terms- Cold-formed steel, Hot-rolled steel, Hybrid system, Hysteretic behavior

I. INTRODUCTION

The increased demand for mid-rise light weight steel frames in recent years has resulted in various research activities being undertaken in order to enhance the performance of these systems in compliance with the increased demands of mid-rise and modular construction [1]. In spite of several advantages provided by CFS structures, there are some drawbacks limiting the wide efficient application of such structures compared to hotrolled structures. One limiting criterion is the lack of adequate background research. Although CFS structures have been introduced to the market since 1940s [2], their application as the main lateral load resisting system is relatively new. There is a small body of literature addressing the main limitations contributed to the thin walled behaviour of such systems. Some of the common CFS lateral load resisting systems are X bracing, K bracing and, fibre cement sheathed boards [3-6]. Despite of all noteworthy advantages, none of the mentioned lateral load resisting systems necessarily provides a favourable lateral load capacity due to the thin walled behaviour of CFS members.

The present study provides a discussion on studies on lateral behaviour of an innovative hybrid panel to investigate the possibility of any further improvements in the system. Each hybrid panel consists of a hot rolled steel frame laterally attached to a cold formed panel **Error! Reference source not found.**. This study involves evaluating the lateral behaviour of a hybrid wall panel system using finite element analysis and physical tests. The hot rolled part of the panel can be a frame made of rectangular hollow sections forming a box frame. According to the required storey drifts, this part can be stiffened using gusset plates or knee elements. Once the cyclic behaviour of the hybrid system is investigated, it is applied to a 4-storey building to be designed according to the relevant seismic structural codes.

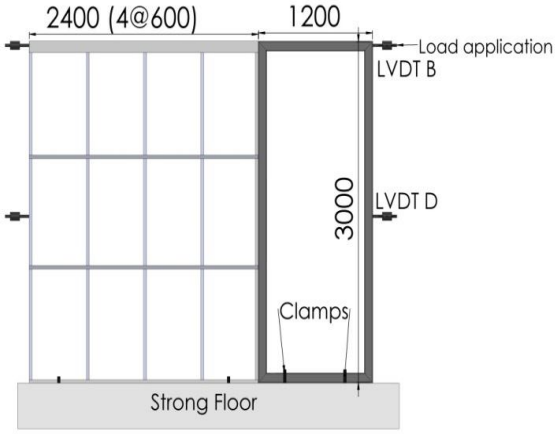


Figure 1- schematic view of the proposed HWPS

II. MODULE LEVEL STUDY

The experimental and numerical studies were conducted on bare HRS and hybrid panels simultaneously. **Error! Reference source not found.** shows the hybrid specimens investigated in this study. For the type I and II panels, the HRS part is not braced and due to relatively low stiffness it was found to be applicable for 1-2 storey buildings. The panels of type III and IV are improved regarding to lateral stiffness using brackets and knee elements and the strength is improved accordingly. The latter types are proposed to be applied to multi-storey buildings (up to 6 stories).

The monotonic push test results for different combinations of the panels are shown in Figure 1

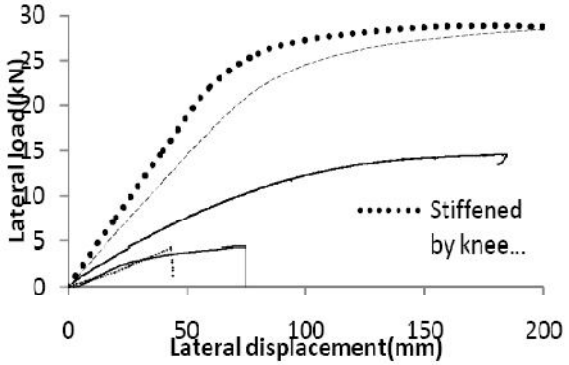


Figure 1- Monotonic test results for plain and stiffened hybrid wall panel systems

Once the maximum capacity of the hybrid wall panel is identified, their hysteretic response is to be experimentally tested. **Error! Reference source not found.** illustrates the hysteretic response of the proposed panels.

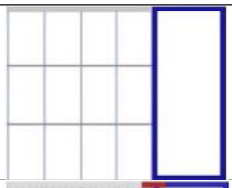
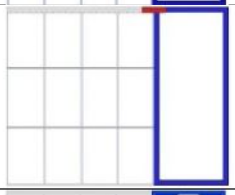
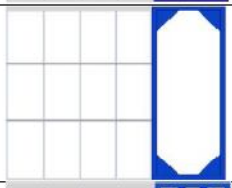
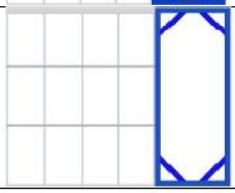
III. BUILDING LEVEL STUDY

A practical engineering analysis and design process is investigated for a 4-storey building with the proposed lateral load resisting system. The proposed hybrid panel utilizes a hot rolled steel panel as the main lateral load resisting element connected to a cold formed steel panel bearing the major portion of vertical loads. A typical architectural plan is chosen and according to the required openings and architectural limitations, the results are compared to that of an ordinary hot rolled steel frame building. The hot rolled steel panel is applicable in all external and internal walls with openings of 1.2m width or less. The hybrid system gives architectural engineers the same design and construction flexibility as ordinary moment resisting steel frame system. The system also offers the advantage of prefabrication and modular construction process. It is light which gives the benefit of being easy to transport and construct while remaining tough to withstand shipping and strong enough to be relied on as lateral load resisting element. In other words, the proposed hybrid system provides the advantages of cold formed steel and hot rolled steel structural systems simultaneously. The finite element results obtained from this part of the studies facilitates the analysis and design process of the proposed system which is extendable to structures with extended number of stories.

