Study of the Effect of Porcelain Sheathing Direction on the Lateral Resistance of Cold-Formed Steel Shear Wall under Constant Gravity Loading by Experiment

S. R. Sowlat-Tafti[1], M. R. Javaheri-Tafti [2*], H. R. Ronagh[3]

[1]Department of Civil Engineering, Taft Branch, Islamic Azad University, Yazd, Iran
[2]Department of Civil Engineering, Yazd Branch, Islamic Azad University, Yazd, Iran
[3]School of Civil Engineering, Queensland University, Brisbane, Australia

ABSTRACT

The lateral behavior of cold-formed steel shear wall is dependent on several factors including the type of sheathing used. However, only a limited number of sheathing types have been studied using specific installation method. In this study, due to the high demands of builders to use local materials for sheathing light steel frames, which, in addition to being abundant and easy to obtain, can also create a variety of designs such as stone or brick to match the facade of existent parts of the building, two full-scale samples of cold-formed steel shear walls in dimensions of 1.2×2.4 meters sheathed by porcelain ceramic with different configurations have tested under combined constant gravity loading and standard cyclic lateral loading regime. After calculation of ductility and response factors by using of specimens tests results, The seismic effect of the sheathing rectangular pieces orient, which can be installed in either horizontal or vertical strips, is investigated. The study also evaluates the failure modes of the systems. The results of the tests show that porcelain sheathing pieces installation in vertical strips instead of horizontal strips causes a decrease of approximately 50% in Energy Dissipation and 18% in ultimate lateral resistance without effect on seismic response modification factor, *R*.

KEYWORDS

Cold-formed steel shear wall, porcelain sheathing, hysteretic cycle, sheathing strips direction, constant gravity loading

[*] Corresponding Author: Email: javaheri@taftiau.ac.ir

1. **Introduction**

Cold-formed steel (CFS) structures have brought about a massive evolution in the construction of low-rise buildings, as they benefit from unique advantages such as low weights and simple constructions. CFS shear walls have recently become a popular lateral load-resisting system and are considered a novel structural system in some countries. As a result, the seismic design of CFS structures is still in its gestation period, and the well-known seismic codes do not effectively cover the seismic design of this system. Therefore, further research should be conducted to obtain deep insights into different seismic aspects of CFS shear walls including the estimation of response modification factor, strength, and ductility.

According to the literature review [[1]-[6], there is no comprehensive consensus on the response modification factor of CFS structures. In particular, no CFS shear walls with screwed porcelain sheathing (SPS–CFS) structure provisions determined the response modification factor, and further research is required in this respect. The increased expansion rate of Lightweight steel framing (LSF) buildings and the necessity of research on the seismic parameters of CFS shear walls have encouraged academics to test a variety of bracing sheaths that could offer an optimal lateral performance. Advances in the ceramic industry and the emergence of new-generation high-strength porcelain ceramics widely employed in the external and interior walls of buildings can help improve the seismic behavior of buildings, accelerate their construction, and reduce costs. Hence, this study proposes and experimentally evaluates a novel porcelain sheath with a particular installation. The effects of sheath components orientation and double middle stud also additional horizontal struts therewith flat straps (additional blockings) were assessed. The horizontal sheath strips provide more proper lateral behavior than the vertical sheath strips. Double middle stud enables local buckling at higher strength before yielding and provides a more ductile response versus single stud and additional blockings lead to failure at a larger displacement.

2. **Seismic response modification factor (*R*)**

The *R*-factor is consisted of two main components, namely the ductility reduction factor R_d and structural over-strength factor Ω_O [7], [8]. The R factor is defined as:

$$R = R_d \times \Omega_0 = \frac{Ve}{Vy} \times \frac{Vy}{Vs} = \frac{Ve}{Vs} \tag{1}$$

Fig. 1 illustrates the components of the *R*-factor by plotting the actual load-displacement curve, equivalent elastic performance linear curve, and idealized bilinear curve. Where V_e, V_y and V_s correspond to the structure elastic response strength, the idealized yield strength and the first "significant yield" strength, respectively. This idealized bilinear load-displacement curve was determined based on FEMA 356 [9].

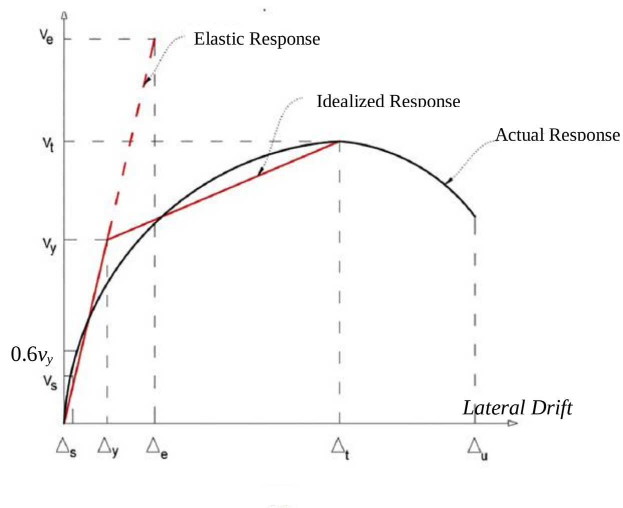

Figure 1. Actual and idealized load-displacement curves

3. **Discussion and Results**

The failing of ceramics in specimen D-H-3 with horizontal sheathing and the vertically sheathed specimen (D-V-3) began at a displacement of 48 mm. for D-V-3 sustained the more widespread level of damage.

According to Figs. 2, the hysteretic cycle curves of the specimens were plotted by using the load-displacement data obtained from the computer system to find the actual behavior of the specimens. Fig. 3 plots the idealized bilinear curves, and Table 1 provides the energy dissipation (*E*), ductility factor, ultimate strength, lateral displacement magnification ratio C_d and other seismic parameters.

Table 1. Characteristic values of the specimens

Specimen	V_y (kN)	V_{max} (kN)	E (joule)	μ	Ω_0	R
D-H-3	8.2	21.1	5503	3.9	1.6	4.1
D-V-3	12.1	17.4	2829	3.9	1.6	4.1

Furthermore, D-V-3 had the smallest ultimate strength V_{max} and the lowest maximum sustained drift, even though it did have the same *R*-factor.