Once the HRS parts are designed as per relevant structural codes, the CFS parts are designed using the axial forces obtained from analysis in addition to local application of the wind loads on internal and external walls.

In terms of the weight of consumed HRS material a comparison between 4-storey buildings designed using the proposed system and an intermediate moment resisting frame is provided in **Error! Reference source not found.**. It is clearly shown that involving the CFS studs in resisting the vertical loads results in lower weight of HRS material to be consumed.

Table 1- HWPS specimens

Description	Schematic view	Maximum lateral capacity
Type I: - Plain hot rolled frame - CFS top chord acting as collector		5 kN
Type II: - Plain hot rolled frame - CFS top chord acting as collector - Improved connection between CFS and HRS parts		15 kN
Type III: - HRS panel braced by 350x350x4mm gusset plates - Increased stiffness and strength - HRS top beam acting as the collector		30 kN
Type IV: - HRS panel braced by SHS89x89x3.5 knee elements - Increased stiffness and strength - HRS top beam acting as the collector		30 kN

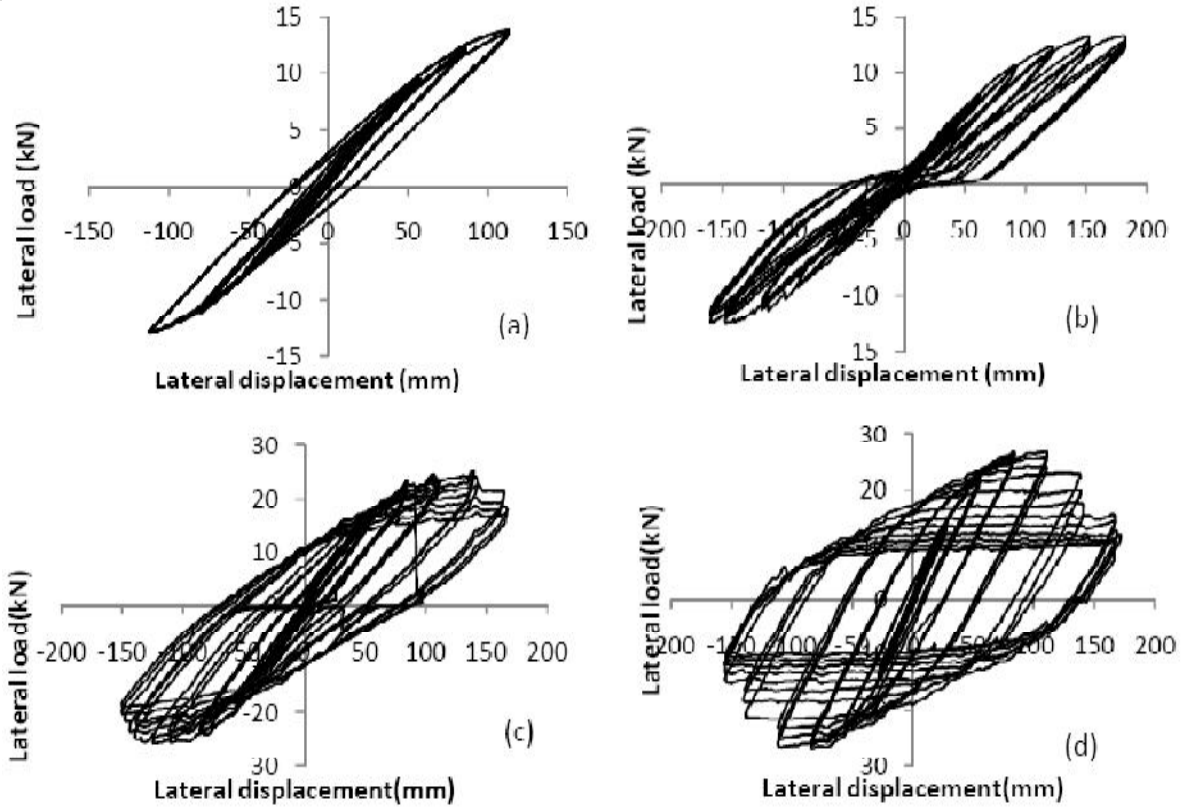


Figure 3- Cyclic response of : a) hot-rolled steel panel b) hybrid panel with bare hot tolled part a) hybrid panel stiffened by gusset plates b) hybrid panel stiffened by knee elements

Table 2- Weight of the structural steel and total weight for both systems.

	Intermediate moment resisting frame	Hybris system
Hot rolled steel weight (kN)	397.5	192.5
Cold formed steel weight (kN)	23.7	44.4
Total weight of steel (kN)	421.2	236.9
Total weight of structure (kN)	3894	2363

CONCLUSION

This paper provided an introduction for a new lateral force resisting system consisting of CFS and HRS panels. The lateral behavior of an individual hybrid system was evaluated and according to the preliminary design and analysis, the final design for a particular building was compared for a hybrid system and intermediate moment resisting frame. The proposed system is successfully reducing the HRS material consumption and is capable of extending the number of stories to four.

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