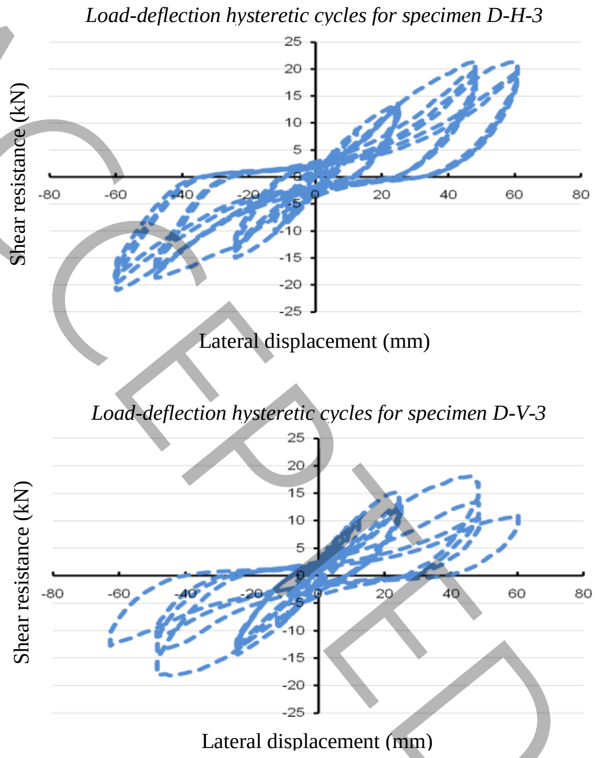

Figure 2. Hysteresis cycle curves of the specimens

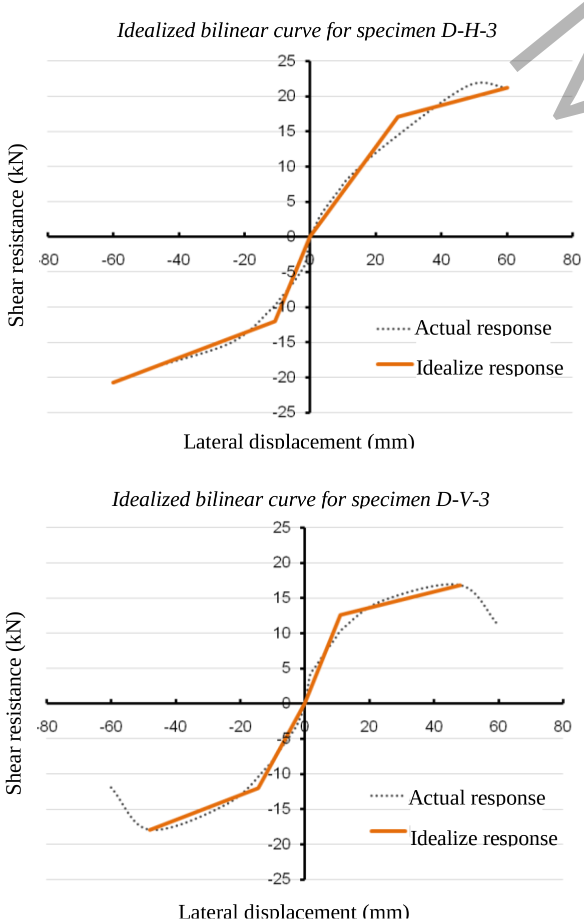

Figure 3. The idealized bilinear curves of specimens

4. Conclusions

In conclusion, porcelain sheaths in LSF systems lead to a 30% rise in the R-factor and ultimate lateral strength as opposed to unofficial sheaths, e.g., GWB and fiber-cement board sheaths with a recommended R-factor of 2–3 in international codes.

The consequences can be summarized as below:

- A comparison of D-V-3 and D-H-3 indicated the effects of the sheath strip direction. The *R*-factor and μ of both specimens were equal.
- The ultimate shear of the specimens was 17.4 for the vertically sheathed specimen and 21.1 for the horizontally sheathed specimen.
- The *R*-factor of the specimens was measured 4.1. This indicates that the coded *R*-factors of 2–3 would be conservative.

5. References

[1] Ronagh H.R., et al., 2018. "Lateral Force Resisting Systems in Lightweight Steel Frames: Recent Research Advances". Thin-Walled Structures, 130, pp. 231–253.

[2] Javaheri-tafti M.R., et al. 2014. "An Experimental Investigation on the Seismic Behavior of Cold-Formed Steel Walls Sheathed by Thin Steel Plates". Thin-Walled Structures, 80, pp. 66–79.

[3] BHRC, 2013. Cold-Formed Light Steel Structures Design and Construction Code (Structural), NO. 612, Building and Housing Research Center, Iran. https://sama.mporg.ir/sites/publish/SitePages/ZabetehView.aspx?mdid=4877. In Persian.

[4] AISI-S400, 2015. North American Standard for Seismic Design of Cold-Formed Steel Structural Systems, the American Iron and Steel Institute, Washington.

[5] AS/NZS4600, 2005. Cold-Formed Steel Structures, Australian Building Codes Board.

[6] Zhang W., et al., 2017. "Experiments and Simulations of Cold-Formed Steel Wall Assemblies Using Corrugated Steel Sheathing Subjected to Shear and Gravity Loads". J. Structures Eng., 143 (3).

[7] FEMA-P750, 2009. NEHRP Recommended Seismic Provisions for New Buildings and Other Structures, Building Seismic Safety Council, Washington.

[8] FEMA-356, 2000. Pre Standard and Commentary for the Seismic Rehabilitation of Building, Building Seismic Safety Council, USA.

[9] Ayatollahi S.R., Usefi N., Ronagh H.R., et al., 2020. "Performance of Gypsum Sheathed CFS Panels under Combined Lateral and Gravity Loading". J. Constr. Steel Res., https://doi.org/10.1016/j.jcsr.2020.106125.